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WRT-1051

PROGRAM MANAGERS GUIDE TO DIGITAL AND AGILE SYSTEMS ENGINEERING PROCESS TRANSFORMATION

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Disclaimer

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EXECUTIVE SUMMARY

This report presents the results of the first phase of research on research task WRT-1051: Program Managers Guide to Digital and Agile Systems Engineering Process Transformation. This research task feeds into a companion research task, WRT-1058: Systems Engineering Modernization Policy, Practice, and Workforce Roadmaps. Together these support a larger set of activities being led by OUSD/RE under the term “Systems Engineering Modernization” (SEMOD). The motivation for SEMOD stems from the need to integrate across independent guidance provided down to the DoD SE and acquisition communities related to Digital Engineering, Modular Open Systems Approach, Mission Engineering, and Software Engineering/Agile/Devops across the multiple pathways of the Adaptive Acquisition Framework. The SERC/government research team found *there is a lack of an integrated approach to implementation of SE Focus Areas that is creating a delay in full implementation of the Digital Transformation which is necessary to ensure the relevant guidance, skills, and training are available to deliver a robust, disciplined approach to weapon systems acquisition*.

The SERC has been tasked with three research threads in this research:

1. Policy and Guidance: review existing SE related policy and guidance, align and integrate to selected acquisition pathways, and develop recommended modifications.

2. SEMOD Framework: create an integrating framework that incorporate the key activities in each domain and generate options for program implementation.

3. SEMOD Roadmaps: Develop a set of related artifacts for an initial categorization and information framework and develop the meta data for a body of knowledge.

Research in each of these areas was partially completed in this effort and will be iterated upon in WRT-1058. Primary findings of this report include:

- SE Modernization responds to the ongoing digital transformation of DoD acquisition and sustainment activities which have traditionally followed rigorous systems engineering processes. The systems engineering processes remain valid, but the practices need to change to take advantage of the digital transformation. The transformation is guided by the DoD Digital Engineering strategy as an "*an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal*."[1] We derived a primary value statement from digital transformation as “**seamless and efficient transformation of data and models into views in order to visualize, communicate, and deliver data, information, and knowledge to stakeholders**.” To date DoD DE efforts have been more focused on the creation of authoritative sources of data and models than the value achieved by digitizing the

[1] DoD Digital Engineering Strategy, 2018.

underlying transformations. This is creating slow uptake of modernized systems engineering capabilities and processes in DoD program offices.

- DoD policy and guidance as related to the four focus areas, systems engineering and engineering of defense systems, and the six Adaptive Acquisition pathways[2] is poorly integrated. Current policy and guidance suffer from independent terminology and jargon across each focus area and acquisition pathway. Current policy and guidance provide only limited communication of the intent of the digital transformation. In addition, current policy and guidance remain highly milestone driven, overly focused on new development, and lack focus on update and sustainment - despite DoD calls for more continuous and rapid deployment of capabilities. Finally, the vision in the DoD Data Strategy of “a data-centric organization that uses data at speed and scale for operational advantage and increased efficiency” is not sufficiently captured into engineering policy and guidance.[3]

- As a result, the systems engineering and related acquisition guidance, as well as much of the systems engineering professional community guidance, continues to operate with a mental model of linear, milestone driven technical and management processes as determined by static, often document based artifacts. The culture is proving difficult to overcome in the DoD and defense industrial base. In this research we developed and have been promoting a new mental model of a systems lifecycle that is continuously iterated and layered from data to models to decision artifacts. This mental model helped to organize a much more focused set of SEMOD pain points which can be used to define change modernization roadmaps. The model also clearly defines the need for standardized reference implementations of these data transformation layers to generate the necessary lessons learned to accelerate uptake of the transformation.

- This report proposes the need for and actions that should be taken to establish such an exemplar reference architecture.

The organization of this report starts with the question “Why Modernize” and summarizes the intent of the four focus areas. Next, we describe the SEMOD integration framework and present the revised mental model and its derivation. This is followed by the recommended reference implementation.

Following this the report summarizes several analyses that centered on current policy and guidance to initiate an SEMOD body of knowledge. This was combined with several workshops targeted at collecting state of the practice and future needs from a broad cross-section of government and industry. These activities resulted in a detailed set of pain points that integrate across policy, guidance, and implementation.

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[2] DoD Instruction 5000.2, Operation of The Adaptive Acquisition Framework, 2020.
[3] DoD Data Strategy, 2020.

1. Task Summary

There is a need to develop Systems Engineering (SE) Guidance for Program Managers that address the correct toolkit (methods, processes, and tools) inclusive of priorities pertaining to Digital Engineering, Agile Methods, Modular Open Systems Approach (MOSA), Mission Engineering, Modeling and Simulation, and other relevant methodologies. These approaches need to be aligned with current DoD digital transformation strategies. Program managers today are facing a myriad of acquisition process changes centered on the need for more rapid deployment of capabilities, better weapon system portfolio management, and efficiencies created through digital transformation. There is a need for documentation of lessons learned, program best practices, and standard guidance for program Systems Engineering that incorporates a holistic approach inclusive of a combination of SE Modernization Focus Areas. In addition, recent updates to DoD 5000 lifecycle guidance identified six acquisition pathways that will require different approaches to program SE activities and associated guidance. The research goals for this task include:

1. Create an integrating framework that incorporates the key activities in each domain and generate options for a management and process structure for program implementation. This framework is expected to define the information flows between related program guidance and SE activities. The framework will include a metamodel of these information flows.
2. Provide recommendations for implementation of a digital environment and descriptive modeling practices across these guidance areas consistent with the DoD's digital transformation initiatives.
3. Develop an initial set of related artifacts (policies, instructions and guidance, plans, lessons learned, interview narratives, technical data, etc.) that can be used to build an initial categorization and information framework and accessible body of knowledge.
4. Provide outreach to government acquisition leads, program offices, science and technology organizations, and other entities related to SE modernization.

2. PROBLEM STATEMENT

Modern systems engineering (SE) evolved in the 1940's through 1960's as an approach to manage both technical and programmatic risk in large complex systems. Systems engineering principles and methods were adopted by the DoD in the late 1960's/early 1970's as a way to manage technical and programmatic development and risk across the engineering and management components of large complex weapon systems. When the first iteration of DoD 5000.01 "The Defense Acquisition System" was published in 1971, it defined a systems engineering related set of guidance, including consideration for problem/operational needs, alternatives, test and evaluation, and support and update as well as contracting, risk, source selection, and documentation. SE has been a foundation of DoD acquisition policy since it was formally defined as a system itself.

WHY SE MODERNIZATION?

The discipline and its use in DoD acquisition has long been associated with realization of physical systems and related equipment. Today many defense capabilities are not only physical; they are software intensive, highly connected, and have extensive automation and user configuration capabilities. Software engineering became a discipline in 1967, manufacturing automation (the third industrial revolution) began in the 1970's, and the World-Wide-Web was invented in 1989. The DoD's Defense Modeling and Simulation Office was opened in the early 1990's and large-scale networked simulation of defense systems followed. All of these have continued to evolve the SE discipline, not as a whole, but as a set of related subdisciplines (software systems engineering, information technology and enterprise architecture, distributed modeling & simulation, and automated manufacturing systems).

Following successful evolution of the Unified Modeling Language (UML) in the software discipline, the Systems Modeling Language (SysML) was published in 2007 and started the growth in Model-Based Systems Engineering (MBSE) as an improved approach to manage technical and programmatic risk. "Industry 4.0" originated in 2011 and introduced the concept of a "digital twin" as a non-physical product realization. The DoD's Digital Engineering (DE) Strategy was published in 2018, ushering in the vision of a digital era of systems engineering. As the International Council on Systems Engineering noted in their Vision 2035 document: "The future of Systems Engineering is Model Based, leveraging next generation modeling, simulation and visualization environments powered by the global digital transformation, to specify, analyze, design, and verify systems."

Throughout all of this change, the "mainstay" of systems engineering in the DoD, and associated DoD acquisition guidance, has continued to center on physical realization of large-scale monolithic systems and other critical capabilities intended to persist for many years. The need for rigorous definition, analysis and test of these critical systems will always exist, but the time has come to reintegrate the systems engineering subdisciplines into a common framework that responds to the digital age.

SE MODERNIZATION FOCUS AREAS

The SERC was funded by the DoD to conceptualize and build an integration framework for SE Modernization as applied to all DoD acquisition life cycles. The DoD published its latest 5000 series guidance, "The Adaptive Acquisition Framework" in 2021. The AAF recognized new development and acquisition pathways for software, IT and business systems, services, and a streamlined "middle tier" acquisition for more mature rapidly fielded systems. This followed a series of legislative directions to the DoD around four focus areas for SE Modernization as defined below:

1. **Digital Engineering (DE)** – Defined in the DoD DE Strategy as "an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal." As directed in DoD policy, "DE will provide for the development, validation, use, curation, and maintenance of technically accurate digital systems, models of systems, subsystems, and their components, at the appropriate level of fidelity to ensure that test activities adequately simulate the environment in which a system will be deployed."

2. **Modular Open Systems Approach (MOSA)** – Defined in DoD policy as "an acquisition and design strategy consisting of a technical architecture that adopts open standards and supports a modular, loosely coupled and highly cohesive system structure." This modular open architecture includes publishing of key interfaces within the system and relevant design disclosure. MOSA introduces the 'build for change, not to last' philosophy from software architecture across all aspects of DoD systems.

3. **Mission Engineering (ME)** – Defined in DoD guidance as "the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired mission effects. Mission Engineering is intended to provide engineered mission-based outputs to the requirements process, guide prototypes, provide design options, and inform investment decisions."

4. **Agile Development** – Defined in DoD guidance as "approaches based on iterative development, frequent inspection and adaptation, and incremental deliveries, in which requirements and solutions evolve through collaboration in cross-functional teams and through continuous stakeholder feedback. Agile approaches begin not with detailed requirements, but with a high-level capture of business and technical needs that provides enough information to define the software solution space, while also considering associated quality needs (such as security)."

These four focus areas can be viewed as a layered model with data at the core, as shown in Figure 1. At the center, as envisioned by the DoD Digital Engineering strategy, is shared and authoritatively managed data. Modernization of systems engineering strives for seamless interoperability and integration of all engineering and management disciplines using authoritative sources of system data and models as the continuum that links the disciplines.

