Leveraging Modern Systems Engineering Principles to Enhance the Department of War Software Acquisition Pathway

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The Department of War (DoW) is at a pivotal moment in modernizing its software (SW) acquisition practices to meet the demands of an evolving threat landscape and the rapid speed of technology advancement. In March 2025, the Secretary of War (SECWAR) directed that software acquisition emphasize speed, flexibility, digital integration, and the rapid infusion of commercial innovation via the Software Acquisition pathway. The SECWAR released additional guidance regarding acquisition transformation and reforming the requirements generation process. In parallel, the Office of the Under Secretary of War for Research and Engineering (OUSW(R&E)) is leading Systems Engineering Modernization (SEMOD) to implement digital transformation across technical reviews and systems engineering (SE) process flows to support the acquisition decision process. Each of the SEMOD principles align with the SECWAR transformation initiatives by providing the methods to accelerate capabilities to the warfighter while also ensuring the ability to allow future upgrades. This paper provides considerations and metrics for integrating rigorous, modern SE principles into the Software Acquisition pathway, enabling rapid, iterative delivery of software capabilities for timely, data-driven acquisition decisions.

The Software Acquisition Pathway

The Software Acquisition pathway is a two-phased approach, encompassing Planning and Execution, designed for rapid and iterative software delivery. (Figure 1).

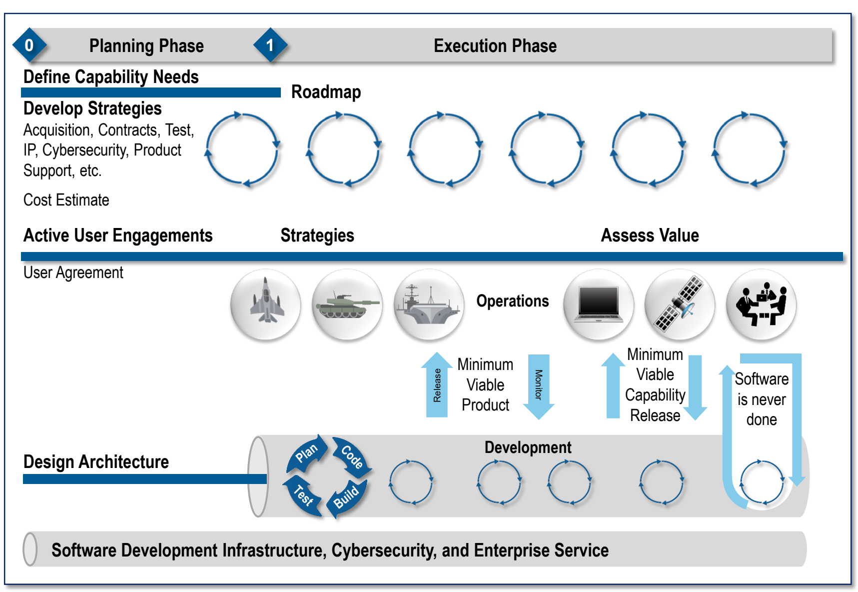

Figure 1. Software Acquisition Pathway (Source: Adapted from DoDI 5000.02)

During the Planning phase, programs engage closely with users to define and prioritize mission needs, develop a Capability Needs Statement, and establish tailored strategies for acquisition, testing, cybersecurity, intellectual property (IP), and product support. The system architecture is defined and modeled, including both the SW development and the deployed SW execution architectures. This phase culminates in execution approval, ensuring the program is resourced and aligned for Agile development.

The Execution phase focuses on iterative design, development, integration, testing, and delivery of software in operationally representative environments, with frequent user feedback and automated testing. Programs are expected to demonstrate viable operational capability within one year of initial funding and to continue delivering updates at least annually, while balancing cost, schedule, performance, and cybersecurity throughout the lifecycle.

