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Essential Elements of Systems Engineering In Early DoD Major Capability Acquisition

3 April 2023

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Introduction

In this paper we examine the early DoD Major Capability Acquisition (MCA) processes from Pre-Materiel Development Decision (Pre-MDD), through the Materiel Solutions Analysis (MSA) phase, to Milestone A. We reviewed the Adaptive Acquisition Framework (AAF) to better understand the changes to the Defense Acquisition System (DAS) processes to derive the essential elements of DAS processes for MCA. This was a "challenging" discovery process requiring a search across multiple sources: DoD instructions, DoD guidance documents, DoD handbooks, DoD manuals, statutes, and industry standards. During this process, we also discovered that there were many inconsistencies among the different guidance documents. Changes in DoD instructions and guides are required to bring completeness and consistency to DoD acquisition guidance, and to enhance and "speed up" the acquisition process, while still employing Best Practices. In development of defense systems, regardless of the acquisition pathway chosen, sound System Engineering (SE) practices need to be specified and required, even if a "tailored" process is utilized. This paper concludes with recommendations for the necessary changes.

Background

Over twenty years ago the GAO reported to the Senate Committee on Armed Services, that . . . *Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes.*[1] The report details that DoD was not capturing sufficient design and manufacturing knowledge to make good decisions at key investment points. Programs were often passing through each development phase and into production with an unstable design and insufficient knowledge about critical manufacturing processes and product reliability. Additionally, the lack of proper incentives to encourage the use of best practices in capturing knowledge early in its development programs was detrimental to program cost and schedule.

Since that time, many improvements have been made in the DoD acquisition process, as visible in GAO reporting; however, as recently as 2019, with the title *Limited Use of Knowledge-Based Practices Continues to Undercut DOD's Investments*, showed there was still a need for improvement. DOD Major Defense Acquisition Programs (MDAPs) continue to ". . . not fully implement key knowledge-based acquisition practices."

In 2019, DoD initiated changes in the acquisition culture by simplifying policy, empowering program managers (PMs), tailoring acquisition approaches, conducting data driven analysis, actively managing risk, and emphasizing sustainment by introducing the AAF.[2] The AAF contains many new policies and guidance documents (see Appendix I), but there are many inconsistencies and omissions in the documents. There has been a constant desire to move manufacturing involvement in systems acquisition to earlier in the acquisition cycle to enable warfighter capabilities that can be produced feasibly and that will meet requirements.[3] The benefits of including Manufacturing & Quality (M&Q) in this early stage are many, including improvements in schedule, cost, and performance as the system proceeds through

[1] GAO-02-701, Jul 2002
[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.

development.[4] In the AAF, DoD has accomplished a major update to how acquisitions are conducted with most policies, instructions, and guidance were issued by the end of 2021.

While the ultimate impact has yet to be fully realized, these updates have streamlined some processes and highlighted 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 Materiel Development Decision (MDD) the entry point of all MCA programs.

The Adaptive Acquisition Framework

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. The DoD has accomplished major updates to acquisition policies, instructions, and guidance. While most of these updates were issued in 2021 with some guidance in 2022, the ultimate impact has yet to be realized. These updates have streamlined some processes, but they have resulted in inconsistencies in acquisition documents.

DoD has changed the initiation of acquisition to MDD as the mandatory entry point into the major capability acquisition process.[5] Additionally, the AAF was established in these updates to enable faster delivery of DoD systems and/or capabilities through the means of multiple acquisition pathways and tailored processes. These changes resulted in revision or creation of multiple documents, policies, and instructions for each pathway; policies and instructions for all pathways; and updated guidance for engineering disciplines (see Appendix I and Table I). Several of the other "guides" are placeholders and currently in development (see Appendix I). Many of these are complementary to and endorse previously developed Industry standards such as the IEEE 15288 series, SAE AS9100 series, and SAE AS6500. Additionally, the *Early Manufacturing and Quality Engineering Guide* was not contained in the original process, but was added in July 2022.

DoDD 5000.01	*The Defense Acquisition System*	Sep 2020	Revision
DoDI 5000.02	*Operation of the Adaptive Acquisition Framework*	Jan 2020	Revision
DoDI 5000.73	*Cost Analysis Guidance and Procedures*	Mar 2020	Revision
DoDI 5000.81	*Urgent Capability Acquisition*	Dec 2019	New
DoDI 5000.84	*Analysis of Alternatives*	Aug 2020	New
DoDI 5000.85	*Major Capability Acquisition*	Aug 2020	New
DoDI 5000.88	*Engineering of Defense Systems*	Nov 2020	New
	Engineering of Defense Systems Guidebook	Feb 2022	New
	Systems Engineering Guidebook (includes the AAF) (formerly Defense Acquisition Guidebook (DAG))	Feb 2022	Revised, renamed
	Early Manufacturing and Quality Engineering Guide	Jul 2022	New

Table 1. Guidance and Policies

The change in the acquisition process is a significant refinement and improvement; however, there are some inconsistencies among the policies and guidance that are not consistent with supporting sound Systems Engineering. SE activities are specified in three different documents: *Engineering of Defense Systems Guidebook*, Feb 2022; *Systems Engineering Guidebook*, Feb 2022; and DoDI 5000.88, *Engineering*

[4] *Early M&Q Engineering Guide*, Jul 2022
[5] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.5.a.

of Defense Systems, Nov 2020. For MCA programs, the purpose of the MSA phase is to conduct an Analysis of Alternatives (AoA) and *other activities* needed to choose the concept (for the product to be acquired). The other activities are not specified in DoDI 5000.85, other than requiring an Independent Cost Estimate (ICE) and an Independent Technical Risk Assessment (ITRA), and beginning product support and sustainment planning. Additionally, there are several other DoD instructions and guides that should be modified to address shortfalls and improve completeness and consistency.

Pre-Materiel Development Decision

During DoD acquisition a thorough, but appropriately tailored, series of SE technical reviews and audits take place. These provide key points to evaluate achievements and to assess technical maturity and risk, issues, and opportunities. To provide management a sound basis for analysis and any required actions or decisions, assessments should be performed prior to decision points. Analysis of the results should inform management on actions that reduce risk, increase performance, recognize and capitalize on opportunities, improve affordability, shorten schedule, and enhance performance.[6]

Systems Engineering activities are specified in three different documents. The first document is DoDI 5000.88, *Engineering of Defense Systems*, Nov 2020, which is the policy document. The second document of interest is *Engineering of Defense Systems Guidebook*, Feb 2022. This is a guidance document, which describes the activities, processes, and practices involved in the development of DoD systems with respect to each of the AAF pathways. The third document is the *Systems Engineering Guidebook*, Feb 2022, formerly known as the DAG. This is also a guidance document, which explains all SE activities in depth to plan and execute program SE activities across the system life cycle. Other documents that impact SE activities include DoDI 5000.84 and DoDI 5000.85, but these do not consider SE prior to MDD.