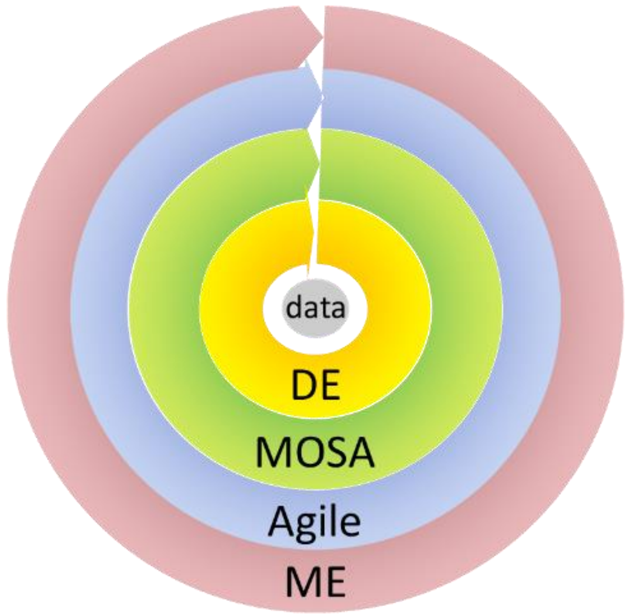

Figure 1. Four focus areas as a layered model.

The SERC's SE Modernization project has three primary goals: build an integrating framework that incorporates key activities across these domains and focus areas; align and integrate these systems engineering practices to specific acquisition pathways; and develop a set of artifacts and associated meta-data for a categorization and information framework that captures policy, guidance, and lessons learned into a body of knowledge.

3. SE MODERNIZATION – INTEGRATION FRAMEWORK

Task: Create an integrating framework that incorporates the key activities in each domain and generate options for a management and process structure for program implementation. This framework is expected to define the information flows between related program guidance and SE activities. The framework will include a metamodel of these information flows.

At the core of this integration framework is "shared and authoritatively managed data" that can be transformed through various models and tools to create Digital Artifacts. These artifacts are used by various decision makers (in development) and others needing digital access to the design and descriptions of the system across its life cycle. In early years these artifacts were almost always paper documents or drawings, now they are mostly based on digital technologies but far from "seamlessly integrated and interoperable." The cartoon in Figure 2 might best describe the current state of digital artifact development.

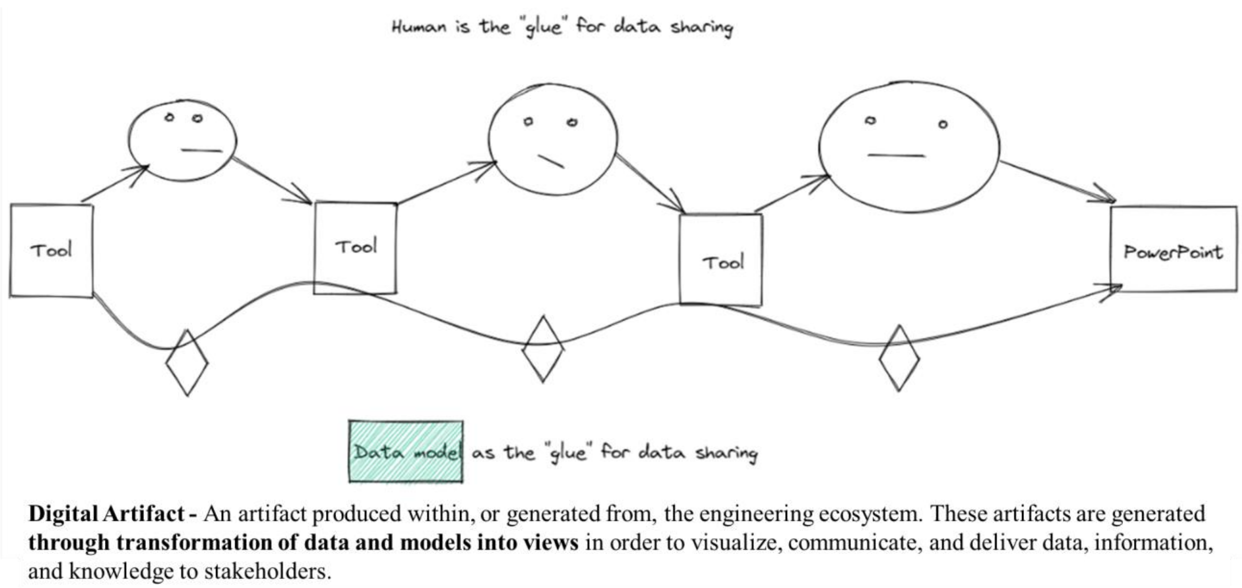

Figure 2. Data Transformation Mental Model.

Systems engineers have long used digital data and various modeling and analysis tools to produce digital artifacts for decision-making. However, the underlying data model has not been "seamlessly shared" and authority for that data has been distributed across independent activities, generally organized by discipline. Much of the "transformation" is still manual interpretation of disparate data and analyses. One might describe the current state of systems engineering as seeing the whole while looking through a set of soda straws. We desire a fully integrated workflow. Today's primary challenge in digital engineering is not so much being "model-based," it is understanding and creating this underlying data model.

Systems engineering and related acquisition processes can be visualized as a set of data transformations from sources of truth that produce artifacts for human consumption – across all stages of a system life cycle.

In Figure 3 we redraw the widely depicted Learn->Build->Measure (Define->Realize->Deploy & Use) stages of the SE Lifecycle in a circular process to represent it as a:

1) set of data transformations at the core;
2) layered across disciplines & tasks;
3) in continuous processes that could be entered from any point.

In the SE process data is transformed through models into views, which support analyses leading to decisions. These transformations have traditionally produced decision artifacts that were disconnected from the underlying data and models, captured in independent static document or presentation forms. Digital artifacts may still be documents or presentable views but should remain digitally connected to the underlying data and models.

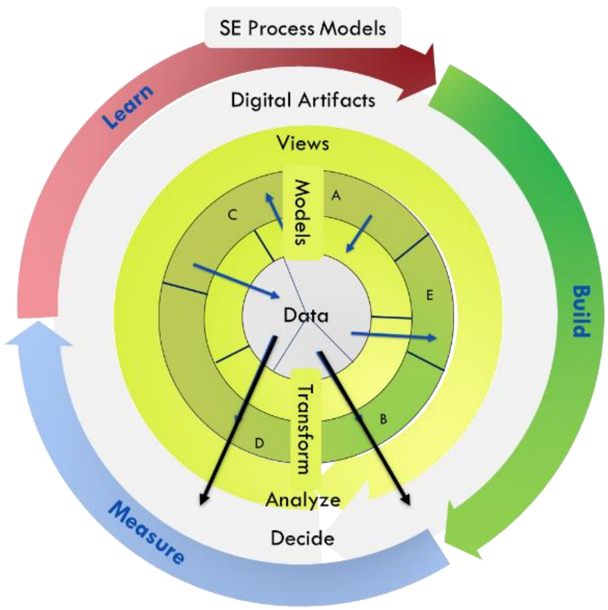

Figure 3. Circular Processes with Data at the Core.

SE lifecycle processes as defined by ISO/IEC/IEEE 15288 do not define a specific ordering of process areas, but much of the literature and existing mental models imply a process ordering that is entered in the learn or define stages. SE lifecycle processes have been used not just in critical systems where up-front system definition and learning are essential, but also in system innovation, prototyping, and incremental definition activities where build-first is the pathway to learning; and in sustainment life cycles where deployed system measurement and learning should define the next build. This SEMOD circular mental model better recognizes that SE can be applied to any life cycle in any type of system.

The DoD published the Adaptive Acquisition Framework (AAF) in 2019. Between 2019 and 2021, the AAF recognized new development and acquisition pathways for software, IT and business systems, services, and a streamlined "middle tier" acquisition for more mature rapidly fielded systems. In the AAF, the Major Capability Acquisition pathway continues the traditional use of upfront SE rigor but the Urgent Capability, Middle Tier, Software Acquisition pathways promote abbreviated definition phase and rapid learning through builds. The challenge of SE Modernization is to maintain appropriate SE rigor and associated process definition in these other pathways. SE rigor is maintained using the data – transform – analyze – decide flow of Figure 3 at all stages of the development.

The workflow view in Figure 4 shows conceptually how shared and authoritatively managed data is transformed into digital artifacts in different life cycle stages in any pathway. This linear workflow model is familiar and comfortable to system engineers but does not represent the fact that these data transformations into and out of the shared and authoritatively managed data actually happen continuously and recursively across a life cycle. Increasing speed to the warfighter (or market) does not mean eliminating these critical SE processes, just increasing the number of iterations and shortening the cycle time between them.

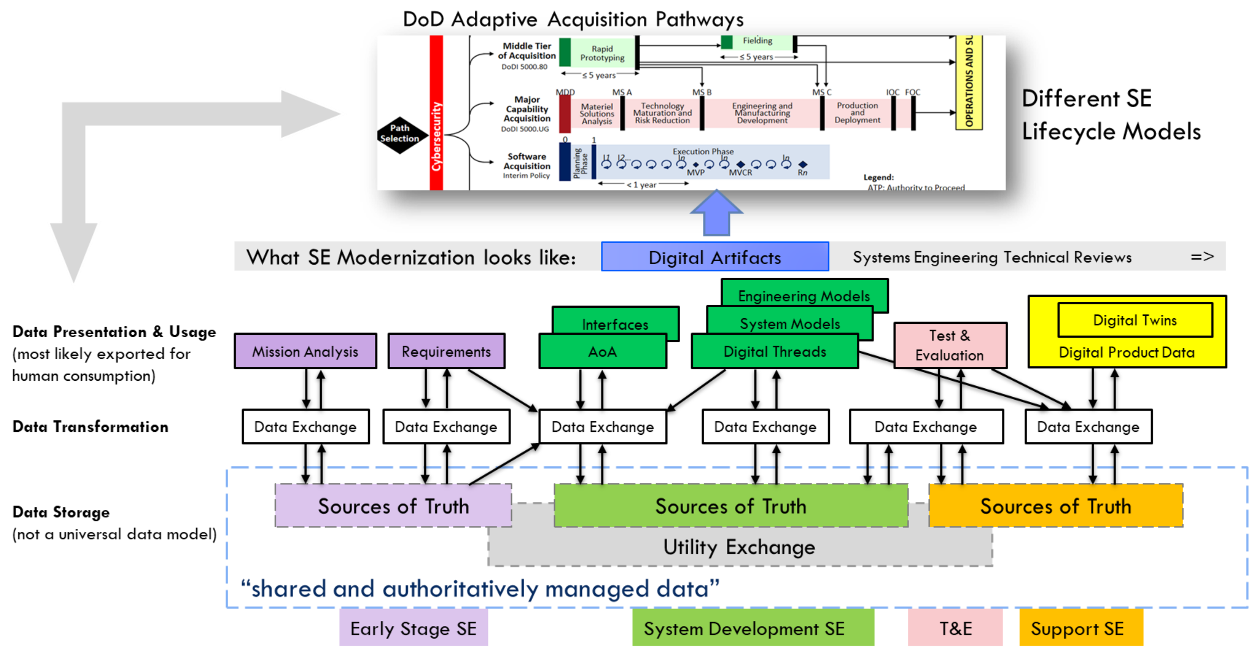

Figure 4. Data Transformation into the Life Cycle.

