APT
Advanced Product Transitions Corp.

Manufacturing Readiness Level (MRL) Guidebook

Version 2026

5 May 2026

Advanced Product Transitions Corporation

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Document Revisions

This Guidebook is not a Department of War (DoW) publication. It is intended as a supplement to the 2025 MRL Deskbook. This Guidebook includes excerpts from APT's publications, as well as materials discussed by the MRLWG, but not in the Deskbook. It also includes, APT's Systems Engineering and manufacturing experience, TRL and MRL training, assessments, and feedback experience from multiple Industry sectors and interactions both domestic and international.

2026-04-30 First publication

Advanced Product Transitions Corp.

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Executive Summary

This *Guidebook* is intended as a complement to the *2025 MRL Deskbook*, but includes essential MRL material beyond what is in the Deskbook. It is written with the understanding that the DoW is in the process of restructuring department activities by means of the Acquisition Transformation Strategy (ATS). If changes to the Major Capability Acquisition process, as a result of the ATS, have an impact on the MRL process, this document will be updated.

This *Guidebook* contains eight sections addressing specific topics as follows:

- The description and definitions for use of MRLs and MRL assessments are discussed in §2.0 , which is similar to the material in the *2025 MRL Deskbook*.
- Section 3.0 introduces the concept of phased maturity, where the lower tier subsystems, items, and components are required to be more mature than the upper level.
- Section 4.0 describes how MRL assessments integrate into the Major Capability Acquisition Life-Cycle by phase, from Pre-Acquisition through Production & Deployment.
- Section 5.0 is a discussion of streamlined MRL assessments, which is intended to reduce the burden of assessments.
- Section 6.0 is a discussion of the MRL-TRL alignment based on best practices versus the MRL-TRL relationship presented in the 2025 MRL Deskbook.
- Sections 7.0 and 8.0 discuss the use of maturity and risk assessments for Rapid Prototyping, Rapid Fielding, and Urgent Capability Acquisition as in the Adaptive Acquisition Framework.

There are also multiple appendices addressing specific topics:

- Appendix A shows how MRLs integrate and complement the Systems Engineering process, beginning with the Concept Design Review through requirements, preliminary and critical design, production readiness, and the final configuration audit.
- Appendix B is a description of a system level assessment, including how to incorporate phased maturity into the assessment process.
- Appendix C is a discussion of the key product resulting from the MRL assessment, an MMP, which addresses the manufacturing risks and provides a mitigation plan for each risk area, including supplier and sub-tier supplier risk management shortfalls.
- Appendix D contains additional discussions of TRL and MRL assessments of Science & Technology and Manufacturing Technology programs, as well as the transition to pre-acquisition concepts, experimenting, and prototyping.

- Appendix E is a discussion of the Digital Manufacturing Maturity Framework developed by the MRL Working Group to assess the level digital manufacturing maturity is assessed organizations.
- Appendices F and G show the detailed MRL Matrix criteria for full MRL and streamlined MRL assessments. The matrices incorporate the discussion of TRLs in §6.0, increasing the level of TRL maturity to recommended best practices.

In summary, this Guidebook is intended as a supplement to the 2025 MRL Deskbook. It includes materials not in the Deskbook, but discussed by the MRLWG. This Guidebook also includes excerpts from APT's publications, material based on APT's Systems Engineering and manufacturing experience, APT's TRL and MRL training and assessments, and feedback from multiple Industry sectors including interactions both domestic and international.

1.0 Introduction

Purpose and Scope

This Guidebook is intended for use by those tasked with conducting MRL Assessments and is based on lessons learned, best practices in manufacturing, collected requirements from DoW policy, and real-life manufacturing experience of industry and government.

The goal of all acquisition programs is to put required capability in the field in a timely manner with acceptable affordability and supportability. MRL Assessments aid this effort by increasing understanding of manufacturing maturity, and identification and management of manufacturing risk. This ultimately aids program success through cost, schedule, and performance improvements. MRL metrics assist acquisition Program Managers (PM) mitigate these risks.[1]

This Guidebook provides best practices for conducting assessments of manufacturing maturity and risk during the Major Capability Acquisition life-cycle (MCA) shown in Figure 1-1. The consideration of manufacturing maturity and risk begins before the Materiel Development Decision (MDD). The understanding of technology and manufacturing maturity is essential and begins with Science & Technology (S&T) and Manufacturing Technology (ManTech) program projects. As product development becomes of interest to system developers, concepts are examined, experimentation is conducted, and prototypes are produced. Technology and manufacturing maturity is developed to support rapid and affordable development into a system.

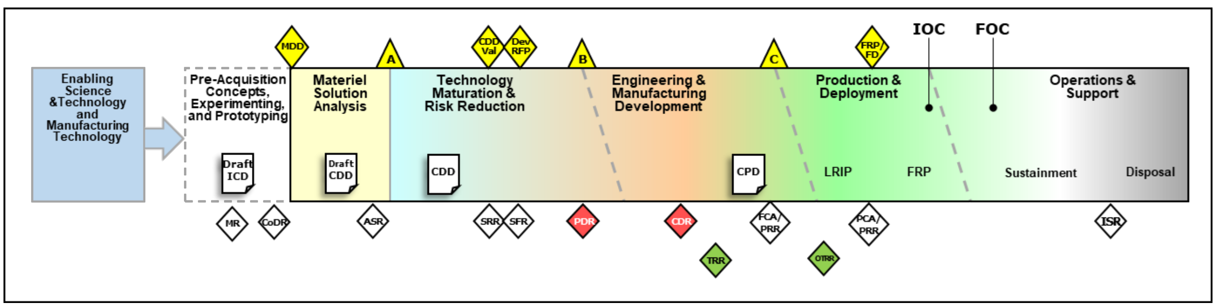

Figure 1-1 MCA Life-Cycle

This Guidebook also provides information on how to apply assessment using the MRL criteria not only at the MCA level, but also how to apply risk identification activities to projects and programs without Milestone Decisions.

The following sections of this Guidebook describe:

[1] *MRL Deskbook 2025*

- MRL definitions, subject area threads, the criteria matrix organization, and MRL environments (Section 2) with reference to Appendix G
- Manufacturing programs and Phased Maturity (Section 3)*
- MRLs for Major Capability Acquisitions (Section 4)
- Streamlined MRLs and their application (Section 5)*
- The MRL–TRL alignment in DoW acquisitions (Section 6)*
- MRLs for Middle Tier Acquisitions (Section 7)
- MRLs for Urgent Capability Acquisitions (Section 8)

This Guidebook also includes:

- The MRL Role in Systems Engineering (Appendix A)*
- Conducting MRL Assessments (Appendix B)
- Manufacturing Maturation Plan (Appendix C)
- MRLs and TRLs Prior to MDD (Appendix D)
- Digital Manufacturing Maturity Framework (Appendix E)*
- Acronyms (Appendix F)
- Detailed MRL Matrix Criteria (Appendix G) (all criteria with larger format for printing)
- Detailed Streamlined MRL Matrix Criteria (Appendix H) (System and Lower Tier)*

The items above designated by * are subjects that are part of the MRL process or the Acquisition process not covered in the MRL Deskbook. There are two areas in the Deskbook not included here: 6.0 Contract Language and Appendix C – Effectively Adapting and Using MRL Criteria.

Note: For the purposes of this Guide, the use of *responsible organization* refers to the group performing the MRL assessment. The term *assessed organization* is intended to refer to those performing the acquisition activities. They can be the same organization in the case of an internal (self) assessment.

Note: The MRL Body of Knowledge (BoK) beyond this document can be found at the DoD MRL website DoDmrl.org or DoDmrl.com.

2.0 Manufacturing Readiness Levels

Overview of MRLs

The MRL process is organized by having criteria in a matrix that consists of 10 levels of maturity against nine subject area threads with subthreads for each level. Maturity is the left to right scale of the matrix from MRL 1 to MRL 10. The subject areas are the top to bottom scale with items such as cost, materials,

MRL Maturity Definitions

MRL maturity criteria are comprised of 10 levels. The table below (Figure 2-1) shows the basic definition, the description, and a brief explanation of each maturity level.

MRL	Definition	Description	Explanation
1	Basic manufacturing implications identified	Basic manufacturing implications identified	Criteria addresses manufacturing research, state-of-the-art techniques, and advanced manufacturing processes not yet in the mainstream of manufacturing.
2	Manufacturing concepts identified	Manufacturing concepts identified	
3	Manufacturing proof of concept developed	Manufacturing proof of concept developed	
4	Capability to produce the technology prototype in a laboratory environment	Capability to produce the materiel solution (prototype product) that includes the "new technology" in a laboratory environment (includes digital)	Criteria addresses identification of the maturity of the manufacturing processes, procedures, and techniques for the selected materiel solution (product).
5	Capability to produce prototype components in a production-relevant environment	Capability to produce prototype product (selected solution) in a production-relevant environment (includes digital)	Criteria addresses maturation of the needed manufacturing processes, procedures, and techniques (could be simulation) for the product to meet requirements.
6	Capability to produce a prototype system or subsystem in a production-relevant environment	Capability to produce a product preliminary system design in a production-relevant environment (includes digital)	Criteria addresses maturation of the needed manufacturing processes, procedures, and techniques (could be simulation) to manufacture a preliminary design product.
7	Capability to produce system, subsystems, or components in a production-representative environment	Capability to produce a product detailed design in a production-representative environment	Criteria address maturation of manufacturing processes, procedures, and techniques for the product, to manufacture a detailed design product.
8	Pilot line capability demonstrated; ready to begin LRIP	Capability to produce products on a Pilot line; ready to begin LRIP	Criteria encompasses demonstrating the manufacturing processes, procedures, and techniques for the product on the designated "pilot line"

9	Low-rate production demonstrated; capability in place to begin FRP	Capability to produce products in low rate production; capability in place to begin FRP	Criteria address meeting quality, throughput, and rate to enable the product manufacturing to transition to FRP.
10	Full-Rate Production demonstrated and lean production practices in place	Capability to produce products in full rate production; lean production practices in place	Criteria measure aspects of lean practices and continuous improvement for product manufacturing in ongoing production.

Figure 2-1 TRL Definition, Description, and Explanation[2]

MRLs begin at pre-systems acquisition, progress through the Systems Engineering Technical Review (SETR) process, the acquisition decision points and milestones, and culminate in production. Each of these levels are associated with the evolution of system maturity (*i.e.*, developmental state changes such as breadboard, brass-board, prototype, production configuration, Low-Rate Initial Production (LRIP), Full-Rate Production (FRP)). The criteria address maturation of the required manufacturing processes, procedures, and techniques specific to the maturity of the product in the acquisition life-cycle.

The Figure 2-2 below is a depiction of the DoW MCA life-cycle, beginning with the pre-acquisition activities. Manufacturing processes are developed and matured during the early phases before the acquisition process begins. During S&T and ManTech development projects, maturity can be advanced to almost "operational" levels (i.e., MRL 7). The planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects are part of the processes prior to the MDD including experimenting and prototyping. All of these activities should enable candidate concepts to mature to a minimum of MRL 3 for the MDD.

Post MDD, the Materiel Solution Analysis (MSA) phase is focused on identification of a preferred concept and an analysis of alternatives, as guided by the Initial Capabilities Document (ICD), the Analysis of Alternatives (AoA) Study Guidance, and AoA Study Plan. The resulting preferred materiel solution should provide adequate knowledge of manufacturing risks with the manufacturing maturity achieving a minimum MRL 4 for a Milestone A decision.

The purpose of the Technology Maturation and Risk Reduction (TMRR) phase is to reduce technology, engineering, integration, and life-cycle cost risk. At this point a decision to contract for Engineering and Manufacturing Development (EMD) can be made with confidence in successful program execution for development, production, and

[2] *Technology Readiness Assessment Guidebook,* Feb 2025

sustainment. The focus for TMRR should be on whether subsystems, items, and components are sufficiently matured to ensure product preliminary design is robust and ready to proceed into system/product EMD with minimal risks. The product level manufacturing maturity should achieve a minimum MRL 6 for Milestone B.

The purpose of the EMD phase is to develop, build, test, and evaluate the product and verify that all operational and implied requirements (including those for security) have been met, and support production, deployment, and sustainment decisions. In the early EMD, from Milestone B to the Critical Design Review (CDR), product development will complete all needed hardware and software detailed designs. At the CDR, the minimum MRL is 7.

Post-CDR, the program proceeds into fabrication, system integration, and demonstration and test. Stated performance requirements should be met within budget, schedule, risk, and other system constraints. The EMD phase ends with the Milestone Development Authority's (MDA's) decision at Milestone C to approve and authorize the program to proceed to the Production & Deployment (P&D) phase and enter initial production (LRIP). At this point, the product should meet manufacturing maturity of MRL 8.

Post Milestone C, the product is in LRIP. The purpose of this next phase, P&D phase, is to achieve an operational capability that satisfies mission needs. In LRIP, the production effort should target the MRL 9 criteria and metrics to be met prior to the FRP decision to mitigate risks to an acceptable level.

After the FRP decision, rate production is demonstrated with a goal of implementing lean manufacturing practices. Changes are limited to continuous improvement or obsolescence issues. System meets all engineering, performance, quality, and reliability requirements. Continuous process improvements are ongoing to achieve MRL 10.

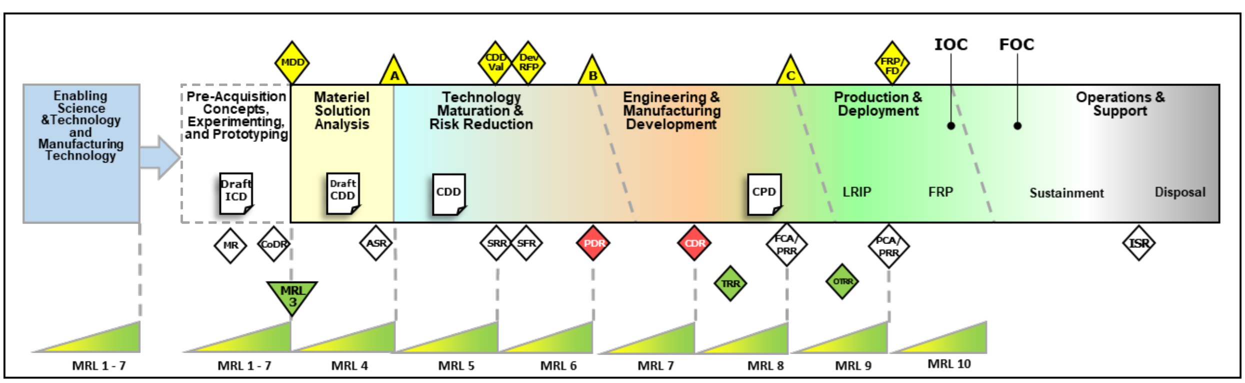

Figure 2-2 MCA Life-Cycle with MRLs

MRL Subject Area Threads and Subthreads

To support a comprehensive view of manufacturing readiness, the MRL matrix categorizes the primary manufacturing risks into nine key threads with 24 subthreads, addressing the essential elements of manufacturing. Together, these threads and subthreads provide a structure for evaluating manufacturing maturity and identifying risks.

The threads and subthreads are:

A. **Technology and Industrial Base:**

A.0 **Technology Maturity** – status of the least mature technology incorporated into the system that could impact cost, performance, and/or schedule

A.1 **Industrial Base** – analysis of capacity and capability of the industrial base to support manufacturing of the product through production, operations, support, and disposal

Industrial base is not equivalent to the contractor supply chain, it is total resources in the industrial sectors of which the supply chain is part. Information about these criteria can be obtained both from program management and the supply chain management organization. This includes information about obsolescence, trends, direction of the sector, and potential Diminishing Manufacturing Sources and Material Shortages (DMSMS). Awareness of the industrial base can provide information about alternate sources for mitigation purposes.

A.2 **Manufacturing Technology Development** – status of efforts for improvement to manufacturing processes, procedures, and techniques

The criteria in this subthread are concerned with manufacturing process, procedures, or technique improvements as well as integration and implementation of "new" manufacturing technology (unknown or never used) in the organization.

B. **Design:**

B.1 **Producibility Program** – evaluation of the manufacturability and producibility of the product through assessments and trade studies

B.2 **Design Maturity** – analysis of requirements, features, and stability of the evolving product design, key or critical characteristics, and their impact on manufacturing

C. **Cost and Funding:**

C.1 **Production Cost Knowledge (Cost Modeling)** – analysis showing inclusion all available actual cost information and status of the Cost Model

C.2 **Cost Analysis** – evaluations using actual costs and identified manufacturing cost drivers

C.3 **Manufacturing Investment Budget** – analysis of funding adequacy to achieve target manufacturing readiness levels on schedule

D. **Materials:**

D.1 **Maturity** – analysis of materials maturity and specifications in the appropriate manufacturing environment

D.2 **Availability of Materials (Raw Materials, Components, Subassemblies and Subsystems)** – evaluation of materials availability, obsolescence, lead times, DMSMS, and mitigation of these risks and issues

D.3 **Supply Chain Management** – identification and assessment of the supply chain including capability and capacity to support product manufacturing

While not shown as a thread by itself, Supply Chain Management (SCM), quality, and scheduling are essential for successful program execution. In general, roughly a substantial portion of the system (subsystems, items, and components) are from the supply chain. Direct interaction with the SCM organization is important.

D.4 **Special Handling (i.e. GFP[3], shelf life, security, hazardous materials, storage environment, ESH, etc.)** – Environment, Safety, and Health (ESH) requirements, procedures, and compliance applied, implemented, and demonstrated in the appropriate environment

Security in this subthread is concerned with handling, transportation, and storage of materials. Security of the manufacturing facility should be addressed in H.2. subthread. ESH evaluated here is with respect to the manufacturing requirement, procedures, and compliance.

E. Process Capability and Control:

E.1 **Modeling & Simulation (Product & Process)** – evaluation of modeling and simulation to identify system constraints and improvements

E.2 **Manufacturing Process Maturity** – analysis of manufacturing processes in appropriate environment with data collection for verification

E.3 **Process Yields and Rates** –assessment of manufacturing process yields and rates and establishment of targets in the appropriate environment

F. **Quality:**

F.1 **Quality Management** – evaluation of quality strategy development, quality management system, quality planning, and product specific plan, quality targets development and assessment, and continuous quality improvement

[3] GFP - Government Furnished Property

F.2 **Product Quality** – development of process inspection, acceptance testing, and final inspection, Key Characteristics (KC) management approach, control plans, measurement procedures, data collection verification

F.3 **Supplier Quality/Management** – analysis and assessment of supply chain quality and quality management systems to include: audits, acceptance testing, KC management, qualification and first article inspections

Some of the information required to address these metrics may be obtained in discussion with the supply chain management organization and some in discussion with quality personnel. Both organizations should address these criteria.

G. **Manufacturing Workforce:**

G.1 **Manufacturing Workforce** – identification of product manufacturing requirements for workforce skills, availability, training, and other specialized product requirements

H. **Facilities:**

H.1 **Tooling/STE/SIE** – identification of tooling, Special Test Equipment (STE), and Special Inspection Equipment (SIE) requirements that are subsequently demonstrated, validated, and proven in manufacturing

H.2 **Facilities** – analyses of the capacity and capabilities of key manufacturing facilities including prime contractor(s), subcontractors, suppliers, vendors, and maintenance/repair

Not specifically included in this subthread, but mentioned elsewhere, should be physical access controls that restrict unauthorized access to the manufacturing environment. Plant safety and manufacturing ergonomics are included in this subthread. MRLs do not evaluate product safety and ergonomics.

I. **Manufacturing Management:**

I.1 **Manufacturing Planning & Scheduling** – development of manufacturing strategy, approach and plan; development of Integrated Master Plan/ Integrated Master Schedule (IMP/IMS); and development and validation of work instructions and effective production control system

As part of planning and scheduling for manufacturing, integration of the supply chain is essential.

I.2 **Materials Planning** – development and completion of the Bill of Materials (BOM) including make/buy decisions

I.3 **Manufacturing OT Cybersecurity** – development, implementation, and validation of Operational Technology (OT) Cybersecurity capabilities and solutions, including cyber and physical/digital controls, access requirements, incident reporting, and workforce training

This subthread includes physical and digital controls for the manufacturing environment, but does not necessarily include physical access security, which should be included in the Facilities subthread.

The MRL Matrix

The MRL Matrix provides detailed criteria for each MRL from MRL 1 to MRL 10, by thread and sub-thread, throughout the acquisition life-cycle (shown graphically in Figure 2-3 below and in detail in Appendix G). The MRL matrix allows a user to separately evaluate and understand the progress of maturation in each of the subject areas (both threads and sub-threads) as MRLs increase from MRL 1 to MRL 10.

The levels are organized from left to right in the matrix with MRLs 3 to MRL 10 consistent with the MCA life-cycle framework and coordinated with key decision points. The subject area threads and subthreads shown in the matrix may be assessed in any order convenient to the organization and are all of equal importance and not weighted.