Systems Engineering Modernization Practices: Considerations and Metrics

To successfully execute the Software Acquisition pathway, programs should adopt modern SE practices in both the Planning and Execution phases that align with the Department's digital transformation initiatives. OUSW(R&E)'s SEMOD effort provides the foundation for this transformation by integrating digital engineering, modular open systems approach (MOSA), mission engineering, and Agile Development, Security and Operations (DevSecOps) practices into program planning and execution. These practices are critical for maintaining authoritative digital models, enabling data-driven decisions and ensuring program teams can respond rapidly to evolving requirements without compromising cost, schedule, or performance. To enhance the execution of the Software Acquisition pathway and deliver timely, resilient, and upgradable capabilities to the warfighter, program managers (PMs) and chief systems engineers (CSEs) should consider these SEMOD principles when applying digital, iterative, and model-centric approaches (Figure 2):

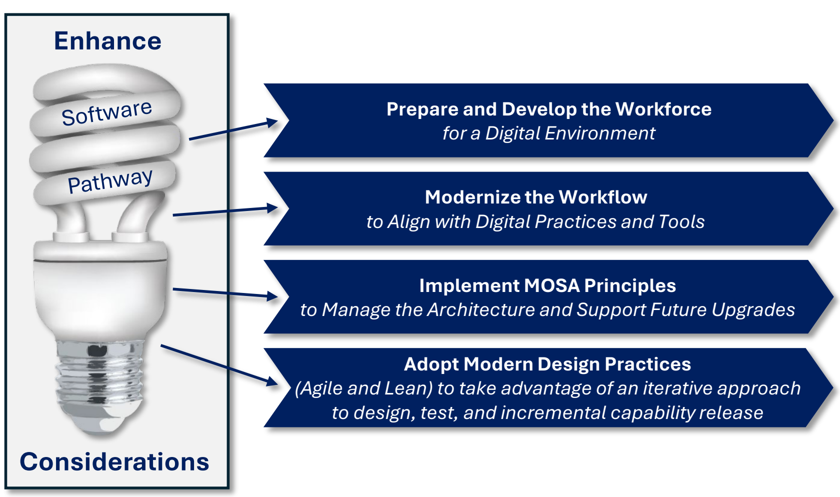

Figure 2. Considerations to Enhance Execution of the Software Acquisition Pathway

1. **Prepare and Develop the Workforce** for a digital environment by adopting a "digital -first mindset."

- **Modernize the Workflow** to align with digital practices and tools.
- **Implement MOSA principles** to manage architecture that supports future upgrades, modifications and enables integration

2. **Adopt Modern Design Practices (relying on Agile and Lean practices)** to apply an iterative approach to design, test and incremental capability release that is informed by continuous user input.

Each consideration is critical to achieving rapid, iterative delivery and continuous capability evolution for software acquisition, whether the software is embedded in hardware-centric systems or delivered as a standalone application to meet the warfighter's needs.

Also, considerations are paired with a set of implementation metrics that help programs track progress, assess outcomes, and guide decision making. Consistent with Systems Engineering Research Center (SERC) research on SEMOD, these metrics encourage programs to focus on data-driven assessment and continuous improvement rather than static compliance. Each program and domain may implement a different combination of these metrics and decompose into sub metrics that reflects its priorities.

Many of these metrics are qualitative, requiring programs to conduct self-assessments and determine how to balance cost, schedule, and performance in alignment with their operational priorities and risk posture. PMs and practitioners must manage these trade-offs while tailoring their approaches to model-based development, collaborative engineering, and integrated testing across the lifecycle. The target values for these metrics are not finite, but rather are intended to scale with the maturity and complexity of the program. For instance, the Table 2 metric "MBSE Training Rate," suggests a target of 95%. A mature, digitally enabled program might achieve this rate or higher coverage, while an early-stage effort may start at 10% and over time build their modeling capability. These tailoring decisions are typically made collaboratively between the PM and the CSE, ensuring that digital engineering rigor supports timely, data-informed acquisition decisions without imposing unnecessary cost or schedule burden. The following sections discuss each SEMOD consideration, along with supporting elements and example metrics relevant for the Software Acquisition pathway.

