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Transition Maturity Framework (TMaF)

A Framework to Guide New Technologies Transitioning to Department of Defense (DOD) Acquisition Programs

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Introduction

Too often, groundbreaking technologies within the Department of Defense (DOD) become trapped in the research and development (R&D) phase, never advancing to full-scale deployment. To progress past this phase, science and technology (S&T) teams must strategically identify and prioritize key activities that pave the way for a successful technology transition. The Defense Acquisition University (DAU) defines technology transition as the *"process of inserting critical technology into military systems to provide an effective weapons and support system in the quantity and quality needed by the warfighter to carry out assigned missions*."[1] This transition can occur as integration into an existing DOD acquisition program to enhance its current capabilities, as the creation of a brand new program, or even as a transfer to a Defense Industrial Base partner. The stakes are high, and the path to new technology adoption demands careful planning and execution.

Many federal organizations have developed approaches to navigate the technology transition Valley of Death[2] since neglecting crucial technology transition steps can lead to spiraling costs, missed deadlines, performance shortfalls, or even the complete cancellation of promising projects. There are frameworks for portfolio managers to assess project/portfolio transition risk,[3,4] two-factor readiness comparisons,[5,6] and general transition planning guidance for S&T teams.[7] However, there is still a gap in providing S&T teams with a holistic means to assess transition maturation, and to identify and break down crucial technology transition steps.

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[1] Defense Acquisition University. (n.d.). *Technology Transition*. Retrieved August 9, 2024, from https://www.dau.edu/glossary/technology-transition

[2] A. Belz et al. Mapping the "Valley of Death": Managing Selection and Technology Advancement in NASA's Small Business Innovation Research Program. IEEE Transactions on Engineering Management, Vol 68, No 5, Oct 2021.

[3] Nuclear Command, Control, and Communications (NC3) Directorate, Office of the Under Secretary of Defense for Acquisition & Sustainment Strategic, Space, and Intelligence Portfolio Management (SSIPM). (2023). Technology Transition Framework. pp.1-20

[4] A. Belz et al. Mapping the "Valley of Death": Managing Selection and Technology Advancement in NASA's Small Business Innovation Research Program. IEEE Transactions on Engineering Management, Vol 68, No 5, Oct 2021.

[5] Davis, A. and T. Ballenger. Bridging the "Valley of Death." Defense AT&L: January–February 2017, p. 13-17.

[6] The MITRE Corporation. (2013). Managing Research Projects Beyond Cost and Schedule. Retrieved September 27, 2024. https://www.mitre.org/sites/default/files/publications/5-managing-research-projects.pdf

[7] Irregular Warfare Support Directorate. (2022). *Technology Transition Handbook*. Retrieved Sept 27, 2024 from https://www.tswg.gov/Documents/TechTransition/2022-02-02%20Technology%20Transition%20Handbook.pdf

The Transition Maturity Framework (TMaF) is a tool that provides actionable steps that teams can use to pursue technology transition within the DOD Adaptive Acquisition Framework (AAF) pathways and DOD R&D and acquisition-related policies. What sets the TMaF apart is its streamlined and targeted design, tailored specifically for S&T teams that may not have extensive experience navigating the complex DOD R&D and acquisition ecosystem. Implementing TMaF activities will empower S&T teams to reduce programmatic risks and instill confidence among operational users and acquisition stakeholders.

Background: Technology Transition Within the DOD

The DOD technology transition and acquisition environment is extremely complex—driven by a myriad of continually evolving statutes and regulations. Its purpose is to manage weapon system capabilities and support systems from “cradle to grave” across the program life cycle. The acquisition workforce, sometimes referred to as “aquirers,” consists of program managers, contracting officers, lawyers, financial managers, engineers, and logisticians—and each has a specific role to play in developing and deploying new technological capabilities for the warfighter. The warfighters are often referred to as “requirers” since their operational needs lead to the formal requirements of the capabilities being developed.[8]

S&T teams wishing to support the warfighter may find the acquisition environment daunting. However, it is possible to simplify technology transition into a manageable framework, providing S&T teams the ability to create successful transition plans without needing to become experts in the DoD acquisition life cycle.

S&T teams work within the DOD’s *Research, Development, Test & Evaluation (RDT&E)* construct, which is designed to fund the exploration, advancement and transition of new technologies (i.e., S&T and R&D activities). The DOD has eight RDT&E categories, or as they are officially called, Budget Activities (BAs).[9] Table 1 defines the BA areas and aligns the areas with the affiliated Technology Readiness Levels (TRLs – see Figure 4).[10] Note that BA-4 Advanced Component Development and Prototypes (ACD&P) can be included in both S&T and R&D Research Types.

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[8] Defense Acquisition University. (n.d.). *Requirements Definition*. Retrieved November 11, 2024, from https://www.dau.edu/glossary/requirements

[9] U.S. Department of Defense, Office of the Under Secretary of Defense (Comptroller). (2004). *Volume 2B, Chapter 5: Military Construction/Family Housing Appropriations* [PDF]. Retrieved from https://comptroller.defense.gov/portals/45/documents/fmr/archive/02barch/02b_05old.pdf

[10] "Crosswalk Card: Budget Activity to Technology Readiness Level," Defense Acquisition University, Retrieved October 27, 2024 from https://www.dau.edu/sites/default/files/Migrated/CopDocuments/Crosswalk%20Card%2C%20Budget%20Activity%20to%20TRL.pdf.

Table 1: RDT&E Type Aligned to Budget Activities and TRL

RDT&E Type	Budget Activity Areas	Description	TRL Range
Science and Technology (S&T)	BA-1: Basic Research	Systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products in mind.	TRL 1-2
	BA-2: Applied Research	Systematic study to understand the means to meet a recognized and specific need. It is a systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods.	TRL 3-5
	BA-3: Advanced Technology Development (ATD)	Development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.	TRL 4-6
	BA-4 *S&T* Advanced Component Development and Prototypes (ACD&P)	Includes system specific efforts that help expedite technology transition from the laboratory to operational use. Emphasis is on proving component and subsystem maturity prior to integration in major and complex systems and may involve risk reduction initiatives.	TRL 6-7
Applied Research and Development (R&D)	BA-4 *Non-S&T* Advanced Component Development and Prototypes (ACD&P)	Includes system specific efforts that help expedite technology transition from the laboratory to operational use. Emphasis is on proving component and subsystem maturity prior to integration in major and complex systems and may involve risk reduction initiatives.	TRL 6-7
	BA-5: Systems Development and Demonstration	System Development and Demonstration programs have passed Milestone B approval and are conducting engineering and manufacturing development tasks aimed at meeting validated requirements prior to full-rate production.	TRL 8-9
	BA-6: Research, Development, Test & Evaluation (RDT&E) Management Support	Support for RDT&E efforts and funds to sustain and/or modernize the installations or operations required for general RDT&E.	N/A
	BA-7: Operational System Development	Development efforts to upgrade systems that have been fielded or have received approval for full rate production.	TRL 8-9
Software	BA-8: Software and Digital Technology Pilot Programs*	Software, electronic tools, systems, applications, resources, acquisition of services, business process re-engineering activities, functional requirements development, technical evaluations, and other activities in direct support of acquiring, developing, deploying, sustaining, enhancing, and modernizing Software Digital Technology Pilot Programs.	TRL 1-9