Thread	Sub-Thread	MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
A - Technology and Industrial Base	A.0										
	A.1										
	A.2										
B - Design	B.1										
	B.2										
C - Cost & Funding	C.1										
	C.2										
	C.3										
D - Materials	D.1										
	D.2										
	D.3										
	D.4										
E - Process Capability & Control	E.1										
	E.2										
	E.3										
F - Quality	F.1										
	F.2										
	F.3										
G - Manufacturing Workforce	G.1										
H - Facilities	H.1										
	H.2										
I - Manufacturing Management	I.1										
	I.2										
	I.3										

Figure 2-3 MRL Matrix Format

MRL Levels, Criteria, Metrics, and Artifacts

The MRL number is used as a convenience for referring to the maturity level for MRL criteria used in the assessment. The numbers are a "non-linear"[4] ordinal scale that identifies what the manufacturing maturity *should be* as a function of where a program is in the acquisition life-cycle. The level of manufacturing maturity for the program element being assessed is the objective and should address the following two questions:

1. Has the program element met the appropriate manufacturing maturity; and
2. If not, what must be accomplished to meet the metric?

The MRLs are numbered, which represent a target used to focus the team on the potential risks associated with reaching program goals**.** Using numbers is simply a convenient designation that identifies manufacturing maturity. The number is a function of where a program should be in the acquisition life-cycle (Figure 2-1). Additionally, the MRLs demonstrate risk management considerations within progressively complex manufacturing environments (i.e., laboratory, production-relevant, production-representative, and pilot line) as previously described.

For each MRL, the subthreads for each subject area contain the criteria to be met and are an accomplishment that requires an artifact as evidence.

For example: In subject area subthread D.1. Materials Maturity for:

- MRL 4 the matrix says "New materials and components for preferred materiel solution demonstrated in a laboratory environment." To meet this, the materials have been tested in a lab and the test results show that the materials have the properties needed for manufacturing the product. The test report is the artifact to show MRL 4 D.1 is met.
- MRL 6 (at PDR) the matrix says "Material maturity verified through technology demonstration articles. Preliminary material specifications in place. Material properties adequately characterized." To meet this, there is an artifact showing testing of technology demonstration articles that satisfy the preliminary design requirements. Material specifications and properties have been verified by characterization in the production-relevant environment (artifact is the test report).
- MRL 7 (at CDR) the matrix says "Material maturity sufficient for pilot line build. Material specifications approved." To meet this, materials have been tested and utilized in the production-representative environment; validating the properties as

[4] "Non-linear" suggests that the effort needed to move between MRLs varies in level of effort, time, and resources needed to achieve the next higher MRL target level.

ready for the pilot line. Material specifications have been approved (artifact is the sign-off by appropriate authority).

As the product has progressed from MRL 4 to MRL 7, meeting the criteria requires increasing maturity with more demanding requirements, while progressing through higher fidelity environments from lab to “ready for pilot line.” This is the same for all 9 subject area threads as product development proceeds in manufacturing through MRL 10.

“This information is determined in the assessment process using the MRL Matrix, not by assigning a number to the element being assessed. When a target MRL criteria is not achieved, decision-makers must evaluate the identified risk to program success when determining whether or not to proceed to the next phase. The goals of an MRL Assessment are to determine manufacturing maturity and to identify risks; not to be used as a “go/no-go” decision based on a target MRL number.”[5]

MRL Environments

Environments prior to the MDD include enabling S&T and ManTech and separately the pre-acquisition environment, which includes concepts, experimenting, and prototyping as in Figure 2-4.

As a separate effort from acquisition programs, between Government and Industry S&T, R&D, and ManTech projects the manufacturing maturity can range from MRL 1 to MRL 7 (blue box). These programs/projects develop manufacturing technologies and products of varying maturities that can be integrated into either pre-MDD activities or ongoing acquisition programs.

The range of maturity in S&T can be from very immature (MRL 1 or 2) to a mature demonstration in a production-representative environment (MRL 7). S&T programs use assessments to measure progress and may also develop unique manufacturing processes, procedures, or techniques.

DoW ManTech programs will develop manufacturing processes, procedures, and techniques for existing products, demonstrate application to new products, and develop manufacturing capabilities to the point where they can be integrated into production of the product. The ManTech programs are most often maturing manufacturing from MRL 4 to MRL 7.

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[5] MRL Deskbook 2025, §2.4

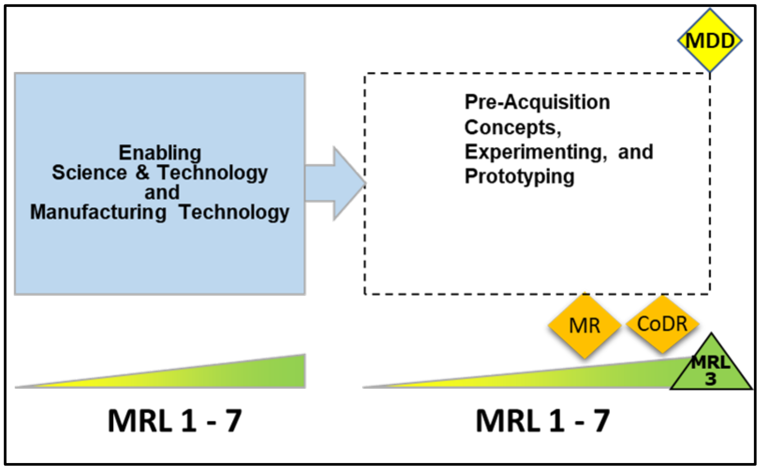

Figure 2-4 Pre-MDD Environments

During pre-acquisition (dotted box), early-stage ideas and strategies are examined before the formal acquisition process begins. Concepts are explored for potential solutions envisioning novel approaches, while identifying capability gaps. Experimentation is performed using systematic testing and exploration to gain insights and validate approaches and hypotheses. Prototypes are developed to validate designs, reduce technical risk, and gather feedback. Collectively, these activities are used to mature manufacturing and contribute to informed decision making, technological advancement, and development of capabilities.

The above activities result in identification of those candidate concepts and alternatives that meet the mission objectives and could be the preferred materiel solution. The environments for this can vary from manufacturing research at MRL 1, to laboratory demonstration, to production-relevant, to production-representative at MRL 7.[6]

All of the above activities provide the basis or inputs to the engineering process described in both the Engineering of Defense Systems Guidebook and DoDI 5000.88, which results in identification of candidate concepts and alternatives that could meet the mission objective.

Once initiated at MDD, the program will mature through multiple environments from laboratory, to production-relevant, to production-representative, to pilot, and ultimately production. Definitions of these can be found in the MRL Deskbook Section 2.3.

Initially the MRL criteria focus on manufacturing feasibility by identifying manufacturability and producibility of the preferred materiel solution; reducing the manufacturing risk.

[6] *MRLs and TRLs in DoD Major Capability Acquisition*, Apr 2024

Typically, before Milestone A decision, these proposed concepts are generally demonstrated in a laboratory environment.

Subsequent to Milestone A, the focus changes to the capability to manufacture outside the lab environment. The parameters defining a production-relevant environment should be based on the risks and uniqueness associated with demonstrating that manufacturing processes, procedures, and techniques meet program requirements. This environment includes evaluations of producibility, manufacturability, and improvements in processes and/or techniques. An emphasis should be placed on addressing higher risk areas (e.g., more advanced manufacturing technologies and newer manufacturing capabilities) and completion of a preliminary design prior to Milestone B.

The next stage of product development is the detailed design, during which the demonstration manufacturing capability occurs in a production-representative environment. By CDR, this demonstration will provide a better understanding of manufacturing risk to the program meeting cost, schedule, and performance requirements.

The final stage of product development is the manufacture of pre-production products intended for demonstration and test (Developmental Test & Evaluation (DT&E), and Initial Operational Test & Evaluation (IOT&E)). These units are built on a pilot line to demonstrate all key manufacturing processes, procedures, and techniques; and validate all key product requirements for transition to LRIP. Without pilot line realism, it would be more difficult to have confidence that the manufacturing processes will be able to meet cost, schedule, and performance requirements in production.

After the decision to enter low rate production (Milestone C decision), the program enters a phase that begins with LRIP and transitions to full rate production while meeting required yields and rates.

As stated in the Deskbook, the definitions of production-relevant, production-representative, pilot line, and production line environments are intended to demonstrate the natural progression of manufacturing maturity throughout the acquisition life-cycle. The responsible organization and any assessed organization must reach agreement on the detailed manufacturing realism content for each definition above. This agreement must be based on the specific situation and its associated manufacturing risk in order to mitigate that risk in a timely and thorough manner.

3.0 Phased Maturity

MCA products or systems will consist of multiple lower tier subsystems, items, and components. These lower tiers should be more advanced in their developmental maturity than the system level. This should be by two MRL levels such that at the system level PDR, the lower tier subsystems are ready for initial production with items and components in production (Figure 3-1).

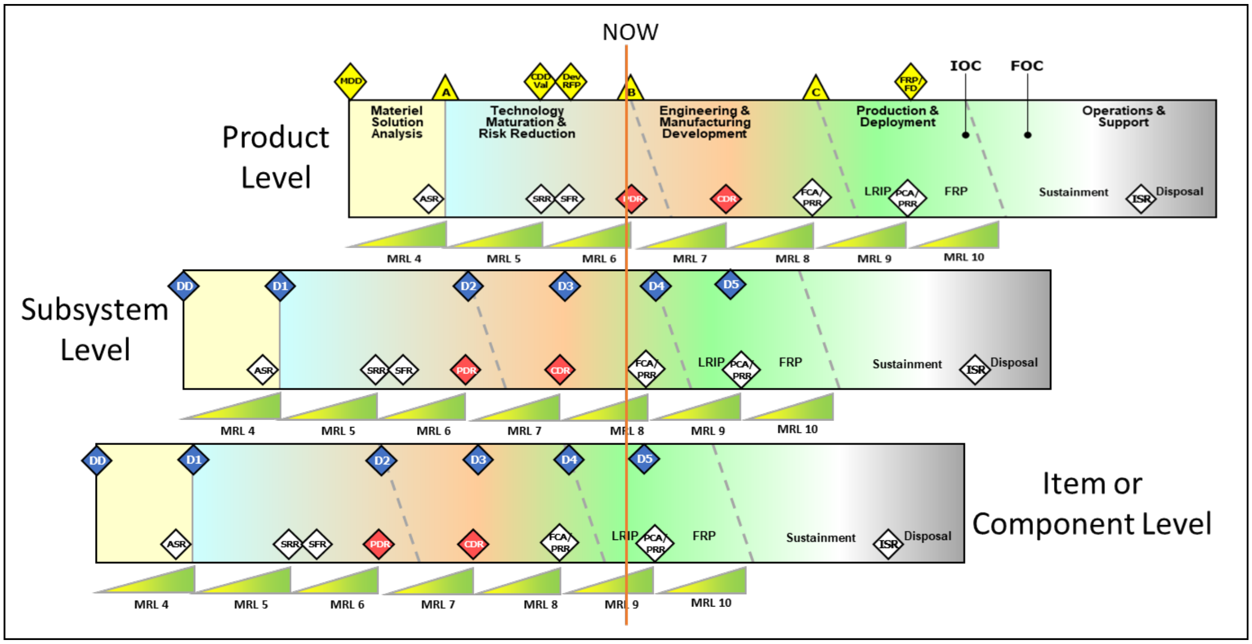

Figure 3-1 Phased Maturity

This point was made clear in a 2002 GAO report that states:

> "Companies have found that trying to capture the knowledge required to stabilize the design of a product that requires significant amounts of new content is an unmanageable task, especially if the goal is to reduce cycle times and get the product into the marketplace (or to the warfighter) as quickly as possible. Design elements not achievable in the initial development were planned for subsequent development efforts in future generations of the product, but only when technologies were proven to be mature and other resources available."[7]

At the system level PDR, the lower tier subsystems are beginning initial production with items and components in production. Having the lower tiers at least two levels in advance of the system level provides several benefits. At a minimum, this approach reduces

[7] GAO-02-701, Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes, Jul 2002

overall program risks and reduces the time to production, allowing production to meet schedule requirements. This approach shows that when technologies and manufacturing processes are mature, items and components are in initial production, subsystems have completed initial testing. Maturity at this level allows the program to integrate subsystems with minimal engineering changes or other issues.

System prototypes can be made available for the CDR that demonstrate performance requirements and/or indicate what areas of the design needs improvement. This means that programs should only incorporate technologies that are sufficiently mature to meet MRL 8 at the subsystem level, higher at the item and component level, and ready to be included in the system level pre-production test units to demonstrate a successful system level critical design.

This has the effect of shortening the time from system PDR to system CDR and the time to build final engineering test units. For the last several years, DoW has had multiple efforts to “speed up” programs using various different approaches, one of which is the Adaptive Acquisition Framework (AAF) pathway approach. This AAF approach when combined with phased maturity development should significantly improve program time to production with fewer risks and delays to cost, schedule, and performance.

4.0 MRLs for Major Capability Acquisitions

Introduction

The MCA life-cycle is a pathway in the AAF based on Systems Engineering (SE) processes, which follows development of a weapons system from concept (dotted white box in Figure 4-1) through disposal. MRL assessments are performed as inputs to SE and milestone reviews providing status of manufacturing maturity and risk identification. This is detailed in Appendix A: MRL Role in Systems Engineering. The SE process begins before acquisition in development of the mission and concept requirements as part of Mission Engineering.[8]

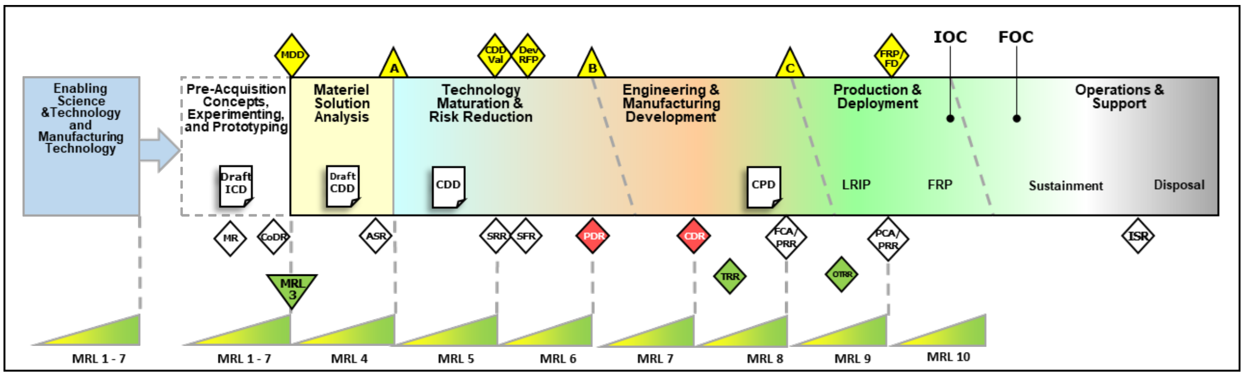

Figure 4-1 MRLs in MCA

MRLs for Pre-Acquisition

Prior to the MDD, there may be enabling S&T and/or ManTech projects that will impact the concepts under consideration, or future components, items, and subsystems, which will require an MRL assessment in support of a development decision. For a discussion of S&T and ManTech, see Appendix D.

The MDD is the mandatory entry point into the MCA process.[9] It ends with the MDA decision to initiate a program of record[(10)] based upon the transition of mature technologies and manufacturing processes with manageable risk. Technology developed in S&T and ManTech programs, pre-acquisition concepts, experimenting, and prototyping should be assessed as mature enough to transition smoothly (i.e., meet cost, schedule, and performance requirements) into the MSA phase.

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[8] A significant amount of the material in this section is adapted from the MRL Deskbook, much of which was originally written or edited by APT.

[9] DoDI 5000.85, Section 3.5

[10] Program of record: An acquisition program that has been formally initiated by the Milestone Decision Authority and has been fully funded throughout the Future Years Defense Program.

Additionally, if the program or project office is not yet established, and prime contractors have not have been selected, the lead DoW responsible organization will have to carry out the requirements for an MRL Assessment of the concepts, experiments, and prototypes under consideration. These early assessments should be performed using the streamlined MRL process described in Section 5.0. The responsible organization will likely be the DoW component MDA. Each concept under consideration should be assessed for the CoDR that at a minimum meets the requirements of MRL 3 as shown in Figure 4-1 and discussed in Appendix A.

Materiel Solution Analysis Phase

The MDD marks the start of the MSA phase. The MSA phase precedes the Milestone A decision with requirements from DoDI 5000.85.

In this phase, the viable alternative is selected by conducting an AoA with the goal of identifying the most promising option(s) that satisfy the capability need through a comparison of the operational effectiveness, suitability, and life-cycle cost of alternatives. Manufacturing Subject Matter Experts (SMEs) should participate in the AoA. Streamlined MRL 4 assessments (see Section 5.0) should be conducted for each competing materiel solution being examined in the AoA.

Inputs are provided by the MRL assessment to an Alternative Systems Review (ASR) (see Appendix A), conducted by the PM, to assure the preferred materiel solution(s) meets the requirements prior to the Milestone A review. An Independent Technology Risk Assessment (ITRA) is required before granting Milestone A approval, which should use the MRL assessment as input.

MSA phase ends when the ITRA has been conducted, a draft Acquisition Strategy has been developed, the ASR is complete, and a Milestone A decision has been made for the proposed materiel solution. To ensure that adequate knowledge of technology and manufacturing risks is available to support all of the decisions required at Milestone A, the manufacturing maturity should meet a minimum MRL 4.

Technology Maturation and Risk Reduction (TMRR) Phase

The Milestone A decision point marks the entry into the TMRR phase of acquisition. The purpose of the TMRR phase is to reduce technology, engineering, integration, and life-cycle cost risks to the point that a decision to contract for EMD can be made with confidence in successful program execution for development, production, and sustainment. The focus for TMRR should be on maturing subsystems, items, and components to ensure product preliminary design is sufficiently robust to proceed into system/product engineering and manufacturing development with minimal risks. This phase includes conduct of a Systems Requirements Review (SRR) and a System

Functional Review (SFR), discussed in Appendix A. An MRL 6 Assessment should be conducted and provided as input to the both the ITRA and the PDR, as well as the Milestone B decision.

Engineering and Manufacturing Development (EMD) Phase

The Milestone B decision point marks the entry into the EMD phase of acquisition. "The purpose of the EMD phase is to develop, build, test, and evaluate a materiel solution [pre-production development products] to verify that all operational and implied requirements, including those for security, have been met, and to support production, deployment and sustainment decisions."[11] Systems Engineering Technical Reviews (SETR) normally conducted during this phase are the CDR, the Test Readiness Review (TRR), the System Verification Review (SVR), the Functional Configuration Audit (FCA), and the Production Readiness Review (PRR) as shown in Figure 4-1 and discussed in Appendix A or IEEE 15288.2.[12]

Product Development

Early in EMD, from Milestone B to CDR, product development will complete all needed hardware and software detailed designs. Completion of product baseline, detailed design for production, and verification that product performance requirements have been met, along with identification and development of key manufacturing processes and key characteristics.

At the end of product development, an MRL 7 assessment is conducted as an input to the CDR. A CDR assesses design maturity, design build-to or code-to documentation, and remaining risks, and establishes the initial product baseline.

Product Demonstration

Post-CDR, EMD product demonstration will conduct developmental testing and evaluation to demonstrate the product meets requirements. Manufacturing processes will be demonstrated as under control by conducting an MRL 8 assessment on the pilot line as an input to a PRR. The criteria associated with MRL 8 reflect a maturity level consistent with requirements for the approaching Milestone C decision.

Production and Deployment (P&D) Phase

The Milestone C decision point marks the entry into the P&D phase of acquisition. The purpose of this phase is to achieve an operational capability that satisfies mission needs. During the LRIP production effort the program should target the MRL 9 criteria and

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[11] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020
[12] IEEE 15288.2 *Standard for Technical Reviews and Audits on Defense Programs*, Nov 2014

metrics. After successful completion of Operational Test & Evaluation (OT&E) and system validation, an MRL 9 assessment should be conducted as input to the Physical Configuration Audit (PCA) as discussed in Appendix A. The PCA and OT&E results are inputs to the FRP decision, which requires that manufacturing risk be understood and that the manufacturing processes for the system be capable, in (statistical) control, and affordable.

Production and Continuous Improvement

Once a program has entered FRP, the focus in on continuous improvement or product upgrades. Engineering or design changes are few. Rate production unit costs meet goals, and funding is sufficient for manufacturing at required rates. Continuous process improvements are ongoing. The supply chain is proven and monitored with predictive indicators in place. All manufacturing risks and issues are managed. If assessed, this phase is associated with MRL 10.

MRL Assessments for Lower Tiers in MCA Acquisitions

Lower tiers in an MCA, i.e., at the subsystems, items, and component levels, should be more advanced in their developmental maturity than at the system level. For these lower tiers during MCA acquisitions, there are usually no “Milestones,” but there are decision points. The development of system elements will follow a schedule marked by System Engineering reviews (CoDR, ASR, PDR, CDR, etc.) and decision points to proceed as discussed in Section 3.0 Phased Maturity.

Below the system level at the subsystem, item, and component levels, the filter questions should be applied to prioritize which elements could be subject to a streamlined MRL assessment at a minimum. If there is significant risk found either through application of the filter questions or the streamlined MRL assessment, a full MRL assessment of these elements should be performed. See Section 5.0 for the details of the filter questions.

5.0 Streamlined MRLs

One of the Manufacturing Readiness Level Working Group (MRLWG) thrust areas discussed in the past was to reduce the burden of MRL assessments. The discussion included the concept of "MRL Lites" (also described as "Tailored MRLs"), but no subsequent actions were taken. The *Early Manufacturing & Quality Engineering Guide*, Jul 2022, discusses use of a tailored assessment approach, "MRA Lite," in §3.3 and then refers in the appendix to the topic as "MRL Lite," as if they are synonymous terms.