The SE activities and key decision points are shown in Figure 1, the framework for MCA programs. This figure is not shown in either DoDI 5000.88 or DoDI 5000.85, but is derived from the information in 5000.85. It is, however, included in the *Engineering of Defense Systems Guidebook*, Feb 2022, and in the *Systems Engineering Guidebook*, Feb 2022.

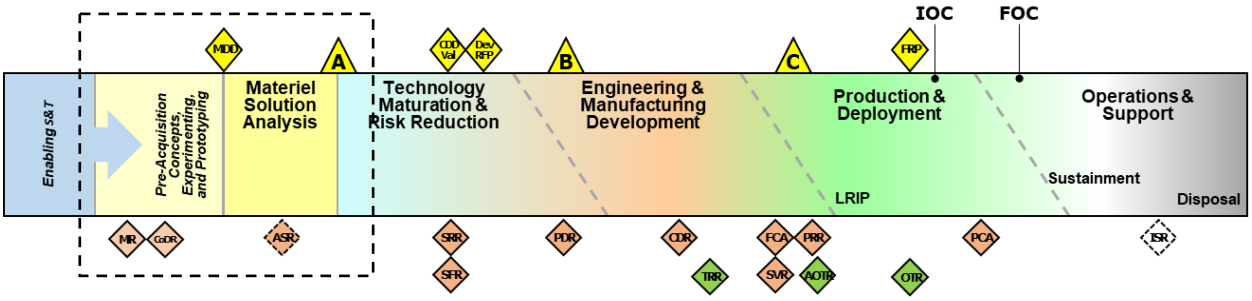


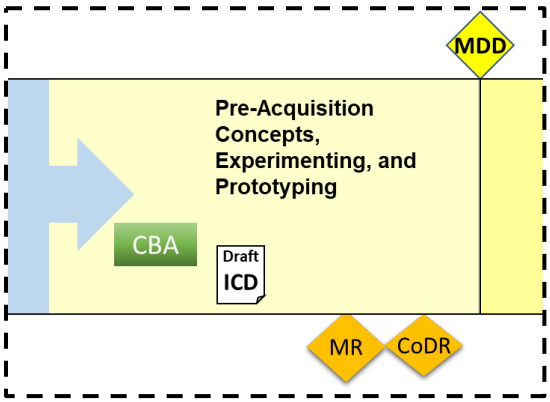
Figure 1. MCA Program Framework

The engineering activities that occur prior to a MDD include the following:

- Capability Based Analysis (CBA)
- Draft Initial Capabilities Document (ICD)
- Mission Engineering (ME) activities and the Mission Review (MR)
- Concepts Design Review (CoDR)

[6] Technical reviews or audits should be conducted using sound and thorough SE which includes feasibility, producibility, and manufacturability as well as other Industry best practices as required by SAE AS6500, *Manufacturing Management Program*.

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. The draft ICD is assigned to a lead Service or Services. 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. These activities include manufacturing feasibility, studies from the S&T community, and other supporting studies (threat analysis, gap studies, etc.) contributing pertinent data and information for the MDD.



-derived from DoDI5000.85

Figure 2. Pre-MDD

The policies and guidance documents are specifying 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 Mission Review 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[7] considerations to address the needs of the Mission Baseline.[8] Together the outputs of these reviews provide inputs to the MDD.[9]

The following subsections detail the essential SE and other activities in Pre-MDD as summarized above.

[7] DOTMLPF-P – doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy
[8] *Engineering of Defense Systems Guidebook*, Feb 2022
[9] In the APT Corporation paper titled *Essential Manufacturing & Quality Activities In Early DoD Major Capability Acquisition*, Apr 2023, the essential engineering and programmatic activities are addressed with a focus on the details of M&Q functions supporting the acquisition process from Pre-MDD through Milestone A. This paper also points out the activities that provide the necessary "design and manufacturing knowledge" to make informed decisions at investment/decision points and some of the inconsistencies in and between both policies and guidance documents as they apply to System Engineering activities.

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 (SMEs) who may contribute to and participate in the CBA and initial development of an ICD for the respective Joint Capability Area is the responsibility of Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)).[10]

The CBA identifies:

- the capabilities (and operational performance criteria) required to successfully execute missions
- the shortfalls in existing weapon systems to deliver those capabilities and the associated operational risks; and the
- 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 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.[11]

Draft Initial Capabilities Document

The Draft ICD documents one or more new capability requirements, associated capability gaps, and the intent to address identified capability gap(s) with a 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. [12]

An ICD is usually not updated once it is validated and approved, but rather, is superseded by successor JCIDS documents, such as the Draft Capabilities Development Document (CDD).[13] 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.[14]

[10] CJCSI 5123.01I, Enclosure C, Oct 2021
[11] CJCSI 3170.01F, May 2007
[12] *HSI and ESOH Handbook for Pre-Milestone A JCIDS and AoA Activities*
[13] Ibid
[14] *Engineering of Defense Systems Guidebook*, Feb 2022

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 non-materiel [sic] solutions.[15]

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.[16]

The *Mission Engineering Guide*[17] establishes the following steps for ME, which incorporate the direction from NDAA 2017 section 855:

1. Problem Statement, encapsulating key questions, suspected capability gaps, current and planned technologies, and operational concepts
2. Mission Characterization
3. Mission Metrics
4. Design of Analysis, defining mission threads
5. Analysis/Modeling, capturing mission effectiveness
6. Documented Conclusions

The MR is primarily an OUSD/(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: [18]

- 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.[19]

- 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[20] evaluations to support maturation of the Concept Design

[15] JCIDS Manual, Aug 2018
[16] *Systems Engineering Guidebook*, Feb 2022
[17] *Mission Engineering Guide*, Nov 2020
[18] *Engineering of Defense Systems Guidebook,* Feb 2022, §2.1.1
[19] Ibid
[20] DOTMLPF-P – doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy

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 should include manufacturing and quality engineering analyses and inputs.[21] For Service-specific missions the CoDR is chaired by the Service; for joint missions, the CoDR is chaired by a USD/(R&E) representative.[22] 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[23]:

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

The *Engineering of Defense Systems Guidebook* states that the CoDR should establish the operational Concept Baseline, 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 teams 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.

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

- 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 materiel solution concepts for further analysis/refinement in the next acquisition phase

[21] *Engineering of Defense Systems Guidebook*, Feb 2022
[22] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020,
[23] Ibid

- Informed DAS alternative pathway selection (quantitatively linking the mission definition, time frame, gap and potential solution maturity level to the appropriate acquisition model)[24]
- Updated AoA study guidance that incorporates USD(R&E) and ME-based direction [25]

Materiel Development Decision

The stated purpose of DoDI 5000.85 establishes policy and prescribes procedures that guide the acquisition of MCA programs only. 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.[26] The DCAPE (or DoD Component equivalent 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 both 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 are the extent of the discussion of MDD in DoDI 5000.85. The Milestone Decision Authority (MDA) will determine the acquisition phase of entry and the initial review milestone. The MDD decision process leads to an Acquisition Decision Memorandum (ADM) that includes program staffing and funding activities to reach the next decision point, usually Milestone A.