* Software and Digital Pilot Programs are BA-8 and span S&T thru R&D

Advanced technology prototyping activities mostly occur during BA-1 (Basic Research) to BA-4 (ACD&P), and BA-8 (Software and Digital Pilots) when S&T teams are building out and demonstrating concept components, breadboards, models, and prototypes. When RDT&E-funded projects complete a successful R&D process, then the technologies are ready for integration into military systems, Concepts of Operation (CONOPs), and/or Tactics, Techniques, and Procedures (TTPs).[11]

Since S&T teams focused on R&D often lack acquisition expertise connecting with the right DOD acquisition organizations and managing the complexities of the technology transition ecosystem, new technologies can face delays, missed opportunities, or even failure due to the unintentional neglect of critical transition activities. To transition technologies from S&T projects into acquisition programs, ongoing and close collaboration is essential among diverse groups of S&T teams, acquirers, and requirers.

DOD Acquisition Pathways Anticipate New Technology Insertion

Collaboration to transition technologies occurs within the framework of the DOD's Defense Acquisition System (DAS), as outlined in DOD Directive (DODD) 5000.01; and the AAF, as outlined in DOD Instruction (DODI) 5000.02.

The DAS is the overarching acquisition management system and considers a program's complete life cycle from R&D through disposition/disposal, and involves multiple policies, stakeholders, and budget categories as described above. In the DAS, requirements serve as the foundational blueprint that guides the development and procurement of military systems, defining the specific capabilities and performance standards needed to meet operational needs. Fortunately, the DAS is designed for the regular integration of new technologies into weapon and support system portfolios, as warfighter requirements continually evolve to meet changing national defense demands.

Within the DAS, the AAF is a structure consisting of six tailorable pathways that enable the execution of acquisition activities in support of authorized and funded programs. Each pathway is designed to address the diverse needs of different acquisition programs, guiding projects from concept to deployment, and ensuring they meet their specific requirements and standards. Each pathway has a unique role, defined in a DODI as listed in Table 2, which assigns responsibilities and prescribes procedures for its application:[12]

All pathways address a program's complete life cycle spanning R&D, test, production, fielding, sustainment (operations and support), and disposition. Because the pathways are designed to oversee the acquisition program's complete life cycle, they include planning for new technology insertion points. Of the six pathways, S&T teams are most

[11] Defense Acquisition University. (n.d.). *CONOPS Definition*. Retrieved November 11, 2024, from https://www.dau.edu/acquipedia-article/concept-operations-conops

[12] U.S. Department of Defense. (2020, January 23). Operation of the Adaptive Acquisition Framework (DODI 5000.02). https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/500002p.pdf

likely to encounter Middle Tier of Acquisition (MTA), Major Capability Acquisition (MCA), and/or Software Acquisition—all depending on the kind of technology solution (hardware, software, stand alone, integrated, etc.).

Table 2: The Six AAF Pathways

AAF Pathway	Basic Application
Urgent Capability Acquisition (DODI 5000.81)	Warfighter need in < 2 years
Middle Tier of Acquisition (MTA) (DODI 5000.80)	Rapid prototyping and rapid fielding (≤ 5 years each)
Major Capability Acquisition (MCA) (DODI 5000.85)	Acquiring and modernizing enduring DOD capabilities
Software Acquisition (DODI 5000.87)	Agile software development
Defense Business Systems (DODI 5000.75)	Information systems for DOD business ops
Acquisition of Services (DODI 5000.74)	Contracted services for DOD

Below is a short overview of these three pathways. For additional information on a specific pathway, consult DAS professionals and/or refer to the DODI.

AAF Pathway: Middle Tier of Acquisition (MTA)

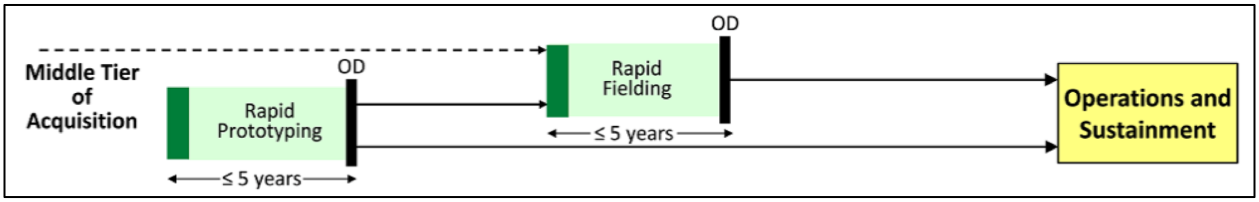
The MTA pathway (Figure 1) "is intended to fill a gap in the Defense Acquisition System (DAS) for those capabilities that have a level of maturity to allow them to be rapidly prototyped. … [t]he MTA pathway may be used to accelerate capability maturation before transitioning to another acquisition pathway or may be used to minimally develop a capability before rapidly fielding."[13] Examples of programs using the MTA pathway as a part of their acquisition strategies include the United States Air Force's (USAF's) B-52 Commercial Engine Replacement Program, the Army's Future Long Range Assault Aircraft, and the U.S. Space Force's (USSF's) NextGen Overhead Persistent Infrared (OPIR) Block 0-Geosynchronous Earth Orbit Satellites.