As the team developed the integration framework, we came to realize first that existing SE mostly linear lifecycle mental model depictions like the "Vee" model and the DoD's "Defense Acquisition Wall Chart" do not promote the future vision of data and models at the core of SE. Secondly, since future systems will be "built for change" using concepts of continuous iterative development, do the somewhat linear models of existing SE lifecycle representations still adequately guide us? In response, the team shifted to developing a new conceptual view of the full SE Modernization Lifecycle, shown in Figure 5. This view is complex, but with study it becomes insightful in several ways.

First, it illustrates systems engineering as a cyclic approach, rather than a linear one. Although almost all literature attempting to standardize on a lifecycle model will say that activities are ongoing and should continue through the lifecycle, the circular illustration drives this point home more visually and directly.

Second, this integration framework makes the digital transformation clear using a layered model with data storage and transformation at the core, models as the data transformation layer, and systems engineering process areas as the outer layers.

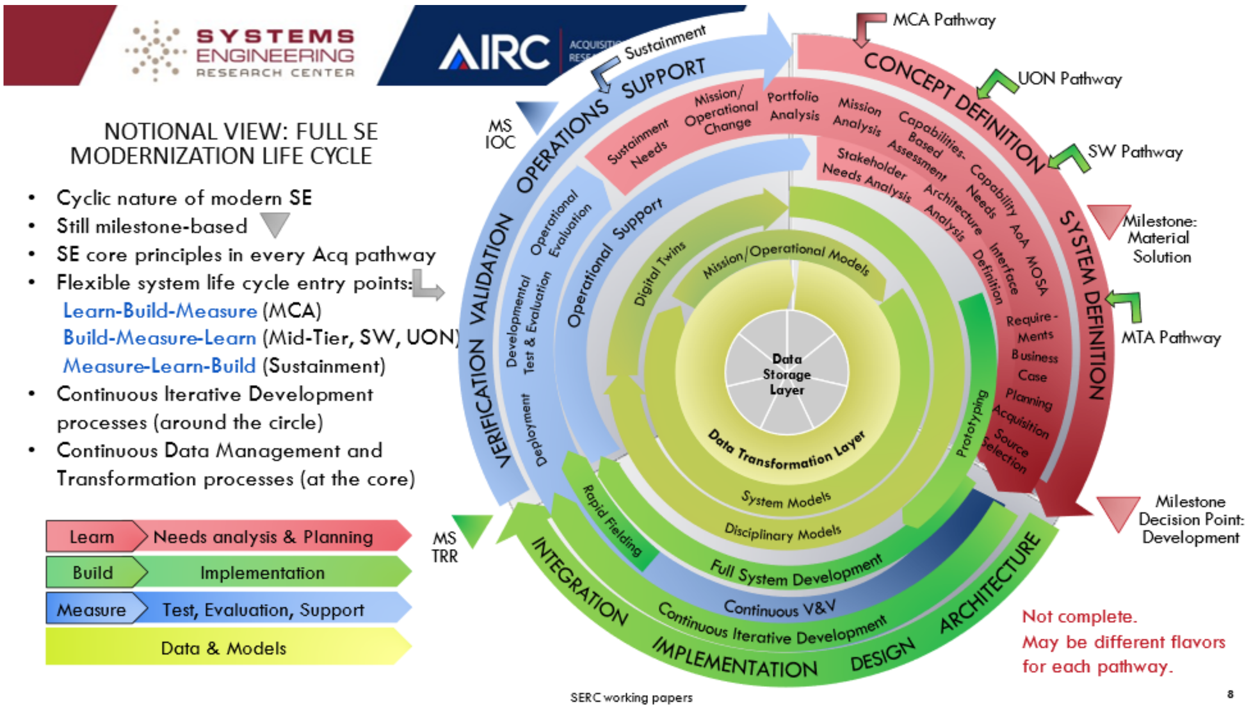

Figure 5. Full Integration Framework.

Finally, it organizes the colors of the outer ring and related SE process in the "Build/Measure/Learn" context, capturing the underlying goal of continuous iterative development.

The integration framework depicted here incorporates traditional DoD acquisition milestones (triangles). However, it highlights them in the context of the multi-faceted work going on and where they fall within the broader context. It highlights the different DoD acquisition pathways and associate SE process instantiations. These fundamentally begin at different points in the system life cycle but should still follow a rigorous SE process model.

The SE Modernization Lifecycle is still a work in progress and will continue to iterate as the WRT-1058 project proceeds. This view is an attempt to capture everything in one mental model. It will be tailored and redrawn based on differing types of development, delivery, and support processes. As the WRT-1058 project proceeds, we will use this conceptualization to organize guidance and lessons learned. SE Modernization will be a lengthy multi-year process. This is our attempt to define how modernization might evolve.

4. Recommended Reference Implementation

The DoD's future of genuinely integrated digital engineering modernization will depend heavily on establishing managed authoritative high-confidence data sources, typically known as authoritative sources of system data and models, and the means to have it used throughout the enterprise. Collaboration between DoD contractors, government, and academia requires establishing high assurance interfaces between multiple applications in a digital engineering ecosystem. These interfaces use known, standards-based data exchange mechanisms, not peer-to-peer proprietary vendor interfaces. This initiative requires establishing an exemplar reference implementation (ERI) for such an ecosystem producing a physical, digital engineering environment to mature data standards, establishing data exchange methodologies between applications, and baselining the needed interface capabilities. The ERI initiative demonstrates digital engineering capabilities and technology to transition to service program offices as adaptable technology supporting and formalizing the development and integration of models for enterprise and program decision making. The ERI can capture and retain digital engineering artifacts using shared semantic data models (ontologies) between applications using data exchange, product control, operational configuration, and traditional document production. The ERI implements digital engineering practices and policies, providing a consistent, coherent, and controlled environment that is context-independent, scalable, and federated.

Actions Required for Establishing an ERI

Establishing an ERI is more than acquiring applications, hosting them on a server in a series of virtual machines with users interacting with the particular applications, and then performing extract-transform-load (ETL) operations to process non-integrated digital artifacts. Establishing an ERI requires understanding the ontology of the digital artifact data, digitalizing those relationships, and creating the appropriate data exchange mechanisms with configuration management supporting and accelerating accepted workflows. As shown in Figure 6, the relationships between the sources of managed authoritative data have a data exchange infrastructure working with the federated data storage supporting a data presentation layer for user consumption and control. Applications at the presentation layer can be a variety of applications familiar to the user.

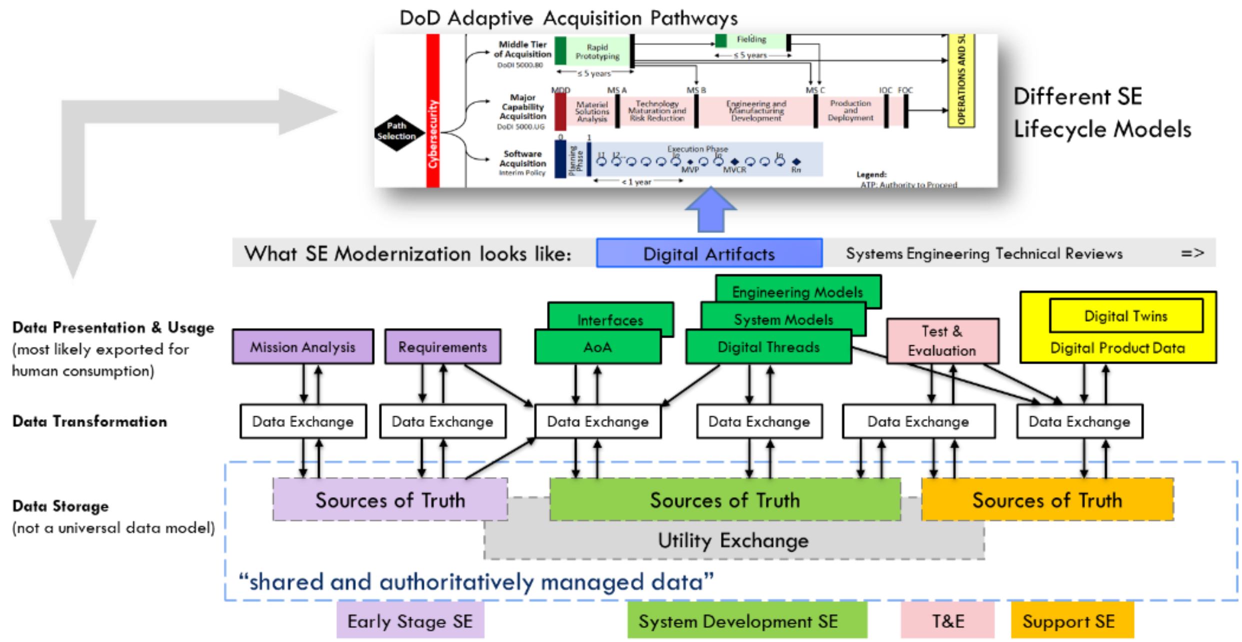

Figure 6. Use of Data Exchange in a Digital Engineering Environment

UNDERSTANDING WHAT CONSTITUTES THE DIGITAL ENGINEERING ECOSYSTEM (DEE)

According to the DoD Digital Engineering Strategy [1], the need for model integration was well known, as shown in Figure 7. In consideration to this figure, the following definition expanded integrated digital engineering as "An integrated approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal." [2] This strategy can scale from a single subsystem to developing entire weapons platforms. The key to executing a digital engineering strategy is having digital artifacts for each step of the lifecycle and with authoritative sources of system data and models to create the digital artifacts produced or queried in each step. Digital artifacts include system models, design models, analysis models, management models such as risk models, verification and validation models, and cost and budget models. Multiple applications are available for each of these model sets, as well as tools to integrate the models and visualize the digital thread across the full scope of the project. Figure 8 shows various digital engineering elements for a notional ecosystem.

