APT
Advanced Product Transitions Corporation

Essential Manufacturing & Quality Activities

In Early DoD

Major Capability Acquisition

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Advanced Product Transitions Corporation

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I. Introduction

This paper will focus on the essential[1] Manufacturing & Quality (M&Q) activities (i.e., functions and inputs) supporting the MCA acquisition process under the AAF. Additionally, we will illuminate some of the inconsistencies between policies and guidance documents, as they apply to the M&Q activities.

In our companion paper, *Essential Elements of Systems Engineering in Early DoD Major Capability Acquisition*, Apr 2023, we examined the early DoD Major Capability Acquisition (MCA) processes from Pre-Materiel Development Decision (Pre-MDD), through the Materiel Solutions Analysis (MSA) phase, to the Milestone A decision and review. We reviewed the Adaptive Acquisition Framework (AAF) to better understand the changes to the Defense Acquisition System (DAS) processes and to derive the essential elements of DAS processes for MCA. While the ultimate impact has yet to be fully realized, these updates have streamlined some processes and highlight the need for early involvement of manufacturing expertise prior to Milestone A. DoD has increased the emphasis on mission engineering and early concepts in DoD systems prior to the Pre-MDD, and made the MDD the entry point of all MCA programs.

Background

In 2019, DoD initiated a change in the acquisition culture by simplifying policy, empowering Program Managers (PMs), tailoring acquisition approaches, conducting data driven analysis, actively managing risk, emphasizing sustainment, and introducing the AAF.[2] The AAF with the objective to streamline and accelerate acquisition, contains many new policies and guidance documents. In addition to that objective, there is a desire to move manufacturing involvement in systems acquisition earlier in the acquisition cycle. The intent is to enable warfighter capabilities that are feasible and can be readily produced to meet requirements.[3] The benefits of including M&Q in this early stage are many, including improvements in schedule, cost, and performance as the system proceeds through development.[4]

Early Development

During DoD acquisition, an appropriately tailored but thorough series of Systems Engineering (SE) technical reviews and audits take place. These occur at key points to evaluate achievements and to assess technical maturity, risk, issues, and opportunities prior to decision points. These technical reviews or audits should be conducted using thorough processes and Systems Engineering Best Practices. This includes feasibility, producibility, quality, and manufacturability as well as Industry Best Practices as required by SAE AS6500A[5] and SAE AS9100D[6].

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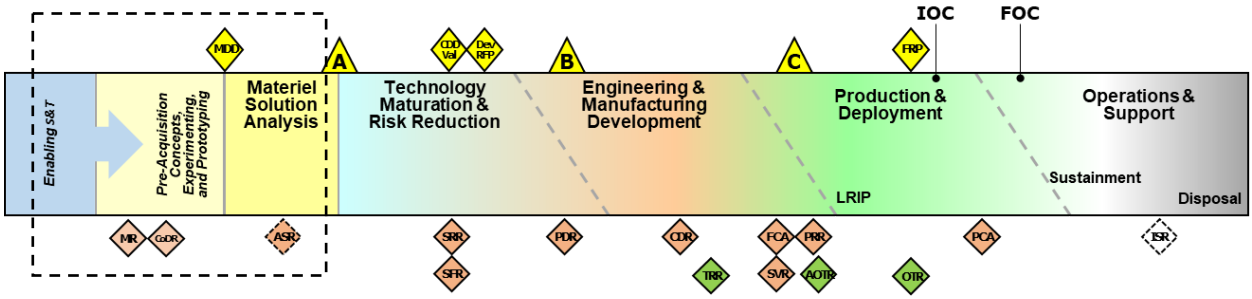
[1] What is meant by essential is, with limited resources, the activities that provide the necessary "design and manufacturing knowledge" to make informed decisions at investment/decision points.
[2] *DoD 5000 Series Handbook*, Jan 2020
[3] This is often described as moving to the left because of the acquisition graphics with maturity increasing from left to right.
[4] *Early M&Q Engineering Guide*, Jul 2022
[5] AS6500A *Manufacturing Management Program*, Jul 2021
[6] AS9100D, *Quality Management Systems - Requirements for Aviation, Space, and Defense Organizations,* Sep 2016

Analyses of the results from the technical reviews or audits should inform management to take actions that reduce risk, increase performance, recognize, and capitalize on opportunities, improve affordability, shorten schedule, and enhance performance.

The SE activities and key decision points for MCA programs are shown in Figure 2. The figure, derived but not shown in DoDI 5000.85, is included in the *Engineering of Defense Systems Guidebook*, Feb 2022, and in the *Systems Engineering Guidebook*, Feb 2022.



derived from DoDI 5000.85

Figure 2. MCA Program Framework

The engineering activities for MCA programs that occur during Pre-Acquisition Concepts, Experimenting, and Prototyping (hereafter referred to Pre-MDD) prior to an MDD are the following: the Capability Based Assessment (CBA), a draft Initial Capabilities Document (ICD), Mission Engineering (ME) activities and the Mission Review (MR), Concepts Design Review (CoDR), all leading to the MDD. That decision transitions the program into the MSA phase, which includes the Analysis of Alternatives (AoA), the ICD, the Acquisition Strategy (AS), the Systems Engineering Plan (SEP), an Independent Technical Risk Assessment (ITRA), an Independent Cost Estimate (ICE), and a Manufacturing Readiness Assessment (MRA).

Additionally, an Alternative Systems Review (ASR), is conducted by the PM to assure the selected materiel solution meets requirements prior to the Milestone A decision Review (Figure 3.).

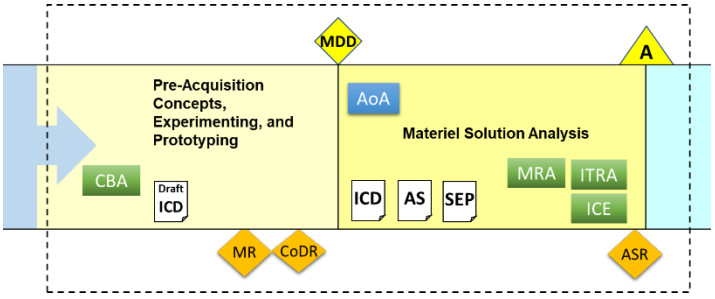
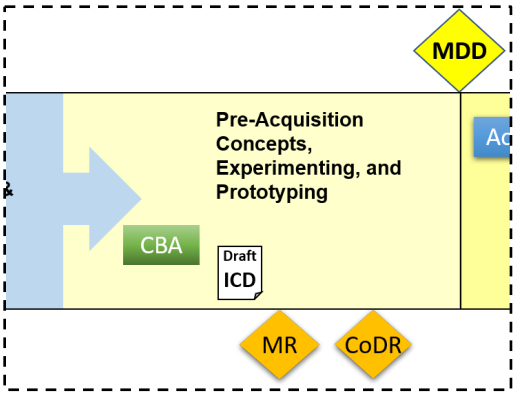


Figure 3. Early Development

In the following sections, this paper will address the essential engineering and programmatic activities with a focus on the details of M&Q functions supporting the acquisition process from Pre-MDD through Milestone A. The paper will also point out some of the inconsistencies in and between both policies and guidance documents as they apply to the M&Q functional activities.

II. Pre-MDD Activities

The Joint Staff conducts a CBA, and/or other studies as part of the Joint Capabilities Integration and Development System (JCIDS) process, producing a draft ICD. The draft ICD contains the initial Key Performance Parameters (KPP), Key System Attributes (KSA), and Additional Performance Attributes (APAs). The draft ICD is assigned to a lead Service(s). Before determining if a materiel solution should be developed, the lead Service initiates activities to develop the AoA Study Plan, and the Director of Cost Assessment and Program Evaluation (DCAPE) will develop the AoA Study Guidance. ME will conduct deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects leading to the MR. The CoDR is a multidisciplined review of the potential joint warfare concepts, Service-specific concepts, and considerations to establish the Concept Baseline and as such should include manufacturing and quality engineering analyses and inputs.[7] These activities include manufacturing feasibility, studies from the science and technology community, and other supporting studies (threat analysis, gap studies, etc.) contributing pertinent data and information for the MDD.



-derived from DoDI 5000.85

Figure 4. Pre-MDD

The policies and guidance documents specify the reviews and analyses that should be performed to achieve a rigorous analysis of the concepts being evaluated as potential materiel solutions.

Both DoDI 5000.88, *Engineering of Defense Systems*, and the *Engineering Defense Systems Guidebook* describe the Pre-MDD processes with two distinct reviews, the MR and the CoDR. The MR establishes and places under configuration control a validated and well-articulated set of Mission Baselines. The CoDR is a multidisciplined review of the potential joint warfare concepts, Service-specific concepts, and DOTMLPF-P[8] considerations to address the needs of the Mission Baseline.[9] Together the outputs of these reviews provide inputs to the MDD.