From a program planning perspective, MTA "enables programs to prove out emerging capability by prototyping before making a larger 'investment' decision on a major program acquisition. … [t]hese rapid prototyping activities reduce engineering and development risks, thereby reducing costs."[14]

The MTA pathway planning anticipates that new technologies will transition into a program upon successful completion of rapid prototyping activities. MTA is an effective tool for transitioning advanced technologies from concept to operational use swiftly and efficiently because its approach offers flexibility in acquisition strategies, supports

[13] U.S. Department of Defense. (2019, December 30). Operation of the Middle Tier of Acquisition (MTA) (DODI 5000.80). https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/500080p.PDF
[14] Ibid.

iterative development for continuous improvement, and enhances risk management by identifying and addressing issues early.



*Acronym in figure: Outcome Determination (OD)

Figure 1: AAF Middle Tier of Acquisition (MTA) Pathway[15]

For technologies aiming to integrate into existing platforms, the MTA pathway offers rapid prototyping to demonstrate compatibility and effectiveness. This enables real-world testing and refinement, ensuring that the technology meets operational requirements and fits within the existing system architecture. Furthermore, the MTA pathway also supports the creation of new programs by providing a streamlined process that accommodates the unique requirements and challenges of advanced technologies, facilitating their successful transition into full-scale operational capabilities. S&T projects transitioning via the MTA pathway will collaborate with the acquiring organization to understand the requirements for a successful rapid prototyping Outcome Determination (Figure 1) and integrate necessary activities into the S&T project plan.

AAF Pathway: Major Capability Acquisition (MCA)

The MCA pathway (Figure 2) is used "to acquire and modernize military unique programs that provide enduring capability. These acquisitions typically follow a structured approach to analyze, design, develop, integrate, test, evaluate, produce, and support acquisition. This process is designed for major defense acquisition programs, major systems, and other complex acquisitions."[16] Programs progress through well-defined phases that culminate with Milestone (MS) Decisions (e.g., MS A, MS B, MS C). Examples of programs using the MCA pathway include Army's M10 Booker (formerly Mobile Protected Firepower), the USAF's Advanced Pilot Training System (T-7A), and the Marine Corp's Amphibious Combat Vehicle.

From a program planning perspective, MCA programs are "designed to facilitate capability enhancements by using open systems architectures and common, open, and consensus-based standards. An open system design supports sustainment and rapid integration of new or updated subsystems into the platform."[17]

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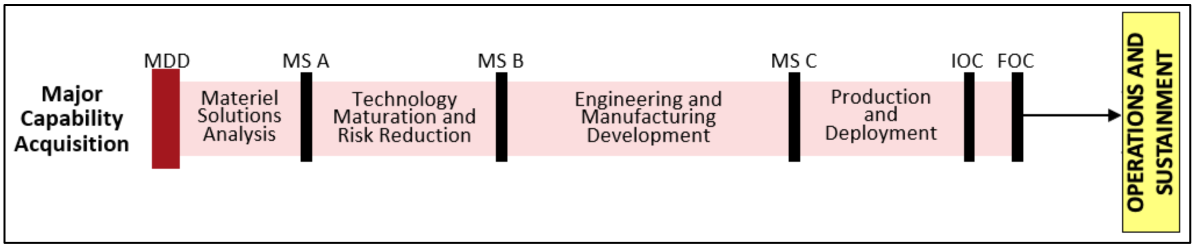
[15] Defense Acquisition University. (n.d.). *Middle Tier of Acquisition (MTA)*. Adaptive Acquisition Framework. Retrieved July 17, 2024, from https://aaf.dau.edu/aaf/mta/

[16] U.S. Department of Defense. (2019, December 30). Operation of the Middle Tier of Acquisition (MTA) (DODI 5000.80). Retrieved from https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/500080p.PDF

[17] U.S. Department of Defense. (2020, August 6). Major Capability Acquisition (MCA) (DODI 5000.85). Retrieved from https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/500085p.pdf



*Acronyms in figure: Material Development Decision (MDD), Milestone (MS), Initial Operational Capacity (IOC), Full Operational Capacity (FOC)

Figure 2: AAF Major Capability Acquisition (MCA) Pathway[18]

MCA planning anticipates new technology integration in the program. The pathway specifically consists of technology maturation phases including the Materiel Solutions Analysis phase, the Technology Maturation and Risk Reduction (TMRR) phase, and the Engineering and Manufacturing Development (EMD) phase, dedicated to defining and maturing new capabilities (e.g., S&T R&D activities), all prior to the Production and Deployment phase where the capability is fielded to the warfighter. S&T projects transitioning via the MCA pathway will likely engage in pre-Milestone B TMRR activities (i.e., RDT&E funding aligns to pre-Milestone B activities). And they will collaborate with the acquiring organization to understand the requirements for successful Milestone B completion and incorporate necessary activities into the S&T project plan.

AAF Pathway: Software Acquisition

The Software Acquisition pathway (Figure 3) "is for the timely acquisition of custom software developed for the DoD."[19] It focuses on addressing DOD-specific requirements that cannot be met with commercially available software solutions.

From a program planning perspective, the Software Acquisition Pathway includes two phases (Planning and Execution) and "require[s] government and contractor software teams to use modern iterative software development methodologies (e.g., agile or lean), modern tools and techniques (e.g., development, security, and operations [DevSecOps]), and human-centered design processes to iteratively deliver software to meet the users' priority needs."[20]

The Software Acquisition pathway acknowledges that, unlike hardware, "software is never done" (refer to Figure 3's Design Architecture plan-code-build-test iterative model) and engineers base its development on a Capability Needs Statement (CNS) that captures the users' needs, priorities, and environment.

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[18] Defense Acquisition University. (n.d.). *Middle Tier of Acquisition (MTA)*. Adaptive Acquisition Framework. Retrieved July 17, 2024, from https://aaf.dau.edu/aaf/mca/
[19] U.S. Department of Defense. (2020, October 2). Software Acquisition Pathway (DODI 5000.87).
[20] U.S. Department of Defense. (2020, October 2). Software Acquisition Pathway (DODI 5000.87).

