Engineering of Defense Systems Guidebook

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Office of Systems Engineering and Architecture

Office of the Under Secretary of Defense
for Research and Engineering

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July 2024	Feb 2022, Change 1	Update references, links, and outline.
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Introduction

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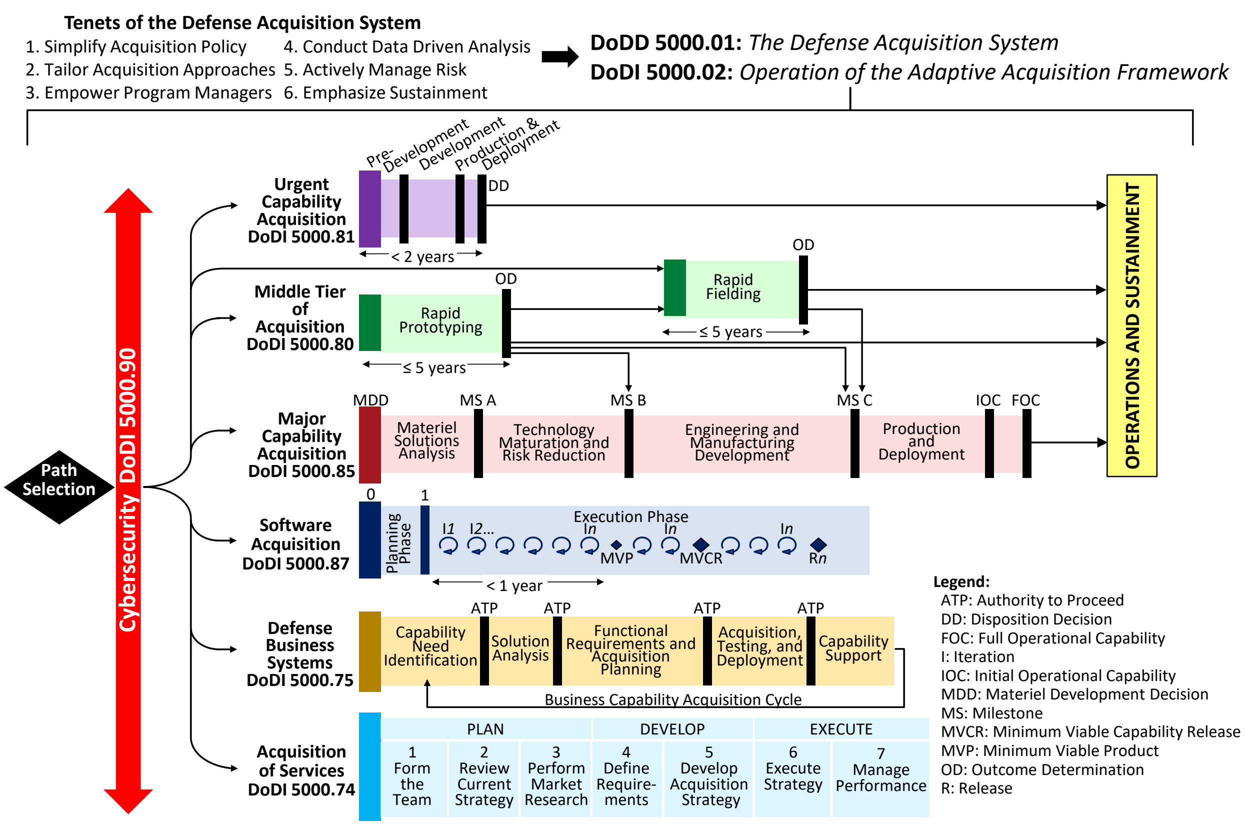
1 Purpose and Scope

This guidebook describes the activities, processes, and practices involved in the development of Department of Defense (DoD) systems. The guidebook aligns with the engineering disciplines covered in DoD Instruction (DoDI) 5000.88, Engineering of Defense Systems, and focuses on recommended engineering best practices for the DoD Adaptive Acquisition Framework (AAF) acquisition pathways (see Figure 1-1 and DoDI 5000.02, Operation of the Adaptive Acquisition Framework).

This guidebook is intended for Program Managers (PMs), systems engineers, and other defense acquisition professionals and may be tailored for programs in any of the AAF pathways. Programs can use the guidebook, along with other acquisition business resources, to plan and execute program engineering activities across the system life cycle.



Source: DoDI 5000.02

Figure 1-1. Adaptive Acquisition Framework

This document presents systems engineering (SE), mission engineering (ME), and other engineering guidance as applied to the acquisition pathways to support DoD acquisition programs. The DoD Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)) prepared this guidebook in cooperation with subject matter experts (SMEs) from the Military Services, defense agencies, industry, and academia.

Engineering provides the technical foundation for all DoD acquisition activities regardless of Acquisition Category (ACAT) or acquisition pathway. In addition to the Acquisition Strategy, PMs and systems engineers should develop an engineering approach that matches the acquisition pathway processes, reviews, documents, and metrics to the character and risk of the capability being acquired.

Although this guidance employs terminology mainly applicable to the Major Capability Acquisition (MCA) pathway, the principles and practices should be applied, as appropriate and tailored, to all DoD system development. Although a Major Defense Acquisition Program (MDAP) or major system using the MCA pathway will typically employ the majority of activities and events described in this document, it is prudent for the PM and systems engineer to consider all of these activities and events for their respective program regardless of pathway.

2 Pre-Materiel Development Decision Engineering

The objectives of the pre-Materiel Development Decision (MDD) effort are to obtain a clear understanding of user mission capability 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 decision to:

1. Authorize entry into the acquisition life cycle to pursue a materiel solution.
2. Select the appropriate acquisition pathway and milestone dates.
3. Define the acquisition mandates that are to be tailored and waived based on schedule and resources.
4. Define risk acceptance authorities for schedule, cost, performance, quality, security, testing, training, maintenance, and human factors.

Programs achieve the pre-MDD objectives primarily through ME and other development planning activities. Development planning includes early engineering analyses and technical planning that provide the foundation for informed investment decisions to meet operational needs effectively, affordably, and sustainably. Programs should initiate development planning activities in advance of the MDD and continue throughout the Materiel Solution Analysis (MSA) phase for MCA programs.

Often there is no assigned PM or systems engineer at this point in the acquisition life cycle. The engineers performing pre-MDD work should document all ME results so the PM and systems engineer, when assigned, will benefit from an understanding of the basis of the mission, the derived need (requirements), and the art of the possible (concepts and materiel solutions). In addition, the program should continue to update the ME products to reflect the evolving mission and threats. This ME analysis will then guide the PM and acquisition leadership at every acquisition decision point to inform whether the materiel solution is still relevant to the battlespace.

ME is an iterative analysis and multidisciplinary activity in the form of studies to analyze, organize, and integrate current and emerging operational and system capabilities to achieve desired warfighting mission effects. ME activities in the pre-MDD phase allow programs to characterize trade space, risks, and mission interdependencies to support the start of the Analysis of Alternatives (AoA).

Pre-MDD policy comes from two perspectives: the Joint Capabilities Integration and Development System (JCIDS) defined in Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 5123.01I and the Defense Acquisition System (DAS) defined in DoD Directive (DoDD) 5000.01, The Defense Acquisition System.

SE and ME are essential during early phases in acquisition to ensure programs ultimately deliver capabilities that meet the intended needs on time and on budget. Mission understanding, design considerations, analyses, and associated activities during pre-MDD are critical to determine feasibility and to characterize trade space (see the Systems Engineering (SE) Guidebook for the definition of "design considerations"). During pre-MDD, risks in mission concept and design may emerge that will need to be addressed before the MDD and throughout the acquisition life cycle.

2.1 Pre-MDD Mission Engineering Activities

The pre-MDD effort has two important aspects: (1) establish the ME reference materials that guide materiel solution decisions throughout the life cycle, and (2) narrow the field of possible solutions to a reasonable set that engineers analyze in the AoA. The systems engineer or requirements manager should engage with mission engineering practitioners and the end user or end user representatives before the Joint Requirements Oversight Council (JROC) validates the Initial Capabilities Document (ICD) or equivalent requirements document and associated operational architecture as described in the SE Guidebook.

ME activities are critical to refining the options. By defining and characterizing the mission(s), the capability gaps to be addressed in the future fight, and potential warfighter concept solutions in a structured format, the engineers and analysts help ensure the Service appropriately trades materiel solutions and targets the evolving needs of the battlespace. ME studies help ensure a consistent understanding of the constraints and technical feasibility so concept developers can eliminate initial ideas that lack the potential to meet the need in a timely, sustainable, and cost-effective manner, while ensuring the remaining range of alternatives is sufficiently broad for the AoA.

The Government Accountability Office (GAO) has 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" (GAO-09-665, page 6.) ME and AoA study teams can consider more alternatives and design variations by using modeling and simulation tools.

Digital engineering approaches including models and other digital representative products are essential to understanding complex systems and interdependencies in this phase. Likewise, they provide a means to explore concepts, system characteristics, and alternatives; open up the trade space; facilitate informed decisions; and assess overall system performance. Whether a program adopts a robust digital engineering approach or not, ME analysis (see ME Guide), models, and simulations (SE Guidebook Section 2.2.1) are critical to assessing alternative solutions and will also play a role throughout the program life cycle. The designated Service representative should consider issuing a Request for Information to industry to help identify alternative concepts, solutions, and their model equivalents.

During pre-MDD, engineering personnel should use digital artifacts (models, simulations, etc.) from many disciplines and across a hierarchy of perspectives that range from strategic, campaign, and mission levels to analyze overall requirements, employment options, and battlespace efficacy. The program should maintain, refine, and repurpose digital artifacts developed in early acquisition phases for activities during later phases (e.g., engineering models can be used in training simulations). Developing new digital artifacts can be costly. An option for new development is to consider leveraging existing models and simulations, using various interoperability standards to create needed capability. ME and SE personnel should consider how to leverage models, simulations, and their interoperability as they plan for their use throughout a program's life cycle. Modeling and simulation can also support developmental test and evaluation (DT&E) and operational test and evaluation (OT&E).

ME and SE personnel should continue to mature modeling and simulation tools used during the pre-MDD phase and throughout the acquisition life cycle to represent the final system configuration. Maintaining the models and simulations allows the program to perform additional assessments as the system progresses.

Roles and Responsibilities

If there is no PM or systems engineer assigned at this point, a designated Service representative (e.g., requirements manager) is leading the activities prior to MDD. This leader is responsible for synthesizing the necessary information to support a favorable decision. As a best practice, leadership should consider designating a Service engineering representative to orchestrate or perform ME activities and support concept and requirements definition and associated decisions in preparation for the MDD.

Inputs

Table 2-1 summarizes the primary inputs associated with pre-MDD. Unlike the acquisition pathways that follow, this period is the bridge between JCIDS and the DAS.

Table 2-1. Inputs Associated with Pre-MDD

Inputs for Pre-MDD
Mission definition artifacts: • Future time frame in which the mission is set • Future threats/adversary capabilities • Scenario details • Mission objectives, constraints, and measures of success • Expected and alternative force laydown(s)
Laws, mandates, policies, Executive Orders
Other program needs/failures
Lessons learned
Joint Warfare Capability definitions and gaps; Service Component capability area definitions and gaps
USD(R&E) Technology Modernization roadmaps

Inputs for Pre-MDD
Draft ICD or equivalent (See CJCSI 5123) • Product of Capability-Based Assessment or equivalent
Other analyses • Other prior analytic, experimental, prototyping and/or technology demonstration efforts provided by the science and technology community • Results of market research: (1) to identify existing technologies and products; and (2) to understand potential solutions, technologies and sources • Conference findings, federally funded research and development center input, strategy papers, 4-year outlooks

Activities

During pre-MDD, ME and SE activities include the following:

- Achieve an in-depth understanding of the current and evolving operational capability gaps defined in the ICD or equivalent requirements documentation, and identify the sources of the gap(s), which, if addressed by a materiel solution, could achieve the needed capability.
- Identify an appropriate range of candidate materiel solutions from across the trade space to meet the need.
- Identify near-term opportunities to provide a more rapid interim response to the capability need.
- Work 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 including experimentation and prototyping.
- Analyze trade space to determine performance versus cost benefits of potential solutions.
- Plan for the technical efforts required during the next phase.
- Perform an early evaluation of risks associated with the alternatives to be analyzed in the next phase.
- Work with requirements developers to ensure the quality of all operational requirements.

Outputs and Products

The pre-MDD effort ends after a successful MDD review in which the Milestone Decision Authority approves entry into the DAS.

The MDD review requires an ICD, or equivalent, that represents an operational capability need validated in accordance with CJCSI 5123. The Joint Staff provides this document, which is generally the output of a Capability-Based Assessment, ME analysis, or other studies. The designated Service representative should have access to both the ICD and supporting studies. Other technical information (such as models, simulations, etc.) 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, or analysis.

The MDD is documented in an Acquisition Decision Memorandum (ADM) signed by the Milestone Decision Authority. The ADM specifies the approved entry point, typically the MSA phase for the MCA pathway. Pre-MDD outputs (Table 2-2) also include approved AoA Guidance and an AoA Study Plan, which should be informed by ME and SE activities.

Table 2-2. Technical Outputs Associated with Pre-MDD

Technical Outputs from Pre-MDD
• Configuration-controlled Mission Baseline including validated mission definition(s) the program will maintain and use to measure mission efficacy of the materiel solution and a basis for future acquisition decision points.
• Configuration-controlled operational Concept Baseline including validated reference mission threads and recommended candidate materiel solution concepts for further analysis/refinement in the next acquisition phase. • Validated mission threads: o Of the mission if executed with expected forces in the future time frame. These are titled the “As-Is” mission thread(s) and should highlight or illustrate the potential gap or shortfall. o Of alternative concept (regardless of materiel solution) mission approaches. These are titled the “To-Be” mission thread concept(s). o Suggested Mission Engineering Threads that preliminarily incorporate promising DOTMLPF-P considerations and materiel solution concepts.
• Informed advice to the ICD, or equivalent
• Informed advice to the AoA Guidance and Study Plan (See the Analysis of Alternatives Cost Estimating Handbook (AoA Handbook) (2021))
• 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 Milestone Decision Authority may authorize entry at any point in the acquisition life cycle based on the solution’s technical maturity and risk. If the Service-recommended entry point into the MCA pathway is beyond the MSA phase, for example, partway through the Technology Maturation and Risk Reduction (TMRR) phase, the program should document evidence that all MSA and TMRR 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. Technical risk has several elements: mission risk, technology risk, engineering risk, and integration risk. The Service or designated representative should ensure the soundness of supporting technical information and plans in order to inform the Milestone Decision Authority’s decision. The technical plan and budget presented at the MDD should reflect the full range of activities required in the next phase.

2.2 Pre-MDD Mission Engineering Reviews

2.2.1 Mission Review

DoD Joint Publication 3-0 (Joint Operations) defines a "mission" as the task, together with the purpose, that clearly indicates the action to be taken and the reason therefor. The mission definitions (validated by the Joint Staff and Combatant Commands) are the fundamental basis for evaluating materiel solutions and trades. The Mission Review should ensure that the definition of the mission(s), either today or in the future, and the desired mission outcomes (measured by mission metrics) have been adequately established and are sufficiently defined to conduct ME (see ME Guide). In accordance with DoDI 5000.88, a USD(R&E) representative will chair Mission Reviews for joint missions, and the applicable Service representative will chair Mission Reviews for Service-specific missions.

The Mission Review should establish and place under configuration control a validated and well-articulated set of Mission Baselines. The Mission Baselines should include mission definitions and time frames of interest in which the missions are set. Mission definitions include scenario setting, threats, allies and partners, mission assumptions, mission objectives, constraints, mission measures of success, and expected force laydown (i.e., position and qualities of platforms or systems). These terms and the ME methodology are further described in the ME Guide.

There may be multiple (or a family of) Mission Baselines but with varying elements of the mission definition – for example a change in the time frame of interest (i.e., 2025, 2030, 2035), or multiple vignettes. The family of Mission Baselines should evolve to reflect the changing threats, Defense Planning Guide, and National Defense Strategy. The baseline(s) should be updated and revised at a minimum every 2 years to support the Future Years Defense Program (FYDP) cycle and in sufficient time to guide ME activities in support of OUSD(R&E) investment and DAS-based decisions. The Mission Review should trace the mission definition to the Joint Capability Areas and provide scenario details to guide analyses of potential concept, technological, DOTMLPF-P and materiel solutions.

Roles and Responsibilities

- Under Secretary of Defense for Research and Engineering (USD(R&E))
  - Provide guidance for defining components and details of Mission Baselines and associated mission definitions.
  - Coordinate access to appropriate data repository(ies) and instructions (upload/download, tagging, configuration control, etc.) to share Mission Review products (i.e., Mission Baseline artifacts and other relevant data/material). Products may include architectures, models, etc.
  - Provide, along with Joint Staff, guidance and criteria for conduct of the Mission Review.
  - Chair, or co-chair with Joint Staff, Mission Reviews for joint missions.

- Joint Staff – for joint missions
  - Host, or co-host with OUSD(R&E), Mission Reviews.
  - Provide validated mission definitions and baselines with support of combatant commands (COCOMs).
  - Include representatives of OUSD(R&E) and OUSD for Acquisition and Sustainment (OUSD(A&S)).
  - Provide for sharing Mission Review products across the Department following instructions and repository guidance from OUSD(R&E).
- Services/Components – for Service-specific missions
  - Host Mission Review.
  - Derive mission definitions from joint mission definitions and baselines.
  - Provide validated mission definitions and baselines with support of COCOMs.
  - As needed, include representatives of OUSD(R&E) and OUSD(A&S) in Mission Reviews.
  - Provide for sharing Mission Review products across the Department.

Inputs and Review Criteria

- Mission definition(s)
  - Time frame of intended mission(s) (year of conflict)
  - Known strategic gaps in capability
  - Traceability to Defense Planning Guide, Joint Capability Areas, Joint Task Lists, or Service tasks lists
  - Environmental conditions, geopolitical setup, expected threat, etc.
- Assumptions and constraints that should be used for analyses
- Mission measures of success
  - Objectives of the mission in quantifiable terms
  - Definitions of measures of effectiveness (MOEs) or other measures of performance (MOPs) as well as key target values for these measures
- Trades that are needed to inform mission refinement
- Other interrelated Mission Baseline(s)

Outputs and Products

- Documented Mission Baseline(s) that encompass the agreements and final products to address the inputs and review criteria of the Mission Review
- Traceability to Defense Planning Guide, Joint Capability Areas, and Joint Tasks Lists

  - Documented capability gaps
- Data or products needed to guide concept exploration and DOTMLPF-P evaluations to support maturation of the Concept Design
  - Questions requested by leadership to inform trades and support decisions
  - Analyses needed to refine the mission definition(s)
- All products should be made readily available to the Office of the Secretary of Defense (OSD) and other DoD Components for use and integration across mission definitions

2.2.2 Concept Design Review

In accordance with DoDI 5000.88, a Concept Design Review (CoDR) will be conducted before the MDD, during which CoDR the initial Concept Baseline(s) will be established. The CoDR will be chaired by a USD(R&E) representative for joint missions and by the applicable Service representative for Service-specific missions. The review is the culmination of concept exploration and DOTMLPF-P evaluations to address preliminary solution trades to meet mission needs. The CoDR should be a multidisciplined review of the potential joint warfare concepts, Service-specific concepts, and DOTMLPF-P considerations to address the needs of the Mission Baseline. The review should serve to evaluate the rigor used to identify the candidate alternatives (both materiel and non-materiel) that should be further explored to address the baseline missions. The Service representative informs the CoDR by performing top-level ME analyses of future concepts and exploring integrated joint force possibilities. These analyses should provide balanced and quantifiable insight to help leadership prioritize candidate concepts, non-materiel solutions, and likely materiel solutions (integrated joint, Service agnostic, as well as partner alliance). The CoDR products will inform the MDD or provide guidance for non-materiel action by COCOMs.

The CoDR should establish the operational Concept Baseline and include recommended candidate materiel alternatives and an update to the Mission Baseline materials (i.e., the mission definition(s)). The Service representatives document the Concept Baseline to depict the mission definition, the future time frame in which it is set, threats, scenario specifics, mission objectives, constraints, mission measures of success, and expected force laydown (see ME Guide). The CoDR should also include a review of the supporting technology roadmaps and prototyping or experimentation efforts (plans and results) that enable each of the concepts and alternatives. The Service presents these candidates at the MDD to shape what the SE and ME team will further evaluate as part of the AoA. The CoDR should include a technical sufficiency evaluation of the AoA Study Guidance to ensure it is grounded to the Mission Baseline, it equally considers Service-specific and joint alternatives, and it addresses the candidate “To-Be” mission thread(s) resulting from the CoDR.

Roles and Responsibilities

- USD(R&E)
  - Provide guidance and details for establishing the Concept Baseline.
  - Provide guidance and criteria on the conduct of the CoDR.
  - For non-delegated studies, perform ME analyses to inform the Concept Baselines and alternatives to support the CoDR and MDD.
  - Update and provide technology and prototyping or experimentation roadmaps.
  - Provide procedures, infrastructure, or a repository to share elements of Concept Baselines, candidate alternatives, and decisions.
- USD(A&S)
  - Provide DAS portfolio capability performance and schedules.
- Joint Staff – for joint missions
  - Provide updated validated mission definitions and baselines with support of CCMDs.
  - Provide Joint Warfighting Concept roadmaps/architectures.
  - Provide for sharing ME and CoDR products across the Department.
  - Perform a Capability Portfolio Review as part of the CoDR if it was not conducted separately.
- Services or Components
  - Perform ME analyses to inform the Concept Baselines and alternatives to support the CoDR and MDD.
  - Provide updated validated mission definitions and baselines with support of CCMDs.
  - As needed, include representatives of OUSD(R&E) and OUSD(A&S).
  - Provide for sharing ME and CoDR products across the Department.

Inputs and Review Criteria

- Mission Baseline(s), including updated mission definitions informed by evolving mission and threats
- Technology, prototyping, and experimentation roadmaps, and Joint Warfighting Concept architectures
- Program of Record (DAS portfolio) capability performance projections and schedules
- ME analyses

Outputs and Products

- Updated Mission Baseline(s)
- Initial Concept Baseline(s), including:

    - Identification of candidate concepts and alternatives that could meet the mission objectives (initial rank ordering of the most promising solutions)
    - Framing assumptions
    - Concept Design Trade Matrix
    - Concept of Operations (CONOPS), or Operational Mode Summary/Mission Profile (OMS/MP)
    - Mapping to contributing technology and prototyping/experimentation roadmaps
    - Program risk assessment (with technology development and other risk mitigation activities, appropriate affordability targets, and initial schedule basis)
    - Initial Security/Cybersecurity/Protection Assessment (identification of Critical Technical Parameters, etc.)
    - Validated reference mission threads
        - The mission, if executed, with expected forces in the future time frame. These are titled the "As-Is" mission thread(s) and should highlight or illustrate the potential gap/shortfall.
        - Alternative concept (materiel solution agnostic) mission approaches. These are titled the "To-Be" mission thread.
        - Suggested ME threads that preliminarily incorporate promising DOTMLPF-P considerations and materiel solution concepts for further analysis/refinement in the next acquisition phase.
- ME-informed Capability-Based Assessment
- ICD
- Informed DAS alternative pathway selection (quantitatively linking the mission definition, time frame, gap and potential solution maturity level to the appropriate acquisition model)
- Updated AoA study guidance that incorporates USD(R&E) and ME-based direction

Part II
Engineering Guidance for DoD Acquisition Pathways

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3 Major Capability Acquisition

Major Capability Acquisitions (MCAs) follow a process designed to support MDAPs, major systems, and other complex acquisitions. The MCA pathway includes steps to analyze, design, develop, integrate, test, evaluate, produce, and support the system. Programs tailor acquisition and product support processes, reviews, and documentation (including digital artifacts and models as representations of reality) depending on the program size, complexity, risk, urgency, and other factors. Programs may acquire software-intensive components via the Software Acquisition pathway and integrate the products and align dependencies into the MCA program.

3.1 Systems Engineering

3.1.1 Life Cycle Expectations

The SE described in this document spans the acquisition life cycle and is based on DoDD 5000.01, DoDI 5000.02; DoDI 5000.85, Major Capability Acquisition; and DoDI 5000.88. Programs should tailor the SE content to fit the technology maturity, risks, interdependencies, related characteristics, and context for the program or the system of interest. The following 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 3-1 identifies the objectives of each SE technical review or audit and the technical maturity point marked by each review. The MDD review is the entry point into the MCA process and is mandatory for all programs in accordance with DoDI 5000.85, Section 3.5.a.

Depending on the maturity of the preferred materiel solution, at the MDD review the Milestone Decision Authority officially designates the MSA phase as the entry point or may designate the entry point as Milestone B or C, as appropriate. The Milestone Decision Authority documents the decision in a signed ADM published immediately after the MDD event. Since the review milestone must be consistent with the maturity of the preferred materiel solution, entry at any milestone requires evidence of the associated solution maturity.

Department experience (e.g., GAO Report 12-400SP) demonstrates that successful programs use knowledge-based product development practices that include steps and techniques to gather and curate knowledge to confirm the program’s technologies are mature, their designs are stable, and their production processes are in control. Successful materiel developers ensure programs acquire a high level of knowledge about a system at key junctures in development.

Table 3-1. Technical Maturity Points

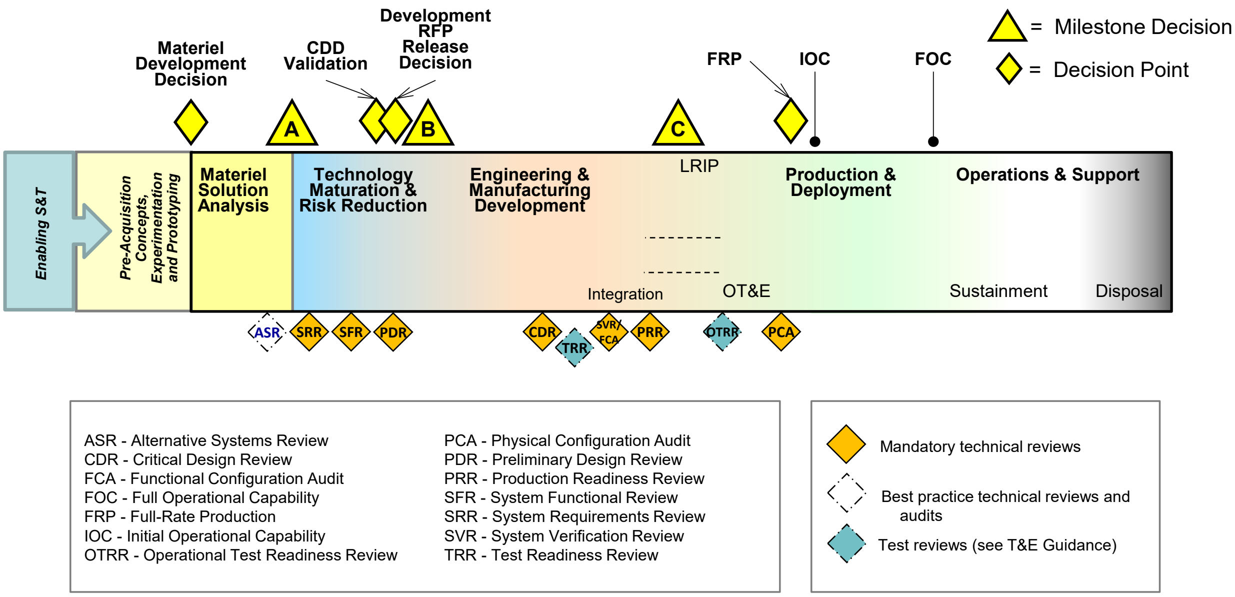
Technical Maturity Points			
DoD Acquisition Milestone/Decision Point and Technical Review/Audit	**Objective**	**Technical Maturity Point**	**Additional Information**
Materiel Development Decision (MDD)	Decision to assess potential materiel solutions and appropriate phase for entry into acquisition life 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 (e.g., assessing technical maturity and associated risks) 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. 10 USC 2366a certification, if applicable.	Affordability goals identified and technology development plans, time, funding, and other resources match customer needs. Prototyping and end-item development strategy for TMRR 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/ performance requirements is adequate to support further requirements analysis and design activities.	Government and contractor mutually understand system /performance requirements including: (1) the preferred materiel solution (including its support concept) from the MSA phase; (2) plan for technology and manufacturing maturation; and (3) maturity of interdependent systems.
System Functional Review (SFR)	Recommendation that functional baseline satisfies performance requirements and to begin preliminary design with acceptable risk.	Functional baseline established and under formal configuration control. System functions in the system performance specification decomposed and defined in specifications for lower level elements, that is, system segments and major subsystems.	Functional requirements and verification methods support achievement of performance requirements. Acceptable technical risk of achieving allocated baseline. See SE Guidebook Section 4.1.6, Configuration Management Process for a description of baselines.

Technical Maturity Points			
DoD Acquisition Milestone/Decision Point and Technical Review/Audit	**Objective**	**Technical Maturity Point**	**Additional Information**
Capability Development Document (CDD) Validation	Requirements validation authority action. Provides a basis for preliminary design activities and the PDR.	Major cost and performance trades have been completed and enough risk reduction has been completed to support a decision to commit to the set of requirements (i.e., CDD or equivalent)	Support preparation for CDD validation by performing systems engineering trade-off analysis with MOSA considerations addressing relationships of cost, requirements, design, and schedule. Once validated, a Configuration Steering Board assumes responsibility to review all requirements changes and any significant technical configuration changes for ACAT I and IA programs in development, production, and sustainment that have the potential to result in cost and schedule impacts to the program.
Preliminary Design Review (PDR)	Recommendation that allocated baseline satisfies user requirements and developer ready to begin detailed design with acceptable risk.	Allocated baseline established such that design provides sufficient confidence to proceed with detailed design. Baseline also supports 10 USC 4252 certification, if applicable.	Preliminary design and appropriate architecture products support capability need and affordability goals and/or caps achievement. For MDAPs, Secretary of Defense (SecDef) approved program cost, fielding, and performance goals are achievable. See SE Guidebook Section 4.1.6. Configuration Management Process for a description of baselines.
Development Request for Proposal (RFP) Release Decision Point	Determination that program plans are affordable and executable and that the program is ready to release RFPs for EMD or LRIP.	Systems engineering trades completed and have informed program requirements. Competitive and risk reduction prototyping and the development of the preliminary design have influenced risk management plans and should-cost initiatives.	The RFP reflects the program's plans articulated in the draft (as defined in DoDI 5000.88, Section 3.9) Acquisition Strategy and other draft, key planning documents such as the SEP, PPP, TEMP, and LCSP. The RFP also includes a MOSA Strategy that clearly describes the MOSA to be used for the program (as described in DoDI 5000.88, Section 3.7)

Technical Maturity Points			
DoD Acquisition Milestone/Decision Point and Technical Review/Audit	**Objective**	**Technical Maturity Point**	**Additional Information**
Milestone B	Decision to invest in product development, integration, and verification as well as manufacturing process development; decision on LRIP quantity.	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. Clearly define modular system interfaces between the major system platform and major system components and between major system components and modular platforms. Ensure that the MOSA strategy addresses standardized interfaces and appropriate arrangements for obtaining necessary IP rights have been addressed and implemented (as described in DoDI 5000.88, Section 3.7).
Critical Design Review (CDR)	Recommendation to start fabricating, integrating, and testing test articles with acceptable risk.	Product design is stable. Initial product baseline established.	Product baseline is initially established by the system detailed design documentation; affordability/should-cost goals confirmed. Government assumes control of initial product baseline as appropriate. See SE Guidebook Section 4.1.6. Configuration Management Process for a description of baselines.
System Verification Review (SVR)/Functional Configuration Audit (FCA)	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 FCA. See SE Guidebook Section 4.1.6. Configuration Management Process for a description of baselines.
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.

Technical Maturity Points			
DoD Acquisition Milestone/Decision Point and Technical Review/Audit	**Objective**	**Technical Maturity Point**	**Additional Information**
Milestone C and Limited Deployment Decision	Decision to produce production-representative units for OT&E and/or decision that increment of capability is ready for Limited Deployment.	Manufacturing processes are mature enough to support LRIP (and/or Limited Deployment) and generate production-representative articles for OT&E. Increment of capability has stable design.	Production readiness meets cost, schedule, and quality targets. Begin initial deployment and/or deploy increment of capability.
Physical Configuration Audit (PCA)	Recommendation to start full-rate production and/or full deployment with acceptable risk.	Product baseline established. Verifies the design and manufacturing documentation, following update of the product baseline to account for resolved OT&E issues, matches the physical configuration.	Confirmation that the system to be deployed matches the product baseline. Product configuration finalized and system meets user's needs. Conducted after OT&E issues are resolved. See SE Guidebook Section 4.1.6. Configuration Management Process for a description of baselines.
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 3-1 provides the end-to-end perspective and the integration of SE technical reviews and audits across the system life cycle.



Source: Derived from DoDI 5000.85

Figure 3-1. Major Capability Acquisition Life Cycle

The systems engineer supports the PM in developing and implementing a technical program strategy. SE processes within this technical program strategy 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 the program reaches preplanned technical maturity points during the acquisition life cycle as the system and system elements mature. The systems engineer facilitates the program's ability to achieve the entry criteria for these points by identifying and mitigating technical risks leading up to reviews and audits (see DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.)

The systems engineer should strive to ensure consistency among analyses that support key decision and transition points throughout a program's life cycle. For instance, models, simulations, tools, and data should be integrated into the SE activities and reused to the greatest extent possible (see SE Guidebook Section 2.2.1. Models and Simulations and Section 2.2.2 Digital Engineering). This knowledge forms part of the authoritative source of truth for the system (see Digital Engineering Strategy), as well as the basis for the systems engineer's recommendations to the PM regarding how to technically proceed with the program.

3.1.2 Systems of Systems and Mission Engineering

Whether or not a system is acknowledged as a system of systems (SoS), nearly all DoD systems function as part of an SoS to deliver a necessary capability to the user. SoS engineering is an ongoing, iterative process, as shown in the SoS SE implementers' view in Figure 3-2. The backbone of SoS SE implementation is a continuous ME analysis that considers changes from the broader operational mission environment as well as feedback from the ongoing engineering process.

As previously mentioned, ME is an iterative analysis and multidisciplinary activity to analyze, organize, and integrate current and emerging operational and system capabilities to achieve desired warfighting mission effects. Implementing a digital engineering technical approach at the beginning of a program's life cycle may greatly facilitate this iterative ME approach.

ME provides the quantitative basis for developing SoS architectures, evaluating contributions of constituent systems within the SoS, and guiding changes to achieve mission success. Ensuring a robust ME approach provides structure to the maturation of systems within the SoS, which are typically on different life cycle timelines, and helps ensure systems and CONOPS/OMS/MP adapt and integrate to meet the evolution of the mission.

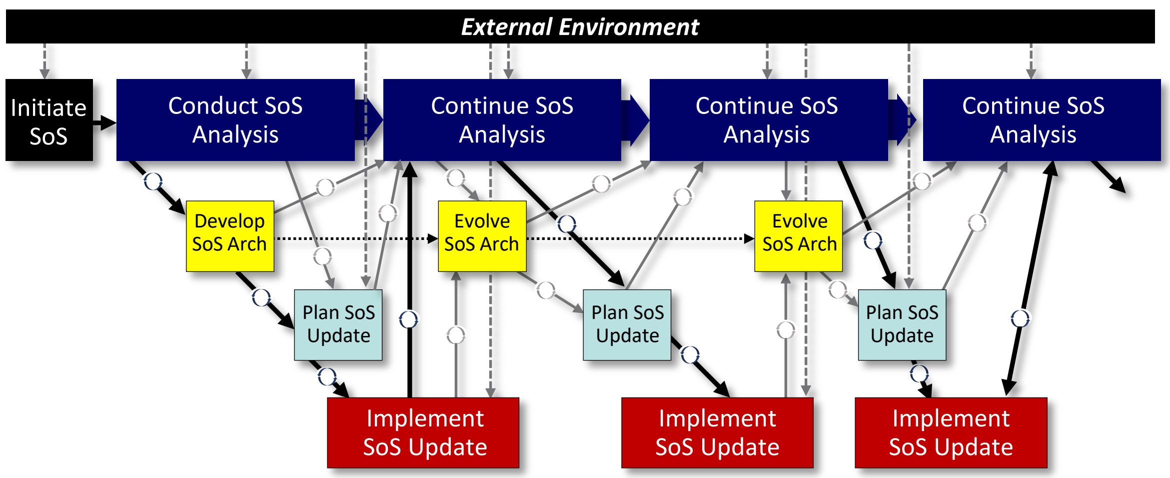


Figure 3-2. SoS SE Implementers' View

ME 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. ME planning and implementation should consider and leverage the development plans of the individual systems in order to balance SoS needs with individual system needs. ME analyses contribute to the development of an architecture and balance the technical management of the SoS. ME provides a basis for digital engineering, modeling and simulation, and MOSA to rapidly adapt as adversaries change. Refer to the SE Guidebook, Section 3, for additional information on SoS.

3.1.2.1 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, the system performs effectively in the environment. From the JCIDS Capability-Based Assessment through sustainment activities, it is important to recognize how the system context influences system requirements. An up-to-date CONOPS/OMS/MP for the system is essential 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 collaborate to ensure the program addresses SoS considerations and risks throughout the acquisition life cycle:

- Identify system dependencies and interoperability needs (see SE Guidebook, Section 5.12. Interoperability and Dependencies) through ME analysis.
- Factor these dependencies into the development of system concepts, requirements, and risks.
- Address these dependencies through trade analysis, system architecture and design, interface development and management, and verification and validation.
- Clearly define modular system interfaces between major system platform and major system components, between major system components, and between major system platforms (see DoDI 5000.88 Section 3.7).

From an individual system perspective and from the SoS perspective, PMs and systems engineers may find it difficult to balance the acquisition objectives and strategies for a given system with those of other systems.

DoD engineers have determined the following as best practice:

- Closely monitor interdependent programs, with checkpoints at scheduled design reviews to assess program progress, assess related risks, and determine actions to mitigate potentially negative impacts.
- Allow technical representatives from each system to participate in one another’s System Functional Review (SFR), Preliminary Design Review (PDR), and Critical Design Review (CDR).
- Establish a senior governance body to provide a forum for discussion and decision. This forum should address functional capabilities, technical plans, configuration management, and strategies with respect to interfaces, interdependencies, risks, and risk mitigation. It is critical that the program address all equities and make collective decisions that can be implemented as changes to a system’s configuration.

In all cases the programs should support an ME methodology (see ME Guide) to fully examine the relationships and contributions of the system and SoS relative to a mission context and in a selected mission thread(s).

Table 3-2 lists ME and 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 SEP.