[7] *Engineering of Defense Systems Guidebook*, Feb 2022
[8] DOTMLPF-P – doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy
[9] *Engineering Of Defense Systems Guidebook*, Feb 2022

Manufacturing & Quality Activities in Pre-MDD

To meet the objectives of DoDI 5000.85 and DoDI 5000.88, M&Q analysis and development must begin during the earliest stages of concept development. The M&Q inputs should be part of the CBA and the draft ICD, and should be included in the AoA Study Guidance for the MDD.[10] Pre-MDD policy comes from two perspectives: the JCIDS defined in Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 5123 and the DAS defined in DoD Directive DoDD 5000.01. The Pre-MDD effort has two important aspects: Establish the ME reference materials that guide materiel solution decisions throughout the life cycle, and narrow the field of possible solutions to a reasonable set that engineers analyze in the AoA.[11]

Before the MDD, M&Q engineering analyses and inputs should be focused on assisting the lead Service activities for each concept to identify gaps, potential constraints, risks, and capabilities of the concepts as part of the CBA and to validate the draft ICD. The lead Service should include the results of these M&Q activities as part of the AoA Study Plan and as support the CoDR to establish the Concept Baseline.

The following sections detail the essential systems engineering and M&Q activities in Pre-MDD summarized above.

A. Capabilities Based Assessment

The JCIDS provides the baseline for documentation, review, and validation of capability requirements across the Department. In cases where there are urgent requirements for capabilities which do not exist in the Joint Forces, the Combat Command (CCMD) may generate a Joint Urgent Operational Need, Joint Emergent Operational Need, or Urgent Operational Need for review and validation. In the case of long-term planning, DoD Services and CCMDs conduct a CBA and generate an ICD as the normal starting point for Pre-MDD activities. Providing Subject Matter Experts (SME) who may contribute to and participate in CBA and initial document development of an ICD for the respective Joint Capability Area is the responsibility of USD(R&E).[12]

The CBA identifies:

- Capabilities (and operational performance criteria) required to successfully execute missions
- Shortfalls in existing weapon systems to deliver those capabilities and the associated operational risks
- Possible solution space for the capability shortfalls

The results of the CBA are documented in a Joint Capabilities Document (JCD) or an ICD. The Joint Requirements Oversight Council (JROC) approves a JCD or an ICD and validates that there is a need to address the capability gaps (and that there are potentially affordable and technically feasible solutions available). The approved JCD or ICD becomes the basis for further analysis by the

[10] *Engineering Of Defense Systems Guidebook*, Feb 2022
[11] Ibid
[12] CJCSI 5123.01I, Enclosure C, Oct 2021

Services and/or agencies to identify the most appropriate weapon system to provide the desired capability.[13]

Manufacturing & Quality Inputs to CBA

M&Q SMEs assigned by USD(R&E) should participate in the CBA to provide[14]:

- Understanding of the Industrial Base (IB) capability and gaps
- Understanding of the production system capability and gaps
- Analysis of the design and manufacturing trade space to determine alternative product and production system solution concepts
- Identification opportunities for the use of advanced M&Q technology and processes for the concepts being considered

M&Q SMEs should provide assessments and analyses to support successful execution of missions and address the shortfalls in existing weapon systems production to deliver those capabilities.

B. Initial Capabilities Document

The ICD documents one or more new capability requirements, the associated capability gaps, and the intent to address identified capability gap(s) with a potential materiel solution. For each capability requirement identified in the CBA, the ICD includes an explanation of why the capability requirements are essential to achieve assigned goals and objectives. Capability requirements are described in terms of the required operational attributes with qualitative parameters and metrics included.[15]

An ICD is usually not updated once it is validated and approved, but rather, is superseded by successor JCIDS documents, such as the Draft Capability Development Document (CDD).[16] 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 CBA, ME analysis, or other studies. The designated Service representative should have access to both the ICD and supporting studies.[17]

A validated ICD is an entrance criterion necessary for the MDD. It recommends partially or wholly mitigating identified capability gap(s) with a materiel capability solution(s) or some combination of materiel and nonmateriel solutions.[18]

Manufacturing & Quality Inputs to an ICD

M&Q SMEs assigned by USD(R&E) should provide IB analyses to support one or more new capability requirements, and the associated capability gaps identified in the ICD. M&Q SMEs should address the identified capability gap(s) partially or wholly associated with each materiel

[13] CJCSI 3170.01F, May 2007
[14] *Early Manufacturing and Quality Engineering Guide,* Jul 2022
[15] *HSI and ESOH Handbook for Pre-Milestone A JCIDS and AoA Activities*
[16] Ibid
[17] *Engineering Of Defense Systems Guidebook*
[18] JCIDS Manual, Aug 2018

solution. For each potential materiel solution identified, M&Q SMEs should provide an assessment of the ability of the IB to support the required operational attributes, with qualitative parameters and metrics included.

C. Mission Engineering and the Mission Review

ME is the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects. ME provides a quantifiable basis to inform technical and budgetary planning decisions on potential solutions to fulfill mission capability gaps, and to synergize mission concepts, system requirements, technologies, and budgets.[19]

The *Mission Engineering Guide,* Nov 2020, establishes the following steps for ME, which incorporate the direction from NDAA 2017 Section 855: [20]

- Problem Statement, encapsulating key questions, suspected capability gaps, current and planned technologies, and operational concepts
- Mission Characterization
- Mission Metrics
- Design of Analysis, defining mission threads
- Analysis/Modeling, capturing mission effectiveness
- Documented Conclusions

The MR is primarily an OSD/R&E led effort focused on providing guidance for defining components and details of Mission Baselines and associated mission definitions. The MR has the following inputs and review criteria from ME efforts: [21]

- Mission definitions – time frame, strategic gaps, traceability, environmental conditions
- Assumptions and constraints
- Mission measures of success
- Trades that are needed
- Other interrelated Mission Baselines

The MR establishes and places under configuration control a validated and well-articulated set of Mission Baselines as outputs. [22]

- Documented Mission Baseline(s) that encompass the agreements and final products to address the inputs and review criteria of the MR
- Traceability to Defense Planning Guide, Joint Capability Areas, and Joint Tasks Lists
- Data or products needed
- DOTMLPF-P[23] evaluations to support maturation of the Concept Design

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[19] *Systems Engineering Guidebook*, Feb 2022
[20] *Mission Engineering Guide*, Nov 2020
[21] *Engineering of Defense Systems Guidebook,* Feb 2022, §2.1.1
[22] Ibid
[23] DOTMLPF-P is an acronym for doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy.

Manufacturing & Quality Support to a Mission Review

M&Q SMEs should be aware of the outputs of the MR and the potential impact to the IB from MR activities. M&Q SMEs should be prepared to support conduct of tests, demonstrations, exercises, and experiments to support the MR.

D. Concepts Design Review

The CoDR 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 considerations to establish the Concept Baseline and as such should include manufacturing and quality engineering analyses and inputs.[24] For Service-specific missions the CoDR is chaired by the Service; for joint missions, the CoDR is chaired by OSD(R&E).[25] There are multiple guidance or instructions on the content of a CoDR: DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020*,* and the *Engineering of Defense Systems Guidebook,* Feb 2022*.*

According to DoDI 5000.88, the following are the key aspects to be addressed[26]:

- Framing assumptions
- Capabilities-based assessment (CBA)
- Initial capabilities document (ICD)
- Concept design trade matrix
- ME analysis (MR output)
- A concept of operations (CONOPS) or Operational Mode Summary/Mission Profile.
- Assessment of program risks
- Cyber security assessment

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 should 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. The CoDR should 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 also include a technical sufficiency evaluation of the AoA Study Guidance to ensure it is grounded to the Mission Baseline.[27]

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[24] *Engineering of Defense Systems Guidebook*, Feb 2022
[25] DoDI 5000.88, *Engineering of Defense Systems*
[26] Ibid
[27] *Engineering of Defense Systems Guidebook*, Feb 2022

Additionally, the *Guidebook*, adds the following to the outputs of the CoDR[28]:

- Identification of candidate concepts and alternatives that could meet the mission objectives (initial rank ordering of the most promising solutions)
  - Mapping to contributing technology and prototyping/experimentation roadmaps
  - Validated 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 (material solution agnostic) mission approaches. These are titled the "To-Be" mission thread concept(s)
- Suggested ME Threads that preliminarily incorporate promising DOTMLPF-P considerations and potential materiel solution concepts for further analysis/refinement in the next acquisition phase
- 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

Manufacturing & Quality Inputs and Support to a CoDR

M&Q SMEs should provide support in the following areas:

- Capability Based Assessment – Participate in the CBA to provide an understanding of the IB capability and gaps
- Concept design trades – Provide feasibility/producibility/manufacturability analyses of concepts as a characteristic of the solution
- Concepts Risk Assessments – Provide an assessment of concepts to include risks, issues, and opportunities in development of potential materiel solutions, appropriate affordability targets, and initial schedule basis
- Perform an MRL Assessment on potential concepts – An MRA using MRL criteria and metrics should be conducted on the potential concepts to MRL 3 to identify manufacturing maturity and risk[29]
- Cybersecurity assessment – Perform assessment of Operational Technologies (OT) utilized in realization of concepts
- Prototyping/experimentation roadmaps – Provide expertise in planning and execution for Design of Experiments and prototypes of concepts
- DOTMLPF-P considerations and potential materiel solution concepts – Support analyses focusing on materiel(s), personnel (workforce), and facilities (and tooling) aspects
- Informed DAS alternative pathway selection – Provide support to linking the mission definition, time frame, gaps, and maturity levels to the appropriate acquisition model

Detailed descriptions of the M&Q support to these areas are in CoDR Appendix (Appendix I)

[28] Ibid
[29] *MRL Deskbook*, Jul 2022

III. Materiel Development Decision

The purpose of DoDI 5000.85 is to establish policy and prescribes procedures that guide the acquisition of major capability acquisition programs only, whereas the purpose of DoDI 5000.88 is to establish policy, assign responsibilities, and provide procedures to implement engineering for defense systems. This means that DoDI 5000.88 is applicable to all defense acquisitions, while DoDI 5000.85 is applicable only to Major Defense Acquisition Programs (MDAPs).