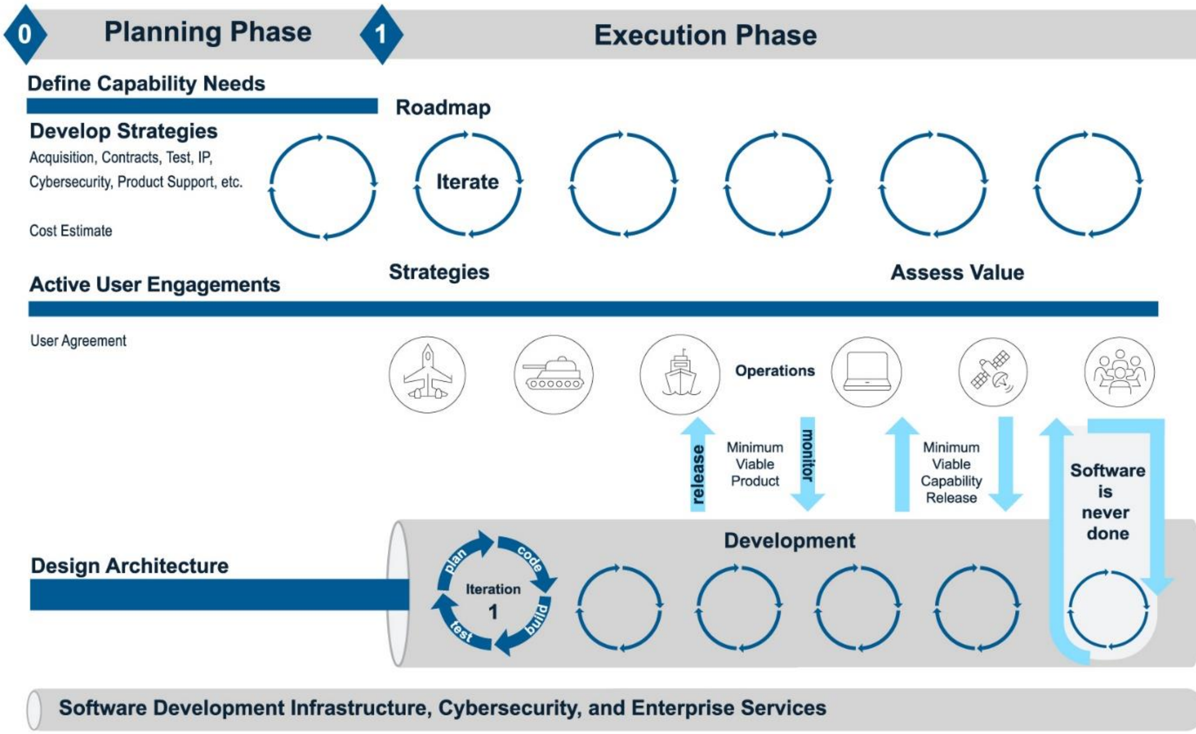

Figure 3: AAF Software Acquisition Pathway[21]

Understanding the unique nature of software development within the Software Acquisition pathway highlights the importance of aligning with the appropriate AAF pathways. S&T projects transitioning to the Software Acquisition pathway must integrate into its iterative processes and collaborate with the acquiring organization to understand the requirements and incorporate necessary activities into the S&T project plan.

For S&T teams, understanding these three acquisition pathways is crucial, as acquisition program partners will determine the best route for transitioning technology to field capabilities for the warfighter. The chosen pathway will dictate the need to incorporate specific activities into the S&T project plan to ensure sufficient data is collected for a successful transition. Additionally, a technology might initially be validated through one pathway and later transition to another, depending on whether the capability is fielded as standalone or integrated into another system. Demonstrating knowledge of these pathways, identifying project activities to gather information, and aligning resources in the project plan will help instill confidence in decision makers that the project is ready to transition.

Finally, as mentioned earlier, the technology insertion process is not simple, so S&T projects should start with technology transition in mind and plan to develop a transition plan as a part of their activities. Understanding which acquisition pathway(s) a potential acquirer is likely to use to adopt the technology enables the S&T team to effectively plan

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[21] Ibid.

for the transition. This involves identifying and executing the necessary activities to ensure a seamless integration, aligning project goals with acquisition requirements, and proactively addressing potential challenges. By doing so, the team can build a robust transition plan that enhances the likelihood of successful technology transition and/or software deployment.

Planning for a Successful Transition to an Acquisition Program

Successful technology insertion into a DOD acquisition program relies on additional factors beyond the technology's readiness. The technology must also demonstrate sufficient maturity of cost, schedule, and performance to be incorporated into a program's baseline. Maturity of cost emphasizes developing the transition-related Cost Estimate[22] and understanding the affiliated major cost drivers to develop, produce, field, and sustain the new capability. Maturity of schedule emphasizes understanding the critical path activities affiliated with the transition. Finally, performance emphasizes setting clear objectives and parameters such as alignment to program Key Performance Parameters (KPPs). This facilitates communication among all stakeholders by providing a concise summary of the program's objectives and parameters. Overall, this baseline of knowledge is essential for the successful execution of a program, providing a clear roadmap for goals, timelines, and costs. While the program baseline[23] provides a structured framework for guiding program execution and stakeholder communication, transitioning new technology into a program requires more than just alignment with these plans.

The Transition Maturity Framework (TMaF)

For a program to adopt a technology, it is not sufficient to only mature the technology. The technology must also be operationally valuable and programmatically feasible. That is, it must (1) demonstrate operational suitability through demonstration, experimentation, or testing to meet Service or Combatant Command (CMMD) published requirements or, if not an existing requirement, address capability gaps and offer value to the warfighter; (2) be manufacturable and affordable; and (3) integrate technically and programmatically into an existing system's architecture if it is not a standalone capability.

The Transition Maturity Framework, as shown in Figure 4, provides a holistic systems approach to assessing and identifying systemic barriers that S&T programs face when transitioning advanced technologies. The TMaF addresses these challenges by providing S&T teams with a structured approach to identify, prioritize, and communicate the necessary activities for successful transition. By aligning with AAF pathways such as the MTA and MCA, the TMaF highlights steps that help reduce programmatic risk

[22] Defense Acquisition University. (n.d.). *Cost Estimate Definition*. Retrieved November 11, 2024, from https://www.dau.edu/glossary/cost-estimating
[23] Defense Acquisition University. (n.d.). *Baselines Definition*. Retrieved November 11, 2024, from https://www.dau.edu/glossary/baselines

and build confidence among acquisition stakeholders, preparing S&T teams to navigate the intricate DOD acquisition ecosystem. The TMaF is designed to help S&T projects transition to acquisition programs via the MCA and MTA pathways. A future release of the TMaF is planned to incorporate the Software Acquisition pathway due to its unique, "software is never done" iterative processes.