DoDI 5000.88 extensively addresses Pre-MDD activities with discussion about ME, Mission Integration Management (MIM) [statutory requirement], and an MR by a Service representative or OUSD(R&E) for joint missions. Additionally, there is a major review, the CoDR, chaired by the DoD Component (or USD(R&E) representative 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.[27]

DoDI 5000.85 discusses the MDD, touching on the purpose, presentation of the AoA Study guidance by the DCAPE and the AoA Study Plan by the DoD component. There is no discussion or reference to any of the Pre-MDD knowledge and analyses from the MR and the CoDR on the 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 (USD/(A&S) or designate)[28] 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.[29]

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[24] See DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, for a discussion of pathways, selection processes, formality of these processes, and application to specific products/systems.
[25] *Engineering of Defense Systems Guidebook*, Feb 2022
[26] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020
[27] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.3.e. & f.
[28] A&S serves as the MDA for the Materiel Development Decision, Milestone A, the Request for Proposal Release Decision Point for the Engineering and Manufacturing Development Phase, Milestone B, and Milestone C for acquisition category ID programs. DoDI 5000.02, Jun 2022, 2.1.c(1)
[29] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.5.c.

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 acquisition strategy for the product. The MDA is the USD/(A&S), according to DoDD 5135.02, July 15, 2020. The other activities **are not specified** other than requiring an ICE and an ITRA, and beginning product support and sustainment planning.

According to the *Engineering of Defense Systems Guidebook*, technical activities during the MSA phase include:[30]

- Conduct an AoA (according to DoDI 5000.84, *Analysis of Alternatives*, Aug 2020),
- Perform analysis to support selection of a preferred materiel solution,
- Perform operational analysis on preferred materiel solution, perform engineering and technical analysis on preferred materiel solution,
- Establish program framework and strategies (e.g., the Acquisition Strategy and the Systems Engineering Plan), and
- 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.

As part of a 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)
- Manufacturing Readiness Assessment (MRA)
- Alternative Systems Review (ASR)

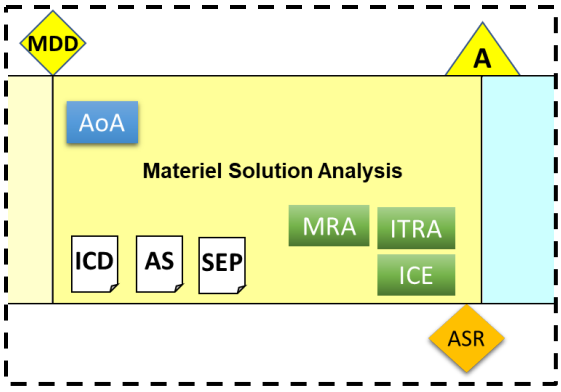

Figure 2. MSA Phase

[30] *Engineering of Defense Systems Guidebook*, Feb 2022, §3.2.1.3.1

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.[31] Once a preferred concept is selected, an ICE and an ITRA should be initiated, as both are required before granting Milestone A approval.[32] [33] [34] Either DoD Component Heads[35] or the Component Acquisition Executive (CAE)[36], 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.[37]

One of the actions necessary during the MSA phase is for the PM to develop and document the program's Acquisition Strategy, to be approved at the Milestone A Review (Appendix III). This document is the PM's plan for program execution across the entire program life cycle. The Lead System Engineer (LSE) will develop, under the direction of the PM, a SEP, as required, in order to document and guide the program's specific systems engineering activities (Appendix IV).[38] An approved SEP is required for the Milestone A decision.[39] 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.

During the MSA phase, manufacturing readiness and risk will be assessed and documented in the SEP,[40] with an MRA conducted utilizing the Manufacturing Readiness Level (MRL) process.[41] An ASR is conducted by the PM to assure the preferred concept meets requirements prior to the Milestone A Decision Review.[42] [43] Once the PM has completed an ASR which reviews the necessary analysis and the activities the program can proceed to the Milestone A decision point. 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 acquisition strategy, any PM waivers requested, release of the final request for proposals (RFPs) for TMRR activities, the exit criteria for TMRR, and the entrance criteria for the Engineering and Manufacturing Development (EMD) phase.[44]

The following subsections detail the essential SE and other activities in the MSA phase summarized above.

Analysis of Alternatives

The AoA process plays a key role in support of the MSA phase. Using study guidance developed by the DCAPE per DoDI 5000.84, the AoA is focused on cost analysis. The AoA includes "affordability analysis, sustainment considerations, early systems engineering analysis, threat projections, and coalition

[31] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.a
[32] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(3)
[33] ICE, section 2334, and section 2366a of Title 10 USC
[34] ITRA, section 2448 of Title 10 USC
[35] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §2.4.b
[36] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(2)
[37] Ibid
[38] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.4.a(1)(a)
[39] Ibid, §3.4.a
[40] Ibid, §3.6.c
[41] *SEP Outline Version 4.0*, §3.2.4.2
[42] *Engineering of Defense Systems Guidebook*, Feb 2022, §3.2.1.3.1 and Table 3.14
[43] *Systems Engineering Guidebook*, §3.1
[44] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.7.c

interoperability as identified in the ICD"[45] as part of the analysis that is input to the Milestone A decision. The updated version of DoDI 5000.84 omits instruction and discussion of selection decisions to be made during AoA, and does not include any AoA output requirements. The document ends with how to conduct an AoA, but provides no specifics (e.g., Table 2. "Perform AoA") and appears to be incomplete.[46] The IEEE 15288.2 standard states that ASR acceptability criteria (input) includes a "completed AoA." The standard states a completed AoA contains acceptable coverage of alternative solutions, adequate details of analyses, comprehensive rationale for the preferred materiel solution(s), and scoring results for the preferred system concept(s).[47]

After a program has an approved MDD, the AoA process is required to better define the trade space across cost, schedule, and performance to enable the Defense Acquisition Executive[48] and Service Sponsor to select a preferred materiel solution that addresses the capability gaps documented in the approved ICD. The AoA is an assessment of the potential identified materiel solution(s) to satisfy the capability need documented in the approved ICD. At the top level, the AoA focuses on:[49]

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

The specific analysis for each alternative should include:[50]

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

The *Analysis of Alternatives Cost Estimating Handbook* states that the AoA should identify 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.[51] The best practices detailed in GAO-15-37, "*Analysis of Alternatives* . . ." and from the *Analysis of Alternatives Cost Estimating Handbook* are in Appendix II. The

[45] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b
[46] DoDI 5000.84, *Analysis of Alternatives*, Aug 2020
[47] IEEE 15288.2, *Standard for Technical Reviews and Audits on Defense Programs,* Nov 2014, §6.2 Table 1
[48] The USD(A&S) is the Defense Acquisition Executive (DAE) and establishes policies on and supervises all elements of the Department relating to acquisition (including system design, development, and production and procurement of goods and services) and sustainment (including logistics, maintenance, and materiel readiness). DoDI 5000.85, Aug 2020, §2.1
[49] *Analysis of Alternatives Cost Estimating Handbook*, Jan 2022
[50] Ibid
[51] Ibid

handbook statements are based on observations from successful AoA cost analyses conducted in the DoD over the past five years.