According to DoDI 5000.85, the MDD is the mandatory entry point into the major capability acquisition process and is informed by a validated requirements document (e.g., an ICD or equivalent) and the completion of the AoA study guidance and the AoA study plan.[30] The DCAPE (or DoD Component for ACAT II or below programs) will present the AoA study guidance, and the DoD Component will present the AoA study plan. For MDAPs, DCAPE issues the AoA study guidance and approves the AoA study plan. The DoD Component will provide the plan to staff and fund program activities up to and including the next decision point, usually Milestone A. The guidance, plans, and documents mentioned above (in this paragraph) are the extent of the discussion of MDD in DoDI 5000.85. There is no discussion or reference to any of the Pre-MDD activities as specified in DoDI 5000.88. The MDD Review process leads to an Acquisition Decision Memorandum (ADM) that includes program staffing and funding activities to the next decision point (e.g., Milestone A).

DoDI 5000.88 extensively addresses Pre-MDD activities with discussion about ME, Mission Integration Management (statutory), and an MR by the Service representative or USD(R&E) for joint missions. Additionally, there is a major review, the CoDR, chaired by the DoD Component (or OSD(R&E) for joint programs), that provides consolidated, coordinated, and significant inputs to the MDD, allowing an informed decision. However, DoDI 5000.88 does not discuss the MDD.[31]

DoDI 5000.85 discusses the MDD, briefly mentioning the purpose, the presentation of AoA Study guidance and plan by the DCAPE and the DoD component, and the MDA decisions; however, there is no discussion or reference to any of the Pre-MDD knowledge and analyses from the MR and the CoDR on the potential materiel solution concept(s). An MDD requested by Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)), is conducted to make the decision to proceed. The MDA (A&S or designate)[32] will determine the acquisition phase of entry and the initial review milestone. MDA decisions will be documented in an ADM with the approved AoA study guidance and study plan attached.[33]

Manufacturing & Quality Support to the MDD

M&Q should provide support to the MDD from assessments and analyses for the CBA, ICD, and CoDR.

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[30] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020
[31] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.3.e. & f.
[32] A&S serves as the MDA for the MDD, Milestone A, the Request For Proposal Release Decision Point for the Engineering and Manufacturing Development Phase, Milestone B, and Milestone C for acquisition category (ACAT) ID programs. DoDI 5000.02, *Operation of the Adaptive Acquisition Framework*, Jun 2022, §2.1.c(1)
[33] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.5.c.

IV. Materiel Solutions Analysis Phase

For MCA programs, the MSA phase precedes the Milestone A decision with requirements from DoDI 5000.85. According to DoDI 5000.85, the purpose of the MSA phase is to conduct the AoA and other activities needed to choose the concept for the product to be acquired, to begin translating validated capability gaps into system-specific requirements, and to conduct planning to support a decision on the AS for the product. The MDA is the USD/A&S, according to DoDD 5135.02, July 15, 2020. Other than requiring an ICE and an ITRA, beginning product support, and sustainment planning; the other activities are not specified.

In the *Engineering of Defense Systems Guidebook*, technical activities during the MSA phase include:[34]

- Conduct an AoA (according to DoDI 5000.84, *Analysis of Alternatives*, Aug 2020)
- Perform analysis to support selection of a preferred materiel solution(s)
- Perform operational analysis on preferred materiel solution(s)
- Perform engineering and technical analysis on preferred materiel solution(s)
- Establish program framework and strategies (e.g., the AS and the SEP)
- Prepare for initial review milestone and next phase as designated by the MDA

However, the *Guidebook* does not address how the program prepares for the milestone review. There is nothing in this guidance that recommends a programmatic review after the AoA prior to the milestone decision.

The MSA phase is focused on identification of a preferred concept and analysis of alternatives, as guided by the ICD, the AoA study guidance, and AoA study plan.[35] An ICE and an ITRA should be initiated, once a preferred concept is selected, as both are required before granting Milestone A approval.[36] [37] [38]

Either DoD Component Head[39] or the Component Acquisition Executive[40], appointed by the DoD Component Head, will select a PM and establish a program office during the MSA phase to complete the actions necessary to plan the acquisition program and prepare for the next decision point.[41] The PM will develop the Acquisition Strategy, a comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, product support, security, and supportability strategies that the PM plans to employ to manage program risks and meet program objectives.[42]

The Lead System Engineer (LSE) will, under the direction of the PM, develop a SEP as required in accordance with the DoD SEP Outline in order to document and guide the program's specific

[34] *Engineering of Defense Systems Guidebook*, 3.2.1.3.1
[35] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.a
[36] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(3)
[37] ICE, section 2334, and section 2366a of Title 10 USC
[38] ITRA, section 2448 of Title 10 USC
[39] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §2.4.b
[40] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(2)
[41] Ibid
[42] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3C.3.a

systems engineering activities.[43] Additional Systems Engineering activities will identify measures of effectiveness; perform key trades between cost and capability; establish life cycle cost, schedule, and concepts of operations; and identify overall risks.

An approved SEP is required for the Milestone A Review, according to DoDI 5000.88, §3.4.b. SEPs are required for all MDAP programs and all ACAT II and III programs, unless waived. Also required during the MSA phase, manufacturing readiness and risk will be assessed and documented in the SEP.[44] According to the required SEP Outline Version 4.0, §3.2.4.2, the MRA is conducted utilizing the MRL process, creating Manufacturing Maturation Plans, including a table of MRA results.[45] An Alternative Systems Review, is conducted by the Program Manager to assure the preferred materiel solution(s) meets requirements prior to the Milestone A Decision Review.[46] [47] Once the PM has completed an ASR, which is a review of the necessary analyses and activities, the program can proceed to the Milestone A decision point as depicted in Figure 2.

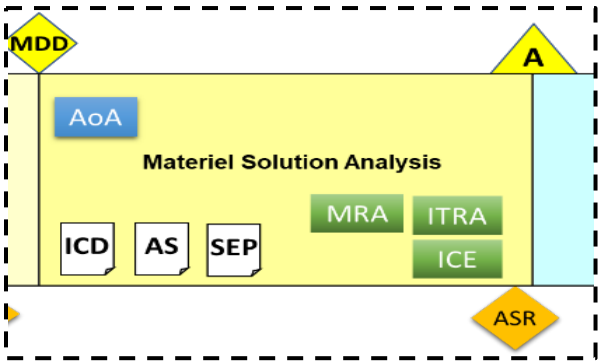

Figure 2. MSA Phase

In summary for an MCA, the MSA phase includes:

- Analysis of Alternatives (AoA)
- Independent Technical Risk Assessment (ITRA)
- Independent Cost Estimate (ICE)
- Selection of a Program Manager (PM)
- Acquisition Strategy (AS)
- Systems Engineering Plan (SEP) and approval
- Manufacturing Readiness Assessment (MRA)
- Alternative Systems Review (ASR)

At a Milestone A review, approval of program entry into the Technology Maturation and Risk Reduction (TMRR) phase occurs. The MDA will approve the program AS, any PM waivers requested, release of the final RFPs for TMRR activities, exit criteria for TMRR, and entrance criteria for EMD.[48]

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[43] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.4.a(1)(a)
[44] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.6.c
[45] *SEP Outline Version 4.0*, §3.2.4
[46] *Engineering Defense Systems Guidebook*, §3.2.1.3.1 and Table 3.14
[47] *Systems Engineering Guidebook*, §3.1
[48] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.7.c

Manufacturing & Quality Inputs and Support in the MSA Phase

According to the *Systems Engineering Guidebook*, the PM and LSE are responsible for assessing manufacturing readiness. In support of the PM and the LSE, M&Q SMEs should participate and provide input to the AoA. Once a preferred materiel solution(s) is chosen, the M&Q SMEs should provide input to the ICE, ITRA, SEP, and AS by conducting an MRA using MRL 4 criteria and metrics.[49] The results of the MRL 4 assessment should also be used in support of the ASR, and ultimately as input to the Milestone A decision.

The following sections detail the essential System Engineering and M&Q activities in the MSA phase summarized above.

A. Analysis of Alternatives

The AoA process plays a key role in support of the MSA Phase. The AoA includes "affordability analysis, sustainment considerations, early systems engineering analysis, threat projections, and coalition interoperability as identified in the ICD"[50] as part of the analysis that is input to the Milestone A decision. After a program has an approved MDD, the AoA process is necessary to better define the trade space across cost, schedule, and performance to enable the Defense Acquisition Executive and Service Sponsor to select a preferred materiel solution(s) that addresses the capability gaps documented in the approved ICD.