Table 3-2. Key ME and SoS Considerations for Systems by Acquisition Phase

Acquisition Phase	Considerations
Pre-Materiel Development Decision (Pre-MDD)	• Role of the system in supporting a mission capability, including relationship to other systems in the SoS that support that capability • Mission architecture with various scenarios (e.g., mission thread) of capability gap in context of specified mission • Mission threads that describe the flow of tasks/activities in relationship to other systems and context • Identification of relevant Joint DOTMLPF-P • Identification of stakeholders • Provided by the ME analysis and the evidence provided at MDD
Materiel Solution Analysis (MSA)	• In the AoA, consider the alternatives in the context of the larger SoS supporting the capability; use ME processes as part of the AoA • Include a SoS context for the ME analysis that includes the preferred materiel solution: evaluate dependencies and relationships with other systems, modular system interfaces, modular systems, and technical risks based on SoS considerations to be addressed in TMRR • Identify non-materiel changes needed to implement a specific materiel solution, e.g., changes to tools, techniques and procedures to enable the SoS capability • AoA criteria or results relevant to SoS dependencies or modular system interfaces • Identify and define system dependencies and modular system interfaces that influence system requirements • Initial management plans with supporting MOAs, including draft Interface Control Agreements for collaborations with other systems in a SoS • System safety engineering activities (e.g., Physical Hazard Analysis, System Safety Management Plan, etc.) to assess materiel solutions by identifying inherent hazard risks and develop criteria to define key objectives for the System Safety Program • Risks associated with SoS dependencies (both programmatic and technical) and interoperability requirements, including system safety, environment, occupational health, and security risks to be accepted by Joint Authorities • Modeling and simulation tools to support trade space analysis and manufacturing feasibility evaluations • SoS-related requirements in draft system performance specification or pre-Milestone A RFP • MOAs with key parties in SoS dependencies or relationships
Technology Maturation and Risk Reduction (TMRR)	• 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 modular interfaces) • Address considerations of changes needed in other systems for the systems in acquisition to meet capability objectives • An interface management plan, including MOAs and a schedule, that is a part of a configuration management plan, including Interface Control Agreements • Risks associated with SoS dependencies (both programmatic and technical) and interoperability requirements, including system safety, environment, and occupational health, and security risks to be accepted by Joint Authorities • Models and simulation tools used to support early assessment of requirement trade space, performance specifications, operational suitability and affordability, and manufacturing processes • Initiation of a digital engineering ecosystem with digital artifacts to support the system’s life cycle and program decision making

Acquisition Phase	Considerations
	• Output of studies which validate the technical fit and operational suitability of the system under development within the SoS • Final interface specifications • Progress with respect to schedule and plan milestones • Progress with respect to expected performance
Engineering and Manufacturing Development (EMD)	• Develop, verify, and validate the detailed design that addresses system requirements, considering the SoS context including recognized dependencies and modular system interfaces • Interface documentation, digital artifacts, test plans and test reports • Update to MOAs with system's dependencies • Risks associated with SoS dependencies (both programmatic and technical) and interoperability requirements, including system safety, environment, and occupational health, and security risks to be accepted by Joint Authorities • Digital engineering ecosystem and implementation plan (models, simulations, etc.) to support concurrent and collaborative engineering, reduce defects and rework costs, accelerate the development schedule, improve system design, and software reliability and quality • Successful development and test of interfaces • Verification and compliance of modular system interfaces with widely supported and consensus-based standards (if available and suitable) • Progress with respect to SoS schedule and plan milestones • Progress with respect to expected performance
Production and Deployment (P&D) and Operations and Support (O&S)	• Verify the as-built system and interdependent systems' interfaces meet standards and specifications and support operational needs • Support effective system operation in a SoS context • Test reports • Digital artifacts (models, simulations, etc.) reflect the production configuration to rapidly evaluate changing threats, explore solution space, and support design reuse • Mature digital engineering ecosystem to support future system enhancements and upgrades, sustainment activities, decision making, and assessments such as mission engineering

3.1.3 Systems Engineering Activities in Life Cycle Phases

This section describes the objectives and technical activities typically performed in each of the five life cycle phases of the MCA pathway (MSA, TMRR, EMD, Production and Deployment (P&D), and Operations and Support (O&S)). For each phase, the description includes the roles and responsibilities of a systems engineer in the program office, inputs normally required to constrain the technical activities, activities the systems engineer performs, and outputs and products of the phase. Although this section mentions technical reviews and audits, more details are covered in the SE Guidebook Section 3, Technical Reviews and Audits.

3.1.3.1 Materiel Solution Analysis Phase

The objective of the 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. Before completing the MSA Phase, the Component Acquisition Executive (CAE) selects a PM and establishes a program office to complete the necessary actions associated with planning the acquisition program. Usually, but not always, the next milestone is a decision to invest in technology maturation, risk reduction activities, and preliminary design in the TMRR phase. During the MSA phase the SE team develops several products including the following:

- A system model or architecture that captures operational context and envisioned concepts, describes the system boundaries and interfaces, and addresses operational and functional requirements
- Foundation of the program's digital engineering ecosystem
- Preliminary system performance specification that defines the performance of the preferred materiel solution
- Advice to the PM regarding what components of the system should be prototyped, why, and how

The MSA phase has two major blocks of activity: (1) the AoA led by the Director, Cost Assessment and Program Evaluation and conducted by a designated DoD Component and (2) the post-AoA operational analysis and concept engineering to prepare for a next program milestone designated by the Milestone Decision Authority (Figure 3-3).

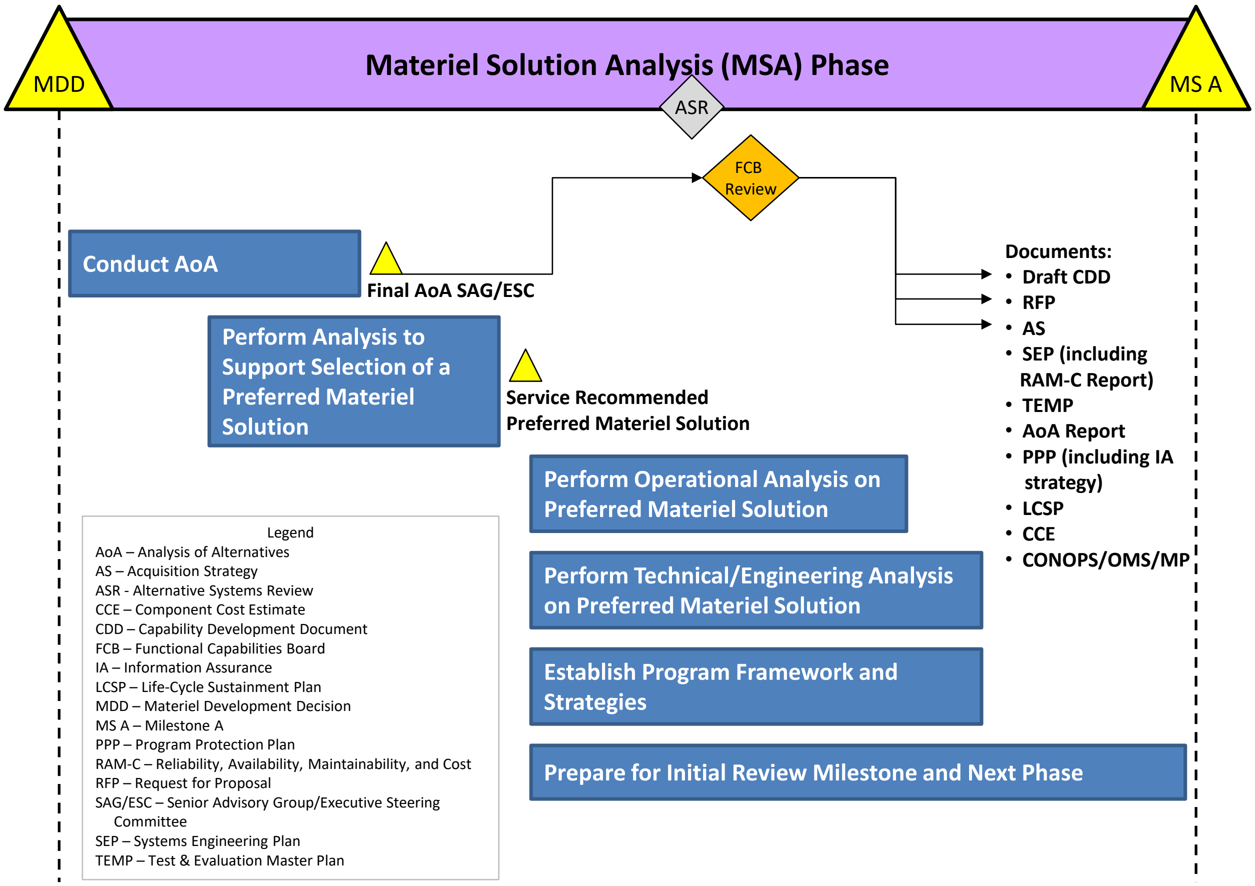


Figure 3-3. Activities in Materiel Solution Analysis Phase

During the MSA phase, the program team identifies a materiel solution to address current and evolving user capability gaps partially based on the AoA. Once the Service sponsor selects a preferred materiel solution, the program team prepares for the next life cycle phase by focusing engineering and technical analysis on this solution to ensure the development plans, schedule, funding, and other resources match customer needs and the complexity of the preferred materiel solution. The program should integrate SE activities with MSA phase-specific test, evaluation, logistics, and sustainment activities identified in the T&E Enterprise Guidebook (2022) and the Product Support Manager Guidebook (2022).

The AoA team considers a range of alternatives and evaluates them from multiple perspectives as directed by the AoA Guidance and AoA Study Plan. The guidance and plan should address engineering considerations including technical risk. For MDAPs, the guidance and plan also should include considerations of evolutionary acquisition, digital engineering, prototyping, and MOSA, pursuant to 10 USC 4402.(b).

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 should participate in the AoA to conduct ME activities as indicated in the

ME Guide, including analyzing the impact of performance, technology, and manufacturing feasibility on mission efficacy.

Using the AoA results, the Service sponsor may conduct additional engineering analysis to support the selection of a preferred materiel solution. As the Milestone Decision Authority selects preferred solutions, the Service sponsor will further mature them in preparation for the next program milestone. After the AoA, systems engineers establish the technical performance requirements consistent with the draft Capability Development Document (CDD), required at the next program milestone designated by the Milestone Decision Authority. These requirements form the basis for the system performance specification placed on contract for the TMRR phase; they also inform plans to mitigate risk in the TMRR phase.

In the MSA phase, the DoD Component combat developer (e.g., requirements manager) prepares a CONOPS/OMS/MP, consistent with the validated/approved capability requirements document, typically an ICD. The CONOPS/OMS/MP includes the operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel solution is to perform each mission and each phase of a mission. The CONOPS/OMS/MP informs the MSA phase activities and the development of plans for the next phase.

During MSA, the program addresses several planning elements to frame the way forward for the Milestone Decision Authority's decision at the next program milestone. SE is a primary source for addressing several of these planning elements (see SE Guidebook Section 4.1.1. Technical Planning Process):

- Capability need, architecture
- System concept, architecture
- Modular system interfaces
- Acquisition approach
- Engineering/technical approach
- Program protection approach
- Manufacturing and quality (M&Q) approach
- Test and evaluation (T&E) approach
- Program management approach
- External dependencies/agreements
- Schedule
- Resources
- Risks

The program documents the plans in the Acquisition Strategy, TEMP, PPP, next-phase RFP, and the SEP. The SEP describes the SE efforts necessary to provide informed advice to these other planning artifacts (see SEP Outline).

SE provides, for example, the technical basis for TMRR phase planning and execution, including identification of critical technologies, development of a competitive and risk reduction prototyping strategy to include physical and digital prototyping considerations, and establishment of other plans that drive risk reduction efforts. This early SE effort lays the foundation for the TMRR phase contract award(s) and preliminary designs, which confirm the system's architecture. The program should consider conducting the TMRR activities within a digital engineering ecosystem, which will facilitate the digital infrastructure to transfer into the program of record activities.

Roles and Responsibilities

In addition to the general responsibilities identified in SE Guidebook Section 2.3, Engineering Resources, the PM is responsible for 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 the development of the draft CDD, assuming the next phase is TMRR.
- Develop the Acquisition Strategy, 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 SE Guidebook Section 2.3, 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 the system's technical maturity using digital artifacts, techniques, and the authoritative source of truth, when possible.
- Identify technologies that should be included in an assessment of technical risk.
- Perform trade studies.
- Support preparations for the RFP package and assist in structuring the evaluation teams for technical aspects of the review.
- Develop the system performance specification. See SE Guidebook Section 4.1.6, Configuration Management Process. The SEP and other plans should capture a particular program's naming convention for specifications.
- 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 3-3 summarizes the primary inputs associated with this part of the life cycle (see DoDI 5000.85, Section 3.6). The table assumes the next phase is TMRR, but most of the technical outputs would be applicable going into any follow-on phase.

Table 3-3. Inputs Associated with MSA Phase

Inputs for MSA Phase
ICD or equivalent (See CJCSI 5123): • Product of a Capability-Based Assessment or equivalent
VOLT Report (See AAFDIT and Intelligence Support Guidebook (2021).)
AoA Guidance and AoA Study Plan (See AoA Handbook (2021).)
ADM (may contain additional direction)
Other analyses generated pre-MDD 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 Results of market research: (1) to identify existing technologies and products; and (2) to understand potential solutions, technologies, and sources

The ICD, AoA Guidance, and AoA Study Plan should be available before the start of the MSA phase. Results of other related analyses may be available, for example, from the Capability-Based Assessment (see SE Guidebook Section 4.2.1. Stakeholder Requirements Definition Process) or other prior analytic or prototyping efforts conducted by the S&T community.

Activities

The MSA phase activities begin after a favorable MDD review (see Section 2. Pre-Materiel Development Decision Engineering) and end when the program meets the phase-specific entrance criteria for the next program milestone, designated by the Milestone Decision Authority.

The major blocks of technical activities in the MSA phase include the following:

- **Conduct AoA.** Includes all activities and analyses conducted by the AoA Study team under the direction of the Senior Advisory Group/Executive Steering Committee and Cost Assessment and Program Evaluation, or Service equivalent. Concludes with a final Senior Advisory Group/Executive Steering Committee and AoA Report. Systems engineers should support this activity.

- **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 review, and the development of the draft CDD (see CJCSI 5123 JCIDS and SE Guidebook Section 4.2.1. Stakeholders Requirements Definition Process). The systems engineer should support the operational requirement/user/operational test community to ensure the CONOPS/OMS/MP 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 modular system interfaces and establish interoperability requirements.
- **Perform Engineering and Technical Analysis on Preferred Materiel Solution.** 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 performance specification, and technical plans for the next phase.
- **Establish Program Framework and Strategies.** Assumes all activities converge on the overarching strategies and plans for the acquisition of the system. Includes 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 Milestone Decision Authority. See DoDI 5000.85, Section 3.6 for phase objectives and exit criteria.

During the MSA phase the typical program review is the Alternative Systems Review (ASR) (see SE Guidebook Section 3.1. Alternative Systems Review).

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 matches user needs and is affordable with reasonable risk (Table 3-4).

Table 3-4. Technical Outputs Associated with MSA Phase

Technical Outputs from MSA Phase
Informed advice to the draft CDD
Informed advice to ADM and, when applicable, 10 USC 2366a certification
Informed advice to the AoA Report (See AoA Handbook (2021))
Informed advice to the selection of the preferred materiel solution • Selection of the preferred materiel solution is documented in the ADM
SEP (See DoDI 5000.88, Section 3.4.a. and SE Guidebook Section 1.5. Systems Engineering Plan)
M&Q Plans (See SE Guidebook Section 5.14) • Attached to SEP
RAM-C Report (See DoDI 5000.88, Section 3.6.b and SE Guidebook Section 5.18.) • Attachment to SEP
RGC (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18.) • Included in SEP
PPP (See DoDI 5000.83, Section 3.4.c. and T&PP Guidebook (2022).)
Trade-off analysis 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
System safety engineering program and management planning, preliminary hazard analysis, HTS (See DoDI 5000.88, Section 3.6.e. and SE Guidebook Section 5.23.)
Digital engineering ecosystem planning
Model/simulation plans and initial set of digital artifacts
ESOH planning (See DoDI 5000.88, Section 3.6.e. and SE Guidebook Section 5.23.)
Assessment of technical risk and development of mitigation plans (See SE Guidebook Section 4.1.5. and the DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.)
Manufacturing readiness (See DoDI 5000.88, Section 3.6.c. and SE Guidebook Section 5.14.5.) • Assessment of manufacturing feasibility and capability to produce in a lab environment • Ensure M&Q are in place and able to produce prototypes in TMRR phase
Consideration of technology issues
Initial identification of critical technologies
Interdependencies/interfaces/MOAs • Understanding of the unique program interdependencies, modular system interfaces, and associated MOAs
LMDP for IMD-dependent programs (See SE Guidebook Section 5.11. Intelligence (Life Cycle Mission Data Plan) and Intelligence Support Guidebook (2021)) • Initial LMDP
Draft system performance specification

Technical Outputs from MSA Phase
Other technical information generated during the MSA phase: • Architectures, system digital artifacts (models, simulations, etc.) • Results of market research: 1) to identify existing technologies and products; and 2) to understand potential solutions, technologies, and sources appropriate for maturing the product in the next phase
Prototyping strategy (See DoDI 5000.85, Section 3.8 and the AAFDIT, Acquisition Strategy)) • Relationship between draft system performance specification and prototyping objectives is established and plans for next phase are consistent with it, both from a prototyping and preliminary system design perspective • Includes identification of key system elements to be prototyped before Milestone B • Documented in the Acquisition Strategy
Informed advice to Affordability and Resource Estimates (See SE Guidebook Section 2.2.7. Value Engineering, PM Guidebooks (2022), and AoA Handbook (2021)) • Affordability goals are established and treated as KPPs at the next program milestone designated by the Milestone Decision Authority • Identify the likely design performance points where trade-off analyses occur during the next phase • Value engineering results, as appropriate
Informed advice to the SecDef approved program goals (See AAFDIT)
Informed advice to the LCSP (See Product Support Manager Guidebook (2022))
Informed advice to the TEMP (See T&E Enterprise Guidebook (2022))
Informed advice to the DMSMS Management Plan
Informed advice to the SCG
Informed advice to the DT&E planning including EOAs (See T&E Enterprise Guidebook (2022))
Informed advice to the RFP • Informed advice including system performance specification, SOW, CDRLs, and source selection criteria
Informed advice to the Acquisition Strategy (See PM Guidebooks (2022)) • Informed advice on engineering approaches and strategies, external dependencies, resource requirements, schedule and risks
Informed advice for the Spectrum Supportability Risk Assessment (See DoDI 4650.01 and SE Guidebook Section 5.19.)

3.1.3.2 Technology Maturation and Risk Reduction Phase

The primary objective of the TMRR phase is to reduce technical risk and develop a sufficient understanding of the materiel solution to support sound investment decisions at the pre-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 (Figure 3-4). Usually the systems engineer implements a strategy of 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 prototyping may include physical or digital prototypes, and the objectives should focus on risk reduction or competition.

The major efforts associated with the TMRR phase are:

- Determine the appropriate set of technologies to integrate into a full system.
- Mature the technologies and their associated representation in digital models and simulations, including demonstrating and assessing them in a relevant environment.
- Conduct prototyping of the system 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 activities as appropriate.
- Develop a digital engineering ecosystem to transfer into the program of record.

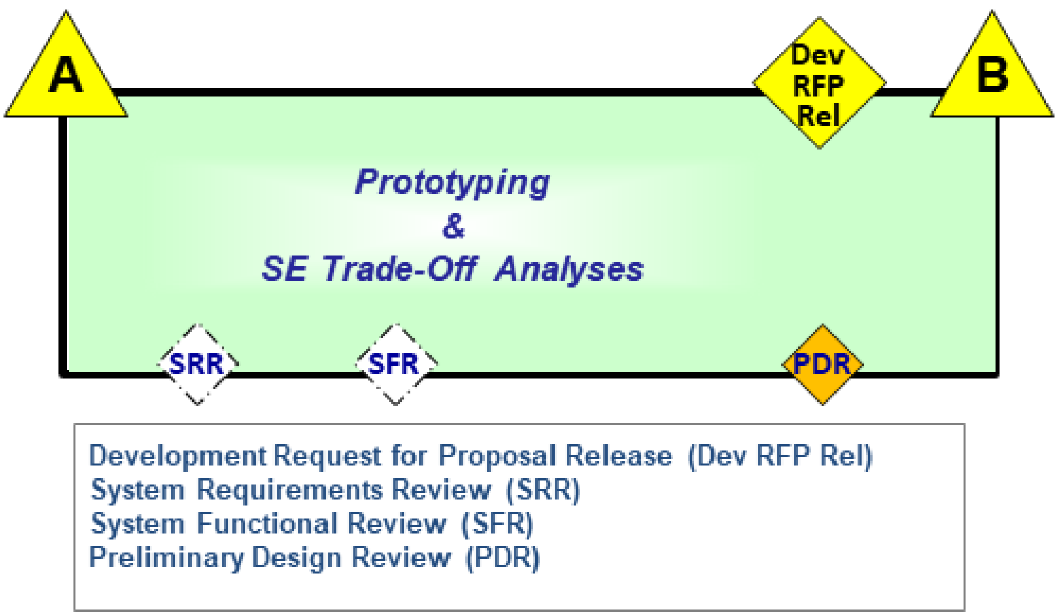


Figure 3-4. Systems Engineering Activities in the TMRR Phase

SE activities should be integrated with TMRR phase-specific T&E and logistics and sustainment activities identified in T&E Enterprise Guidebook (2022) and Product Support Manager Guidebook (2022), respectively.

During the TMRR phase, the program develops and demonstrates prototype designs to reduce technical risk, validate design approaches, validate cost estimates, and refine requirements. In addition, the TMRR 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 ICD, the Acquisition Strategy, the SEP, and the CDD guide the efforts of this phase. The CDD enters the TMRR phase as a draft (as described in the AAFDIT and CJCSI 5123.01I) and is validated during this phase to support preliminary design activities and the PDR.

The TMRR phase includes two key technical objectives: technical risk reduction and initial system development activity, culminating in preliminary design. In the TMRR phase the systems engineer manages activities to evaluate prototyped solutions (competitive and risk reduction 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 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 TMRR phase provides the PM with a preliminary design and allocated baseline that are realistic and credible. The TMRR phase also provides the opportunity to establish the technical planning and digital engineering ecosystem needed during the design and development phase.

Roles and Responsibilities

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

In addition to the general responsibilities identified in SE Guidebook Section 2.3 Engineering Resources, the PM focuses on the following TMRR activities, which rely on and support SE efforts:

- Awarding TMRR phase contract(s).
- Providing resources for technical reviews.
- Planning and executing the Technology Readiness Assessment (TRA) (MDAPs only).
- Influencing development of the CDD.
- Developing the Acquisition Strategy.
- Developing the strategy and objectives for use of prototypes; considering both contracted efforts and Government sources.
- Establishing the foundation for the program’s digital engineering ecosystem.
- Supporting the Development RFP Release Decision Point.
- Ensuring the Government preserves the rights needed to be consistent with the life cycle acquisition and support strategy. During TMRR, proprietary development and design can

often lead to issues with intellectual property and associated data rights (see SE Guidebook Section 4.1.7. Technical Data Management Process).

- Supporting the Configuration Steering Board in accordance with DoDI 5000.88, Appendix 3C.3.e. once the CDD has been validated. This board assumes responsibility to review all requirements changes and any significant technical configuration changes for ACAT I and IA programs in development, production, and sustainment that have the potential to result in cost and schedule impacts to the program.

In addition to the general roles and responsibilities described in SE Guidebook Section 2.3. 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.
- Establish a digital engineering ecosystem to support the design, development, test, and verification activities during the life cycle of the program.
- Plan and execute technical reviews, including the SRR, SFR, and PDR.
- Measure and track program maturity using Technical Performance Measures, requirements stability, and integrated schedules.
- Support award of TMRR phase contract(s), as necessary.
- Balance and integrate key design considerations.
- Maintain the SEP, including generating the update in support of Milestone B.
- Lead the initial development of the system including functional analysis, definition of the functional and allocated baselines, and preliminary design (see SE Guidebook Section 4.2.2. Requirements Analysis Process and SE Guidebook Section 4.2.3. Architecture Design Process).
- Ensure digital artifacts (models and simulations, etc.) are properly managed and controlled as part of the program's technical baseline.
- 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 Development RFP Release Decision Point.
- Conduct a rigorous and persistent assessment of technical risk, determine risk mitigation plans, and work with the PM to resource the mitigation plans.
- Develop the plan to proactively manage and mitigate Parts Management and Diminishing Manufacturing Sources and Material Shortages (DMSMS) issues across the life cycle and identify technical data needs to support parts and DMSMS risk mitigation. Include DMSMS resilience considerations in preliminary and build-to-print designs.

- Support the TRA including creation of the plan, the pre-EMD preliminary TRA, and the TRA final report (MDAPs only).
- Support requirements management, and monitor for unnecessary requirements growth (e.g., derived versus implied requirements).
- Manage all interfaces and dependencies.
- Maintain oversight of the system (software and hardware) development processes, system testing, documentation updates, and tracking of the system development efforts.
- Support the PM's interactions with the Configuration Steering Board.
- Support execution of the system safety engineering program.

Inputs

Table 3-5 summarizes the primary inputs associated with the TMRR phase.

Table 3-5. Inputs Associated with TMRR Phase

Inputs for TMRR Phase
DoD Component combat developer (e.g., requirements manager) provides: • Draft CDD • CONOPS/OMS/MP
AoA Report and AoA Sufficiency Report (See AoA Handbook (2021))
Preferred materiel solution • Selection of preferred materiel solution is documented in the ADM
ADM (may contain additional direction)
SEP (See DoDI 5000.88, Section 3.4.a. and SE Guidebook Section 1.5. Systems Engineering Plan)
M&Q Plans (See SE Guidebook Section 6.14) • Attached to SEP
RAM-C Report (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18.) • Attachment to SEP
RGCs (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18.) • Included in SEP
PPP (See DoDI 5000.83, Section 3.4.c. and T&PP Guidebook (2022))
Trade-off analysis results • Results could include knee-in-the-curve sensitivity analyses, product selections, results of automation trades, etc.
Assumptions and constraints • Rationale for all assumptions, constraints and basis for trades
Digital engineering ecosystem planning
Digital artifacts (e.g., models, simulations, etc.)
System safety engineering and management planning (See DoDI 5000.88, Section 3.6.e. and SE Guidebook Section 5.23.)

Inputs for TMRR Phase
ESOH planning (See DoDI 5000.88, Section 3.6.e. and SE Guidebook Section 5.23.)
Risk assessment (See SE Guidebook Section 5.1.5. and Section 6.14.5) • Key risks identified at Milestone A guide TMRR phase activities
Consideration of technology issues
Initial identification of critical technologies • MSA phase may have identified an initial list of critical technologies
Interdependencies/interfaces/MOAs
LMDP for IMD-dependent programs (See SE Guidebook Section 5.11. Intelligence (Life Cycle Mission Data Plan) and Intelligence Support Guidebook (2021))
Draft system performance specification
Other technical information generated during the MSA phase • Architectures, system models and simulations • Results of Market Research: 1) to identify existing technologies and products; and 2) to understand potential solutions, technologies, and sources appropriate for maturing the product in this phase
Prototyping strategy (See DoDI 5000.85, Appendix 3C.3.a. and AAFDIT, Acquisition Strategy)) • Includes identification of key system elements to be prototyped before Milestone B
VOLT Report (See AAFDIT) and Intelligence Support Guidebook (2021))
Affordability Assessment (See PM Guidebooks (2022). and SE Guidebook Section 5.2.) • Affordability goals are established and treated as a KPP at Milestone A • Affordability goals drive TMRR phase engineering trade-offs and sensitivity analyses about capability priorities • MDAPs have SecDef approved program goals at Milestone A
Acquisition Strategy(See PM Guidebooks (2022))
LCSP (See Product Support Manager Guidebook (2022))
DMSMS Management Plan (See DoDI 4245.15)
TEMP (See T&E Enterprise Guidebook (2022))
Draft and final RFP
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
Spectrum Supportability Risk Assessment (See DoDI 4650.01 and SE Guidebook Section 5.19.)

Activities

The TMRR phase activities begin with a favorable Milestone A decision (see Section 3.1.3.1. Materiel Solution Analysis Phase) and end with a successful Milestone B decision.

The TMRR phase addresses a set of critical activities leading to the decision to establish a program of record. The SE activities aim to reduce technical risk and 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 TMRR phase, systems engineers follow comprehensive, iterative processes to accomplish the following:

- **Mature the Technologies.** The Acquisition Strategy identifies technologies requiring further maturation before they can be implemented within a solution. Technology maturation involves design, development, integration, and testing. The technologies could present one or more risk areas related to hardware, software, or information technology, and there may be multiple industry contracts or Government efforts for maturing the technology. The TEMP should stipulate the T&E approach for assessing the results of the technology maturation activities (see T&E Enterprise Guidebook (2022)). The systems engineer participates in the TRA. The TRA focuses only on technology maturity as opposed to engineering and integration risk (see DoD TRA Guidance).
- **Perform Prototyping.** Prototyping is an engineering technique employed for several reasons: to reduce risk, inform requirements, and encourage competition. For example, the primary objective for competitive prototyping is to acquire more innovative solutions at better value by ensuring competition. Competitive prototyping is addressed in statute for MDAPs (see P.L. 114-92 (Section 822 para (c))). Other prototypes should be considered if they materially reduce engineering and manufacturing development risk at an acceptable cost.

  At this point in the life cycle, the competitive prototyping 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 with competitive prototyping strategy goals. These goals most often emphasize cost, schedule, and performance realism and quantification but may also consider a contractor's digital engineering approach and implementation. Contract goals should require that the contractor use the solutions demonstrated during competitive prototyping in the subsequent PDR and CDR designs.

  The competitive prototyping strategy should be identified in the SEP and Acquisition Strategy and related tasks specified in RFPs and Task Orders. The program office should manage the strategy and include it in the TEMP with specific test objectives. Risk reduction prototypes can be at the system level or can focus on technologies, subcomponents, or components and may or may not include objectives associated with competitive contracts. In nearly all cases, prototypes can be extremely useful in assessing technical performance, supporting trade studies, and updating requirements. Using a digital engineering and model-based systems engineering (MBSE) approach assists with this endeavor.

- **Perform System Trade Analysis.** The systems engineer assesses alternatives with respect to performance, cost, schedule, and risk, and makes a recommendation to the PM. The SE assessment should consider the full range of relevant factors, for example, affordability goals and caps, technology maturity, development and deployment constraints, modular open system approaches (MOSA), 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 SE Guidebook Section 4.2.3. Architecture Design Process for additional information.
- **Develop Functional Baseline.** See SE Guidebook Section 4.1.6. Configuration Management Process for additional information.
- **Develop Allocated Baseline.** See SE Guidebook Section 4.1.6. Configuration Management Process for additional information.
- **Develop Preliminary Design(s).** May involve competitive, preliminary design activities up to and including PDRs. See SE Guidebook Section 3.4. Preliminary Design Review for additional information.
- **Develop Allocated Technical Performance Measures.** The allocated baseline establishes the first physical and digital representation of the system as system elements with system-level capabilities allocated to system element-level Technical Performance Measures.
- **Support CDD Validation.** The purpose of this support is to inform the Milestone Decision Authority and requirements validation authority about the technical feasibility, affordability, and testability of the proposed requirements. The CDD (or an equivalent requirements document) forms a basis for the set of requirements used for design activities, development, and production. Systems engineers carefully consider trade-off analysis, showing how cost varies as a function of system requirements (including Key Performance Parameters), major design parameters, and schedule. The results of trade-off analyses should identify major affordability drivers.
- **Support Development RFP Release Decision Point.** The purpose of the Milestone Decision Authority-level review is to assess the Acquisition Strategy, RFP, and key related planning documents and determine whether program plans are affordable and executable and reflect sound business arrangements. Systems engineers consider engineering trades and their relationship to program requirements and risk management. Typically, this decision point occurs after PDR to allow for feedback from the PDR into the technical aspects of the RFP. The Development RFP Release event can come before the PDR if the decision authority is confident the RFP will not need substantial changes.

- **Finalize Documents.** The systems engineer updates the SEP and PPP and provides input for updating the LCSP, TEMP, and other program documents.

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. A method for doing this is to identify technical risks associated with achieving entrance criteria at each of these points (see DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs). Technical reviews typically conducted in the TMRR phase are:

- **System Requirements Review (SRR)** (see SE Guidebook Section 3.2. System Requirements Review).
- **System Functional Review (SFR)** (see SE Guidebook Section 3.3. System Functional Review).
- **Software Specification Review (SSR)** for programs with significant software development; a program typically performs the SSR 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 SE Guidebook Section 3.4. Preliminary Design Review).

TMRR phase test activities that depend on SE support and involvement include DT&E of the system or system element prototypes and Early Operational Assessments (EOAs). For example, the engineering and test communities should coordinate closely on DT&E activities as these activities support:

- Technical risk identification, risk assessment, and risk mitigation
- Providing empirical data to validate models and simulations
- Assessing technical performance and system maturity (see T&E Enterprise Guidebook)

Outputs and Products

Table 3-6 identifies some of the TMRR technical outputs necessary to support SE activities in the following 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 document.

Table 3-6. Technical Outputs Associated with TMRR Phase

Technical Outputs from TMRR Phase
Informed advice to the ADM and, when applicable, 10 USC 4252 certification • For MDAPs that use MOSA, see Section 3.4.
Preliminary system design • Updated functional and allocated baselines • Associated technical products including associated design and management decisions
SEP (updated) (See DoDI 5000.88, Section 3.4.a., and SE Guidebook Section 1.5. Systems Engineering Plan) • If programs enter the acquisition life cycle at Milestone B, this is their initial SEP
Updated Integrated Master Plan (IMP), Integrated Master Schedule (IMS) and MOAs/ memorandums of understanding (MOUs)
RAM-C Report (updated) (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18.) • Attachment to SEP • If programs enter the acquisition life cycle at Milestone B, this is their initial RAM-C Report
RGC (updated) (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18.) • Included in SEP and TEMP
PPP (updated) (See DoDI 5000.83, Section 3.4.c. and T&PP Guidebook (2022)) • If programs enter the acquisition life cycle at Milestone B, this is their initial PPP
Trade-off analysis results • Updated results could include knees-in-the-curves sensitivity analyses, product selections, etc. • Updated results of automation trades: Informed advice for automation levels as related to system architecture or software and personnel cost trades • Informed advice for CDD validation; showing how cost varies as a function of system requirements (including KPPs), major design parameters and schedule; identify major affordability drivers
Assumptions and constraints • Rationale for all assumptions, constraints and basis for trades • Interdependencies defined
Digital engineering ecosystem established
System safety hazard analyses (See DoDI 5000.88, Section 3.6.e. • Preliminary Hazard List/Analysis • Functional Hazard Analysis
Environment, safety and occupational health (ESOH) analyses (See DoDI 5000.88, Section 3.6.e. • Programmatic Environment, Safety and Occupational Health Evaluation (PESHE) and NEPA/EO 12114 Compliance Schedule
Assessment of technical risk (See SE Guidebook Section 4.1.5. and the DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.) • Ensure key risks are adequately mitigated before exiting the TMRR phase • Include SoS risks associated with governance, interdependencies and complexity
Manufacturing readiness (See DoDI 5000.88, Section 3.6.c. and SE Guidebook Section 5.14.5.) • Assess contractor’s manufacturing capability to produce in a production relevant environment • Manufacturing processes have been defined and characterized • Manufacturing processes have been demonstrated in a production-relevant environment

Technical Outputs from TMRR Phase
Consideration of technology issues
TRA (MDAPs only) (See AAFDIT) • TRA Plan • Confirmation at the end of TMRR phase that critical technologies have been demonstrated in a relevant environment • Preliminary TRA required at Development RFP Release Decision Point • TRA final report
Interdependencies/interfaces/MOAs • Understanding of the unique program interdependencies, all modular system interfaces and associated MOAs
LMDP for IMD-dependent programs (updated) (See Intelligence Support Guidebook (2021) and SE Guidebook Section 5.11. Intelligence (Life Cycle Mission Data Plan))
Updated system performance specification
System preliminary design including functional baseline and allocated baseline
Other technical information generated during the TMRR phase • Architectures, system models and simulations • Results of Market Research: 1) to identify existing technologies and products; and 2) to understand potential solutions, technologies and sources appropriate for maturing the product in the next phase
Prototyping strategy and results of TMRR prototyping activities • Including identification of key system elements to be prototyped in EMD Phase and documented in the Acquisition Strategy
PDR assessment (See DoDI 5000.88, Section 3.5.a., and SE Guidebook Section 3.4.) • For ACAT ID programs, USD(R&E) performs the assessment to inform the Milestone Decision Authority • For ACAT IC and IB programs, the CAE conducts the PDR assessment
Informed advice to 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 documentation (See AoA Handbook (2021) and HSI Guidebook (2022))
Informed advice to Affordability and Resource Estimates (See SE Guidebook Section 2.2.7. Value Engineering, SE Guidebook Section 5.2. Affordability – Systems Engineering Trade-Off Analyses, PM Guidebooks (2022). and AoA Guidebook) • Affordability caps 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 • For MDAPs, provide informed advice to SecDef approved program goals
Informed advice to Acquisition Strategy (See PM Guidebooks (2022)) • Informed advice on engineering approaches and strategies, external dependencies, resource requirements, schedule, and risks
Informed advice to LCSP (updated) (See Product Support Manager Guidebook (2022)) • System support and maintenance objectives and requirements established; updated will-cost values and affordability goals and caps as documented in the LCSP, including Informed advice to manpower documentation

Technical Outputs from TMRR Phase
Informed advice to DMSMS Management Plan (updated)
Initial ISP (See Digital Capabilities Guidebook (2022))
Informed advice to TEMP (See T&E Enterprise Guidebook (2022))
Early DT&E assessments, including EOAs (See T&E Enterprise Guidebook (2022))
Informed advice to draft and final Development RFP • Informed advice including system performance specification, SOW, CDRLs and source selection criteria • Support preparation for Development RFP Release Decision Point
Informed advice for the Spectrum Supportability Risk Assessment (See DoDI 4650.01 and SE Guidebook Section 5.19.)
Informed advice for Waveform Assessment Application (See DoDI 4630.09)

3.1.3.3 Engineering and Manufacturing Development Phase

The primary objective of the EMD phase is to develop the initial product baseline, verify it meets the functional and allocated baselines, and transform the preliminary design into a producible design, all within the schedule and cost constraints of the program. The program establishes the initial product baseline at the CDR, at which point the program first puts the product baseline under formal official configuration control.

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 or deployment (Figure 3-5).

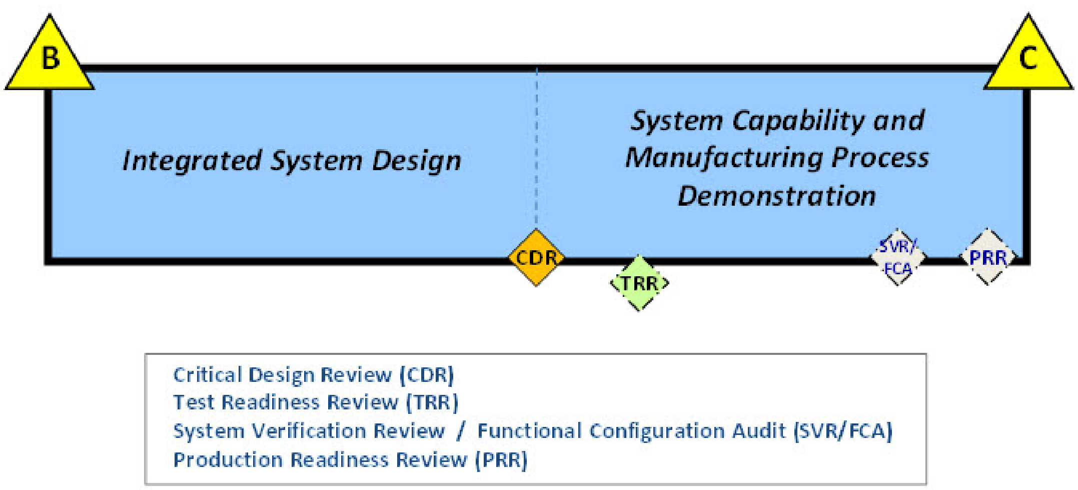


Figure 3-5. Systems Engineering Activities in the Engineering and Manufacturing Development Phase

Primary SE focus areas in EMD include:

- Completing the detailed build-to design of the system.
- Establishing the initial product baseline.
- Conducting the integration and tests of system elements and the system (where feasible).
- Demonstrating 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 to effectively manage risks and increase confidence in meeting system performance, schedule, and cost goals. SE activities should be integrated with EMD phase-specific T&E and with the logistics and sustainment activities identified in the T&E Enterprise Guidebook (2022) and Product Support Manager Guidebook (2022), respectively. The planning, scheduling, and conduct of event-driven technical reviews (CDR, System Verification Review (SVR)/ FCA, and Production Readiness Review (PRR)) are vital to provide key points for assessing system maturity and the effectiveness of risk-reduction strategies.