According to DoDI 5000.84, §3.1.d. the DoD Component is required to submit an AoA Study Plan certifying they are ready to begin an AoA that can be competed in 9 months. If they do not believe that completion in 9 months is likely, they submit a waiver request for the Secretary of Defense approval. The date of the final AoA results briefing to the SAG is the AoA completion date.[52]

Once the AoA is complete, the operational requirements community and the acquisition community collaboratively identify one or more preferred materiel solution(s) with the potential to be the affordable, operationally effective, and suitable, sustainable, and technically and technologically achievable solution(s). The preferred materiel solution is selected by the DoD Component[53] (or potentially the MDA in joint programs).

Independent Cost Estimate

As soon as the MDD is completed, ICE planning should be initiated by the Cost Assessment and Program Evaluation (CAPE) staff. DoDI 5000.85 states that an ICE will be conducted for MDAPs before Milestone A approval.[54] The CAPE conducts or approves ICEs and cost analyses for all MDAPs and major subprograms.[55] "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."[56]

The assessment and cost estimate should begin at the AoA down select by the DoD Component or MDA.[57] The ICE will be conducted on the preferred solution before granting Milestone A approval for an MDAP.[58] The ICE is a full life-cycle cost estimate of a program and includes all costs of:[59]

- 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

All cost estimates including ICEs 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

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[52] DoDI 5000.84, *Analysis of Alternatives*, Aug 2020, §3.1 and §3.2
[53] *Systems Engineering Guidebook*, Feb 2022, §3.1
[54] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(3)
[55] Ibid
[56] Ibid
[57] DODI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(3)
[58] Ibid
[59] DoDI 5000.73, *Cost Analysis Guidance and Procedures,* Mar 2020, and pursuant to section 2334 of USC Title 10
[60] Ibid

- 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 budget(s)

Independent Technical Risk Assessment

An ITRA will be conducted before granting Milestone A approval for an MDAP.[61] For MDAPs, beginning with Milestone A, ITRAs are conducted before each acquisition milestone. 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. ITRA team members may be engaged early to enable better understanding of the risks[62]; however, the ITRA will be on the preferred materiel solution(s) after the DoD Component down select and is primarily intended to inform a Milestone A decision.

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 Appendix V. ITRAs conducted before Milestone A should identify critical technologies and manufacturing processes that need to be matured.[63]

Selection of a Program Manager

The DoD Component Head or the CAE, 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.[64] DoDI 5000.85, in describing PM selection, does not specify when selection should occur. The latest point at which to select a PM should be at the down select point of the preferred materiel solution(s) by the DoD Component.

In DoDI 5000.88, under responsibilities of DoD Component Heads, PMs "will embed the engineering disciplines, management, and technical focus described in this issuance into program planning and execution to support the entire system life-cycle."[65] This is the sole responsibility for PMs under section 2. (Responsibilities). In the section 3.3.g. (ME and Concept Development), multiple PM

[61] DODI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(3)
[62] *ITRA Execution Guide*, Dec 2020
[63] *ITRA Execution Guide*, §1.b.
[64] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(2)
[65] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §2.4.b

responsibilities are delineated for all MDAPs without specifically stating when these are to be met. In the SEP §3.4.a. (Program Technical Planning and Management), the LSE, under the direction of the PM, will develop a SEP in accordance with the *DoD SEP Outline*,[66] to document and guide the program's specific SE activities.[67]

Manufacturing Readiness Assessment

As required in DoDI 5000.88, the Production, Quality, and Manufacturing (PQM) Lead[68], working for the PM, will ensure manufacturing, producibility, and quality risks are identified and managed throughout the program's lifecycle.[69] This begins in the materiel solution analysis phase with manufacturing readiness and risk assessed using the MRL process and documented in the SEP, as stated in the DoD *SEP Outline*.[70] Assessments of manufacturing maturity utilizing the MRL criteria 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 as specified in the MRL 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 MRL Deskbook provides "best practices" for conducting assessments of manufacturing maturity and risk using the MRL criteria. It is intended for those tasked with conducting MRL Assessments, as well as acquisition program managers, system engineers, manufacturing managers, quality managers, and managers of technology development and pre-systems acquisition technology demonstration projects. [71]

A review of M&Q activities assessed by 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. Additionally, the ITRA methodology does not assess actual quality activities 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.

An MRA using MRL criteria should be conducted on the selected concept to MRL 4 criteria. As part of the MRA, consider the section in *The Early Manufacturing and Quality Engineering Guide* that suggests Essential Manufacturing Functional Inputs to the ASR by asking the following questions:

- What are the production limits on the number of prototype units that might be developed?
- Have facility requirements been identified to support the prototype build?
- Have material requirements been identified, and are all materials available (long lead, sole source, foreign source, etc.)?
- Are hazardous materials embedded in the system or used in manufacturing processes?

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[66] https://ac.cto.mil/wp-content/uploads/2021/10/SEP-Outline-4.docx
[67] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.4.a(3)
[68] This is the sole requirement that references "PQM Lead" as a functional personnel description in all DoD documents referenced in this paper.
[69] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.6.c
[70] https://ac.cto.mil/wp-content/uploads/2021/10/SEP-Outline-4.docx, §3.2.4
[71] *Manufacturing Readiness Level Deskbook*, Jul 2022

- Has Programmatic Environmental, Safety, and Occupational Health Evaluation (PESHE) and National Environmental Policy Act (NEPA) compliance planning been initiated?
- Has the schedule been evaluated for M&Q impacts?
- Has a project plan been developed with a critical path identified for design build?
- Have cost estimates been developed, and do they identify M&Q cost drivers?
- Has the WBS been evaluated, and have risks been identified to include M&Q risks?
- Have design alternatives been identified and evaluated for M&Q risks?
- Has the program office conducted any modeling and simulation on the preferred concept?
- Have any trade studies been identified, and do they include M&Q concerns?

The *Guide* does not require an MRA in MSA phase, it suggests asking the above questions which are based on MRL criteria. The *SEP Outline*, on the other hand, does require an MRA using MRL criteria. The results of the assessment using MRL 4 criteria should be provided to the program for the ASR. The results of this assessment should also be an input to the ITRA, as well as to the Milestone A decision.

Alternative Systems Review

The *Engineering of Defense Systems Guidebook* includes discussion of the ASR as a Best Practice. The *Guidebook* states that "During the MSA phase the typical program review is the Alternative Systems Review (ASR)"[72], but this statement does not adequately emphasize the importance of holding this review, nor is it recommended as a Best Practice. In Table 3-1 of the *Guidebook*, the objective of the ASR is to provide a "Recommendation that the preferred materiel solution can affordably meet user needs with acceptable risk"[73]. ASR is a technical maturity point where system parameters are defined and balanced with cost, schedule, performance, and risk. During ASR, the initial system performance is established and a plan for further analyses to support the Milestone A criteria (decision) is also established.