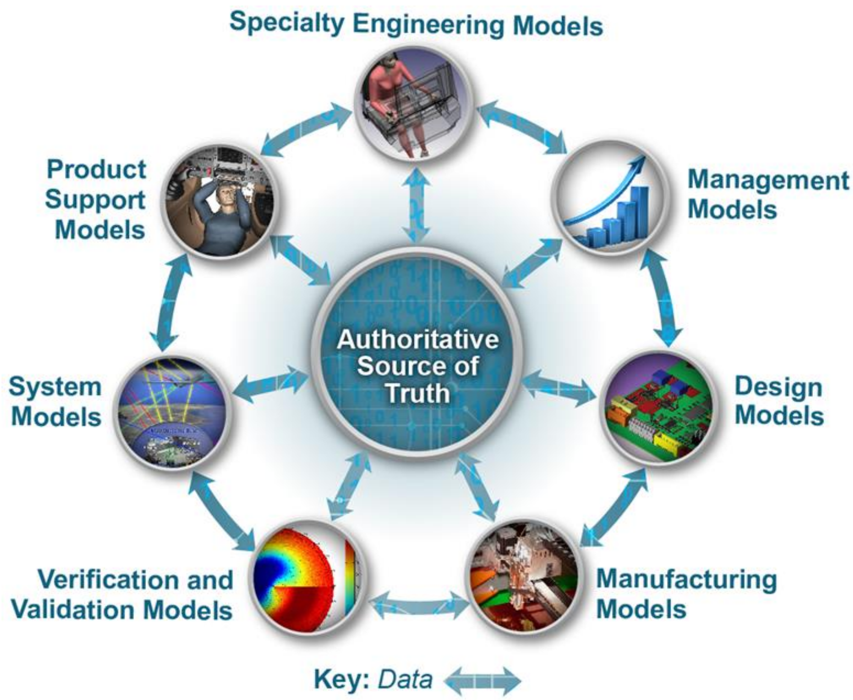

Figure 7. Models as the cohesive element across a system's lifecycle.

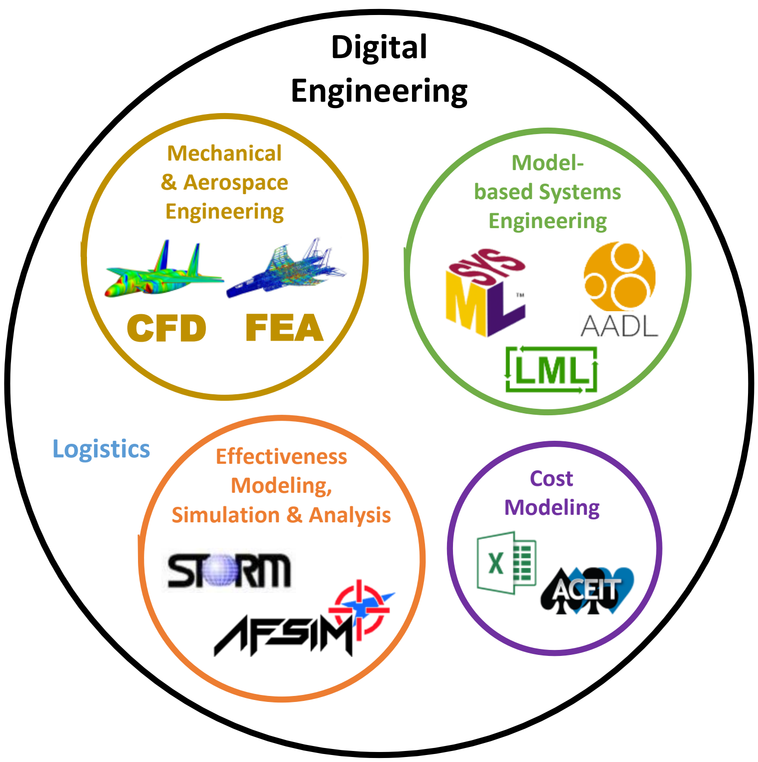

Figure 8. High-level Digital Engineering elements (with examples) for a notional ecosystem.

Nominal Applications in a DEE

Figure 9 indicates nominal applications expected for each activity area. This figure is extended from one presented by MITRE at NDIA [3]. Note that the acronym "ASoT[4]" in the older diagram is present but we no longer use it in the integration framework. The purpose of Figure 9 is not an exhaustive list—as other applications could be included—but does illustrate each relationship with the authoritative sources of system data and models. These relationships will be the data exchanges between the applications and the authoritative sources of system data and models.

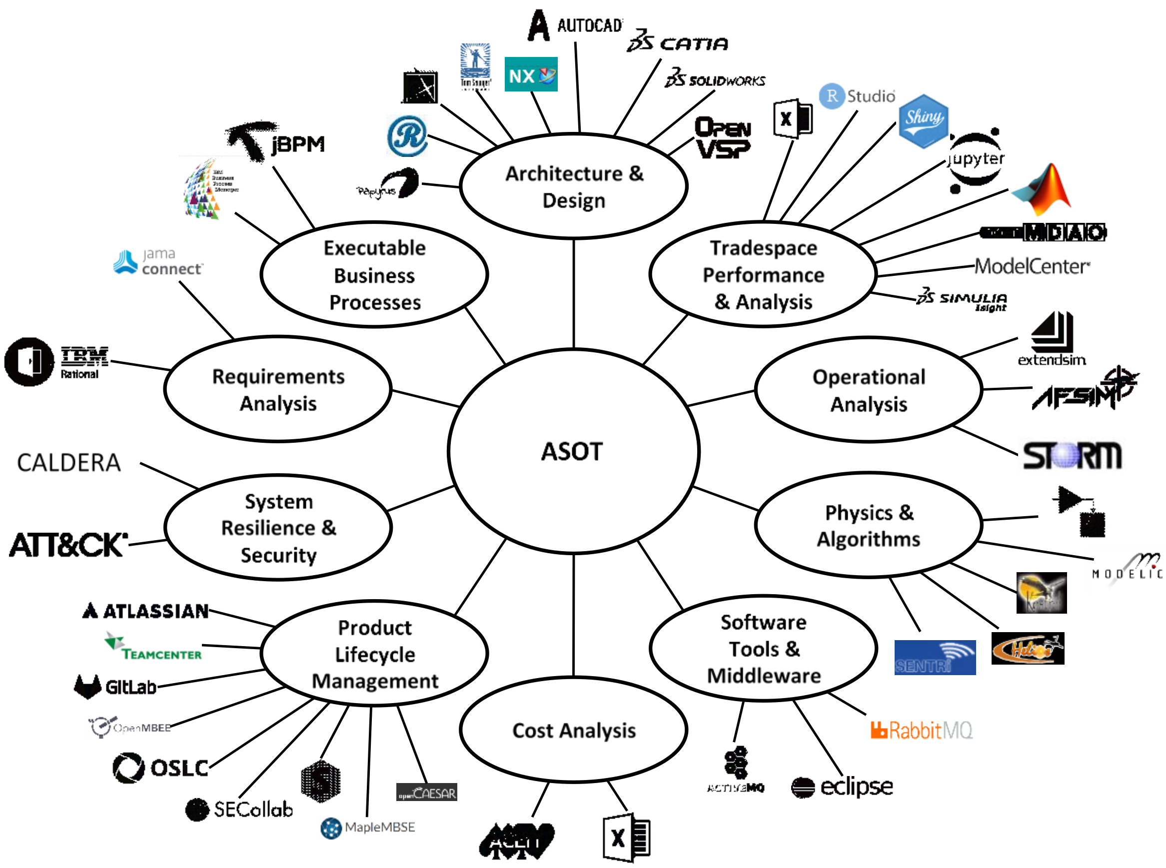

Figure 9. Digital Engineering Toolchain Components.

Digital Engineering Data Exchange

Applications within the lifecycle provide modeling, simulation, analysis, and data presentation. Collectively, these applications exist within the ecosystem but lack the

[4] Authoritative Source of Truth (ASoT). A term that does not have a clear, consistent, or coherent definition and use. ASoT is now deprecated. The correct phrase is, "authoritative sources of system data and models."

data exchange interoperability to improve the decision-making speed and accuracy. Interoperability requires an infrastructure for exchanging data between applications with the application's unique data storage needs. Applications typically do not share information or work interactively with other applications. Each application was independently developed to be standalone or work with a vendor's application suite but not with other vendors. In the current application market, vendors have been motivated to provide interfaces that benefit the vendor's application (i.e., increase that vendor's market share). Some efforts have been nominally successful in creating a vendor consortium for interfaces[5], but the entry into the consortium is through vendor contributions. Applications used in systems engineering today lack a modular open systems approach (MOSA) for data exchange between vendor applications, and, in fact, there are no significant ongoing efforts to address this. The ERI will achieve the MOSA attributes and provide solutions to meet data exchange challenges. Establishing links between digital engineering applications is crucial, creating a digital engineering ecosystem that transforms digital artifacts and provides data exchange mechanisms flowing these artifacts from one application to another.

Data exchange between applications is technically a set of collaborative REST[6] APIs for query and response. While this is the open system method, it is insufficient to create the necessary digital threads for data flow between functional organizations and applications. An ERI is mandatory for determining and demonstrating data relationships in a flow of digital artifacts. The ERI will be a development environment. It has an orchestrator for transforming data by creating queries requesting the correct data from the application using the REST API and ensuring that the resulting data flow to a receiving application in the form and rate needed. An ERI will use a publish-subscribe (i.e., Pub-Sub) messaging pattern. Ideally, the ERI Pub-Sub server is hosted as a service accessible to all applications on the network (i.e., cloud-based). An ERI will have a data modification language to perform the required data transformations from a parent data source to one or more child receivers. There are simple, known data transformations that can be immediately used, but no "out of the box" set of data transformations directly implementing complex workflow data transformations for the DoD infrastructure and environments for engineering, acquisition, test, logistics, and financial activities. The ERI creates the required functionally correct digital threads of digital artifacts, with data exchanges performed on data sets under configuration management for collaboration and communication across stakeholders.

[5] Open Services for Lifecycle Collaboration, OSLC, https://open-services.net/

[6] Representational state transfer (REST) is a software architectural style describing a uniform interface between decoupled components in an Internet Client-Server architecture. REST defines four interface constraints: a)Identification of resources, b)Manipulation of resources, c)Self-descriptive messages, and d)hypermedia as the engine of application state (Roy T. Fielding from his dissertation)

ENGAGING IN THE ERI INITIATIVE

The ERI addresses a number of the "pain points"[7] that are identified later in this report. These fall into two primary categories: “Need agreement on means to share data and models” and “stovepiped. Unintegrated tool flows.” Table 1 details some of the capabilities needed to improve ability to share data or models either with other organizations or other functional groups. Table 2 details the some of the capabilities needed to address stovepiped, unintegrated data flows – addressing functional organizations that do not have access to, or do not use, data sharing or integrated applications. The ERI will be used to develop processes and procedures addressing the need to transform the culture and workforce to adopt and support exchange of authoritative sources of system data and models across the lifecycle. This is crucial. No matter what applications, data exchange, and supporting DEE integrations are built, if personnel do not understand the need and how their job depends on using the ERI in their workflow, they will not use it. The ERI would help to define and standardize data and model exchange practices as they pertain to the workflow of each functional area, and also how the data exchange needs to be crafted so that digital artifacts flow in workflows, along the digital threads, in the DEE. The ERI would also support accelerated development of tool solutions using standardized approaches to address use cases that are developed in its implementations.