A well-planned EMD phase SEP builds on the results of previous activities and significantly increases the likelihood of a successful program compliant with the approved APB.

Programs should use digital artifacts (models, simulations, etc.) to support informed, data-driven decisions throughout a program's life cycle. During EMD, a program matures and implements the digital engineering environment formed during the TMRR phase. Using a digital system model can help ensure consistency and integration among SE and analytical tools and can provide the program with a capability to assess potential design changes or system upgrades throughout the life cycle. The digital environment supports collaboration among program participants and enables stakeholders to interact with digital tools and technologies. Model and simulation tools developed in early acquisition phases may be repurposed for activities during later phases (e.g., engineering models can be used in training simulations).

A digital engineering acquisition framework is the set of disciplined, collaborative processes and systems that plan for, acquire, and control an interoperable flow of product definition data and product configuration information. The information includes SE, product engineering, design, test, procurement, manufacturing planning, operational, maintenance, and sustainment information throughout the product and data life cycles. The framework defines and incorporates the associated information used to manage, execute, and curate the life cycle of product data from its conception through design, test, and manufacturing to service and eventual disposal. The framework integrates definition and product development data, processes (elements), tools, and business and analytical systems to provide users with a digital product information backbone for defining product configuration information in support of programs.

The program should develop digital artifacts (models, and simulations, etc.) including metadata and widely supported and consensus-based standards (if available and suitable) to maximize opportunity for reuse and repurposing (both within the program and in support of other acquisition efforts). The artifacts need to be properly managed and controlled as part of the program's technical baseline and should be included as part of the technical data package to be transitioned into the next life cycle phase or into other efforts. Models, data, and 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.

During EMD, the program should consider developing a digital twin of the system under development. A digital twin is a virtual representation (model) that serves as the real-time digital counterpart of a physical object or process. It is also the conceptual model underlying product life cycle management and creates opportunities to achieve higher productivity and rapid design changes or enhancements during the P&D phase.

The Limited Deployment Decisions are the points at which an increment of capability is reviewed to deploy a limited number of assets to the field. Approval depends in part on specific criteria defined at Milestone B and included in the Milestone B ADM. 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 DT&E activities. The SEP also highlights the linkage among the 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 P&D phase.

Roles and Responsibilities

In addition to the general responsibilities identified in SE Guidebook Section 2.3. Engineering Resources, the PM focuses on the following EMD activities, which rely on and support SE efforts:

- Conducting activities to support the EMD contract award.
- Resourcing and conducting event-driven CDR, FCA, SVR, and PRR, and assessing whether review criteria are met.
- Ensuring the Government preserves the rights they need, consistent with the life cycle acquisition and support strategy.
- Establishing and curating the initial product baseline (including digital artifacts) established at the CDR.
- Determining the path forward on configuration changes to the initial product baseline after CDR, to the extent the competitive environment permits (see SE Guidebook Section 4.1.6. Configuration Management Process).

- Accepting system deliveries (i.e., DD-250), as appropriate.
- Supporting the Configuration Steering Board in accordance with DoDI 5000.85, Appendix 3C.3.e.

In addition to the general roles and responsibilities described in SE Guidebook Section 2.3. 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 PM on review criteria readiness.
- Lead preparation and conduct of technical reviews.
- Track and report initial product baseline changes after CDR and recommend the path forward in accordance with the Configuration Management process, to the extent the competitive environment allows (see SE Guidebook Section 4.1.6. Configuration Management Process).
- Implement a digital engineering ecosystem to support SE activities and program decision making across the stakeholders. This ecosystem should reflect the design status throughout EMD and reflect the current baseline configuration as appropriate.
- Develop a digital twin to support program life management phase activities.
- Develop digital artifacts (models, simulations, etc.) to support assessments, risk identification and mitigation, program performance progress, and verification of functionality and performance to specified needs.
- Support determination of production rates and delivery schedules.
- Support T&E activities: identify system evaluation targets driving system development and support operational assessments as documented in the TEMP (see T&E Enterprise Guidebook (2022)).
- Align the SEP with the TEMP on SE processes, methods, and tools identified for use during T&E.
- Analyze deficiencies discovered from operational assessments and verification methods (DT&E); develop and implement solutions, including but not limited to rebalancing system requirements.

- Support logistics and sustainment activities as documented in the LCSP (see Product Support Manager Guidebook (2022)).
- Maintain the SEP, including generating the update in support of Milestone C.
- Ensure the program has developed manufacturing processes and maturation efforts.
- Develop approaches and plans to verify mature fabrication and manufacturing processes and determine manufacturing readiness (see 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).
- Apply value engineering techniques to system design features to ensure they achieve their essential functions at the lowest life cycle cost consistent with required performance, reliability, quality, and safety.
- 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 updates 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 deployment.
- Maintain oversight of the system (software and hardware) development processes, system testing, documentation updates, and tracking of the system development efforts.
- Support the PM's interactions with the Configuration Steering Board.
- Support the execution of the system safety engineering program.

Inputs

Table 3-7 summarizes the primary inputs associated with the EMD phase.

Table 3-7. Inputs Associated with EMD Phase

Inputs for EMD Phase
CDD and CONOPS/OMS/MP
ADM (may contain additional direction)
Preliminary system design including functional and allocated baselines (see SE Guidebook Section 4.1.6. Configuration Management Process)
SEP (See DoDI 5000.88, Section 3.4.a. and SE Guidebook Section 1.5. Systems Engineering Plan) • If programs enter the acquisition life cycle at Milestone B, this is their initial SEP
M&Q Plans (See SE Guidebook Section 6.18) • Attachment to SEP
RAM-C Report (See DoDI 5000.88, Section 3.5.b. and SE Guidebook Section 5.18.) • Attachment to SEP • If programs enter the acquisition life cycle at Milestone B, this is their initial RAM-C Report
Digital artifacts (models, simulations, etc.) tools
RGCs (See DoDI 5000.88, Section 3.5.b. and SE Guidebook Section 5.18.) • Included in SEP and TEMP
PPP (See DoDI 5000.83, Section 3.4.c. and T&PP Guidebook (2022)) • If programs enter the acquisition life cycle at Milestone B, this is the initial PPP
Trade-off analysis 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
System Safety • Subsystem Hazard Analysis • System Hazard Analysis
ESOH analyses (See DoDI 5000.88, Section 3.6.e.and SE Guidebook Section 5.23.) • PESHE and NEPA/EO 12114 Compliance Schedule
Assessment of technical risk (See SE Guidebook Section 4.1.5.)
Manufacturing Readiness (See SE Guidebook Section 6.14.5.) • Assess capability to produce in a production representative environment • Initial manufacturing approach has been developed • Critical manufacturing processes have been identified
Consideration of technology issues
TRA (MDAPs only) (See AAFDIT) • Confirmation that critical technologies have been demonstrated in a relevant environment
Interdependencies/interfaces/memorandums of agreement (MOAs)
LMDP for IMD-dependent programs (See SE Guidebook Section 5.11. Intelligence (Life Cycle Mission Data Plan) and Intelligence Support Guidebook (2021))
System performance specification, including verification matrix

Inputs for EMD Phase
Other technical information, such as architectures, and digital artifacts generated during the TMRR phase
Prototyping strategy (See DoDI 5000.83, Appendix 3C.3.a. and AAFDIT, Acquisition Strategy)
VOLT Report (See AAFDIT) and Intelligence Support Guidebook (2021))
APB
Affordability Assessment (See PM Guidebooks (2022) and SE Guidebook Section 5.2.) • Affordability caps 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 • For MDAPs, there are SecDef approved program goals at Milestone A
Acquisition Strategy (See PM Guidebooks (2022))
LCSP (updated) (See Product Support Manager Guidebook (2022))
DMSMS Management Plan (updated)
Initial ISP (See Digital Capabilities Guidebook (2022))
TEMP (See T&E Enterprise Guidebook (2022)) • System Test Objectives
Draft and final RFP
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
Spectrum Supportability Risk Assessment (See DoDI 4650.01 and SE Guidebook Section 5.19.)

Activities

The EMD phase activities begin with a favorable Milestone B decision (see Section 3.1.3.2. Technology Maturation and Risk Reduction Phase) and end with a successful Milestone C decision.

SE activities to support the EMD effort include:

- Develop the system architecture.
- Perform system element trade-offs.
- Use prototypes to mature system designs and drawings. If the program strategy includes competitive development, this may include competitive prototyping during the EMD phase.
- Mature and implement the digital engineering ecosystem (including computational space, tools, models, simulations, training, etc.) formed during the TMRR phase to design the desired system and support program decision making.

- Mature system model and simulation tools to be used in the verification of system functionality and conformance to specified needs.
- Conduct human systems integration analysis such as task and functional analysis, develop mission use and operational use scenarios, and establish initial human performance thresholds.
- Develop the initial product baseline and a stable design that conforms to program cost, schedule, and performance requirements (see SE Guidebook Section 4.1.6. Configuration Management Process).
- Support the establishment of the DT&E environment and associated resources (e.g., people, equipment, test cases, and test ranges).
- Support materiel readiness and logistical support efforts.
- Prepare for production by identifying critical manufacturing processes, key product characteristics, and any manufacturing risks.
- Build, integrate, and test system elements.
- Fabricate and assemble the system elements and system to the initial product baseline.
- Manage changes of software requirements, projected changes to software size, and integration of software components.
- Update the plan and continue to proactively manage and mitigate parts and DMSMS issues throughout the life cycle and identify necessary and appropriate technical data needs to support parts management processes and DMSMS risk mitigation. Include DMSMS resilience considerations in critical designs.
- Integrate the system and verify compliance with the functional and allocated baselines through DT&E efforts (see T&E Enterprise Guidebook (2022) for more on DT&E).
- Update risk, issue, and opportunity plans. Identify, analyze, mitigate, and monitor risks and issues; and identify, analyze, manage, and monitor opportunities. (See DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.)
- 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 updates to the CDD.
- 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 deployment options and training development.

- Execute activities in the system safety engineering program to conduct system safety analyses to identify hazards, control measures, and assess risks.
- 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 SE Guidebook Section 2.4. Certifications).
- Develop the system architecture to reflect EMD trade-off decisions and incorporate stakeholder feedback.

Verify, validate, and accredit digital artifacts (models, simulations, etc.) to establish a trust level. The systems engineer uses technical reviews and audits to assess whether the program meets preplanned technical maturity points during the acquisition life cycle as the system and system elements mature. To assess the status, the program should identify technical risks associated with achieving entrance criteria at each of these points (see DoD Risk, Issue and Opportunity Management Guide for Defense Acquisition Programs). Technical reviews and audits typically conducted in EMD include the following:

- CDR: Mandated; establishes initial product baseline (See SE Guidebook Section 3.5. Critical Design Review)
- SVR/FCA (See SE Guidebook Section 3.6. System Verification Review/Functional Configuration Audit)
- PRR (SE Guidebook Section 3.7. Production Readiness Review)

Test activities during the EMD phase that depend on SE support and involvement include Test Readiness Reviews (TRRs), DT&E, and operational assessments. 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 TEMP. Associated SE activities and plans should be in the SEP (see SE Guidebook Section 1.5. Systems Engineering Plan, 3. Technical Reviews and Audits, and T&E Enterprise Guidebook (2022)).

Outputs and Products

The technical outputs and products identified in Table 3-8 are some of the inputs necessary to support SE processes in the following phase, P&D. They should support the technical recommendation at Milestone C that manufacturing processes are mature enough to support LRIP and generate production-representative articles for OT&E. Technical outputs associated with technical reviews in this phase are addressed later in this document.

Table 3-8. Technical Outputs Associated with EMD Phase

Technical Outputs from EMD Phase
Informed advice to CDD
Informed advice to ADM and 10 USC 4252 certification (if Milestone C is program initiation)
For MDAPs, informed advice to brief summary report for 10 USC 2366c certification (not later than 15 days after granting Milestone C approval)
Verified system • Updated functional, allocated, and initial product baselines; verified production processes and verification results/ decisions • Associated technical products including associated design and management decisions
Digital Engineering Ecosystem • Digital Twin • Verified Models, simulations, tools
SEP (updated) (See DoDI 5000.88, Section 3.4.a. and SE Guidebook Section 1.5. Systems Engineering Plan)
Updated IMP, IMS, and MOAs/MOUs
RAM-C Report (updated) (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18.) • Attachment to SEP
RGC (updated) (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18) • Included in SEP and TEMP
PPP (updated) (See DoDI 5000.83, Section 3.4.c. and T&PP Guidebook (2022))
Trade-off analysis 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 (See DoDI 5000.88, Section 3.6.e.) • Updated PESHE and NEPA/E.O. 12114 Compliance Schedule
Human Systems Integration Analysis results (See HSI Guidebook (2022)) • Mapping of all tasks/functions to human and/or system, • Mission and Operational Use scenarios that support downstream testing and • Informed advice relative to crew/maintainer skill level and numbers of personnel required to support operations
Assessment of technical risk (See SE Guidebook Section 4.1.5. and the DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.) • 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
Manufacturing readiness (See DoDI 5000.88, Section 3.6.c. and SE Guidebook Section 5.14.5.) • Assessment of manufacturing readiness supports Milestone C and initiation of production • Manufacturing processes have been effectively demonstrated and are under control
Interdependencies/interfaces/MOAs • Understanding of the unique program interdependencies, all modular system interfaces and associated MOAs

Technical Outputs from EMD Phase
LMDP for IMD-dependent programs (updated) (See SE Guidebook Section 5.11. Intelligence (Life Cycle Mission Data Plan) and Intelligence Support Guidebook (2021))
System performance specification (updated if necessary), including verification matrix • System element specifications, including verification matrix
Initial product baseline
Other technical information, such as architectures, digital artifacts, (models, simulations, etc.) system models and simulations generated during the EMD phase
Results of EMD prototyping activities
Manufacturing prototyping activities support P&D phase
CDR Assessment (See DoDI 5000.88, Section 3.5.a. and SE Guidebook Section 3.5.) • For ACAT ID programs, USD(R&E) performs the assessment to inform the Milestone Decision Authority • For ACAT IC and IB programs, the CAE conducts the CDR assessment
Informed advice to APB • Updated will-cost values and affordability caps as documented in the Acquisition Program Baseline and Acquisition Strategy
Establishes technical information that is the basis of the updates to the CARD and manpower documentation (See AoA Handbook (2021) and HSI Guidebook (2022))
Informed advice to Affordability and Resource Estimates (See SE Guidebook Section 2.2.7. Value Engineering, SE Guidebook Section 5.2. Affordability – Systems Engineering Trade-Off Analyses, PM Guidebooks (2022) and AoA Handbook (2021)) • Should-cost goals updated to achieve efficiencies and control unproductive expenses without sacrificing sound investment in product affordability • Value engineering results, as appropriate • For MDAPs, provide informed advice to SecDef approved program goals.
Manufacturing, performance and quality metrics critical to program success are identified and tracked (See SE Guidebook Section 6.14.4.) • Manufacturing drawings are sufficiently complete • First article testing validates production capabilities • Manufacturing processes and controls provide acceptable product
Production budget/cost model validated and resources considered sufficient to support LRIP and FRP • Inputs to Milestone C, LRIP, and FRP DR
Informed advice to Acquisition Strategy (See PM Guidebooks (2022)) • Informed advice on engineering approaches and strategies, external dependencies, resource requirements, schedule and risks
Informed advice to LCSP (updated) (See Product Support Manager Guidebook (2022)) • System Support and Maintenance Objectives and Requirements established • Updated will-cost values and affordability caps as documented in the LCSP, including Informed advice to manpower documentation • Confirmation of logistics and sustainment needs (i.e., facilities, training, support equipment) and implementation supporting initial deployment efforts
Informed advice to the DMSMS Management Plan (updated)
ISP of Record (See Digital Capabilities Guidebook (2022))

Technical Outputs from EMD Phase
Informed advice to TEMP (updated) (See T&E Enterprise Guidebook (2022)) • System test objectives
Informed advice to the DT&E assessments (See T&E Enterprise Guidebook (2022)) • System test objectives
Informed advice to draft and final RFP for LRIP • Informed advice, including system performance specification, SOW, CDRLs, and source selection criteria
Informed advice for the Spectrum Supportability Risk Assessment (See DoDI 4650.01 and SE Guidebook Section 5.19.)
Informed advice for Waveform Assessment Application (See DoDI 4630.09)

3.1.3.4 Production and Deployment Phase

The objective of the 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. In the P&D phase, SE delivers the 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 T&E and logistics and sustainment activities identified in T&E Enterprise Guidebook (2022) and Product Support Manager Guidebook (2022), respectively. This phase typically includes several major efforts as shown in Figure 3-6: LRIP, OT&E, Full-Rate Production (FRP) and Full Deployment (FD), and deployment of capability in support of the Initial Operational Capability (IOC) and Full Operational Capability (FOC). The FRP DR and/or Full Deployment Decision Review (FD DR) serves as a key decision point between LRIP (and OT&E) and FRP/FD.

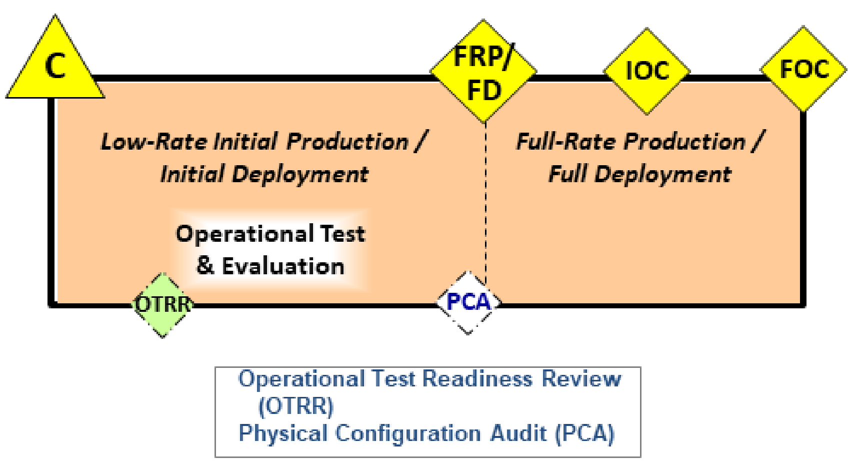


Figure 3-6. Systems Engineering Activities in the Production and Deployment Phase

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, the program may discover 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.

The systems engineer plays a key role in assessing a system to ensure it is ready to enter OT&E (see T&E Enterprise Guidebook (2022)), and this assessment is significant. The program will waste scarce resources if it has to halt or terminate an operational test early because of technical problems the program team could have resolved before the start of OT&E.

During deployment, units attain IOC, then FOC.

Besides ensuring a successful FOC, SE activities include:

- 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 before FRP/FD. Revise digital artifacts (models, simulations, etc.) to reflect the system's production configuration.

Roles and Responsibilities

In addition to the general responsibilities identified in SE Guidebook Section 2.3. Engineering Resources, the PM focuses on the following P&D activities, which rely on and support SE efforts:

- Conduct activities in support of the production contract award(s).
- Ensure Government intellectual property and data rights information are captured in the technical baseline.
- Resource and conduct event-driven technical reviews (including the PCA, Post Implementation Review, and FRP and/or FD DR) and ensure that criteria are met.
- Update the digital engineering artifacts and models (as part of the authoritative source of truth) to reflect the "as-is" built system in order to support sustainment activities and future enhancements.
- Manage and control the product baseline.
- Manage risks, in particular the manufacturing, production, and deployment risks.
- Accept system deliveries (i.e., DD-250).

- Support the Configuration Steering Board in accordance with DoDI 5000.85, Appendix 3C.3.e.

In addition to the general responsibilities identified in SE Guidebook Section 2.3. Engineering Resources, the systems engineer is responsible for:

- Analyzing deficiencies discovered from OT&E, acceptance tests, production reports, and maintenance reports and providing corrective actions.
- Maintaining the digital engineering environment, digital artifacts, modeling and simulation tools, etc., to support capability life cycle management activities.
- Conducting rigorous production risk assessments; planning and resourcing effective risk mitigation actions.
- Continuing conducting producibility trade studies to determine the most cost-effective fabrication/manufacturing process.
- Developing approaches and plans to validate fabrication/manufacturing processes.
- Assessing FRP 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.
- Identifying long-lead items and critical parts and materials; manage DMSMS risks and implement measures to mitigate impacts to production and sustainment.
- Updating production costs as a part of life cycle cost management.
- Supporting updates to the production schedules.
- Supporting technical reviews and production decisions.
- Supporting materiel readiness and logistical activities, including deployment and training.
- Continuing to support the configuration management process to control changes to the product baseline during test and deployment.
- Updating and maintain system certifications and modular system interfaces, as necessary.
- Maintaining oversight of the system (software and hardware) development processes, system testing, documentation updates and tracking of the system development efforts.
- Supporting the PM in his or her interactions with the Configuration Steering Board.
- Supporting execution of the system safety engineering program activities. Providing required safety confirmations and certifications.

Inputs

Table 3-9 summarizes the primary inputs associated with this part of the life cycle.

Table 3-9. Inputs Associated with P&D Phase

Inputs for P&D Phase
CDD updates and CONOPS/OMS/MP
ADMs 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 (See DoDI 5000.88, Section 3.4.a. and SE Guidebook Section 1.5. Systems Engineering Plan) • Updated functional, allocated and product baselines; verified and validated production processes and validation results/decisions • Updated technical products including associated design and management decisions
M&Q Plans (See SE Guidebook Section 6.18) • Updated and attached to SEP
RAM-C Report (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18.) • Attachment to SEP
RGCs (See DoDI 5000.88, Section 3.6.b. and SE Guidebook Section 5.18.) • Included in SEP and TEMP
PPP (See DoDI 5000.83, Section 3.4.c. and T&PP Guidebook (2022)) • Updated at FRP DR and/or FD DR
Trade-off analysis 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
Digital artifacts (models, simulations, digital twin(s) etc.) that represent the production configuration. Digital engineering ecosystem that supports program decision making and life cycle support activities.
System safety hazard analysis, control measures and assessment of risks. Update and maintain HTS
Environment, Safety and Occupational Health (ESOH) analyses (See DoDI 5000.88, Section 3.6.e. and SE Guidebook Section 6.23.) • PESHE and NEPA/EO 12114 Compliance Schedule
Risk assessment (See SE Guidebook Section 4.1.5.) • Risk mitigation plans • Acceptable risks for achieving IOC and FOC
Manufacturing readiness (See DoDI 5000.88, Section 3.6.c. and SE Guidebook Section 5.14.5.) • Assessment of manufacturing readiness supports Low Rate and Full Rate production
Interdependencies/interfaces/MOAs • Understanding of the unique program interdependencies, all modular system interfaces and associated MOA
Life Cycle Mission Data Plan for IMD-dependent programs (See SE Guidebook Section 5.11. Intelligence (Life Cycle Mission Data Plan) and Intelligence Support Guidebook (2021))

Inputs for P&D Phase
System performance specification (updated if necessary) including verification matrix • System element specifications (updated if necessary) including verification matrix
M&Q activities and metrics critical to program success are identified and tracked (See SE Guidebook Section 6.18.4) • M&Q support program documentation • M&Q metrics provide evidence of successful production
Product baseline
Product acceptance test
Other technical information such as digital artifacts (architectures, models, simulations, etc.) generated during the EMD phase
Results of EMD prototyping activities
VOLT Report (See AAFDIT) and Intelligence Support Guidebook (2021))
Acquisition Program Baseline (APB)
Affordability and Resource Estimates (See SE Guidebook Section 2.2.7. Value Engineering, SE Guidebook Section 5.2. Affordability – Systems Engineering Trade-Off Analyses, PM Guidebooks (2022) and AoA Handbook (2021)) • Affordability goals treated as KPPs • Should-cost goals to achieve efficiencies and control unproductive expenses • Updated will-cost values and affordability caps as documented in the LCSP, including informed advice to manpower documentation • Value engineering results, as appropriate For MDAPs, there are SECDEF approved program goals at Milestone A.
Supply chain sources
Updated Manufacturing processes
Production budget/cost model validated and resources considered sufficient to support LRIP and FRP
Acquisition Strategy (See PM Guidebooks (2022))
LCSP (See Product Support Manager Guidebook (2022))
DMSMS Management Plan
Human Systems Integration (HSI) analyses (See HSI Guidebook (2022)) • Manpower, personnel and training requirement updates • Refinement of HSI inputs to specifications, user centered design, multi-domain verification, testing and usability evaluations
TEMP (See T&E Enterprise Guidebook (2022)) • System test objectives
DT&E assessments (See T&E Enterprise Guidebook (2022)) • System test objectives
Draft and final RFP
SCG
ISP of Record (See Digital Capabilities Guidebook (2022))
Other analyses • Other prior analytic, prototyping and/or technology demonstration efforts completed by the S&T community; technology insertion/transition can occur at any point in the life cycle
Spectrum Supportability Risk Assessment (See DoDI 4650.01 and SE Guidebook Section 5.19.)

Activities

The P&D phase SE activities begin when a favorable Milestone C decision has been made (see Section 3.1.3.3. Engineering and Manufacturing Development Phase) and end when FOC is achieved. SE activities that occur throughout the P&D phase include:

- Provide technical support to prepare for the O&S phase; review and provide input on the maintenance approach, Acquisition Strategy, training, and technical manuals.
- Maintain digital artifacts (models, simulations, etc.) to represent the current configuration of the acquired system as part of the authoritative source of truth.
- Update risk, issue, and opportunity plans. Identify, analyze, mitigate, and monitor risks and issues; and identify, analyze, manage, and monitor opportunities. (See DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.)
- Assess the impact of system requirements changes resulting from evolving threats, changes to operational environment, or in response to changes within the SoS or interfacing systems.
- 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 FRACAS.
- Manage and control 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:

- Assess of DT&E, coordinated with the Chief Developmental Tester, to support approval to enter OT&E.
- Analyze the system's progress in achieving performance metrics (see SE Guidebook Section 4.1.3. Technical Assessment Process).
- Assess technical risk.
- Assess software maturity and status of software trouble reports.
- Identify potential design constraints affecting the system's expected performance during OT&E.

In the P&D phase, the systems engineer should identify and mitigate potential DMSMS and parts management issues that may disrupt production. Since parts, material, and DMSMS issues in production may have an impact on already deployed assets, the systems engineer should also ensure that resolution is robust enough to mitigate impact on deployed assets. Furthermore, the systems engineer should forecast future DMSMS and parts management issues and plan for resolutions in conjunction with planned modifications.

The PCA is an SE audit typically conducted in the P&D phase (see SE Guidebook Section 3.8. Physical Configuration Audit for additional information regarding the PCA). The systems engineer should identify technical risks associated with achieving entrance criteria for this audit (see DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.)

Test activities during the P&D phase that depend on SE support and involvement include the DT&E Assessment, Operational Test Readiness Reviews, initial and follow-on OT&E, and live-fire test and evaluations (LFT&Es), as appropriate (see T&E Enterprise Guidebook (2022)). 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 the technical support needed for operational assessments and document it in the TEMP. Associated SE activities and plans should be in the SEP (see SE Guidebook Section 1.5. Systems Engineering Plan, SE Guidebook Section 3. Technical Reviews and Audits Overview, and T&E Enterprise Guidebook (2022)).

During P&D, digital artifacts (e.g., models, simulations, artifacts, etc.) need to represent the current system configuration so they may be used to support supply chain management, monitor performance and adjust product support, train users, conduct supportability assessments, validate failures and examine root causes, determine system risk and hazard severity, and support engineering change analysis efforts.

Outputs and Products

The technical outputs and products from the P&D phase identified in Table 3-10 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 document.

Table 3-10. Technical Outputs Associated with P&D Phase

Technical Outputs from P&D Phase
Informed advice to CDD Update • CDD 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 • Validated models and tools representative of the current system configuration
PPP (updated) (See DoDI 5000.83, Section 3.4.c. and T&PP Guidebook (2022)) • Updated at FRP DR and/or FD DR
Trade-off analysis 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
System safety hazard analyses, control measures and risk assessment. Update and maintain HTS.
ESOH analyses (See DoDI 5000.88, Section 3.6.e. and SE Guidebook Section 5.23.) • Updated PESHE and NEPA/EO 12114 Compliance Schedule
Assessment of technical risk (updated) (See SE Guidebook Section 4.1.5. and the DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.) • Risk assessment identifying mitigation plans, acceptable risks for achieving FOC
Interdependencies/interfaces/MOAs • Understanding of the unique program interdependencies, all modular system interfaces and associated MOA
Life Cycle Mission Data Plan for IMD-dependent programs (updated) (See SE Guidebook Section 5.11. Intelligence (Life Cycle Mission Data Plan) and Intelligence Support Guidebook (2021))
System performance specification (updated if necessary) including verification matrix; system element specifications (updated if necessary) including verification matrix
M&Q metrics (See SE Guidebook Section 6.14.4)
PCA results and an updated product baseline (See SE Guidebook Section 3.8.)
Acceptance test data to assess product conformance and to support DD250 of end items
Other technical information such as architectures, digital artifacts, (models, simulations, digital twin, etc.) generated during the P&D phase
Digital engineering ecosystem to support program decision making
Technical information that is the basis of the updates to the CARD and manpower documentation (See T&E Enterprise Guidebook (2022) and HSI Guidebook (2022))
Industrial base capabilities; updated manufacturing processes and supply chain sources

Technical Outputs from P&D Phase
Informed advice to LCSP (See Product Support Manager Guidebook (2022)) • Updated at FRP DR and/or FDDR • Updated will-cost values and affordability caps as documented in the LCSP, including informed advice to manpower documentation • Value engineering results, as appropriate (see SE Guidebook Section 2.2.7.) • Updated list of production tooling and facilities that need to be retained post-production to support continued operational and maintenance of the system
Informed advice to DMSMS Management Plan (updated)
HSI analyses (See HSI Guidebook (2022)) • Final manpower and personnel requirements • Training program implementation • HSI participation in Engineering Change Proposal (ECP) process • Human performance results (includes workload, situation awareness, time to perform tasks, errors)
Informed advice to TEMP (updated) (See T&E Enterprise Guidebook (2022)) • System Test Objectives
OT&E Assessments/Reports (See T&E Enterprise Guidebook (2022)) • System Test Objectives
Draft and final RFP(s) for production and SE support to O&S activities
Informed advice for Spectrum Supportability Risk Assessment (See DoDI 4650.01 and SE Guidebook Section 5.19.)

3.1.3.5 Operations and Support Phase

The objective of the 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 MSA phase, matures through the TMRR and EMD phases, and is documented in the LCSP. SE in the O&S phase assesses whether the deployed system and enabling system elements continue to provide the needed capability in a safe, sustainable and cost-effective manner in an evolving threat environment. 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 ESOH assessments, technology refresh, DMSMS, parts and material management issues, functionality modification, and life-extension modifications. (See SE Guidebook Section 5. Design Considerations for other technical factors needing continued attention during this phase.)

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 O&S is engineering analysis to identify and mitigate potential future DMSMS, parts, and material impacts often in conjunction with planned modifications. Parts management and DMSMS problems are an increasing concern as the service lives of weapon systems are extended and the product life cycle for high-technology system elements decreases (see SE Guidebook Section 5.8. Diminishing Manufacturing Sources and Material Shortages).

Roles and Responsibilities

In addition to general responsibilities identified in SE Guidebook Section 2.3. Engineering Resources, the PM focuses on the following O&S activities, which rely on and support SE efforts:

- Working with the user to document performance and sustainment requirements in performance agreements, specifying objective outcomes, measures, resource commitments and stakeholder responsibilities.
- Employing effective Performance-Based Life Cycle Product Support implementation and management.
- Maintaining operational readiness.
- Following acquisition program practices for major modifications or Service Life Extension Program.
- Supporting the Configuration Steering Board in accordance with DoDI 5000.85, Section 3C.3.e.
- Assessing changing threat environment or new vulnerabilities to determine the appropriate course of action to mitigate the loss of DoD’s technological advantage.

In addition to the general responsibilities identified in SE Guidebook Section 2.3. Engineering Resources, the systems engineer is responsible for the following tasks:

- Refining the maintenance program to minimize total life cycle cost while achieving readiness and sustainability objectives.
- Assessing end-user feedback and conducting engineering investigations as required.
- Leading teams to translate end-user feedback into corrective action plans and recommending technical changes.
- Developing and implementing approved system changes to meet end-user needs.
- Conducting ESOH risk assessments and maintaining oversight of critical safety item supply chain management.
- Conducting parts and DMSMS risk analysis to identify, prioritize, and mitigate near term and future potential DMSMS and other adverse impacts.
- Maintaining digital artifacts (models, simulations, etc.) as part of the authoritative source of truth, to represent the current system configuration in support of program decision making and sustainment activities.

- Supporting implementation of follow-on development efforts in response to formal decisions to extend the weapon system's service life (e.g., through a Service Life Extension Program) or to initiate a major modification (may be treated as a stand-alone acquisition program).
- Updating and maintaining system certifications and external SoS and modular interfaces.
- Supporting the PM in his interactions with the Configuration Steering Board.

Inputs

Table 3-11 summarizes the primary inputs associated with this part of the life cycle.

Table 3-11. Inputs Associated with O&S Phase

Inputs for O&S Phase
ADMs associated with Milestone C and FDDR • 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-off analysis results • P&D phase trade studies may support manufacturing or other system modifications (technology insertion, technology refresh, etc.)
System safety hazard analyses updated. Continue updating and maintaining HTS
ESOH analyses (updated) (See DoDI 5000.88, Section 3.6.e. and SE Guidebook Section 5.23.) • ESOH analyses continue during O&S including hazard analysis and supporting NEPA/EO 12114 compliance for modifications and disposal
Risk assessment (See SE Guidebook Section 4.1.5.)
Manufacturing assessment (See SE Guidebook Section 5.14.5.)
Interdependencies/interfaces/MOAs
System performance specification
Field failures
Other technical information, such as architectures, system models and simulations generated during the P&D phase
LCSP
DMSMS Management Plan
ISP of Record (See Digital Capabilities Guidebook (2022))
TEMP (See T&E Enterprise Guidebook (2022))
RFP for SE support to O&S activities
PPP (See DoDI 5000.83, Section 3.4.c. and T&PP Guidebook (2022))
Other analyses • End-user feedback and trouble reports • Other prior analytic, prototyping, and/or technology demonstration efforts conducted by the S&T community • Technology insertion/transition studies can occur at any point in the life cycle
Spectrum Supportability Risk Assessment (See DoDI 4650.01 and SE Guidebook Section 5.19.)
LMDP for IMD-dependent programs (See SE Guidebook Section 5.11. Intelligence (Life Cycle Mission Data Plan) and Intelligence Support Guidebook (2021))

Activities

The O&S phase overlaps with the P&D phase since O&S activities begin when the first system is deployed. O&S ends when a system is demilitarized and disposed of.

SE activities should be integrated with O&S phase-specific T&E and logistics and sustainment activities identified in the T&E Enterprise Guidebook (2022) and Product Support Manager Guidebook (2022), respectively. The O&S activities in which the systems engineer should participate include:

- Update risk, issue, and opportunity plans; identify, analyze, mitigate, and monitor risks and issues; and identify, analyze, manage, and monitor opportunities (see DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs).
- Address problem/failure reports through the use of a comprehensive data collection approach such as a FRACAS.
- Process and analyze mission data.
- Manage preplanned product improvements (P3I) and assess the impact of system requirements changes resulting from evolving threats, changes to operational environment, or in response to changes within the SoS or interfacing systems.
- Make changes to the system technical baseline to maintain it as the authoritative source; changes may be due to PCAs, Engineering Change Proposals (ECPs), or changes to interfaces to external and modular systems.
- Update digital artifacts (models, simulations, architectures, etc.) to maintain them as the authoritative source.
- Maintain the digital engineering ecosystem to facilitate program decision making.
- Develop and implement technology refresh schedules.
- Conduct technology insertion efforts as needed to maintain or improve system performance.
- Update system safety assessments.
- Perform parts and DMSMS risk analysis to identify, prioritize, and mitigate near-term and future potential DMSMS and other adverse impacts and develop resolutions as appropriate.
- Work with vendors and the general technical community to determine opportunities for technology insertion to improve 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.

Outputs and Products

The technical outputs and products identified in Table 3-12 are necessary to support SE processes to sustain the system, including modifications.

Table 3-12. Technical Outputs Associated with O&S Phase

Technical Outputs from O&S Phase
Safe, sustainable, and reliable system that meets operational needs
Trade-off analysis results • O&S phase trade studies support system modifications and/or disposal efforts
Assessment of technical risk (See SE Guidebook Section 4.1.5. and the DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs.)
Interdependencies/interfaces/memorandums of agreement (MOAs)
ISP of Record (See Digital Capabilities Guidebook (2022))
In-service performance and failure data
Value engineering results, as appropriate (See SE Guidebook Section 2.2.7. Value Engineering)
Validated models and simulations representing the fielded system
ECP packages

3.2 Software Engineering

3.2.1 Overview

The AAF provides multiple pathways and allows programs to combine pathway approaches to increase the flexibility and efficiency needed to capitalize on accelerated acquisition methods and benefit from modern commercial software development practices (e.g., Agile/Development, Security, and Operations (DevSecOps), continuous integration/continuous delivery (CI/CD)). Software is a main cause of system complexity, and software performance is critical to dominating the battlefield and maintaining operational advantage in an environment of change. Accordingly, software development and sustainment frequently require a major portion of total system life cycle cost, schedule, and risk and should be considered throughout the acquisition life cycle.

3.2.2 Software Acquisition within the MCA Decision and Process Model

Programs following the MCA pathway may incorporate software into the MCA pathway or may choose to implement a hybrid acquisition approach, especially for software-intensive components. In this case the program uses the software acquisition pathway in parallel with the MCA, so outputs and dependencies are integrated with the overall development. While software depends on the hardware being procured for most cyber-physical weapon systems, a digital engineering environment for the hardware and a robust software factory for the software will help streamline the overall acquisition of both. Whether using a hybrid or single pathway, the program should document its planned approach in the Acquisition Strategy.

3.2.2.1 MSA Phase Software Engineering Considerations

In the MSA phase, the PM, systems engineer, and software engineer should identify system requirements that map directly to software requirements to facilitate trade-offs and studies to optimize design and reduce vulnerabilities, risks, and life cycle cost.