Elements of the TMaF

The TMaF is a combination of four independent readiness/confidence measures that, when considered in total, provide an objective view of a project's status. The TMaF comprises two widely used readiness measures, Technology Readiness Level (TRL) and Manufacturing Readiness Level (MRL); one lesser-known measure, Special Operations Command's (SOCOM's) Transition Confidence Level (TCL); and a novel measure created and defined in this paper, the Requirements Readiness Level (RRL).

TRL and MRL are well understood by the DOD community and are used to assess whether a technology is mature enough to include in a larger system or to manufacture in a production line, respectively (note: software-only technology solutions should disregard MRL alignment, as it is intended for hardware solutions; instead, they should align with the Agile DevSecOps construct and the AAF Software Acquisition Pathway iteration methodology). TCL is the measure that evaluates a project's readiness to advance between acquisition phases by assessing its funding, integration into program strategy, and alignment with technical, programmatic, and operational goals. In combination, these measures can be used to track the progress of technology development, manufacturability, and transition, but they do not address the process of going from an operational need to an official, well-defined requirement. Without alignment to a formal requirement, a technology cannot transition to an acquisition program because it will not be approved for incorporation into an Acquisition Strategy. Therefore, MITRE introduced RRL, which measures the alignment of technology solutions to a Joint Capabilities Integration and Development System (JCIDS), Service-issued validated requirements, a CNS,[24] or, in some instances, other policy-defined warfighter needs that are sufficient to receive approval for incorporation into the acquisition strategy.

The TMaF confidence/readiness levels range from 1 (lowest maturity) to 9 (highest maturity). Aligned to the scale are the maturation milestones of the project for the independent measures of TCL, TRL, MRL, and RRL.

[24] Per DODI 5000.87, Software Acquisition Pathway, "Programs using the software acquisition pathway are not subject to JCIDS, except pursuant to a new process as discussed in Paragraph 2.8.a., but must be effective in capturing users' needs, priorities, and environment. The sponsor will oversee development of a draft CNS to support the initiation of a software acquisition and use of this pathway." Software Acquisition and CNS placement in the RRL metric will be further addressed in a future TMaF release.

Scale	Transition Confidence Level (TCL)	Technology Readiness Level (TRL)	Manufacturing Readiness Level (MRL)	Requirements Readiness Level (RRL)	Transition Likeliness
9	• Transition to Program Executive Office (PEO) funding and acquisition strategy completed	**Actual system proven through successful mission operations.** Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.	**(Level 9) Pilot line capability demonstrated; Ready to begin Low Rate Initial Production (LRIP).** • The system, component, or item has been previously produced, is in production, or has successfully achieved low-rate initial production. Technologies should have matured to TRL 9. This level of readiness is normally associated with readiness for entry into Full Rate Production (FRP). All systems engineering/design requirements should have been met such that there are minimal system changes. Major system design features are stable and have been proven in test and evaluation. **(Level 10) Full Rate Production (FRP) demonstrated and lean production practices in place.**	• Technology meets *Funded* JCIDS or Service validated requirement; CNS (for Software Acquisition pathway); technology addresses validated eKPP or related JPR, KPP, KSA from Capability Development Document (CDD), Enterprise Capability Document (ECD), or Service equivalent.	
8	• Signed transition agreement between the Program Manager (PM) and technology developer • Transition funding committed	**Actual system completed and qualified through test and demonstration.** Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	**Pilot line capability demonstrated; Ready to begin Low-Rate Initial Production.** The system, component, or item has been previously produced, is in production, or has successfully achieved LRIP. Technologies should have matured to TRL 9. This level of readiness is normally associated with readiness for entry into FRP. All systems engineering/design requirements should have been met such that there are minimal system changes. Major system design features are stable and have been proven in test and evaluation.	• Technology meets *Unfunded* JCIDS or Service validated requirement; CNS (for Software Acquisition pathway); technology addresses validated eKPP or related JPR, KPP, KSA from Capability Development Document (CDD), Enterprise Capability Document (ECD), or Service equivalent (ref UFR lists).	High
7	• Integration strategy defined • Transition cost estimate complete • Potential funding sources identified	**System prototype demonstration in an operational environment.** Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	**Capability to produce systems, subsystems, or components in a production representative environment.** System detailed design activity is nearing completion. Material specifications have been approved and materials are available to meet the planned pilot line build schedule. Manufacturing processes and procedures have been demonstrated in a production representative environment. Detailed producibility trade studies are completed and producibility enhancements and risk assessments are underway. Technologies should be on a path to achieving TRL 7.	• Technology meets *Pre-validated* (i.e., draft) JCIDS or Service requirement; CNS (for Software Acquisition pathway); technology addresses eKPP or related JPR, KPP, KSA from Capability Development Document (CDD), Enterprise Capability Document (ECD), or Service equivalent.	
6	• Transition technical goals approved by acquisition PM and technology developer • Transition schedule estimate developed • Project included in PM plans as a potential source	**System/subsystem model or prototype demonstration in a relevant environment.** Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.	**Capability to produce a prototype system or subsystem in a production relevant environment.** This MRL is associated with readiness for a Milestone B decision to initiate an acquisition program by entering into the Engineering and Manufacturing Development (EMD) Phase of acquisition. Technologies should have matured to at least TRL 6. The majority of manufacturing processes have been defined and characterized, but there are still significant engineering and/or design changes in the system itself.	• Technology meets the needs expressed in the Chairman's Risk Assessment or similar Joint Capability Development assessment or study.	
5	• Expressed interest from PM office • Active communication with named PM contact	**Component and/or breadboard validation in relevant environment.** Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.	**Capability to produce prototype components in a production relevant environment.** Manufacturing strategy refined and integrated with Risk Management Plan. Identification of enabling/critical technologies and components is complete. Prototype materials, tooling, and test equipment, as well as personnel skills, have been demonstrated on components in a production-relevant environment, but many manufacturing processes and procedures are still in development.	• Technology meets the needs expressed in Combatant Command Integrated Priority List (IPL) or similar statement of support from one or more combatant commanders (memo, public statements, etc.).	Medium
4	• Target PMs briefed and provided progress updates • Key transition stakeholders named • Relevant programs named	**Component and/or breadboard validation in laboratory environment** Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	**Capability to produce the technology in a laboratory environment.** This level of readiness acts as an exit criterion for the MSA Phase approaching a Milestone A decision. Technologies should have matured to at least TRL 4. This level indicates that the technologies are ready for the Technology Development Phase of acquisition. Producibility assessments of design concepts have been completed. Key design performance parameters have been identified as well as any special tooling, facilities, material handling, and skills required.	• Technology meets the needs expressed in formal DOD or Services strategies for capability development, budgeting, or concepts of operations.	
3	• Specific project technical goals established • Target acquisition programs identified • Potential transition stakeholders identified	**Analytical and experimental critical function and/or characteristic proof of concept.** Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	**Manufacturing Proof of Concept Developed.** This level begins the validation of the manufacturing concepts through analytical or laboratory experiments. Experimental hardware models have been developed in a laboratory environment that may possess limited functionality.	• Technology aligns to Joint Concept of Operations.	Low
2	• Project initiated • TRL goals established (baseline)	**Technology concept and/or application formulated.** Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	**Manufacturing Concepts Identified.** This level is characterized by describing the application of new manufacturing concepts. Applied research translates basic research into solutions for broadly defined military needs.	• Technology aligns to Joint or Service need expressed in lessons learned or warfighter feedback from experimentation, exercises, or operations (e.g., JLLIS).	
1	• Working Group interest expressed • Active tech discovery • Acknowledged gap	**Basic principles observed and reported.** Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.	**Basic Manufacturing Implications Identified.** Basic research expands scientific principles that may have manufacturing implications. The focus is on a high-level assessment of manufacturing opportunities. The research is unfettered.	• Technology aligns with a general Joint or Service need expressed in studies or analysis. Or an informal, promising "idea" or "user story" relayed by "boots on the ground" (i.e., Lessons Learned, Field Reports, informal warfighter feedback, etc.).	