It should be remembered that the term "MRA" is a generalized reference to assessments of manufacturing maturity and risks as part of systems engineering. MRLs, however, were developed by the MRLWG as a structured approach to accomplishing a manufacturing risk assessment and are now the preferred approach by DoW.

The terms "Tailored MRL" and "MRL Lite" imply choosing which threads to apply or answer and results in an MRA, similar to, but not equivalent to, an assessment using the MRL process. The *Guide* shows a sample, which is not consistent with the existing MRL criteria at the appropriate levels. This "Lite" approach is limited by the *Guide* to early pre-MDD candidate solution set development. This approach is not a reduced burden nor a streamlined MRL assessment.

The approach presented here, detailed in APT's publication "*Streamlining Manufacturing Readiness Level Assessments*," Apr 2025[13], is to streamline MRLs by retaining all 9 threads and MRL levels in sequence, but reducing the number of subthreads to 12. These streamlined criteria and metrics can be applied during pre-MDD evaluations and/or in the MSA phase for MCA systems. They can also be applied throughout the acquisition life-cycle for the lower tier subsystems, items, and components. This approach to MRL assessments addresses the interest shown by the MRL community as a means of reducing the burden of performing MRL assessments, while still identifying products or elements that are likely to have manufacturing risks.

Early in the MCA process, if the program office is not established (assuming no prime contractors either), the lead DoW responsible organization should identify who will carry out the requirements for the MRL Assessment as input to the CoDR and the ASR for the MCA system. These may be streamlined assessments. Additionally, to support the CoDR and ASR, the corresponding assessments of the lower tier subsystems, items, and components in different phases of development will be streamlined assessments.

After the system level Milestone A, streamlined criteria and metrics can also be applied throughout the acquisition life-cycle to the lower tier elements (i.e., subsystems, items,

[13] See APTCorp-US.com/resources for complete publication

and components). This streamlined approach to MRL assessments reduces the burden of performing MRL assessments, yet still identifies products or elements that are likely to have manufacturing risks.

The streamlined criteria and subthreads that are included in a streamlined MRL assessment are focused on the 12 most essential subthreads. The Matrices for system level and subsystem, items, and components are shown in Appendix H. These include the following threads and subthreads:

A. Technology & Industrial Base
   A.0 – Technology Maturity
   A.1 – Industrial Base

B. Design
   B.2 – Design Maturity

C. Cost & Funding
   C.1 C.2 C.3 – Cost & Funding

D. Materials
   D.1 – Materials Maturity

E. Process Capability and Control
   E.2 – Manufacturing Maturity and (E.3) Yields

F. Quality
   F.2 – Product Quality
   F.3 – Supplier Quality and (D.3) Supply Chain Management

G. Manufacturing Workforce
   G.1 – Manufacturing Workforce

H. Facilities
   H.2 – Facilities

I. Manufacturing Management
   I.2 – Materials Planning and (D.2) Availability
   I.3 – Manufacturing OT Cybersecurity

Filter Questions

The responsible organization in conjunction with the assessed organization will determine which subsystem, item, or component will need to be assessed with a schedule that includes them. This activity is detailed in Appendix B on conducting an MRL assessments for a system.

The filter questions below in conjunction with the Work Breakdown Structure (WBS) or BOM will allow creation of a prioritized list. The number of responses to filter question risk areas by each subsystem, item, and component will provide the priority by frequency that an MRL assessment may be needed. This prioritized list, together with the schedule and budget, will dictate which elements should be assessed using a streamlined MRL assessment at a minimum. If the risks are sufficiently high, a full MRL assessment may be necessary.

The following filter questions are directly related to the threads and streamlined subthreads:

Technology Maturity (A.0): Is any of the technology to be used new or novel in the current application?

Industrial Base (A.1): Is the industrial base footprint capable of meeting the program's needs or are there identified critical shortfalls or gaps in the industrial base?

Design Maturity (B.2): Does the item design contain nonstandard dimensions, geometries, or tolerances?

Cost & Funding (C.1, C.2, & C.3): Is this item a cost driver that has a significant impact on unit or life-cycle cost (development, unit, or Operations & Support phase costs)? Is the technology new with excessively uncertain cost?

Materials Maturity (D.1): Does the item include new and/or unique materials that have not been demonstrated in similar products or manufacturing processes?

Manufacturing Maturity (E.2): Will the item require use of manufacturing technology, processes, inspection, or capabilities that are unproven in the current environment?

Product Quality (F.2): Does the item have historical or anticipated yield or quality issues; or are there new quality requirements (i.e., inspection techniques, test equipment) that must be developed and proven?

Supplier Quality and Supply Chain Management (F.3 & D.3): Does the item have anticipated or historical sub-tier supplier problems (e.g., sole source, foreign source) that could negatively impact cost, quality, or delivery?

Manufacturing Workforce (G.1): Does the product require workforce skills and personnel that are not currently available?

Facilities (H.2): Does this item require a new manufacturing facility or major updates of existing facilities (e.g., new capability or capacity) to meet production and scale-up requirements?

Materials Planning & Availability (I.2 & D.2): Does this item present lead time issues, manufacturing concerns, or DMSMS concerns on the critical path that could significantly impact the program schedule?

Manufacturing OT Cybersecurity (I.3): Are there anticipated cybersecurity weaknesses and vulnerabilities associated with manufacturing, supply chain or OT related to critical program information in the Program Protection Plan (PPP) or that need to be addressed?

Subsystems, Items, and Components Streamlined Matrix

At the lower levels, even though there are normally no "Milestone Decisions," there are still similar decision points at the system level from following the Systems Engineering reviews (specified in IEEE 15288.2[14]).

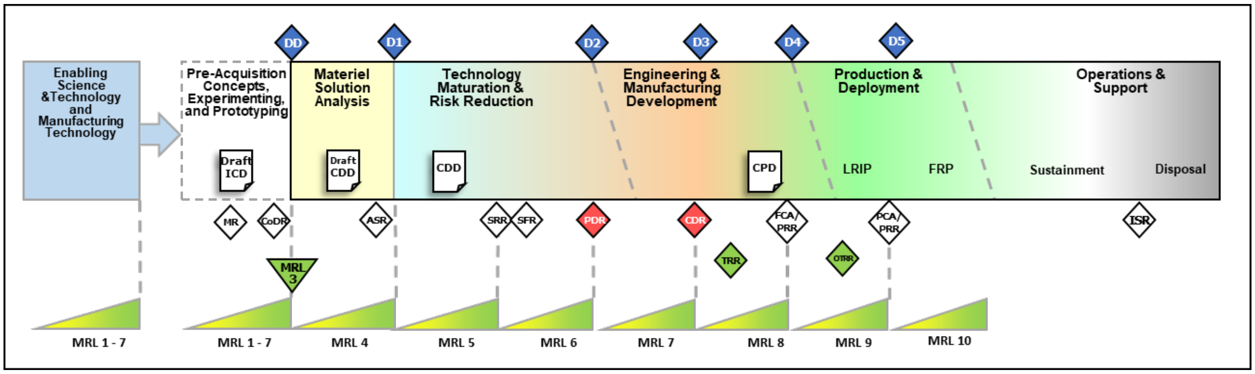

Figure 5-1 Lower Tier Assessments

As above in Figure 5-1, the Development Decision (DD) is supported by the results of the CoDR, allowing refinement of the concept to a materiel solution during MSA.

- Decision Point 1 (D1), supported by the ASR, transitions to the technology maturation and risk reduction activities, culminating in a preliminary design.
- Decision Point 2 (D2) transition into product development is supported by the PDR.
- Product development ends with completion of the critical design, transitioning to product demonstration and pilot line production with Decision Point 3 (D3).
- Decision Point 4 (D4) is the point of transition to initial production at low rate. This is supported by a PRR to address readiness for production.
- The last Decision Point (D5) will again be supported by a PRR to begin rate production.

The matrix for these assessments is shown in Appendix H.

[14] IEEE 15288.2, *Standard for Technical Reviews and Audits on Defense Programs*, Nov 2014

6.0 The MRL - TRL Alignment in DoW Acquisitions

Many technologies and manufacturing processes are developed and matured before the acquisition process begins.[15] Government S&T, Industry R&D, and ManTech projects technology maturity can range from TRL 1 to 7 and the manufacturing maturity from MRL 1 to MRL 7 (the blue box in Figure 6-1 below). These programs/projects develop technologies and products of varying maturities that can be integrated into either pre-MDD activities or ongoing acquisition programs.

The range of maturity in S&T can be from very immature (TRL 1 or 2) to a mature demonstration in an operational environment (TRL 7). Maturing technology is not always responsive to funding and effort, and ***may not be achieved on a schedule***. Technologies must be sufficiently mature, with technical risks judged to be acceptable, to warrant insertion in a program.

ManTech programs develop manufacturing processes, procedures, and techniques for existing products, demonstrate application to new products, and develop manufacturing capabilities to the point where they can be integrated into production of a product. The ManTech programs are most often maturing the manufacturing aspects from MRL 4 to MRL 7.

TRL assessments provide design maturity status and aid in identifying new or unique processes requiring further manufacturing development. Evaluating technical risk (e.g., through evidence to determine the TRL can provide information for program development.

[15] NOTE: Portions of this section are extracted from the APT paper, *Manufacturing Readiness Levels and Technology Readiness Levels in DoD Major Capability Acquisition*, Apr 2024.

6.0 The MRL/TRL Relationship in DoW Acquisitions

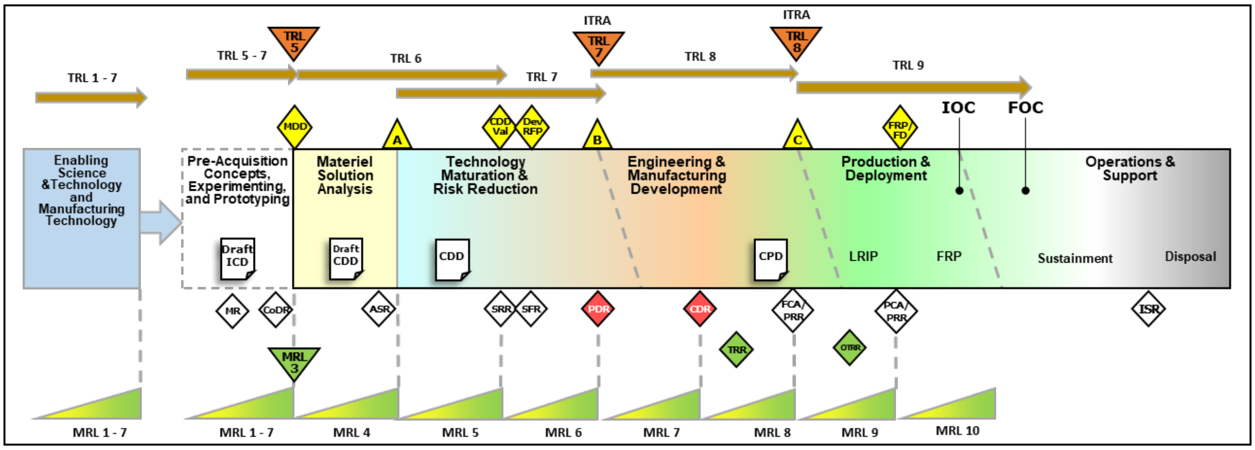

Figure 6-1 Life Cycle with MRL and TRL Alignment

During pre-acquisition, early-stage ideas and strategies are examined before formal acquisition processes begin and concepts are explored for potential solutions envisioning novel approaches, while identifying capability gaps. Advanced technology demonstration programs play a crucial role in evaluating and maturing advanced technologies for potential use. Experimentation is performed using systematic testing and exploration to gain insights and validate approaches and hypotheses. Prototypes are developed to validate designs, reduce technical risk, and gather feedback. Collectively, these are used to contribute to informed decision making, technological advancement, and development of capabilities.

The prototypes, which have been developed to validate designs and reduce risk, should have been used to validate technologies in an environment that used the most stressing aspects of the operational environment. Systems for development should therefore not enter the MSA phase without having validation in a relevant environment.

As a result of the above activities, immature technologies will have been matured to between TRL 5 and 7 with a minimum of TRL 5 at the product level, which is the recommended entrance criterion for MDD. Manufacturing maturity could have likewise matured up to MRL 7, but should meet a minimum of MRL 3 as a recommended entrance criterion for MDD (dotted white box in Figure 6-1).

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 the AoA Study Plan. Once a preferred materiel solution is selected, an MRA using the MRL process, an Independent Cost Estimate (ICE), and an ITRA are be performed. The selected solution is the one that provides adequate knowledge of technology and manufacturing risks with

6.0 The MRL/TRL Relationship in DoW Acquisitions

the least mature technology at the ***product level*** of TRL 6 and manufacturing maturity achieving a minimum MRL 4 for a Milestone A decision.

The TMRR phase purpose is to reduce technology, engineering, integration, and life-cycle cost risk (DoW's "technical risks") to the point that a decision to contract for EMD can be made with confidence in successful program execution for development, production, and sustainment. The focus for TMRR should be on whether subsystems, items, and components are sufficiently matured to ensure the product preliminary design (system level) is robust and ready to proceed into engineering and manufacturing development with minimal risks.

If a system or product has less than TRL 7 by PDR, the program does not have a solid technical basis for its design and could be at risk of approving a design that is less likely to remain stable.[16] At Milestone B, the least mature technology at the product level should preferably meet TRL 7 with the manufacturing maturity achieving a minimum MRL 6.

The purpose of the EMD phase is to develop, build, test, and evaluate a materiel solution and verify that all operational and implied requirements, including those for security, have been met, and to support production, deployment, and sustainment decisions.[17] In early EMD, from Milestone B to CDR, product development will complete all needed hardware and software detailed designs.[18] At the CDR, the minimum TRL is 7 with a minimum of MRL 7. Post-CDR, the program proceeds into fabrication, system integration, system demonstration, and test; meeting stated performance requirements within budget, schedule, risk, and other system constraints. The EMD phase ends with the MDA's decision at Milestone C to approve and authorize the program to proceed to the P&D phase and enter initial production.[19] At this point, the least mature technology at the product level should meet TRL 8 and manufacturing maturity achieving a minimum of MRL 8.

Figure 6-1 shows the end-to-end perspective, the alignment of technology and manufacturing maturity, and the integration of SETRs and audits for all pre-acquisition and MCA activities. Achieving technical and manufacturing maturity as described above will yield the best possible outcome and lowest risks for the system or product development effort.

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[16] GAO-20-48G, *Technology Readiness Assessment Guide*, Jan 2020
[17] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020
[18] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020
[19] DoDI 5000.85, *Major Capability Acquisition,* Aug 2020

7.0 MRLs for Middle Tier of Acquisition (MTA)

Introduction

The MTA pathway is used to rapidly develop fieldable prototypes within an acquisition program to demonstrate new capabilities or to rapidly field production quantities of systems with proven technologies that require minimal development.

The MTA pathway is intended to fill a gap in the defense acquisition for those capabilities that have a level of maturity to allow them to be rapidly prototyped within an acquisition program or rapidly fielded within five years of MTA program start. The MTA pathway may be used either to accelerate capability maturation before transitioning to another acquisition pathway or to minimally develop a capability before rapidly fielding.[20]

MRLs for Rapid Prototyping

"The Rapid Prototyping path provides for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging military needs. The objective of an acquisition program under this path will be to field a prototype meeting defined requirements that can be demonstrated in an operational environment and provide for a residual operational capability within five years of the MTA program start date. Virtual prototyping models are acceptable if they result in a fieldable residual operational capability. MTA programs may not be planned to exceed five years to completion and, in execution, will not exceed five years after MTA program start without a Defense Acquisition Executive (DAE) waiver."[21]

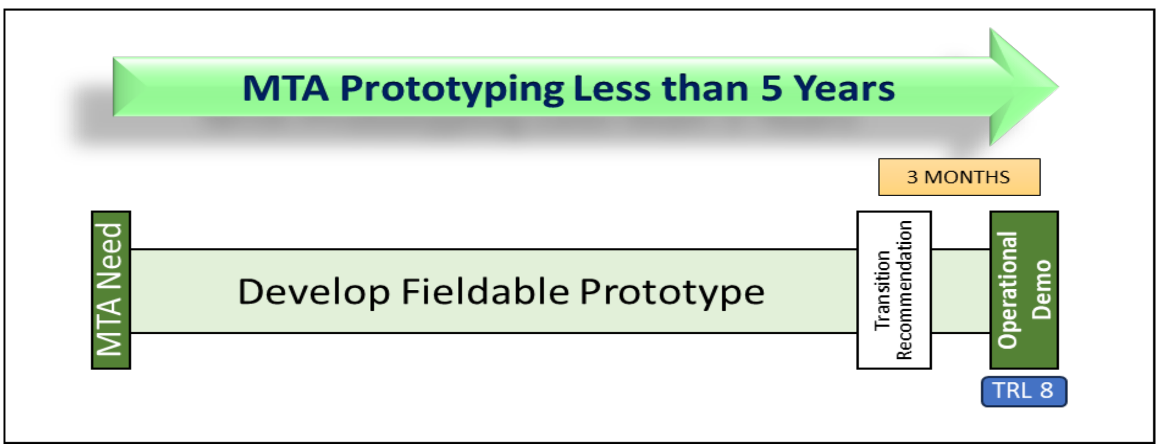

Figure 7-1 Rapid Prototyping

The Rapid Prototyping pathway (Figure 7-1), based on direction from DoDI 5000.80, there is no specific MRL requirement for the operational demo. However, this pathway was

[20] *MRL Deskbook 2025*
[21] DoDI 5000.80*, Operation of the Middle Tier of Acquisition,* Nov 2024

created to provide a means for developing technology outside of an MCA program and allows development and test as a prototype to TRL 8. As part of the transition recommendation, an MRL 8 assessment needs to be accomplished if transitioning to a manufacturing program. This may be met using a streamlined MRL assessment.

MRLs for Rapid Fielding

The Rapid Fielding path provides for the use of proven technologies to field production quantities of new or upgraded systems with minimal development required. The objective of an acquisition program under this path will be to begin production within six months, complete fielding within five years of the MTA program start date, and enter into operations and sustainment. MTA program production start date will not exceed six months after the MTA program start date without a DAE waiver. MTA programs may not be planned to exceed five years to completion and, in execution, will not exceed five years after MTA program start without a DAE waiver.[22]

For Rapid Fielding acquisitions, a PRR supported by an MRL 8 assessment must be completed prior to initial production. A PRR will be conducted supported by an MRL 9 assessment prior to rate production (See Figure 7-2 below). Both of these PRRs could be supported by streamlined MRL assessments.

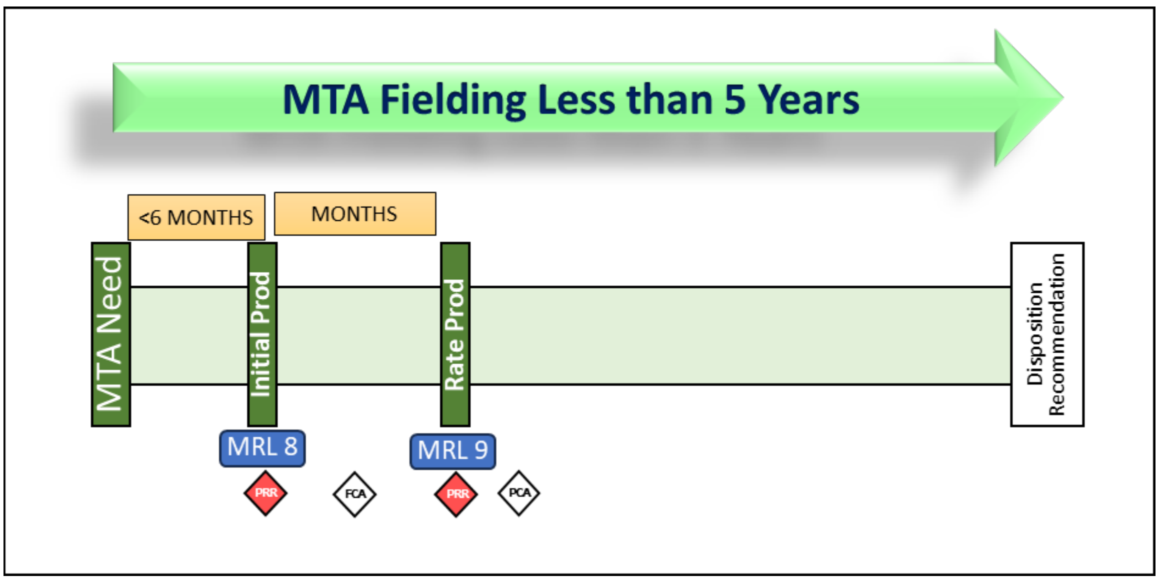

Figure 7-2 MRLs and Rapid Fielding

[22] DoDI 5000.80, pg 3

8.0 MRLs for Urgent Capability Acquisition

The Urgent Capability Acquisition (UCA) is an urgent need that must meet the following criteria:

- Is based on technologies that are proven and available
- Does not require substantial development effort
- Can be fielded within two years
- Can be acquired under a fixed price contract

If the MDA determines at the Development Milestone (shown in Figure 8-1) that the fielding of the capability cannot be accomplished in the required timeline, then the MDA may direct partial or interim solutions that can be fielded more rapidly or may direct that the program be managed under a different authority.[23]

To field the capability in the required timeline, the preferred solution at the Course of Action Decision Point (COA DP) should meet MRL 7, can be adapted from a currently manufactured product(s), or adapted from a commercial-off-the-shelf (COTS) product. At the Development Milestone, the maturity should be assessed to MRL 8 with gaps identified. To achieve MRL 8 in the months prior to the Initial Production Milestone, the gaps must be minimal, with an objective of meeting MRL 9 during production and fielding capability within two years.