Mission-driven capability analysis informs the sequencing of software capabilities. An incremental approach will focus on specific content in a first build or increment, followed by additional builds that add or refine capability. The PM, systems engineer, and software engineer should emphasize mission understanding to set the stage for good systems and software architecture and capability-based releases.

For an integration-intensive system that relies substantially if not completely on non-developmental item/commercial off-the-shelf/government off-the-shelf (NDI/COTS/GOTS) software, trade-space analysis can provide important information to understand the feasibility of capability and mission requirements. The program should consider software and system alternatives to refine the system concept and prevent vendor “lock-in.” To discover and mitigate risks, the program should consider materiel solution opportunities for early software development prototyping, integration, and reuse of NDI/COTS/GOTS software. To the extent possible at this early stage, the program should ensure MSA contracts reduce technical and programmatic risk related to software, particularly for high-risk components. The MSA phase should factor software sustainment considerations to inform cost and Acquisition Strategy, including Government technical data rights.

3.2.2.2 TMRR Phase Software Engineering Considerations

In the TMRR phase, the program may use competitive prototyping 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. Software prototypes that reflect the results of trade-off analyses should be demonstrated during the TMRR phase. These demonstrations will provide software performance data (e.g., latency, security architecture, integration of legacy services and scalability) to inform decisions as to maturity; furthermore, EMD estimates (schedule and life cycle cost) often depend on reuse of software components developed in TMRR.

Hardware-dominant programs may conduct a Software Specification Review during TMRR to assess requirements and interface specifications for CSCIs in support of the system PDR. Software programs typically conduct a Software Specification Review to assess the software requirements and interface specifications for CSCIs in support of the PDR. Programs focused on a given build, release, or increment may produce artifacts only for that limited scope, but the chief engineer may need a more comprehensive system-level architecture or design in order to handle capabilities across multiple releases. A PDR or its equivalent needs to maintain this system-level and longer-term, end-state perspective, as one of its functions is to provide data for the Milestone Decision Authority to assess before Milestone B.

In an integration-intensive environment, software and system models may be difficult to develop and fully explore if many software or system components come from proprietary sources or commercial vendors with restrictions on data rights. Validating end-to-end system and internal software performance assumptions may be difficult or even impossible. The program should work proactively with commercial vendors to support developing the models. To the extent possible at this early stage, the program should ensure TMRR contracts reduce technical and programmatic risk related to software, particularly for high-risk components. When feasible, the TMRR phase should factor software sustainment considerations to inform cost and the Acquisition Strategy, including Government technical data rights.

The PM, systems engineer, and software engineer should carefully establish and manage criteria for technical reviews in order to properly focus the scope and purpose of the reviews. Increasing knowledge and definition of elements of the integrated system design should include details of support and data rights. The program should establish initial Service-Level Agreements with the user community and vendor community as an important tool for understanding and managing the details of support requirements in a diverse system environment.

3.2.2.3 EMD Phase Software Engineering Considerations

Software documentation at the CDR or its equivalent should represent the design, performance, and test requirements, along with development and integration facilities for coding and integrating the deliverable software. Software engineers should validate and verify software and systems used for CSCI development (e.g., simulations and emulations) so they are ready to begin coding upon completion of the CDR or its equivalent. Software engineers should select problem report metadata so the reports are relevant to tracking and assessments in development, test, and operation. The program can use legacy problem report tracking information to generally profile and predict which types of software functions may accrue what levels of problem reports. Assessments of patterns of problem reports among software components of the system can provide valuable information to support program progress decisions.

For a program using an incremental software development approach, technical debt may accrue within a given build or increment, or across multiple builds or increments. Technical reviews, both at the system and build or increment levels, should have a baseline of minimum viable requirements and architecture at the system level, and the review should fulfill a build- or increment-centric set of review criteria and requirements. For build or increment content that may need to evolve across builds or increments, the PM, systems engineer, and software engineer should ensure system-level risks are captured and mitigated to ensure any related development or risk reduction activities occur in a timely manner. Configuration management and associated change control/review boards can facilitate the recording and management of build/increment information.

For an integration-intensive system, the program may need to emphasize implementation and test more than development. The software engineer should install system components in a System Integration Lab (SIL) and evaluate the components continuously (i.e., shifting all levels of testing as far left as possible) through EMD. The software engineer should disclose and validate the details regarding the use of modular system interfaces to ensure the interfaces are scalable and suitable for use. The program should require progressive levels of integration, composition, and use to evaluate ever higher levels of system performance, ultimately encompassing end-to-end testing based on user requirements and expectations. As needed, the software engineer may pursue the use of "glue" code and other extensions to the system environment to provide capability. Software engineers should address glue code in as rigorous a manner as any developed software (i.e., the program should keep the code configuration management, and review and inspect the code; updates should be properly regression-tested and progressively integrated and tested).

3.2.2.4 P&D Phase Software Engineering Considerations

During the P&D phase, the program may refine software as needed in response to OT&E activities and in support of the FRP/FDD and IOC. To reduce overall cost and schedule, the program should consider shifting OT&E activities as far left as possible (i.e., performing operational assessments in the SIL during development/rework).

For a program using an incremental software development approach, OT&E activities are generally associated with a given build or increment delivery. In Agile/DevSecOps-based software processes, collaboration between the test community and the development community increases understanding of system performance and verification requirements. Development and operational test may occur in phases or continuously (preferably as frequent integrated tests and operational assessments) as the program updates the system.

The program may opt for progressive deployment of an integration-intensive system to provide infrastructure, services, and higher-level capabilities as the program validates and verifies each release. A rigorous release process includes configuration management and a mature software factory, with a high degree of automation, toolchain integration, and automated high-fidelity testing. The PM, systems engineer, and software engineer should involve users to gain understanding and concurrence with changes to form, fit, and functions. As much as possible, programs should synchronize, test, and support builds in units to avoid forced upgrades or other problems at end-user sites. End-user sites that perform their own customization or tailoring of the system installation should provide feedback to the integrator or developer, so the program teams responsible for reporting problems and resolving issues fully understand the operational and performance implications of site-specific changes. Such customizations may also serve as leading indicators of user community preferences or needs when considering future system upgrades and enhancements.

3.2.2.5 O&S Phase Software Engineering Considerations

A program uses a defined block change or follow-on increment to deliver new or evolved capability, maintenance, safety, or urgent upgrades to the field in a controlled manner. Procedures for updating and maintaining software on fielded systems often require individual user action and may require specific training. Procedures should be in place to facilitate and ensure effective configuration management and control. There are inherent risks involved in modifying software on fielded weapon systems in use in frontline activities; software updates to business and IT systems can also pose risks to operational availability. PMs and systems and software engineers should maintain vigilance as part of supply chain risk management (see Section 3.3.2.5 Assessing Manufacturing Readiness and Risk), since maliciously altered devices or inserted software can infect the supply chain, creating unexpected changes to systems.

In an integration-intensive environment, security upgrades, technical refreshes, and maintenance releases can proliferate, causing confusion and problems at end-user sites. System upgrades or updates should be timed and coordinated to limit the proliferation of releases and maintained baselines, to conserve maintenance and support resources. Problem reporting and associated severity should track impacts on other system elements to help establish the true priority of upgrades and updates. The program should use configuration management and regression testing to ensure system coherence. The program should focus on automating testing to enable cycle time improvements and reduce fielding risk and escapes.

3.2.3 “Shift Left” Test Activities

As part of the DoD goal to “shift engineering and software development left” (DoD Software S&T Strategy 2021), the Department advocates conducting all test activities (e.g., CSCI, integration, system, developmental test, operational test) as early in the acquisition life cycle as possible and in closer collaboration with development. The goal promotes a collaborative teaming and pairing of the DoD’s research scientists with the engineering community. Connecting S&T with weapon system programs to insert new technology quickly requires engineering rigor during the ideation phase of R&D and shifting development and test left with the pervasive use of automation.

The term “shift left” refers to distinct sequential phases that move left to right, with the test phase just before the deployment phase. In an Agile/DevSecOps environment, “shift left” does not mean just moving testing earlier in the delivery cycle. Rather, it brings test into close collaboration with development and inserts it into every step of every iteration. From a cost and effort perspective alone, it makes sense to shift deficiency discovery as early in the cycle as possible. Defects found out of phase and late within a system’s life cycle are much more expensive to address and can incur significant schedule impacts due to unplanned work.

The test and software development teams should collaborate and integrate software information as early as possible in the life cycle to allow the teams to incorporate appropriate test equities into the CI/CD pipelines. This information should also include the acceptance criteria (e.g., definition of “done”) for each feature or capability. The program should detail in the feature or capability acceptance criteria any equities that cannot be automated (manual) and integrated into the CI/CD pipelines, to prevent them from being overlooked in the pursuit of speed. This documentation is particularly important when the equities are security related. Without creation of the feature or capability acceptance criteria, it is more likely that software developers will stray (e.g., unintentionally due to lack of information, lack of subject matter expertise) from the desired functionality or capability. As noted in the DoD S&T Strategy, it is the pervasive use of automation that enables the CI/CD pipelines to deliver speed without sacrificing quality.

3.3 Specialty Engineering

DoD Specialty Engineering encompasses several focused disciplines including reliability and maintainability (R&M) engineering, manufacturing and quality (M&Q), human systems integration (HSI), system safety engineering, and parts management.

3.3.1 Reliability and Maintainability Engineering

The purpose of 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 allowing the program to prevent or identify 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 EMD phase.

DoDI 5000.88, Sec 3.6.b. requires PMs to implement a comprehensive R&M engineering program as an integral part of the 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 as a minimum integrate the following activities across the program’s engineering organization and processes:

- Provide adequate R&M staffing, resources, and funding.
- Ensure R&M engineering is fully integrated into SE activities, Integrated Product Teams (IPTs), engineering processes, the digital representation of the system being developed, and other activities (i.e., logistics, T&E, and system safety). A best practice is to develop an R&M engineering program plan to ensure that this integration occurs.
- Ensure specifications contain realistic quantitative R&M requirements translated from the ICD and CDD. Note: The ICD may not contain quantitative user threshold requirements. The draft CDD is the first opportunity to review the Sustainment Key Performance Parameter and supporting R&M Key System Attributes (KSAs). The systems engineer should conduct a RAM-C analysis to determine whether the KPPs and KSAs are valid and feasible (see RAM-C Rationale Report Outline Guidance). Once the program determines them to be valid and feasible, the systems engineer then translates the R&M KSA threshold requirements to design specification requirements and allocates the requirements to subsystems.
- Ensure that R&M engineering activities and deliverables in the RFP are appropriate for the program phase and product type.
- Ensure that R&M Data Item Descriptions (DIDs) that will be placed on contract are appropriately tailored (see Guidance for Tailoring R&M Engineering Data on the OUSD(R&E) website https://cto.mil/rm/).
- Integrate R&M engineering activities and reliability growth planning curve(s) in the SEP at Milestones A and B and at the Development RFP Release Decision Point.
- Plan verification methods for each R&M requirement.
- Ensure the TEMP describes the verification methods for each R&M requirement, along with a reliability growth planning curve beginning at Milestone B.
- Plan for system and system element reliability growth (i.e., Highly Accelerated Life Test, Accelerated Life Test or conventional reliability growth tests for newly developed equipment).
- Ensure 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.
- Identify and track R&M risks and Technical Performance Measures.
- Assess R&M status during program technical reviews.
- Include 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 the acquisition phase outlined in Table 3-13.

Table 3-13. R&M Activities by Acquisition Phase

Acquisition Phase	R&M Activities

Materiel Solution Analysis (MSA) Phase. During the MSA 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.
	• Develop an R&M engineering program plan. The plan should address the full life cycle of the program. Planning activities typically commence in the MSA phase and continue through the O&S phase.
	  ○ A properly tailored R&M engineering program ensures that all elements are cost-effectively implemented and properly conducted, evaluated, reported, and integrated in a timely manner for design, analysis, development, testing, and manufacturing.
	  ○ Planning the early stages should include the approach and procedures by which the contractor will ensure compliance with the proposed contractual requirements. The approach should also provide results of R&M design analyses and test results needed to support all major design reviews, program reviews, and milestones. These planning activities should be documented in the appropriate DoD acquisition component program plans and IMS.
	• Conduct RAM-C analysis. For MDAP, prepare a preliminary RAM-C Rationale Report and attach the report to the SEP for Milestone A.
	• Translate ICD performance capabilities and draft CDD thresholds to R&M specification requirements based on the CONOPS/OMS/MP, failure definitions, and utilization rates.
	• Develop a system reliability growth planning curve and include it in the SEP. Reliability growth curves should be stated in a series of intermediate goals and tracked through fully integrated, system-level test and evaluation events until the reliability threshold is achieved. If a single curve is not adequate to describe overall system reliability, curves for critical subsystems, with rationale for their selection, should be provided.
	• Use data from the RAM-C Rationale Report to provide the following for logistics design support:
	  ○ The initial failure mode assessment, including effects of failure on system performance and the probable manner in which each failure mode would be detected to provide guidance to planning and the conceptual design of the diagnostics concept and maturation process.
	  ○ Failure rate and removal rate estimates, for both corrective and preventive maintenance, to provide a realistic basis for equipment and replaceable unit spares provisioning planning.
	  ○ Define contractor R&M engineering activities in the RFP and contract Statement of Work for the TMRR phase, which should include:
	    a. Allocations
	    b. Block diagrams and modeling
	    c. Predictions
	    d. FMECA
	    e. Subsystem and system-level reliability growth planning activities
	    f. R&M tests and demonstrations
	    g. FRACAS

Acquisition Phase	R&M Activities
Technology Maturation and Risk Reduction (TMRR) Phase. During the TMRR 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 use of all test data for R&M assessment. Comprehensive test planning should include subsystem reliability growth and maintainability and BIT demonstrations as appropriate. • Understand schedule and resource constraints, and adjust the reliability growth planning curve based on more mature knowledge points. Include updated reliability growth planning curve in the SEP at the Development RFP Release Decision Point and at Milestone B, and in the TEMP at Milestone B. • Integrate R&M engineering analyses with logistics design support in the following areas: requirements and functional analysis; test planning; Reliability Centered Maintenance and Condition Based Maintenance Plus; and refinement of the maintenance concept, including the Level of Repair Analysis and maintenance task analysis. • 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 SOW for the EMD phase, during which R&M quantitative requirements and verification methods are incorporated. • Update the RAM-C analysis to support the Development RFP Release Decision Point ensuring the JCIDS Sustainment Thresholds in the CDD are valid and feasible. For MDAPs, attach the updated RAM-C Rationale Report to the SEP for Milestone B.
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. • Update the RAM-C analysis, ensuring the JCIDS Sustainment Thresholds are valid. For MDAPs, attach the updated RAM-C Rationale Report to the SEP for Milestone C. • 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.

Acquisition Phase	R&M Activities
	• Coordinate with the Chief Developmental Tester (T&E Lead) and Operational Test Agencies 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 SOW for the P&D phase to ensure adequate R&M engineering activities take place during P&D and 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) and MIL-STD-11991 (General Standard for Parts, Materials, and Processes).
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 ECP, operational mission/deployment changes, and variations for impact on R&M. • Update R&M predictions and FMECAs based on production tests, demonstration tests, operational evaluation and field results and apply them to the models previously developed to assess impacts on maintenance procedures, spares, manpower, packaging design, test equipment, missions and availability. • Verify engineers use parts, materials and processes management requirements for limiting reliability risk and lessons learned 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 planning, features and procedures; provisioning plans, test equipment design; and maintenance training. • 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.

3.3.2 Manufacturing and Quality

M&Q management share common characteristics. All programs should include the concept of producibility in their M&Q plans and strategies. The Government develops a Manufacturing

Strategy and Quality Strategy. The contractor develops a Manufacturing Plan and Quality Plan. The program should integrate these plans into the SEP.

- A Manufacturing Strategy should be tied to the program's Acquisition Strategy and focus on how the resources of the manufacturing system can be used to support critical business and technical objectives. For example, a business strategy may be to use an existing facility with standard, stable processes to reduce costs and risks.
- A Manufacturing Plan addresses, in detail, how the company and manufacturing facility will meet contract requirements and deliver the product as requested. The plan should be linked to the Work Breakdown Structure and Bill of Materials and describe steps necessary to fabricate and assemble the end item. Specific data deliverables that should be considered include: Manufacturing Plan, DI-MGMT-81889.

Three important parts of execution include the following:

- The contractor should be required to develop and implement a Manufacturing Management System (MMS) and a Quality Management System (QMS). Program Management Offices (PMOs) should not dictate the contract-specific MMS or QMS, but these systems should share common elements or framework with industry best practices.
- The PMO team should include members of the Defense Contract Management Agency (DCMA) to help support contractor surveillance and oversight.
    - Note: PMOs need to accomplish 78 Contract Administration service functions. Many of these can be partially transferred to DCMA for onsite performance based on the development and execution of a MOA or MOU. PMOs need to recognize that DCMA resources are limited, thus the MOA/MOU should focus on specific M&Q requirements and negotiate a level of oversight commensurate with risks.
- The PMO team and contractor should assess risk and develop risk mitigation strategies.

3.3.2.1 Manufacturing Management Program

A Manufacturing Management Program describes the proven manufacturing management practices. The DoD has adopted the Society of Automotive Engineers (SAE) standard for Manufacturing Management, SAE AS6500, "Manufacturing Management Program" and implements it as detailed in MIL-HDBK-896A, "Manufacturing Management Program Guide." The PMO team should identify the appropriate contract manufacturing requirements.

AS6500 and MIL-HDBK-896A address many requirements including:

- Design and Producibility Analysis
- Variability Reduction and Key Characteristics
- Process Capability and Continuous Improvement

- Manufacturing Planning and Control
- Manufacturing Surveillance and Risk Assessments
- Supply Chain Management
- Manufacturing Modeling and Simulation
- Facilities, Tooling, and Test Equipment (Special Tooling, Test, and Inspection Equipment)
- Manufacturing Workforce
- Cost Estimating, Tracking, Management, and Cost Reduction

A Manufacturing Management Program provides a system to promote the timely development, production, and fielding of affordable and capable weapon systems by addressing manufacturing risks and issues throughout the program acquisition cycle. PMs of programs with a manufacturing component should ensure contractors have a robust manufacturing management system.

Manufacturing management is closely linked to the SE process and the SEP in several ways. The manufacturing organization should provide representation to the design function and ensure producibility and inspectability are addressed as design considerations. Manufacturing engineers should provide process capability data to the designers and compare proposed tolerances, materials, and assemblies to current capabilities. Typically, a representative from the manufacturing function must coordinate on designs to ensure the design takes manufacturing considerations into account. Because of the close linkage to SE, manufacturing personnel should:

- Support all design reviews and SE technical reviews to ensure manufacturing considerations are addressed early.
- Support the development of the SEP with planned manufacturing management activities and metrics. In addition, previous and subsequent phases should be summarized in the SEP.
- Provide information for the SEP to support efficient and cost-effective manufacturing, mapping key design considerations into contracts as a key design consideration.
- Support the identification, tracking, and management of technical risks.

Manufacturing should be a TPM for the program, and the program’s Manufacturing Strategy should be incorporated into the program’s SEP. Typical TPMs for manufacturing include:

- Capacity Utilization Rates
- Overall Operating Efficiency
- Overall Equipment Effectiveness

- Inventory Turns and Accuracy
- On-Time Delivery
- Quality (First Pass Yield, Scrap, Rework and Repair, Cost of Quality, Customer Returns, etc.)

3.3.2.2 Quality Management Program

A Quality Management Program includes the overall approach to meet customer quality requirements to include proven quality management practices, often documented in the contractor's Quality Plan. To meet program quality objectives, DoD has adopted standards such as SAE AS9100, "Quality Management Systems," and ISO 9001, "Quality Management Systems Requirements" to guide Quality Management Programs on individual defense acquisition programs. A QMS details the processes, policies, goals, measurement, reporting, organization, resources, and functions involved in the determination and achievement of quality (i.e., customer satisfaction). The PMO team should identify the appropriate quality requirements per Federal Acquisition Regulation (FAR) 46 Quality Assurance and FAR 52 Contract Provisions. Quality planning should include the development of a Quality Strategy (Government) and a Quality Plan (contractor).

- A Quality Strategy is the Government's approach to meet required quality objectives and should be tied to the program's Acquisition Strategy. As an example, the strategy may include use of commercial standards (e.g., ISO 9001), DoD-unique quality management processes, or other agency standards (e.g., Federal Aviation Administration).
- A Quality Plan is the contractor's plan that addresses, in detail, how the company and facility will meet contract requirements and deliver the product as requested. The plan should address fabrication and assembly and describe how in-process and end-item inspection will lead to lower costs and better reliability. Specific data deliverables that should be considered include a Quality Assurance Program Plan, DI-QCIC-81794.

SAE AS9100 and ISO 9001 focus on these areas of concern:

- First Article Inspection
- Variation Reduction of Key Characteristics
- Non-conformance Documentation
- Qualification Procedure for Aerospace Standard Parts (Supplier Quality)
- Advanced Product Quality Planning and Production Part Approval Process

To ensure consistency in applying quality planning and process control, the program should establish a QMS early, ideally at Milestone A (see PM Guidebooks (2022) for more information on Quality Management). The QMS should be defined and documented in the Acquisition

Strategy. Quality should be integrated into the Acquisition Strategy as an SE practice that supports the successful transition of a capability from development, through LRIP, and ultimately FRP and delivery of systems to support warfighter missions.

The primary focus of the QMS should be to ensure the effectiveness of processes; a best practice is to employ Statistical Process Control (SPC) techniques to eliminate defects and control variation in production.

The PM 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 the process and product development.

Two more valuable tools to assist in creating quality in design are Lean/Six Sigma and Quality Function Deployment. Lean/Six Sigma techniques strive to identify and reduce all sources of product variation and waste — machines, materials, methods, measurement system, the environment, and the people in the process. Quality Function Deployment is a structured approach to understanding customer requirements and translating them into products that satisfy those needs.

Quality of Design

Quality of design focuses on the concurrent development of product and 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 established at this point. The Manufacturing Management Program and Quality Management Program should aid the transition from development to production by controlling and reducing life cycle cost by reducing complexities that are often found when quality and producibility are 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 that:

- Processes to produce the end product are in statistical control (uniformity in manufacturing and production).
- Design specifications align with manufacturing process capabilities.
- Functional design integrates producibility requirements (measure of relative ease of manufacturing) with no significant compromises to quality and performance.

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.

Quality of Conformance

Quality of conformance is the degree to which a product or service meets or exceeds its design specifications and is free of defects or other problems that could degrade its performance. The fabricating, processing, assembling, finishing, and review of early production units (i.e., “first articles”) is the first opportunity to measure effectiveness of the quality of conformance efforts. Any operation that causes a product characteristic to deviate from the specified target renders the configuration of the product different from that which was originally intended, which can have an impact on cost, schedule, and performance.

3.3.2.3 Producibility

NAVSO-P-3687, Producibility System Guidelines, provides best practices for producibility and defines producibility as “the relative ease by which a product can be manufactured in terms of yield, cycle times, and the associated costs of options in product designs, manufacturing processes, production and support systems, and tooling.”

Producibility is a design accomplishment focused on ensuring the program considers manufacturing cost and capability during trade-offs. Like manufacturing and other key system design functions, producibility is integral to delivering capability to the warfighter effectively and efficiently. Producible designs are lower risk, more cost-effective, and more repeatable, and they enhance product reliability and supportability. The program should assess producibility at both a product and enterprise (i.e., organizational, prime contractor facility) level. The PM should implement producibility engineering and planning efforts early and should regularly assess the integrated processes and resources needed to successfully achieve producibility.

To assess producibility on a product level, the program should assess both the product and its manufacturing processes. The contractor should monitor and control manufacturing processes through measurement to ensure the processes can repeatedly produce accurate, high-quality products, which helps the program meet objectives for limiting process variability to a tolerable range.

The PM should ensure the contractor’s producibility activities focus on the following elements:

1. Establish a producibility infrastructure:
    - Organize for producibility.
    - Integrate producibility into the program’s risk management program.
    - Incorporate producibility into the new product strategy.
    - Employ producibility design guidelines.

2. Define manufacturing requirements early along with methods to ensure the verification and validation of requirements to be met:
    - Determine Process Capability (Process Capability Index (Cp) and Process Capability Centering Index (Cpk)) and Process Performance (Process Performance Index (Pp) and Process Performance Centering Index (Ppk)) as appropriate.
    - Understand and document contractor requirements and processes.
    - Verify and validate requirements can be and are met by production processes.
    - Plan for future process capabilities and performance.
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 PDR, CDR, PRR, and FRP DR.
    - Optimize manufacturing plans as the design matures.
5. Measure producibility processes, products, and systems.

Producibility should be the basis of a TPM for the program. The SEP should include the program's strategy for producibility and should summarize completed and planned producibility engineering activities. The SEP should note producibility as a key design accomplishment, mapping key design considerations into the RFP and subsequently into the contract.

3.3.2.4 Manufacturing and Quality Activities

M&Q considerations begin early in the acquisition process and continue through all acquisition phases (Table 3-14). Often M&Q activities are driven by other functions. For example, the procuring contracting officer in developing the contract and RFP may look to M&Q personnel for Section L and M criteria. Financial personnel may ask M&Q personnel to support Government independent cost estimates, evaluate contractor cost proposals, or monitor production costs.

Table 3-14. M&Q Activities by Phase

Acquisition Phase	Typical Manufacturing and Quality Activities
Materiel Solution Analysis (MSA)	• Participate in AoA and provide inputs to the draft CDD. • Provide inputs to the draft Acquisition Strategy and SEP, and develop Manufacturing/Quality Plan/Strategy. • Support development of the draft RFP, review contractor proposals, support cost estimating and tracking. • Review and provide inputs to trade studies, LCSP, TEMP, IMP, and IMS. • Support all Program/Technical Reviews and Audits (ASR, MRA, and ITRA).
Technology Maturation and Risk Reduction (TMRR)	• Participate in prototyping and design development through the IPT structure to identify and mitigate M&Q risks in the product to be developed in the next phase. • Inputs to Acquisition Strategy, SEP, final CDD, TEMP, LCSP, IMP/IMS, and draft RFP. Develop, implement, and monitor M&Q plans. • Support Prototype build/testing, assess manufacturing readiness (MRL 6). • Support all Program and Technical Reviews and Audits (SRR, SFR, TRA, MRA, ITRA, and PDR) and trade studies. • Support development of the draft RFP, review contractor proposals, support cost estimating and tracking.
Engineering and Manufacturing Development (EMD)	• Participate in trade studies and design development activities through the IPT structure. • Provide inputs to the Acquisition Strategy, SEP, CPC planning, LCSP, IMP/IMS, and draft RFP. Develop, implement, and monitor M&Q plans. • Support build/testing, assess manufacturing readiness (MRL 7 and 8). • Support all Program and Technical Reviews and Audits (CDR, TRR, TRA, MRA, SVR/FCA, PRR, and ITRA). • Support development of the draft RFP, review contractor proposals, support cost estimating and tracking.
Production and Deployment (P&D)	• Participate in initial Configuration Control Board process. • Support LRIP and FRP, assess manufacturing readiness (MRL 9 and 10). • Support Initial and Full Operational Capability (IOC and FOC). • Provide inputs to the LCSP and PBL Plan. Develop, implement, and monitor M&Q plans. • Support development of the draft RFP, review contractor proposals, support cost estimating and tracking.
Operations and Support (O&S)	• Support FRP decision. • Provide inputs to the Acquisition Strategy, SEP, TEMP, LCSP. Develop, implement, and monitor M&Q plans. • Analyze system use data such as deficiency reports, hazard reports, regulatory violations, etc. • Support build and text activities, along with P3I and block updates. • Support development of the draft RFP, review contractor proposals, support cost estimating and tracking.

Additional information on required M&Q tasks and activities can be found at https://cto.mil/sea/mq/.

3.3.2.5 Assessing Manufacturing Readiness and Risk

DoDI 5000.85 establish policy on the requirement to address manufacturing risks over the entire life cycle of a program.

- The PM is responsible for assessing manufacturing feasibility to ensure the program integrates manufacturing readiness and risk as part of design activities.
- PMs should consider use of existing contractor manufacturing processes whenever practical to support low-risk manufacturing. When the design requires new manufacturing capability, the PM may need to consider new manufacturing technologies or process flexibility (e.g., rate and configuration insensitivity), which introduces risk. DoDI 5000.88, Section 3.6.c. defines the requirements for manufacturing processes and manufacturing risks. Defense Federal Acquisition Regulation Supplement (DFARS) Subpart 207.105 – Contents of Written Acquisition Plans) provides specific guidance on manufacturing actions the PM can plan in order to execute the approach in the Acquisition Strategy and to guide the implementation of the contract. The PM should:
    - Consider the requirements for efficient manufacture during the design and production of the system.
    - Assess the availability of raw materials, special alloys, composite materials, components, tooling, and production test equipment.
    - Use advanced manufacturing technology, processes, and systems.
    - Use contract solicitations that encourage competing offerors to acquire modern technology, production equipment and production systems (including hardware and software).
    - Encourage investment in advanced manufacturing technology, production equipment and processes.
    - During source selection, emphasize the efficiency of production.
    - Expand the 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. M&Q personnel should assess manufacturing risk through Manufacturing Readiness Assessments (MRAs) and integrate the results into existing program assessments. The PM should assess manufacturing readiness in the program's earliest phase and regularly throughout the life cycle. The PM should report on the program's manufacturing readiness progress and status during each SE technical review and before each milestone decision.

Successful manufacturing has many dimensions. Industry and Government have identified best practices in the following nine manufacturing risk categories. A program should tailor implementation of these best practices according to product domains, complexity, 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 the 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 PM needs to understand the contractor or vendor business strategy and the impacts to Government risk identification and mitigation efforts, such as the Make/Buy decisions and supply chain risks assessments. Additional guidance on assessing manufacturing risks can be found in the Manufacturing Readiness Level 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 PM and SE technical team should consider the manufacturing readiness and manufacturing-readiness processes of potential contractors and subcontractors as a part of the source selection for MDAPs (see DFARS (Subpart 215.304)).

The PM and SE technical team should assess manufacturing readiness during the acquisition life cycle, as described in Table 3-15.

Table 3-15. Minimum Points (When) to Assess Manufacturing Readiness

Key Assessment Points	Considerations
1. Materiel Solution Analysis Phase supporting Milestone A Decision. As the program approaches the Milestone A decision, manufacturing risks should have been assessed for each of the competing alternatives and preferred system concept. Note: Manufacturing Readiness Level Deskbook and MRL Users Guide are one source of specific assessment factors.	• Assess manufacturing feasibility and capability to produce in a lab environment. • Program critical technologies are ready for the Technology Maturation and Risk Reduction phase. • Required investments in Manufacturing Technology development have been identified (Manufacturing Technology Program (DoDI 4200.15 Manufacturing Technology Program) focuses on the development and application of advanced manufacturing technologies and processes that will reduce the acquisition and sustainment manufacturing/repair cycle times and cost http://www.dodmantech.com). • 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.
2. Technology Maturation and Risk Reduction Phase supporting Milestone B and Development RFP Release Decision. As the program approaches the Development RFP Release Decision and the Milestone B decision, critical technologies and manufacturing processes should have been sufficiently matured and demonstrated in a relevant environment. The overall assessment should consider:	• Assess contractor's manufacturing capability to produce in a production-relevant environment. An initial manufacturing approach has been developed. • Manufacturing processes have been defined and characterized, but there are still significant engineering 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. • The program should be nearing acceptance of a preliminary system design. 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 for Milestone B) has confirmed the viability of the supplier base.
3. Engineering and Manufacturing Development (EMD) Phase, Critical Design Review.	• Assess contractor's manufacturing capability to produce in a production representative environment. An initial manufacturing approach has been developed.

Key Assessment Points	Considerations
As the program approaches the CDR, the system should have been sufficiently matured to start fabrication, demonstration, and testing of pre-production articles with acceptable risk. A rule of thumb is that 75-90 percent of product drawings and associated instructions should be complete, and 100 percent of the safety-critical components are complete. Production should be demonstrated in a relevant environment. The overall assessment should consider:	• Critical manufacturing processes that affect the key product characteristics have been identified, process control plans have been developed, and the capability to meet design tolerances has been determined. • Detailed design is producible and assessed to be within the production budget. • Detailed producibility trade studies using key design characteristics and related manufacturing process are completed. Materials and tooling are available to meet the pilot line schedule. • Long-lead procurement plans are in place; supply chain assessments are complete. • Verify configuration control of the initial product baseline as demonstrated by the completion of build-to documentation for hardware and software configuration items, production models, drawings, software design specifications, materials lists, manufacturing processes, and qualification plans/procedures.
4. Engineering and Manufacturing Development (EMD) Phase, Milestone C. As the program approaches a Milestone C Decision, a series of PRRs should have been conducted to identify the risks of transitioning from development to production (LRIP). It is important that key processes have been considered and evaluated during the PRRs. Production should be demonstrated on a pilot line. The overall assessment should consider:	• Assess contractor's manufacturing capability to produce on a pilot line. • The detailed system design is complete and stable to support LRIP. • Technologies are mature and proven in a production environment, and M&Q 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.
5. Production and Deployment Phase, Full Rate Production (FRP) Decision Review. As the program approaches the Full Rate Production (FRP) Decision, Manufacturing readiness should have been assessed and there should be no significant manufacturing risks remaining. Manufacturing readiness results should include recommendations for mitigating any remaining low (acceptable) risk, based on assessment of manufacturing readiness for FRP. The overall assessment should consider:	• Assess LRIP and FRP environments. • LRIP learning curves that include tested and applied continuous improvements have been assessed and validated. • Meeting all systems engineering and 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.

3.3.2.6 Assessing Industrial Capabilities

DFARS 207.105, Contents of Written Acquisition Plans, provides guidance on manufacturing actions the PM should take to execute the approach established in the Acquisition Strategy.

Current legislation and policies governing industrial base capabilities are intended to ensure that the PM and technical team address:

- The industrial needs of the acquisition program
- The impacts of acquisition programs on industrial capabilities
- The manufacturing needs of acquisition programs

PMs should be interested in three broad risk areas from an industrial base perspective that go beyond classical supply chain considerations:

- The Capability to Produce (one unit)
- The Capacity to Produce (all units required over the life of the program)
- The Financial Stability (the company will endure long enough to complete all production)

Industrial Capabilities Planning

Industrial capabilities planning should address current and future status of unique manufacturing capabilities. The planning should identify:

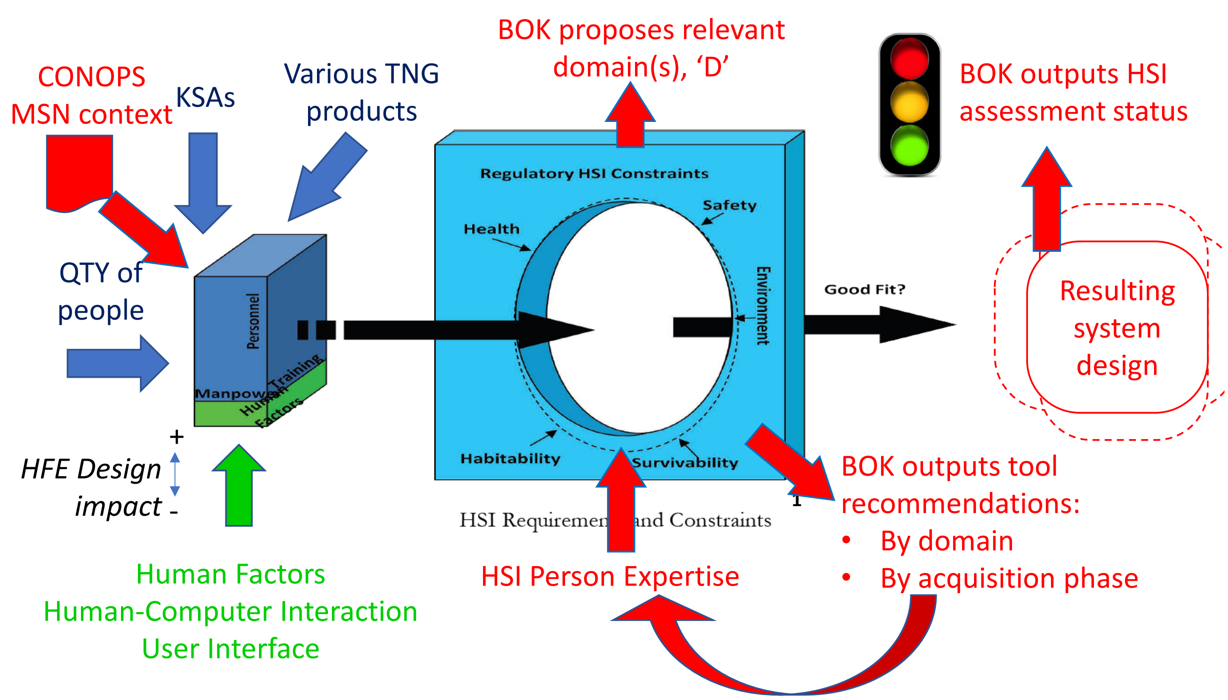
- Adequacy of industrial capabilities to meet acquisition needs.
- Ability to cost-effectively design, develop, produce, maintain, support, and restart the program (if necessary).
- Approach to meeting required production rate and quantity changes in response to contingency and support objectives.
- Planning and infrastructure considerations, including prime and subtier contractors.
  - Vulnerable suppliers
  - Component obsolescence
- Unique items projected to go out of production. For each item, planning should address:
  - Product/technology obsolescence
  - Replacement of life-limited items
  - Production line re-start

M&Q personnel in the program office should identify all unique manufacturing capabilities. In addition to identifying unique items, any facilities or corporations that provide unique services or products also need to be identified.

3.3.3 Human Systems Integration

The PM has overall responsibility for integrating the HSI effort into the program. The HSI Guidebook (2022) provides more detail regarding PM responsibilities and tailoring HSI activities to each AAF pathway.

The systems engineer supports the PM by leading HSI efforts with the HSI practitioner. The systems engineer should work with the HSI practitioner and, when necessary, the HSI domain-level SMEs (e.g., manpower, personnel, training, safety, occupational health, habitability, personnel survivability, and human factors engineering) and 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 (Figure 3-7).



BOK: Body of Knowledge; CONOPS: Concept of Operations; HFE: Human Factors Engineering; HSI: Human Systems Integration; KSA: Knowledge, Skills, and Abilities; MSN: Mission; QTY: Quantity; TNG: Training

Figure 3-7. Integration of Human Capability Considerations

SE addresses the three major elements of each system through HSI: hardware, software, and the 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 capabilities and limitations of the human operators, maintainers, and users.

Throughout the acquisition life cycle, the systems engineer should apply HSI design criteria, principles, and practices such as those described in MIL-STD-1472 (Human Engineering) and MIL-STD-46855 (Human Engineering Requirements for Military Systems, Equipment and Facilities).

The HSI effort assists the PM and systems engineer to minimize ownership costs and ensure 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, training and training devices, and operational and support infrastructure.