Figure 4: Transition Maturity Framework

When using the TMaF to assess a project's transition maturity, it is crucial to recognize that each of the four maturity scales operates independently. As an example, a project assessed at TCL 4 does not require its TRL, MRL, and RRL to also be at Level 4. While these scales are distinct, correlations between them do exist. For instance, a low RRL might suggest a similarly low TCL. If the TRL is low, it is likely the MRL is low. Understanding the nuances helps to accurately evaluate and advance project maturity.

Depending on how the S&T project has been planned and executed, different measures may lead or trail the others. For example, an advanced technology project born out of a funded JCIDS requirement would have a high RRL because it is tied to a formal requirement (see RRL 9 in the TMaF), but a low TRL because the S&T team is just starting to design the technology at the breadboard level (see TRLs 4/5 in the TMaF). Also, since the S&T team is just starting to understand the technology, they may not have engaged a potential transition program yet, so the TCL would also be lower (see TCLs 3/4 in the TMaF). In short, each measure allows project decision makers to recognize potential shortfalls and risks, so they prioritize resources where they will make the most difference, increasing the confidence in successful transition.

Notional Scenario: S&T UAS Project Enhancement via TMaF Application

Scenario Overview

Taylor leads an S&T team focused on enhancing the time-on-station capability of an Unmanned Aerial System (UAS) platform. The team successfully advances its technical solution from TRL 2 to TRL 5, and the team develops a manufacturing proof of concept that meets MRL 3 requirements. Encouraged by rapid prototyping and proof of concept experiments, the team is optimistic about the solution's potential.

Challenges Identified

Despite the technical and manufacturing progress, the team has not engaged with potential warfighters or program offices, nor has the team analyzed DOD mission requirements. Consequently, the system remains at TCL 1 and RRL 1. This lack of alignment with end-user needs and mission requirements poses a significant risk to the project's transition from R&D to an acquisition program.

Strategic Pivot

Recognizing the importance of ensuring the team's solution meets operational needs and aligns to the needs of an acquisition program, Taylor determines the team needs to shift its focus. Rather than continuing to advance from TRL 5 to TRL 6, the team prioritizes application of resources (e.g., funds, people, time) to increasing the RRL and TCL to 4 or higher. The team creates a project plan and timeline with a set of critical activities needed to coordinate with requirements and acquisitions communities and mature the RRL and TCL levels.

S&T teams can assess the likelihood of a successful transition by evaluating project status against each of the four TMaF measures. The goal is not necessarily to achieve the same level across each of the measures, though drastic imbalances should be investigated. Rather, the objective is to (1) assess the project's current "as is" levels across each TMaF measure, (2) determine the necessary "to be" TMaF levels required for initiating the technology transition into one of the chosen AAF pathways,, and (3) identify the critical activities to incorporate into the project plan that mature the program from the “as is" state to the “to be” state. When the S&T team has secured an acquisition partner (see TMaF TCLs 3 and 4), the transition maturity levels and the critical activities should be codeveloped to ensure both parties have clarity and consensus. Documenting agreed-upon minimum levels for each measure will enable the S&T team to apply its resources effectively. A specific notional scenario is considered above.

Example TMaF Use: Operational Energy – Innovation

The Office of the Deputy Assistant Secretary of Defense for Energy Resilience and Optimization Operational Energy – Innovation (OE-I) office is the first DOD organization to implement the TMaF for enhancing the transition of advanced operational energy technologies from S&T activities to acquisition programs. The office has defined sets of minimum entry and exit TMaF levels for projects within its two portfolios: the Operational Energy Capability Improvement Fund (OECIF), which uses RDT&E BA-3 funding (ATD) and the Operational Energy Prototyping Fund (OEPF), which uses RDT&E BA-4 funding (ACD&P). Furthermore, OE-I has operationalized the TMaF by outlining specific critical activities that must be planned and executed at each TMaF level. Table 3 details the OECIF and OEPF minimum entry and exit levels.

Table 3: OECIF and OEPF TMaF Measure Entry and Exit Criteria

TMaF Measure	OECIF Minimum Entry Criteria	OECIF Minimum Exit Criteria	OEPF Minimum Entry Criteria	OEPF Minimum Exit Criteria
TCL	3	5	5	8
TRL	4	6	6	7
MRL	1	3	3	7
RRL	1	5	5	8

Thus, for an S&T project to be included in the OECIF portfolio, it must demonstrate TMaF measures of at least TCL 3, TRL 4, MRL 1, and RRL 1. If the project proposal cannot demonstrate it meets these minimum entry criteria, it is considered insufficiently mature to receive RDT&E BA-3 funds and is thus ineligible for selection. Similarly, for an S&T project to be included in the OEPF portfolio, it must demonstrate entry TMaF measures of TCL 5, TRL 6, MRL 3, and RRL 5. If the OEPF project proposal cannot demonstrate it meets these minimum entry criteria, it is considered insufficiently mature to receive RDT&E BA-4 funds and is thus ineligible for selection. This also enables OE-I to reconsider an ineligible OEPF proposal for the OECIF portfolio if it meets the less mature OECIF entry criteria.