Figure 10 provides an OV-1 view of the proposed ERI. Note that the primary focus of this diagram is the data exchange mechanisms between the different functional areas, processes, and disciplines in a typical large program, each of which will still likely be operating with their own models.

[7] A persistent or recurring problem with a product or service that frequently inconveniences or annoys customers

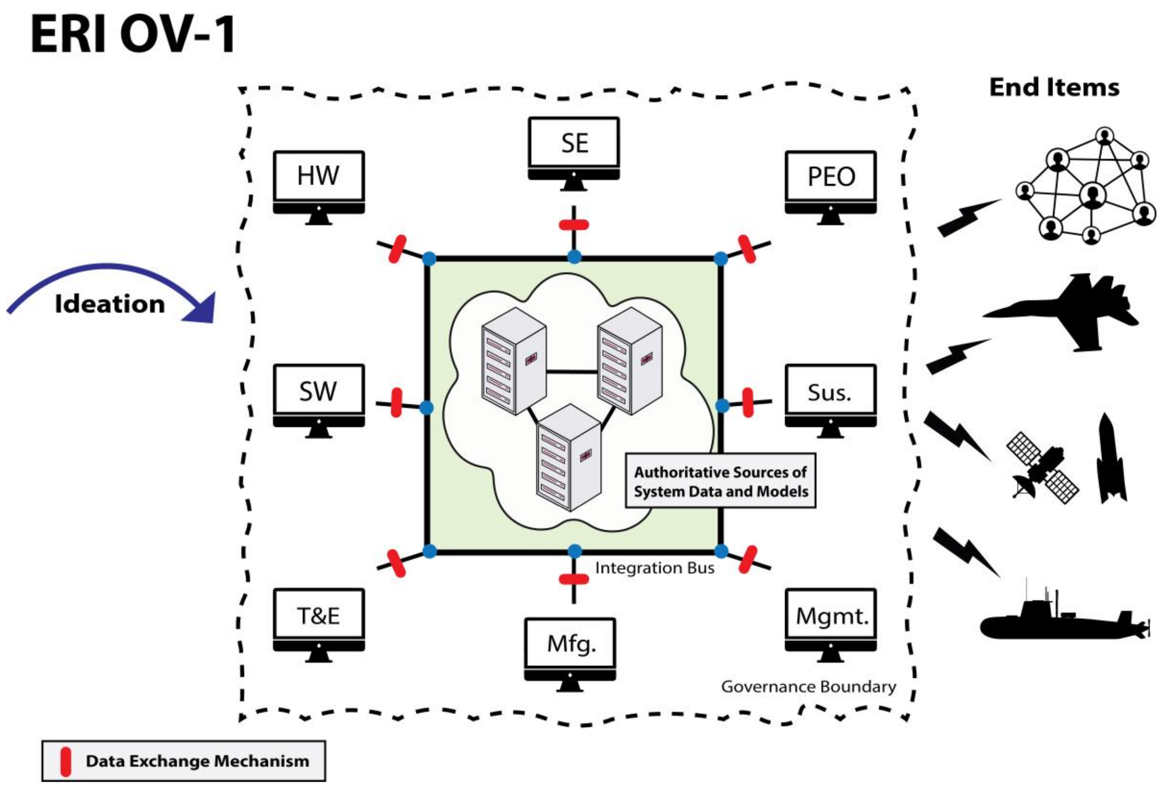

Figure 10. ERI OV-1.

Table 1. Means to Share Data.

Major Category	**Capability Needed**
Means to share data and models	1. A "Seamless and efficient" ability to easily drill down from review artifacts to models to data, tools and methods with the ability to easily view/extract data at different levels
	2. Guidance and lessons learned on the appropriate fidelity of models for different decision processes
	3. Guidance and lessons learned on how to collaborate around models and data
	4. A means to efficiently drill down from decision artifacts to models to data (a modernized technical review process)
	5. Effective configuration management processes
	6. Effective Intellectual Property and data protection processes
	7. Culture enablement to share data & models
	8. Policies that incentivize program managers and contractors to adopt new approaches
	9. Shared examples and lessons learned in management of data/model portfolios

Table 2. Unintegrated Tool Flows.

Major Category	Capability Needed
Stove piped, unintegrated application data flows	1. Improved methods and capabilities for managing data (today's focus is primarily modeling tools)
	2. Standard approaches to integrate data across various functional disciplines, particularly engineering and program management
	3. Improved connectivity and efficiency in integration of data and models from different functions
	4. Lessons learned and tool support to improve efficiency of converting from legacy tools and processes
	5. Developed, demonstrated, and shared approaches, workflows, and tool integrations
	6. Improved tool automation, particularly model-based test strategies
	7. A modular open systems approach enabling both the data/model infrastructure and the product data lifecycle

CYBER SECURITY AND SECURITY ENGINEERING

An often-overlooked pain point is the risk assessment and certification authority acceptance of risk. Security engineering is a functional organization that participates in all aspects of digital engineering and significantly impacts digital threads. The ERI provides the DEE with a practical cross-cutting, cyber security test bed for all portions of the engineering effort for acquisition and operations. The highest needs for security engineering that can be vetted in the DEE are:

- Security engineering involvement at the start of the acquisition effort—from Analysis of Alternatives (AoA) onward—helps the development of the digital artifacts for system requirements and Contract Data Requirements Lists (CDRLs) for contracts
- Developing a complete security system model for the end item that can be updated and controlled throughout the lifecycle
- Use this model as a true digital twin of the end item as the exact configuration and composition of an end item is the basis for performing security assessments. The most challenging document is the architectural analysis report, as the writer has to have intimate knowledge of the system being built (down to the bus communication protocols and authorization behaviors, e.g., can you write to the bus, can you read from the bus, etc.). Security engineering is looking for all that detail to properly assess vulnerabilities.
- Use of the Cyber Survivability Attributes (CSAs). Determining the requirements for resilience and security of the system and the DEE.

Security engineering depends on having authoritative sources of system data and models from a DEE. For example, security engineering uses a series of products for cyber security assessment, such as the Avionics Systems Susceptibility and Risk Analysis Toolkit (ASSURANT), which is used to create artifacts and reports on the system's conformance to security controls. ASSURANT has an output for a Security Assessment Report/Risk Assessment Report (SAR/RAR) for the NIST Risk Management Framework (RMF). By building a SysML model and having that input to ASSURANT, ASSURANT will output tables for input to an application that automates the RMF assessment of cyber and cyber-physical systems based on NIST SP 800-37 and security controls based on NIST SP 800-53 and assessment reports in accordance with NIST SP 800-53A. All of these are held in the authoritative sources of system data and models with the proper relations providing security control traceability to all digital artifacts for a system.

As the DoD pursues genuine digital engineering capability in collaboration with industry, the data exchange hurdles and interoperability constraints will most certainly need to be overcome. The establishment and iterative maturation of the ERI in a controlled environment will enable the Services to work in partnership with industry to deploy engineering ecosystems to program offices that provide high assurance, configuration-managed authoritative models for the future weapon systems and theatres. Through its iterative development, the ERI will facilitate proper governance boundaries for the environment to be usable by these program offices. Pursuing this environment definition will take time and should be now embarked upon to avoid the further divergence of today's complex environments and tool suites.

5. SE Modernization – Policy and Guidance Body of Knowledge

Task: Develop an initial set of related artifacts (policies, instructions and guidance, plans, lessons learned, interview narratives, technical data, etc.) that can be used to build an initial categorization and information framework and accessible body of knowledge.

Initial Data Collection by Focus Area

The policy review effort began by identifying major DoD policy documents for each focus area for inclusion into an SEMOD Body of Knowledge (SEModBoK). The team identified over 40 policy documents and guides related to the SEMOD focus areas across the DoD and services. These documents are listed in Appendix B, including short abstracts of their content. From this, the team determined which policy and guidance should be included and collected into an initial Body of Knowledge. We then developed metadata for each document for an initial SEModBoK prototype, an on-line BoK repository under development by the Sponsor. At the same time, the research team used various text analysis tools across the documents to identify possible threads and themes among the documents, and possible gaps as well. This also allowed the team to created key phrases and words to further Body of Knowledge development.

The meta data developed in this exercise is listed in Table 3. Metadata definition for the first SEModBoK iteration. Figure 11. SEModBok vision and strategy (sponsor diagram).describes the vision and strategy for an eventual SEModBoK tool hosted and maintained by the sponsor. A prototype of this tool was developed and demonstrated in association with this project, but future development and use will likely evolve into a different format.

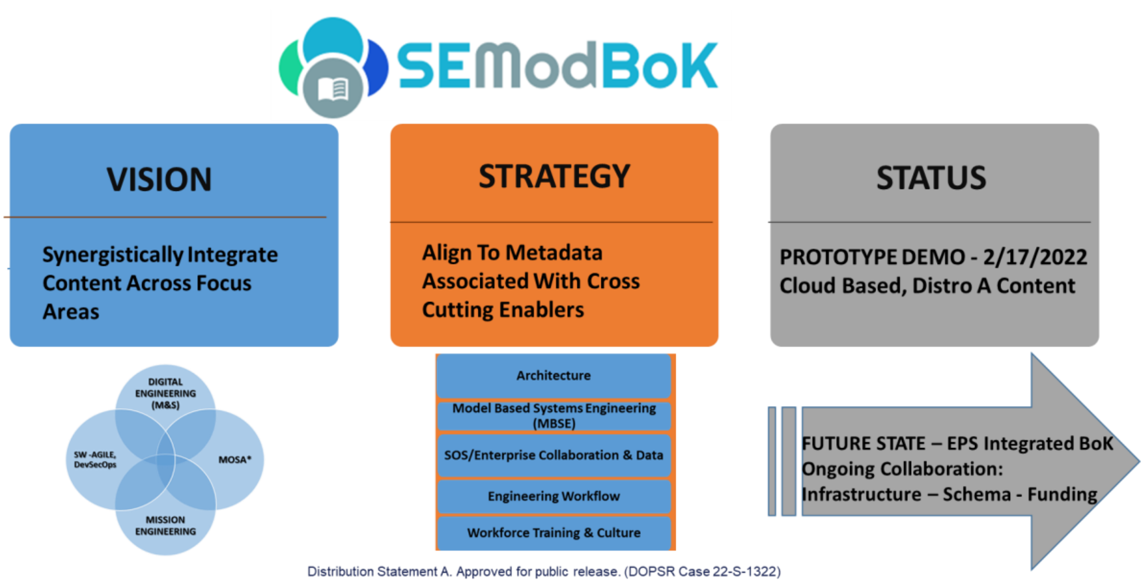

Figure 11. SEModBok vision and strategy (sponsor diagram).

Table 3. Metadata definition for the first SEModBoK iteration.