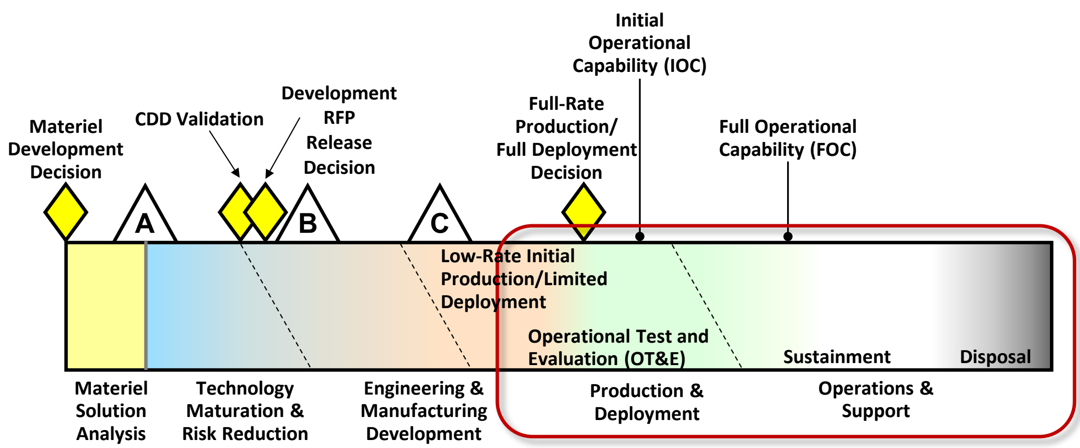
Requirements for conducting HSI efforts should be required in the Statement of Work and contract, along with appropriate DIDs. The PM and systems engineer should address HSI in the SEP, specifications, TEMP, Software Development Plan, LCSP, and other appropriate program documentation. The SEP Outline requires that programs address HSI as a design consideration.

An effective HSI effort, described in the HSI Guidebook (2022), should:

- Provide a better operational solution to the warfighters.
- Lead to the development or improvement of all human-machine interfaces.
- Achieve required effectiveness of human performance during system testing, operation, maintenance, support, transport, demilitarization, and disposal.
- Ensure the demands upon personnel resources, skills, training, and costs are planned and accounted for at every stage in the system life cycle.
- Ensure that overall human performance is within the knowledge, skills, abilities, and other attributes of the designated user population (i.e., target audience description) to support mission tasking.

The MCA pathway requires the greatest level of HSI involvement with the earliest consideration for total ownership cost affordability to the PM, and it allows the greatest opportunity for requirements addressing human performance. The different AAF pathways require differing approaches to the HSI activities and functions to gain total ownership cost return on investment. HSI practitioners should be involved in each phase of development. The requirements for HSI practitioner engagement to accomplish the intended activities are described in more detail in the HSI Guidebook (2022).

HSI practitioners should be involved in testing events in which operators, maintainers, and supporters are going to use the system to meet the mission need. Since training devices and training materials that were previously developed are now in use, HSI practitioners should assess the efficacy of those products and obtain user feedback to articulate whether users are achieving the expected levels of performance and if the sustainment and support activities in place are adequate (Figure 3-8).



Production & Deployment Phase
- Personnel Training
- Test & Evaluation Activities
- System Sustainment & Support Activities
- Initial Operational Capability

Operations & Support Phase
- Follow-on Test & Evaluation
- Collection of Performance Metrics in Operational Settings
- System Sustainment & Support Activities
- Data Collection for Next Increment or System
- Disposal

Figure 3-8. P&D and O&S HSI Challenges and Opportunities

In the O&S phase, HSI practitioners should stay engaged because program offices will be collecting performance metrics on the system usage. The HSI practitioners should be analyzing the collected data in terms of the HSI domains and making recommendations for improvements with respect to total ownership cost reductions:

- Is the manpower sufficient for the system?
- Is there evidence of workload being too high or too low?
- Do the operator, maintainer, and support personnel seem to have the requisite knowledge, skills, and abilities?
- Has the training prepared those personnel for what they need to do with or on the system?
- Are the working conditions hampering their performance?
- Are the operating conditions hazardous in any way?
- Finally, when it is time for the system to be decommissioned, HSI practitioners are active in the disposal process, particularly as it relates to identifying the personnel who will have the responsibility for disposal.

3.3.4 System Safety Engineering

System safety is a key element of SE that provides a standard, generic method for the identification, classification, and mitigation of hazards. MIL-STD-882 defines system safety as "The application of engineering and management principles, criteria, and techniques to achieve acceptable risk within the constraints of operational effectiveness and suitability, time, and cost throughout all phases of the system life cycle." It defines system safety engineering as "An engineering discipline that employs specialized knowledge and skills in applying scientific and engineering principles, criteria, and techniques to identify hazards and then to eliminate the hazards or reduce the associated risks when the hazards cannot be eliminated."

DoDI 5000.88, Section 3.6.e., requires a strategy for the system safety engineering program to be documented in the SEP in accordance with MIL-STD-882. The standard reinforces integration of other functional disciplines into SE to ultimately improve consistency of hazard management practices across programs. To fully integrate system safety into SE activities, IPTs, and other stakeholder organizations (i.e., Logistics, T&E, and Software, Software Quality), the PM must establish a safety and risk management program through which the PM communicates the process for managing uncertainty and safety risks that the program determines it must eliminate or control, as well as the rationale for accepting certain risks as appropriate, while observing cost, schedule, and performance objectives (DoDI 5000.85, subsection 3.C.3.d.(2)(a)).

DoD expands the objective and use of the system safety methodology to integrate risk management into the overall SE process. MIL-STD-882 defines system safety management as "All plans and actions taken to identify hazards; assess and mitigate associated risks; and track, control, accept, and document risks encountered in the design, development, test, acquisition, use, and disposal of systems, subsystems, equipment, and infrastructure." System safety management consists of general engineering requirements and design criteria for safety risk management during system design and development. It identifies safety risk management requirements, including procedures for test, O&S, and disposal. MIL-STD-882 provides a matrix and defines probability and severity criteria to categorize risks. According to DoDI 5000.85, before exposing people, equipment, or the environment to known system-related hazards, the risks must be accepted by the appropriate authority. The system configuration and associated documentation that support the formal risk acceptance decision must be provided to the Government for retention through the life of the system.

MIL-STD-882 covers hazards as they apply to systems, products, equipment, and infrastructure, including both hardware and software, throughout design, development, test, production, use, and disposal. Hazards, control measures, and risks as they apply to autonomy, artificial intelligence (AI), and unmanned systems, including autonomous weapon systems, need to be assessed as part of the system safety process. The system safety engineering program identifies safety certification such as the Airworthiness Release, Fuse Safety Reviews, Hazard of Electromagnetic Radiation to Ordnance Classification and Certification, Energetic Material

Qualification, Hazard Classification, Ignition Safety Review, Health Hazard Assessment and Joint Weapon Safety reviews and assessments, and ESOH.

3.3.4.1 Environment, Safety, and Occupational Health

ESOH analyses are an integral, ongoing part of the SE process throughout the life cycle. DoDI 5000.88, Section 3.6.e., requires programs to use the system safety methodology in MIL-STD-882 to manage their ESOH considerations as an integral part of the program's overall SE process. This starts with including ESOH management planning in the Milestone A SEP to cover TMRR activities and continues throughout the system's life cycle.

ESOH is defined in MIL-STD-882 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."

The PM should use the system safety methodology for the identification, documentation, and management of environmental, occupational, and health hazards and their associated risks during the system's development and sustainment. The PM, with support from the systems engineer and system safety SMEs, eliminates hazards where possible, and manages environmental, occupational, and health risks where hazards cannot be eliminated.

The PM, systems engineer, and system safety SMEs should also identify and integrate environmental, occupational, and health hazard requirements into the SE process, including but not limited to complying with NEPA, EO 12114, and applicable environmental quality requirements. The program will need to assess the system's operation and maintenance pollutant emissions, prohibiting or strictly controlling the use of banned or restricted hazardous materials such as hexavalent chrome and ozone-depleting substances. Results of environmental, occupational, and health hazards and concerns are documented in the PESHE and their NEPA/EO 12114 Compliance Schedule. The PESHE consists of the environmental, occupational and health hazard data; hazardous materials management data; and any additional environmental, occupational and health compliance information required to support analyses at test, training, fielding, and disposal sites.

3.3.4.2 Software System Safety

Software system safety (SSS) as defined in MIL-STD-882 is "the application of system safety principles to software." DoDI 5000.88, Section 3.6.e., requires the SEP to be used to document a strategy for the system safety engineering program including SSS in accordance with MIL-STD-882. The standard provides a structured, yet flexible and tailorable, framework for hazard analysis and risk assessment for a specific system application (including system hardware and software).

The system safety engineering program and activities include the SSS activities (e.g., Hazard Analyses: Physical Hazard Analysis, Functional Hazard Analysis, Hazard Tracking System (HTS)) to identify SSS constraints to input into the development of critical and new technologies including AI, autonomy, and unmanned capabilities, and functionality. As an example for software, SMEs use the MIL-STD-882 process for assessing the assessments of software contribution to system risk. The assessment of risk for software, and consequently for software-controlled or software-intensive systems, considers the potential risk severity and degree of control the software exercises over the hardware, and dictates the analysis and the level of rigor (LOR) tasks needed to reduce the risk level. The LOR tasks and analyses specify the depth and breadth of software analysis and verification and validation activities and analyses (e.g., design, requirements, architecture, and code analysis, software quality, T&E V/V, safety-specific testing) necessary to provide a sufficient level of confidence and safety assurance that a safety-significant software function will perform as required.

The system safety and SSS hazard analysis processes and the successful execution of LOR tasks are key elements to increase the confidence that the software will perform as specified to software performance requirements, while reducing the number of contributors to hazards that may exist in the system. All software contributions to system risk are documented in the HTS.

The Joint Services Software Safety Authorities' Software System Safety Implementation Process and Tasks Supporting MIL-STD-882 is a concise implementation guide to assist in the implementation of the software system safety requirements and guidance contained in MIL-STD-882. The Joint Software System Safety Engineering Handbook process descriptions complement MIL-STD-882 for these analyses. Allied Ordnance Publication (AOP) 52, "Guidance on Software Safety Design and Assessment of Munitions Related Computing Systems" provides additional guidance on how to conduct required software analyses.

The Unmanned System Safety Engineering Precepts Guide for DoD Acquisition is intended to support the development and design of safe unmanned systems (UxS), associated safety significant software, support hardware and firmware, and Service safety reviews. The guide is directed toward UxS system safety engineers as well as UxS PMs, Systems Engineers, system designers, and T&E managers. The precepts are intended to be general, to be complemented by systems specific to a program office. The guide is intended to provide the PM with a point of initiation for precepts that can aid the development of a system safety engineering program. The guide includes a summary of the three types of safety precepts (Programmatic, Design, and Operational), an analysis of the major UxS safety concerns, and an assessment of the state of the art of AI and autonomous capabilities, which, when integrated properly, can enable the desired performance of UxS autonomy, human-machine interaction, and command and control.

3.3.4.3 Hazard Tracking System

A closed-loop HTS is used to document, track, and maintain hardware and software-related hazards and their associated risk data. The HTS includes subcontractor, vendor, and supplier hazard tracking data. The minimum data elements for the tracking system are hazard, system, subsystem, applicability, requirements references, system mode, causal factor, effects, mishap, initial risk, event risk, target risk, control measures, hazard status, verification and validation method, acting person(s), record of risk acceptance(s), and hazard management log. The HTS is maintained throughout the system's life cycle.

The following minimum data for each hazard is included with the HTS identification number:

- Identified hazards (including descriptions)
- Associated mishaps (potential mishaps resulting from the hazard)
- Risk assessments (including the initial, target, and event(s) Risk Assessment Codes and risk levels)
- Identified risk mitigation measures
- Selected (and funded) control measures
- Hazard status (current risk assessment code and risk level based on any control actions that have been implemented, verified, and validated)
- Verification of risk reductions (i.e., status of assessments of mitigation effectiveness)
- Risk acceptances (records of each risk acceptance decision including the names of the risk acceptance authority and user representative(s)
- Dates of risk acceptance and user concurrence(s))

Table 3-16. System Safety Activities by Acquisition Phase

Acquisition Phase	Typical System Safety (including ESOH) Activities
Materiel Solution Analysis (MSA)	• Participate in AoA. • Provide inputs to the SEP, draft CDD, corrosion prevention and control planning, Acquisition Strategy, LCSP, draft RFP, and SOW. • Develop system safety engineering activities (e.g., Preliminary Hazard Analysis, System Safety Management Plan) to assess materiel solutions by identifying inherent hazard risks and develop criteria to define key objectives for the system safety program.
Technology Maturation and Risk Reduction (TMRR)	• Participate in prototyping and design development through the IPT structure to identify and mitigate ESOH risks in the product to be developed in the next phase. • Prepare initial PESHE and NEPA/EO 12114 Compliance Schedule. • Ensure NEPA/EO 12114 compliance, ESOH risk acceptance, PDR risk reporting, and safety releases. • Develop inputs to SEP, CPC Planning, final CDD, TEMP, LCSP, and draft RFP. • Develop system safety engineering activities (e.g., Hazard Analyses: Physical Hazard Analysis, Functional Hazard Analysis, HTS) to identify safety constraints to input into the development of critical and new technologies including AI, Autonomy, and Unmanned capabilities.

Acquisition Phase	Typical System Safety (including ESOH) Activities
Engineering and Manufacturing Development (EMD)	• Participate in trades and design development activities through the IPT structure. • Evaluate T&E results, including assessment of ESOH risk mitigations. • Develop/Update system safety engineering activities (e.g., Hazard Analysis: System Safety Hazard Analysis, System Hazard Analysis, Safety Assessment Report, HTS, Software System Safety Assessment) in accordance with MIL-STD-882 to define requirements and implementation through verification and provide assessment in preparation for product baselining. • 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, and draft RFP.
Production and Deployment (P&D)	• Participate in initial Configuration Control Board process. • Evaluate T&E results, including assessment of ESOH risk mitigations. • Analyze deficiency reports. • Review the 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 IOC and FOC. • Provide inputs to the LCSP, CPC Planning, and product support package. • Develop/Update system safety engineering activities (e.g., Hazard Analysis: O&SHA, HTS) in accordance with MIL-STD-882 to ensure risks have been accepted and minimize impact to safety and continuously monitor systems for new or updated hazards. Obtain Safety Confirmation and Safety Certification.
Operations and Support (O&S)	• Participate in mishap investigations and the Configuration Control Board process. • Analyze system use data such as deficiency reports, hazard reports, regulatory violations, etc. • Keep the PESHE data current; support NEPA/EO 12114 compliance activities and ESOH risk acceptance. • Provide inputs to draft JCIDS documents and CPC Planning.

AoA: Analysis of Alternatives
CDD: Capability Development Document
CPC: Corrosion Prevention and Control
EMD: Engineering and Manufacturing Development
ESOH: Environment, Safety, and Occupational Health
FOC: Full Operational Capability
HTS: Hazard Tracking System
IOC: Initial Operational Capability
IPT: Integrated Product Team
JCIDS: Joint Capabilities Integration and Development System
LCSP: Life Cycle Sustainment Plan
MIL-STD: Military Standard
MSA: Materiel Solution Analysis
NEPA/EO: National Environmental Protection Act/Executive Order
O&S: Operations and Support
OSHA: Occupational Safety and Health Administration
PCA: Physical Configuration Audit
P&D: Production and Deployment
PESHE: Programmatic Environment, Safety and Occupational Health Evaluation
RFP: Request for Proposals
SEP: Systems Engineering Plan
SOW: Statement of Work
T&E: Test and Evaluation
TMRR: Technology Maturation and Risk Reduction

3.3.5 Parts Management

In accordance with DoDI 5000.88, section 3.6.f. Parts Management, “The PM will ensure that a parts management process is used for the selection of parts during design to consider the life cycle application stresses, standardization, technology (e.g., new and aging), reliability, maintainability, supportability, life cycle cost, and diminishing manufacturing sources and material shortages.”

Parts management is an essential element of SE during the early design phase of the acquisition process. It serves a fundamental role in achieving many SE and manufacturing objectives; influences cost, schedule, and performance; and impacts acquisition technical reviews. Parts management remains a vital element of the acquisition process through the O&S phases for system sustainment. Implementing parts management early in the engineering and design phase of a system has multiple benefits:

- Reduced Costs. Robust parts management during design and production saves design and life cycle costs of equipment by promoting the application of commonly used or preferred parts.
- Enhanced Logistics Readiness and Interoperability. Using common components simplifies logistics support, enhances substitutability, and translates to savings in procuring, testing, warehousing, and transporting parts.
- Reduced Acquisition Lead Time. When using preferred parts, Government and industry avoid the expenses and delays of designing and developing parts.
- Increased Supportability and Safety of Systems and Equipment. Preferred parts reduce risk, improve the likelihood that equipment will perform reliably, and reduce mission failure or loss of life.
- Enhanced Reliability and Maintainability Engineering. Ensuring that parts meet contractual requirements and proper design results in enhanced reliability, availability, and maintainability.

Implementing DMSMS management early in the life cycle contributes to these benefits. DMSMS management contributes toward reducing the cost and impact on schedule and performance of a system by ensuring DMSMS design resilience in design, minimizing the scope of out-of-cycle redesigns, eliminating DMSMS-related production schedule impacts, and eliminating readiness degradation due to DMSMS issues.

In addition, since the reliability, maintainability, and supportability of the end item are dependent on hardware stability and readiness, selecting and applying an effective parts management program is key to achieving SE and manufacturing objectives. DMSMS management assists in a program’s parts management efforts.

The parts management and DMSMS management processes should be tailored to meet the needs of the program and acquisition pathway. Parts management applies to three of the six acquisition pathways—MCA, Urgent Capability Acquisition (UCA), and Middle Tier of Acquisition (MTA)—while DMSMS management applies to five of the six acquisition pathways—MCA, UCA, MTA, Software Acquisition, and Defense Business Systems (DBS). Regardless of the chosen pathway, all program offices should implement parts management and DMSMS management during the early design phase of the program when SE design considerations are addressed. These considerations include standardization, technology, reliability, maintainability, supportability, DMSMS resilience, cyber weaknesses and vulnerabilities, and cost in the selection of parts. Parts management considerations should also address legacy issues throughout the life of the system, including availability, logistics support, and DMSMS.

Major Capability Acquisition

Parts management and DMSMS resilience are some of the many considerations informing design and redesign decisions. The parts management of a system or product design provides the opportunity to design out items that are high risk, for example, if parts are near their end of life, replacing them would be difficult or complex after they are part of the design, and requalifying the system after replacing the items would be costly. DMSMS resilience in a system's design delays the occurrence of DMSMS issues and reduces the need for out-of-cycle redesigns. A program office's DMSMS management activities should assist in its parts management efforts. Contractual requirements for parts management and DMSMS management are the most important factors in ensuring the implementation of an effective parts management program and ensuring that there is DMSMS resilience in the design, obsolete items are not designed into the system, and an approach is in place to monitor for and resolve DMSMS issues before they impact the system. Parts management and DMSMS management requirements should be specified in the RFP's Statement of Work for the TMRR, EMD, P&D, and O&S phases.

To ensure successful parts management and DMSMS management programs, the PM should, at a minimum, integrate the following activities into each of the following phases of the program's engineering processes:

Materiel Solution Analysis (Pre-Milestone A)

The program should address parts selection and DMSMS resilience in the SEP and LCSP and should identify risks to inform plans to mitigate parts management issues, including DMSMS management, in the TMRR phase and in the later phases of the acquisition process.

Technology Maturity and Risk Reduction Phase (Milestone A)

The program should include the requirement for a parts management plan and a DMSMS management plan in the RFP statement of work, in accordance with MIL-STD-3018, DoDI 4245.15, SD-22, or other applicable standards. Before system development, program offices should begin DMSMS management activities (often performed by a contractor) to ensure

DMSMS resilience in design, conduct DMSMS risk analyses, and develop mitigation strategies and plans for technology refreshment.

Engineering and Manufacturing Development Phase (Milestone B)

The program office should implement a Government-approved parts management plan and DMSMS management plan, in accordance with MIL-STD-3018, DoDI 4245.15, SD-22, and/or other applicable standards. Parts management plan and DMSMS management plan requirements should flow down to subcontractors, and the prime contractor should review subcontractors' processes for approval and implementation.

During the EMD phase, the program office identifies and documents its processes for proactively monitoring and resolving DMSMS issues throughout the life of the system. Program offices should program and budget for the DMSMS activities outlined in the DMSMS management plan. Depending on the availability of preliminary parts lists, monitoring should help the program ensure DMSMS resilience, prevent the inclusion of obsolete items in system designs, and identify resolutions and/or technology refresh plans to mitigate the impact of any obsolete items.

Production and Deployment Phase (Milestone C)

The program should continuously monitor for obsolete items continues during the P&D phase. Long-lead time items and critical materials are examples of indicators that the program may need to mitigate risks. When the program identifies obsolete items that present risk to the system, engineers should identify and implement resolutions to support production and, to the extent possible, sustainment. Parts management is necessary for changes or modifications to the design, such as engineering changes or parts obsolescence issues.

Operations and Support Phase

Monitoring for obsolete items continues during the O&S phase. As a system ages, the risk of DMSMS issues may increase. Program offices should identify and implement resolutions for DMSMS issues before those issues affect the ability to sustain the system and ultimately readiness. The program should identify long-lead items and critical materials, plan for obsolescence, and implement DMSMS measures to mitigate impacts to production and sustainment. Avoiding the extremely high cost of resolving DMSMS problems helps control life cycle costs.

Chapters 2-7 of the SD-22 outline best practices for implementing DMSMS management for the MCA pathway.

3.4 Modular Open Systems Approach

Pursuant to 10 USC 4401, PMs are responsible for evaluating and implementing MOSA to the extent feasible and cost-effective. In accordance with 10 USC 4401, the term "modular open systems approach" means, with respect to an MDAP, an integrated business and technical strategy that:

(A) employs a modular design that uses modular system interfaces between major systems, major system components and modular systems;
(B) is subjected to verification to ensure that relevant modular system interfaces
(i) comply with, if available and suitable, widely supported and consensus-based standards; or
(ii) are delivered pursuant to the requirements established in subsection (a)(2)(B) of section 804 of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, including the delivery of—
(I) software-defined interface syntax and properties, specifically governing how values are validly passed and received between major subsystems and components, in machine-readable format;
(II) a machine-readable definition of the relationship between the delivered interface and existing common standards or interfaces available in Department interface repositories; and
(III) documentation with functional descriptions of software-defined interfaces, conveying semantic meaning of interface elements, such as the function of a given interface field;
(C) uses a system architecture that allows severable major system components and modular systems at the appropriate level to be incrementally added, removed, or replaced throughout the life cycle of a major system platform to afford opportunities for enhanced competition and innovation while yielding-
(i) significant cost savings or avoidance;
(ii) schedule reduction;
(iii) opportunities for technical upgrades;
(iv) increased interoperability, including system of systems interoperability and mission integration; or
(v) other benefits during the sustainment phase of a major weapon system; and
(D) complies with the technical data rights set forth in section 2320 of this title. Refer to the SE Guidebook, Section 2.2.5, for additional information regarding data rights.

This approach integrates technical requirements with contracting mechanisms and legal considerations to support a more rapid evolution of capabilities and technologies throughout the product life cycle. MOSA is an acquisition and design strategy consisting of a technical architecture that uses modular system interfaces compliant with widely supported and consensus-based standards (if available and suitable). MOSA supports a modular, loosely coupled, and highly cohesive system structure that allows severable major system components at the appropriate level to be incrementally added, removed, or replaced throughout the life cycle of a major system platform to afford opportunities for enhanced competition and innovation.

As part of the implementation of MOSA, the program should include identifying, defining, and publishing modular system interfaces along with providing relevant design disclosure. Interface definition for modular system interfaces includes defining the internal interfaces between system components and the external interfaces with other systems. Relevant design disclosure is necessary for system interfaces, along with the interface requirement specifications necessary for system operation, interface standards and standards profiles, and other documentation that fully describes the physical and functional interfaces needed to ensure compatibility between interfacing components, systems, and platforms. In addition, the program should ensure all interfaces (including external, internal, key, and modular system interfaces) are clearly defined, documented, and controlled. Interface documentation should include requirement specifications necessary for system operation, interface standards and standards profiles, and other documentation that fully describe the physical and functional interfaces needed to ensure compatibility among components, systems, and platforms.

PMs should ensure they adopt 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 using an open systems architecture and an open business model permits the acquisition of systems that are modular and interoperable, allowing for system elements to be added, modified, replaced, removed, and/or supported by different vendors. Moreover, MOSA is not an end result sought by the warfighter or end-item user; it is an approach to system design that can enable additional characteristics in the end item.

DoD identifies the primary benefits of MOSA as:

- Increased interoperability, including system of systems interoperability and mission integration
- Enhanced competition
- Facilitation of technology refresh and evolutionary upgrades
- Increased innovation
- Potential cost savings or cost avoidance
- Reduced time to field capability to the warfighter

MOSA applies a general set of principles to help the program manage system complexity by breaking up complex systems into discrete pieces, which can then communicate with one another through well-defined interfaces.

Acquisition programs adopting MOSA may benefit from:

- Reduced life cycle costs without sacrificing capability
- Reduced reliance on single-source vendors (“vendor lock”)
- Shortened program acquisition timeline
- Enhanced rapid and agile development

- Accelerated transition from science and technology into acquisition due to modular insertion
- Increased ability and flexibility to retrofit or upgrade system elements for new and evolving capability
- Enhanced incremental approach to capabilities
- Increased competition and innovation
- Enhanced ability to create security structures within a design to reduce security risk

MOSA may also benefit 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

Although acquisition programs may employ MOSA to achieve some or all of these benefits, the methods used, and the associated business implications, can vary widely and may drive different techniques and additional responsibilities into programs. The implementation strategy chosen should consider impacts both to the program and to the system's performance (e.g., its effectiveness and feasibility). These factors underpin DoD policy for MOSA in acquisition.

DoDI 5000.88, Section 3.7.a. directs PMs to evaluate and implement MOSA where feasible and cost-effective. MDAPs that receive Milestone A or B approval after January 1, 2019, are required to be designed and developed with MOSA to the maximum extent practicable, pursuant to 10 USC 4401. The overarching business case for DoD is increasing the level of competition by enabling small and large businesses to participate in competition for new or upgraded capabilities. Programs should develop a business model, documenting the strategy for use of MOSA and associated data rights.

In addition, the DoD Open Systems Architecture Contract Guidebook for Program Managers contains guidance regarding contract language that programs should leverage to acquire data rights in support of a program's MOSA strategy. Additional information and supporting details amplifying each aspect of MOSA are available on the OUSD(R&E) website https://cto.mil/sea/mosa/.

The PM should:

- Establish supportive requirements; business practices; and technology development, acquisition, T&E, and product support strategies for effective development of open systems.

- Ensure data deliverables support the Intellectual Property Strategy (see Acquisition Strategy template) and secure the necessary data rights to support and sustain the system.
- Map modular open systems strategy and functional architecture to SOW requirements, DIDs, and CDRL items consistently across the enterprise.
- Ensure compliance.
- Consider including MOSA as one of the evaluation criteria for contract proposals.
- Determine the appropriateness of MOSA by considering software constraints, security requirements and procedures, availability and cost of data rights, life cycle affordability, and reliability of widely supported and consensus-based standards, as well as other relevant factors such as environmental constraints (e.g., temperature, humidity) and ESOH considerations.

The systems engineer should:

- Employ an overall plan for MOSA that supports the system functional architecture and uses prescribed USD(R&E) business case analyses.
- Ensure the system functional architecture is structured to accommodate open systems architecture where feasible to take advantage of the potential to reduce risk and cost.
- Assess performance.
- Balance current implementation of MOSA with performance and evolving technology at the physical level. MOSA establishes a technical baseline that may support modular architecture but formally constrains interfaces between modules, where interfaces close to current performance limits may quickly become obsolete.
- Evaluate the technical appropriateness of MOSA by considering software constraints, security requirements and procedures, availability and cost of data rights, life cycle affordability, and reliability of widely supported and consensus-based standards, as well as other relevant factors, such as environmental constraints (e.g., temperature, humidity) and ESOH considerations.

The program may not realize the benefits of open systems without deliberate planning and guidance at the Program Executive Office level. Reuse may be challenging if the program does not develop and modularize open systems and software in a common way with other systems (even other open systems). As an example, an aviation platform may develop an Automatic Dependent Surveillance-Broadcast (ADS-B) software application that is MOSA conformant, but that application may never be reused by a sister platform that may have its ADS-B and Tactical air navigation software combined in a single module.

For MDAPs that use a MOSA, the program may not receive Milestone B approval under 10 USC 4252 until the MDA determines in writing that:

- The program incorporates clearly defined modular system interfaces between major systems and between major system components and major systems;
- Such modular system interfaces are consistent with the widely supported and consensus-based standards that exist at the time of the milestone decision, unless such standards are unavailable or unsuitable for particular modular system interfaces; and
- The Government has arranged to obtain appropriate and necessary intellectual property rights with respect to such modular system interfaces upon completion of the development of the modular system platform.
- In the case of an MDAP that does not use a MOSA, the program is required to justify in writing that the use of a MOSA is not practical.

PMs and Systems Engineers should analyze modular open system designs, developed from the system architecture, at each design review because there is a link between MOSA and the level and type of technical data, computer software, and data rights the Government needs for life cycle support. Programs using MOSA system elements may find increased opportunities for competitive sourcing for a system during life cycle sustainment and a lesser need for detailed design data and associated data rights. This benefit enables the program to employ an incremental approach to capability adaptation in MOSA-enabled systems and is a benefit of the modularity originally specified in the functional architecture.

The AoA for an MDAP should include considerations of each alternative's use of MOSA (see AoA Handbook (2021) for more information). As the solution matures before Milestone A, the PM and systems engineer should continue to assess the MOSA strategy. The engineering trade analyses conducted before Milestone B help the PM determine which system elements can be adapted to MOSA in order to reduce program cost and development timelines. Programs that correctly apply MOSA principles and practices will have developed modular system elements having well-defined functions and modular system interfaces compliant with widely supported and consensus-based standards. Threat analyses, functional criticality analyses, technology opportunities, and evolved capability assessments are examples of assessments against the functional architecture to determine which system elements should be MOSA-enabled. When these system elements require an upgrade, replacement should be competitive, faster, and cheaper because the MOSA-enabled system elements are modular.

Because system functional architecture maps from the higher-level enterprise architecture, engineering trade analyses and assessments supporting MOSA should be completed, and MOSA-enabled system elements specified, before contracts are let for technology development of those system elements. The Milestone Decision Authority for an MDAP that uses a MOSA should ensure that an RFP for the EMD or P&D phase of the program describes the MOSA and the minimum set of major system components that must be included in the design of the MDAP, in accordance with 10 USC 4402. Successful implementation of MOSA approaches requires the synchronized acquisition of data rights for modular open systems 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.

Figure 3-9 depicts an example architectural approach for mapping and identifying modular system interfaces. The figure presents a top-level system view of the MOSA characteristics of system elements. Not all modular system interfaces need to be open, only those that are required to meet anticipated incremental capability updates, changes in threat, or technology insertion. A system view such as this can include a record of the data rights that are required to enable the planned MOSA design. The levels of data rights that need to be required for each MOSA-enabled system element are determined in order to assert the requisite contract requirements to obtain them. The accompanying Intellectual Property/Data Rights strategy addresses enterprise-level data rights that support the system architecture (see IP Guidebook (forthcoming)).

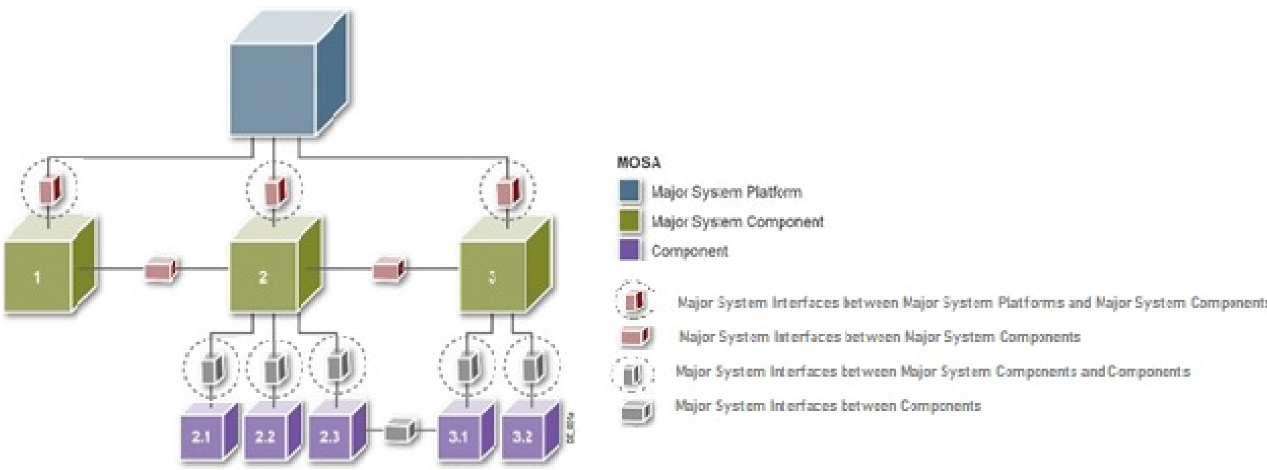


Figure 3-9. MOSA and Modular System Interfaces

Programs successfully implementing a MOSA strategy will benefit from identifying the required technical data and software deliverables necessary to field and maintain weapon systems and their logistics support. The Acquisition Strategy should be updated throughout the system's life cycle to reflect changes in the MOSA approach resulting from technology and software evolutionary developments. In accordance with DoDI 5000.85, Section 3C.3.a.(5), for a MDAP that uses a MOSA, the program's Acquisition Strategy should:

- Describe the modular open system approach to be used for the program.
- Differentiate between the major system platform and major system components being developed under the program, as well as major system components developed outside the program that will be integrated into the MDAP.
- Describe the evolution of major system components that are anticipated to be added, removed, or replaced in subsequent increments.
- Identify additional major system components that may be added later in the life cycle of the major system platform.

- Describe how intellectual property and related issues, such as technical data deliverables, that are necessary to support a modular open system approach, will be addressed.
- Describe the approach to systems integration and system-level configuration management to ensure the system can operate in the applicable cyber threat environment.

The SEP is also updated to reflect the MOSA-related updates and modifications employed throughout the system and its system elements.

Specific MOSA-related data deliverables that should be considered include the following:

- Open Systems Management Plan (DI-MGMT-82099)
- Software Development Plans (DI-IPSC-81427)
- Software Development Status Reports (DI-MCCR-80459)
- Software Development Summary Reports (DI-AVCS-80902)
- Software Design Descriptions (DI-IPSC-81435)
- Hardware Development Plans and Hardware Design Descriptions

In addition, the PM should maintain an open systems management plan. The plan describes the offeror's approach for:

- OSA, modularity, and open design
- Intersystem element 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 COTS/NDI system elements, their functionality and proposed function in the system
- Copies of license agreements related to the use of COTS/NDI system elements for Government approval

The OSMP should also include a statement explaining why each COTS/NDI system element was selected for use.

Program products typically used in making decisions regarding MOSA include:

- System Requirements
- Acquisition Strategy
- PPP
- SEP
- AoA
- Enterprise Architecture

MOSA and requirements should be addressed at design reviews, e.g., SRR, PDR, and CDR.

See DoDM 5010.12-M for data deliverables, and DoDM 4120.24 for DoD procedures pertaining to development and distribution of defense specifications and standards, e.g., MOSA-enabling standards, DIDs. PMs and systems engineers should use ASSIST, formerly known as Acquisition Streamlining and Standardization Information System, to gain access to data item deliverables (DIDs), MOSA-enabling standards, and other defense standardization documents (e.g., MIL-STD-188, MIL-STD-1472, STANAG-5616) that may be appropriate for each specific program.

3.5 Digital Engineering

The DoD Digital Engineering Strategy (https://www.cto.mil/wp-content/uploads/2023/06/Dig-Eng-Strat-2018.pdf) defines digital engineering as an "integrated digital approach using authoritative sources of system data and models as a continuum across disciplines to support life cycle activities from concept through disposal." Digital engineering updates traditional SE practices to take advantage of computational technology, modeling, analytics, and data sciences. As evidenced across the Services and industry, digital engineering is a necessary practice to support acquisition in an environment of increasing global challenges and dynamic threat environments. As such, programs are required to implement digital engineering in accordance with DoDI 5000.97, Digital Engineering.

3.5.1 Benefits of Digital Engineering

The overall vision of DoD digital engineering is to "modernize how the Department designs, develop, delivers, operates, and sustains systems" (The DoD Digital Engineering Strategy (https://www.cto.mil/wp-content/uploads/2023/06/Dig-Eng-Strat-2018.pdf)). The expected benefits of adopting a digital engineering approach to system design/development are:

- Informed decision making and greater insight through increased transparency
- Enhanced communication
- Increased understanding for greater flexibility and adaptability in design
- Increased confidence that the capability will perform as expected

- Increased efficiency in engineering and acquisition practices

3.5.2 Project/Program Office Digital Engineering Roles, Responsibilities, and Activities

The extent to which a project or program office will need to embrace digital engineering will depend on multiple factors including but not limited to the following:

- Where the development is in its life cycle
- What previous investments were made in digital engineering during prior stages of the life cycle
- For an acquisition program, which of the adaptive acquisition framework pathways of the new DoD 5000 acquisition policy and guidance this program falls under
- The respective organization’s experience and lessons learned in implementing DE within similar or adjacent projects/programs (e.g., organizationally adjacent; functionally adjacent)
- The remaining activities to be performed (e.g., design, testing, sustainment, retirement, reuse)

3.5.3 Considerations for Implementing Digital Engineering

Models and simulations are integral to digital engineering as they capture data and help the PM make informed, data-driven decisions throughout a project’s life cycle. The goals of the DoD Digital Engineering Strategy are to “promote the use of digital representations and components and the use of digital artifacts as a technical means of communication across a diverse set of stakeholders.” As such, activities embracing digital engineering depend upon a well-defined plan for what models and simulations are needed at various way points along the life cycle. The opposite is not true, however. A project does not need to fully embrace a digital engineering approach to be able to make good use of models and simulations throughout its life cycle.

3.5.4 Digital Threads

The digital thread is a term for the lowest level design and specification for a digital representation of a physical item. The digital thread is a critical capability in model-based systems engineering (MBSE) and the foundation for a digital twin. The digital thread refers to the communication framework that allows a connected data flow and integrated view of the asset’s data throughout its life cycle across traditionally siloed functional perspectives.

3.5.5 Digital Twins

A digital twin is a virtual representation that serves as the real-time digital counterpart of a physical object or system that spans its life cycle, is updated from real-time data, and uses simulation, machine learning, and reasoning to help decision making. The object could be a missile system, a building, a ship, a sensor, or a jet engine. Connected sensors on the physical asset collect data that can be mapped onto the virtual model. Anyone looking at the digital twin can review crucial information about how the physical item is performing.

Digital twins of a system or a component can be a means to overcome the significant development, testing, and validation challenges and timelines needed to support quicker fielding of new verified capabilities. Digital twins are possible because of "Internet of Things" sensors that gather data from the physical world and send it to be virtually reconstructed. These include design and engineering details that describe the asset's geometry, materials, components, and behavior, or performance. When combined with analytics, data from a digital twin data can unlock hidden value for an organization and provide insights about how to improve operations, increase efficiency, or discover and resolve problems before the real-world asset is affected.

3.6 System Security Engineering

System Security Engineering (SSE) integrates disciplines such as anti-tamper (AT), Defense Exportability Features (DEF), hardware assurance, software assurance, and supply chain risk management. The desired outcome is a comprehensive program and system protection within the constraints of cost, schedule, and performance while maintaining an acceptable level of risk. The system security engineer leads the evaluation and balancing of security contributions to produce a coherent security approach. Additional information is provided in the T&PP Guidebook (2022) for the MCA pathway.