To ensure OECIF and OEPF project teams meet the TMaF measures’ minimum exit criteria by the end of their work plans, OE-I has established essential activities that must be planned, resourced, and executed to validate accomplishment of each measure level. Figure 5 below illustrates an example of the critical activities for OECIF TCL Levels 3, 4, and 5.

Transition Readiness Levels for TCL

	TCL Description	OECIF TCL Critical Activities
5	• Expressed interest from PM office • Active communication with named PM contact	• Onboard Program of Record PM • Conduct discussions with potential program offices to determine if their portfolios have performance requirements/gaps/opportunities to leverage the advanced technology • Conduct deep dive discussions with PM to determine transition technical goals • Initiate cost estimate planning
4	• Target PMs briefed and provided progress updates • Key transition stakeholders named • Relevant programs named	• Set up recurring engagements with program office PM POC • Create and maintain a transition stakeholder tracker • Potential transition stakeholders identified—set up a communication plan to engage stakeholders
3	• Specific project technical goals established • Target acquisition programs identified • Potential transition stakeholders identified	• Verify TRL goals are established (baseline) from TRL 2 • Establish specific project technical goals • Review potential transition pathways and identify potential program offices (see list of PEOs, organization charts) • Reach out to program offices to present project and request a PM POC to help with transition; add the PM to OE-I project team • Identify transition stakeholders (S&T, acquisitions, requirements communities)

Figure 5: OECIF Critical Activities to Complete TCL Levels 3 Through 5

OECIF expects that by a project's work plan completion, all TCL critical activities through TCL 5 will have been accomplished. Thus, by the end of the OECIF project work plan, the project team must have onboarded the targeted acquisition Program Manager (PM), conducted discussions with potential program office(s) to determine whether its portfolio has performance requirements/gaps/opportunities to leverage the OECIF technology, conducted deep dive discussions to determine the transition technical goals, and initiated cost estimate planning required to incorporate the OECIF capability into the program baseline. Similar work plan completion requirements are expected for all OECIF and OEPF TMaF measures.

Because RRL is a novel concept, it is worthwhile to also show critical activities required to meet the RRL OECIF entrance and exit criteria. As with TCL, these activities must be planned, resourced, and executed to validate accomplishment. Figure 6 below illustrates an example of the critical activities for OECIF RRL Levels 1 thru 5.

OECIF expects that by a project's work plan completion, all RRL critical activities through RRL 5 will have been accomplished. So, by the end of the OECIF project work plan, the project team must have validated that the project's initial capabilities align to the CONOPs to meet needs for (1) an Office of the Secretary of Defense (OSD), Joint, Combatant Command (CCMD), and/or Service defined capability with documented buy-in from Service or CCMD staff at working level (e.g., Initial Capabilities Document) and/or (2) a documented Service/OSD policy goal.

Transition Readiness Levels for RRL	RRL Description	OECIF RRL Critical Activities
5	• Technology meets the needs expressed in CMMD Integrated Priority List (IPL) or similar statement of support from one or more combatant commanders (memo, public statements, etc.).	• Validate the project's initial capabilties align to CONOPS to meet needs for (1) an OSD, Joint, CMMD, and/or Service defined capability with documented buy-in from Service or CMMD staff at working level (Example: an Initial Capabilities Document) and/or (2) a documented Service/OSD policy goal
4	• Technology meets the needs expressed in formal DOD or Services strategies for capability development, budgeting, or CONOPs.	• Conduct research that connects the project's basic technologies to CONOPS for (1) a defined capability need mission and/or (2) a documented Service/OSD policy goal
3	• Technology aligns to Joint CONOPS.	• Conduct research that connects the project's basic technologies to CONOPS for a mission and/or OSD/Service policy goal
2	• Technology aligns to Joint or Service need expressed in lessons learned or warfighter feedback from experimentation, exercises, or operations (e.g., JLLIS).	• Conduct research in support of studies that connects basic technologies to CMMD, OSD, Joint, or Service need(s)
1	• Technology aligns with a general Joint or Service need expressed in studies or analysis, or an informal, promising "idea" or "user story" relayed by "boots on the ground" (i.e., Lessons Learned, Field Reports, informal warfighter feedback, etc.).	• Conduct initial research in support of studies that connects basic technologies to DOD-related needs

Figure 6: OECIF Critical Activities to Complete RRL Levels 1 Through 5

In summary, the OE-I office has pioneered the use of the TMaF to streamline the transition of advanced operational energy technologies from S&T activities to acquisition programs. By establishing minimum entry and exit TMaF levels for its OECIF and OEPF portfolios, OE-I ensures projects meet specific maturity criteria before receiving funding. Projects must demonstrate readiness through defined TMaF measures, with critical activities planned and executed to validate each level. This structured approach not only facilitates project selection but also guides teams in achieving necessary milestones, ensuring alignment with operational goals, and planning for technology transition into acquisition programs.

Employing the TMaF for Your S&T Project

The TMaF is a tool designed to assess an S&T project's transition maturity level and identify risks it will face in the transition process. It breaks down four measures of confidence and readiness, explaining how they collectively inform decision makers as to the status and risk of a project. The framework is intended to assist S&T teams in navigating transition without becoming experts in the acquisition process. That acquisition process and associated TMaF critical activities will vary depending on which AAF pathway is being used (e.g. MTA, MCA, Software). The following is a practical guide to help S&T teams use the TMaF to maximize a project's probability of success.

To start, assess the current state of the project's transition maturity, utilizing the four TMaF measures. Begin by evaluating each measure to identify both the known and unknown transition risks. This assessment will provide clarity on areas that require risk reduction strategies. For software-intensive programs, avoid using the MRL; instead, apply the software pathway iteration methodology to ensure a more accurate evaluation. By systematically analyzing these measures, the team can effectively address potential risks and enhance the project's transition maturity. (Note: For projects that are not at TCL 5 and have yet to identify an acquisition partner, focus on both independently assessing your project's transition maturity using the TMaF measures and actively seeking out potential acquisition transition partners by networking and leveraging connections.)

Once you have identified your transition partner, collaborate with them to address the necessary TMaF measure levels required for initiating technology transition. The required measure levels are subjective to your specific transition partner's needs—some organizations may require higher levels of maturity than others. The partnership will ensure that both parties are aligned on the specific maturity levels needed, facilitating a smoother transition process. By working together, you can tailor the measures to address project-specific needs and enhance the likelihood of successful technology integration.