The AoA is an assessment of potential materiel solutions to satisfy the capability need documented in the approved ICD. At the top level, the AoA focuses on:[51]

- Identification and assessment of potential materiel solutions
- Key trades between cost and capability
- Total life cycle cost, including:
  - Sustainment
  - Schedule
  - Concepts of operations
  - Overall risks, issues, and opportunities

The analyses for each alternative should include:[52]

- Affordability analysis
- Cost analysis
- Sustainment considerations
- Early systems engineering analyses
- Threat projections
- Market research

[49] *Manufacturing Readiness Level Deskbook*, 2022, §3.2.2
[50] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b
[51] *Analysis of Alternatives Cost Estimating Handbook*, Jan 2022
[52] Ibid

The AoA identifies the most cost-effective solution that has a reasonable likelihood of providing the validated capability requirement(s). AoAs are required for MDAPs, and additionally, may be conducted at comparable points for other AAF pathways as appropriate.[53] Once AoA is complete, the operational requirements community and the acquisition community collaboratively identify one or more preferred materiel solution(s) with the potential to be affordable, operationally effective, and suitable, sustainable, and technically and technologically achievable (i.e., able to provide a timely solution to the stated operational capability need at an acceptable level of risk). The preferred materiel solution(s) is selected by the DoD Component[54] (or potentially the MDA in joint programs).

The Best Practices for an AoA from *GAO-15-37, Analysis of Alternatives Could Be Improved by Incorporating Best Practices,* Dec 2014, and from *Analysis of Alternatives Cost Estimating Handbook,* Jan 2022*,* are located in the AoA appendix (Appendix II).

Manufacturing & Quality Inputs and Support to an AoA

Per the *Systems Engineering Guidebook*, the minimum points to consider during MSA are[55]:

- Manufacturing feasibility and capability to produce in a lab environment
- Program critical technologies are ready for the TMRR phase
- Required investments in manufacturing technology development identified
- Processes to ensure manufacturability, producibility, and quality are in place and are sufficient to produce prototypes
- Manufacturing risks and mitigation plans are in place for building prototypes
- Cost objectives established and manufacturing cost drivers identified
- Draft KPPs identified as well as any special tooling, facilities, material handling and skills required
- Producibility assessment of the preferred [material solution] system concept completed
- All IB capabilities surveyed
- Current state of all critical manufacturing processes surveyed
- All potential supply chain sources surveyed

The requirements in DoDI 5000.88 to assess and document manufacturing risk and readiness, and the M&Q support required by the *SE Guidebook*, as listed above, represent many of the criteria in the MRL process that identify and document the manufacturing and quality risks, issues, and opportunities, and the mitigation strategies for each alternative. M&Q SMEs should utilize the MRL process to provide inputs to the AoA for each potential materiel solution's gaps to MRL 4 criteria and metrics.[56] For criteria and metrics of an MRL 4 assessment, see the Manufacturing Readiness Assessment section below and/or the *Manufacturing Readiness Level Deskbook*.

[53] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6
[54] *Systems Engineering Guidebook*, Feb 2022, §3.1
[55] *Systems Engineering Guidebook*, Feb 2022, Table 5-5
[56] MRL Matrix, 2022

B. Independent Cost Estimate

An ICE will be conducted on the preferred materiel solution(s) before granting Milestone A approval for an MDAP.[57] The ICE is a life cycle cost estimate of a program and includes costs of:

- Development
- Procurement
- Military construction
- Operations and support
- Disposal
- Trained manpower to operate, maintain, and support the program or subprogram upon full operational deployment, without regard to funding source or management control
- Additionally, at Milestone A, identification and sensitivity analysis of key cost drivers that may affect life-cycle costs

The Cost Assessment and Program Evaluation (CAPE) conducts or approves ICEs and cost analyses for all MDAPs and major subprograms.[58] "The MDA may not approve entering a milestone phase of an MDAP or major subprogram unless an ICE, conducted or approved by DCAPE, has been considered by the MDA."[59]

All cost estimates conducted for DoD programs must[60]:

- Include a discussion of risk, the potential impacts of risk on program costs and schedule, and approaches to mitigate risk
- Include analysis to support decision making that identifies and evaluates alternative courses of action that may:
  - Reduce cost and risk
  - Result in more affordable programs
  - Result in less costly systems
- Be developed, to the extent practicable, based on historical actual cost information that is based on demonstrated contractor and government performance and provide a high degree of confidence that the program can be completed without the need for significant adjustment to the program's budget or subprogram's budgets

Manufacturing & Quality Inputs to an ICE

M&Q SMEs should provide to the CAPE the results of the MRA performed on the preferred materiel solution(s) that:

- Show the highest M&Q risks to the program
- Discuss the risks and issues with estimated mitigation costs
- Provides any cost data or information related to alternative strategies or approaches to the selected program
- Provides any historical manufacturing cost data or information

[57] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020
[58] DoDI5000.73, Cost Analysis Guidance and Procedures, Mar 2020, pursuant to Section 2334 of Title 10
[59] Ibid
[60] DoDI5000.73, Cost Analysis Guidance and Procedures, Mar 2020

C. Independent Technical Risk Assessment

For MDAPs, starting with Milestone A, ITRAs are conducted before each acquisition milestone.[61] The ITRA approval authority must be independent and may not be in the program's chain of command. The project technical team [an undefined group] should be aware that they may need to support and participate in ITRA activities beginning prior to Milestone A.[62]

Although ITRA team members may be engaged throughout the concept development, industry days, and the AoA, to enable better understanding of the risks; the ITRA is to inform a Milestone A decision will be on the preferred materiel solution(s) after the DoD Component downselect.[63]

According to DoDI 5000.88, *Engineering of Defense Systems*, an ITRA will "consider the full spectrum of technology, engineering, and integration risk. These areas could include mission capability, technology, system development, MOSA (Modular Open Systems Approach), software, security, manufacturing, sustainment, and their potential impacts to cost, schedule, and performance." The framework for ITRAs is found in the Defense Technical Risk Assessment Methodology (DTRAM), Sep 2020, and is organized into eight technical risk areas across seven factors. Other ITRA details are in the ITRA Appendix (Appendix III). ITRAs conducted before Milestone A will identify critical technologies and manufacturing processes that need to be matured.[64]

However, a review of the manufacturing "evaluation criteria" for an ITRA during the MSA phase shows that many of the criteria are not appropriate for the maturity and development status of a program at Milestone A.

Additionally, the ITRA methodology has limited actual quality activities considered as part of the "performance and quality" factor for each area.

Most of the "evaluation criteria" in an ITRA do not relate to or address quality. Quality is not considered as a risk area, rather "quality" was paired with "performance" as a factor for all risk areas. Quality should be considered as a standalone risk area, as manufacturing is, or combined with Manufacturing as a Manufacturing & Quality risk area.

Manufacturing & Quality Inputs to an ITRA

M&Q SMEs should provide support and input to the technical risk areas identified in the ITRA guidance document. M&Q activities have an impact on several of the eight technical risk areas across the seven factors as seen in the ITRA Appendix (see "evaluation criteria" in Appendix III). M&Q inputs to the ITRA should be the results of the prior MRL assessment of the preferred materiel solution(s) to MRL 4 criteria and metrics.

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[61] Pursuant to 10 USC 2448b state in DoDI 5000.88, §3.5.b(1)(b)
[62] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.5.b(2)
[63] DoD *ITRA Executive Guide*, Dec 2020
[64] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.5.b(1)(d)

D. Manufacturing Readiness Assessment

According to DoDI 5000.88, 3.6.c., M&Q personnel working for the PM, will ensure manufacturing, producibility, and quality risks are identified and managed throughout the program's life cycle. Beginning in the MSA phase, manufacturing readiness and risk will be assessed and documented in the SEP. Assessments of manufacturing maturity utilizing the MRL criteria and metrics have been designed to identify and manage manufacturing risk in acquisition, decreasing the risk of technology transition for new technology to weapon system applications. MRL criteria and metrics create a measurement scale and vocabulary for assessing and discussing manufacturing maturity and risk. Using the MRL criteria and metrics, an MRL Assessment is a structured approach for evaluation of a manufacturing processes, procedures, and techniques for technology, components, items, assemblies, subsystems, and systems. An MRA utilizing the MRL criteria and metrics as specified in the *Manufacturing Readiness Level Deskbook*, is performed to:

- Define current level of manufacturing maturity
- Identify maturity shortfalls and associated risks and costs
- Provide the basis for management of manufacturing maturation and risk

The *Manufacturing Readiness Level Deskbook* provides "Best Practices" for conducting assessments of manufacturing maturity and risk using the MRL criteria and metrics.

Considerations in an MRL assessment are as follows[65]:

- Technology maturity
- IB capacity and capability
- Manufacturing technology (for preferred materiel solution(s))
- Design Maturity
- Producibility
- Cost & Funding
- Materials availability and maturity
- Supply chain
- Modeling product and process
- Manufacturing process maturity
- Rate and yields
- Quality management and product quality
- Workforce
- Facilities & tooling
- Manufacturing management and planning
- Cybersecurity for Manufacturing

The MRL process is intended for those tasked with conducting MRL Assessments, as well as acquisition program managers, system engineers, manufacturing managers, and managers of technology development and pre-systems acquisition technology demonstration projects.[66]

Manufacturing & Quality Conduct of an MRA

[65] *Manufacturing Readiness Level Deskbook*, Jul 2022
[66] Ibid, §1.2

M&Q should conduct an MRA in support of the PM using MRL criteria and metrics on the selected materiel solution[67] to MRL 4 criteria and metrics.[68] The results of this MRA using MRL 4 criteria and metrics included in the SEP is provided to the program for the ASR and the Milestone A decision. The results of this assessment should also be an input to the ICE and ITRA.