3.7 Technical Reviews and Assessments

In accordance with DoDI 5000.88, PMs will conduct technical reviews and audits of program progress for systems in development as a basis for transitioning between phases within the development plan of work. Reviews should be event-driven and based on entrance criteria as documented in the SEP. Section 3 of the SE Guidebook covers technical reviews, but selective information is amplified in the following sections.

3.7.1 Independent Review Teams

As a best practice fundamental to engineering and risk management, a program should allow periodic reviews by independent technical personnel. The CAE will implement a technical review process, in accordance with DoDI 5000.88. Ideally, the Independent Review Team (IRT) remains consistent throughout the program life cycle and serves as a trusted technical adviser to the CAE. The IRT identifies and documents critical issues that jeopardize achieving safety and security thresholds, and program and mission objectives. The team recommends corrective actions and risk mitigation activities necessary to reduce risk. Results are provided directly to the CAE, with coordination but not undue influence from the PMO. The PM, with support from the systems engineer, will review, develop, and implement corrective action to the satisfaction of the

CAE. The CAE should approve team members to ensure all organizational, professional, and relational influences from the program management office are avoided.

3.7.2 Independent Technical Risk Assessment

In accordance with 10 USC 2448, all MDAPs will undergo an ITRA before Milestone A and B approval and before any decision to enter into LRIP or FRP. Although only MDAPs are required to undergo the ITRA, as a best practice all acquisition programs should conduct independent risk assessments throughout the life of the program. ITRAs provide a means to independently assess a program's technical risk at key points. ITRAs should be conducted in accordance with DoDI 5000.88, sec 3.5.b., the DoD ITRA Execution Guidance, and the DoD ITRA Framework for Risk Categorization. ITRAs consider the full spectrum of technology, engineering, and integration risk. The organization conducting the ITRA designates a lead, who forms a team composed of technical experts with in-depth domain knowledge of technical considerations associated with the program under assessment. Team members should be independent from the program office and the direct chain of command between the program office and Milestone Decision Authority.

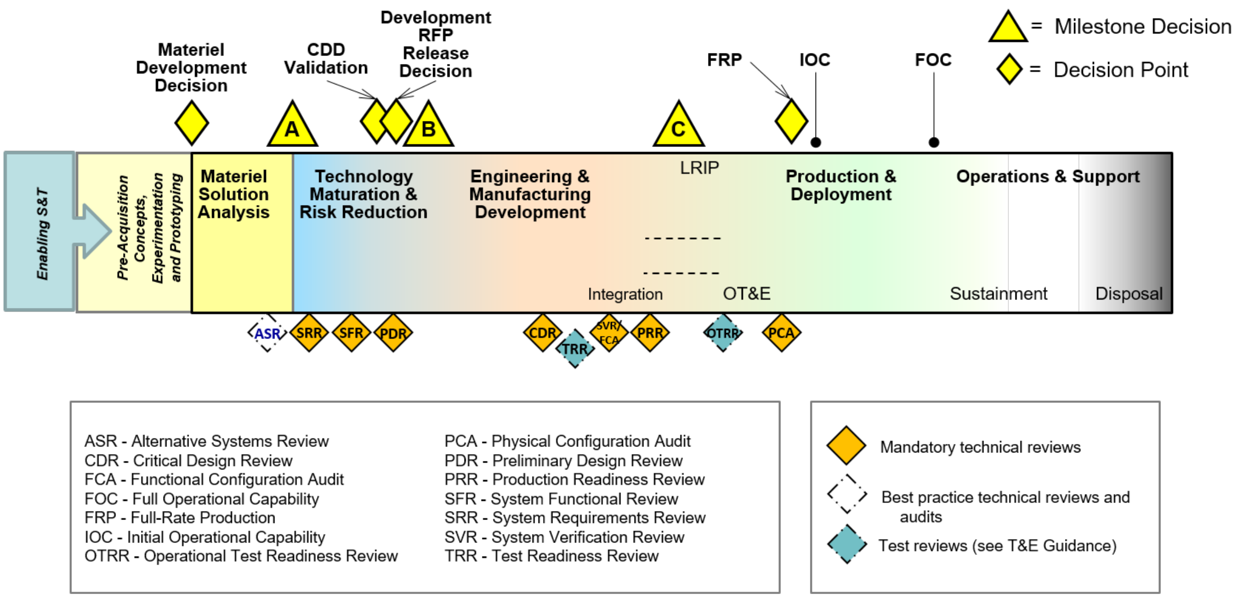
3.7.3 Systems Engineering Technical Reviews

PMs should plan for and conduct technical review and audits to establish the technical baselines, assess the system's technical maturity, and review and assess technical risks. The SEP should include design review planning. In accordance with DoDI 5000.88, Sec 3.5.a., unless waived through the SEP approval process, the PM will conduct these system-level reviews, or equivalent:

- System Requirements Review (SRR) or System Functional Review (SFR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- System Verification Review (SVR) or Functional Configuration Audit (FCA)
- Production Readiness Review (PRR)
- Physical Configuration Audit (PCA)

For all ACAT ID programs, the PM will invite representatives from the office of USD(R&E) to participate in all design reviews.

Figure 3-10 provides the end-to-end perspective and the integration of SE technical reviews and audits for the MCA pathway.



Source: Derived from DoDI 5000.85 Major Capability Acquisition Model

Figure 3-10. Technical Reviews and Audits for the Major Capability Acquisition Life Cycle

3.7.4 PDR and CDR Assessments

In accordance with 10 USC 4252, programs will undergo a PDR assessment before approval of Milestone B, unless the Milestone Decision Authority waives the assessment. The Office of USD(R&E) conducts PDR assessments for ACAT ID programs. In addition, OUSD(R&E) will conduct CDR assessment for ACAT ID programs. The results of these assessments will be used to inform the Milestone Decision Authority of any technical risks, maturation of the technical baseline, and the program's readiness to proceed. For all other MDAPs, the DoD Component concerned will conduct PDR and CDR assessments.

- PDR Assessment - The PDR assesses the maturity of the preliminary design supported by the results of requirements trades, prototyping, and critical technology demonstrations. The PDR should establish the allocated baseline and confirm that the system under review is ready to proceed into detailed design (development of build-to drawings, software code-to documentation, and other fabrication documentation) with acceptable risk. The PM should consider conducting the PDR before contract award for EMD. The timing of the PDR relative to the Development RFP Release Decision Point is at the discretion of the DoD Component. The Component should balance the need for more mature design information to support source selection with the costs of either: extending multiple sources' design activities from the PDR until award of the full EMD contract or having a gap in development before EMD award.
- CDR assessment. The CDR assesses design maturity, design build-to or code-to documentation, remaining risks, and is where the initial product baseline is established. It should be used as the decision point that the system design is ready to begin

developmental prototype hardware fabrication or software coding with acceptable risk. In accordance with DoDI 5000.88, a system-level CDR assessment will be conducted for MDAPs. For ACAT ID programs, OUSD(R&E) will conduct the CDR assessment to inform the Milestone Decision Authority of the program's design maturity, technical risks, and the program's readiness to begin developmental prototype hardware fabrication and/or software coding with acceptable risk. For ACAT IC and IB programs, the CAE will conduct the CDR assessment.

3.7.5 Technology Readiness Assessment

A Technology Readiness Assessment (TRA) is a systematic, evidence-based process that evaluates the maturity of technologies (hardware, software, and processes) critical to the performance of a larger system or the fulfillment of the key objectives of an acquisition program.

10 USC 4252 requires the Milestone Decision Authority certify that the technology in an MDAP has been demonstrated in a relevant environment before Milestone B approval. DoD assesses the maturity of program technologies and any associated risks, by conducting TRAs.

For programs for which an ITRA is conducted, a TRA report is not required as the ITRA report forms the basis for 10 USC 4252 certification. ITRA teams may leverage technology maturation activities and receive access to results in order to perform independent technical reviews and assessments.

In accordance with DoDI 5000.88, programs will assess and document the technology maturity of all critical technologies consistent with the TRA guidance maintained by USD(R&E).

PMs of MDAPs should conduct knowledge-building TRAs throughout the DoD acquisition life cycle, including at PDR, CDR, and Milestone C. These assessments should include the reassessment of all elements of the system design to identify any new critical technology elements and their associated Technology Readiness Levels (TRLs) as a result of any system design changes or new knowledge obtained during the engineering and manufacturing development phase. See the DoD Technology Readiness Assessment (TRA) Guidance for additional information.

4 Middle Tier of Acquisition

The MTA pathway is intended to fill a gap in the DAS for those capabilities that have a level of maturity to allow them to be rapidly prototyped within an acquisition program or fielded within 5 years of MTA program start. The MTA pathway may be used to accelerate capability maturation before transitioning to another acquisition pathway or may be used to minimally develop a capability before rapidly fielding.

4.1 Rapid Prototyping

The rapid prototyping pathway provides for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging military needs. The objective of an acquisition program under this pathway will be to field a prototype meeting defined requirements that can be demonstrated in an operational environment and provide for a residual operational capability within 5 years of the MTA program start date. Virtual prototyping models are acceptable if they result in a fieldable residual operational capability. MTA programs may not be planned to exceed 5 years to completion and, in execution, will not exceed 5 years after MTA program start without a Defense Acquisition Executive waiver.

4.1.1 Systems Engineering

The MTA pathway does not mandate specific SE processes, technical reviews, or documents. PMs and systems engineers should tailor and apply SE processes and practices to maximize the benefit to rapid prototyping program objectives by considering the prioritization of the requirements and priorities while also considering funding and other design considerations. Most rapid prototyping programs exploit mature technologies, so integration and interoperability are important considerations, and the programs require collaborative information and knowledge sharing to succeed. SE processes should add value and not require excessive bureaucracy. Systems engineers should collaborate with the PM to decide where to include, truncate, or eliminate non-mandatory SE processes. Systems engineers should review other sections of this guide for further recommendations.

Work is ongoing to accumulate an SE Body of Knowledge, best practices, and use cases. In the interim, the following sources may be helpful to programs implementing SE in rapid capability development and fielding: (1) Expedited Systems Engineering for Rapid Capability and Urgent Needs A013 Final Technical Report SERC-2012-TR-034 (2012) and (2) INCOSE Systems Engineering Body of Knowledge, www.sebokwiki.org.

4.1.2 Software Engineering

The term “prototype” has been defined in numerous ways in DoD, industry, and academic literature. This section uses the following definition:

- Prototype: a model (e.g., physical, digital, conceptual, and analytical) built to evaluate and inform its feasibility or usefulness

As stated previously in this guidebook, software is often the basis of system complexity and performance, providing functionality critical to battlefield dominance and maintaining operational advantage in an environment of change. Software development and sustainment frequently contribute a major portion of total system life-cycle cost, schedule, and risk. As system complexity has increased, so too has the demand to provide new capabilities to the warfighter at an ever quicker pace. To tackle these challenges, programs can reduce technical risk by taking an approach to capability development that makes extensive use of prototyping and experimentation:

- Validating designs and feasibility of design concepts
- Increasing warfighter/operational collaboration, early feedback, and learning ("shift left" – see Section 3.2.3) from rapid iterative prototype demonstration
- Exposing integration challenges early
- Refining and validating performance requirements can be met
- Providing insight into technology maturity
- Verifying analytical and simulation models
- Reducing uncertainty/unknowns
- Identifying potential reliability and sustainability issues, and cost drivers
- Compressing the feedback loop cycle time

These benefits not only reduce risk and generate real data to support critical decisions but also increase responsiveness and flexibility to deliver timely solutions to warfighter needs.

The increased use of prototyping within and outside of DoD in recent years is partially attributable to the tools and methods available today that enable the rapid building, testing, rework, and retesting of prototypes in very short time cycles. To take full advantage of these developments, the Department will need engineers with new competencies and skill sets (see Section 6.2.1 Software Engineering Enablers, Activities, and Competencies).

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. Programs should demonstrate software prototypes that reflect the results of key trade-off analyses to generate real representative data. The data from these demonstrations provide software performance (e.g., latency, security architecture, integration of legacy services and scalability) and reference data to inform decisions as to the concept maturity.

Programs often use competitive prototyping, usually involving two or more competing contractor teams, to identify and mitigate technical risks. Programs may use prototyping in source selection leading to formal acquisition contract award(s). DoD has used competitive prototyping for programs such as aircraft, but use of competitive prototyping in software-intensive system developments is a relatively recent occurrence.

Below are some software engineering considerations:

- Solid SE and software engineering habits provide the foundational basis to build on.
- Staffing size, skill, and experience promote success. Successfully managing a prototyping effort, particularly a competitive effort, requires more staffing, skillsets, and expertise than commonly expected. The program office team must have the resources and knowledge to skillfully plan, monitor, manage, and evaluate the effort.
- As with any Agile/DevSecOps effort, programs should cultivate collaboration among requirements and operational stakeholders and employ frequent demonstrations and feedback loops for better product results. Prototyping efforts, including competitive efforts, must be designed to encourage active participation from the end users and other stakeholders throughout the life cycle. Frequent iterative demonstrations of progress facilitate stakeholder involvement. Active engagement with warfighter and operational users is crucial to understanding and satisfying requirements and performance needs.
- Technical risk reduction is the primary focus and goal of prototyping to eliminate or burn down technical risk as much as possible. With this in mind, the program needs to consider how these risks will be decomposed, the burn down planned, and how progress to plan and performance will be monitored, managed, and tracked/measured.
- Programs should not overlook “traditional downstream” stakeholders. The eventual deliverable of this effort and the different authorities that will be involved in this process, such as certification and accreditation authorities, are often overlooked in prototyping efforts. These stakeholders need to be identified and planned into the efforts early to ensure their engagement throughout the life cycle (“shift left”).
- Programs need to consider the deliverables necessary for the program to support the competitive down-selection or to verify and validate whether program goals and requirements have been met. What intellectual capital, data rights, and core competencies must be retained? Particularly, with competitive down-selection the program should consider what contract vehicles can ensure that the losing competitors’ capital and experience can be retained if needed. This consideration works to the program’s interests, and to that of the competitors.
- Programs should thoroughly consider the transition of the prototype for production and fielding. This transition is particularly important with competitive prototyping evaluations. What are the potential risks? How much effort will production require? What

weaknesses do the prototypes have, for instance, in architecture, requirements, integration, maintainability, or scalability?

Pathway Transition: Rapid Prototyping to Rapid Fielding

The MTA pathway authorizes a Rapid Fielding pathway (DoDI 5000.80 Sec 3.2) for prototypes that meet the following criteria:

- Proven technology to field production quantities of new or upgraded systems is utilized with minimal development required.
- The original prototyping project was successfully completed and demonstrated in a relevant environment.
- Production is expected to begin within 6 months and be completed within 5 years of the development of an approved requirement.

The Rapid Prototyping pathway enables DoD PMs to burn down technical risk early, inform requirements, mature technology for warfighter use, and ensure delivery of integrated and interoperable capability, driving down costly technical risk and discovery during procurement.

Work is ongoing to accumulate further software engineering considerations, best practices, and lessons learned. Additions will be addressed in a future version of this guidebook.

4.1.3 Specialty Engineering

4.1.3.1 Reliability and Maintainability Engineering

R&M engineering activities should be tailored to meet the objectives of the MTA program. Middle Tier Rapid Prototyping (MTRP) programs should consider approaches for capturing reliability and maintainability performance. To identify MTRP program risk related to R&M, at a minimum in demonstration, programs should plan for testing in relevant and operational environments and ensure that design reviews identify and mitigate failure modes.

Guidance for the R&M engineering activities applicable to the MTA pathway is in development and will be added to the R&M Engineering Management Body of Knowledge (https://cto.mil/sea/rm/).

In the interim, the PM, systems engineer, and lead software engineer should work to properly align the applicable R&M Engineering activities needed to reduce program risk. Table 3-13 “R&M Activities by Acquisition Phase” should be used as a starting point to assess appropriate activities needed to deliver capability that is reliable, maintainable, and supportable.

4.1.3.2 Manufacturing and Quality

M&Q personnel, working with the PM, systems engineer, and other IPT members, identify and manage manufacturing, quality, and producibility requirements and risks throughout the Rapid Prototyping process. M&Q personnel should:

- Support the development of program documentation to include acquisition strategies
  - Systems Engineering Plan (SEP) with planned M&Q management activities
- Support the development and implementation of efficient and cost-effective M&Q activities and processes
  - Cost estimating (identify M&Q cost drivers)
  - Cost tracking and improvement
- Support demonstration and evaluation of prototype design, build, and test activities
  - Identification, tracking, and management of technical risks
  - Systems engineering technical reviews, to ensure M&Q considerations are addressed early

The manufacturing of the prototype(s) to include proposed components, subsystems, and systems should occur under the umbrella of M&Q best practices, thus any proposed contractors should be operating under a documented M&Q management system consistent with industry best practices such as those described in:

- AS6500, Manufacturing Management Program
- MIL-HDBK-896A, Manufacturing Management Program Guide
- AS9001, Quality Management System, or
- ISO 9001, Quality Management System

Prototyping contractors should have developed and provided to the Government their M&Q Plans for the proposed prototype system or subsystems. M&Q personnel should assess these plans for completeness and adequacy.

In order to field a prototype system within 5 years, the technologies and manufacturing processes used to implement these final system configurations must be significantly mature and assessed using the appropriate TRL/MRL criteria based on acceptable program risk. Final risk assessments should indicate that critical manufacturing processes and technologies are matured sufficiently to support fielding. A tailored MRA and PRR are recommended before entering production.

4.1.3.3 Human Systems Integration

Prototyping projects should take into account the manner in which those who will operate, maintain, and support the technical system will interact with that system. HSI practitioners should engage early due to the accelerated pace and the PM's authority to use a "tailor in" approach.

HSI Practitioner Engagement for Planning

In MCA programs, HSI is a required element in the Acquisition Strategy and should be included in an MTA pathway Acquisition Strategy. Cost estimates that include funding for HSI, such as training and user testing, will increase the likelihood that the system will meet user needs.

HSI Practitioner Engagement for Development

The MTA team contracts with industry or works with Government organizations to design, develop, and test prototypes based on the approved Acquisition Strategy.

HSI Practitioner Engagement for O&S

Ensuring the system has a viable product support package is essential to the operators, maintainers, and supporters of the system.

Regardless of whether the prototype transitions to another pathway or is returned to the technical base, HSI practitioners need to document all HSI activities that the program accomplished as well as those HSI activities that remain to be accomplished for successful transition. Requirements should include HSI considerations throughout the MTA pathway. The PM and systems engineer should ensure the HSI SMEs participate during planning, and the HSI SMEs should advocate for HSI to become part of the MTA process.

If HSI practitioners have been successful in influencing activities in the planning phase, this planning will help ensure the program implements HSI considerations during development. If the contract with industry or the agreement with the Government organization developing the prototype specifies that the program address HSI issues, then HSI practitioners can work with industry and Government counterparts to ensure the program continues to address HSI issues. HSI practitioners should do their best to ensure personnel collect human performance data during tests and demonstrations.

For a system to be viable and meet requirements in the prototype operations and sustainment activity, it must be fielded with the necessary number of maintainers, proper training for those maintainers, and the test equipment and tools needed to maintain the system.

4.1.3.4 System Safety Engineering

For MTRP programs, PMs and systems engineers should develop and implement a tailored system safety program to ensure the program identifies and assesses potential hazards (hardware and software), mitigating controls, and safety risks during prototyping tests, demonstrations, and fielding. PMs and systems engineers should use the system safety methodology in MIL-STD-882 to manage system safety and environmental and occupational health considerations as an integral part of the program's overall SE process.

PMs and systems engineers should tailor system safety risks and requirements to minimize the injury to or loss of personnel and degradation of their equipment, and to reduce impact on the environment. In accordance with MIL-STD-882, the program will eliminate hazards when possible or will accept and manage the risks when it is not possible to eliminate them.

The program should use MIL-STD-882, Table 3-16 "System Safety Activities by Acquisition Phase," and the guidance provided in the DoD Joint Software Systems Safety Engineering Handbook as a starting point to assess appropriate activities needed to deliver capability that minimizes system safety risks and the contribution of software to system safety risks.

The program should use a closed-loop HTS to document, track, and maintain hardware and software-related hazards and their associated risk data.

4.1.3.5 Parts Management

The PM should address and implement parts management and DMSMS management during design reviews, parts selection, and parts redesign, where appropriate. During parts selection the PM should avoid introducing obsolete parts into a system design. A program office's DMSMS management activities should assist its parts selection and parts redesign efforts.

Program offices should include a DMSMS management team that begins managing DMSMS upon the initiation of the MTA program. DMSMS management should be considered part of supportability during rapid prototyping and in the lead-up to production, during which period the program office should focus its DMSMS management effort on assessing system designs for DMSMS resilience. The DMSMS management team should prepare a DMSMS management plan, including a risk-based approach to determine items to monitor for obsolescence.

Section 2.2.3.3. of the SD-22 contains more information on the tailoring of MCA DMSMS management to the MTA pathway.

4.1.4 Modular Open Systems Approach

Implementing MOSA for the rapid development of technology provides greater flexibility to insert new capabilities that provide a technological advantage to the warfighter. Moreover, MOSA provides the ability to separate the development of higher risk prototype components and subsystem technology maturation efforts from the major system platform development efforts. MOSA is generally used to advance mature technologies to facilitate modularity in MDAP platforms in the traditional MCA pathway. Using MOSA for MTA rapid development, prototyping, and experimentation of weapon system components or other technologies, including those based on commercial items and technologies, apart from acquisition programs of record, enables innovation and encourages competition. A modular design and open architecture, along with an open business model, facilitate incremental modular development. In the MTA pathway, MOSA enables PMs to focus on developing more rapidly evolving technologies internal to the system.

4.1.5 Digital Engineering

A digital engineering-based systems engineering approach is highly encouraged for all new programs of record, enhancement efforts, and early engineering efforts such as prototyping. The program's Acquisition Strategy and SEP should describe the approach and implementation. The extent to which an effort incorporates digital engineering practices including a digital environment depends on the requirements and desired end state of the effort. The program may tailor the level of implementation. Refer to Section 3.5 for more information.

4.1.6 System Security Engineering

SSE integrates system security engineering disciplines such as anti-tamper, Defense Exportability Features, hardware assurance, software assurance, and supply chain risk management. The desired outcome is a comprehensive program and system protection within the constraints of cost, schedule, and performance while maintaining an acceptable level of risk. The system security engineer leads the evaluation and balancing of security contributions to produce a coherent security plan. Additional information is provided in the T&PP Guidebook (2022) for the Middle Tier of Acquisition Rapid Prototyping pathway.

4.1.7 Technical Reviews and Assessments

4.1.7.1 Independent Review Teams

Periodic reviews conducted by independent technical personnel are a core best practice to engineering development and risk management. The CAE should implement a technical review process, tailored for this acquisition pathway, to identify and document critical issues that jeopardize achieving program safety, security thresholds, and mission objectives. The CAE should recommend the necessary corrective actions and risk mitigation activities required to reduce risk. Results should be provided directly to the CAE, with coordination but not undue influence from the PMO. The PM, with support from the systems engineer, should review, develop, and implement corrective action to the satisfaction of the CAE. The CAE should approve team members to avoid organizational, professional, and relational influences from the PMO.

4.1.7.2 Independent Technical Risk Assessment

There are generally three circumstances in which an ITRA must be conducted on a rapid prototyping program:

- When preparing to transition to the MCA pathway as an MDAP
- As directed by the Secretary of Defense
- As directed by the CAE or appropriate decision authority

In accordance with 10 USC 2448b, all MDAPs undergo an ITRA before Milestone A or B approval, or before any decision to enter into LRIP or FRP. The PM and the office responsible for conducting the ITRA should begin planning and coordinating the ITRA at least 12 months before the planned MCA entry milestone. See Section 3.7.2 of the MCA pathway for more details on conducting an ITRA to support milestone entry into the MCA pathway.

The Secretary of Defense may also direct an ITRA, in accordance with 10 USC 2448b. In addition, as the decision authority, the CAE may direct that an ITRA be conducted on a program. These ITRAs are to advise the PM and decision authority on technical risk earlier in the program and can be used to inform program objectives, Test Strategy, Acquisition Strategy, and other program aspects. Often, the ITRA conducted for this purpose identifies risks not previously considered by the PM's risk management process, increasing the PM's ability to proactively mitigate risks to key program objectives.

4.1.7.3 Systems Engineering Technical Reviews

In accordance with DoDI 5000.80, paragraph 2.5.b, PMs will 'tailor- in' reviews, assessments, and relevant documentation that result in an Acquisition Strategy customized to the unique characteristics and risks of their program. PMs will ensure operational, technical, and security risks are identified and reduced so that fielded systems are capable, effective, and resilient." In addition, PMs regularly report on program status and technical maturity.

To accomplish these responsibilities, PMs should consider conducting the following technical reviews and audits, or equivalent, to establish the technical baselines, assess the system's technical maturity, and review and assess technical risks:

- System Requirements Review (SRR) or System Functional Review (SFR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- System Verification Review (SVR) or Functional Configuration Audit (FCA)
- Production Readiness Review (PRR)
- Physical Configuration Audit (PCA)

The PM should "tailor-in" the technical reviews applicable to the program's Acquisition Strategy, development and fielding activities, and overall level of technical maturity. The PM should consider where the MTA program is entering the pathway and where it is planned to transition. Tailoring-in of technical reviews should also be informed by the program's technical risks.

See Section 3.7.3 and Section 3 of the SE Guidebook for more details on each technical review.

4.1.7.4 PDR and CDR Assessments

PDR and CDR assessments are not required for MTA programs; however, a follow-on MCA program entering at Milestone B will require a PDR assessment in accordance with 10 USC 4252, unless waived by the Milestone Decision Authority. MTRP programs that plan to transition to an MDAP at Milestone B should consider conducting a PDR and providing the PDR assessment to support the milestone at transition.

Likewise, MTRP and Middle Tier Rapid Fielding (MTRF) programs with complex requirements, a high degree of schedule concurrency, or integration of multiple maturing technologies should consider a CDR assessment to ensure a strong technical baseline and to identify risks that could delay fielding the capability.

See Section 3.7.4 of the MCA pathway for more details on PDR and CDR assessments.

4.1.7.5 Technology Readiness Assessment

A TRA is a systematic, evidence-based process that evaluates the maturity of technologies (hardware, software, and processes) critical to the performance of a larger system or the fulfillment of the key objectives of an acquisition program. DoD assesses the maturity of program technologies and any associated risks, by conducting TRAs.

For MTA programs, the PM should assess and document the technology maturity of all critical technologies consistent with the TRA guidance maintained by USD(R&E). The maturity of critical technologies should inform the Test Strategy and Acquisition Strategy, with the goal for MTRPs to mature critical technologies and demonstrate a residual operational capability. The PM should regularly assess and report the maturity of critical technologies.

For an MTA program transitioning to an MDAP, 10 USC 4252 requires that the Milestone Decision Authority certify that the technology has been demonstrated in a relevant environment before Milestone B approval. PMs of MDAPs should conduct knowledge-building TRAs throughout the DoD acquisition life cycle, including at PDR, CDR, and Milestone C. These assessments should include the reassessment of all elements of the system design to identify any new critical technology elements and their associated technology readiness levels as a result of any system design changes or new knowledge obtained during the engineering and manufacturing development phase (see DoD Technology Readiness Assessment (TRA) Guidance).

4.2 Rapid Fielding

The Rapid Fielding pathway provides for the use of proven technologies to field production quantities of new or upgraded systems with minimal development required. The objective of an acquisition program under this pathway is to begin production within 6 months and complete fielding within 5 years of the MTA program start date. The MTA program production start date is not to exceed 6 months after MTA program start date without Defense Acquisition Executive waiver. MTA programs may not be planned to exceed 5 years to completion and, in execution, will not exceed 5 years after MTA program start without Defense Acquisition Executive waiver.

Rapid Fielding is detailed in DoDI 5000.80, Operation of the Middle Tier of Acquisition, paragraph 3.2, Rapid Fielding. The MTA instructions discuss operational needs, demonstrating and evaluating performance, acquisition and funding strategies, life cycle cost, logistics support, interoperability, reducing total ownership cost, and transitioning Rapid Fielding programs.

4.2.1 Systems Engineering

The Rapid Fielding pathway includes no mandated SE processes, technical reviews, or documents. Because of the streamlined nature of this pathway, the SE activities focus primarily on support to the PM for entrance criteria, requirements management, and other SE-related documentation as applicable such as the Acquisition Strategy. Additional information regarding Rapid Fielding is available at the Defense Acquisition University (DAU) website at https://aaf.dau.edu/aaf/mta/fielding/planning/. Section 3.1. includes related information and lessons learned. Systems engineers should review the specialty engineering sections of this guidebook for further recommendations on implementing SE in these areas in each pathway.

4.2.2 Software Engineering

The focus of the MTA Rapid Fielding acquisition pathway is to provide a path for proven technologies, to field production quantities of new or upgraded systems with minimal development effort, and to begin production within 6 months of the start date. MTA may not be a principal pathway for software development and engineering efforts. Instead, programs will most likely transition software from another pathway to MTA to field matured and completed software efforts, as described in the Section 4.1.2 Software Engineering – Pathway Transition: Rapid Prototyping to Rapid Fielding. As any relevant software engineering lessons learned and best practices for this pathway are accumulated, they will be reflected in this guidebook.

4.2.3 Specialty Engineering

4.2.3.1 Reliability and Maintainability Engineering

R&M engineering activities should meet the objectives of the MTA program. To identify MTRF program risk related to R&M, at a minimum, programs should plan for testing in relevant and operational environments and ensure that design reviews identify and mitigate failure modes.

Guidance for the R&M engineering activities applicable to the MTA pathway is in development and will be added to the R&M Engineering Management Body of Knowledge at https://cto.mil/sea/rm/.

In the interim, the PM, systems engineer, and lead software engineer should work to properly align the applicable R&M engineering activities needed to reduce program risk. Table 3-13 "R&M Activities by Acquisition Phase" should be used as a starting point to assess appropriate activities needed to deliver capability that is reliable, maintainable, and supportable.

4.2.3.2 Manufacturing and Quality

M&Q personnel, working with the PM, lead systems engineer, and other IPT members, will ensure the program identifies and manages manufacturing, quality, and producibility requirements and risks throughout the Rapid Fielding process. Manufacturing and QA personnel should:

- Support the development of program documentation to include acquisition strategies.
  - Incorporate planned M&Q management activities into SEP.
- Support the development and implementation of efficient and cost-effective M&Q activities and processes.
  - Identify M&Q cost drivers for cost estimates
  - Contribute to cost tracking and improvement
- Support demonstration and evaluation of prototype design, build, and test activities.
  - Support the identification, tracking, and management of technical risks.
  - Support all SE technical reviews, to ensure M&Q considerations are addressed early.

M&Q best practices should apply to the manufacturing of the proposed Rapid Fielding system, including proposed components, subsystems, and systems. Any proposed contractors should operate under a documented M&Q management system such as:

- AS6500, Manufacturing Management Program
- MIL-HDBK-896A, Manufacturing Management Program Guide
- AS9001, Quality Management System, or
- ISO 9001, Quality Management System

Contractors involved in the Rapid Fielding efforts should have developed and provided to the Government their M&Q Plans for the proposed system or subsystems. These plans should be assessed for completeness and adequacy.

To field a system within 5 years, the technologies and manufacturing processes used to implement the final system configurations must be significantly mature and assessed at a high TRL/MRL based on acceptable risk. A tailored MRA and PRR are recommended before entering production.

4.2.3.3 Human Systems Integration

During the planning phase of the Rapid Fielding pathway, the systems engineer should elicit HSI SME support to assist in developing human performance characteristics within the requirements and Acquisition Strategy. HSI practitioners should be involved in ensuring fielded COTS and GOTS adequately cover human performance requirements.

4.2.3.4 System Safety Engineering

For MTRF programs, PMs and systems engineers should develop and implement a tailored system safety program to align with the MTA and Rapid Fielding acquisition approach to ensure the identification and assessment of potential hazards (hardware and software), mitigating controls and safety risks during Rapid Fielding test, demonstrations, and fielding. The program should use the system safety methodology in MIL-STD-882 to manage system safety, environmental, and occupational health considerations as an integral part of the overall SE process.

System safety risks and requirements should be tailored and managed to minimize the injury to or loss of Service members and degradation of their equipment, and to reduce impact on the environment. In accordance with MIL-STD-882, the hazards should be eliminated when possible, and accepted and managed when not.

In addition to MIL-STD-882, programs should use Table 3-16 “System Safety Activities by Acquisition Phase” and the DoD Joint Software Systems Safety Engineering Handbook to assess appropriate activities needed to deliver capability that minimizes system safety risks and the contribution of software to system safety risks.

4.2.3.5 Parts Management

PMs should address Parts management and DMSMS management during design reviews and implemented during parts selection and parts redesign, where appropriate. The program should continue to strive to avoid introducing obsolete parts into the system design. A program office’s DMSMS management activities can assist its parts management efforts.

Since COTS assemblies are particularly prone to become obsolete within the more than 4 years of production of an MTA program, product “roadmapping” for supportability should be considered mandatory. DMSMS management activities should inform product roadmapping for supportability during production and operations. During this time, the program office should seek to identify obsolescence issues as early as possible and should put in place resolutions before obsolescence issues impact the system.

Section 2.2.3.3. of the SD-22 contains more information on the tailoring of MCA DMSMS management to the MTA pathway.

4.2.4 Modular Open Systems Approach

Implementing MOSA for the rapid fielding of proven technologies in new or upgraded systems is beneficial when a system requires minimal development. MOSA facilitates the development of modularly upgradable systems with flexible architectures. Designs can be competitively reconfigured or technologically refreshed to respond to evolving or unstable conditions in the environment in which the system operates. Adopting a modular technical design and an open system approach enables competition and platform independence and reduces vendor lock.

Hardware and software interfaces should use widely supported, consensus-based standards that are appropriately defined and disclosed. This implementation of MOSA can provide operational flexibility to meet rapidly changing operational requirements and address emerging commercial technology, maturing technology from Government labs, technology from defense prime research and development efforts, and technology from small business innovation research solutions. Employing modular open system architectures that include modular systems, standardized modular system interfaces, and open specifications affords programs the flexibility to field incremental updates and deploy new capabilities to the warfighter.

4.2.5 Digital Engineering

A digital engineering-based SE approach is highly encouraged for all new programs of record, enhancement efforts, and early engineering efforts such as prototyping. The program's Acquisition Strategy and SEP should describe the approach and implementation. The extent to which a Rapid Fielding effort incorporates digital engineering practices to include a digital environment depends on the engineering heritage of the technologies that are being accelerated into production and the end-state requirements for future engineering and sustainment. A program may tailor the level of implementation. See Section 3.5 for more information.

4.2.6 System Security Engineering

SSE integrates system security engineering disciplines such as anti-tamper, Defense Exportability Features, hardware assurance, software assurance, and supply chain risk management. The desired outcome is a comprehensive program and system protection within the constraints of cost, schedule, and performance while maintaining an acceptable level of risk. The system security engineer leads the evaluation and balancing of security contributions to produce a coherent security. Additional information is provided in the T&PP Guidebook (2022) for the MTA Rapid Fielding pathway.

4.2.7 Technical Reviews and Assessments

4.2.7.1 Independent Review Teams

Periodic reviews conducted by independent technical personnel are a core best practice fundamental to engineering development and managing risk. The CAE should implement a technical review process, tailored for this acquisition pathway, to identify and document critical issues that jeopardize achieving safety and security thresholds or program and mission objectives. The CAE should recommend the necessary corrective actions and risk mitigation activities required to reduce risk. Results should be provided directly to the CAE, with coordination but not undue influence from the PMO. The PM, with support from the lead engineer, will review, develop, and implement corrective action to the satisfaction of the CAE. The CAE should approve team members to avoid organizational, professional, and relational influences from the PMO.

4.2.7.2 Independent Technical Risk Assessment

There are generally three circumstances in which an ITRA should be conducted on a Rapid Fielding program:

- When preparing to transition to the MCA pathway as an MDAP
- If directed by the Secretary of Defense
- If directed by the CAE or appropriate decision authority

In accordance with 10 USC 2448b, an ITRA will be conducted on all MDAPs before Milestone A or B approval, or any decision to enter into low-rate or full-rate production. The PM and the office responsible for conducting the ITRA should begin planning and coordinating the ITRA at least 12 months before the planned MCA entry milestone. See Section 3.7.2 of the MCA pathway for more details on conducting an ITRA to support milestone entry into the MCA pathway.

The Secretary of Defense may also direct an ITRA, in accordance with 10 USC 2448b. In addition, as the decision authority, the CAE may direct an ITRA be conducted on a program. These ITRAs are to advise the PM and decision authority on technical risk earlier in the program, and can be used to inform program objectives, Test Strategy, Acquisition Strategy, and other program aspects. Often, the ITRA conducted for this purpose identifies risks not previously considered by the PM's risk management process, increasing the PM's ability to proactively mitigate risks to key program objectives.

4.2.7.3 Systems Engineering Technical Reviews

PMs should consider conducting the following technical reviews and audits to establish the technical baselines, assess the system's technical maturity, and review and assess technical risks:

- System Requirements Review (SRR) or System Functional Review (SFR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- System Verification Review (SVR) or Functional Configuration Audit (FCA)
- Production Readiness Review (PRR)
- Physical Configuration Audit (PCA)

In general, MTRF programs are more likely to benefit from a CDR, SVR, PRR, and PCA. These reviews are especially appropriate for a Rapid Fielding MTA program that ultimately plans to enter sustained production through the MCA pathway.

See Section 3.7.3 and Section 3 of the SE Guidebook for more details on the specific technical reviews.

4.2.7.4 PDR and CDR Assessments

PDR and CDR assessments are not required or recommended for MTA – Rapid Fielding programs.

4.2.7.5 Technology Readiness Assessment

A TRA is a systematic, evidence-based process that is used to evaluate the maturity of technologies (hardware, software, and processes) critical to the performance of a larger system or the fulfillment of the key objectives of an acquisition program. DoD assesses the maturity of program technologies, and any associated risks, by conducting TRAs.

For MTA programs, the PM will assess and document the technological maturity of all critical technologies consistent with the TRA guidance maintained by USD(R&E). The maturity of critical technologies should inform the Test Strategy and Acquisition Strategy, with the goal for MTRPs to mature critical technologies and demonstrate a residual operational capability. The PM should regularly assess and report the maturity of critical technologies.

For an MTA program transitioning to an MDAP, 10 USC 4252 requires that the Milestone Decision Authority certify that the technology has been demonstrated in a relevant environment before Milestone B approval. PMs of MDAPs should conduct knowledge-building TRAs throughout the DoD acquisition life cycle, including at PDR, CDR, and Milestone C. These assessments should include the reassessment of all elements of the system design to identify any new critical technology elements and their associated technology readiness levels as a result of any system design changes or new knowledge obtained during the engineering and manufacturing development phase (see DoD Technology Readiness Assessment (TRA) Guidance).

5 URGENT CAPABILITY ACQUISITION

The purpose of the UCA pathway is to field capabilities to fulfill urgent existing or emerging operational needs or quick reactions in less than 2 years.