The next step is to collaboratively develop and prioritize the "to-do" list of transition-related activities for each TMaF measure with the gaining acquisition organization. This co-developed version of the "to do" list ensures the S&T collects sufficient information required to initiate the transition with the acquisition partner. The list should focus on advancing the project from its initial level to the desired transition maturity level. By working together, you can ensure that each activity is strategically aligned and prioritized to effectively mature the project, facilitating a successful transition.

With the current status of the TMaF measures, the desired end state, and a prioritized "to-do" list in hand, you can seamlessly integrate these elements into your S&T project plan, budget, and schedule. The next step is to focus on executing the prioritized activities, systematically addressing each transition-related task. Collaborate closely with your acquisition partner to ensure alignment and continuously monitor progress. Regularly review and adjust the plan to address emerging risks or changes in requirements, ensuring the project remains on track for a successful technology transition.

Conclusion

The Transition Maturity Framework offers a structured approach to help S&T teams navigate the complexities of transitioning new technologies into DOD acquisition programs. TMaF enables science and technology (S&T) teams to strategically identify and prioritize the essential activities necessary for successful technology transition. It combines four readiness measures—TCL, TRL, MRL, and RRL—to provide a comprehensive view of a project's maturity, its acquisition and requirements/warfighter partners, and to ensure technologies are technically, operationally, and programmatically viable for integration.

An exemplary application of the TMaF is seen in the OECIF and OEPF programs, where it has been operationalized to enhance technology transitions. By establishing specific milestones and entry/exit levels, the TMaF ensures critical activities are planned and executed in a timely way and partners from the acquisition and requirements communities are engaged, increasing the likelihood of successful integration. This framework equips S&T teams with a clear roadmap, fostering collaboration and communication, and ultimately contributing to maintaining DOD's technological edge.

About the TMaF Team

The TMaF has been developed by a cross-functional team of senior experts in DOD S&T, R&D, acquisition, warfighting, requirements, and staffing. This diverse expertise makes the TMaF exceptionally beneficial for S&T teams aiming to transition new technologies into DOD acquisition programs. A cross-functional team is crucial in building weapon and support systems because it integrates varied expertise and perspectives, ensuring comprehensive solutions. By collaborating across fields such as engineering, acquisition, operations, and logistics, the team addresses complex challenges, enhances innovation, and streamlines processes. This approach reduces risks, improves efficiency, and ensures that the final product meets operational requirements and strategic goals effectively.

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Appendix A: Acronyms

Acronym	Definition
AAF	Adaptive Acquisition Framework
ACD&P	Advanced Component Development and Prototypes
ADM	Acquisition Decision Memorandum
APB	Acquisition Program Baseline
AS	Acquisition Strategy
ATD	Advanced Technology Development
BA	Budget Activity
CCMD	Combatant Command
CDD	Capability Development Document
CONOPs	Concept of Operations
DAS	Defense Acquisition System
DevSecOps	Development, Security, and Operations
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DOTmLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy
DSB	Defense Science Board
ECD	Enterprise Capability Document
eKPP	Energy Key Performance Parameter
EMD	Engineering and Manufacturing Development
FOC	Full Operational Capability
FRP	Full Rate Production
GO/FO	General Officer/Flag Officer
ICD	Initial Capabilities Document
IOC	Initial Operational Capability
IPL	Integrated Priority List
JCIDS	Joint Capabilities Integration and Development System
JLLIS	Joint Lessons Learned Information System
JPR	Joint Performance Requirement
JWA	Joint Warfighting Assessment
KPP	Key Performance Parameter
KSA	Key System Attribute

Acronym	Definition
LRIP	Low Rate Initial Production
MCA	Major Capability Acquisition
MDA	Milestone Decision Authority
MDD	Material Development Decision
MRL	"Manufacturing Readiness Levels (MRLs) are used with assessments and are designed to assess the maturity of a given technology, system, subsystem, or component from a manufacturing perspective. MRLs provide decision-makers (at all levels) with a common understanding of the relative maturity (and attendant risks) associated with manufacturing technologies, products, and processes being considered to meet DOD requirements."[25]
MS	Milestone
MS A	Milestone A – the decision point for an acquisition program to move from Materiel Solutions Analysis (MSA) to Technology Maturity and Risk Reduction (TMRR)
MS B	Milestone B – the decision point for an acquisition program to move from TMRR to Engineering and Manufacturing Development (EMD)
MS C	Milestone C – the decision point for an acquisition program to move from EMD to Production and Deployment
MSA	Materiel Solutions Analysis
MTA	Middle Tier of Acquisition
OD	Outcome Determination
ODASD(ER&O)	Office of the Deputy Assistant Secretary of Defense for Energy Resilience and Optimization
OE-I	Operational Energy – Innovation
OECIF	Operational Energy Capability Improvement Fund
OEPF	Operational Energy Prototyping Fund
OSD	Office of the Secretary of Defense
PEO	Program Executive Officer
PM	Program Manager
R&D	Research and Development
RDT&E	Research, Development, Test & Evaluation
RRL	Requirements Readiness Level. RRL is the measure of the maturity of a technology's linkage to JCIDS-validated requirement(s) that is prioritized sufficiently to receive funding for integration, fielding, and sustainment. The RRL is MITRE-invented, with readiness levels from 1 through 9 that define the maturity of an operational requirement from a stated DOD need (Level 1) to a validated and funded Joint or Service Requirement (Level 9). This new RRL dimension allows PMs and stakeholders to assess the alignment of the capability to an existing requirement, and the level of effort to mature the requirement in parallel with the capability.

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Acronym	Definition
S&T	Science and Technology
SDD	Systems Development and Demonstration
TCL	"The Transition Confidence Levels (TCLs) are a measure of the holistic situation of a potential transition candidate. This includes funding and integration into program strategy—technical, programmatic, and operational, and tracking to completion."[26]
TMaF	Transition Maturity Framework
TMRR	Technology Maturity and Risk Reduction
TRL	"Technology Readiness Levels (TRL) are a type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the project's progress. There are nine technology readiness levels. TRL 1 is the lowest and TRL 9 is the highest."[27]
UAS	Unmanned Aerial System
UFR	Unfunded Requirement
USAF	United States Air Force

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Appendix B: Additional Reading

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