E. ASR

The ASR shall be conducted to help ensure the selected materiel solution(s) has the potential to affordably meet the user's needs and expectations, and that there is sufficient understanding of the technical maturity, feasibility, and risk of the "proposed" materiel solution.[69] The ASR shall be held after the system parameters for the selected materiel solution(s) are defined and that solution is balanced with cost, schedule, and risk.[70] The ASR occurs after the AoA is complete and after a preferred materiel solution(s) is selected by the lead Service or Component. [71] This timing allows the focus of the ASR to be on the proposed materiel solution(s) rather than on all the alternatives, and allows for some post-AoA technical analysis to be completed. The ASR should not begin until the all criteria are met (see Appendix IV.). A resource for ASR preparation is IEEE 15288.2, *Standard for Technical Reviews and Audits on Defense Programs*, Nov 2014. An ASR is presented as a best practice review in the *Systems Engineering Guidebook.*[72] In DoDI 5000.88, an ASR is not mentioned in the list of reviews required to be conducted by the PM.[73]

Manufacturing & Quality Inputs to an ASR

M&Q SMEs should participate and provide input to the ASR on the preferred materiel solution(s). M&Q should provide results of the risks, issues, and opportunities based on the MRA conducted to an MRL 4. Risks should be based on how closely the MRL 4 criteria and metrics are met and gap analysis with the degree of difficulty to meet MRL 6 criteria and metrics by the completion of TMRR.[74] [75]

[67] *SEP Outline Version 4.0*, §3.2.4
[68] *Manufacturing Readiness Level Deskbook*, Jul 2022
[69] IEEE 15288.2, *Technical Reviews and Audits on Defense Programs*, Nov 2014, §5.2.1
[70] Ibid, §5.2.3
[71] *Systems Engineering Guidebook*, Feb 2022, §3.1, ASR Inputs and Review Criteria
[72] Ibid
[73] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.5.a
[74] *Manufacturing Readiness Level Deskbook*, Jul 2022
[75] Section 2366a 10 USC - MDAPs: Determination required before Milestone A approval

V. Milestone A

The purpose of Milestone A, as described in DoDI 5000.85, is to approve program entry into the TMRR phase, to approve the program AS, and to release of the final RFPs for TMRR activities. A draft CDD approved by the DoD Component informs the AS and the RFP for TMRR.[76]

- Principal considerations for Milestone A include[77]:
  - Justification for and the affordability and feasibility of the preferred military [materiel] solution
  - Identification of the technologies that must be matured during the TMRR phase
  - The scope of the capability requirement trade space and an understanding of the priorities within that trade space
  - Technical, cost and schedule risks, and the plans and funding to offset them during the TMRR phase
  - A proposed AS, including intellectual property (IP), program protection, and exportability and acquisition planning
  - The test strategy
  - A life-cycle mission data plan for each intelligence mission data-dependent program (including cyber) and the projected threat and its impact on the materiel solution

At the Milestone A Review[78]:

- The PM will present the AS, the business approach, "Should Cost" targets, framing assumptions, an assessment of program risk and planned mitigation actions, and initial PS planning

- For MDAPs, the DoD Component will present a quantitatively supported affordability analysis based on the resources projected to be available in the DoD Component portfolio(s) or mission area(s) associated with the program under consideration. Similar, appropriately-scaled affordability analyses will be required for all other programs. The analysis will demonstrate the DoD Component's ability to afford the program over its life cycle, and the DoD Component will demonstrate that the program will be fully funded within the Future Years Defense Program

- Pursuant to Section 2366a of Title 10, U.S.C., MDAs for MDAPs must determine, with a high degree of confidence, that the technology developed within the program will not delay the fielding target of the program. If the MDA determines that a technology related to a major system component will delay the program:
  - The technology must be sufficiently matured and demonstrated in a relevant environment separate from the program, using the prototyping authorities in subchapter II of Chapter 144B of Title 10, U.S.C., or other authorities, as appropriate.
  - The MDA must have an effective plan for adoption or insertion by the relevant program

Milestone A Decisions[79]:

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[76] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.7.a(1)
[77] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.7.a(2)
[78] Ibid, §3.7.b.
[79] Ibid, §3.7.c.

- The MDA will approve:
  - AS to determine the materiel solution
  - Strategy for the TMRR phase
  - PM waiver requests
  - Release of the final RFP for the TMRR phase
  - Exit criteria required to complete TMRR
  - Entrance criteria for the engineering and manufacturing development (EMD) phase
- The MDA will document decisions in an ADM

The above Milestone A guidance from DoDI 5000.85 (§3.7.a, b., and c.) does not explicitly call for review of the mandated ITRA, the mandated ICE, the statutorily required SEP with MRA , and the ASR outputs. The ICE and ITRA are mentioned as requirements to conduct in DoDI 5000.85 in the MSA phase section (3.6), but not in the Milestone A section (3.7).

Manufacturing & Quality Inputs to a Milestone A

M&Q subject areas should be included as input to a Milestone A decision review. M&Q SMEs should provide:

- Analysis on affordability and feasibility of the preferred materiel solution(s) based on the results of the ICE and the MRA (as presented at the ASR)
- Status of technology maturity, which is specifically examined during an ITRA and an MRA to identify the technologies that must be matured during the TMRR phase (reviewed at the ASR)
  - Results of gap analysis of the technology and manufacturing maturity to MRL 6 criteria and metrics that show if technology development will or will not delay the fielding target of the program
- Status of the IB as part of an ITRA and MRA, which significantly influences the requirements trade space
- Technical, cost, and schedule risks, issues, opportunities that were identified in the ITRA and the MRA; and the plans and funding to offset them presented at the ASR
- Input on IB risks, manufacturing strategy, quality strategy, and capability requirements to the proposed AS
- Strategy for acceptance test procedures identified in the MRA as input to the test strategy as presented at the ASR
- Should Cost targets from the ICE and the MRA
- Quantitative support to the affordability analysis from the ICE as reviewed at the ASR

Many of the above M&Q provided inputs should also be included in the SEP that was initiated post-MDD as a program guiding document, which is not included by DoDI 5000.85 as part of the Milestone A review.

VI. Conclusions and *Recommendations*

The AAF was established in this updated process to enable faster delivery of DoD systems and/or capabilities through the means of multiple acquisition pathways and tailored processes. Throughout the acquisition documentation, the various updated guidances provide descriptions of the activities that are required; however, many descriptions are not consistent, appear incomplete, or at times are

conflicting between the various acquisition documents. While the ultimate impact of the updated acquisition guidance released in support of the AAF process has yet to be fully realized, these updates have only streamlined some processes.

The updated guidance, with details on the essential SE processes in early DoD systems acquisition from Pre-MDD through the MSA phase in the various documents, has highlighted the need for M&Q expertise prior to Milestone A, i.e., “Move manufacturing to the left.”

With M&Q resources currently limited, the essential set of M&Q activities and support required, as documented in this paper and summarized below, should be specific and clearly defined starting with Pre-MDD and continuing throughout the acquisition process. (Conclusions are below with r*ecommendations in italics.)*

1. The Warfighter and the JCIDS process initiate Pre-MDD activities by conducting a CBA. The results of the CBA are documented in a JCD or a draft ICD. The JROC approves a JCD or an ICD and validates that there is a need to address the capability gaps (and that there are potentially affordable and technically feasible solutions available). The approved JCD or ICD becomes the basis for further analysis by the Services and/or agencies to identify the most appropriate weapon system to provide the desired capability.
   a. ***M&Q analysis and development should be initiated at this time to support the CBA and the draft ICD for an understanding of the capabilities of the IB, the production and manufacturing systems capabilities and gaps, potential constraints, quality gaps, risks, issues, and opportunities.***
2. The DoD Component is also responsible for conduct of the CoDR (unless a joint program). The intent for CoDR is to quantitatively link the mission definition, time frame, gaps, and potential solution(s) maturity level to the appropriate acquisition model.

   a. ***M&Q efforts should be required to assist the lead Service with an MRA on potential concepts (using MRL 3 criteria and metrics) and analyses of the potential concept(s) as input to the CoDR.***

   b. ***M&Q subject matter expertise in IB and M&Q support of DAS activities should include support to the development of the AoA Study Guidance by the DCAPE and the AoA Study Plan by the Service component.***

3. CoDR is the final engineering design review prior to the MDD and entry into the MSA phase.

   a. ***M&Q support to the CoDR linking the mission definition, the time frame, the capability gap(s), and the potential concept(s) maturity level(s) to the appropriate acquisition model.***

   b. ***Following the CoDR, M&Q should be required to provide support to the MDD based on assessments and analyses performed for the CBA, ICD, and CoDR.***

4. DoDI 5000.85 states that during the MSA phase an ICE, an ITRA, initial product support and sustainment planning, and "other activities” are required.

   a. ***M&Q SMEs should be active participants and provide inputs to the AoA process from an assessment to MRL 4 criteria and metrics[80], which will update the previous assessments.***

   b. ***M&Q SMEs should provide support to the PM in development of the AS and the SEP.***

   c. ***M&Q SMEs should also provide support to the CAPE from the results of the MRAs performed on the preferred materiel solution(s) with any cost estimates, cost models, cost data, cost analysis, or other information related to the selected solution(s) for the ICE.***

   d. ***Any M&Q inputs from the technical risk areas identified in the ITRA guidance document should be provided as support to the ITRA.***

   e. ***The "other activities" should include conduct of an MRA on the selected concept(s) to MRL 4 criteria and metrics (mentioned as a "potential artifact" in the Early M&Q Guide), support conduct of an ASR, as well as support to the Milestone A review and decision.***