The suggested Best Practice standard[74] is IEEE 15288.2, *Standard for Technical Reviews and Audits on Defense Programs,* Nov 2014. The *System Engineering Guidebook* lists an abbreviated summary of ASR products and criteria extracted from IEEE 15288.2, Table 6.1, to be reviewed at the ASR, including:

- Refined joint requirements
- Initial architecture for the preferred materiel solution(s)
- System functional and performance requirements documentation
- Preferred materiel solution(s) documentation
- Program risk assessment

However, the *Systems Engineering Guidebook* does not include definitive ASR details, but instead references IEEE 15288.2, and only recommends ASR as a best practice review. This *Guidebook* concludes with a single statement that defines ASR outputs and products as a "refined description of the preferred materiel solution to support further development,"[75] but provides no further direction on the ASR. In contrast, as discussed in the IEEE standard, the exit criteria and the closure of the review should address all action items, documentation, technical review products, funding requirements, and risk assessments.[76]

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[72] *Engineering Defense Systems Guidebook*, Feb 2022
[73] ibid
[74] *Best Practices for Using Systems Engineering Standards (ISO/IEC/IEEE 15288, IEEE 15288.1, and IEEE 15288.2) on Contracts for Department of Defense Acquisition Programs*, Apr 2017
[75] *Systems Engineering Guidebook*, Feb 2022, §3.1
[76] IEEE 15288.2, *Standard for Technical Reviews and Audits on Defense Programs,* Nov 2014, §5.2.6 and §6.2.4

DoDI 5000.85 states that "the (MSA) phase ends when the DoD Component has completed the necessary analysis and the activities necessary to support a decision to proceed to the next decision point/phase in the acquisition process."[77] Again, mentioning the activities needed, only implying a review be conducted, but does not require an ASR. The question is what other guidance, process, or activity determines that all the analyses and activities are complete. This is answered by IEEE 15288.2, "the ASR shall be conducted to help ensure the preferred materiel solution 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."[78]

In DoDI 5000.88, every other major Milestone and/or decision point is preceded by a formal technical review of the program, including a "concept design review" before MDD (§3.3.e.), a Preliminary Design Review (PDR) prior to Milestone B, and a Production Readiness Review (PRR) prior to Milestone C. The exception is Milestone A.

Milestone A Decision

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

Principal considerations include:[79]

- Justification for and the affordability and feasibility of the preferred military 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 acquisition strategy, including intellectual property, 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:[80]

- The PM will present the acquisition strategy, the business approach, "Should Cost" targets, framing assumptions, an assessment of program risk and planned mitigation actions, and initial Program Support 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

[77] DoDI 5000.85, *Major Capability Acquisition*, Aug 2020, §3.6.b(5)
[78] IEEE 15288.2, *Standard for Technical Reviews and Audits on Defense Programs,* Nov 2014, §5.2.1
[79] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.7.a.
[80] Ibid, §3.7.b.

- Pursuant to section 2366a of Title 10 USC, 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 USC, or other authorities, as appropriate
  - The MDA must have an effective plan for adoption or insertion by the relevant program

Milestone A Decisions:[81]

- The MDA will approve:
  - Acquisition strategy 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 EMD phase
- The MDA will document decisions in an ADM

The above Milestone A guidance from DoDI 5000.85 (sections 3.7.a, b., and c.) does not explicitly call for review of the mandated ITRA, the mandated ICE, the statutorily required SEP[82] with MRA[83], and the ASR outputs. The ICE and ITRA are mentioned as requirements in DoDI 5000.85 to be conducted in the MSA phase section (3.6), but not in the Milestone A section (3.7)."[84]

Pursuant to section 2448b of Title 10, USC, ITRAs are required for MDAPs.[85] This is stated as: "In General, with respect to a major defense acquisition program, the Secretary of Defense shall conduct or approve ITRAs before any decision to grant Milestone A approval for the program pursuant to section 2366a of this title, that identifies critical technologies and manufacturing processes that need to be matured."

Additionally, according to the *DoD Cost Estimating Guide*, Dec 2020, section 2334 of Title 10 USC establishes the DCAPE statutory authority for independent cost estimation and cost analysis. Furthermore, section 2366a defines the responsibilities, written determination, and submissions required for an MDAP to receive Milestone A approval. As part of the determination prior to granting Milestone A approval, the DCAPE must concur that the level of resources required to develop, procure, and sustain the program is sufficient for successful program execution. Additionally, the program MDA is required to submit the program cost and schedule estimates, as well as the ICE, to the Congressional Defense committees.

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[81] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.7.c.
[82] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.4.a
[83] *SEP Outline Version 4.0*, §3.2.4
[84] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020, §3.6.b(3)
[85] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, For programs initiated or having a Milestone A after October 1, 2017. For programs initiated or having a Milestone A before October 1, 2017, ITRAs are regulatory and may be waived at the discretion of the USD(R&E). Formal requests will provide appropriate justification and will be submitted through the MDA.

Conclusions and *Recommendations*

The Adaptive Acquisition Framework (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 documentation, the updated acquisition guidances provide descriptions of the activities that are required, but the descriptions are not consistent with the stage of development or appear to be an incomplete term, or at times conflict between the various acquisition documents. While the ultimate impact of the updated acquisition guidance released in support of the AAF process has yet to realized, these updates have streamlined some processes. It is recommended that the inconsistencies and omissions should be addressed that are covered in the following sections.

The overarching AAF graphic (see Appendix I, Figure 1) shows a black diamond labeled "Pathway Selection." In the attempt to simplify a complex process, the graphic does not adequately (nor accurately) depict the analyses, evaluations, and engineering activities that lead to a pathway selection.

> *The AAF pathway selection process should be, at a minimum, included and delineated in the AAF Guidance, DoDI 5000.02.*

Concept Design Review

There is inconsistency between guidance documents in the discussion and details concerning CoDR. The CoDR is described in detail in the *Engineering of Defense Systems Guidebook,* not mentioned in any section of the *Systems Engineering Guidebook,* and included in DoDI 5000.88, but only generally described in one subsection.

> *DoDI 5000.88 and the Engineering of Defense Systems Guidebook should be consistent in descriptions and content for Pre-MDD activities including ME, MIM, MR, and CoDR. The Systems Engineering Guidebook should include consistent descriptions and content for ME, MIM, MR, and CoDR.*

Additionally, in the *Engineering of Defense Systems Guidebook,* it is stated that one of the outputs of the CoDR is an "informed DAS alternative pathway selection." The guidance does not discuss the details required to support that decision.