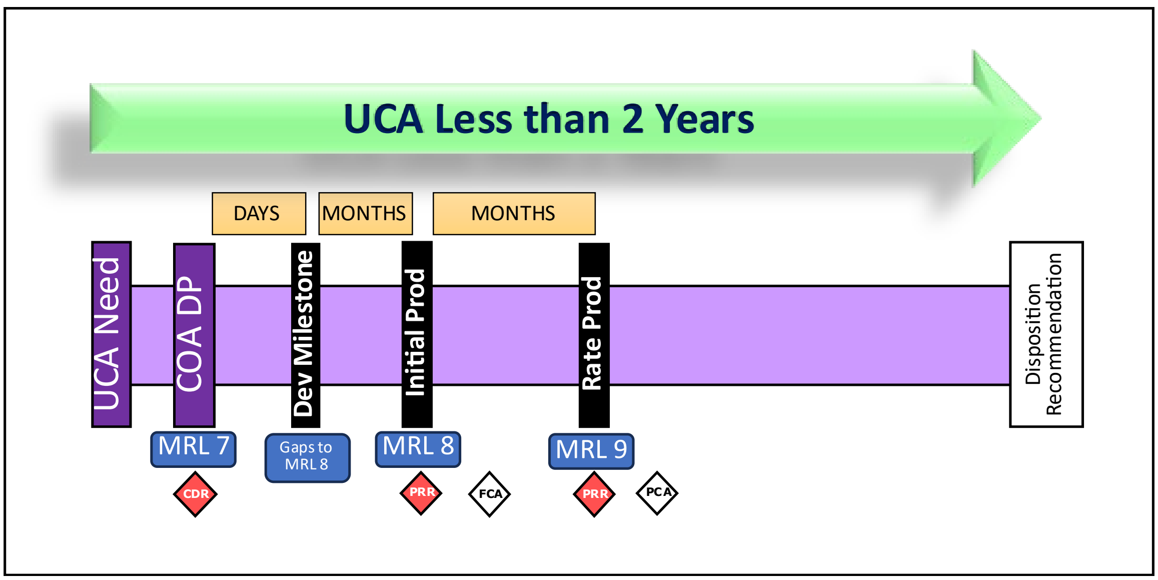

Figure 8-1 MRLs for UCA Pathway

[23] *MRL Deskbook 2025*

Appendix A: MRL Role in Systems Engineering

Introduction

With AAF implementation, MDD is the mandatory entry point into the MCA process. Additionally, the AAF was established in these updates to enable faster delivery of DoW 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 aaf.dau.edu). Many of these are complementary to and endorse previously developed Industry standards such as the IEEE 15288 series, SAE AS9100, and SAE AS6500. Additionally, the *Early Manufacturing and Quality Engineering Guide* was not contained in the original process, but was added in July 2022.

Systems Engineering

During DoW acquisition, a thorough but appropriately tailored series of SETRs and audits takes place. These provide the opportunity to evaluate achievements and to assess technical maturity, risks, issues, and opportunities. A key input to these reviews is an MRL assessment of manufacturing maturity and risks. Analysis of the SETRs should inform management on actions that reduce risk, increase performance, recognize and capitalize on opportunities, improve affordability, shorten schedule, and enhance performance.

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 DoW systems with respect to each of the AAF pathways. The third document is the *Systems Engineering Guidebook*, Feb 2022, formerly known as the Defense Acquisition Guidebook. This is also a guidance document, which explains all Systems Engineering activities in depth to plan and execute program activities across the system life-cycle. Other documents that impact Systems Engineering activities include DoDI 5000.84[24] and DoDI 5000.85, but these do not consider development prior to MDD.

[24] DoDI 5000.84, *Analysis of Alternatives,* Aug 2020

Appendix A: MRL Role in Systems Engineering

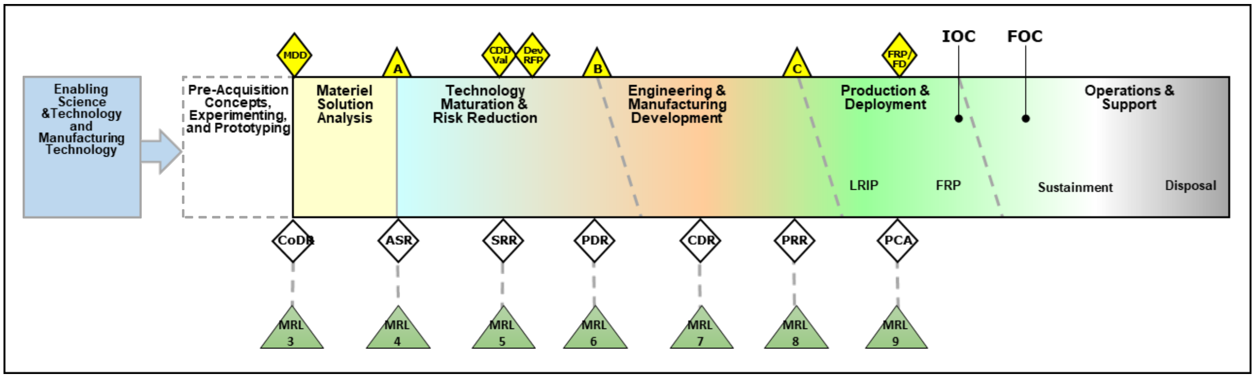

Figure A-1 Systems Engineering Activities and Key Decision Points

The Systems Engineering activities and key decision points are shown in Figure A-1, the framework for MCA programs.

Concepts Design Review (CoDR)

The CoDR should be a multidisciplined review of the potential joint warfare concepts, Service-specific concepts, and considerations to establish the Concept Baseline. CoDR should include manufacturing and quality engineering analyses and inputs.[25] There are multiple guidance or instructions on the content of a CoDR, both in DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, and in the *Engineering of Defense Systems Guidebook,* Feb 2022. DoDI 5000.88 contains the key aspects to be addressed:[26]

Manufacturing & Quality SMEs should provide support to the CoDR in assisting with the Capability Based Assessment (CBA), the concept design trades and concepts risk assessments, an MRL assessment on potential concepts, a cybersecurity assessment, prototyping and experimentation roadmaps, DOTMLPF-P[27] considerations and potential materiel solution concepts, and the informed Defense Acquisition System (DAS) alternative pathway selection.

An MRA using MRL criteria and metrics should be conducted on the potential concepts to determine if the manufacturing maturity and risks meet the MRL 3 criteria.

Alternative Systems Review (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

[25] *Engineering of Defense Systems Guidebook*, Feb 2022
[26] DoDI 5000.88. Section 3.3
[27] DOTMLPF-P – Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy Analysis

understanding of the technical maturity, feasibility, and risk of the “proposed” materiel solution.[28] 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.[29] The ASR occurs after the AoA is complete and after a preferred materiel solution(s) is selected by the lead Service or Component.[30] This allows the focus of the ASR to be on the proposed materiel solution(s) rather than on all the alternatives, and also allows for some post-AoA technical analysis to be completed. The ASR should not begin until all criteria are met (see IEEE 15288.2).[31] A resource for ASR preparation is. An ASR is presented as a best practice review in the *Systems Engineering Guidebook.*[32] In DoDI 5000.88, an ASR is not mentioned in the list of reviews required to be conducted by the PM.[33]

Manufacturing & Quality SMEs should participate and provide input to the ASR on the preferred materiel solution(s). Manufacturing & Quality personnel 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 by the completion of TMRR.[34] [35]

Systems Requirements Review (SRR) & System Functional Review (SFR)

The SRR shall be conducted to help ensure the level of understanding of top-level system requirements is adequate to support further requirements analysis and design activities, and that the system can proceed into initial system design with acceptable risk.

The SRR confirms the system, performance, and technical requirements are captured in the system specification documentation. It also confirms that the preferred materiel solution is feasible given available technologies, is consistent with program budget, schedule, and meets the program’s objectives with manageable risk. The SRR shall be held when the level of understanding of top-level system requirements is adequate to support further requirements analysis and design activities.

The SFR shall be conducted to help ensure the system under review can proceed into preliminary design with acceptable risk. The SFR confirms that system requirements and

[28] IEEE 15288.2, *Technical Reviews and Audits on Defense Programs*, Nov 2014, §5.2.1
[29] IEEE 15288.2, §5.2.3
[30] *Systems Engineering Guidebook*, Feb 22, §3.1, ASR Inputs and Review Criteria
[31] IEEE 15288.2, *Standard for Technical Reviews and Audits on Defense Programs*, Nov 2014
[32] *Systems Engineering Guidebook*, Feb 22
[33] DoDI 5000.88, *Engineering of Defense Systems,* Nov 2020, §3.5.a
[34] *Manufacturing Readiness Level Deskbook*, 2025
[35] 10 U.S. Code § 4251 - MDAPs: Factors to be considered before Milestone A approval

functional performance requirements derived from the approved preliminary system specification are defined and consistent with the program budget, program schedule, and risk. Also confirmed are other program and system constraints.

The SFR also confirms that lower-level performance requirements and plans for design and development form a satisfactory basis for proceeding to preliminary design. The SFR shall be held after the system functionality has been fully defined and all functional baseline documentation is complete.

Manufacturing & Quality SMEs should participate and provide input to the SRR and SFR on the selected materiel solution(s). Manufacturing & Quality personnel should provide results of the risks, issues, and opportunities based on the MRL assessment conducted to an MRL 5. Risks should be based on how closely the MRL 5 criteria and metrics are met and gap analysis with the degree of difficulty to meet MRL 6 by the completion of TMRR.[36] [37]

Preliminary Design Review (PDR)

The PDR shall be conducted to help ensure the preliminary design for the system under review is sufficiently mature and ready to proceed into detailed design. The design should also meet the stated performance requirements within program budget, schedule, risk, and other program and system constraints.

The PDR confirms that system-level functional and performance requirements have been correctly decomposed or directly allocated, trades have been conducted, and allocated baseline is complete. It also confirms the design satisfies all requirements from the SRR and SFR, interfaces have been documented, and development specifications are complete. PDR will include review of artifacts that all critical technologies have been demonstrated in an environment that addresses user operational requirements and specifications, and program risks have been identified with mitigation plans in place. PDR shall be held when the acquirer and supplier concur that the system-level preliminary design and allocated baseline documentation are complete.

Manufacturing & Quality SMEs should participate and provide results of the risks, issues, and opportunities based on the MRA conducted to an MRL 6. Risks should be based on how closely the MRL 6 criteria and metrics are met and gap analysis with the degree of difficulty to meet MRL 7 by the completion of the detailed design for CDR.

[36] *Manufacturing Readiness Level Deskbook*, 2022
[37] 10 U.S. Code § 4251 - MDAPs: Factors to be considered before Milestone A approval

Appendix A: MRL Role in Systems Engineering

Critical Design Review (CDR)

The CDR confirms that the initial product baseline is complete and describes the detailed design for production, fielding/deployment, and operations & support down to the lowest system element level. It should also confirm detailed designs for all interfaces (external and internal) satisfy the requirements contained in the control documentation defined at the PDR. The CDR will include artifacts showing demonstration of designed-in technologies in an environment that addresses user operational requirements and specifications. Additionally, critical manufacturing processes for key characteristics should be identified for a production-representative environment.

The CDR shall be held when the acquirer and supplier concur that the initial product baseline is complete, and the system is expected to meet system performance requirements within budget, schedule, risk, and other system constraints. The CDR shall ensure the detailed design for the system under review is adequate to proceed into fabrication, system integration, and demonstration & test.

Manufacturing & Quality SMEs should participate and provide results of the risks, issues, and opportunities based on the MRL assessment conducted to an MRL 7. Risks should be based on how closely the MRL 7 criteria and metrics are met and gap analysis with the degree of difficulty to meet MRL 8 in the pilot line demonstration for transition to LRIP.

Production Readiness Review (PRR)

A PRR evaluates the entire production-configured system to determine if it correctly and completely implements all system requirements. The system PRR should provide evidence that the system can be manufactured with acceptable risk and no breaches in cost, schedule, or performance thresholds. The PRR should also consider what production systems should be retained to sustain and maintain the system through its life-cycle. The PRR confirms the system design is ready for production and that adequate planning for entering LRIP or FRP has been accomplished.

The review confirms that the design is stable; the system meets validated capability requirements demonstrated by testing; the manufacturing processes are under control; the software sustainment processes are in place and functioning; the industrial production capabilities are reasonably available; the program security remains uncompromised; and the program has met or exceeds all directed criteria.

Manufacturing & Quality SMEs should participate and provide results of the risks, issues, and opportunities based on the MRL assessment conducted to an MRL 8 or MRL 9. For LRIP, risks should be based on how closely the MRL 8 criteria and metrics are met and gap analysis with the degree of difficulty to meet MRL 9 in LRIP for transition to FRP. For

FRP, risks should be based on how closely the MRL 9 criteria and metrics are met and gap analysis with the degree of difficulty to meet MRL 10 in ongoing production.

Physical Configuration Audit (PCA)

The PCA shall validate conformance of the as-built configuration of the system to its design documentation and the product baseline. The PCA shall confirm that the drawing release system, nomenclature, unique identification numbers, part numbers, manufacturing processes, software development processes & documentation, quality control system, measurement & test equipment, and training are adequately planned, followed, and controlled. It shall also confirm that all production-related activities (tooling, acceptance/inspection equipment, instructions, molds, jigs, and make-buy decisions) are validated and the Technical Data Package is complete.

"The PCA shall be held after successful completion of OT&E and system validation, but prior to the full rate production or full deployment (FD) decision review and operational use."[38] At this point, Manufacturing & Quality SMEs should conduct the MRL assessment to an MRL 9 for the FRP decision. Risks should be based on how closely the MRL 9 criteria and metrics are met.

After the FRP decision during on-going rate production, Manufacturing & Quality SMEs should conduct an MRL 10 assessment to evaluate how well the organization is implementing lean manufacturing and continuous improvement.

[38] IEEE 15288.2, *Technical Reviews and Audits on Defense Programs*, Nov 2014

Appendix B: Conducting MRL Assessments

The MRL Deskbook describes how to organize and conduct an assessment from the viewpoint of an MCA program with assessment by the Program Office. It assumes that all levels are assessed at the same level and the team has received a completed self-assessment. This is an adequate description of the process for an MCA program, but does not include the best practice of more advanced lower tier elements.

In this appendix, we will provide a description of a system level assessment including how to include phased maturity into the process.

The first action in assessing a product at the top level (system), is to determine where it is in the development process (maturity based on program schedule in Figure B-1). This is typically determined by what is the next System Engineering review to be conducted and when is it planned to occur (Appendix A). For example, if the next major review is PDR and transition to product development, then the system level should be assessed to MRL 6.

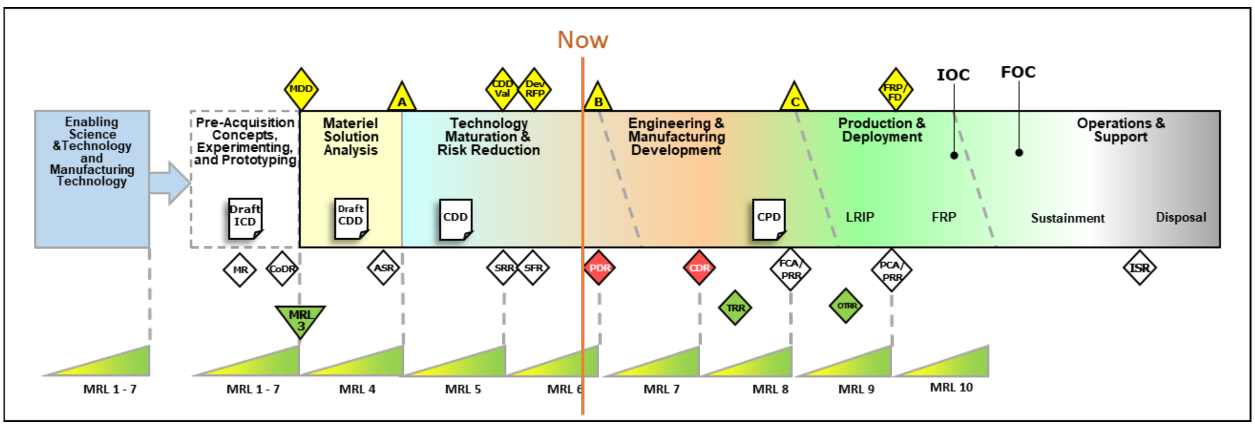

Figure B-1 Program Status

The second action is to determine, using the WBS or the BOM (Figure B-2), which subsystems, items, and components are included in the system that also require assessment in addition to the system (identify assessment scope).

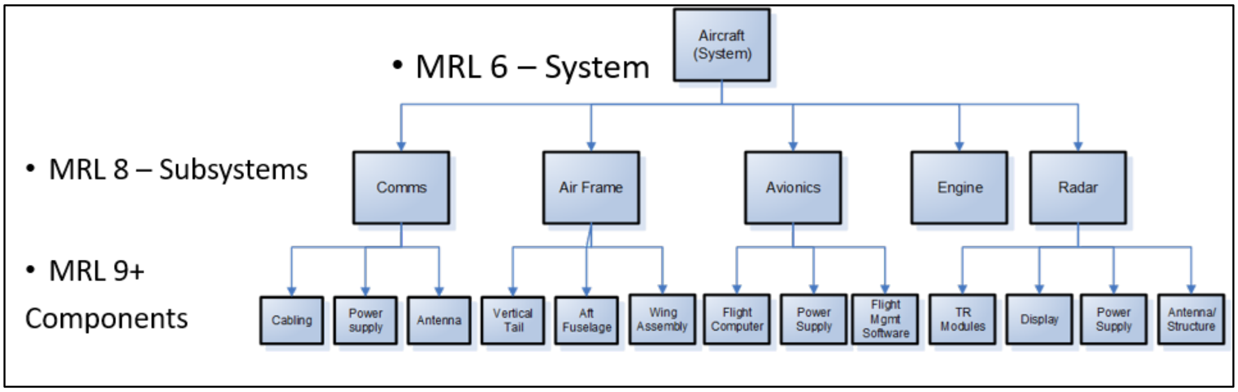

Figure B-2 Abbreviated WBS

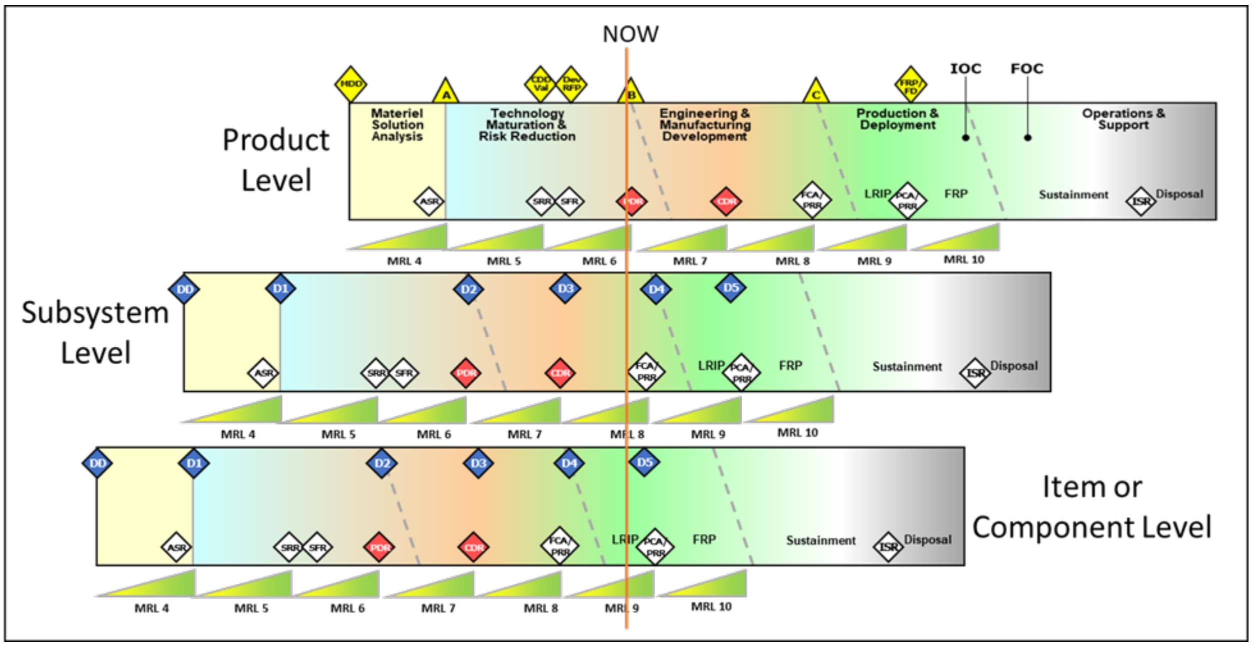

Figure B-3 Phased Maturity

Recall that based on a phased maturity approach (§ 5.0), and with the system level at PDR (MRL 6), the minimum maturity for subsystems should be at or near MRL 8 with items and/or components ready for production or already in production (Figure B-3). If programs or projects have more concurrency than this scenario, there is a significant increase in risk to programs or projects.