5. An ASR is not merely a Best Practice as stated in DoDI 5000.88 and the other guidance documents, but the key and final SE review by the program, prior to the Milestone A review and decision. The ASR should not begin until the all criteria are met.

   a. ***Conduct of the ASR should follow the recommended guidance in IEEE 15288.2 §5.2.***

   b. ***DoDI 5000.88, §3.5.a(2), should be updated to add ASR to the list of required SE reviews.***

6. For the Milestone A review and decision, the PM is required to "present the acquisition strategy, the business approach, "Should Cost" targets, framing assumptions, an assessment of program risk and planned mitigation actions . . ."[81]

   a. ***All Guidance documents should also clearly state that the outputs from the ICE, the ITRA, and the MRA, and the ASR are required for the Milestone A review. For example: In DoDI 5000.88, §3.5.b(1)(b), ITRAs are conducted on all MDAPs and included in decision reviews before approval of Milestone A, Milestone B, and any decision to enter into low-rate initial production or full-rate production.***

   b. ***DoDI 5000.85 should specifically state that these outputs are part of the decision process, especially as ICE and ITRA are required by statute.***

The above recommended changes in the policies, guidance, and documentation would the most efficient way to "move manufacturing to the left." These changes are required to bring completeness and consistency to DoD acquisition to enhance and "speed up" the acquisition process, while employing Best Practices. In support of the effort to streamline and shorten acquisition, guidance on Pre-MDD activities should direct earlier and consistent involvement of M&Q SMEs.

[80] MRL Matrix, 2022
[81] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.7.b(1)

VII. Summary

In summary, as detailed in this paper, Systems Engineering assessments and analyses identified as Best Practices must be required, even if tailored. The following recommendations for M&Q support of MCA in the AAF process should be consistent and included in all the guidance documents.

M&Q SMEs should be required to provide:

- Assessments and analyses to the CBA in support of successful mission execution and shortfall resolution in existing weapon system's production to deliver required capabilities
- Support to the JCIDs process in development of the draft ICD
- Monitoring of ME activities for IB impacts and support of testing, demonstrations, exercises, and experiments to support the MR
- Support to the DCAPE for development of the AoA Study Guidance
- Support to the DoD Component Head in development of the AoA Study Plan
- Conduct assessments of potential concepts to MRL 3 for input to CoDR
- Support to the CoDR (including the alternative pathway selection) by supporting the linking of the mission definition, the time frame, the capability gap, and the potential concept(s) maturity level to the appropriate acquisition model
- Support to the MDD
- Support to the AoA
- Support to the PM in development of the AS and the SEP
- Support to the CAPE in conduct of an ICE
- Support to the review team in conduct of an ITRA
- Assessment of the selected materiel solution(s) to MRL 4 criteria and metrics
- Support to the PM in conduct of an ASR
- Support to the Milestone A review and decision

Thorough Systems Engineering processes and practices will allow identification, quantification, and management of the risks and issues to cost, schedule, and performance (acquisition and operational) in support of the decision process and the acquisition pathway chosen. In summary, support of the AAF process with these recommended updates will require earlier involvement of M&Q SMEs and provide more consistent guidance in the MCA defense acquisition process.

VIII. Appendix

Appendix I. CoDR

Manufacturing & Quality SMEs should provide support in the following areas:

- **Capability Based Assessment –** Participate in the CBA to provide an understanding of the IB capability and gaps
    - Understanding of the production system capability and gaps
    - Analyzing the design and manufacturing trade space to determine alternative product and production system solution concepts
    - Identify the requirement for the use of advanced M&Q technology and processes for the concepts being considered
- **Concept design trades –** Provide feasibility/producibility/manufacturability analyses of concepts as a characteristic of the solution
    - Analyzing the design and manufacturing trade space to determine alternative product and production system solution concepts
    - Identifying an appropriate range of candidate production system solutions
    - Identify the requirement for the use of advanced M&Q technology and processes for the concepts being considered
    - Investigate initial product models in development for materiel solution approaches and the behavior of modeled materiel solutions in simulated “real-world” conditions
- **Concepts Risk Assessments –** Provide an assessment of concepts to include risks, issues, and opportunities in development of potential materiel solutions, appropriate affordability targets, and initial schedule basis
    - Identifying an appropriate range of candidate production system solutions
    - Evaluating risks associated with the alternative production system concepts to be analyzed during the MSA phase
    - Identifying critical product and production system technologies and associated technology maturation and prototyping approaches
- **Perform MRL 3 assessments on selected concepts**
- **Cyber security assessment –** Perform assessment of Operational Technologies (OT) utilized in realization of concepts
- **Prototyping/experimentation roadmaps –** Provide expertise in planning and execution for Design of Experiments and prototypes of concepts
    - Identifying production system solution opportunities to provide a more rapid response
    - Analyzing the design and manufacturing trade space to determine alternative product and production system solution concepts
    - Planning the production system capability development for the subsequent technical efforts required during the MSA phase
    - Identifying M&Q management approaches for follow-on program phases
- **DOTMLPF-P considerations and materiel solution concepts –** Support analyses focusing on materiel(s), personnel (workforce), and facilities (and tooling) aspects
    - Identifying an appropriate range of candidate production system solutions
    - Identifying production system solution opportunities to provide a more rapid response

- **Informed Defense Acquisition System alternative pathway selection –** Provide support to linking the mission definition, time frame, gaps, and maturity levels to the appropriate acquisition model
    - Identifying an appropriate range of candidate production system solutions
    - Identifying critical product and production system technologies and associated technology maturation and prototyping approaches

The above M&Q support areas were derived from the *Engineering of Defense Systems Guidebook and* the *MRL Deskbook.*

Appendix II. AoA

The Best Practices listed below are from *GAO-15-37, Analysis of Alternatives Could Be Improved by Incorporating Best Practices, Dec 14*, and from *Analysis of Alternatives Cost Estimating Handbook, Jan 22.* The handbook statements are based on observations from successful AoA cost analyses conducted in the DoD over the past five years. Below is a consolidated list of Best Practices:

- Start cost analysis early
  - Time to conduct limited to 9 months
- Build a robust team
  - members with diverse areas of expertise (i.e., SMEs, PMPs, cost estimating, and risk management)
- Coordinate with functional SMEs to understand design, fielding, maintenance, and support challenges for each alternative, then document the resulting technical baseline
  - Include understanding of current industry state-of-the-art and capabilities
- Select appropriate cost estimating methodology
  - Documented in a plan prior to beginning analyses
- Use actual cost data
- Use a common Work Breakdown Structure (WBS) for all alternatives
- Assess interaction of cost and schedule
- Conduct sensitivity analysis and highlight inflection points
  - sensitivity of both the cost and benefit/effectiveness estimates for each alternative to risks and changes in key assumptions are documented
- Provide time-phased results
  - quantified benefits/effectiveness from each alternative over the full life cycle
- Present results in appropriate dollar types
  - Provide life-cycle cost estimate in present value terms, explain the specific discount rate used
- Identify cost contributors within and across alternatives to assist with tradeoff discussions involving cost and capability
- Follow DoD cost policy and guidance for preparing DoD cost estimates
- Engage early and provide regular updates to Service Headquarters and OSD
- Document the life-cycle cost estimate for each alternative and ensure reproducibility
  - All costs from inception of the project through design, development, deployment, operation, maintenance, and retirement
  - Present each alternative as a range or with a confidence interval, not a point estimate
- Use a standard process to quantify the benefits/effectiveness of each alternative and document the process
- Quantify the benefits/effectiveness resulting from each alternative over the full life cycle
- Explains how each measure of benefit/effectiveness supports the mission need
- Identify and documents the significant risks, issues, and opportunities, and the mitigation strategies for each alternative
- Write the cost section and/or appendix of the final AoA report

Appendix III. ITRA

For MDAPs, starting with Milestone A, ITRAs are conducted before each acquisition milestone.[82] The ITRA approval authority must be independent and may not be in the program's chain of command. The project technical team [an undefined group] should be aware that they may need to support and participate in ITRA activities beginning prior to Milestone A.[83]

According to DoDI 5000.88, *Engineering of Defense Systems*, an ITRA will "consider the full spectrum of technology, engineering, and integration risk. These areas could include mission capability, technology, system development, MOSA (Modular Open Systems Approach), software, security, manufacturing, sustainment, and their potential impacts to cost, schedule, and performance." ITRAs conducted before Milestone A will identify critical technologies and manufacturing processes that need to be matured.[84]

The framework for ITRAs is found in the Defense Technical Risk Assessment Methodology (DTRAM), Sep 2020, is organized into **eight technical risk areas**:

- Mission capability
- Technology
- System development and integration
- Modular open systems approach (MOSA)
- Software
- Security and cybersecurity
- Manufacturing
- Reliability, availability, and maintainability (ram)/sustainment)

across **seven factors**:

- Performance and quality
- Scope and requirements
- Design and architecture
- Evaluation
- Schedule
- Decision and control
- Resources

In the DTRAM the manufacturing technical risk area consists of 22 "evaluation criteria" to consider for manufacturing. Although ITRA team members may be engaged throughout the concept development, industry days, and the Analysis of Alternatives, to enable better understanding of the risks; the ITRA is to inform a Milestone A decision will be on the selected materiel solution(s) after the DoD Component downselect.[85]

[82] Pursuant to 10 USC 2448b state in DoDI 5000.88, 3.5.b(1)(b)
[83] 3.5.b(2)
[84] DoDI 5000.88, 3.5.b(1)(d)
[85] DoD *ITRA Executive Guide*, Dec 2020

Technical Risk Area Criteria – Manufacturing

A review of M&Q activities occurring for an ITRA during the MSA phase shows that many of the criteria are not appropriate for the maturity and status of development of a program at Milestone A. Furthermore, the DTRAM does not contain objective criteria, but only mentions subjective criteria without appropriate metrics.