5.1 Systems Engineering

The UCA pathway includes no mandated SE processes, technical reviews, or documents. As these products are usually NDI or near-NDI products, the primary SE considerations are to ensure the capability is safe and secure and that it meets warfighter and national security needs. The systems engineer can support the PM throughout the process as needed to achieve the program goals and objectives. The system's engineer's role generally includes requirements validation and decision analysis support. Additional information on the acquisition of urgent capabilities can be found at the DAU website: https://aaf.dau.edu/aaf/uca/. Programs may adapt information and lessons learned from the traditional SE processes in Section 3.1, and systems engineers should review the specialty engineering sections of this guidebook for further recommendations on implementing these areas for each pathway.

5.2 Software Engineering

For the UCA pathway and operational urgency, programs will aggressively streamline the normal acquisition processes. The goal is to plan for the capability in a few weeks with development and production measured in months. Programs still need to observe sound systems and software engineering practices, as anything fielded or delivered will have to be sustained and must support the potential for rapid updates.

A typical use case for this pathway would be the need to respond to a new threat that puts warfighters or the nation at risk. Rapidly responding requires an agile acquisition system and active stakeholder collaboration to succeed under these constraints. Such projects lend themselves to a DevSecOps methodology, which emphasizes software development and deployment speed to intertwine development, security, and operations to achieve rapid value.

Given the compressed schedule timelines of the UCA pathway, it is critical to quickly assemble a cross-functional team that ensures warfighter or operational user representation. Small, highly collaborative cross-functional teams with their short communication and quick decision pathways foster agility and have produced the best results. Programs should employ a highly iterative approach that quickly demonstrates small progressive updates and provides hands-on stakeholder participation to reduce rework and help focus the minimum viable product (MVP) solution.

Programs should evaluate any potential capability solutions or partial capability solutions available internally within the DoD and Services and externally from industry or commercial sectors. Programs supporting fielded systems that have established these connections and regularly exercise rapid or accelerated delivery pathways will be in the best position to use the UCA pathway. Programs should use enterprise platforms and services to the maximum extent possible, as opposed to independently developing a software factory or DevSecOps pipeline. Programs can tailor established enterprise offerings (e.g., Platform One, Black Pearl, Army Code Repositories and Transformation Environment (CReATE)) to specific needs, saving time and effort compared with developing a new product or method. For more information on the software factory, see the R&E Software Engineering Guide (2023).

5.3 Specialty Engineering

5.3.1 Reliability and Maintainability Engineering

R&M engineering activities should meet the objectives of the UCA program. To identify UCA program risk related to R&M, at a minimum, programs should plan for testing in relevant and operational environments and ensure that design reviews identify and mitigate failure modes.

Guidance for the R&M engineering activities applicable to the UCA pathway is in development and will be included as an appendix to the R&M Engineering Management Body of Knowledge (https://cto.mil/sea/rm/).

In the interim, the PM, systems engineer, and lead software engineer should work to properly align the applicable R&M engineering activities needed to reduce program risk. Table 3-13 “R&M Activities by Acquisition Phase” should be used as a starting point to assess appropriate activities needed to deliver capability that is reliable, maintainable, and supportable.

5.3.2 Manufacturing and Quality

M&Q personnel, working with the PM, lead systems engineer, and other IPT members, should ensure that manufacturing, quality, and producibility requirements and risks are identified and managed throughout the process of fielding an urgent capability. Manufacturing and QA personnel should:

- Support a review of “Courses of Action” for M&Q implications and risks.
- Support the development of program documentation to include acquisition strategies.
  - SEP with planned M&Q management activities
- Support the development and implementation of efficient and cost-effective M&Q activities and processes.
  - Cost estimating (identify M&Q cost drivers)
  - Cost tracking and improvement
- Support demonstration and evaluation of prototype design, build, and test activities.

- Identification, tracking, and management of technical risks
- Systems engineering technical reviews, to ensure M&Q considerations are addressed early

Given the urgent need, the M&Q efforts should be tailored to address the identified risk. Since the nature of the urgent capability program implies that a capability can be fielded on an accelerated timeline, M&Q personnel should use existing documentation and manufacturing plans, when possible.

The manufacturing of the proposed urgent capability including proposed components, subsystems, and systems should occur under the umbrella of M&Q best practices. Any proposed contractors should be operating under a documented M&Q management system such as:

- AS6500, Manufacturing Management Program
- MIL-HDBK-896A, Manufacturing Management Program Guide
- AS9001, Quality Management System, or
- ISO 9001, Quality Management System

Contractors should have developed and provided to the Government their M&Q Plans for the proposed system or subsystems as early as possible. These plans should be assessed for completeness and adequacy.

To field an urgent capability within 2 years, the technologies and manufacturing processes used to implement these final system configurations must be significantly mature and assessed using the appropriate TRL/MRL criteria based on acceptable program risk. The program should undergo a tailored MRA and PRR before entering production.

5.3.3 Human Systems Integration

Successful HSI in the UCA requires: highly experienced HSI practitioner SMEs, full-time presence by the HSI SME to support the systems engineer, interpersonal skills as a “team player,” excellent negotiating skills, and access to a responsive support network.

Pre-development HSI practitioner engagement includes the following:

- Obtain and study the Urgent Operational Need that initiates the UCA process.
- Join the requirements analysis and requirements review processes.
- Participate in the course of action analysis and advocate for the choices that capitalize most on the HSI considerations.
- Contribute to the Acquisition Strategy and the program baseline.

- Identify HSI risks, issues, and opportunities that need to be tracked through the remainder of the pathway.

Development HSI practitioner engagement includes the following:

- Track the HSI issues identified during pre-development.
- Assess training materials.
- Review the Acquisition Strategy and program baseline.
- Contribute to the testing strategy.
- Participate in performance, safety, suitability, supportability, and training assessments.
- Call out deficiencies and safety issues deemed not acceptable to the systems engineer.

P&D HSI practitioner engagement includes the following:

- Contribute to milestone decision reviews (train maintenance and operating personnel).
- Ensure organization acquiring the capability provides required training.
- Identify and communicate known hazards and accepted mishap risks.
- Verify that necessary facilities, maintenance, and support equipment are provided.
- Track and resolve HSI issues as needed.

O&S HSI practitioner engagement includes the following:

- Collect data on the fielded system's operators, maintainers, and supporters.
- Provide feedback and advocate for any proposed urgent improvements.
- Participate in operational test activities, if possible.
- Assist in the disposition analysis.
- Collaborate with other program office team members to share HSI information and data.
- Inform the disposition official of relevant HSI issues or concerns.

5.3.4 System Safety Engineering

The PM and systems engineer should develop and implement a tailored system safety program to align with the UCA approach to ensure they identify and assess potential hardware and software hazards, mitigating controls, and safety risks during Rapid Prototyping test, demonstrations, and fielding. DoD programs use the system safety methodology in MIL-STD-882 to manage system safety, environmental, and occupational health considerations as an integral part of the program's overall SE process.

The PM and systems engineer tailor and manage system safety risks and requirements to minimize the injury to or loss of Service members and degradation of equipment, and to reduce impact on the environment. In accordance with MIL-STD-882, the program will eliminate hazards when possible, and if not the PM will accept and manage the hazards.

In addition to MIL-STD-822, programs should use the guidance in the DoD Joint Software Systems Safety Engineering Handbook to assess the contributions of software to system-level hazards.

The PM and systems engineer should use a closed-loop HTS to document, track, and maintain hardware- and software-related hazards and their associated risk data.

5.3.5 Parts Management

In the UCA pathway, the purpose of pre-development is to assess and select a course(s) of action to field a quick-reaction capability and develop an acquisition approach. Once the acquisition approach is identified, the PM should implement parts management for parts or systems, as required, such as parts that require modification if the UCA system enters longer term sustainment. A program office's DMSMS management activities, including a DMSMS management team and plan, should inform the parts management effort.

During pre-development, program offices should begin planning DMSMS management focusing on which items to monitor during an assumed relatively short life cycle of the system; which items, such as commercial items, industry will resolve; and which items will require more management and oversight by the program office. Once in the development phase, the DMSMS management focus should be on DMSMS resilience in design, but this design emphasis may be limited by the generally minimal scope of a UCA program's development efforts.

The program office may have limited ability to monitor for DMSMS issues during pre-development because parts lists may not be available for the commercial assemblies incorporated in the system design. To mitigate this challenge, the program office should use technology roadmapping to assist in forecasting when technologies will become obsolete and require changes to the product roadmap for supportability. The DMSMS management activities begun in the pre-development phase should continue through the production and deployment phase and the O&S phase. The results of a UCA program's disposition analysis one year into the O&S phase should inform the program office's product roadmapping for supportability and DMSMS management processes.

Section 2.2.3.2. of the SD-22 contains more information on the tailoring of MCA DMSMS management to the UCA pathway.

5.4 Modular Open Systems Approach

Programs should tailor MOSA considerations to align with the UCA approach. Detailed OUSD(R&E) MOSA engineering considerations for UCAs will be addressed in a future version of this guidebook.

5.5 Digital Engineering

A digital engineering-based SE approach is highly encouraged for all new programs of record to include UCAs. The program's Acquisition Strategy and SEP should describe the approach and implementation. The extent to which a UCA effort incorporates digital engineering practices depends on the engineering heritage of the capabilities being accelerated into fielding and the end-state requirements for future engineering and sustainment. A program may tailor the timing and level of implementation. See Section 3.5 for more information.

5.6 System Security Engineering

SSE integrates system security engineering disciplines such as anti-tamper, Defense Exportability Features, hardware assurance, software assurance, and supply chain risk management. The desired outcome is a comprehensive program and system protection within the constraints of cost, schedule, and performance while maintaining an acceptable level of risk. The system security engineer leads the evaluation and balancing of security contributions to produce a coherent security. Additional information is provided in the T&PP Guidebook (2022) for the UCA pathway.

5.7 Technical Reviews and Assessments

5.7.1 Independent Review Teams

As a best practice, the CAE should implement a technical review process, tailored for this acquisition pathway, to identify and document critical issues that jeopardize safety and security thresholds, program and mission objectives, and to recommend the necessary corrective actions and risk mitigation activities required to reduce risk. Reviews should be conducted by independent technical personnel, who should provide results directly to the CAE, with coordination but not undue influence from the PMO. The PM, with support from the lead engineer, will review, develop, and implement corrective action to the satisfaction of the CAE. The CAE should approve team members to avoid organizational, professional, and relational influences from the PMO.

5.7.2 Systems Engineering Technical Reviews

PMs should consider conducting tailored technical reviews and audits to assess the system's technical maturity and technical risks. See Section 3.7.3 and Section 3 of the SE Guidebook for more details.

6 SOFTWARE ACQUISITION

The Software Acquisition pathway, as described in DoDI 5000.87, Operation of the Software Acquisition Pathway, is for software-intensive systems whose objective is to facilitate rapid and iterative delivery of software capability to the user. This pathway integrates modern software development practice such as Agile software development, DevSecOps, and Lean practices. Capitalizing on active user engagement and leveraging enterprise services, working software is rapidly and iteratively delivered to meet the highest priority user needs. Tightly coupled mission-focused Government-industry software teams leverage automated tools for development, integration, testing, and certification to iteratively deploy software capabilities to the operational environment.

6.1 Systems Engineering

The Software Acquisition pathway includes no mandated SE processes, technical reviews, or documents. Because of the iterative nature of the development, test, and release using this pathway, the PM tailors SE support to meet the relevant objectives. The systems engineer can support the PM in selecting and using tools and implementing modern practices such as Lean and Agile/DevSecOps. The Software Acquisition pathway is also covered at the DAU website: https://aaf.dau.edu/aaf/software/. Section 3.1 discusses traditional SE processes, which may offer lessons learned, and systems engineers should review the individual specialty engineering sections of this guidebook for recommendations on implementing SE for each pathway.

6.2 Software Engineering

6.2.1 Software Engineering Enablers, Activities, and Competencies

The DoD competes for the same digital talent as many large companies nationwide and worldwide. Cultivating a skilled software development workforce is imperative to harness the growing and fast-paced digital technology competition to improve program outcomes and performance. Program success is often directly related to staff competencies and their knowledge, skills, and abilities.

There is a significant difference in how software is developed today compared with 10 to 15 years ago, when hardware development was a main focus area and software was typically considered later in the SE process. To improve the effectiveness of software acquisition in DoD, programs must adopt modern software development best practices and skill sets. Agile/DevSecOps is the preferred approach for software development in DoD. People, processes, and tools are the key components to instantiate a DoD DevSecOps software factory. The software factory requires the following support:

- An Agile/DevSecOps software development and orchestration pipeline, using continuous integration and continuous deployment tools and techniques

- Software architecture designs using cloud native micro-services and automated tools
- Software estimation, software measures, and automated metrics generation
- Software development using automated and continuous testing
- Software assurance, cybersecurity, and site reliability engineering
- Machine learning, AI, and the pervasive use of automation

The 48 software engineering competencies listed below are intended to augment but not replace any existing DoD competencies for acquisition (e.g., contract management, program/project management, SE, mission assurance). The software engineering competencies are wide ranging and described in terms of DoD work activities and tasks (see Robson et al. 2020). Critical software engineering competencies and definitions for DoD software acquisition professionals supporting the pathway include the following:

Problem Identification

- Capabilities Elicitation – Engage with stakeholders (to include representative end-user organizations, owners, developers, integrators, certification authorities, independent validation and verification personnel, and operators) to elicit capability objectives (i.e., functional requirements) and quality attributes (i.e., nonfunctional requirements) for the proposed system.
- Business Case Development – Explore the problem space and identify focal areas for acquisition.

Solution Identification

- Strategic Risk/Reward Analysis – Evaluate and balance risk/reward from various stakeholder perspectives, including the sponsoring organization, end users, T&E teams, cybersecurity compliance officers, and data rights managers.
- Cloud Computing – Identify resources needed to operate and sustain DoD unique cloud platforms.
- Software Ecosystems – Leverage existing and emerging DoD, open source, or third-party tech to support shared resources.
- Model-Based Software Engineering – Create a digital environment that uses high-fidelity hardware- and software-in-the-loop models, prototyping, visualization, simulation, and dependency analysis.

Development Planning

- Development Tempo – Determine the software life cycle approach to be used and the tempo of software construction, release, and deployment to operations.

- Release Planning – Determine the MVP and acceptance criteria (e.g., definition of done) for each release.
- Software Development Planning – Identify methods, processes, and training needed for software construction (design, code, test, build, build, integration, release). Identify tools and methods for backlog management, continuous integration, automated regression testing, and release management.
- Planning for Continuous Delivery – Identify methods (e.g., DevSecOps), tools, processes, and training for automating the software release process.
- Planning for Continuous Deployment – Identify the software that could benefit from rapid delivery into operations.
- Systems and Software Engineering Planning – Develop methods, processes, and training that are aligned to the software development life cycle, tempo, release plans.
- Software Metrics – Select appropriate metrics and measures at the team, program, and stakeholder level to monitor software scope, cost, schedule, and quality.
- Configuration and Version Control – Develop strategies for identifying and managing the configuration of the system and software development and test environment.

Transition and Sustainment Planning

- Software Documentation – Include document software planning, requirements, design, code, validation, verification, and sustainment needs in the program planning.
- Contracting for Software Development – Ensure that contract requirements, constraints, end items, and data deliverables are compatible with the selected tempo, release planning, software, and system development planning, metrics, and documentation requirements.
- Data and Proprietary Rights Management – Identify data rights up front if elements of the software or system will be acquired from DoD-external sources (i.e., open-source repositories, COTs software, GOTs software, or from private entities) to ensure DoD will have assured access to all mission-critical software throughout the life of the supported system.

System Architecture Design

- Architectural Design Approaches – Determine "how much" architectural design effort is needed to ensure a successful acquisition. Consider benefits and risks of adapting practices from modern architectural design methods such as artifact driven, use/abuse case driven, attribute driven, domain driven (i.e., manage by architecture), or human-centered design when selecting an architectural design approach.
- Software Orchestration and Choreography Patterns – Determine the patterns the software will use and consider common orchestration and choreography patterns (e.g.,

client/server, publish/subscribe, peer-to-peer, and services/microservices) that balance quality attributes for timing performance (latency, throughput), safety, and security.

- Software Deployment Patterns – Determine how the software will be deployed onto the computing infrastructure in the operational system.
- AI and Machine Learning Applications – Identify and implement architectural components, methods, processes, and training of incorporating AI and machine-learning techniques to create autonomous cyber-physical systems, automated or augmented decision support tools, or other emerging AI-based systems.
- Augmented and Virtual Reality (VR) Applications – Identify and implement architectural methods and processes that balance correctness and safety in augmented VR applications.
- Embedded Systems – Employ explicit strategies for incremental realization of capabilities within the constraints of the hardware supply chain.
- Balancing Quality Attributes – Evaluate alternative design solutions and architectures to effectively balance the quality attributes for critical mission threads or other identified scenarios.
- Emerging Technologies – Maintain an understanding of emerging technologies and of the implications these technologies may have on a given organizational need and solution space.

Modeling Functional Capabilities and Quality Attributes

- Use/Abuse Case Modeling – Use static and dynamic views to model the software components that implement the required capabilities of the software to identify the use cases.
- Validation of Performance Efficiency Requirements – Validate the capability to meet performance efficiency requirements (with margin as appropriate to the life cycle phase) under realizable nominal, best, and worst-case conditions for each mission-critical thread.
- Validation of Sustainability Requirements – Implement sustainability features of the software architecture with consideration for specific needs associated with high availability and safety-critical systems.
- High-Fidelity System Modeling – Create a digital, high-fidelity representation of the as-built system that reflects lessons learned in test or operations to support the analysis of critical quality attributes.

Building Secure, Safe, and High-Availability Systems

- Software Assurance – Determine appropriate coding standards, static and dynamic analysis rules, test code coverage, and fuzz testing standards needed to ensure the integrity of the acquired software.

- Cybersecurity – Identify and continuously evaluate the key security components of the architecture (such as zero trust, security technical implementation guides, white lists, audit traces, and multilevel security guards), and specify the methods and processes that will be used to assure their integrity throughout the program life cycle.
- Safety-Critical Systems – Relevant to safety-critical systems (e.g., aircraft, nuclear systems, ground combat systems, missile systems, space systems) or portions of systems (e.g., deployment mechanisms that interface with live ordnance), apply available best practices or required standards such as DO 178C, MIL-STD-882, and successors to increase the safety of operational software.
- High-Availability Systems – Establish service-level indicators to measure reliability/stability of the software and system from the user perspective over time (this includes identifying user-defined mission-critical threads, stressing test cases such as max load) in off-nominal conditions, and having actual users demonstrate their standard operating procedures.

Software Construction Management

- Life Cycle Management – Update plans to address obsolete or emerging technologies, methods, processes, and tools. Identify timing, content, and stakeholders for retrospective reviews.
- Backlog Management – Develop and maintain a list of capabilities (the product backlog) and the tasks required to realize those capabilities mapped to the release plan.
- Release Management – Synchronize software releases with the development of models, simulations, test beds, and operations environment(s) as needed to ensure compatibility. Use the acceptance criteria from the release planning to identify the required verification steps (inspection, analysis, unit, integration, or acceptance test) for each release to higher levels of integration testing, certification activities, or operations.
- Change Management – Implement mechanisms to ensure that decisions regarding proposed and approved changes are communicated clearly to all stakeholders for the program planning, requirements, architectural design decisions, and code, as well as validation and verification artifacts.
- Automated Test and Continuous Integration – Automate the tests (from unit tests to system integration tests) when feasible to allow for rapid discovery of integration issues. Identify a subset of the test to function as a “smoke test” for daily or on-demand builds of the software.

Software Program Management

- Software Effort Estimation – Create and maintain an estimate of the total software acquisition effort (labor and material), accounting for software size, complexity, precedent, team cohesion, and the development team’s direct experience. Use parametric, historical comparisons (analogies) and bottom-up effort estimates from the development team, as appropriate, to support developing the business case and Acquisition Strategy. Revise the Acquisition Strategy accordingly.

- Product Roadmap and Schedule Management – Implement plans for capability/feature development and release (the product roadmap) and monitor velocity of software production.
- Cost Management – Monitor actual software production metrics versus labor and material expenditures, and update effort estimates and cost baselines as needed.
- Legal Policy and Regulatory Environment Management – Understand and adhere to relevant laws, congressional budgets (fiscal year funding constraints), regulations and certification requirements, and policies (e.g., data and property rights, ownership, export rules).
- Risk, Issue, and Opportunity Management – Implement and manage a closed-loop process to actively track risks and issues as they arise, identify opportunities for improving products and processes that add to customer value, and continuously reassess program plans to mitigate risks and realize opportunities.

Mission Assurance

- Quality Assurance – Establish criteria for reviewing and auditing the software supply chain across all subtiers as necessary to ensure program success.
- Root Cause Corrective Action – Monitor the program and software metrics to identify early indicators of adverse trends, defects, and technical debt and determine root causes. Use statistical control or other methods to proactively propose changes.
- System Integration and Testing – Automate integration and test activities to the fullest extent practical, and build them into the software release process.

Professional Competencies

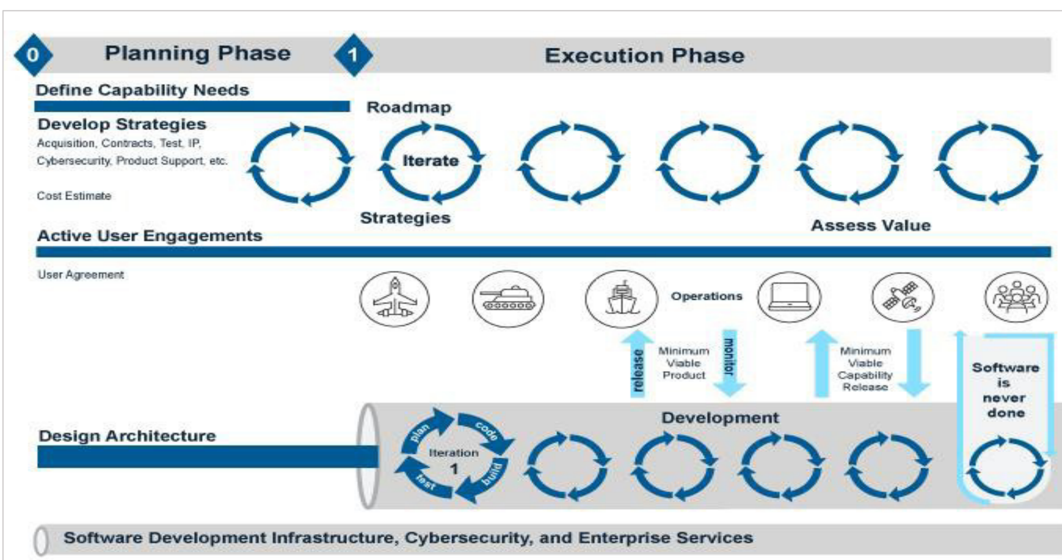
- Strategic Planning and Change Management – Take a long-term view and build a shared vision with others; act as a catalyst for organizational and cultural change. Influence others to translate strategic planning into action.
- Innovation and Entrepreneurship – Provide transformational solution-based approaches to problem solving and building products by employing an iterative process to empathize, define, ideate, build/prototype, and test (i.e., design thinking); and institute a culture that encourages continuous learning and innovation.

Service components and agencies should organize, optimize, and continuously improve their program software engineering Government and contractor workforce. Focus on the people, culture, and team cohesion. Create a constructive Government and contractor working environment and positive outcomes will follow. Below are example position titles within a program management office using an Agile/DevSecOps software factory. All of the aforementioned competencies should be organic across these software acquisition positions.

- Product manager/owner
- Product designer (user research, UX, UI, visual design)
- Software engineer
- Software developer
- Architect
- Platform engineer
- IT engineer
- Data scientist
- Data engineer

6.2.2 Software Acquisition Model

The Software Acquisition model has been streamlined to be more responsive to capability delivery speed expectations demanded to operate in a more dynamic and rapidly changing world. DoDI 5000.02 exempts the Software Acquisition pathway from MDAP milestone and heavier JCIDS requirements. The Software pathway has two phases, Planning and Execution, with no five mandatory documents but no defined milestones (Figure 6-1).



Source: DoDI 5000.87

Figure 6-1. Software Acquisition Pathway Phase Illustration

The Software Acquisition pathway includes two subpaths: "applications" and "embedded software."

- The applications sub-path is suited to cloud native microservices architectural design using DevSecOps tool chains in a continuous integration and continuous delivery environment. The pathway requires a value assessment and MVP within one year and annual or more frequent operational deliveries thereafter.
- The embedded software subpath is for software with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints, or software applications embedded in a platform (e.g., air vehicle, ground vehicle, or ship). Embedded software in the context of this issuance does not apply to firmware or software dedicated to controlling devices (i.e., supervisory control and data acquisition). For programs using the embedded software path, the annual operational delivery requirement applies after initial operational acceptance of the system in which the software is embedded. Before operational acceptance of the system, the developer will be required to deliver software to an operationally representative environment at least annually.

6.2.2.1 Planning Phase

The program uses the planning phase (DoDI 5000.87, Section 3.2) to understand the warfighter's mission needs and develop a plan to deliver the software capabilities into the operational environment in a rapid and iterative fashion (MVP, Minimum Viable Capability Release (MVCR)). Five artifacts are required to transition to the execution phase: a Capability Need Statement (CNS), a User Agreement, an Acquisition Strategy, a Test Strategy, and a cost estimate (DoDI 5000.87, Section 3.2.b.4). The sections below identify software engineering considerations in general and for each required artifact.

General Software Engineering Considerations

Programs in the Software Acquisition pathway noted the following lessons learned:

- Establish solid cross-functional user engagement as early as possible within the planning phase to improve the continuity and fidelity of the planning and aid generation of artifacts.
- Make sure engineers and developers and the participating extended user community have adequate Agile/DevSecOps knowledge. Emphasize and provide training opportunities. Consult with DAU for training solutions.
- Develop and maintain a relationship with the Software Acquisition Enabler (AE) team (mail: osd.mc-alex.ousd-a-s.mbx.osd-sw-pathway@mail.mil). The AE team provides advice and support to programs pursuing the Software Acquisition pathway, such as how to navigate and interpret the SWP required tasks and policy expectations, and useful tips and examples for the five required phase transition artifacts.
- Prepare the Acquisition Strategy product roadmap before developing the CNS, which may help organize and time-phase the program's capabilities and may help focus CNS

work on near-term needs (see the Acquisition Strategy SE Considerations section for more information on the product roadmap).

- For programs transitioning to the Software Acquisition pathway, try to use existing documents and seek approval credit toward meeting the planning phase requirements.
- Delegate approval authority for each required artifact (CNS, User Agreement, Acquisition Strategy, Test Strategy, and cost estimate) to the lowest practical level to simplify and expedite the approval process.

Capability Need Statement Software Engineering Considerations

DoDI 5000.87 is intended to streamline the requirements process. The CNS is intended to be a concise high-level definition of the project software scope to accomplish operational mission needs. Per DoDI 5000.87, the operational community will draft a CNS to start the planning phase. A program sponsor–approved CNS is required to exit the planning phase to begin the execution phase.

Below are some CNS software engineering considerations:

- Existing programs with established JCIDS requirements/capabilities that wish to transition to the Software Acquisition pathway should migrate them to a CNS. The capabilities should be prioritized by mission need and urgency to inform how the backlog will be sequenced for incremental operational deliveries.
- Programs receiving valid requirements from multiple sources should facilitate stakeholder discussions early to determine the most streamlined requirements document approach.
- The CNS is the foundation for managing mission requirements or capabilities and key to informing the mission-driven sequencing of software capabilities for operational delivery. As such, it must provide enough details to convey:
  - The specific capability need, shortfall, or gap to be addressed
  - The capability’s operational content, which defines how the capability contributes to the mission
  - How to prioritize or sequence the capability based on the mission/operational need and timeline urgency
  - Additional supporting information, such as operational constraints, threats, interoperability needs, performance attributes
- Modern iterative software development practices (e.g., Agile/DevSecOps, human-centered design) are designed to be responsive to change, from shifts in mission priorities, evolving threats, and advances in technology. It is critical to involve the user community and provide them with an opportunity to use the system’s capabilities so they can provide feedback early to help shape the development of the mission capability. An

incremental and iterative delivery approach will put working software and usable capabilities in users' hands more quickly, allowing capability maturation and refinement, leading to reduced overall risk and to improved time to value.

User Agreement (UA) Software Engineering Considerations

The UA defines the roles and responsibilities of the program and user community and stakeholders to clarify who is empowered and how decisions will be made with respect to identifying and prioritizing capability, content, and the scope of iterations and releases.

Below are some UA software engineering considerations:

- The specific roles required by a program will vary with the scope, size, and circumstances of the effort.
- As mentioned in the CNS software engineering considerations, it is critical that the user community be fully represented and engaged during the software development, test, and operational delivery process. Modern iterative software development practices require extensive and continuous user engagement to encourage strong communication between technical and operational/business users to reduce risk and produce better user and warfighter outcomes.
- DoDI 5000.87 requires that the UA produce a binding (written) commitment to continuous user involvement. The program and users (acquirers, developers, testers, and operational users) must commit to the staffing resources required to collaborate, evaluate, and provide feedback on interim and fielded software and to shape future requirement details (e.g., capabilities, features, user stories).

The UA should describe the user engagement strategy:

- How will the program engage the user community – end users, developers, contractors, and other stakeholders? Will the program office take on the product owner role? How will the product owner interact with the user community? How will decisions be reached?
- How will the user community be organized and managed? How will communication and feedback flow? What training and mentoring will the user community need? Who will provide it?

Acquisition Strategy Software Engineering Considerations

The primary function of the Acquisition Strategy is to identify and describe the acquisition approach, assumptions, and other factors that will guide acquisition decisions to meet the program's objectives. Although DoDI 5000.87 focuses on streamlining the acquisition processes, methods, reviews, etc., the Acquisition Strategy must still provide enough detail to justify the investment decision.

A product roadmap is required to fulfill the Acquisition Strategy. The product roadmap is a time-based execution plan providing a high-level view of the capabilities and features planned to be delivered. The product roadmap is an important tool to focus direction, engage, and align the team (users, management, and development) on the priority and sequencing of the capability/feature set(s) to be delivered first.

The roadmap is an iteration and increment planning document and is therefore aligned with the development cadence, usually organized by program increments (PIs), which are generally 10-12 weeks in duration. The "active" planning window for most programs is generally 12-18 months depending on the planned release cadence (MVP, MVCRs).

The roadmap is a living document that should accurately reflect the current planning and prioritization. The program should conduct iteration retrospectives and planning sessions, and solicit product owner inputs to maintain an up-to-date document.

- The Acquisition Strategy should provide the overarching strategy for how the program plans to iteratively acquire, develop, and deliver software capabilities, determining if the software will be (1) newly developed; (2) be provided as GOTS, COTS, or OSS; or (3) acquired from a combination of sources.
- Software acquisition is a high risk for most programs; as such, risk management is an integral part of program management and systems and software engineering. A description of the risk management approach used to maintain consistent awareness of its contribution to overall program, system, and software risk, and should manage those aspects of the program. The Acquisition Strategy should describe the risk management approach used to identify, analyze, mitigate, track, and control performance and technical cost, schedule, sustainment, and programmatic risk throughout the life of the program.
- Contracting representatives should have a working knowledge of the concepts and processes associated with modern iterative software development practices, such as Agile/DevSecOps, Lean, and human-centered design, as it will greatly aid in selecting the proper contract vehicles for the effort.
- Contracting for the Software pathway acquired capabilities should take into account the rapid iterative and incremental nature of the software development methodology, and its inherent flexibility and ability to address a dynamic and changing warfighter environment. The vehicle(s) selected should provide the most flexible vehicle/format to meet the program and warfighters' needs.

Test Strategy Software Engineering Considerations

The Test Strategy's primary function is to identify the process by which capabilities, features, functions, use cases, etc., will be tested and evaluated to satisfy developmental and OT&E criteria to demonstrate operational effectiveness, suitability, interoperability, and survivability. The Test Strategy should include information on the verification, validation, and accreditation of the software. Note that DOT&E is the final approver on test strategies for programs on the DOT&E Oversight List.

For more information on Test Strategy considerations, see T&E Enterprise Guidebook (2022).

Cost Estimate Software Engineering Considerations

DoDI 5000.87 requires completion of the cost estimate before entry into the execution phase. To gain executive-level stakeholders' confidence to support funding decisions, DoD acquisition programs must be able to demonstrate a high-level understanding of associated costs and benefits. The four other required planning documents, the CNS, UA, Acquisition Strategy, and Test Strategy, form the basis to establish the cost projection.

The costing approach should consider the difference between traditional and modern software development practices. Traditional software development approaches generally have a fixed capability delivery scope and require detailed requirements understanding and decomposition up front, possibly providing executive leadership greater confidence in the cost estimate. In a dynamic and changing environment, this appearance of higher fidelity may be an illusion, such that environment requirements may considerably change over the long development horizon of many programs. Modern software development practices (e.g., Agile/DevSecOps) encourage stable staffing levels and development cadence, with a more variable or dynamic capability/work delivery scope. Initial program-level planning estimates have low fidelity; only near-term estimates will have high fidelity.

6.2.2.2 Execution Phase (DoDI 5000.87 Section 3.3)

The purpose of this phase is to use the understanding gained of the warfighters' mission needs and maturing the strategies, roadmap, and other artifacts during the planning phase to rapidly and iteratively design, develop, integrate, test and deliver operationally resilient software (MVP, MVCRs) that meet the warfighters priorities and mission needs.

In order to enter the execution phase, the program sponsor must review and approve the five required artifacts: CNS, UA, Acquisition Strategy, Test Strategy, and cost estimate. During the approval process the program sponsor should validate the artifacts have the appropriate maturity and resources are in place to successfully transition to execution.

Below are some execution phase software engineering considerations.

Software Architecture

The software architecture of a system is very important, as it can either accelerate or obstruct the ability of the program to rapidly integrate, test, and deliver resilient small batch software updates to operations. Legacy systems often have monolithic (versus modular) architectures that may make it challenging to deliver resilient software releases within the 1 year or less required delivery cadence.

For more information on software architecture see the Software Architecture section of the OUSD(R&E) Software Engineering Guide (2023).

Software Factory

The Defense Science Board's "Design and Acquisition of Software for Defense Systems" report (2018) made seven recommendations regarding how to improve software acquisition in defense systems. One recommendation was singled out for its importance: "A base recommendation underlying all others is to emphasize the importance of the software factory." Programs should establish a rigorous release process and mature software factory, which incorporates a high degree of automation, toolchain integration, and automated high-fidelity testing, to meet the Software pathway's accelerated operational delivery timeline requirements (1 year or less).

A key focus of DevSecOps is delivering secure resilient code. Security must be embedded (not bolted on) throughout the entire software development life cycle. Advancing cybersecurity and resilience in DoD software factories/DevSecOps pipelines should be an area of major focus.

Programs should leverage enterprise platforms and services to the maximum extent possible, as opposed to independently developing a separate instance of a Software Factory/DevSecOps pipeline. The program can save time and effort by tailoring already established enterprise offerings (e.g., Platform One, Black Pearl, Army Code Repositories and Transformation Environment (CReATE)).

For more information on the software factory, see OUSD(R&E) Software Engineering Guide (2023).

Metrics

Quantitative insight in software engineering and measurement is crucial for program success. Commitment to a quantitative (i.e., data-driven) software engineering and SE approach is vital to shape program and software development plans, monitor execution, identify risk early, and inform leadership to support decision making throughout the life cycle. The lack of effective measurement plans and practices to address team, product, and enterprise needs exposes the enterprise to high risk. The PM should establish operational context and a clear definition of measures to be collected to ensure the program has a sufficient level of product team transparency with which to make informed decisions.

The PM, systems engineer, and software engineer should plan and use predictive metrics frequently and rigorously to (1) measure and control software product performance and (2) assess software schedule realism and software maturity or operational readiness throughout the development life cycle. Leading indicators provide "early warning" to enable the program to mitigate risk in a timely way. The program's measurement process and its associated goals, level of access to data, metrics, and reports should be planned and contracted for early in the life cycle to ensure maximum insight across the prime and subcontractor suppliers or developers. The plan should consider both knowledge points (and associated decision makers) and inflection points (changes in metric values and trends that alert decision makers to emerging problems).

With DoD's push to modernize and improve the agility of software acquisition and development, there is an increased focus on measuring the impact of the initiatives.

Within industry, the currently accepted best practice for agility measures are the DORA (DevOps Research and Assessment) 4: Deployment Frequency, Lead Time for Changes, Change Failure Rate, and Time to Restore. These metrics are highly useful and recommended to measure the enterprise's increase in agility over time. Improved software agility is critical for U.S. ability succeed in an era of Great Power competition.

For more in-depth information on software metrics best practices, lessons learned, recommendations and choosing the right metrics for managing a software program's needs, see OUSD(R&E) Software Engineering Guide (2023).

6.3 Specialty Engineering

6.3.1 Reliability and Maintainability Engineering

R&M engineering activities should meet the objectives of the software acquisition program. To identify software acquisition program risk related to R&M, at a minimum programs should plan for testing in relevant and operational environments and ensure that design reviews identify and mitigate failure modes.

- Software Reliability Metrics – If the program does not have software reliability or availability metrics, it should adopt them aligned with the current program operating and logistics profiles. Suggested metrics include:
  - Continuous operating time without error (which should be measured as a threshold value, not a mean time)
  - Software availability measured as (uptime)/(uptime downtime). Uptime must be continuous operating and downtime must be the mean time to auto-correct, hang-time, or reboot.
  - Software stability (e.g., Can the software operate over a defined period of time without error?)
  - Mean time to reboot (restore)
- Software Maturity Level – Higher maturity levels are desired for reliability. Software at Capability Maturity Model Integration (CMMI) Level 4 is quantitatively managed and Level 5 is optimized through continuous process improvements. Software at a CMMI Level 5 can be expected to have the highest reliability.
- Software Failure Modes and Effects Analysis – Used to identify and eliminate software failure modes, this analysis can be performed before testing but requires continuous

updating during testing. Continuous updating may require simulation testing before the program begins full system testing.

- Software Testing – Testing should be embedded in test plans to collect data to compare against the software metrics. Perform predictive analysis during testing to compare the test data with benchmarks set before testing.
- Failure Review Board (FRB) – The FRB should:
    - Include both hardware and software experts to identify root causes of problems and assign to either hardware or software
    - Determine appropriate corrective action
    - Maintain a FRACAS to collect and report metrics
    - Report the state of the system's reliability and availability

Additional guidance for the R&M engineering activities applicable to the software acquisition pathway is in development and will be added to the R&M Engineering Management Body of Knowledge (https://cto.mil/sea/rm/).

In the interim, the PM, systems engineer, and lead software engineer should work to properly align the applicable R&M Engineering activities needed to reduce program risk. Table 3-13 "R&M Activities by Acquisition Phase" should be used as a starting point to assess appropriate activities needed to deliver capability that is reliable, maintainable, and supportable.

6.3.2 Human Systems Integration

The PM and systems engineer should apply HSI expertise to address user interface and other HSI areas in the Software Acquisition pathway. This pathway intends to ensure users play a central role in the software system design. User-centered design is a key HFE Domain activity.

As in the UCA and MTA pathways, the Software Acquisition pathway can be tailored by the CAE to enable rapid and effective acquisition and delivery of software. The process can be expedited even more by delegating decisions and approvals to the lowest practical levels. Here it is even more critical for the systems engineer to engage with the HSI SME to meet the demands of the program.

6.3.2.1 Planning Phase

The systems engineer can contribute successfully to HSI by having HSI SME involvement with the development of the CNS, user agreements and personas, Acquisition Strategy, cost estimates, and metrics and reporting mechanisms.