The third action is to perform the analysis of the sub-tiers with consideration of the schedule and MRL level as to how many and what type of assessments should be performed. The analysis can consist of asking the filter questions (in Section 5.0) and ranking by highest number of positive responses. At the subsystem, item, and component levels, the filter questions should be applied to prioritize which elements could be subject to a streamlined MRL assessment at a minimum. If there is significant risk found either through application of the filter questions or the streamlined MRL assessment, then a full MRL assessment of these elements should be performed. The table below shows the responses to the filter questions from the abbreviated WBS (Figure B-4).

	FILTER QUESTIONS											
Subsystems • Assemblies, Items, and Components	Technology	Industrial Base	Design	Cost & Funding	Materials Maturity	Manufacturing Maturity	Product Quality	SCM & Supplier Quality	Manufacturing Workforce	Facilities	Materials Planning &	Manufacturing OT Cybersecurity
Communications	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y
• Cable assembly	N	N	Y	N	N	Y	Y	N	Y	N	N	N
• Power Supply (comms)	N	Y	N	N	N	N	N	Y	N	N	Y	N
• Antenna (comms)	Y	N	Y	N	N	N	Y	N	N	N	N	N
Air Frame	N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	N
• Vertical Tail	N	N	N	Y	N	N	Y	N	Y	N	Y	N
• Aft Fuselage	N	N	N	Y	N	N	Y	N	Y	N	Y	N
• Wing Assy	N	N	Y	N	Y	Y	N	N	Y	Y	N	N
Avionics	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y
• Flight Computer	Y	Y	N	N	N	Y	N	Y	N	N	Y	N
• Flight Management Software	Y	N	Y	Y	N	N	Y	N	N	N	N	Y
• Power Supply (avionics)	N	Y	N	N	N	N	N	Y	N	N	Y	N
Engine	Y	N	Y	N	N	Y	N	Y	N	N	Y	N
Radar	Y	Y	Y	Y	Y	N	Y	Y	N	N	Y	N
• TR Modules	Y	N	N	N	Y	N	Y	N	N	N	Y	N
• Display	Y	N	N	Y	N	N	N	Y	N	N	N	N
• Power Supply (radar)	N	Y	N	N	N	N	N	Y	N	N	Y	N
• Antenna/ Structure	Y	N	Y	N	Y	N	Y	N	N	N	N	N

Figure B-4 Filter Question Responses

The fourth action is a ranked list of positive responses (e.g., there is likely risk in this element). The list below shows the following ranked responses:

Communications subsystem	9
Avionics subsystem	9
Air Frame subsystem	8
Radar subsystem	8

Engine subsystem	5
Flight computer	5
Flight management software	5
Wing assembly	5
Cable assembly	4
Vertical tail assembly	4
Aft fuselage assembly	4
TR modules	4
Antenna/structure (radar)	4
Antenna (comms)	3
Power Supply (comms)	3
Power Supply (avionics)	3
Power Supply (radar)	3
Display (radar)	3

The results indicate that the potential for risks is high in the subsystems that scored 9 or 8 positive responses, which will be assessed to MRL 8. These and the other subsystems would be candidates for on-site assessments and could possibly include the sub-tier items if co-located. The sub-tier items/assemblies with 4 and 5 positives, could be on-site or on-line based on factors of location, historical quality issues/risks, and which subsystem they impact. The lowest response items/assemblies with 3 positives, are candidates for online assessments. In addition to the considerations above, on-site assessments are typically reserved for locations where one or more of the following apply:

- The highest percentage of manufacturing cost is incurred
- Final assembly and test are conducted
- The most sensitive manufacturing tasks are accomplished
- The materials, components or subsystems that are the least technologically mature are produced or availability issues exist
- Known significant problems or risks (e.g., low yields, high costs, immature manufacturing processes) exist

Items not on this list that have no issues or did not trigger filter question positive responses will require monitoring of risks during integration and test for any new manufacturing risks that may occur.

If a system level assessment is to be conducted, the lower tier elements should have already been assessed with risks understood in order to assess the system level at MRL 6. An easy way to display MRL assessment results is shown in Figure B-5.

Appendix B: Conducting MRL Assessments

Thread	Sub-threads	Aircraft	Engine	Comms	Air Frame	Avionics	Radar	Communications			Air Frame			Avionics			Radar			
								Cable Assembly	Power Supply comms	Antenna comms	Vertical Tail	Aft Fuselage	Wing Assy	Flight Computer	Flight Management Software	Power Supply	TR Modules	Displays	Power Supply	Antenna Structure
A - Technology and Industrial Base	A.0 - Technology Maturity	5	6	8	8	8	6	9	9	9	9	9	9	9	9	9	6	9	9	7
	A.1 - Industrial base	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9
	A.2 - Manufacturing Technology Development	6	8	8	8	8	8	8	9	9	9	9	9	9	9	9	7	9	9	9
B - Design	B.1 - Producibility Program	6	6	8	8	8	8	9	9	9	9	9	9	9	9	9	6	9	9	9
	B.2 - Design Maturity	6	8	8	8	8	6	9	9	9	9	9	9	9	9	9	6	9	9	7
C - Cost & Funding	C.1 - Production Cost Knowledge (Cost modeling)	6	8	8	8	8	7	9	9	9	9	9	9	9	9	9	7	9	9	9
	C.2 - Cost Analysis	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	8	9	9	9
	C.3 - Manufacturing Investment Budget	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	8	9	9	9
D - Materials (Raw Materials, Components, Sub-assemblies and Sub-systems)	D.1 - Maturity	6	8	8	8	8	8	7	9	9	9	9	9	9	9	9	7	9	7	9
	D.2 - Availability	6	8	8	8	8	8	7	9	9	9	9	9	9	9	9	9	9	9	9
	D.3 - Supply Chain Management	6	8	8	8	8	8	8	9	9	9	9	9	9	9	9	8	9	8	9
	D.4 - Special Handling	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	8	9	9	9
E - Process Capability & Control	E.1 - Modeling & Simulation (Product & Process)	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	8	9	9	9
	E.2 - Manufacturing Process Maturity	5	6	8	8	8	5	6	9	9	9	9	9	9	9	9	6	9	9	5
	E.3 - Process Yields and Rates	6	8	8	8	8	6	9	9	9	9	9	9	9	9	9	6	9	9	7
F - Quality Management	F1. - Quality Management	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	8	9	9	8
	F2. - Product Quality	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	8	9	9	9
	F3. - Supplier Quality Management	6	6	8	8	8	8	9	9	9	9	9	9	9	9	9	8	9	7	9
G - Mfg Workforce (Engineering & Production)	G1. - Mfg Workforce (Engineering & Production)	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9
H - Facilities	H.1 - Tooling / Special Test and Inspection Equipment	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	8	9	9	9
	H.2 - Facilities	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9
I - Mfg Management	I.1 - Mfg Planning & Scheduling	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9
	I.2 - Materials Planning	6	6	8	8	8	8	9	9	9	9	9	9	9	9	9	9	9	8	9
	I.3 - OT Cybersecurity	6	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9

Figure B-5 Overarching MRL Assessment Dashboard

The dashboard visually points out areas that require needed focused efforts to increase manufacturing maturity and/or mitigate risks. These should be detailed in a Manufacturing Maturation Plan (MMP) as in Appendix C.

An MRL Assessment can be documented in a report in an agreed upon format. The report should include the following content:[39]

- Description of the technologies, components, items, subsystems, and systems assessed, including the current state of manufacturing capabilities.
- Program objectives and requirements, including production rate targets, schedule constraints, and MRL targets.
- Personnel involved in the MRL Assessment from both the assessed organization and the responsible organization.
- Dates, locations, and descriptions of visits conducted as part of the assessment.
- Description of how the MRL Assessment was conducted, including the MRL Criteria Matrix and Deskbook version used, the extent to which criteria were assessed, and any tools or methodologies applied; if any criteria were tailored or not assessed, document the approach and rationale.

[39] DI-SESS-81974, MRL Assessment Reporting, 2026 (Draft, release pending)

- Key and critical manufacturing technologies and processes associated with each assessed technology, component, item, subsystem, and system.
- Assessed MRL value for each applicable thread and subthread within the MRL Criteria Matrix, including description of supporting artifacts used to satisfy criteria.
- Manufacturing maturity gaps, shortfalls, and contributing factors related to MRL thread and subthread criteria, including required actions and artifacts to achieve target MRLs.
- Summary of identified risks to the program and the respective risk likelihood and consequences. Ensure risk is assessed against cost, schedule, and performance objectives.

Appendix C: Manufacturing Maturation Plan

When performing MRL assessments, it is useful to have a Risk Management System. Risk management includes risk planning, risk assessment, risk handling and mitigation strategies, and risk monitoring approaches. Identifying risk is a key part of developing mitigation efforts. Additional information on risk, issue, and opportunity management can be found in the "*DoD Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs*".

The purpose of an MRL assessment is to analyze current conditions and identify manufacturing issues and risks in order to assist the program/project manager in creating a plan or options to reduce or remove those risks.

A key product resulting from an MRL assessment is the MMP, which addresses the manufacturing risks and provides a mitigation plan for each risk area, including supplier and sub-tier supplier risk management shortfalls. Every MRL assessment should have an associated MMP for those subthreads where the MRL has not achieved its target level.

The MMP can be written as a standalone document or as an MMP presentation. If a written document, it can be attached to the MRL assessment report.

If a written document, the MMP should include:[40]

- The applicable technologies, items, components, subsystems, or systems, and indicate whether the activity supports a new insertion, is on the critical path, or represents an alternate path.
- The manufacturing maturity gaps, shortfalls, and risk factors addressed by the activity, its benefits to the product/program, and any consequences if not executed.
- The course of actions, including specific tasks required to execute the activity.
- Deliverables and expected outcomes, including the targeted MRL upon completion (overall MRL or specific threads and subthreads).
- Results, artifacts, and criteria or metrics used to evaluate success and demonstrate advancement in manufacturing maturity.
- Whether the activity is within or outside the scope of an existing program; for activities outside the scope, a Rough Order of Magnitude (ROM) cost estimate to indicate level of effort.
- Assigned personnel and responsible organizations for execution, as well as authorities responsible for review and approval.

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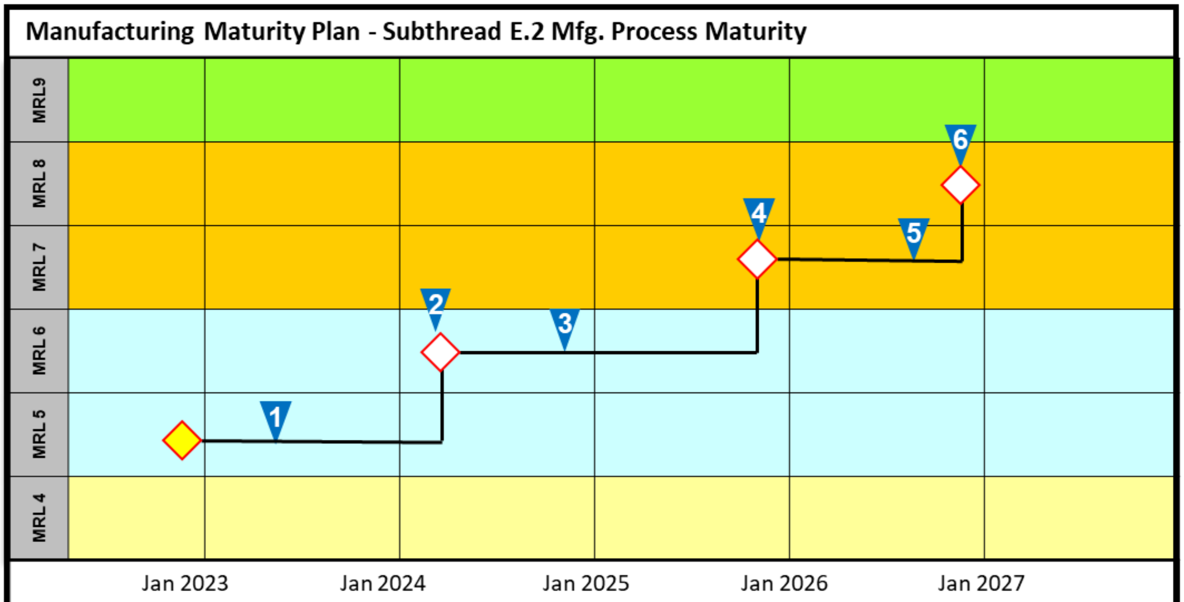
[40] DI-SESS-81974, MRL Assessment Reporting, 2026 (Draft, release pending)

- ROM schedule and timeline, including key milestones and deliverables, and an assessment of alignment with product delivery requirements.
- Potential challenges, constraints, and risks associated with execution, including impacts to required resources (e.g., personnel, equipment, and facilities).

Figure C-1 is an example of visually displaying an MMP for a single subthread from the prior Appendix B system MRL assessment.



Actions	Goals	Cost	Start Date	End Date	Focal Point
1. Supplier Quality Data System	QDS Complete	$XXX	Nov 2022	May 2023	Joe Schlob
2. Manufacturing Relevant	Demonstration in relevant environment	$XXX	Mar 2024	Nov 2025	Fred Smith
3. QDS Supplier	Supplier QDS refining Cpks	$XXX	Nov 2024	Oct 2025	Joe Schlob
4. Manufacturing Representative	Demonstration in production representative environment	$XXX	Nov 2025	Aug 2026	Fred Smith
5. Manufacturing Pilot	Demonstration of Pilot Line	$XXX	Aug 2026	Nov 2026	Fred Smith
6. QDS targets	Cpks meet pilot targets	$XXX	Nov 2026	Nov 2026	Joe Jones

Figure C-1 Manufacturing Maturation Plan

Appendix D: TRLs and MRLs Prior to Acquisition

Enabling Science & Technology and Manufacturing Technology[41]

Between Government and Industry S&T, R&D, and ManTech projects, the technology maturity can range from TRL 1 to TRL 7 and the manufacturing maturity from MRL 1 to MRL 7. These programs/projects develop technologies and products of varying maturities that can be integrated into either pre-MDD activities or ongoing acquisition programs.

As a separate effort from MCA, the range of maturity in S&T can be from very immature (TRL 1 or 2) to a mature demonstration in a TRL 7 operational environment (Figure D-1). Maturing technology is not always responsive to funding and effort, and may not be achieved on a schedule. Technologies must be sufficiently mature, with technical risks judged to be acceptable, to warrant insertion in a program that assumes a sufficient level of manufacturing maturity is also met.

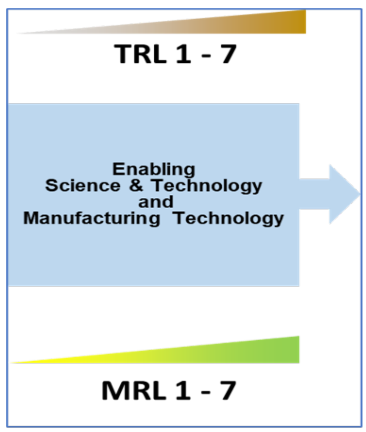


Figure D-1 TRLs and MRLs in S&T and ManTech

S&T programs:

- Use TRLs to measure progress in maturing technologies
- Should develop and mature technologies to a minimum of TRL 5
- May also develop unique manufacturing processes, procedures, or techniques

Also separate from MCA, DoW ManTech programs develop manufacturing processes, procedures, and techniques for existing products; demonstrate application to new products; and develop manufacturing capabilities to the point where they can be integrated into production of the product. The ManTech programs generally mature manufacturing processes, procedures, and techniques from MRL 4 to MRL 7.

[41] Materials in this Appendix are from the APT paper "MRLs and TRLs in DoD Major Capability Acquisition," Apr 2024, which can be found on APTCorp-US.com/resources

Appendix D: TRLs and MRLs Prior to Acquisition

Pre-Acquisition Concepts, Experimenting and Prototyping

During pre-acquisition, early-stage ideas and strategies are examined before formal acquisition processes begin and concepts are explored for potential solutions envisioning novel approaches, while identifying capability gaps. Advanced technology demonstration programs play a crucial role in evaluating and maturing advanced technologies for potential use. Experimentation is performed using systematic testing and exploration to gain insights and validate approaches and hypotheses. Prototypes are developed to validate designs, reduce technical risk, and gather feedback. Collectively, these are used to contribute to informed decision making, technological advancement, and development of capabilities. All of the above activities provide the basis or inputs to the engineering process described in both the *Engineering of Defense Systems Guidebook* and DoDI 5000.88*,* which results in identification of candidate concepts and alternatives that could meet the mission objective.

The Joint Staff conducts a CBA, and/or other studies as part of the Joint Capability Integration and Development System process, producing a draft ICD. The draft ICD contains the initial Key Performance Parameters (KPP), Key System Attributes, 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. Mission Engineering will conduct deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects. The Mission Review is the culmination of requirements and mission engineering activities.

The CoDR is a multidisciplined review of the potential joint warfare concepts, Service-specific concepts, and considerations to establish the Concept Baseline. The CoDR should review the results of experimenting and prototyping these concepts, including a review of manufacturing & quality engineering analyses and inputs. These activities should also include manufacturing feasibility assessment (MRL assessment), studies from the S&T community, and other supporting studies (threat analysis, gap studies, etc.) contributing pertinent data and information for the MDD.

The prototypes, which have been developed to validate designs and reduce risk, should have been used to validate technologies in an environment that used the most stressing aspects of the operational environment. Systems for development should therefore not enter the MSA phase without having validation in a relevant environment.

Appendix D: TRLs and MRLs Prior to Acquisition

As a result of the above activities, immature technologies will have been matured to between TRL 5 and 7 with a minimum of TRL 5 at the product level, which is the recommended entrance criterion for MDD. Manufacturing maturity could have likewise matured up to MRL 7, but should meet a minimum of MRL 3 as a recommended entrance criterion for MDD (Figure D-2).

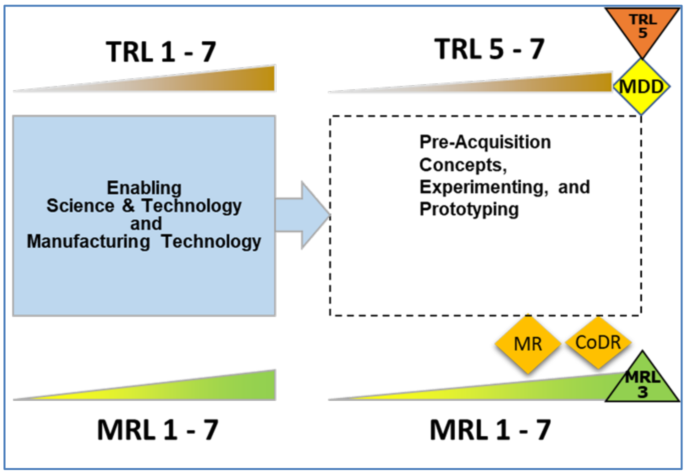


Figure D-2 TRLs and MRLs During Pre-Acquisition

Recall that enabling S&T, ManTech development, and experimenting & prototyping with pre-acquisition concepts are continuously ongoing activities. They are separately funded and independent of any MCA or acquisition approach. Given that systems are designed with modular open systems architecture, the results of these pre-acquisition activities can be inserted into programs at any point, commensurate with the maturity of the products and the program.

Appendix E: Digital Manufacturing Maturity Framework

APT developed a method for assessing the digital maturity of any functional organization or area within such organization. This method is described in "Digital Maturity Framework a Streamlined Approach", Jul 2024, available at APTCorp-US.com/resources.

DoW utilized this streamlined method with elements of the Army's Digital Engineering Maturity Model and the Navy's Model Based Systems Engineering framework to produce a tool for assessing the digital manufacturing maturity of an organization. The result of this effort is shown below as six factors against five levels of maturity with appropriate metrics for each factor and level.

This approach to assessing digital maturity of manufacturing can be performed independent of the MRL assessment process; however, it is consistent with said process by using the 12 subthreads from the streamlined MRL assessment process with generalized versions of the criteria focused on information or data. The 12 subthreads and criteria are detailed in Figure E-3 below.

Assessment Factors

The Digital Manufacturing Maturity Assessment framework (DMMA) construct looks at six factors that are part of any organization's operations and can be improved by digitizing the processes or activities. The factors are those in Figure E-1: data collection and analysis, data storage and access, communication method, operations, interfaces, and decision making.

Factor	**Question**
Data collection and analysis	How is information or data collected and analyzed?
Data storage and access	How is information or data stored and data access managed?
Communication method	How is information or data transmitted and received?
Operations	How are operations, processes, procedures controlled or managed?
Interfaces	How do interfaces function for data, communications, and operations?
Decision making	How is decision making accomplished?

Figure E-1 Factors and Questions

Each of the factors is associated with a question about the level of digitization. The factors/questions will have a specific metric for each maturity level.

Appendix E – Digital Mfg. Maturity Framework

Levels of Digital Maturity

The approach used was to establish five levels, ignoring the level zero analog only state.