Consideration 1: Prepare and Develop the Workforce for a Digital Environment

A successful software acquisition program begins with a workforce that is digitally fluent, cross-functional, and adaptable. In this paper, digital fluency and digital literacy refer to the knowledge, skills and abilities required to use digital tools, models and methods to develop and sustain warfighter capabilities. Team members must develop digital literacy to operate in a model-based, data-driven environment that promotes collaboration, efficiency, and continuous improvement. Establishing a cross-functional team with complementary skill sets is essential to executing a software acquisition program that is modular, Agile, and digitally engineered. These key skill sets enable the PM and CSE to maintain technical rigor, leverage modern tools, and deliver capabilities rapidly while supporting the iterative nature of the Software Acquisition pathway. Table 1 lists the workforce roles and skills that support the SW team.

Table 1. Skill Sets for SE Modernization

Role	Primary Responsibilities	Key Skills and Tools
Chief Systems Engineer	Lead SE strategy, ensure integration across domains. Align SE activities with acquisition strategy and other acquisition documents.	Using MBSE, SysML, and architecture frameworks in SW acquisition
Chief Architect	Integrate systems of systems. Lead SW product strategy, ensure integration across SW products and programs, and align development activities. Define the development and deployed SW execution architectures.	System and system-of-systems architecture tools and execution
Digital Engineering Lead	Manage digital thread, produces modeling, products that enable the SW teams to rapidly build and integrate SW versions into the system as a product and toolchain.	MBSE, modeling & simulation platforms
Modeling Specialist	Design, construct, update, and maintain models using selected modeling language(s) and tools. Build and execute models	Develop and manage models to support the functional activities (e.g., engineering, test).
Data Rights/Intellectual Property (IP) Specialist	Advise on data rights and IP strategy to protect program interests across the lifecycle.	Contracting, legal, intellectual property requirements with regard to data relevant to MOSA and application programming interfaces
Interface Control Manager	Maintain interface definitions and repositories; manage version control.	Interface control databases, versioning tools
Government Reference Architecture (GRA)/ Standards Liaison	Align program with GRAs and standards bodies.	Knowledge of open standards in GRA such as Future Airborne Capability Environment, Sensor Open Systems Architecture
Reuse and Integration Engineer	Identify reusable assets and manage component integration.	Asset libraries, integration tools
Training and Workforce Dev Lead	Collaborate with training entities (e.g., Defense Acquisition University) to determine and implement training requirements for MBSE, digital engineering, Agile, and DevSecOps.	Digital workforce training recommendations

In a digital-first environment, programs must prioritize workforce training to enable upskilling and cultural transformation. Investing in digital engineering, Model Based Systems Engineering

(MBSE), Agile, and DevSecOps training ensures the team can operate effectively in model-driven workflows, leverage modern toolchains, and collaborate across functional domains. A high workforce training rate directly reflects a program's readiness to adopt modern systems engineering practices. Programs with teams trained in MBSE and Agile methods are better positioned to maintain authoritative digital models, streamline decision-making, and deliver capabilities at the speed of relevance.

The metrics in Table 2 track progress in cultivating skills necessary for collaboration and reuse efforts that bring efficiency to the process. The OUSW(R&E) in collaboration with the Warfighting Acquisition University has deployed and is developing relevant in-depth training.

Table 2. Workforce Development Metrics

Metric	Description	Target
MBSE Training Rate	% of digital engineering team trained in MBSE and digital engineering	≥ 95%
Agile Training Rate	% of team trained in Agile/DevSecOps practices	≥ 100%

Tracking portfolio reuse metrics, as indicated in Table 3, enables PMs and CSEs to assess the effectiveness of reuse strategies (including shared personnel), identify integration opportunities, and continuously improve collaboration across teams and portfolios. Maximizing cross-portfolio reuse supports accelerating capability delivery, reducing duplication of effort, and fostering an innovative, resource-efficient ecosystem. By reusing software components, digital models, and hardware elements across programs, teams can reduce development timelines, improve interoperability, and lower lifecycle costs. Establishing and maintaining libraries of reusable assets encourages collaboration between programs and strengthens the digital engineering ecosystem envisioned by OUSW(R&E)'s SEMOD initiative.