Most of the "evaluation criteria" in an ITRA do not relate to or address quality. Prior versions of the criteria adjusted criteria to the phase of development.

M&Q will activities will have an impact on multiple risk areas across the seven factors above as seen below in the "evaluation criteria" in the Manufacturing risk area:

7.1.P (MANUFACTURING - Scope & Requirements) Manufacturing and production capability and requirements are defined, achievable, and support program objectives.

- 7.1.C1 Manufacturing and production requirements are realistic and achievable within program structure and timeline.
- 7.1.C2 Industrial base and manufacturing capabilities support program objectives.
- 7.1.C3 Product baseline (to include configuration items in concurrent development) is complete, stable, and traceable to requirements.

7.2.P (MANUFACTURING - Design & Architecture) Design and maturation of manufacturing capabilities support production quality and rates.

- 7.2.C1 Manufacturing and production processes and manufacturing technology maturation supports program requirements.
- 7.2.C2 Design for producibility is sufficient to meet requirements and affordability objectives.
- 7.2.C3 Procurement and supply chain capability support requirements.
- 7.2.C4 Production cut-in, retrofit, and product improvement sufficiently support requirements.

7.3.P (MANUFACTURING - Decision & Control) The program objectively monitors and sufficiently understands manufacturing and production progress, controls risk, and establishes appropriate technical criteria for development events.

- 7.3.C1 The program employs metrics that track manufacturing and production maturity, are sufficient to control manufacturing and production performance and manage risk.
- 7.3.C2 The program sufficiently analyzes, tracks, and mitigates manufacturing and production risks.
- 7.3.C3 The program has established objective, time-phased criteria and events to assess manufacturing and production maturity and to determine readiness to proceed with the production phase.
- 7.3.C4 Adequate entrance criteria have been set/met (for completion of system development and testing activities or for maturity of the system) in order to enter the production phase.

7.4.P (MANUFACTURING - Schedule) Manufacturing and production capability maturation and required capacity are sufficiently modeled in the program schedule, are achievable, and support manufacturing objectives.

- 7.4.C1 Manufacturing and production activities are realistic, supported by a sound basis of estimate that considers relevant historical schedules, sufficiently sequenced, time phased, and integrated with the program schedule.

7.4.C2 Manufacturing and production activities are sufficiently phased independent from and sufficiently decoupled from concurrent development and test activities.

7.4.C3 Manufacturing and production schedule reflects actual progress.

7.5.P (MANUFACTURING - Resources) Manufacturing and production staffing, facilities, materials, and funding are sufficient to support production quality and rates.

7.5.C1 Manufacturing and production staffing, including skillsets and organization, are sufficient to support program objectives.

7.5.C2 Manufacturing and production investments, design tools, digital environments, tooling, and facilities are sufficient to support program objectives.

7.5.C3 Manufacturing and production funding, materials, and supply chain are sufficient to support production rates.

7.6.P (MANUFACTURING - Evaluation) Manufacturing and production evaluation planning and activities are sufficient to mature manufacturing capability, quality, and rates.

7.6.C1 Manufacturing and production evaluation activities (e.g. FAI) are realistic and sufficient to accurately determine capacity yield, assembly rates and unit quality to support product acquisition and sustainment.

7.6.C2 Test and evaluation execution is on track to support manufacturing and production (e.g. capacities, scope growth, productivity) and is supplying sufficient results to support program decisions.

7.7.P (MANUFACTURING - Performance & Quality) Manufacturing and production supports required product quality and production rates.

7.7.C1 Manufacturing and production capability and processes are maturing to plan sufficiently to demonstrate stable, under-control production in a relevant environment prior to production decisions.

7.7.C2 Manufacturing and production technology and capability maturing to plan.

7.7.C3 Procurement (e.g. supply chain) sufficiently supports production.

7.7.C4 Manufacturing and production meets program quality and performance objectives.

Quality Factors

ITRAs do not include Quality as a risk area together with Manufacturing, as in M&Q, rather “quality” was paired with “performance” as factor for all risk areas as seen below. Additionally, the ITRA methodology has limited actual quality activities considered as part of the “performance and quality” factor for each area. Most of the “evaluation criteria” in an ITRA do not relate to or address quality.

Quality should be considered as an aspect of the risk areas, as in one should consider the quality of the performance (e.g., Was a high quality TRA performed to gauge the technology maturity?).

Performance and Quality factors from the DTRAM across the risk areas:

1.7.P (MISSION CAPABILITY - Performance & Quality) Integrated (end-to-end) mission capability is on track to meet user expectations in the projected operational environment.

1.7.C1 Integrated mission capability will meet user expectations in the projected operational environment, to include the evolution of capabilities to meet changing threats, technology insertion, and interoperability.

1.7.C2 The system is on track to meet requirements and operational measures (e.g. KPPs, KSAs, MOPs, MOEs, MOSs, COIs).

1.7.C3 The system is on track to meet fielding and IOC requirements (e.g. training, support systems, and delivery quantities).

2.7.P (TECHNOLOGY - Performance & Quality) Each critical technology has achieved the required level of technical maturity and is likely to completely mature to meet operational effectiveness and suitability objectives.

2.7.C1 Critical technology is on track to meet maturity objectives, to include integration into the overall system, and demonstrated performance in the relevant operational environment.

2.7.C2 Results are sufficient to evaluate performance of matured technology to support program decisions.

3.7.P (SYSTEM DEVELOPMENT & INTEGRATION - Performance & Quality) System performance and quality is on track to support program objectives.

3.7.C1 System is maturing sufficiently to meet established criteria (e.g. technical performance measures, milestone criteria) and continue acquisition on schedule.

3.7.C2 System performance, to include disposition of technical debt (e.g. deferred, partially implemented, and deficient functionality), is on track to satisfy technical baseline, entrance to IOT&E, and operations.

4.7.P (MOSA - Performance & Quality) System performance is on track to meet MOSA objectives.

4.7.C1 Major system components and major system interfaces are maturing sufficiently to meet established MOSA objectives and continue acquisition on schedule.

4.7.C2 Results are sufficient to evaluate performance of MOSA-enabled capability to support program decisions.

5.7.P (SOFTWARE - Performance & Quality) Software functionality and quality are on track to support program objectives.

5.7.C1 Software architecture, interfaces, and sub-system performance meeting quality and performance objectives.

5.7.C2 Results are sufficient to evaluate software performance in the intended operational environment and support program decisions.

5.7.C3 Software increments are on track to meet program objectives, including resolution of technical debt and defects.

6.7.P (SECURITY / CYBERSECURITY - Performance & Quality) Security and cybersecurity performance is on track to provide protection in support of program objectives.

6.7.C1 Program has sufficiently mitigated security/cybersecurity risks to CPI, CTI, functions, and components, technologies, enabling systems.

6.7.C2 Security implementation is on track to meet program objectives.

7.7.P (MANUFACTURING - Performance & Quality) Manufacturing and production supports required product quality and production rates.

7.7.C1 Manufacturing and production capability and processes are maturing to plan sufficiently to demonstrate stable, under-control production in a relevant environment prior to production decisions.

7.7.C2 Manufacturing and production technology and capability maturing to plan.

7.7.C3 Procurement (e.g. supply chain) sufficiently supports production.

7.7.C4 Manufacturing and production meets program quality and performance objectives.

8.7.P (RAM & SUSTAINMENT - Performance & Quality) Sustainment, supportability and R&M performance are on track to meet program objectives.

8.7.C1 System tracking to the reliability growth curve.

8.7.C2 Other aspects of R&M performance (e.g., stress testing, fatigue testing, corrosion tests and environmental testing) confirms design suitability for the life cycle operating environment.

8.7.C3 System meets R&M requirements (e.g. AoA, MTBF, O&S costs), and operational effectiveness and suitability objectives.

8.7.C4 Sustainment performance (e.g. spares purchase, OEM and organic repair) is on track to meet program objectives.