The CNS is developed by the sponsor to better understand the users' needs and plan the approach to deliver software capabilities to meet those needs. HSI practitioners may not be involved in the creation of the CNS but should review it. The DAU Glossary states a user agreement is, "A commitment between the sponsor and PM for continuous user involvement and assigned decision making authority in the development and delivery of software capability releases." The HSI practitioner should be a member of the team that crafts the user agreement with the user community.

Development of the Acquisition Strategy is another activity in which HSI practitioners should participate. HSI activities should be included in an approved cost estimate and budget to help ensure these activities will happen. Building HSI metrics into the automated testing will ensure HSI practitioners have access to useful data. Some issues do not lend themselves to automated collection – issues in the domains of manpower, personnel, and training. HSI practitioners should formulate metrics for these types of issues and plan to collect data to confirm the system is meeting requirements in those areas as well.

6.3.2.2 Development/Design Sprints

Systems engineers should include the support of HSI practitioners that monitor the minimum viable product's maturation and ensure that before it is redesignated a minimum viable capability release, it has met the HSI-related requirements for a fieldable system and the sponsor, stakeholders, and users are satisfied with it.

A design sprint is an intense process, typically about 5 days in length in which user-centered teams tackle design problems. HSI practitioners need to participate in these sprints because they will add valuable insights into the design process.

Experienced HSI practitioners may be able to lead sprints. The product backlog is the authoritative source the team maintains. HSI practitioners should monitor the backlog to ensure items related to HSI issues are prioritized properly. HSI practitioners should make certain that the appropriate data are being collected so that HSI issues can be assessed in a valid and reliable manner. There is also a role for HSI in cybersecurity.

HSI practitioners should be part of this annual value assessment to determine if the software system is meeting user needs. The HSI practitioners should be part of the planning, execution, and analysis of the value assessment results.

Sustainment is not just about the software program and its durability. Sustainment includes the personnel involved in operating, maintaining, and supporting the program. HSI practitioners can smooth the rollout of new versions by making sure the training manuals are up to date and that the right amount of training is provided. Technical manuals and training materials should include HSI input.

The Software Acquisition pathway is not subject to the requirements in the JCIDS process. The pathway most likely will not involve Capability-Based Assessments, Design Change Requests, ICDs, or CDDs. While creating the opportunity for speed and agility, the systems engineer should keep the HSI SME involved to cover areas or activities that may otherwise have been curtailed or eliminated.

This accelerated process also involves software testing that will be automated. Automated testing is only as beneficial as the planning and programming that goes into developing the automated testing methodology. At some point, a minimum viable product will become a minimum viable capability release.

Some questions to ask include the following:

- Will that methodology consider relevant HSI issues?
- Will it collect data that HSI practitioners can use to identify and address problems before the software is fielded?
- What is that threshold and what criteria does the software have to achieve before that threshold is crossed?
- Does that threshold really meet the needs of the operators, maintainers, and supporters of that software system and has that been demonstrated in the operational context?
- Does that MVCR come with the training needed to successfully engage with the system software?
- Because software systems will be built and delivered incrementally, training should accompany each software version to be released at least annually. Regarding training materials, some questions to ask:
  - Do the operators, maintainers, and supporters receive training or are they supposed to rely exclusively on the training materials that have been produced by the program office?
  - If training is provided, is that training adequate?
  - Will software users have to unlearn what they had been accustomed to doing in a previous version?

Systems engineers can have success with their user population and software delivery by including the HSI practitioner and SMEs early in planning and executing user-centered design (UCD) and other HFE activity.

6.3.3 System Safety Engineering

The program should develop and implement a tailored system safety program to align with the Software Acquisition pathway to ensure the identification and assessment of potential software contributions to system-level hazards, mitigating controls and safety risks. SSS is “the application of System Safety principles to software” (MIL-STD-882). The program should document a strategy for SSS activities and artifacts in accordance with MIL-STD-882. The standard provides a structured, yet flexible and tailorable, framework for the assessment of software contributions to system-level hazards and associated risks.

The assessment of risk for software, and consequently for software-controlled or software-intensive systems, considers the potential risk severity and degree of control the software exercises over the hardware, and dictates the LOR tasks needed to reduce the risk level. The LOR tasks and analyses (e.g., Software Architecture analysis) specify the depth and breadth of software analysis and verification and validation activities necessary to provide a sufficient level of confidence and safety assurance that a safety-significant software function will perform as required. The system safety and SSS hazard analysis processes and successful execution of LOR tasks are key elements to increase the confidence that the software will perform as specified to software performance requirements, while reducing the number of contributors to hazards that may exist in the system. All software contributions to system risk are documented in the HTS.

The Joint Services Software Safety Authorities' "Software System Safety Implementation Process and Tasks Supporting MIL-STD-882" is a concise guide to assist in the implementation of the SSS requirements and guidance contained in MIL-STD-882. The Joint Software System Safety Engineering Handbook process descriptions complement MIL-STD-882 for these analyses. AOP 52 provides additional guidance on how to conduct required software analyses.

The Unmanned System Safety Engineering Precepts Guide for DoD Acquisition provides guidance in support of the development and design of safe UxS, associated safety significant software, support hardware and firmware, and Service safety reviews. The guide is intended for UxS system safety engineers as well as UxS PMs, systems engineers, system designers, and T&E managers. The guide provides the PM with a point of initiation for precepts that can aid the development of a system safety engineering program. It includes a summary of the three types of safety precepts (e.g., Programmatic, Design and Operational), an analysis of the major UxS safety concerns, and an assessment of the state of the art of AI and autonomous capabilities, which, when integrated properly, can enable the desired performance of UxS autonomy, human-machine interaction, and command and control.

6.3.4 Parts Management

Program offices pursuing the Software Acquisition pathway focus on custom software. The program office's DMSMS management activities should focus on potential functional obsolescence. The program office's DMSMS management plan and DMSMS management team should monitor and test for instances of functional obsolescence during the planning and execution phases and should implement the appropriate resolutions when they identify functional obsolescence. Section 2.2.3.5. of the SD-22 contains more information on the tailoring of MCA DMSMS management to the Software Acquisition pathway.

6.4 Modular Open Systems Approach

Programs should tailor MOSA considerations appropriately to align with DoDI 5000.87. Detailed OUSD(R&E) MOSA engineering considerations for Software Acquisition will be addressed in a future iteration of this guidebook.

6.5 Digital Engineering

New programs of record, including software acquisitions, should adopt a digital engineering-based SE approach. The program's Acquisition Strategy and SEP should describe the approach and implementation, which should be based on program requirements and end state objectives including future enhancements and sustainment. A program may tailor the level of implementation. See Section 3.5 for more information.

6.6 System Security Engineering

SSE integrates system security engineering disciplines such as anti-tamper, Defense Exportability Features, hardware assurance, software assurance, and supply chain risk management. The program should implement comprehensive SSE and system protection within the constraints of cost, schedule, and performance while maintaining an acceptable level of risk. The system security engineer leads the evaluation and balancing of security contributions to produce a coherent security. Additional information is provided in the T&PP Guidebook (2022) for the Software acquisition pathway.

6.7 Technical Reviews and Assessments

6.7.1 Independent Review Teams

Programs should conduct periodic reviews by independent technical personnel to assess technical maturity and risk. The CAE should implement a technical review process, tailored for this acquisition pathway, to identify and document critical issues that safety/security thresholds, program/mission objectives, and recommend the necessary corrective actions and risk mitigation activities required to reduce risk. Reviewers should provide results directly to the CAE, with coordination but not undue influence from the PMO. The PM, with support from the lead engineer, will review, develop, and implement corrective action to the satisfaction of the CAE. The CAE should approve team members to ensure all organizational, professional, and relational influences from the program management office are avoided.

6.7.2 Systems Engineering Technical Reviews

PMs should consider conducting tailored software design reviews to assess the system's technical maturity, and technical risks.

7 Defense Business Systems Acquisition

The DBS pathway is used to acquire information systems that support DoD business operations. This pathway applies to defense business capabilities and their supporting business systems, including those with “as-a-service” solutions to include the following: financial and financial data feeder, contracting, logistics, planning and budgeting, installations management, human resources management, training, and readiness systems. Also it may be used to acquire non-developmental, software-intensive programs that are not business systems.

7.1 Systems Engineering

This pathway includes no mandated SE processes, technical reviews, or documents. DBS are not required to use the Systems Engineering Technical or Management Processes and do not require a SEP. Instead, the Business Capability Acquisition Cycle, or “BCAC” provides the approach to system development for using this acquisition pathway. Additional information on the BCAC process is available at the DBS AAF (https://aaf.dau.edu/) and the Digital Capabilities Guidebook (2022). In addition, DBS may benefit from leveraging best practices and lessons learned from traditional SE processes as discussed in Section 3.1. Systems engineers should also review the individual specialty engineering sections of this guidebook for further recommendations on how these areas should be implemented for each pathway.

7.2 Software Engineering

The Business System Requirements and Acquisition policy (DoDI 5000.75) directs that programs and PMs assess their business processes, environment, and needs to identify where existing COTS or GOTS solutions could be employed to satisfy their business operation requirements with a minimal need for customization. The policy also encourages leveraging shared infrastructure and cloud-based solutions and closer alignment with commercial or Government IT best practices.

7.3 Specialty Engineering

7.3.1 Reliability and Maintainability Engineering

R&M engineering activities should meet the objectives of the DBS program. To identify DBS program risk related to R&M, at a minimum, programs should plan for testing in relevant and operational environments and ensure that design reviews identify and mitigate failure modes.

Guidance for the R&M engineering activities applicable to the DBS pathway is in development and will be added to the R&M Engineering Management Body of Knowledge (https://cto.mil/sea/rm/). In the interim, the PM, systems engineer, and lead software engineer should work to properly align the applicable R&M engineering activities needed to reduce program risk. Table 3-13 “R&M Activities by Acquisition Phase” should be used as a starting point to assess appropriate activities needed to deliver capability that is reliable, maintainable, and supportable.

7.3.2 Manufacturing and Quality

M&Q personnel, working with the PM, lead systems engineer, and other IPT members, will ensure that manufacturing, quality, and producibility requirements and risks are identified and managed throughout the process of fielding an urgent capability. Manufacturing and QA personnel should:

- Support the development of program documentation including acquisition strategies.
  - Support industry analysis and market research
- Support the development and implementation of efficient and cost-effective M&Q activities and processes.
  - Cost estimating (identify M&Q cost drivers)
  - Cost tracking and improvement
- Support demonstration and evaluation of prototype design, build, and test activities.
  - Support the identification, tracking, and management of technical risks
  - Support all SE technical reviews, to ensure M&Q considerations are addressed early

The manufacturing of business systems including proposed components, subsystems, and systems should occur under the umbrella of M&Q best practices. Thus any proposed contractors should be operating under a documented M&Q management system such as:

- AS9001, Quality Management System, or
- ISO 9001, Quality Management System

M&Q should consider Industrial Base Capabilities and material availability to produce the required quantities and timelines. Given the potential for rapid technology refresh of commercial technologies, the M&Q technical team should emphasize configuration management and DMSMS in accordance with DoDI 4245.15 and SD-22.

7.3.3 Human Systems Integration

The systems engineer should include HSI SMEs to contribute to the five stages of Figure 7-1.

An Authority to Proceed (ATP) is essentially the same as a Decision Point. The smaller diamonds represent other key program events, such as contract award or business systems being deployed in multiple increments after Limited Deployment ATP. The four overlapping bands represent Market Research, IT Solution, IT Requirements, and Organizational Change Management. The Organizational Change Management band spans the entire life of a program.

DoDI 5000.75 states, “Change management proactively prepares the functional community for upcoming changes resulting from the delivery of a business capability, reduces risk, and increases user adoption.” Here the systems engineer must advocate for the HSI SME involvement. At least seven documents or activities are part of the Capability Implementation Plan to which HSI practitioners should contribute directly.

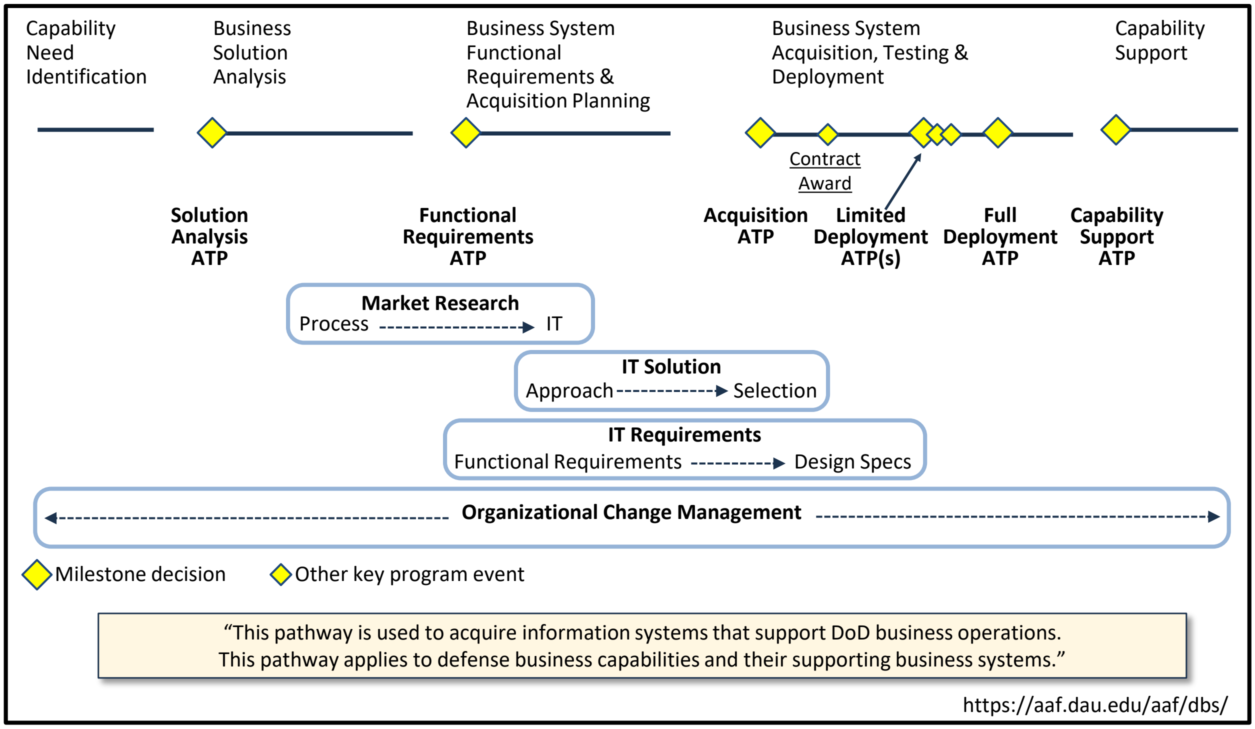


Figure 7-1. Business Capability Acquisition Cycle

7.3.3.1 Functional Requirements and Acquisition Planning phase

In the Functional Requirements and Acquisition Planning phase, two major activities that HSI practitioners can contribute to are the Acquisition Strategy and the RFPs.

7.3.3.2 Acquisition, Testing, and Deployment phase

HSI practitioners should be heavily involved in the Acquisition, Testing, and Deployment Phase. The fit-gap analysis will identify which aspects of the COTS or GOTS system to be acquired fit the needs of the functional community and where there are gaps. If at all possible, HSI practitioners should participate in the fit-gap analysis, as testing is an important activity during this phase. Also during this phase organizational change is in full swing. The new system will change the way the organization conducts its business. Training is needed to ensure organizational members know what to expect and what is expected of them.

7.3.3.3 Capability Support Phase

Any activities that involve interaction with the system users should include the HSI practitioners. Testing and system updates will continue after deployment. HSI should participate in these activities.

7.3.3.4 Challenges and Opportunities

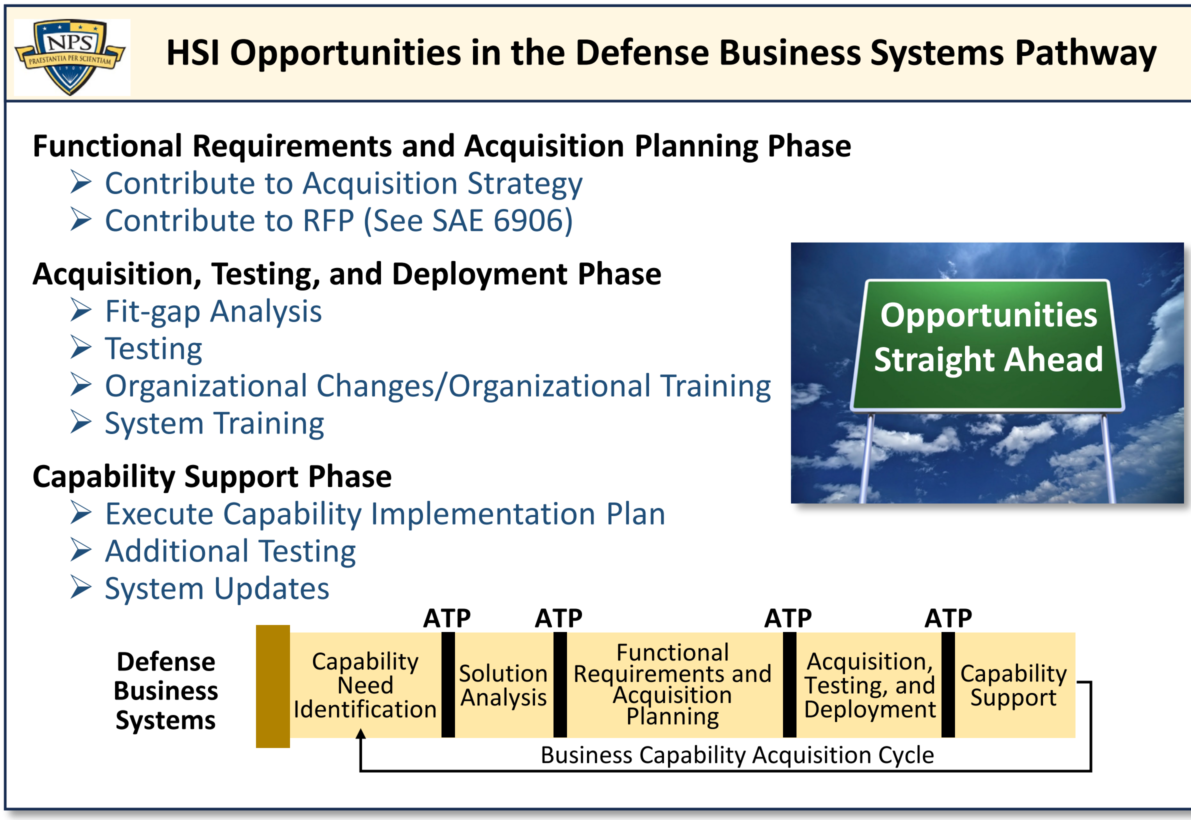
An HSI SME should become familiar with the DBS system definition to determine the requirements to which HSI applies, how to incorporate HSI principles, and user-focused requirements language. DBS rely on COTS, GOTS and legacy systems. If those systems were not designed well from an HSI perspective, there may be little that can be done in the design phase to correct HSI-related issues inherent in those systems. In addition, the T&E activities in the DBS pathway may focus more on the technical aspects of the system and less about the system's impact on those who operate, maintain, and support the system.

HSI SMEs should focus on articulating risk within and among the HSI domains. HSI SMEs can provide HSI trade-off opportunities or mitigations to PMs and SEs with regard to cost, schedule, or performance impacts, and risk identification. The DBS is not subject to the requirements in the JCIDS process. The responsibility for most of the tasks to be completed for program acquisition are generally divided between the user representative and the PM, so the HSI practitioner should expect to engage with these communities to advocate for HSI.

Cost thresholds are much lower for business acquisition categories, which may mean budgets will be tighter to accomplish HSI needs. HSI practitioners should be prepared to negotiate priority HSI needs with the user and PMs to demonstrate how HSI recommendations will add value with quantifying returns on investment. Figure 7-2 illustrates HSI opportunities in the Defense Business Systems pathway.

The DBS pathway presents HSI opportunities. In the Capability Need Identification phase, HSI practitioners should use their perspective to ensure the requirements are not technical in nature only, such as IT processing speed and records transaction accuracy. They should ensure the needs of the system users and the system customers are identified and included in the requirements, which is a personnel domain characteristic.

One of the criteria for a successful ATP decision at the end of the Capability Need Identification phase is a prioritized capability list. Identifying HSI issues on that list with concrete objective and threshold values will facilitate addressing HSI issues appropriately throughout the remainder of the pathway. In the Solution Analysis phase, an organization receiving a new capability will undergo a reengineering of the business processes to ensure that the organization and the capability together will achieve the performance needed. That part of the reengineering process includes a DOTMLPF-P analysis, which should include HSI involvement and comment within each DOTMLPF-P category.



Source: Naval Postgraduate School

Figure 7-2. HSI Opportunities in the Defense Business Systems Pathway

7.3.4 System Safety Engineering

The program should develop and implement a tailored system safety program appropriately to align appropriately the DBS acquisition approach to ensure the identification and assessment of potential hazards (hardware and software), mitigating controls and safety risks. The system safety methodology in MIL-STD-882 will be used to manage system safety, environmental and occupational health considerations as an integral part of the program's overall SE process.

System safety risks and requirements should be tailored and managed to minimize the injury to or loss of Service members and degradation of their equipment, and to reduce impact on the environment. In accordance with MIL-STD-882, hazards will be eliminated when possible, and accepted and managed by the PM when not.

In addition to MIL-STD-822, programs should use the DoD Joint Software Systems Safety Engineering Handbook and the Joint Services – Software Safety Authorities (JS-SSA) Software System Safety Implementation Process and Tasks to assess system-level hazards pertaining to software.

A closed-loop HTS is used to document, track, and maintain hardware and software-related hazards and their associated risk data.

7.3.5 Parts Management

DMSMS management considerations for programs following the DBS pathway begin during the functional requirements and acquisition planning phase. At this point DMSMS management planning, including the development of a DMSMS management plan and the formation of a DMSMS management team, should be initiated by the program office. The program office should also start its monitoring efforts, which will focus on those items that are not readily available commercial software and commercial business equipment. For those commercial items and equipment, program offices will rely on commercial suppliers to monitor for and resolve DMSMS issues. Because market trends change, impacting technologies, program offices should begin to use technology roadmapping to identify when the inclusion of technology refresh in product roadmaps for supportability will be necessary.

When preliminary parts lists are received during the acquisition testing and deployment phase, proactive monitoring should take place for non-commercial equipment. If the Government owns or maintains the business system, the system will most likely require technology refresh over its long system life. A program office's DMSMS management activities can assist in determining the best timing for technology refreshment in combination with capability enhancements.

During the final phase, capability support, some commercial items may no longer be supported by their commercial suppliers. Program offices will need to monitor more items, but the data availability to do so may still be limited. DMSMS management activities should therefore rely more heavily on product roadmapping for supportability.

Section 2.2.3.4. of the SD-22 contains more information on the tailoring of MCA DMSMS management to the DBS pathway.

7.4 Modular Open Systems Approach

Programs should tailor MOSA considerations appropriately to align with the Defense Business Systems Policy, DoDI 5000.75. Detailed OUSD(R&E) MOSA engineering considerations for Acquisition of DBS will be addressed in a future iteration of this guidebook.

7.5 Digital Engineering

A digital engineering-based SE approach is highly encouraged for all new programs of record including DBS, enhancement efforts, and early engineering efforts such as prototyping. Many business systems are good candidates for a digital engineering SE approach. The extent to which a DBS effort incorporates digital engineering practices to include a digital environment depends on program requirements, including future engineering and sustainment needs. The program's Acquisition Strategy and SEP should describe the approach and implementation. A program may tailor the level of implementation. Refer to Section 3.5 for more information.

7.6 System Security Engineering

SSE integrates system security engineering disciplines such as anti-tamper, Defense Exportability Features, hardware assurance, software assurance, and supply chain risk management. The desired outcome is a comprehensive program and system protection within the constraints of cost, schedule, and performance while maintaining an acceptable level of risk. The system security engineer leads the evaluation and balancing of security contributions to produce a coherent security. SSE practices applicable to other acquisition pathways are provided in the T&PP Guidebook (2022). These practices may be useful to the DBS programs as they address similar program protection actions.

7.7 Technical Reviews and Assessments

7.7.1 Independent Review Teams

Programs should conduct periodic reviews by independent technical personnel to assess technical maturity and risk. The CAE should implement a technical review process, tailored for this acquisition pathway, to identify and document critical issues that jeopardize safety/security thresholds, program/mission objectives, and recommend the necessary corrective actions and risk mitigation activities required to reduce risk. Results should be provided directly to the CAE, with coordination but not undue influence from the PMO. The PM, with support from the Lead Engineer, will review, develop, and implement corrective action to the satisfaction of the CAE. The CAE should approve team members to ensure all organizational, professional, and relational influences from the program management office are avoided.

7.7.2 Systems Engineering Technical Reviews

PMs should consider conducting tailored design reviews, such as an SRR or SFR to assess the system's technical maturity and technical risks. See Section 3.7.3 and Section 3 of the SE Guidebook for more details.

8 ACQUISITION OF SERVICES

The Acquisition of Services pathway is used to identify required services, research potential contractors, contract for the services, and manage performance. Services are acquired in accordance with DoDI 5000.74, “Defense Acquisition of Services.” The Acquisition of Services pathway includes three phases (planning, developing, and executing) and seven steps. The seven steps ensure the use of proven, repeatable processes and procedures contributing to successful service acquisitions.

The Guidebook for Acquiring Engineering Technical Services: Best Practices and Lessons Learned provides DoD guidance for acquiring technical services. The following sections include additional recommendations related to contracting for engineering technical services.

8.1 Systems Engineering

This pathway includes no mandated SE processes, technical reviews, or documents. The acquisition of services is based on the “Seven Steps to the Service Acquisition Process” as described in DoDI 5000.74 and the DAU Service Acquisition Mall (SAM). More information on the acquisition of services is available on the DAU website: https://aaf.dau.edu/aaf/services/. See also Section 3.1 for information and lessons learned from traditional SE processes. Systems engineers should review the individual specialty engineering sections of this guidebook for further recommendations on how these areas should be implemented for each pathway.

8.2 Software Engineering

Service acquisition can range from aircraft maintenance to staff augmentation and many items in between. Buying services differs significantly from buying weapon systems. In the context of software engineering, this pathway is used to contract for contractor time and effort to perform an identifiable task, rather than to develop or drive delivery of a software end product.

For more information on using the Acquisition of Services pathway, see guidance provided on the DAU AAF website https:aaf.dau.edu.

8.3 Specialty Engineering

8.3.1 Reliability and Maintainability Engineering

R&M engineering activities should meet the objectives of the Acquisition of Services pathway. To identify risk related to R&M in programs using the Acquisition of Services pathway, at a minimum programs should plan for testing in relevant and operational environments and should ensure that design reviews identify and mitigate failure modes.

Guidance for the R&M engineering activities applicable to the Acquisition of Services pathway is in development and will be added to the R&M Engineering Management Body of Knowledge (https://cto.mil/sea/rm/).

In the interim, the PM, systems engineer, and lead software engineer should work to properly align the applicable R&M Engineering activities needed to reduce program risk. Table 3-13 "R&M Activities by Acquisition Phase" should be used as a starting point to assess appropriate activities needed to deliver capability that is reliable, maintainable, and supportable.

8.3.2 Manufacturing and Quality

Quality personnel, working with the PM, lead systems engineer, and other IPT members, will ensure that quality requirements and risks for services are identified and managed throughout the acquisition and performance of services. Quality personnel should:

- Support the development of program documentation including acquisition strategies
- Support the development and implementation of efficient and cost-effective quality activities and processes
  - Cost estimating (identify quality and service cost drivers)
  - Cost tracking and improvement
- Support demonstration and evaluation of service quality
  - Support the identification, tracking, and management of quality
  - Support program reviews, to ensure quality considerations are addressed early

As indicated in the Guidebook for the Acquisition of Services, the Multi-Functional Team should be familiar with the Quality Assurance provisions in the FAR Part 46 and DFARS Part 246, including its Procedures, Guidance and Information Part 246, before developing the Quality Assurance Surveillance Plan (QASP) that will be supporting the Performance Work Statement or Statement of Objectives.

The QASP is used to manage contractor performance by ensuring that systematic quality assurance methods validate that the contractor's quality control efforts are timely and effective and are delivering the required results. The QASP is intended to be a "living" document that should be reviewed and modified whenever necessary. The method and degree of performance assessment may change over time, depending on the level of confidence in the contractor. The premise is that the contractor, not the Government, is responsible for managing the QASP quality controls and ensuring that the performance meets the terms of the contract. A few ways to assess a contractor's performance that can properly monitor performance and quality include:

- Methods of Surveillance: metrics, random sampling, periodic inspection, 100 percent inspection, customer feedback, and third-party audits.

- Sampling Guide: a written procedure that states what will be checked, the acceptable quality standard, and how the checking will be done.
- Decision Tables: tables that identify examples of unsatisfactory performance, probable cause factors, and the resulting consequences. When a service has failed to meet performance standards, a decision must be made as to who is at fault. A decision table is used for this purpose.
- Checklists: a record of what has been checked by a sampling guide and to record information on contract items not covered by sampling.

Quality managers should consider including DCMA as a part of the program office team to help support contractor surveillance and oversight.

Some of these assessment methods can be partially transferred to DCMA for onsite performance through an MOA or MOU.

8.3.3 Human Systems Integration

HSI practitioners may not have extensive opportunities to support the Acquisition of Services pathway. DoDI 5000.74 cites a “user” and “stakeholder” only a few times; however, HSI practitioners can highlight HSI value within this pathway after by reviewing the pathway stages and understanding the decision points they can inform.

8.3.3.1 Challenges and Opportunities

Contracting activities are regulated, and decision authorities and contracting officers are not likely to add activities such as HSI to their workload without a requirement. In addition, HSI equities and benefits may not be readily apparent to all personnel working in the Acquisition of Services pathway. DoDI 5000.74 lacks language to enforce the development of human performance parameters and requirements, and contracting officials are obliged to adhere to FARs, DFARs, and Service FARs to analyze requirements.

8.3.3.2 Opportunities Use Case

Following is an example of how to incorporate HSI into an acquisition of services activity that involves replacing the current government travel system.

In Step 1 involves identifying stakeholders. One of the stakeholders could be an HSI practitioner representing the hundreds of thousands of DoD travelers who use the travel system. The HSI practitioner should be able to detail the user base, in terms of the required knowledge, skills, abilities, and other attributes of the target population using the travel system.

Step 2 involves stakeholder and user interviews and gap analysis. HSI practitioners should be skilled at eliciting knowledge from the user base.

Step 3 includes market research, which would benefit from an HSI perspective codifying the end user's expected cognitive abilities for human-system interactions and expectations.

Step 4 is a risk analysis. HSI practitioners could add value to that analysis if the system's written technical achievement requirements (i.e., record transaction processing time) included outside user expectations (i.e., reduced operational performance and frustration due to IT delays in processing).

In Step 5, the requirements for the travel system are developed and the Acquisition Strategy drafted. Both would benefit from HSI inputs.

In Step 6, the acquiring organization drafts the RFP. HSI reviewers should help ensure the RFP outlines HSI expectations. Anything not written in the RFP – such as HSI-related and human performance requirements – will not be included in the responses returned by the vendors.

In Step 7, the program manages the contract and assesses system performance. HSI-oriented metrics would inform the functional service manager regarding how well the service provider is meeting the needs of the users, maintainers, and supporters, articulated in terms of human performance needs.

8.3.4 System Safety Engineering

Develop and implement a tailored system safety program appropriately to align with the Acquisition of Services approach to ensure the identification and assessment of potential hazards (hardware and software), mitigating controls and safety risks. The system safety methodology in MIL-STD-882 will be cited and used during the planning, developing, and executing of service acquisition to ensure successful managements of system safety, environmental and occupational health considerations as an integral part of the program's overall SE process.

System safety risks and requirements should be tailored and managed to minimize the injury to or loss of Service members and degradation of their equipment, and to reduce impact on the environment. In accordance with MIL-STD 882, hazards will be eliminated when possible, and accepted and managed by the PM when not.

8.4 Digital Engineering

A digital engineering-based SE approach is highly encouraged for all new programs of record. Depending on the services being acquired, a digital engineering approach may have limited applicability to this pathway. If digital engineering practices are applicable, they should be considered and addressed in the program's Acquisition Strategy and SEP. The digital engineering approach is tailorable based on the services being acquired and end-state objectives. Refer to Section 3.5 for more information.

8.5 System Security Engineering

SSE integrates system security engineering disciplines such as anti-tamper, Defense Exportability Features, hardware assurance, software assurance, and supply chain risk management. The desired outcome is a comprehensive program and system protection within the constraints of cost, schedule, and performance while maintaining an acceptable level of risk. The system security engineer leads the evaluation and balancing of security contributions to produce a coherent security. SSE practices applicable to other acquisition pathways are provided in the T&PP Guidebook (2022). These practices may be useful to the Acquisition of Services contracts as they address program protection actions that could be considered for service contractors.

8.6 Technical Reviews and Assessments

8.6.1 Independent Review Teams

Periodic reviews conducted by independent technical personnel are a core best practice fundamental to engineering development and managing risk. The CAE should implement a technical review process, tailored for this acquisition pathway, to identify and document critical issues that jeopardize safety/security thresholds, program, and mission objectives, and to recommend the necessary corrective actions and risk mitigation activities to reduce risk. Results should be provided directly to the CAE, with coordination but not undue influence from the PMO. The PM, with support from the lead engineer, will review, develop, and implement corrective action to the satisfaction of the CAE. The CAE should approve team members to avoid organizational, professional, and relational influences from the PMO.

8.6.2 Systems Engineering Technical Reviews

PMs should consider conducting tailored design reviews, such as an SRR or SFR to assess the program’s risks. See Section 3.7.3 of the MCA pathway for more details.

ACRONYMS

AAF	Adaptive Acquisition Framework
AAFDIT	Adaptive Acquisition Framework Documentation Identification Tool
AC	Advanced Concepts
ACAT	Acquisition Category
ADM	Acquisition Decision Memorandum
AoA	Analysis of Alternatives
APB	Acquisition Program Baseline
ASR	Alternative Systems Review
AT	Anti-Tamper
ATP	Authority to Proceed
BIT	Built-In-Test
CAE	Component Acquisition Executive
CAPE	Cost Assessment and Program Evaluation
CARD	Cost Analysis Requirements Description
CBM+	Conditioned Based Maintenance Plus
CCMD	Combatant Command
CDD	Capability Development Document
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CE	Chief Engineer
CI/CD	Continuous Integration/Continuous Delivery
CJCS	Chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CMD	Combatant Command
CMMI	Capability Maturity Model Integration
CNS	Capability Need Statement
COCOM	(combatant command) command authority
CoDR	Concept Design Review

CONOPS	Concept of Operations
COTS	Commercial Off-The-Shelf
Cp	Process Capability Index
CP	Competitive Prototyping
CPC	Corrosion Prevention and Control
Cpk	Process Capability Centering Index
CSCI	Computer Software Configuration Item
DAG	Defense Acquisition Guidebook
DAS	Defense Acquisition System
DAU	Defense Acquisition University
DBS	Defense Business Systems
DCMA	Defense Contract Management Agency
DD, ENG	Deputy Director for Engineering
DEF	Defense Exportability Features
DevSecOps	Development, Security, and Operations
DFARS	Defense Federal Acquisition Regulation Supplement
DMSMS	Diminishing Manufacturing Sources and Material Shortages
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DOTMLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy
DR	Decision Review
DT&E	Developmental Test and Evaluation
ECP	Engineering Change Proposal
EMD	Engineering and Manufacturing Development
EO	Executive Order
EOA	Early Operational Assessment
ESOH	Environment, Safety and Occupational Health
FCA	Functional Configuration Audit

FD	Full Deployment
FDD	Full Deployment Decision
FDDR	Full Deployment Decision Review
FHA	Functional Hazard Analysis
FMECA	Failure Mode, Effects and Criticality Analysis
FRACAS	Failure Reporting, Analysis, and Corrective Action System
FRB	Failure Review Board
FRP	Full-Rate Production
FYDP	Future Years Defense Program
GAO	Government Accountability Office
GOTS	Government Off-The-Shelf
GUI	Graphical User Interface
HSI	Human Systems Integration
HTS	Hazard Tracking System
ICD	Initial Capabilities Document
IMD	Intelligence Mission Data
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
INCOSE	International Council on Systems Engineering
IPT	Integrated Product Team
ISO	International Organization for Standards
ISP	Information Support Plan
IT	Information Technology
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Council
JSSSEH	Joint Software System Safety Engineering Handbook
KPP	Key Performance Parameter
KSA	Key System Attribute
LCSP	Life Cycle Sustainment Plan

LOR	Level of Rigor
LRIP	Low-Rate Initial Production
M&Q	Manufacturing and Quality
MBSE	Model-Based Systems Engineering
MCA	Major Capability Acquisition
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MDD	Materiel Development Decision
ME	Mission Engineering
MMS	Manufacturing Management System
MOA	Memoranda of Agreement
MOE	Measure of Effectiveness
MOP	Measure of Performance
MOSA	Modular Open Systems Approach
MOU	Memorandum of Understanding
MP	Mission Profile
MSA	Materiel Solution Analysis
MTA	Middle Tier of Acquisition
MTRF	Middle Tier Rapid Fielding
MTRP	Middle Tier Rapid Prototyping
MVCR	Minimum Viable Capability Release
MVP	Minimum Viable Product
NDI	Non-Developmental Item
NDIA	National Defense Industrial Association
NEPA	National Environmental Protection Act
OA	Operational Assessment
O&S	Operations and Support
OMS	Operational Mode Summary
OSD	Office of the Secretary of Defense

OT&E	Operational Test & Evaluation
OUSD(A&S)	Office of the Under Secretary of Defense for Acquisition and Sustainment
OUSD(R&E)	Office of the Under Secretary of Defense for Research and Engineering
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
P&D	Production and Deployment
PESHE	Programmatic ESOH Evaluation
PHA	Physical Hazard Analysis
PM	Program Manager
PMO	Program Management Office
Pp	Process Performance Index
Ppk	Process Performance Centering Index
PPP	Program Protection Plan
PRR	Production Readiness Review
QASP	Quality Assurance Surveillance Plan
QMS	Quality Management System
RAM-C	Reliability, Availability, Maintainability, and Cost
RGC	Reliability Growth Curve
RCM	Reliability Centered Maintenance
R&M	Reliability and Maintainability
RFP	Request for Proposal
SAE	Society of Automotive Engineers
S&T	Science and Technology
SCG	Security Classification Guide
SE	Systems Engineering
SecDef	Secretary of Defense
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Plan
SFR	System Functional Review

SHA	System Hazard Analysis
SIL	System Integration Lab
SME	Subject Matter Expert
SVR	System Verification Review
SoS	System of Systems
SOW	Statement of Work
SRR	System Requirements Review
SSE	System Security Engineering
SSHA	Subsystem Hazard Analysis
SSS	Software System Safety
SW	Software
TEMP	Test and Evaluation Master Plan
TMRR	Technology Maturation and Risk Reduction
TPM	Technical Performance Measure
TRA	Technology Readiness Assessment
TRR	Test Readiness Review
UCA	Urgent Capability Acquisition
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(R&E)	Under Secretary of Defense for Research and Engineering
UxS	Unmanned System
VOLT	Validated Online Life Cycle Threat

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