Table 3. Portfolio Reuse Metrics

Metric	Description	Target
Reuse Rate	% of components reused across programs with regard to source lines of code, function points, modules or model components	≥ 50%
Asset Library Utilization	Frequency of use of reusable asset libraries	Monthly
Collaboration Index	Number of shared modules or co-developed assets	Increasing trend

Consideration 2: Modernize the Workflow to Align with Digital Practices and Tools

Modernizing the workflow to align with digital practices and tools is a cornerstone of the Software Acquisition pathway. Transitioning from a traditional, document-centric approach to a model-centric, data-driven environment improves traceability, accelerates design iterations, and enhances decision-making across the lifecycle. By adopting a digital-first mindset, programs leverage MBSE, modeling and simulation (M&S), digital threads, and digital twins to create a collaborative ecosystem that connects engineering, testing, contracting, and sustainment teams. Digital transformation supports SEMOD objectives by enabling:

- Early and frequent simulations to evaluate design options and reduce rework.
- Digital reviews that replace static document packages with integrated model-based assessments.
- Cross-discipline collaboration in shared digital environments, ensuring program decisions are visible, traceable, and informed by authoritative data.
- Lifecycle digital threads and digital twins that provide real-time insight into performance, configuration, and sustainment readiness.

Tracking progress toward a digital-first mindset includes metrics that measure the breadth of model-based adoption, continuity of digital threads, frequency of simulation-driven decisions, and degree of cross-functional collaboration. These metrics help PMs and CSEs evaluate how effectively the program is leveraging digital engineering to deliver modular, upgradable, and resilient capabilities.

Table 4. Digital First Mindset Metrics

Metric	Description	Recommended Target
MBSE Coverage (Usage)	% of system elements modeled using MBSE tools	≥ 50%
Digital Thread Continuity	% of lifecycle phases linked via digital artifacts	≥ 50%
Digital Review Adoption	% of reviews conducted via digital assessments	≥ 80%
Cross-Discipline Collaboration	Frequency of shared digital environment usage	Weekly

Consideration 3: Implement MOSA Principles

Implementing a MOSA is key to creating architectures that are scalable, interoperable, and upgradable throughout the lifecycle of a software-reliant system. By applying modular decomposition and open standards, programs can isolate rapidly evolving components, reduce vendor lock-in, and enable flexible integration of new technologies. This approach not only supports rapid modernization and technology insertion but also enhances competition, cost-effectiveness, and sustainability over time.

Achieving a MOSA-aligned architecture begins with the appropriate system decomposition, which establishes clear logical, functional, and physical boundaries that support the capability according to program status: New programs should emphasize logical and functional decomposition first, enabling flexibility in future physical implementations; legacy programs should identify incremental modularization opportunities, particularly during technology refreshes or obsolescence-driven upgrades. MBSE tools enable programs to model, trace, and visualize modular structures, supporting lifecycle decisions and architecture verification. MBSE tools, such as Systems Modeling Language (SysML), are effective for modeling these decompositions, maintaining traceability, and linking architectural decisions to requirements, verification activities, and digital threads. This approach aligns with SEMOD objectives, allowing programs to visualize modularization opportunities, evaluate integration risks, and ensure that architectural flexibility is maintained across the lifecycle.

Applying MOSA principles to interfaces enhances adaptability and competition. Programs should identify and prioritize key interfaces, including those that are mission-critical, likely to change, or subject to rapid technological evolution, and should ensure the interfaces are managed with the appropriate level of visibility, control, and flexibility. Open interfaces should use consensus-based standards or well-defined application programming interfaces (APIs), paired with sufficient data rights to allow flexible integration and vendor competition. Non-MOSA interfaces should be regularly reviewed to identify opportunities for modularization, reducing long-term sustainment risk and enhancing system evolution. A structured approach to interface management supports SEMOD by enabling traceability across digital threads, improving integration testing efficiency, and allowing programs to respond to emerging technologies without full-system redesigns. Achieving the full benefits of MOSA requires balancing modularity, data rights, and lifecycle costs.

While modularity and open interfaces enable flexibility, competition, and faster technology insertion, they can also introduce integration complexity and upfront investment. Programs must manage this trade-off carefully to ensure modularity provides a net return on investment across the system lifecycle. Securing sufficient data rights for critical interfaces is central to sustaining long-term flexibility and ensures the government can upgrade, compete, and integrate future capabilities without excessive costs or vendor dependence. Properly managing data rights, in parallel with modularity, further enables cost-effective sustainment and technology refresh over the lifecycle.