Appendix IV. SEP Outline Version 4.0

3.2.4 Manufacturing and Quality Engineering

3.2.4.1 Manufacturing and Quality Requirements and Engineering Activities

Describe the program approach for implementing and contracting for comprehensive manufacturing and quality (M&Q) programs, and how M&Q integrates with the SE processes, to include planning and timing for key activities (listed in Table 3.2-5). (See https://ac.cto.mil/maq/)

Table 3.2-5 Planning and Timing for M&Q Activities and Requirements (mandatory) (sample)

Activity or Requirement	Planning and Timing
Manufacturing Management	***Expectation:*** *Updates at each Milestone (example references may include MIL-HDBK-896, "Manufacturing Management Program Guide," SAE Standard AS6500, "Manufacturing Management Program," and FAA certified production system IAW 14 CFR Part 21, Certification Procedures for Products and Parts).*
Industrial Capabilities Assessment	***Expectation:*** *Updates at each Milestone (10 USC 2440).*
Technical Reviews and Audits	***Expectation:*** *Manufacturing inputs for each review and audit (SE Guidebook (forthcoming)).*
Producibility Analysis	***Expectation:*** *Describe approach (e.g. MIIL-HDBK-727 or NAVSO P-3678 best practices).*
Production Readiness Reviews (PRRs)	***Expectation:*** *PRR at system, subsystem, and component levels for prime and subcontractor (SE Guidebook (forthcoming)).*
Supplier Qualifications	***Expectation:*** *Description of approach (e.g. risk assessment, First Article Test/Inspection, audits, counterfeit parts mitigation).*
Statistical Process Control (SPC)	***Expectation:*** *Applicable manufacturing processes are under SPC.*
Quality Management and Assurance	***Expectation:*** *Updates for each phase of the program (example references may include applicable standards such as ISO 9100 and SAE AS9100 Quality Management Systems).*
Contractor Oversight	***Expectation:*** *Description of DCMA role to include quality oversight delegated to DCMA.*

Manufacturing Maturity

Describe the program approach to (1) assess manufacturing readiness as the program prepares to enter technical reviews and program milestones; and (2) Manufacturing Maturation Plans for MRL threads that are assessed below the target MRL criteria (refer to the DoD Manufacturing Readiness Level Deskbook www.dodmrl.com).

Results are summarized as reflected in Table 3.2-6 structure.

Table 3.2-6 Summary of MRA Results (mandatory) (sample)

Component, Subsystem, System Assessed	Assessment Description (Describe process, thread, or risk area from MRL Criteria)	Assessed MRLs			
		PDR Entry (Target MRL ≥ 6	CDR Entry (Target MRL ≥ 7)	LRIP (Target MRL ≥ 8)	FRP (Target MRL ≥ 9)

Appendix V. ASR

The ASR has the following set of characteristics of a program's work products that form a sufficient basis to support a successful review (acceptability criteria): [86]

- Refined Joint Requirements
  - Joint context and initial CONOPS/OMS/MP[87]
  - Required related solutions and supporting references (ICD and CDD) identified
  - Joint refined thresholds and objectives (e.g., MOEs, measures of suitability, MOPs, etc.)
- Initial Architecture for the Preferred Materiel Solution(s)
  - High-level description of the preferred materiel solution(s) is available and sufficiently detailed and understood to enable further technical analysis
  - SoS interfaces and external dependencies are adequately defined
- System Performance Specification
  - Clear understanding of the system requirements consistent with the applicable requirements document (from the ICD or draft CDD, if available)
  - System requirements are sufficiently understood to enable functional definition
  - Draft system performance specification has sufficiently conservative requirements to allow for design trade space
  - Relationship between draft system performance specification and risk reduction prototyping and competitive prototyping objectives is established
- Preferred Materiel Solution(s) Documentation
  - Comprehensive rationale is available for the preferred materiel solution(s), based on the Analysis of Alternatives
  - Key assumptions and constraints associated with preferred materiel solution(s) are identified and support the conclusion that this solution can reasonably be expected to satisfy the applicable requirements document in terms of technical, operational, risk and schedule/cost (affordability) criteria
  - Results of trade studies/technical demonstrations for concept risk reduction, if available
  - Initial producibility assessments of solution concepts
- Risk Assessment
  - Technical risks are identified, and mitigation plans are in development
  - Initial hazard analysis/system safety analysis for preferred solution(s) complete
  - Human systems integration risk identification and mitigation plans

The above identifies the products and associated review criteria normally seen as part of the ASR.

[86] IEEE 15288.2 Standard for Technical Reviews and Audits

[87] Concept of Operations/Operational Mode Summary/Mission Profile includes current and evolving capability gap(s), supported missions, mission analysis, Target Audience Description (TAD), interfacing/ enabling systems in the operational architecture; overall system of systems (SoS) context

Appendix VI. AAF

The AAF has resulted in revision or creation of numerous documents, policies, and instructions, such as revisions to: DoDD 5000.01, DoDI 5000.02, and other overarching policies (**Figure 2.**).

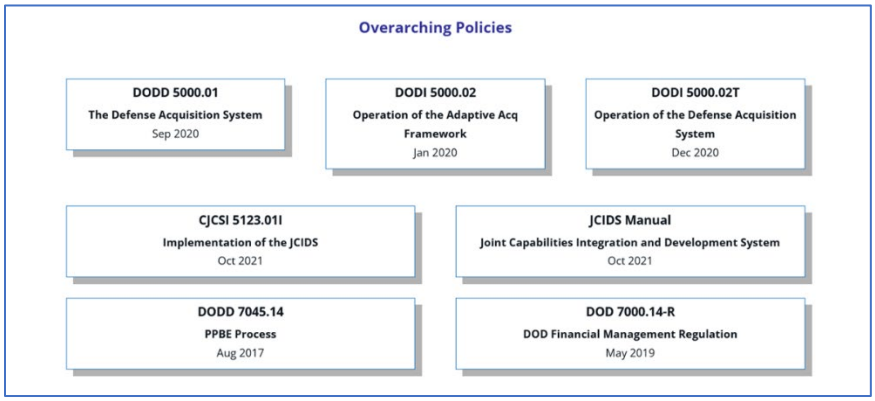

Figure 2. Overarching Policies

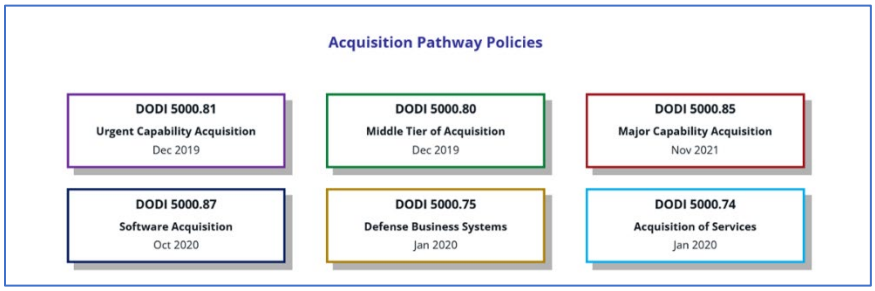

Figure 3. Acquisition Pathway Policies

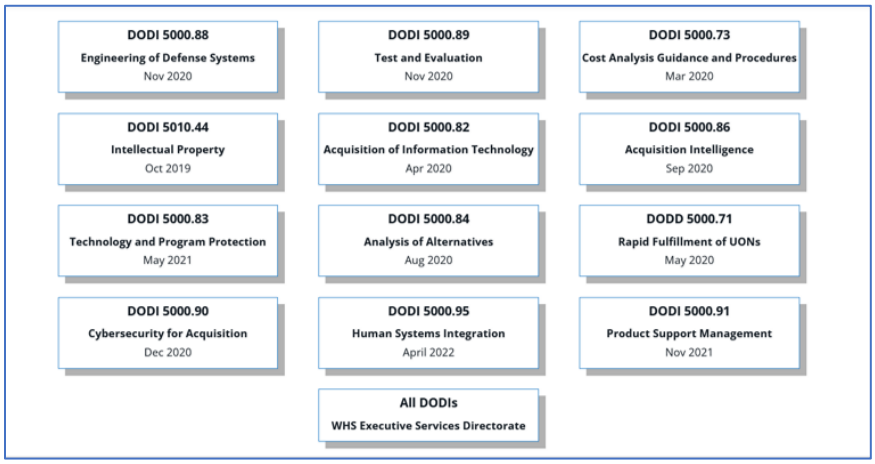

Figure 4. Pathway and Engineering Guidance

Instructions for each pathway (**Figure 3.)** and instructions for all pathways were created (**Figure 4.**). Additionally, updated guidance for each pathway and engineering discipline, such as *Engineering of Defense Systems Guidebook*, formerly the DAG, was updated (**Figure 5.**).

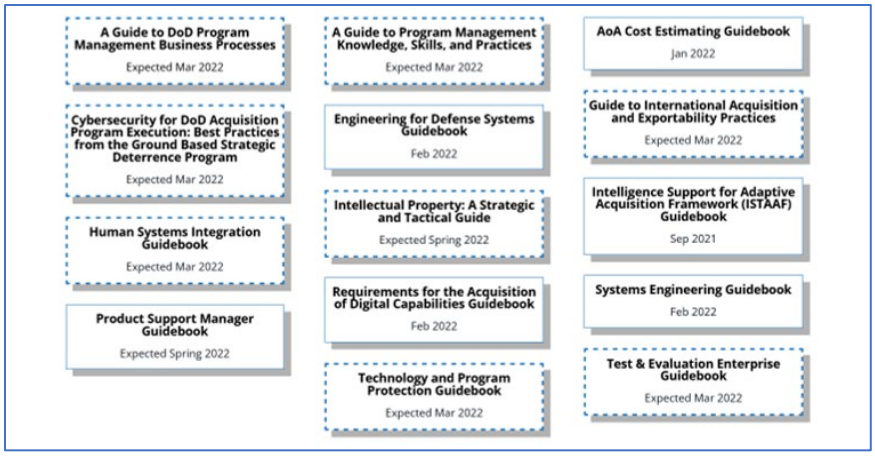

Figure 5. Other Engineering Guidance

At this time, several of these guides are placeholders to be completed. Many of these guides complement and endorse the previously developed Industry standards such as the IEEE 15288 series, SAE AS9100 series, and SAE AS6500.