- Level 1: "Manual and Digital Environment"

  Digital manufacturing practices are primarily manual, with limited or no integration of digital tools.

- Level 2: "Standardized Environment"

  Digital manufacturing practices are standardized across key functions but remain independently executed.

- Level 3: "Integrated Environment"

  Digital manufacturing capabilities are partially integrated across select systems and functions.

- Level 4: "Automated Environment"

  Digital manufacturing systems are fully automated and interoperable across all connected devices and processes.

- Level 5: "Autonomous Environment"

  Digital manufacturing systems operate in a fully autonomous environment with minimal or no human intervention.

These levels will be headings in the matrix of metrics to be met.

Metrics Matrix

The DMMA (Figure E-2) is used to assess the artifacts presented in conjunction with an assessment or review of an organization, program, or functional area to determine the digital maturity.

The DMMA shows six factors/questions that range from data collection and storage, to communications, operations, interfaces, and decision making. Each of the factors have criteria for each level of digital maturity ranging from Level 1 (Manual and Digital Environment) to Level 5 (Autonomous Environment).

Appendix E – Digital Mfg. Maturity Framework

DMMA Framework					
Factor/Question	Level 1	Level 2	Level 3	Level 4	Level 5
	Manual & Digital Environment	Standardized Environment	Integrated Environment	Automated Environment	Autonomous Environment
Data collection and analysis – How is information or data collected and analyzed?	Data is manually collected. Data analysis is manually performed by authorized personnel using the user's preferred methods or tools.	Data is collected is a standardized format. Data analysis is performed by authorized personnel using standardized tools.	Data collection is integrated between select network of independent devices. Data analysis is partially automated using select tools.	Data collection is fully automated from the network of all interdependent devices. Data analysis is supported with predictive or prescriptive automated processes, with human verification.	Data collection and analysis is performed autonomously providing predictive and prescriptive analyses.
Data storage and access – How is information or data stored and data access managed?	Data is stored manually in a standalone or local place. Data is shared by exporting; can be sent by request to verified entities. No data access by external or internal users.	Data is stored in standardized repositories that are configuration managed. Data is shared by access to storage devices by request from verified entities. Data access is granted independently to verify internal or external entities.	Data storage is integrated between select network of independent locations. Data shared to verified entities with minimal or no user intervention, re-entry, or reformatting. Data access is integrated based on controls to verify internal or external entities.	Data is stored automatically in interoperable locations. Data is shared with no user intervention, re-entry or reformatting. Data access is automated based on user role with human verification.	Data is automatically stored and shared to support operations. Data is aggregated and pushed autonomously to authorized users.
Communication method – How is information or data transmitted and received?	Communication is executed manually without traceability and can be flowed physically or digitally.	Communication is executed manually without traceability and can be flowed physically or digitally.	Communication flow is integrated between select nodes with minimal or no re-entry or re-creation, but with human authorization.	Communication is automated between all nodes with human verification.	Communication is fully autonomous between all nodes without human intervention.
Operations – How are operations, processes, procedures controlled or managed?	Operations, processes, and procedures are manually controlled or managed.	Operations, processes, and procedures are standardized and independently controlled or managed.	Operations, processes, and procedures are integrated, controlled or managed by software, with	Operations, processes, and procedures are automated, controlled or managed by software, with	Operations, processes, and procedures are autonomously monitored and controlled.

Appendix E – Digital Mfg. Maturity Framework

			human authorization.	human verification.	
Interfaces – How do interfaces function for data, communications, and operations?	Interfaces for data, communications, and operations are manually controlled or managed.	Interfaces for data, communications, and operations are standardized and independently controlled or managed.	Interfaces for data, communications, and operations are integrated, controlled or managed by software, with human authorization.	Interfaces for data, communications, and operations are automated by software with human verification.	Interfaces for data, communications, and operations are autonomous.
Decision making– How is decision making accomplished?	Decision making by authorized personnel using a mix of manual and digitized processes.	Decision making by authorized personnel using standardized tools.	Decision making is accomplished by authorized personnel using integrated and validated analytical tools and information.	Decision making is automated using information from validated analytical tools, with verification by authorized personnel.	Decision making is autonomous.

Figure E-2 DMMA Framework

To perform an assessment, each of the 12 subthreads is evaluated against the DMMA, identifying a level for each factor. Each subthread utilizes a generalized criterion for the subthread subject area as shown in Figure E-3 below.

Subthread/Subject Area	Criteria
Technology Maturity	How do you validate and demonstrate technology maturity throughout the development process?
Industrial Base	How are industrial base capacities and capabilities to support the product throughout the development process?
Design Maturity	How is product data, including KCs, essential for manufacturing managed throughout the development process?
Cost & Funding	How is product cost data and funding analyzed and tracked against targets during the development process?
Materials Maturity	How is materials maturity data verified and validated throughout the development process?
Manufacturing Maturity	How are processes, yields, and rates demonstrated, refined, and verified across the development process?
Product Quality	How is product quality including KC test and inspection, control plans, and procedures tracked and managed?
Supply Chain	How are supplier quality data and products tracked and managed throughout the development process?

Manufacturing Workforce	How are workforce requirements, skill sets (training), and planning tracked and managed throughout the development process?
Facilities	How are manufacturing facilities capacity and capability tracked and managed throughout the development process?
Materials Planning	How are BOMs and make/buy decisions with availability risks and issues tracked and managed throughout the development process?
Manufacturing OT Cybersecurity	How are OT cybersecurity requirements, solutions, and incident control identified, demonstrated, and managed throughout the development process?

Figure E-3 Streamlined MRL Generalized Criteria

Each subthread is scored for each factor with a digital maturity level. Shown in Figure E-4 is the example for the subthread "Product Quality."

	Summary	Subthread/Subject Area	Criteria	Evidence or Artifact		
	3.0	Product Quality	How is product quality including KC test and inspection, control plans, and procedures tracked and managed?	[Enter Evidence or Artifact]		
		Digital Maturity Framework				
Level		Level 1	Level 2	Level 3	Level 4	Level 5
Factors and question		Manual and Digital Environment	Standardized Environment	Integrated Environment	Automated Environment	Autonomous Environment
Data collection and analysis – How is information or data collected and analyzed?	3	Data is manually collected. Data analysis is manually performed by authorized personnel using the user's preferred methods or tools.	Data is collected is a standardized format. Data analysis is performed by authorized personnel using standardized tools.	Data collection is integrated between select network of independent devices. Data analysis is partially automated using select tools.	Data collection is fully automated from the network of all interdependent devices. Data analysis is supported with predictive or prescriptive automated processes, with human verification.	Data collection and analysis is performed autonomously providing predictive and prescriptive analyses.
Data storage and access – How is information or data stored and data access managed?	3	Data is stored manually in a standalone or local place. Data is shared by exporting; can be sent by request to verified entities. No data access by external or internal users.	Data is stored in standardized repositories that are configuration managed. Data is shared by access to storage devices by request from verified entities. Data access is granted independently to verify internal or external entities.	Data storage is integrated between select network of independent locations. Data shared to verified entities with minimal or no user intervention, re-entry, or reformatting. Data access is integrated based on controls to verify internal or external entities.	Data is stored automatically in interoperable locations. Data is shared with no user intervention, re-entry or reformatting. Data access is automated based on user role with human verification.	Data is automatically stored and shared to support operations. Data is aggregated and pushed autonomously to authorized users.
Communication method – How is information or data transmitted and received?	3	Communication is executed manually without traceability and can be flowed physically or digitally.	Communication is independently executed in a standardized, digital, format with traceability.	Communication flow is integrated between select nodes with minimal or no re-entry or re-creation, but with human authorization.	Communication is automated between all nodes with human verification.	Communication is fully autonomous between all nodes without human intervention.
Operations - How are operations, processes, and procedures controlled or managed?	2	Operations, processes, and procedures are manually controlled or managed.	Operations, processes, and procedures are standardized and independently controlled or managed.	Operations, processes, and procedures are integrated, controlled or managed by software, with human authorization.	Operations, processes, and procedures are automated, controlled or managed by software, with human verification.	Operations, processes, and procedures are autonomously monitored and controlled.
Interfaces – How do interfaces function for data, communications, and operations?	4	Interfaces for data, communications, and operations are manually controlled or managed.	Interfaces for data, communications, and operations are standardized and independently controlled or managed.	Interfaces for data, communications, and operations are integrated, controlled or managed by software, with human authorization.	Interfaces for data, communications, and operations are automated by software with human verification.	Interfaces for data, communications, and operations are autonomous.
Decision making– How is decision making accomplished?	3	Decision making is accomplished by authorized personnel using a mix of manual and digitized processes.	Decision making is accomplished by authorized personnel using standardized tools.	Decision making is accomplished by authorized personnel using integrated and validated analytical tools and information.	Decision making is automated using information from validated analytical tools, with verification by authorized personnel.	Decision making is autonomous.

Figure E-4 Subthread Product Quality Scoring

Scoring all 12 subthreads results in a complete DMMA evaluation. The complete evaluation can be summarized by providing an average level score for each subthread in Figure E-5.

Appendix E – Digital Mfg. Maturity Framework

DMMA Results	Average level	Level 1	Level 2	Level 3	Level 4	Level 5
	2.8	Manual and Digital Environment	Standardized Environment	Integrated and Distributed Environment	Automated Environment	Autonomous Environment
Technology Maturity	2.0					
Industrial Base	2.0					
Design Maturity	3.0					
Cost & Funding	4.0					
Materials Maturity	4.0					
Manufacturing Maturity	3.5					
Product Quality	3.0					
Supply Chain	3.2					
Manufacturing Workforce	2.8					
Facilities	2.5					
Materials Planning	3.0					
Manufacturing OT Cybersecurity	2.0					

Figure E-5 DMMA Results

This assessment process with framework and evaluations has been incorporated into an Excel tool. This DMMA and associated tool were reviewed and modified slightly prior to submission for approval to the Digital Manufacturing Enterprise (DME) Working Group and the Joint Defense Manufacturing Council (JDMC). The submitted version of this tool can be found on the APT website at aptcorp-us.com/resources.

APT
Advanced Product Transitions Corp.

Appendix F: Detailed MRL Matrix Criteria

F-1. MRLs for the Technology and Industrial Base Thread

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				MDD	ASR A	SRR/SFR	PDR B	CDR	PRR/SVR C	PCA FRP	
Thread	Sub-Thread	MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
A - Technology and Industrial Base	A.0 Technology Maturity	Technology concept and/or applications formulated	Component and/or breadboard validation in a laboratory environment.	Component and/or breadboard validation in a relevant environment.	Subsystem model or prototype demonstration in a relevant environment.	System model or prototype demonstration in a relevant environment.	System prototype demonstrated in an operational environment.	System prototype demonstrated in an operational environment.	Actual system completed and qualified through test and demonstration.	Actual system proven through successful mission operations.	Actual system proven through successful mission operations.
	A.1 Industrial Base	Global trends in emerging industrial base capabilities identified.	Potential industrial base capability gaps identified.	Industrial base capabilities for potential sources identified for system concepts.	Industrial base including capacities and capabilities surveyed for preferred materiel solution, key technologies, components, and/or key processes. Industrial base considerations included in AoA with capability risks and issues documented in the AS.	Industrial base analysis initiated to identify potential manufacturing sources. Sole/single/FOCI sources identified and planning initiated to minimize risks.	Industrial base (IB) analysis including capacity and capability for MS B completed. Industrial capability in place to support manufacturing of development articles. Plans to avoid or justification of sole/single/FOCI IB sources complete.	Industrial base capacity and capability to support production analyzed. Justified Sole/single/FOCI industrial base sources assessed and monitored.	Industrial base capacity and capability analysis for MS C completed. Industrial capability is in place to support LRIP.	Industrial base capacity and capability analysis for FRP has been completed and capability is in place to support start of FRP.	Industrial base analysis capacity and capability supports FRP and includes support for modifications, upgrades, surge and other potential manufacturing requirements.
	A.2 Manufacturing Technology Development	Global trends in manufacturing science and technology identified (i.e., concepts, capabilities).	Potential manufacturing science and technology gaps identified.	Manufacturing technology requirements identified to address potential capability gaps for system concepts.	Manufacturing technology development initiatives defined for preferred materiel solution. Manufacturing technology development requirements considered in the AoA.	Required manufacturing technology development efforts initiated.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production relevant environment.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production representative environment.	Primary manufacturing technology efforts concluding. Improvement efforts continuing. Required manufacturing technology solutions validated on a pilot line.	Manufacturing technology process improvements efforts initiated for FRP.	Manufacturing technology continuous process improvements ongoing.

Appendix F: Detailed MRL Matrix Criteria

F-2. MRLs for the Design Thread

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				(MDD)	ASR (A)	SRR/SFR	PDR (B)	CDR	PRR/SVR (C)	PCA (FRP)	
Thread	Sub-Thread	MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
B - Design	B.1 Producibility Program	Hypotheses developed for cause-effect relationships between technology variables and producibility.	Studies performed to test hypotheses regarding cause-effect relationships between technology variables and producibility. Elements identified which have a potential impact to producibility (i.e., materials, processes, capabilities, limitations).	System concept elements evaluated for manufacturability and producibility using experiments and modeling, and simulation.	Initial producibility assessments of preferred materiel solution complete. Results considered in AoA and documented in AS key components/technologies.	Producibility and manufacturability assessments of key technologies and components initiated. Ongoing design trades consider manufacturing processes and industrial base capability constraints. Manufacturing processes assessed for capability to be tested and verified in production. Manufacturing processes assessed for influence on O&S.	Producibility assessments and producibility trade studies (performance vs. producibility) of key technologies/components completed. Results used to shape AS, SEP, manufacturing and producibility plans, and planning for EMD or technology insertion programs. Preliminary design choices assessed against manufacturing processes and industrial base capability constraints. Producibility enhancement efforts (i.e., DFM, DFA, etc.) initiated.	Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (i.e., DFM, DFA, etc.) ongoing for optimized integrated system. Manufacturing processes re-assessed as needed for capability to be tested and verified. Manufacturing processes re-assessed as needed for potential influence on O&S.	Producibility improvements implemented on system. Known producibility risks and issues managed for LRIP.	Prior producibility improvements analyzed for effectiveness during LRIP. Producibility risks and issues discovered in LRIP managed for FRP.	Design producibility improvements demonstrated in FRP. Process producibility improvements ongoing. All modifications, upgrades, DMSMS and other changes assessed for producibility.
B - Design	B.2 Design Maturity	Current capability deficiencies and gaps identified.	Analyses performed to evaluate the feasibility of potential solutions to address capability gaps.	High-level performance, lifecycle, and technical requirements defined and evaluated for system concepts. Trade-offs in design options assessed based on experiments and initial MOEs.	Form, fit, and function constraints identified for preferred materiel solution. SEP and T&E Strategy recognize the need for the establishment and validation of manufacturing capability and management of manufacturing risk for the product life cycle. Initial KPPs identified for preferred materiel solution. System technical requirements and measures to support required capabilities identified.	Lower level performance requirements sufficient to proceed to preliminary design. All enabling/critical technologies and components identified and the product lifecycle considered. Evaluation of the design for KCs initiated. Product data required for prototype component manufacturing released.	System allocated baseline established. Product requirements and features are well enough defined to support PDR. Product data essential for subsystem/ system prototyping has been released, and all enabling/critical components have been prototyped. Preliminary KCs for the design identified and mitigation plans initiated.	Product design and features are well enough defined to support CDR, even though design change traffic may be significant. All product data essential for component manufacturing released. Potential KC risks and issues identified with mitigation plans in place.	Detailed design of product features and interfaces completed. All product data essential for system manufacturing released. Design change traffic does not significantly impact LRIP. KCs are attainable based upon pilot line demonstrations.	Major product design features and configuration are stable. System design has been validated through operational testing of LRIP items. PCA or equivalent complete as necessary. Design change traffic is limited. All KCs are controlled in LRIP to appropriate quality levels.	Product design is stable. Design changes are few and generally limited to those required for continuous improvement or in reaction to obsolescence. All KCs are controlled in FRP to appropriate quality levels.

Appendix F: Detailed MRL Matrix Criteria

F-3. MRLs for the Cost and Funding Thread

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews					MDD ASR	A SRR/SFR	PDR	B CDR	PRR/SVR	C PCA	FRP
Thread	Sub-Thread	MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
C - Cost & Funding	C.1 Production Cost Knowledge (Cost modeling)	Hypotheses developed regarding technology impact on affordability.	Cost model approach defined.	Manufacturing cost estimates for system concepts developed. Initial cost models developed which include high-level process steps and materials.	Cost estimates refined based on anticipated production volumes associated with preferred materiel solution. Cost model updated with identified cost drivers (i.e., process variables, manufacturing, materials, and special requirements). Cost model supports AoA and ASR.	Prototype components produced in a production relevant environment, or simulations drive end-to-end cost models. Cost model includes materials, labor, equipment, tooling/STE/SIE, setup, yield/scrap/rework, WIP, and capability/capacity constraints.	Cost model updated with design requirements, material specifications, tolerances, IMS, results of system/subsystem simulations and production relevant prototype demonstrations.	Cost model updated with the results of systems/sub-systems produced in a production representative environment, production plant layout and design, and obsolescence solutions.	Cost model updated with results of pilot line build.	FRP cost model updated with result of LRIP build.	Cost model validated against actual FRP cost.
	C.2 Cost Analysis	Initial manufacturing and quality costs identified.	Potential manufacturing and quality cost drivers and system affordability gaps identified.	Analysis conducted to refine manufacturing and quality cost drivers, risks, and development strategy (i.e. lab to pilot to factory). Potential cost reduction and system affordability gap closure strategies identified.	Producibility and lifecycle cost risks and issues assessed for preferred materiel solution. Initial cost analysis supports the AoA and ASR.	Costs analyzed using prototype component actuals to ensure target costs are achievable. Decisions regarding design choices, make/buy, capacity, process capability, sources, quality, KCs, yield/rate, and variability influenced by cost models.	Costs analyzed using prototype system/sub-system actuals to ensure target costs are achievable. Cost targets allocated to subsystems. Cost reduction and avoidance strategies developed. Manufacturing cost drivers for "Should-Cost" model provided.	Manufacturing costs rolled up to system/sub-system level and tracked against targets. Detailed trade studies and engineering change requests supported by cost estimates. Cost reduction and avoidance strategies underway. Manufacturing cost drivers for "Should-Cost" model updated.	Costs analyzed using pilot line actuals to ensure target costs are achievable. Manufacturing cost analysis supports proposed changes to requirements or configuration. Cost reduction initiatives ongoing. Manufacturing cost drivers for "Should-Cost" model updated.	LRIP cost goals met and learning curves analyzed with actual data. Cost reduction initiatives ongoing. Touch labor efficiency analyzed to meet production rates and elements of inefficiency are identified with plans in place for reduction.	FRP cost goals met. Cost reduction initiatives ongoing.
	C.3 Manufacturing Investment Budget	Potential manufacturing investment strategy developed.	Program/projects have reasonable budget estimates for reaching MRL 3 through experiment. Manufacturing investment budget ROM estimates identified to support industrial base and manufacturing capability gap closure strategies.	Program/projects have reasonable budget estimates for reaching MRL 4 by MS A. Preliminary manufacturing investment budget estimates for manufacturing gap closure recommendations developed.	Manufacturing technology budget initiatives developed and incorporated to reduce costs. Program has reasonable budget estimate for reaching MRL 6 by MS B. Estimate includes capital investment for production relevant equipment. All outstanding MRL 4 risks and issues understood with approved mitigation plans in place.	Program has updated budget estimate for reaching MRL 6 by MS B. All outstanding MRL 5 risks and issues understood with approved mitigation plans in place.	Program has reasonable budget estimate for reaching MRL 8 by MS C. Estimate includes capital investment for production-representative equipment by CDR and pilot line equipment by MS C. All outstanding MRL 6 risks and issues understood with approved mitigation plans in place.	Program has updated budget estimate for reaching MRL 8 by MS C. All outstanding MRL 7 risks and issues understood with approved mitigation plans in place.	Program has reasonable budget estimate for reaching MRL 9 by the FRP decision point. Estimate includes investment for LRIP and FRP. All outstanding MRL 8 risks and issues understood with approved mitigation plans in place.	Program has reasonable budget estimate for FRP. All outstanding MRL 9 risks and issues understood with approved mitigation plans in place.	Production budgets sufficient for production at required rates and schedule to support funded program.