Resource	Title
Resource Abstract	Short publishable abstract
Resource Type	Policy, Guide, Circular, Report, Publication, Resource List, Platform
Focus area	Digital Engineering, MOSA, Mission Engineering, Software Engineering, Modeling & Simulation, Value Engineering
Cross-cutting enabler	Architecture, SoS/Enterprise collaboration, MBSE, Value engineering, Engineering workflow, Workforce culture
Topic	Accessibility, Acquisition system, Aerospace, Agile, Air Force, Analytics Architecture, Army, Artificial Intelligence, Automation, Best practices, Budgeting, Capital Assets, Continuing education, Contract Language, Cost estimating, Cost Funding, Cost reduction, Cost Scheduling, Complex systems, Culture, Cybersecurity, Data, Data Rights, Decision Making, Digital Acquisition, Digital Campaign, Digital Engineering, Earned Value Management, Gap Analysis, Human System Integration, Information sharing, IT/Software, Interoperability, Leadership, Life Cycle Management, Life Cycle sustainment, Logistics, Management, Manufacturing, Materials, Metrics, Middle Tier, Mission Engineering, Models, Model Based Systems Engineering, Modeling and Simulation, MOSA, Navy, Operations and Support, Planning, Policies, Procedures, Product Support Managers, Program Evaluation, Program Managers, Product Support Managers, Recommendations, Requirements, Risk, Scenarios, Services, Skills, Software, Specialty Engineering, Standards, Systems Architecture, Systems Engineering, Tools, training and development, Workforce, Value Management, Value Engineering, VV&A
Copyright	Public Domain, (at this time only public domain resources)
Source URL	Digital source reference link
Office of Prime Responsibility (OPR)	Responsible government office authority for the reference
Resource version effective date	Publication date
Resource version description	Effectivity

The initial vision of this project was to be able to derive an integration framework across the SEMOD focus areas and cross-cutting enablers in order to develop effective search strategies for programs to find lessons learned. At the start of the project the research team thought we may be able to derive the integration framework by searching and analyzing relationships across these focus areas, cross-cutting enablers, and topic. This proved to be unsuccessful but generated a number of lessons learned that drove the development of the integration framework.

SEMODBoK Metadata Lessons Learned

In the meta-data development process several students were tasked to independently discover the integration points between the four focus areas and SE guidance documents using different types of text analysis tools. This effort proved insightful but relatively unsuccessful. The effort proved that there was very little integration in common terminology and phrasing of guidance across each of these areas. One example student text clustering analysis which is presented in appendix C shows that there is very little cross-referencing from one focus area to another across the initial corpus of documents. A similar text analysis of the widely used Systems Engineering Body of Knowledge (SEBOK)[8] also showed little clustering around the intent of the focus areas, particularly associated with data strategy and digital model transformations.

As a second task, the students were asked to search for examples of typical systems engineering artifacts that were represented in the policy and guidance. These would be candidates for inclusion in both the lessons learned and possibly a program office's authoritative source of truth. Appendix D provides a student derived listing of candidate artifacts captured from the policy and guidance. However, the focus on end-item artifacts proved to be a dead-end with respect to SE Modernization. In general, the systems engineering process areas identified in both acquisition literature and SE literature and the typical decision and management artifacts generated in the process do not change in content, more in the generation process. This led to the mental model discussed previously in Figure 2.

INITIAL POLICY RESEARCH

The direct policy derivation from the focus areas to eventually SE Modernization guidance is shown in Figure 12. Policy Derivation to SE Guidance.. The four focus areas each derive from direction published in different annual National Defense Authorization Acts (NDAA). Of the four focus areas, only MOSA requirements have been codified in Title 10 of the US Code, they others have been taken directly into various acquisition policies and guides. They derive authority through DoD Directives 5000.01 and 5000.02 and are applied through DOD Instruction 5000.88 Engineering of Defense Systems (last release November 2020). From there the derivation to acquisition process is through each of the acquisition pathways, and to systems engineering process in the DoD Systems Engineering Guide.

[8] Sebokwiki.org

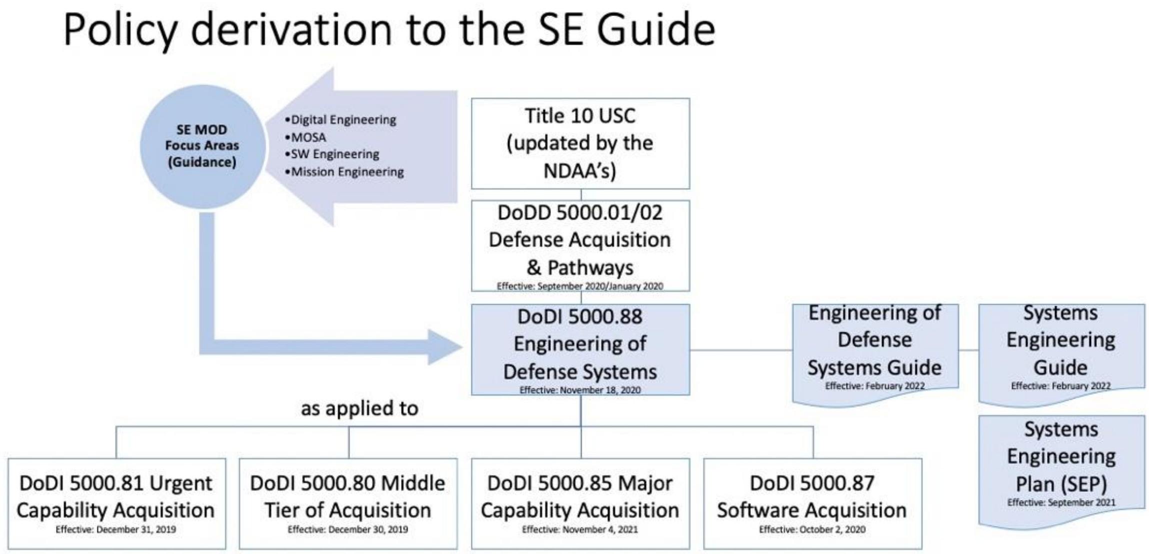

Figure 12. Policy Derivation to SE Guidance.

Based on the lack of a clear integration framework in the policy and guidance, the research team conducted a policy analysis. The initial results are presented in this document, the final results will be completed on project WRT-1058. The policy analysis reviewed existing SE policy, identified major gaps, policy flow, and aligned and integrated specific acquisition pathways to develop recommended modifications. Each document was analyzed for cross-references between the documents, including guides and policies. Select DoD 5000 policies and suggested updates according to initial gaps which the team identified and inclusion of SE Modernization focal areas (Digital Engineering, SW-Agile/DevSecOps, MOSA, Mission Engineering). The following policies & guides were reviewed:

1. DoDI 5000.88 "Engineering of Defense Systems" (November 2020)
2. DoDI 5000.85 "Major Capability Acquisition" (August 2020)
3. DoDI 5000.81 "Urgent Capability Acquisition" (December 2019)
4. DoDI 5000.80 "Operation of the Middle Tier of Acquisition" (December 2019)
5. DoDI 5000.87 "Operation of the Software Acquisition Pathway" (October 2020)
6. DoDD 5000.01 "The Defense Acquisition System"
7. DoDI 5000.84 Analysis of Alternatives (August 2020)
8. DoDI 5000.89 Test & Evaluation (November 2020)
9. DoDI 5000.95 Human Syst. Integration (August 2022)
10. Systems Engineering Plan (September 2021)
11. Systems Engineering Guidebook (February 2022)
12. Engineering of Defense Systems Guidebook (February 2022)
13. DoD Data Strategy (September 2020)

The current view and the modernized view of systems engineering are not fundamentally different in principles but are undergoing significant change in practice. In our research we found there have been many new practices applied to individual disciplinary approaches to systems engineering but little reintegration into the overall practice. In understanding what needs to change the research team came to realize a new mental model is necessary – this was presented in the Integration Framework. This section concentrates individually on focus areas.

Congress passed a series of legislative actions through the annual NDAA that target improvements in acquisition execution but also directly focus in on systems engineering. In each of the focus areas the research team was able to derive statements of intent from the policy language that are relevant to systems engineering. These statements of intent are highlighted below.

- **Mission Engineering (ME)** - The NDAA for Fiscal Year 2017, Section 855, directed DoD to establish Mission Integration Management (MIM) as a core activity within the acquisition, engineering, and operational communities to focus on the integration of elements that are all centered around the mission. ME is the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects. ME is the technical sub-element of MIM as a means to provide engineered mission-based outputs to the requirements process, guide prototypes, provide design options, and inform investment decisions. Primary guidance for ME is published in the OUSD(RE) Mission Engineering Guide, November 2020.

- **Digital Engineering (DE)** - The NDAA for Fiscal Year 2020, Section 231, directed The Secretary of Defense to establish a digital engineering capability to be used: (A) for the development and deployment of digital engineering models for use in the defense acquisition process; and (B) to provide testing infrastructure and software to support automated approaches for testing, evaluation, and deployment throughout the defense acquisition process. The language additionally stated that the DE capability will provide for the development, validation, use, curation, and maintenance of technically accurate digital systems, models of systems, subsystems, and their components, at the appropriate level of fidelity to ensure that test activities adequately simulate the environment in which a system will be deployed. Primary guidance for DE is published in the DoD Digital Engineering Strategy, June 2018. The DoD DE Strategy defines digital engineering as "an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal."

- **Modular Open Systems Approach (MOSA)** – Unlike the other guidance, MOSA requirements for acquisition programs have been codified into Title 10. Title 10 U.S.C. 2446a.(b), Sec 805 states all major defense acquisition programs (MDAP) are to be designed and developed using a MOSA. Title 10 U.S.C 2320(e) requires ACAT I and II Program Managers to assess the IPR and data rights requirements of their program, create a Technical Data Management Strategy and take steps to secure the Government's appropriate rights consistent with the FAR and DFARS. The code additionally states that "A mandate of OSA is that technical requirements be based to the maximum extent practicable on open standards. Where there are no standards, the OSA methodology creates them. At a minimum, technical standards and related specifications, requirements, source code, metadata, interface control documents (ICDs), and any other implementation and design artifacts that are necessary for a qualified contractor to successfully perform development or maintenance work for the Government are made available throughout the life cycle." MOSA guidance was initially published in the Open Systems Architecture Contract Guidebook, June 2013, and is being updated as of this report.

With respect to the SE Modernization integration framework, the intent of MOSA policy needs some interpretation. When developing the integration framework, we used the more general intent of MOSA from software and systems literature: to use modular design, control interfaces, adopt open standards, and measure conformance. This centers the goal of MOSA in SE as both a mandate and an enabler to manage adaptability and change.