To monitor progress toward a modular and open architecture, programs should track key MOSA metrics that assess decomposition (Table 5), modularity and openness (Table 6), interface management (Table 7), mission alignment (Table 8), and standards maturity (Table 9). These metrics enable PMs and CSEs to measure architectural flexibility, ensure compliance with open standards, and verify lifecycle readiness for future upgrades and modifications. They also provide visibility into the completeness of decomposition, the use of MBSE tools to enable digital traceability, and the degree of modularization achieved in legacy components.

Table 5. Decomposition Metrics

Metric	Description	Target
Decomposition Completeness	% of system decomposed logically/functionally	≥ 100%
MBSE Tool Usage Rate	% of decomposition modeled in SysML or equivalent	≥ 95%
Legacy Modularization	% of legacy components modularized	Base on review

Table 6. Modularity and Openness Metrics

Metric	Description	Target
Modular Architecture Score	Degree of logical/functional/physical decomposition	Program Specific
Open Standards Adoption Rate	% of interfaces using open standards/APIs	≥ 90%
Component Replaceability Index	% of components replaceable without redesign	≥ 75%
MOSA Metric Tracking Completeness	% of lifecycle phases with MOSA metrics tracked	100%
Acquisition Document Integration	% of documents embedding MOSA considerations	100%

Table 7. Key Interface and Data Rights Metrics

Metric	Description	Target
Key Interface Management	% of critical interfaces identified and documented	100%
Open Interface Compliance	% of key interfaces using open standards	≥ 90%
Non-MOSA Interface Review Frequency	Frequency of reviews for non-MOSA interfaces	Bi-annually
Data Rights Coverage	% of interfaces with GPR or better	≥ 95%

The metrics in Table 8 help PMs and CSEs track whether their architecture and acquisition strategies are achieving the desired balance between modularity, data rights, and lifecycle cost efficiency. Leveraging Government Reference Architectures (GRAs) supports modular, open, and mission-aligned system design. GRAs provide proven architectural patterns, mature standards, and best practices that reduce design risk, improve interoperability, and promote consistency across programs.

Table 8. GRA Compliance and Mission Alignment Metrics

Metric	Description	Target
GRA Compliance Score	Degree of GRA compliance with Acq Strategy	100%
Mission Architecture Alignment	% of system aligned with mission-specific GRAs	≥ 90%

Although there is no consistent standard for development of or content in a GRA, this paper uses the definition published by the U.S. Air Force Digital Transformation Office. By aligning with GRAs, programs can accelerate development, enhance reuse opportunities, and ensure system decomposition and interface decisions are optimized for mission effectiveness and lifecycle sustainment. Programs should use GRAs to guide contractors in adopting modular design principles and applying appropriate interface standards; incorporate reusable patterns to reduce development effort and mitigate integration risks; support logical and functional decomposition that aligns with mission-specific requirements; and ensure compatibility with domain or mission architectures. Tracking GRA usage metrics allows PMs and CSEs to quantify GRA adoption and alignment across design activities. These metrics demonstrate how effectively the program is leveraging government-provided architectures to reduce risk, enforce consistency, and enable MOSA-compliant evolution.

Applying standards strategically supports SW development of modular, interoperable, and upgradeable systems. Mature standards, such as the Future Airborne Capability Environment (FACE), Sensor Open Systems Architecture (SOSA), and Open Mission Systems/Universal Command and Control Interface (OMS/UCI) reduce integration risk, promote cross-program reuse, and ensure long-term sustainment flexibility. Programs should select and implement standards based on maturity, relevance, and domain applicability, while ensuring that their adoption supports modular software interfaces and Agile development practices.

To maximize lifecycle value, programs should prioritize standards that are at technology readiness level (TRL) 7 or higher and widely adopted to reduce integration and performance risk. Programs should tailor standards maturity to align with the acquisition pathway: (1) Software acquisition programs focus on mature, modular software standards for iterative delivery; (2) Major Capability Acquisition integrate standards that promote MOSA benefits across the lifecycle; and (3) Middle Tier of Acquisition efforts use mature, fieldable standards due to accelerated timelines. Implementing MOSA standards can be complicated, so programs should engage experts such as standards bodies (Open Management Group (OMG)) to ensure they correctly apply and align standards with DoW guidance. Programs should verify compliance and define verification methods, including test plans and documentation, to validate that implemented standards are properly integrated. Table 9 provides metrics to track progress toward the use of mature standards.