Appendix F: Detailed MRL Matrix Criteria

F-4. MRLs for the Materials Thread

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				MDD	ASR	A SRR/SFR	PDR	B CDR	PRR/SVR	C PCA	FRP
Thread	Sub-Thread	MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
D - Materials (Raw Materials, Components, Sub-assemblies and Sub-systems)	D.1 Maturity	New material properties and characteristics surveyed and identified for research (e.g., manufacturability, quality).	Potential effects of new material properties on design application manufacturability and quality predicted based on research.	Effects of new material properties on design concept manufacturability and quality validated using experiments and models.	New materials and components for preferred materiel solution demonstrated in a laboratory environment.	Materials manufactured or produced in a prototype environment (may be in a similar application/program). Maturation efforts in place to address new material production risks for technology demonstration.	Material maturity verified through technology demonstration articles. Preliminary material specifications in place. Material properties adequately characterized.	Material maturity sufficient for pilot line build. Material specifications approved.	Materials proven and validated during EMD as adequate to support LRIP. Material specifications stable.	Materials controlled to specifications in LRIP. Materials proven and validated as adequate to support FRP.	Materials controlled to specifications in FRP.
	D.2 Availability	Global trends for material availability, obsolescence, and DMSMS surveyed and identified for research.	Material availability, obsolescence, and DMSMS gaps identified.	Material availability, obsolescence, and DMSMS gap closure strategy defined.	Projected lead times identified for all difficult to obtain, difficult to process, or hazardous materials. Quantities and lead times estimated. Material availability risks and issues for preferred materiel solution considered in AoA. Mitigation plans incorporated in SEP for the preferred materiel solution.	Availability risks and issues addressed for prototype build. Significant material risks identified for all materials. Planning initiated to address scale-up issues.	Availability risks and issues addressed to meet EMD build. Long-lead items identified. Potential obsolescence issues identified. Components assessed for future DMSMS risk.	Availability risks and issues addressed to meet LRIP builds. Long lead procurements identified and mitigated. Obsolescence plan in place. DMSMS mitigation strategies for components in place.	Availability risks and issues managed for LRIP. Long lead procurement initiated for LRIP. Availability issues addressed to meet FRP builds.	Long lead procurement initiated for FRP. Availability risks and issues managed for FRP.	All material availability risks and issues managed.
	D.3 Supply Chain Management	Global trends for supply chain capability and capacity surveyed.	Potential supply chain capability and capacity gaps identified.	Supply chain capability and capacity gap closure strategies defined.	Survey of potential supply chain sources for preferred materiel solution completed. Supply chain capability and capacity analyses considered in the AoA.	Potential supply chain sources identified and evaluated as able to support prototype build.	Lifecycle Supply Chain requirements updated. Critical suppliers list updated. Supply chain plans in place (e.g. teaming agreements, etc.) supporting an EMD contract award.	Effective supply chain management processes defined, documented, and in place. Plan developed for predictive indicators. Assessment of critical first tier supply chain completed (i.e., capability, capacity, etc.).	Assessment of critical second and lower tier supply chain completed. Robust requirements flow down processes in place and verified. Supplier compliance with program requirements and changes validated. Plan for predictive indicators for use in production updated. Supply chain adequate to support LRIP.	Long term agreements in place where practical. Prime's supplier management metrics (including thresholds and goals) in place and used to manage risks. Predictive indicators to manage suppliers in place. Supply chain is stable and adequate to support FRP.	Supply chain proven and supports FRP requirements.
	D.4 Special Handling (i.e. GFP, shelf life, security, hazardous materials, storage environment, ESH, etc.)	Hazardous materials identified and safety procedures in place.	Raw materials and components assessed for special handling and potential regulatory requirements.	ESH compliance risk identified. List of hazardous materials identified and alternatives evaluated. Special handling procedures applied in the lab. Special handling concerns assessed.	ESH compliance risk mitigated in lab environment. List of hazardous materials updated and alternatives assessed. Special handling procedures applied and disposal procedures evaluated. Special handling requirements identified, analyzed, and documented in the SEP.	ESH requirements and special handling procedures applied in production relevant environment. Special handling requirement gaps identified. New special handling processes demonstrated in lab environment.	ESH requirements addressed and documented. Special handling procedures demonstrated in production relevant environment. Plans to address special handling requirement gaps, risks, and issues complete. Manufacturing assessed for material storage and waste handling risks.	ESH compliance demonstrated in production representative environment. Special handling procedures applied in production representative environment. Special handling procedures developed and annotated on work instructions for pilot line. Hazardous material storage and disposal plan in place for the pilot line.	ESH compliance demonstrated in pilot line production. Special handling procedures applied in pilot line environment and demonstrated in EMD or technology insertion programs. Special handling risks and issues managed for LRIP. All work instructions contain special handling provisions as required. Hazardous material storage and disposal plan evaluated and in place for LRIP.	ESH compliance demonstrated in LRIP. Special handling, and hazardous material storage and disposal procedures demonstrated in LRIP environment. Special handling, and hazardous material storage and disposal risks and issues managed for FRP.	ESH compliance demonstrated in FRP. Special handling and hazardous material storage and disposal procedures effectively implemented in FRP.

Appendix F: Detailed MRL Matrix Criteria

F-5. MRLs for the Process Capability and Control Thread

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews					MDD ASR A	SRR/SFR	PDR B	CDR	PRR/SVR C	PCA FRP	
Thread	**Sub-Thread**	**MRL 1**	**MRL 2**	**MRL 3**	**MRL 4**	**MRL 5**	**MRL 6**	**MRL 7**	**MRL 8**	**MRL 9**	**MRL 10**
E - Process Capability & Control	E.1 Modeling & Simulation (Product & Process)	Modeling and simulation approaches/tools identified to support manufacturing and quality activities.	Modeling and simulation development initiated.	Manufacturing and quality gaps for system concepts identified using modeling and simulation.	Modeling and simulation tools utilized to define manufacturing and quality requirements for preferred materiel solution. Modeling and simulation results considered in the AoA."	Initial modeling & simulations (product or process) developed at the component level and used to determine constraints.	Initial modeling & simulations developed at the sub-system or system level, and used to determine system constraints.	Modeling & simulations used to determine system constraints and to identify improvement opportunities.	Modeling & simulations verified by pilot line build. Results used to improve process and demonstrate that LRIP requirements can be met.	Modeling & simulations verified by LRIP build, assist in management of LRIP, and demonstrate that FRP requirements can be met.	Modeling & simulations verified by FRP build. Production simulation models used as tools to assist in management of FRP.
	E.2 Manufacturing Process Maturity	Hypotheses developed regarding cause-effect relationships between process variables and process stability and repeatability.	Studies performed to test hypotheses regarding cause-effect relationships. Initial process approaches identified.	Cause-effect relationships between process control variables and process stability and repeatability validated through laboratory experiments. Critical process control variables identified.	Maturity of critical processes for preferred materiel solution assessed. Process capability requirements and improvement plans developed and documented in the SEP.	Process Maturity assessed on similar processes in production. Process capability requirements identified for pilot line, LRIP and FRP.	Manufacturing processes demonstrated in production relevant environment. Collection or estimation of process capability data from prototype build and refinement of process capability requirements initiated.	Manufacturing processes demonstrated in a production representative environment. Collection and/or estimation of process capability data and refinement of process capability requirements ongoing.	Manufacturing processes for LRIP verified on a pilot line. Process Capability data from pilot line meets target. Process capability requirements for LRIP and FRP refined based upon pilot line data.	Manufacturing processes are stable, adequately controlled, capable, and have achieved program LRIP objectives. Variability experiments conducted to show FRP impact and potential for continuous improvement.	Manufacturing processes are stable, adequately controlled, capable, and have achieved program FRP objectives.
	E.3 Process Yields and Rates	Hypotheses developed regarding future state manufacturing yields and rates.	Studies performed to test hypotheses regarding yields and rates.	Initial estimates of yields and rates for system concepts identified through laboratory. Yield and rate gaps for system concepts identified.	Yield and rate assessments on preferred materiel solution completed and considered in the AoA. Yield and rate gap closure strategies identified for the preferred materiel solution and documented in the SEP.	Target yields and rates established for pilot line, LRIP, and FRP. Yield and rate issues identified. Improvement plans developed/initiated.	Yields and rates from production relevant environment evaluated against targets and the results feed improvement plan.	Yields and rates from production representative environment evaluated against pilot line targets and the results feed improvement plans.	Pilot line targets achieved. Yields and rates required to begin LRIP refined using pilot line results. Improvement plans ongoing and updated.	LRIP yield and rate targets achieved. Yields and rates required to begin FRP refined using LRIP results. Yield improvements on-going.	FRP yield and rate targets achieved. Yield improvements on-going.

Appendix F: Detailed MRL Matrix Criteria

F-6. MRLs for the Quality Management Thread

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				MDD	ASR	A SRR/SFR	PDR	B CDR	PRR/SVR	C PCA	FRP
Thread	Sub-Thread	MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
F - Quality	F.1 Quality Management	Quality management considerations surveyed and included in early planning activities	Quality management needs assessed, analyzed, and validated.	Quality management requirements for system concepts identified.	Quality strategy for the preferred materiel solution developed, considered in the AoA, and documented in the SEP and the AS.	Quality strategy updated to reflect KC identification activities.	Initial Quality Plan and QMS are in place. Quality risks, issues, and metrics have been identified and improvement plans initiated.	Quality targets established. QMS elements (i.e., control of nonconforming material, corrective action, etc.) meet requirements of appropriate industry standards. Program-specific Quality Program Plan developed.	Program-specific Quality Program Plan established. Program Quality Manager assigned. Quality targets assessed against pilot line, results feed continuous quality improvements.	Quality targets verified on LRIP line. Continuous quality improvement on-going. Management review of Quality measures conducted on regular basis and appropriate actions taken.	Quality targets verified on FRP line. Continuous quality improvement on-going. Statistical controls applied where appropriate.
	F.2 Product Quality	Quality metrology state of the art surveyed. Hypotheses developed regarding cause-effect relationships between technology variables and quality.	Studies performed to test hypotheses regarding cause-effect relationships between technology variables and quality. Elements identified which have a potential impact on quality (i.e., materials, processes, capabilities, limitations).	System concept elements evaluated for quality using experiments, modeling and simulation. Initial product quality requirements, risks, and issues identified. Inspection technologies identified.	Product quality requirements and the inspection and acceptance testing strategy for the preferred materiel solution considered in AoA and documented in the AS. Product quality risk and issue mitigation plans documented in the SEP.	Roles and responsibilities identified for acceptance test procedures, in-process and final inspections, and statistical process controls for prototype units.	KC management approach defined. Initial requirements identified for acceptance test procedures and in-process and final inspection requirements for EMD units. Appropriate inspection and acceptance test procedures identified for prototype units.	Quality data from the production representative environment collected and analyzed and results used to shape improvement plans. Control plans completed for management of KCs. Test and Inspection plans being developed for EMD units.	KCs managed. Measurement procedures and controls in place (e.g. SPC, FRACAS, audits, customer satisfaction, etc.). Pilot line data meets capability requirements for all KCs. Test and Inspection plans complete and validated for production units.	Data from LRIP demonstrates production processes, for all KCs and other manufacturing processes critical to quality, are capable and under control for FRP.	KCs controlled at rate. Results achieve targeted statistical level on all KCs. Results reflect continuous improvement.
	F.3 Supplier Quality/ Management	Supplier quality and quality management systems state of the art surveyed.	Initial supplier quality and quality management systems evaluated.	Supplier quality and quality management system requirements for system concepts identified.	Potential supplier quality capabilities, risks, and issues identified for the preferred materiel solution, including subtier suppliers. Supplier quality management system requirements defined, and documented in the AS.	Supply base quality capabilities and risks identified, including subtier supplier quality management.	Supply base quality improvement initiatives identified addressing supplier QMS shortfalls, including subtier supplier quality management.	Key supplier QMSs meet appropriate industry standards. Supplier quality data from production representative units collected and analyzed. Strategy for audits of critical supplier processes outlined.	Supplier program-specific QMSs adequate. Supplier products qualification testing and first article inspection completed. Acceptance testing of supplier products adequate to begin LRIP. Plan for subcontractor process audits in place and implemented by prime contractor.	Supplier quality management of KCs and other critical manufacturing processes demonstrates capability and control for FRP. Acceptance testing of supplier products reflects control of quality adequate to begin FRP. Subcontractor quality audits performed as necessary to ensure subcontractor specification compliance.	Supplier quality data reflects adequate management of KCs and control of critical manufacturing processes, including quality management down to subtier suppliers. Results achieve high statistical level (e.g., 6-sigma) on all critical dimensions. Subcontractor quality audits performed as necessary to ensure subcontractor specification compliance.

Appendix F: Detailed MRL Matrix Criteria

F-7. MRLs for the Manufacturing Personnel and Facilities Threads

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				MDD	ASR A	SRR/SFR	PDR B	CDR	PRR/SVR C	PCA FRP	
Thread	**Sub-Thread**	**MRL 1**	**MRL 2**	**MRL 3**	**MRL 4**	**MRL 5**	**MRL 6**	**MRL 7**	**MRL 8**	**MRL 9**	**MRL 10**
G - Manufacturing Workforce (Engineering & Production)	G.1 Manufacturing Workforce (Engineering & Production)	Workforce skill sets to support emerging trends in manufacturing and technology surveyed.	Workforce skill sets to support emerging trends in manufacturing and technology evaluated.	Workforce skill set requirements for system concepts identified. Workforce skill set capability gaps identified.	Workforce skill set requirements for preferred materiel solution identified and considered in the AoA. Workforce training and development requirements to close skill set gaps defined. Availability of workforce for the TMRR phase determined.	Skill sets identified and plans developed to meet prototype and production needs. Special skills certification and training requirements established.	Manufacturing workforce skills available for the production relevant environment. Resources (quantities and skill sets) identified and initial plans developed to achieve requirements for pilot line and production.	Manufacturing workforce resource requirements identified and plans developed to achieve pilot line requirements. Plans to achieve LRIP workforce requirements updated. Pilot line workforce trained in production representative environment.	Manufacturing workforce resource requirements identified and plans developed to achieve LRIP requirements. LRIP personnel trained on pilot line where possible. Plans to achieve FRP workforce requirements initiated based on pilot line.	LRIP personnel requirements met. Plan to achieve FRP workforce requirements implemented.	FRP personnel requirements met. Production workforce skill sets maintained in spite of workforce attrition.
H - Facilities	H.1 Tooling/STE/SIE	State of the art tooling, test and inspection equipment surveyed.	Potential tooling, STE, and SIE requirements identified.	Tooling, STE, and SIE requirements and gaps for system concepts identified.	Tooling/STE/SIE requirements for the preferred materiel solution considered as part of AoA.	Tooling and STE/SIE requirements identified with supporting rationale and schedule.	Prototype tooling and STE/SIE concepts demonstrated in production relevant environment. Requirements development efforts for production tooling and STE/SIE complete.	Design and development efforts for production tooling and STE/SIE initiated with STE/SIE validation plans complete. Manufacturing equipment maintenance strategy developed.	Tooling, test and inspection equipment proven on pilot line and additional requirements identified for LRIP. STE/SIE validated as part of pilot line validation IAW validation plan. Manufacturing equipment maintenance demonstrated on pilot line.	All tooling, test and inspection equipment proven in LRIP and additional requirements identified for FRP. Manufacturing equipment maintenance schedule demonstrated. STE/SIE validation maintained as necessary.	Proven tooling, test and inspection equipment in place to support maximum FRP. Planned equipment maintenance schedule achieved. STE/SIE validation maintained as necessary.
	H.2 Facilities	Current facility capabilities and capacity surveyed.	Potential facility capabilities and capacity requirements identified.	Facility capabilities and capacity requirements and gaps for system concepts identified.	Capability and availability of manufacturing facilities for prototype development and production of the preferred materiel solution evaluated, included in the AoA, and documented in the AS and SEP. Human factors & ergonomics and safety requirements for manufacturing (personnel, processes & equipment) identified.	Manufacturing facilities identified and plans developed to produce prototypes. Human factors & ergonomics and safety requirements for manufacturing (personnel, processes & equipment) assessed.	Manufacturing facilities identified and plans developed to produce pilot line build. Human factors & ergonomics and safety requirements for manufacturing (personnel, processes & equipment) verified in a production relevant environment.	Manufacturing facilities identified and plans developed to produce LRIP build. Human factors & ergonomics and safety practices for manufacturing (personnel, processes & equipment) validated in a production representative environment.	Pilot line facilities demonstrated. Manufacturing facilities adequate to begin LRIP. Plans in place to support transition to FRP. Workplace safety is adequate. Human factors & ergonomics and safety practices for manufacturing (personnel, processes & equipment) demonstrated on a pilot line.	Manufacturing facilities in place and demonstrated in LRIP. Capacity plans adequate to support FRP. Human factors & ergonomics and safety practices for manufacturing (personnel, processes & equipment) demonstrated in LRIP .	Production facilities in place and capacity demonstrated to meet maximum FRP requirements. Human factors & ergonomics and safety requirements for manufacturing (personnel, processes & equipment) demonstrated in FRP.

Appendix F: Detailed MRL Matrix Criteria

F-8. MRLs for the Manufacturing Management Thread

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				MDD	ASR A	SRR/SFR	PDR B	CDR	PRR/SVR C	PCA FRP	
Thread	Sub-Thread	MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
I - Manufacturing Management	I.1 Manufacturing Planning & Scheduling	Manufacturing management considerations surveyed and included in early planning activities.	Manufacturing management needs assessed, analyzed and validated.	Manufacturing management requirements for system concepts identified.	Manufacturing strategy for the preferred materiel solution developed, considered in the AoA, and documented in the AS. Prototype schedule risk mitigation efforts documented in the SEP.	Manufacturing strategy refined based upon preferred concept. Prototype schedule risk mitigation efforts initiated.	Initial manufacturing approach developed. All system design related manufacturing events included in IMP/IMS. Manufacturing risk, and issue mitigation approach for pilot line and/or technology insertion programs defined.	Initial Manufacturing Plan developed and included in IMP/IMS. Manufacturing risks and issues integrated into mitigation plans. Initial work instructions developed. Effective production control system in place to support pilot line.	Manufacturing Plan updated for LRIP. All manufacturing risks and issues identified and assessed with approved mitigation plans in place. Work instructions finalized. Effective production control system in place to support LRIP.	Manufacturing plan updated for FRP. All manufacturing risks and issues managed. Effective production control system in place to support FRP.	All manufacturing risks and issues managed.
I - Manufacturing Management	I.2 Materials Planning	Materials planning state of the art surveyed.	Initial availability, lead time, handling and storage requirements for potential materials and components evaluated.	Materials and components list for system concepts developed. Initial materials planning requirements (i.e., availability, lead times, handling, and storage) identified.	Materials and components list with estimates for availability, lead times, handling and storage requirements developed and considered in the AoA.	Make/buy evaluations initiated and include production considerations for pilot line, LRIP, and FRP needs. Lead times and other materials risks and issues identified.	Most material make/buy decisions complete, material risks and issues identified, and mitigation plans developed. BOM initiated.	Make/Buy decisions and BOM complete for pilot line build. Material planning systems in place for pilot line build.	Make/Buy decisions and BOM complete to support LRIP. Material planning systems proven on pilot line for LRIP build.	Make/Buy decisions and BOM complete to support FRP. Material planning systems proven in LRIP and sufficient for FRP.	Material planning systems validated on FRP build.
I - Manufacturing Management	I.3 Manufacturing OT Cybersecurity			OT cybersecurity requirements for system concepts identified. OT cybersecurity vulnerabilities of potential manufacturing facilities identified.	Manufacturing operations cybersecurity capabilities and cyber-vulnerabilities evaluated. OT cybersecurity approach and requirements for the preferred materiel solution considered as part of AoA. OT cybersecurity risks in the anticipated industrial base have been assessed. Identify impacts of cybersecurity measures on manufacturing processes for preferred materiel solutions. Potential supply chain OT cybersecurity and vulnerability risks identified.	Required OT cybersecurity development efforts initiated. OT cyber Incident Reporting procedures developed. (e.g., System Security Plan). Potential OT cybersecurity measures are assessed for impacts to producibility and manufacturability. Supply chain OT cybersecurity and vulnerability risks assessed and risk management plans developed. Workforce trained as appropriate in cybersecurity. Cybersecurity requirements for OT systems identified (i.e., in-house factory systems, production equipment, STE/SIE, and tooling).	Required OT cybersecurity solutions demonstrated in a production relevant environment. OT cyber Incident Reporting procedures in place, including reporting, tracking, and corrective actions. Supply chain OT cybersecurity and vulnerability risk mitigation plans initiated. Workforce trained as appropriate in up-to-date cybersecurity procedures for production relevant environment. Planning for OT systems (i.e., in-house factory systems, production equipment, STE/SIE, and tooling) include cybersecurity and physical/digital access requirements.	Required OT cybersecurity solutions demonstrated in a production representative environment. OT cybersecurity Incident Reporting procedures in-place, including reporting, tracking, and corrective actions. Supply chain OT cybersecurity and vulnerability risk mitigation plans implemented. Workforce trained as appropriate in up-to-date cybersecurity procedures for production representative environment. Design of OT systems for facilities and equipment (i.e., in-house factory systems, production equipment, STE/SIE, and tooling) include cybersecurity and physical/digital controls and access requirements.	OT cybersecurity incidents are identified and assessed. OT cyber incidents throughout the supply chain are identified and assessed. Workforce trained as appropriate in up-to-date cybersecurity procedures for a pilot line environment. Planning and documentation for LRIP facilities and equipment OT systems including cybersecurity and physical/ digital controls and access requirements complete. OT cybersecurity procedures and controls validated on a pilot line.	OT cybersecurity incidents are identified and assessed. OT cyber incidents throughout the supply chain are identified and assessed. Workforce trained as appropriate in up-to-date cybersecurity procedures for production. Planning and documentation for FRP facilities and equipment OT systems including cybersecurity and physical/digital controls and access requirements complete. OT cybersecurity improvement efforts initiated for FRP. OT cybersecurity procedures implemented in LRIP and support FRP.	OT cybersecurity procedures reviewed and updated. OT cybersecurity capabilities and solutions tested to support modifications, upgrades, surge and other potential manufacturing requirements. Minimal cybersecurity incident occurrence. Prompt incident identification and corrective actions minimizing impacts. Workforce trained as appropriate in up-to-date cybersecurity procedures for production. OT cybersecurity continuous improvement efforts ongoing.