- **Software Agile and DevOps** - The NDAA for Fiscal Year 2018, Sections 873/874, directed Pilot Program to Use Agile or Iterative Development Methods to Tailor Major Software-Intensive Warfighting Systems. The NDAA for Fiscal Year 2019, Section 868, directed the DoD to commence implementation of each recommendation submitted as part of the final report of the Defense Science Board Task Force on the Design and Acquisition of Software for Defense Systems. The NDAA for Fiscal Year 2020, Section 800, established the Software Acquisition (SWA) Pathway. Primary guidance is provided in the Agile Software Acquisition Guidebook, February 2020. The intent of SWA with respect to SE Modernization can be found int this guide: "Defining the capability need: Agile approaches to software avoid the need for very detailed upfront, predictive requirements capture. That is, they dispense with the idea that through sufficiently rigorous analysis, all of a system's requirements can be determined and specified upfront. In contrast, Agile approaches begin with a high-level capture of business and technical needs that provides enough information to define the software solution space, while also considering associated quality needs (such as security)."

This last statement summarizes the mental model challenges with current versus modernized SE very succinctly: all stakeholder requirements determined up front versus determine stakeholder needs sufficient to define the solution space. Both approaches remain relevant to SE rigor but there is little integration between the two (at least in acquisition processes).

Several other focus areas are relevant to SE Modernization and defined in policy and guidance but are not called out in legislative activities. These include:

- **Modeling and Simulation (M&S)** – System models are a combination of descriptive models (requirements, architecture) and computational models (physics, behavior, operations, etc.). In DoD acquisition, much of the descriptive modeling in the past has resulted in documents not models. The integration of descriptive models and computational models is the focus of much of the DoD DE and Model-Based Systems Engineering (MBSE) initiatives.

- **Test and Evaluation (T&E)** – T&E methods and processes will follow a similar transformation using authoritative sources of data and models.
- **Human Systems Integration (HSI**) – Technologies related to autonomous systems and human-machine teaming will evolve the HSI and SE disciplines to be much more integrated.
- **Capability Integration** – The processes to move from ME into the Joint Capabilities Integration and Development System (JCIDS) and then into program requirements and acquisition strategies will also evolve through the integration of authoritative data and models.
- **Sustainment and support** – SE Modernization appears to be evolving separately in the acquisition program development and the program sustainment communities.
- **Data strategy** – DoD acquisition is pursuing a broader digital data strategy as defined in the DoD Data Strategy, September 2020. SE is generally viewed as an engineering and technical discipline but has always been strongly integrated with Program Management activities as well as Enterprise Management. In development of the Integration Framework, we found that several areas of the Data Strategy remain significant pain points with respect to SE Modernization: data as a strategic asset, collective data stewardship, data collection, enterprise-wide data access and availability, data fit for purpose, and design for compliance. In particular, at this point the SE community may be overly focused on "System Models" and underly focused on "System Data." Data architecture, data standards, data governance, and talent and culture are all essential components of SE Modernization but are new concepts to systems engineers.

The common modernization driver in all of these focus areas, as discussed in the integration framework, **is seamless and efficient transfer of data and models from underlying performance drivers through models to decisions, as well as ease of drilling back down from decisions to data**. This does not mean everything must be connected (that is unlikely to ever happen) but that the process to move up and down the data transformation space is efficient and produces better quality. With this mental model of improved access and flow, a common integration framework can be pursued. Without it, stove-piping of people, processes and tools across lifecycle stages will continue to occur. The purpose of SE Modernization is thus to support more seamless and efficient digital integration of data and models across all program management, engineering, and acquisition process areas. We found this intent to be generally lacking in the current policy and guidance.

Major Policy Gap Areas

The policies were reviewed against the following gaps that the team identified:

1. Much of the policy remains milestone driven. As noted in the integration framework, milestone processes and approvers specific to each acquisition pathway are not well defined with respect to continuous processes in a digital environment. In particular most of the engineering guidance continues to use language that is associated with the MCA pathway, with little detail on use in other pathways.
2. Application of modernized SE to legacy systems is not well-covered in policy but most of today's implementation examples are legacy systems. This is highlighted in Figure 5. Full Integration Framework. as the set of acquisition activities that are derived from the "measure" side of the learn->build->measure set of lifecycles. This makes formal collection of lessons learned difficult.
3. The breadth/generality of policy at DoD level creates inconsistent flow down to service level. This is intentional to allow flexibility and tailoring in service level guidance but at least some level of compliance needs to be specified to create momentum for adoption of SEMOD activities. As noted later in the pain points discussion, effective compliance measures are needed to enforce adoption at program levels and to build momentum for change. The need for services to define these compliance measures at least should be reflected in DoD-level policy.
4. There is an inconsistent level of descriptive detail across documents by focus area that creates confusion. There is also varying sets of terminology and jargon used in different policies and guides that makes integration difficult. This is a general noted gap in our review of the documents. The ontology effort being conducted in project WRT-1058 will identify the more specific recommendations for language consistency across policy areas.
5. The SE community lacks a desk reference that describes modernization of SE process and focus areas that services can follow prescriptively. This would naturally be the DoD Systems Engineering Guide, which should be evolved over time to capture the core SEMOD concepts. This is noted as a need from interviews and discussions with DoD programs and can be considered as an indication the services would like more prescriptive guidance at the DoD level.

Policy is considered a statement of intent and is implemented as a procedure or protocol. As such, the policies were additionally reviewed to identify gaps in expression of intent and recommendations for future changes. The highlighted intent statements previously noted for each focus area were used to guide this review. Policy is undefined in the DAU glossary but has a useful clarifying descriptive passage in the DoD Dictionary: "Policy directs and assigns tasks, prescribes desired capabilities, and provides guidance for ensuring the Armed Forces of the United States are prepared to perform their assigned roles. Implicitly, policy can create new roles and requirements for new capabilities." Whether or not the policy clearly articulated intent was a central question. There were four guiding principles when assessing this articulation of intent: (1) Provides a clear and concise expression of the purpose of the policy, (2) Provides the desired military & acquisition end state that supports decentralized decision making, (3) Provides focus to the staff, and (4) Helps subordinate and supporting Decision Authorities act to achieve the policy authority's desired results without further instruction, even when the acquisition program does not unfold as initially planned.

The team identified three overarching trends and patterns across all of the policy documents. The first, major policy areas have no mention of the focus areas in their associated instruction (e.g. DODI), although the guides are currently more organized by focus area. This creates confusion as the focus areas are referred to in the relevant sections of the guidebook, but the associated policies make no direct reference to the focus areas. This means that requirements tracing for activities related to the focus areas will be circuitous, very difficult, or impossible. Additionally, this inhibits the DoD's ability to evaluate and enforce adherence to these instructions. As a recommended corrective action, the purpose should be more clearly articulated in the policy document than is currently seen, as well as use (through processes, procedures and standards), and intent behind the desire of the policy authority to include the focus areas to the relevant acquisition section.

Secondly, many sections of reviewed DODI 5000 Instructions appear to aid Decision Authorities in subjective decision making (with regard to compliance) but are insufficient to enable objective decision making as they lack either a specified standard, or the means sufficient to judge the success of a developed standard, for processes and tasks. This is due to a lack of specification of standards whereby the policy can be classified as compliant or non-compliant. Many sections dictate tasks or deliverable items, and some go further to explain the conditions that influence or feed those tasks and products. However, what is severely lacking in the document is a set of standards to aid in the assessment of objective decision making using this policy as a basis for analysis. Often sections will direct the creation of a work product, for example the Systems Engineering Plan (SEP) template, breakdown the various components that would make up a SEP, but not give criteria to judge the sufficiency of projects regarding the standard. From a policy perspective this role is delineated to the approval authority for that work product, but without sufficient knowledge of, or priority laid toward the instructions intersection with the focus areas reviewed, this would create a significant gap. As a recommended corrective action, the addition of a minimum set of specified satisfaction criteria standards beyond the description of a task and its conditions should mitigate this issue. Additionally, if the creation or selection specific standard is desired to be delegated to the decision authority, the DODI should include a direction to a generally sufficient standard (for example ISO 2700 for Information security) as a basis from which a decision authority can build a standard from, and judge that the standard is sufficiently complete in its coverage and detailed in its specification.

Third, and more broadly, the documents do not yet communicate the intent of incorporating SE Modernization processes across the policy areas and they should be updated accordingly. When reviewing the clarity of the policy derivation, the team found that the four focus areas derive from various language in NDAA's, but only MOSA has specific referenceable standardized language in Title 10. As such, appropriate standards should be specified in directives and instruction for the other focus areas. Additional recommendations are as follows:

- Establish clear traceability between policy documents and guidance via appropriate cross-referencing
- Identify appropriate standards (to be developed if necessary) to make policy compliance measurable
- Terms used in DoDD and DoDI lack clear, concise and complete definitions. There needs to be a clear taxonomy/ontology developed at least for SE and related SE Modernization activities. This is the primary focus of the ontology development effort in WRT-1058.
- Systems Engineering is a core technical definition and risk management approach to all Acquisition Pathways. This is reflected in the language of DODD 5000.01 if not in specific directives. There need to be consistent guidance language in each pathway provided and clear intent provided in Engineering of Defense Systems and Systems Engineering guidance reflecting use in each pathway and in sustainment. This will be further assessed in the completion of the policy analysis task.

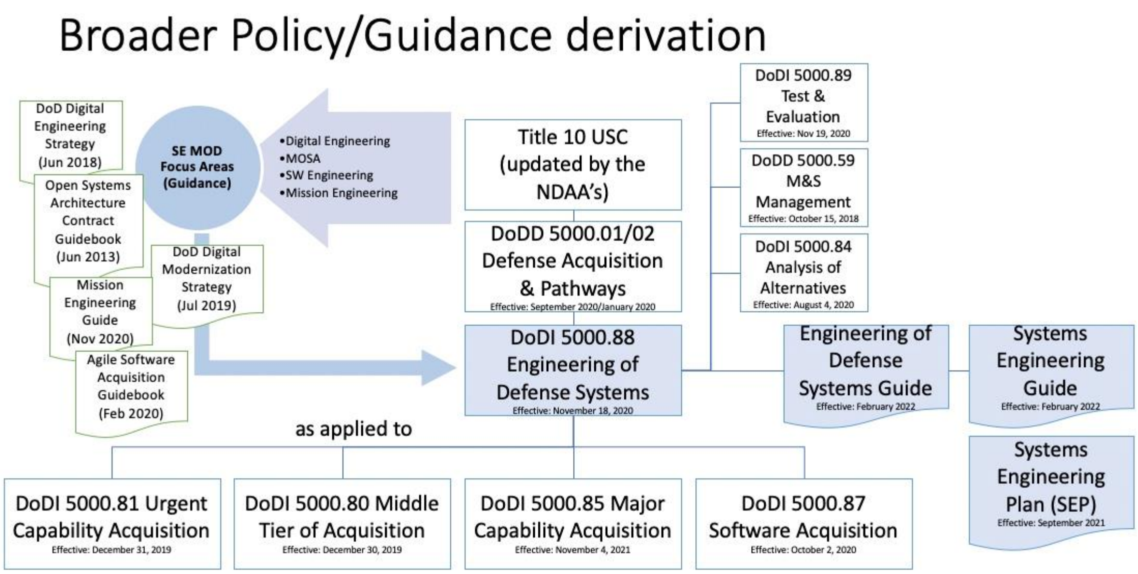

Figure 13. Broader Policy/Guidance with the four focus areas.