> *The alternative pathway selection process as stated in CoDR needs further details and specific definition, which should be consistent with all the guidance documents.*

Materiel Development Decision

During the MDD process specified in DoDI 5000.85, the MDA will determine the acquisition phase of entry and the initial review milestone. The MDD decision process leads to an ADM that includes program staffing and funding activities to reach the next decision point, usually Milestone A. However, in DoDI 5000.85, there is no mention of Pre-MDD activities.

> *DoDI 5000.85 should include a discussion of the activities such as ME, MR, and CoDR that should be included as part of the MDD, referencing other guidance for details and consistency.*

DoDI 5000.88 extensively addresses Pre-MDD activities and includes the CoDR chaired by the DoD Component (or USD/(R&E) designee for joint programs), provides consolidated, coordinated, and significant inputs to the MDD, allowing an informed decision. However, there is no discussion of the MDD process in DoDI 5000.88.

DoDI 5000.88 should include a discussion of MDD detailing the inputs from Pre-MDD engineering activities, ME, MIM, MR, and CoDR, to be included as part of the MDD.

To clarify terminology in referring to the object of the acquisition program (weapon system, subsystem, etc.), there should be a designation consistent with the development timeline before and after the MDD.

Use of "concept", "preferred concept", etc., should only occur pre-AoA. Use of "preferred materiel solution(s)" should only occur post-AoA.

AoA

Preceding the Milestone A decision in an MCA program, the MSA phase's purpose is to conduct an AoA and perform *other activities* needed to choose the concept(s) with requirements in DoDI 5000.85. The AoA discussion in DoDI 5000.84 is overly focused on cost analysis, which includes sustainment considerations, threat projections, and interoperability as part of the analysis. However, it omits instruction and discussion of selection decisions to be made during AoA, and does not include any AoA output requirements. Currently the operational requirements community and the acquisition community collaboratively identify one or more preferred materiel solution(s) not the AoA. DoDI 5000.84 ends after how to conduct an AoA, and provides no specifics, or recommendations, and appears to be incomplete.

DoDI 5000.84 should be updated to require a recommendation for one or more preferred materiel solution(s) and to include selected Best Practices from GAO-15-37 and from the Analysis of Alternatives Cost Estimating Handbook, Jan 2022*, which are in the AoA Appendix.*

ICE

DoDI 5000.85 states that an ICE will be conducted for MDAPs before Milestone A approval, it does not state what the ICE is to address. DoDI 5000.88, *Engineering of Defense Systems*, adds additional inconsistencies. The first is the requirement that prior to MDA approval of Milestone A, only an ITRA must be performed. This is to provide a view of program technical risk, independent of the program. This requirement is not consistent with DoDI 5000.85, which states both an ICE and an ITRA will be conducted before granting Milestone A approval for an MDAP.

DoDI 5000.88 should be updated to include the requirement for both an ITRA and an ICE prior to Milestone A as affordability is a concern in engineering defense systems to improve consistency between both documents.

ITRA

DoDI 5000.85 states that an ITRA will be conducted for MDAPs before Milestone A approval, but it does not specify what the ITRA should address. The *ITRA Execution Guide*, Dec 2020, states that ITRA team members should be engaged throughout the concept development, Industry Days, and the AoA, which will enable the team to better understand the risks. The engagement in concept development and Industry Days implies that the ITRA team exists prior to MDD.

The establishment of an ITRA team should not begin earlier than the MSA phase and the ITRA should be on the selected materiel solution(s). This should be clarified in both DoDI 5000.88 and DoDI 5000.85.

A review of the M&Q "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. ITRAs do not provide the thorough and accurate evaluation against established metrics of manufacturing and quality risks, issues, and opportunities that are provided by an MRL assessment. Additionally, the ITRA methodology only has limited "quality activities" because they are considered a "performance and quality" factor for each area. Most of the "evaluation criteria" in an ITRA do not relate to nor address quality, and do not include Quality as a risk area. Quality was paired with "performance" as a factor for all risk areas (see Appendix III).

> *Quality should be considered as a stand-alone risk area, like manufacturing, or evaluation of quality should be combined with Manufacturing as a Manufacturing & Quality risk area in the ITRA methodology*.
>
> *The MRA performed on the preferred materiel solution(s) should be a required input to the ITRA.*

PM

Selection of the PM is scattered across three DoDIs. The selection process and duties and responsibilities need to be clarified in DoDI 5000.02 and all corresponding related documents.

In DoDI 5000.85, §3.2 (Flexible Implementation), the guidance for MCA specifies the duties and responsibilities of the PM. "PMs will "tailor-in" the regulatory information that will be used to describe their program at the MDD or program inception." This appears to be in conflict with the requirement for assigning a PM in DoDI 5000.85, §3.6.b.2. (MSA Phase Description). "During this phase, the CAE will select a PM and establish a program office to complete the actions necessary to plan the acquisition program and prepare for the next decision point." In section 3.6 there is guidance on when to select and appoint a PM and establish a program office, however this is not under the Responsibilities Section in DoDI 5000.85, §2.3.

> *DoDI 5000.02 should specify the selection process, duties, and responsibilities of the PM.*
>
> *DoDI 5000.85 should clearly designate the timing and responsibility for assigning a PM to an MDAP (i.e., clearly designate the responsibilities of the PM in the appropriate section, and at the appropriate point in the acquisition process). PM assignment should occur no later than the preferred materiel solution(s) downselect point.*

In DoDI 5000.88, §2.4.b (Responsibilities), DoD Component Heads are directed to "appoint PMs who will embed the engineering disciplines, management, and technical focus described in this issuance into program planning and execution to support the entire system life-cycle [sic]." This is the overarching statement on the responsibilities of the PM; however, there are numerous "the PM will" statements in the balance of DoDI 5000.88 delineating additional PM responsibilities.

> *DoDI 5000.88 should clearly delineate the duties and responsibilities of the PM with respect to Systems Engineering.*
>
> *DoDI 5000.02, DoDI 5000.85, DoDI 5000.88, and any other DoDIs, guidance documents, handbooks, etc., on the selection, duties, and responsibilities of the PM should be harmonized.*

MRA

To ensure identification and management throughout the program lifecycle [sic], an assessment of manufacturing readiness and risk with documentation in the SEP begins in the MSA phase.[86] The method of assessment is buried in DoDI 5000.88, §3.4.a.(3t), which refers to factors in sections 3.6 and 3.7 of the *Systems Engineering Guidebook*. The method described in the *Systems Engineering Guidebook*, §5 (Design Considerations), as only one aspect among 24 other design considerations. Additionally, section 5.14.5 of the *Guidebook* discusses using the MRL process for such assessments. Furthermore, in DoDI 5000.88, §3.4.a.(1a).2, the LSE is required to develop the SEP in accordance with the *SEP Outline*, which in section 3.2.4.2 requires that the assessment is to be performed using the MRL process. The *SEP Outline* requires an MRA using MRL criteria.