Appendix G: Detailed Streamlined MRL Matrix Criteria

G-1. Streamlined MRL Matrix for the System Level

Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				MDD	ASR	A SRR/SFR	PDR	B CDR	PRR/SVR	C PCA	FRP
Thread	**Sub-Thread**	**MRL 1**	**MRL 2**	**MRL 3**	**MRL 4**	**MRL 5**	**MRL 6**	**MRL 7**	**MRL 8**	**MRL 9**	**MRL 10**
A - Technology & Industrial Base	A.0 Technology Maturity	Technology concept and/or applications formulated	Component and/or breadboard validation in a laboratory environment.	Component and/or breadboard validation in a relevant environment.	Subsystem model or prototype demonstration in a relevant environment.	System model or prototype demonstration in a relevant environment.	System prototype demonstrated in an operational environment.	System prototype demonstrated in an operational environment.	Actual system completed and qualified through test and demonstration.	Actual system proven through successful mission operations.	Actual system proven through successful mission operations.
	A.1 Industrial Base	Trends in emerging industrial base capabilities identified.	Potential industrial base capability gaps identified.	Industrial base capabilities for potential sources identified for system concepts.	Industrial base including capacities and capabilities surveyed for preferred materiel solution included in AoA.	Industrial base analysis to identify sources and minimize sole/single/FOCI initiated.	Industrial base capacity and capability analyses including avoidance or justification of sole/single/FOCI complete.	Industrial base capacity and capability analyses including sole/single/FOCI justification complete and monitored.	Industrial base capacity and capability analysis for MS C completed and capability is in place to support LRIP.	Industrial base capacity and capability analysis for FRP completed and capability in place to support FRP.	Industrial base analysis capacity and capability supports FRP.
B - Design	B.2 Design Maturity	Current capability deficiencies and gaps identified.	Analyses performed to evaluate the feasibility of potential solutions.	High level requirements defined and evaluated for system concepts.	Initial KPPS and manufacturing capabilities identified for preferred systems concept.	Product data required for prototype component manufacturing released and design KCs identification initiated.	Product data essential for subsystem/ system prototyping released and preliminary design KCs identified.	All product data essential for component manufacturing released and potential KC risks and issues identified.	All product data essential for system manufacturing released.	Major product design features and configuration are stable.	Product design is stable.
C - Cost & Funding	C.1 C.2 C.3 Cost & Funding	Initial manufacturing and quality costs identified and manufacturing investment strategy developed.	Potential manufacturing and quality cost drivers identified and program has funding to reach MRL 3.	Initial cost models and targets developed and program has funding to reach MRL 4 by MS A.	Cost risks and issues assessed against targets for preferred materiel solutions and program has funding to reach MRL 6 by MS B.	Costs analyzed against targets using prototype component actuals and program has funding to reach MRL 6 by MS B.	Costs analyzed against targets using prototype system/sub-system actuals and program has funding to reach MRL 8 by MS C.	Manufacturing costs tracked against targets and program has funding to reach MRL 8 by MS C.	Costs analyzed against targets using pilot line actuals and program has funding to reach MRL 9 by FRP decision.	LRIP cost goals met and program has funding for FRP.	FRP cost goals met and program has funding to support program production at required rates and schedule.
D - Materials	D.1 Materials Maturity	New material properties and characteristics surveyed and identified for research (e.g., manufacturability, quality).	Potential effects of new material properties on design application manufacturability and quality predicted based on research.	Effects of new material properties on design concept manufacturability and quality validated using experiments and models.	New materials and components for preferred materiel solution demonstrated in a laboratory environment.	Materials manufactured or produced in a prototype environment (may be in a similar application/program).	Material maturity verified through technology demonstration articles.	Material maturity sufficient for pilot line build.	Materials proven and validated during EMD as adequate to support LRIP.	Materials proven and validated as adequate to support FRP.	Materials controlled to specifications in FRP.
E - Process Capability	E.2 Manufacturing Maturity	Concepts developed for relationships between process variables, stability, and repeatability including future yields and rates.	Concepts for processes identified and yields and rates tested through experimenting and prototyping.	Critical process control variables and initial yields and rates identified through pre-acquisition experimenting and prototyping.	Maturity assessment of processes, yields, and rates for preferred materiel solution completed and considered in the AoA.	Process maturity assessment of similar processes used to establish target yields and rates for pilot line, LRIP, and FRP.	Manufacturing processes including yields and rates demonstrated in production relevant environment.	Manufacturing processes including yields and rates demonstrated in a production representative environment.	Manufacturing processes including yields and rates refined and verified on pilot line for LRIP.	Manufacturing processes including yields and rates during LRIP are stable, adequately controlled, and capable for FRP.	Manufacturing processes including yields and rates are stable, adequately controlled, and capable.

APT
Advanced Product Transitions Corp.

Appendix G – Detailed Streamlined MRL Matrix Criteria

Thread	Sub-Thread	MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
Acquisition Phase		Pre-Materiel Development Decision (Pre-MDD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				MDD	ASR	A SRR/SFR	PDR	B CDR	PRR/SVR	C PCA	FRP
F - Quality	F.2 Product Quality	Quality metrology state of the art surveyed.	Elements identified which have a potential impact on quality.	Initial product quality requirements, risks, and issues identified. Inspection technologies identified.	Product quality requirements and the inspection and acceptance testing strategy documented.	Roles and responsibilities identified for acceptance test procedures, in-process and final inspections, and statistical process controls.	KC management approach defined with appropriate inspection and acceptance test procedures identified.	KC control plans developed including test and inspection.	KCs managed with test and inspection plans complete and validated.	KCs and other manufacturing processes critical to quality, are capable and under control for FRP.	KCs controlled in FRP.
	F.3 Supplier Quality and D.3 Supply Chain Management	Trends for supply chain quality, capability, and capacity surveyed.	Potential supply chain quality, capability, and capacity identified.	Supply chain requirements, capability, and capacity gap closure strategies defined.	Supply chain requirements, capability, and capacity considered in the AoA.	Potential suppliers and supply chain quality capabilities and risks identified.	Lifecycle Supply Chain requirements updated and Supply chain quality improvements identified.	Supplier quality data from production representative units analyzed including assessment of critical first tier supply chain.	Supplier products qualification testing and first article inspection completed including assessment of critical second and lower tier supply chain.	Supplier management of manufacturing demonstrates capability and control and that the supply chain is stable and adequate to support FRP.	Supplier quality data shows adequate management of manufacturing and that the supply chain proven to supports FRP.
G - Manufacturing Workforce	G.1 Manufacturing Workforce	Workforce skill sets to support emerging trends in manufacturing and technology surveyed.	Workforce skill sets to support emerging trends in manufacturing and technology evaluated.	Workforce skill set requirements for system concepts identified.	Workforce skill set and workforce requirements identified.	Skill sets identified and plans developed.	Manufacturing workforce skills available for the production relevant environment.	Manufacturing workforce resource requirements identified and plans developed to achieve pilot line requirements.	Manufacturing workforce resource requirements identified and plans developed to achieve LRIP requirements.	Plan to achieve FRP workforce requirements implemented.	Production workforce skill sets maintained in spite of workforce attrition.
H - Facilities	H.2 Facilities	Current facility capabilities and capacity surveyed.	Potential facility capabilities and capacity requirements identified.	Facility capabilities and capacity requirements and gaps for system concepts identified.	Capability and availability of manufacturing facilities for prototype development of the preferred materiel solution evaluated.	Manufacturing facilities identified and plans developed to produce prototypes.	Manufacturing facilities identified and plans developed to produce pilot line build.	Manufacturing facilities identified and plans developed to produce LRIP build.	Pilot line facilities demonstrated. Manufacturing facilities adequate to begin LRIP.	Manufacturing facilities in place and demonstrated in LRIP.	Production facilities in place and capacity demonstrated to meet maximum FRP requirements.
I - Manufacturing Management	I.2 Materials Planning and D.2 Availability	Trends for material availability, lead time, obsolescence, DMSMS, handling, and storage surveyed and identified for research.	Initial availability, lead time, obsolescence, DMSMS, handling, and storage requirements for potential materials and components evaluated.	Initial materials planning requirements including availability, lead times, obsolescence, DMSMS, handling, and storage identified.	Materials and components list with estimates for availability, lead times, handling and storage requirements including hazardous materials developed.	Make/buy evaluations including availability risks and issues initiated for pilot line, LRIP, and FRP.	BOM initiated with most make/buy decisions complete including availability risks and issues for EMD.	BOM and make/buy decision complete with availability risks and issues to meet LRIP mitigated.	BOM and make/buy decision complete with availability risks and issues to meet LRIP managed.	BOM and make/buy decision complete with availability risks and issues to meet FRP managed.	Material planning systems validated with material availability risks and issues managed in FRP.
	I.3 Manufacturing OT Cybersecurity	Trends in OT cybersecurity surveyed.	OT cybersecurity strategy and approach identified.	OT cybersecurity requirements for system concepts identified.	OT cybersecurity capabilities and cyber-vulnerabilities evaluated and risks identified including the potential supply chain.	OT cybersecurity requirements identified and development efforts initiated.	OT cybersecurity solutions demonstrated in a production relevant environment including supply chain.	OT cybersecurity solutions demonstrated in a production representative environment including supply chain.	OT cybersecurity incidents are identified and assessed including supply chain.	OT cybersecurity incidents are identified and mitigated including the supply chain.	OT cybersecurity procedures reviewed and updated.

Appendix G – Detailed Streamlined MRL Matrix Criteria

G-2. Streamlined MRL Matrix for the Subsystem, Item, and Component Level

Acquisition Phase		Pre-Development Decision (Pre–DD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Production Phase	
								Development	Demonstration	Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
					DD	D1		D2	D3	D4	D5
Technical Reviews				CoDR	ASR	SRR/SFR	PDR	CDR	PRR/SVR	PCA	
Thread	**Sub-Thread**	**MRL 1**	**MRL 2**	**MRL 3**	**MRL 4**	**MRL 5**	**MRL 6**	**MRL 7**	**MRL 8**	**MRL 9**	**MRL 10**
A - Technology & Industrial Base	A.0 Technology Maturity	Technology concept and/or applications formulated	Component and/or breadboard validation in a laboratory environment.	Component and/or breadboard validation in a relevant environment.	Subsystem model or prototype demonstration in a relevant environment.	System model or prototype demonstration in a relevant environment.	System prototype demonstrated in an operational environment.	System prototype demonstrated in an operational environment.	Actual system completed and qualified through test and demonstration.	Actual system proven through successful mission operations.	Actual system proven through successful mission operations.
	A.1 Industrial Base	Trends in emerging industrial base capabilities identified.	Potential industrial base capability gaps identified.	Industrial base capabilities for potential sources identified for system concepts.	Industrial base including capacities and capabilities surveyed for preferred materiel solution included in Analysis of Alternatives.	Industrial base analysis to identify sources and minimize sole/single/FOCI initiated.	Industrial base capacity and capability analyses for D2 including avoidance or justification of sole/single/FOCI complete.	Industrial base capacity and capability analyses for D3 including sole/single/FOCI justification complete and monitored.	Industrial base capacity and capability analysis for D4 completed and capability is in place to support LRIP.	Industrial base capacity and capability analysis for D5 completed and capability in place to support FRP.	Industrial base analysis capacity and capability supports FRP.
B - Design	B.2 Design Maturity	Current capability deficiencies and gaps identified.	Analyses performed to evaluate the feasibility of potential solutions.	High level requirements defined and evaluated for system concepts.	Initial KPPS and manufacturing capabilities identified for preferred systems concept.	Product data required for prototype component manufacturing released and design KCs identification initiated.	Product data essential for subsystem/ system prototyping released and preliminary design KCs identified.	All product data essential for component manufacturing released and potential KC risks and issues identified.	All product data essential for system manufacturing released.	Major product design features and configuration are stable.	Product design is stable.
C - Cost & Funding	C.1 C.2 C.3 Cost & Funding	Initial manufacturing and quality costs identified and manufacturing investment strategy developed.	Potential manufacturing and quality cost drivers identified and program has funding to reach MRL 3.	Initial cost models and targets developed and program has funding to reach MRL 4 by DD.	Cost risks and issues assessed against targets for preferred materiel solutions and program has funding to reach MRL 6 by D2.	Costs analyzed against targets using prototype component actuals and program has funding to reach MRL 6 by D2.	Costs analyzed against targets using prototype system/sub-system actuals and program has funding to reach MRL 8 by D3.	Manufacturing costs tracked against targets and program has funding to reach MRL 8 by D4.	Costs analyzed against targets using pilot line actuals and program has funding to reach MRL 9 by D5.	LRIP cost goals met and program has funding for FRP.	FRP cost goals met and program has funding to support program production at required rates and schedule.
D - Materials	D.1 Materials Maturity	New material properties and characteristics surveyed and identified for research (e.g., manufacturability, quality).	Potential effects of new material properties on design application manufacturability and quality predicted based on research.	Effects of new material properties on design concept manufacturability and quality validated using experiments and models.	New materials and components for preferred materiel solution demonstrated in a laboratory environment.	Materials manufactured or produced in a prototype environment (may be in a similar application/program).	Material maturity verified through technology demonstration articles.	Material maturity sufficient for pilot line build.	Materials proven and validated during EMD as adequate to support LRIP.	Materials proven and validated as adequate to support FRP.	Materials controlled to specifications in FRP.
E - Process Capability	E.2 Manufacturing Maturity	Concepts developed for relationships between process variables, stability, and repeatability including future yields and rates.	Concepts for processes identified and yields and rates tested through experimenting and prototyping.	Critical process control variables and initial yields and rates identified through pre-acquisition experimenting and prototyping.	Maturity assessment of processes, yields, and rates for preferred materiel solution completed and considered in the Analysis of Alternatives.	Process maturity assessment of similar processes used to establish target yields and rates for pilot line, LRIP, and FRP.	Manufacturing processes including yields and rates demonstrated in production relevant environment.	Manufacturing processes including yields and rates demonstrated in a production representative environment.	Manufacturing processes including yields and rates refined and verified on pilot line for LRIP.	Manufacturing processes including yields and rates during LRIP are stable, adequately controlled, and capable for FRP.	Manufacturing processes including yields and rates are stable, adequately controlled, and capable.

Appendix G – Detailed Streamlined MRL Matrix Criteria

Acquisition Phase		Pre-Development Decision (Pre–DD)			Materiel Solution Analysis (MSA)	Technology Maturation and Risk Reduction (TMRR)		Engineering & Manufacturing Development (EMD)		Production Phase	
								Development	Demonstration	Low-Rate Initial Production (LRIP)	Full-Rate Production (FRP)
Technical Reviews				CoDR DD	ASR D1	SRR/SFR	PDR D2	CDR D3	PRR/SVR D4	PCA D5	
Thread	**Sub-Thread**	**MRL 1**	**MRL 2**	**MRL 3**	**MRL 4**	**MRL 5**	**MRL 6**	**MRL 7**	**MRL 8**	**MRL 9**	**MRL 10**
F - Quality	F.2 Product Quality	Quality metrology state of the art surveyed.	Elements identified which have a potential impact on quality.	Initial product quality requirements, risks, and issues identified. Inspection technologies identified.	Product quality requirements and the inspection and acceptance testing strategy documented.	Roles and responsibilities identified for acceptance test procedures, in-process and final inspections, and statistical process controls.	KC management approach defined with appropriate inspection and acceptance test procedures identified.	KC control plans developed including test and inspection.	KCs managed with test and inspection plans complete and validated.	KCs and other manufacturing processes critical to quality, are capable and under control for FRP.	KCs controlled in FRP.
	D.3 Supplier Management and F.3 Quality	Trends for supply chain quality, capability, and capacity surveyed.	Potential supply chain quality, capability, and capacity identified.	Supply chain requirements, capability, and capacity gap closure strategies defined.	Supply chain requirements, capability, and capacity considered in the Analysis of Alternatives.	Potential suppliers and supply chain quality capabilities and risks identified.	Lifecycle Supply Chain requirements updated and Supply chain quality improvements identified.	Supplier quality data from production representative units analyzed including assessment of critical first tier supply chain.	Supplier products qualification testing and first article inspection completed including assessment of critical second and lower tier supply chain.	Supplier management of manufacturing demonstrates capability and control and that the supply chain is stable and adequate to support FRP.	Supplier quality data shows adequate management of manufacturing and that the supply chain proven to supports FRP.
G - Manufacturing Workforce	G.1 Manufacturing Workforce	Workforce skill sets to support emerging trends in manufacturing and technology surveyed.	Workforce skill sets to support emerging trends in manufacturing and technology evaluated.	Workforce skill set requirements for system concepts identified.	Workforce skill set and workforce requirements identified.	Skill sets identified and plans developed.	Manufacturing workforce skills available for the production relevant environment.	Manufacturing workforce resource requirements identified and plans developed to achieve pilot line requirements.	Manufacturing workforce resource requirements identified and plans developed to achieve LRIP requirements.	Plan to achieve FRP workforce requirements implemented.	Production workforce skill sets maintained in spite of workforce attrition.
H - Facilities	H.2 Facilities	Current facility capabilities and capacity surveyed.	Potential facility capabilities and capacity requirements identified.	Facility capabilities and capacity requirements and gaps for system concepts identified.	Capability and availability of manufacturing facilities for prototype development of the preferred materiel solution evaluated.	Manufacturing facilities identified and plans developed to produce prototypes.	Manufacturing facilities identified and plans developed to produce pilot line build.	Manufacturing facilities identified and plans developed to produce LRIP build.	Pilot line facilities demonstrated. Manufacturing facilities adequate to begin LRIP.	Manufacturing facilities in place and demonstrated in LRIP.	Production facilities in place and capacity demonstrated to meet maximum FRP requirements.
I - Manufacturing Management	I.2 Materials Planning and D.2 Availability	Trends for material availability, lead time, obsolescence, DMSMS, handling, and storage surveyed and identified for research.	Initial availability, lead time, obsolescence, DMSMS, handling, and storage requirements for potential materials and components evaluated.	Initial materials planning requirements including availability, lead times, obsolescence, DMSMS, handling, and storage identified.	Materials and components list with estimates for availability, lead times, handling and storage requirements including hazardous materials developed.	Make/buy evaluations including availability risks and issues initiated for pilot line, LRIP, and FRP.	BOM initiated with most make/buy decisions complete including availability risks and issues for EMD Phase.	BOM and make/buy decision complete with availability risks and issues to meet LRIP mitigated.	BOM and make/buy decision complete with availability risks and issues to meet LRIP managed.	BOM and make/buy decision complete with availability risks and issues to meet FRP managed.	Material planning systems validated with material availability risks and issues managed in FRP.
	I.3 Manufacturing OT Cybersecurity	Trends in OT cybersecurity surveyed.	OT cybersecurity strategy and approach identified.	OT cybersecurity requirements for system concepts identified.	OT cybersecurity capabilities and cyber-vulnerabilities evaluated and risks identified including the potential supply chain.	OT cybersecurity requirements identified and development efforts initiated.	OT cybersecurity solutions demonstrated in a production relevant environment including supply chain.	OT cybersecurity solutions demonstrated in a production representative environment including supply chain.	OT cybersecurity incidents are identified and assessed including supply chain.	OT cybersecurity incidents are identified and mitigated including the supply chain.	OT cybersecurity procedures reviewed and updated.

Appendix H: Acronyms

AAF	Adaptive Acquisition Framework
AoA	Analysis of Alternatives
ASR	Alternative System Review
ATS	Acquisition Transformation Strategy
BOM	Bill of Materials
CDR	Critical Design Review
COTS	Commercial-Off-the-Shelf
DoDI	Department of Defense Instruction
ESH	Environmental, Safety, and Health
EMD	Engineering and Manufacturing Development
FCA	Functional Configuration Audit
FOC	Full Operational Capability
FRP	Full-Rate Production
GAO	Government Accountability Office
ICD	Initial Capabilities Document
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IOC	Initial Operational Capability
KPP	Key Performance Parameter
LRIP	Low-Rate Initial Production
MDAP	Major Defense Acquisition Program
MDD	Materiel Development Decision
MMP	Manufacturing Maturation Plan
MRL	Manufacturing Readiness Level
MS A	Milestone A (DoW decision point)
MS B	Milestone B (DoW decision point)
MS C	Milestone C (DoW decision point)

Appendix H: Acronyms

MSA	Materiel Solution Analysis
MTA	Middle Tier of Acquisition
O&S	Operations and Support (DoW acquisition phase)
OT	Operational Technology
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
Pre-MDD	Pre-Materiel Development Decision (DoW acquisition phase)
PRR	Production Readiness Review
QMS	Quality Management System
R&D	Research and Development
RFP	Request for Proposals
ROM	Rough Order of Magnitude
SAE	Society of Automotive Engineers
S&T	Science and Technology
SEP	Systems Engineering Plan
SFR	System Functional Review
SIE	Special Inspection Equipment
SME	Subject Matter Expert
SRR	System Requirements Review
STE	Special Test Equipment
SVR	System Verification Review
T&E	Test and Evaluation
TBD	To Be Determined
TMRR	Technology Maturation Risk Reduction
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TRR	Test Readiness Review
UCA	Urgent Capability Acquisition
WBS	Work Breakdown Structure