Table 9. Standards Maturity Metrics

Metric	Description	Target
Standards Maturity Rate	% of components using mature standards (TRL7+)	Program phase specific
Modular Software Interface	% of components with modular open interfaces	≥ 90%
Expert Engagement Freq	Number of consultations with standards bodies	Review Quarterly
Verification Coverage	% of standards with defined verification methods	100%

Tracking standards maturity metrics helps PMs and CSEs measure the extent and effectiveness of standards adoption, verify that interfaces remain modular and open, and demonstrate compliance with acquisition and MOSA objectives.

Consideration 4: Adopt Modern Design Principles (Agile)

For SW-intensive programs, Agile and DevSecOps practices enable accelerated software delivery, improving responsiveness to changing mission needs and ensuring that capabilities are continuously validated with the warfighter. By leveraging continuous integration/continuous deployment (CI/CD) pipelines, automated testing, and real-time user engagement, programs can transition from long, document-driven development cycles to iterative, model-informed, and feedback-driven workflows. The key elements for effective integration include the infrastructure and resources that support:

- CI/CD pipelines for rapid and iterative development, ensuring software updates are deployed frequently and reliably.
- Automated testing to accelerate verification, reduce integration risk, and enable early detection of defects.
- Virtual prototyping (as required) to evaluate system configurations and performance in digital environments, especially for hardware-centric or embedded systems.
- Continuous user feedback to validate Minimum Viable Products (MVPs), prioritize features, and guide Agile sprints toward operationally relevant outcomes.

Tracking Agile and DevSecOps metrics provides PMs and CSEs with quantitative insight into the effectiveness of these practices. As artificial intelligence (AI) tools mature they can provide efficient methods to enhance DevSecOps practices. High CI/CD use, automated testing coverage, and short feedback cycles indicate that a program is positioned to deliver resilient, adaptable capabilities at the speed of relevance.

Table 10. Agile and DevOps Metrics

Metric	Description	Recommended Target
CI/CD Pipeline Utilization	% of software modules deployed via CI/CD	100%
Automated Test Coverage	% of test cases automated	≥ 85%
User Feedback Loop	Avg. time from user input to implementation	≤ 3 sprints
MVP Validation Rate	% of MVPs validated by end users	100%
System Delivery Rate	Percent of system capabilities delivered vs planned	>90%

Conclusion

Implementing modern SE principles within the Software Acquisition pathway accelerates the delivery of mission-ready software (embedded and applications based) capabilities to the warfighter. The SEMOD initiative is intended to accelerate digital transformation into SE workflows, reviews, and practices. The SEMOD considerations and metrics outlined in this paper provide a structured approach for managing and assessing progress toward a digital transformation while promoting data-informed decisions and guiding continuous improvement.

Each program's adoption will vary based on risk tolerance, funding, and workforce availability, focusing on the considerations presented including digital workforce development, workflow modernization, MOSA implementation and using modern design principles. By implementing these practices, programs position themselves to adapt rapidly to evolving mission needs, reduce lifecycle costs, and foster a culture of innovation. Even partial implementation yields meaningful benefits, while full integration of these principles enables the Department to realize the promise of truly digital, Agile, and resilient software acquisition.

Program metrics should align with the value proposition that reflects the organizational business goals. The metrics should provide a balanced approach that assesses value either in terms of a schedule reduction or defect reduction that ultimately saves costs. As the role of artificial intelligence tools continue to mature, it's role in managing DEVSECOPS, the CI/CD pipeline and other import elements of the digital ecosystem will be integrated into the digital workforce skills and tools.

Additional information on SEMOD, MOSA, SW modernization, Digital Workforce Training and Agile practices can be found at the following websites: Digital Engineering Body of Knowledge (https://de-bok.org/); USDR&E (https://www.cto.mil/sea/) , Systems Engineering Research Center (https://sercuarc.org/) and the Warfighting Acquisition University ICatalog Home Page - https://icatalog.dau.edu/.