> *In order to provide the PM with sufficient identification of critical technologies and manufacturing processes that need to be matured, pursuant to section 2448b of Title 10, USC, an MRA using the MRL process on the preferred materiel solution(s) should be required.*
>
> *The results of this assessment using MRL 4 criteria should be provided to the program for the ASR.*
>
> *The results of this assessment should also be an input to the ITRA and the ICE, as well as to the Milestone A decision.*
>
> *DoDI 5000.88, DoDI 5000.85, and the Early M&Q Engineering Guide should include a requirement for an MRA using MRL criteria with results documented in the SEP as part of the MSA phase.*

ASR

DoDI 5000.85 has requirements for an ICE, an ITRA, initial product support and sustainment planning, and other activities. However, it does not have a requirement for an SE technical review, the ASR, prior to Milestone A. (DoDI 5000.85 does require a PDR prior to Milestone B.)

DoDI 5000.88 requires SE technical reviews to establish the technical baselines, assess the system's technical maturity, and review and assess technical risks (DoDI 5000.88, §3.5.a.) The instruction requires the following technical reviews prior to program decision points: System Requirements Review or System Functional Review, Preliminary Design Review, Critical Design Review, System Verification Review or Functional Configuration Audit, Production Readiness Review, and Physical Configuration Audit. The omission in this list of required reviews is ASR for Milestone A.

> *DoDI 5000.85 should be updated to include the required SE technical reviews prior to the decision points. This includes an ASR prior to Milestone A.*
>
> *An ASR should be included as the required technical review for Milestone A in the list of required technical reviews in DoDI 5000.88, §3.5.a. An ASR should be included as the required review to provide consolidated analysis and recommendations to the Milestone A decision process. An ASR will provide consolidated analysis and recommendations by the program to the Milestone A decision process and is essential for System Engineering. It should also be included as a requirement in the other guidance documents, not merely a "Best Practice." The Systems*

[86] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.6.c.(1)

Engineering Guide and the Engineering of Defense Systems Guidebook should also be updated to include this requirement.

Milestone A

While the guidance from DoDI 5000.85, §3.7 includes multiple considerations (i.e., affordability, technology maturity, risks, acquisition strategy, etc.) and the PM and the DoD Component are required to present outputs and analyses from the MSA phase activities, there are several required activities not included. Milestone A guidance from DoDI 5000.85 (sections 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 (DoDI 5000.88, §3.4.a; *SEP Outline Version 4.0*, §3.2.4), 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)."

Updates to DoDI 5000.85, §3.7.b. "At the Milestone A Review," should explicitly call for review of the mandated ITRA, the mandated ICE, the statutorily required SEP with MRA, and the ASR outputs.

Summary

In this paper we examined the essential SE processes in early DoD systems acquisition from Pre-MDD, through the MSA phase, to Milestone A. This was a "challenging" discovery process that required a search across multiple sources, documents, guidances, statutes, and standards to delineate the essential elements for a coherent and consistent MCA process. In development of defense systems, System Engineering practices need to be specified and required regardless of acquisition pathway, even if a "tailored" process is utilized. Additional changes in other DoD instructions and guides are required to bring completeness and consistency to DoD acquisition guidance and to enhance and streamline the acquisition process while still employing sound Systems Engineering and industry Best Practices.

Appendix I. AAF

The AAF (**Figure 1.**) was established in this update to enable faster delivery of systems and/or capabilities through the means of multiple acquisition pathways and tailored processes.

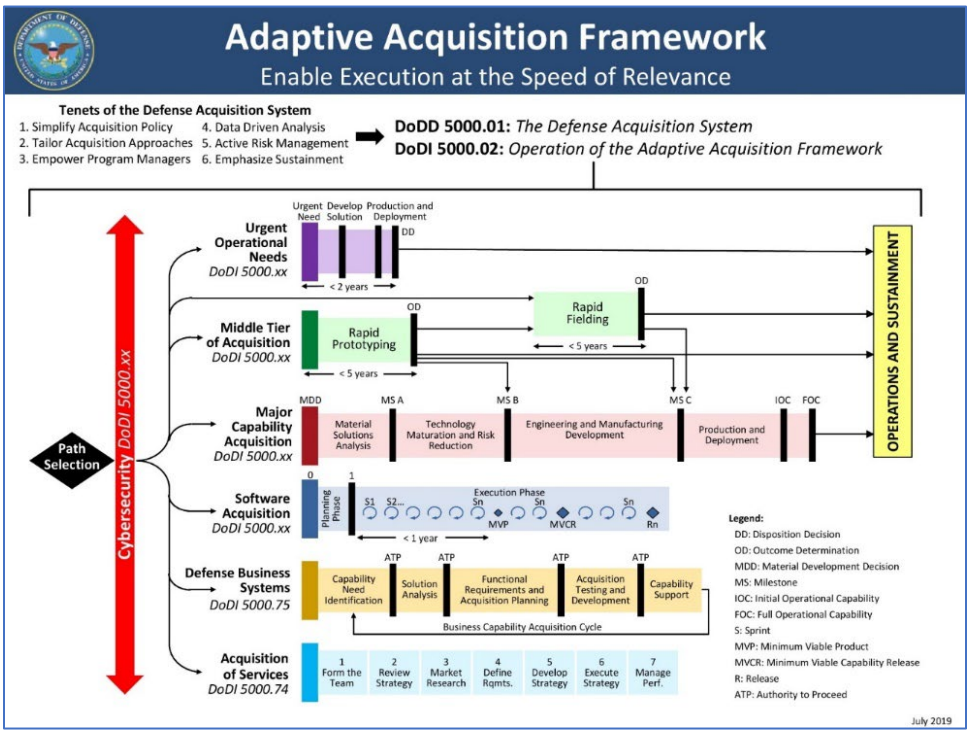

Figure 1. Adaptive Acquisition Framework

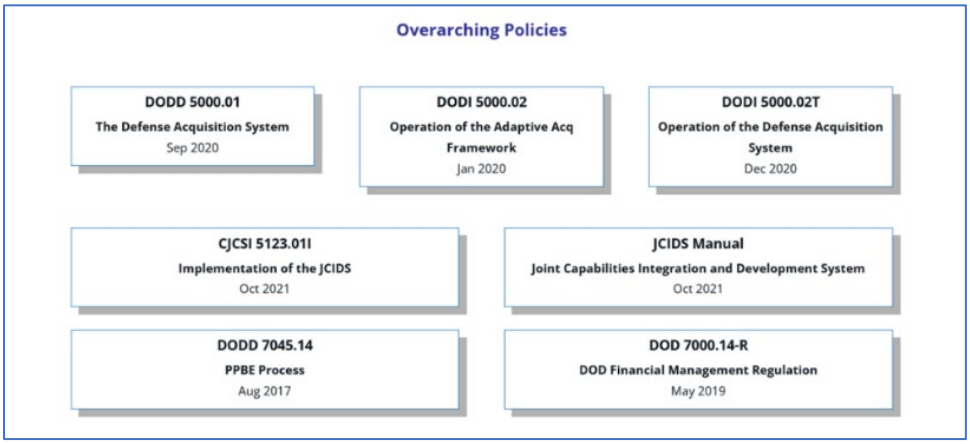

Figure 2. Overarching Policies

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.**).

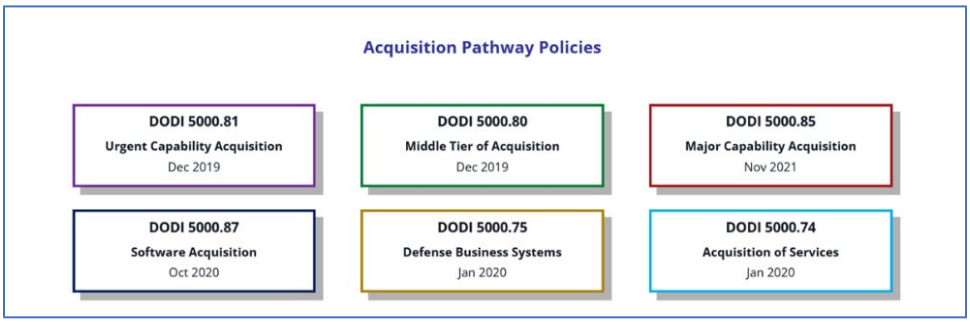

Figure 3. Acquisition Pathway Policies

Instructions for each pathway (**Figure 3.)** and instructions for all pathways were created (**Figure 4.**).

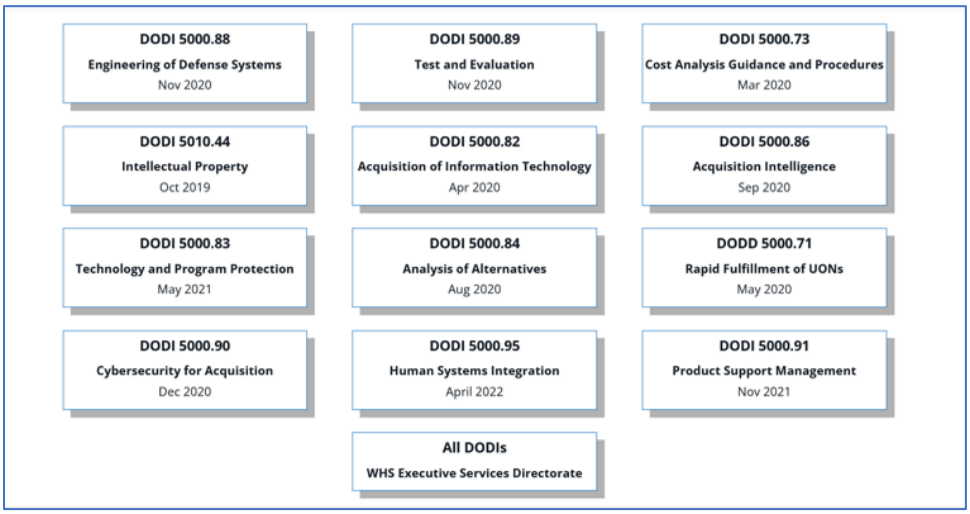

Figure 4. Pathway and Engineering Guidance

Additionally, updated guidance for each pathway and engineering discipline, such as Systems En*gineering Guidebook*, was updated (**Figure 5.**).

Figure 5. Other Engineering Guidance

As previously noted, several of the guides (with dotted lines) in **Figure 5.** are placeholders. Many of these guides complement and endorse the previously developed Industry standards such as the IEEE 15288 series, SAE AS9100 series, and SAE AS6500.

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 OUSD/(A&S)
- 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. AS

According to DoDI 5000.85, Appendix 3C.3, the PM will develop and execute an approved acquisition strategy. This document is the PM's plan for program execution across the entire program life cycle.

- The strategy is 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. The strategy evolves over time and should continuously reflect the current status and desired goals of the program.
- The strategy should address capability requirements for system performance likely to evolve during the life cycle because of evolving technology, threat, or interoperability needs or to reduce program cost or schedule and enable technology refresh. The acquisition strategy defines the relationship between the acquisition phases and work efforts, and key program events such as decision points and reviews.
- The strategy must reflect the PM's understanding of the business environment; technical alternatives; small business strategy; costs, risks and risk mitigation approach; environment, safety, and occupational health (ESOH) risk and requirements management approach; contract awards; the incentive structure; test activities; manufacturing and quality approach and risks; production lot or delivery quantities; operational deployment objectives; opportunities in the domestic and international markets; foreign disclosure, exportability, technology transfer, and security requirements; and the plan to support successful delivery of the capability at an affordable life-cycle price, on a realistic schedule. Acquisition strategies are baseline plans for the execution of the program and should be prepared and submitted in time to obtain approval to support more detailed planning and the preparation of RFPs.
- The strategy is an approved plan; it is not a contract. Minor changes to the plan reflected in the acquisition strategy due to changed circumstances or increased knowledge are to be expected and do not require MDA pre-approval. Major changes, such as contract type or basic program structure, do require MDA approval prior to implementation. All changes should be noted and reflected in an update at the next program decision point or milestone.

Appendix IV. SEP

The purpose of the SEP is to assist PMs to develop, communicate, and manage the overall SE approach that guides all technical activities of the program. The SEP documents technical risks, performance evolution strategy (including use of a modular open systems approach to the maximum extent practicable), processes, resources, metrics, SE products, organizations, design considerations, and completed and scheduled SE activities. The SEP is a living document that should be updated as needed to reflect the program's evolving SE approach or plans and current status. The SEP must be approved by USD/(R&E) or designee prior to Milestone A, according to DoDI 5000.88, §3.4.

In accordance with DoDI 5000.88, the SEP will contain the following elements unless waived:

- Overall technical approach
- Engineering management approach
- Software development approach
- Engineering trade-off analyses
- Planning assumptions,
- Program's integrated master plan (IMP) and integrated master schedule (IMS) process
- Specific technical performance measures and metrics
- Specific technical data, format, frequency
- Reliability growth curve(s)
- Required contract deliverables, technical data, design artifacts, and the periodicity of reporting.
- Timing, conduct, and entry and exit criteria for technical reviews.
- Description of technical baselines
- Digital engineering implementation plan
- High-level description of the CONOPS
- Development strategy enabling early and continuous testing
- Plan to assess and document the technology maturity
- Program's major technical risks, issues, opportunities, and mitigations and planning activities.
- MOSA and program interdependencies
- Plan to manage intellectual property
- Specialty engineering and architectural factors

Appendix V. ITRA

According to DoDI 5000.88, *Engineering of Defense Systems*, MDAPs beginning with Milestone A, ITRAs are conducted before each acquisition milestone (3.5.b(1b)). 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 (3.5.b(2)).

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 (3.5.b(1d)).

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 preferred materiel solution(s) after the DoD Component downselect as stated in the *DoD ITRA Executive Guide*, Dec 2020.

Manufacturing Risk Area Criteria

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. Ao, 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.