The team is continuing to review the associated guides in relation to the SE Modernization focus areas and related policies. The broader policy and guidance documents of Figure 13 are being included in the full review. This activity will be completed under the WRT-1058 research task. As a next step, concrete corrective actions in terms of updates and revisions to the guides for implementation will be provided.

6. SE Modernization – Outreach and Pain Points

Task: Provide outreach to government acquisition leads, program offices, science and technology organizations, and other entities related to SE modernization.

Outreach Activities

The research team conducted three formal workshops with government, industry and academia to gain insights. The details of each workshop are provided in Appendix A. The workshops included:

1. Translating Digital Engineering into Pragmatic Impact (November 2021)
2. SE Modernization Strategy (January and June 2021) – conducted jointly with the International Council on Systems Engineering.
3. Digital Artifact Workshop (February 2022) – conducted jointly with DAU.

In addition, the team had a number of individual discussions with experts and program offices led by the sponsor. These activities generated a number of statements that were used to inform a more comprehensive set of SE Modernization pain points. Individuals from these sessions provided references to lessons learned artifacts which may be used in an updated SEModBoK repository (this will be completed on project WRT-1058).

Pain Points Aggregation

The primary use of the outreach activities was to generate a more comprehensive set of SE Modernization pain points that were mentioned by various participant and ongoing implementation strategies that are being matured at the program and Service level. The integration framework was used to organize these into an Ishikawa (fishbone) diagram. The full diagram is shown in Figure 14.

The detailed pain points in each causal path are not easily readable in the figure and will be explained further. The overall organization of the diagram represents as an input our primary goal from the integration framework:

- **Seamless and efficient digital flows from data to decision artifacts and from decision artifacts back to data.**

And as an output the primary outcome theory resolution of these pain points would address:

- **The slow implementation of modernized systems engineering processes in DoD Program Offices.**

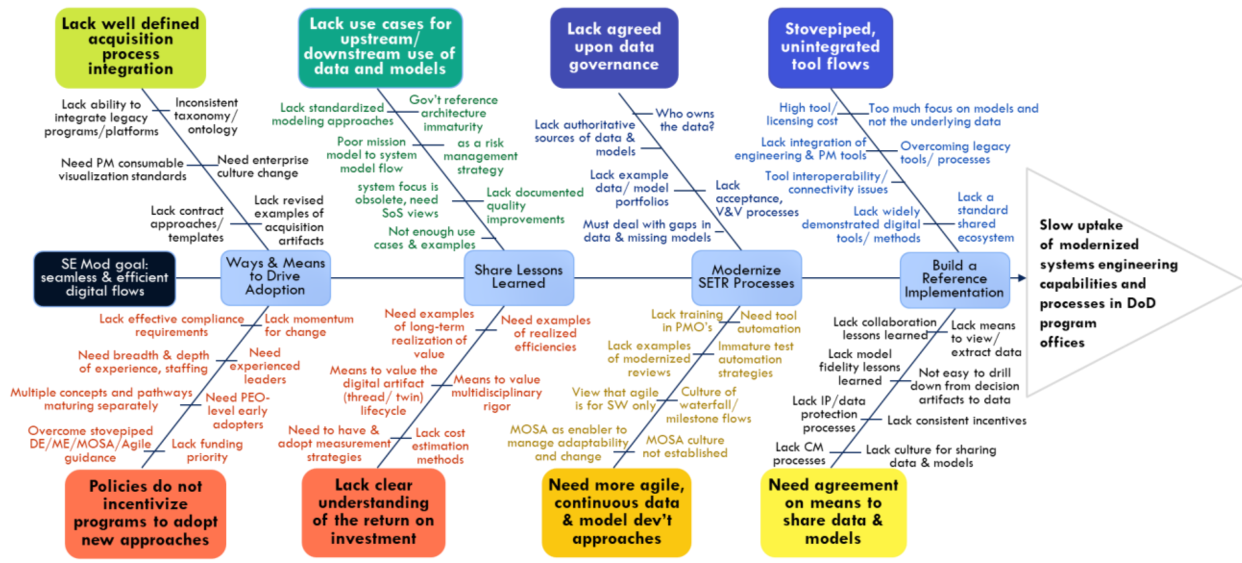

Figure 14. SE Mod Pain Points.

The organization of the diagram represents four primary recommendation areas driven each by two primary aggregated pain points. These are summarized below:

1. **Build a Reference Implementation**
   a. Tool flows are stovepiped and unintegrated
   b. Need agreement on means to share models and data
2. **Modernize Systems Engineering Technical Review (SETR) Processes**
   a. Lack of agreed upon governance for data and models
   b. Need more agile and continuous data and model development approaches
3. **Share Lessons Learned**
   a. Lack of use cases for upstream/downstream use of data and models
   b. Lack clear understanding of the return on investment
4. **Ways and Means to Drive Adoption**
   a. Lack well defined acquisition process integration
   b. policies do not incentivize programs to adopt new approaches

The detailed pain points for each recommendation area are summarized below:

Build a Reference Implementation

1. The DoD should build and share representative reference implementations that support seamless and efficient digital flows of engineering, program management, and acquisition processes
   a. Today there are too many stovepiped and unintegrated data/tool flows and processes
      i. High tool/licensing cost, need enterprise level agreements and standards

    ii. Today the focus is on modeling tools, need a much broader data management focus and set of processes
    iii. Tools lack standard integration of engineering and program management data
    iv. Tools need to support seamless and efficient ways to integrate and connect data & models
    v. The community has been at this for a while, need efficient ways to transition from legacy tools/processes to the latest more capable tools
    vi. Government and contractor tools and methods need to be built into a standard shared ecosystem across programs
    vii. Developed and demonstrated approaches need to be widely shared across programs
  b. Need agreement across programs and across government/ contractors on the means to share data and models and related SE practices
    i. The community has not yet developed a culture for sharing data and models
    ii. Effective configuration management processes need to be developed, along with intellectual property and data protection mechanisms
    iii. PMs and contractors lack the incentives (voluntary or contracted) and means for sharing data & models
    iv. "Seamless and efficient" means ability to easily drill down from review artifacts to models to data, today's tools and methods lack the ability to easily view/extract data at different levels
    v. Need lessons learned and best practices on the appropriate fidelity of models for different decision processes
    vi. Need lessons learned and best practices on how to collaborate around models and data

Modernize Systems Engineering Technical Review (SETR) Processes

2. Lack of agreed upon governance for data and models
  a. DoD needs to modernize their SE technical review (SETR) and collaboration processes to focus on use of data and models instead of static presentation artifacts
    i. Who owns the data? Need standard structural and process approaches
    ii. PMs lack existing authoritative sources of data & models to build from
    iii. PMs lack examples of data/model portfolios and experience in managing them
    iv. PMs lack mature processes and methods for accepting and validating data/models consistent with modern continuous development and integration methods
    v. PMs need ways to identify and manage what data/models are needed when, and experience/risk processes to manage the gaps in data & models

   b. PMs need to develop more agile and continuous data & model development processes
      i. A modular open systems approach (MOSA) is the enabler for both the data/model infrastructure and the product data lifecycle, this must be recognized as a necessary step to adaptability and change as built into the acquisition culture
      ii. The prevailing view of agile as a software development approach must be overcome, and used to change the prevailing view of development as a set of waterfall milestones
      iii. PMs lack examples of modernized technical and management reviews
      iv. PMO's lack training on how to execute modernized SE processes
      v. Efficiency will come from automation, need tool automation and especially model-based evaluation and test strategies

Share Lessons Learned

3. The DoD needs to organize and share lessons learned across all components
   a. PMs lack use cases for upstream and downstream use of data and models
      i. PMs lack standardized approaches in practice for defining and using models and related data to specify and manage their developed and acquired systems
      ii. These would standardize on government reference architectures for both SE infrastructure and portfolios of systems – there is a lack of mature examples
      iii. Models and data should be viewed as a risk management strategy – need a documented process and a program management focus
      iv. The integration of mission/SoS models and system models is immature, PMs need SoS level views as stand-alone system models cannot reflect changes in context/use over time
      v. PMs lack documented examples of SE Mod as a quality improvement process
      vi. There are not enough use cases and examples of SE Mod benefits
   b. The community does not yet understand the benefits of and return on investment for SE Modernization
      i. PMs need revised cost estimation models that reflect efficiency of SE modernization components
      ii. PMs need to have and to adopt measurement strategies and specifications for SE in general and modernized SE
      iii. PMs need a means to value the multidisciplinary rigor and integration that comes with SE Mod
      iv. PMs need means to value the life cycle benefits and use of sustained digital artifacts
      v. PMs need examples of program realized efficiencies, and need long-term examples of the realized value of SE modernization

Ways and Means to Drive Adoption

4. The DoD needs ways and means to drive adoption into Program Offices and other functions
    a. There is a lack of well-defined process integration across all acquisition areas
        i. There is not an effective terminology that integrates across acquisition areas of change, causing confusing and lack of focus
        ii. Digital transformation is an enterprise level cultural change and the top-down/bottoms-up learning needed is just underway
        iii. Most programs involve legacy systems and PMs are unable to/cannot afford to integrate new SE practices into legacy systems improvements
        iv. Standard contract approaches and templates for defining & procuring in the digital ecosystem are not yet available
        v. Need PM consumable visualization standards for dashboards that aid management
        vi. There are not enough examples of acquisition artifacts available from early adopters
    b. Current policies do not incentivize programs to adopt new approaches
        i. Current guidance is stovepiped and inconsistent across acquisition pathways and engineering/PM processes, maturing slowly
        ii. The DoD lacks an enterprise strategy to fund DE infrastructure
        iii. Some programs are early adopters, but digital transformation is not yet at the portfolio level
        iv. The DoD needs experienced individuals who can lead adoption of SE Mod practices, as well as breadth and depth of staffing to implement those practices
        v. Effective compliance measures are needed to force adoption and build momentum for change

These pain points are offered up as a list for further development. In next steps the government should take the initiative to agree upon and formalize each pain point (as was done with the Digital Engineering pain points) then develop plans and measurement approaches to track each item. This list forms the basis for further development on Research Task WRT-1058.

7. Next Steps

This is the final report of Research Task WRT-1051. The intended follow-on research task, WRT-1058, was started in parallel with this task and is currently planned to complete in March 2023. Figure 15 shows the combined schedule and lines of effort for the combined tasks.

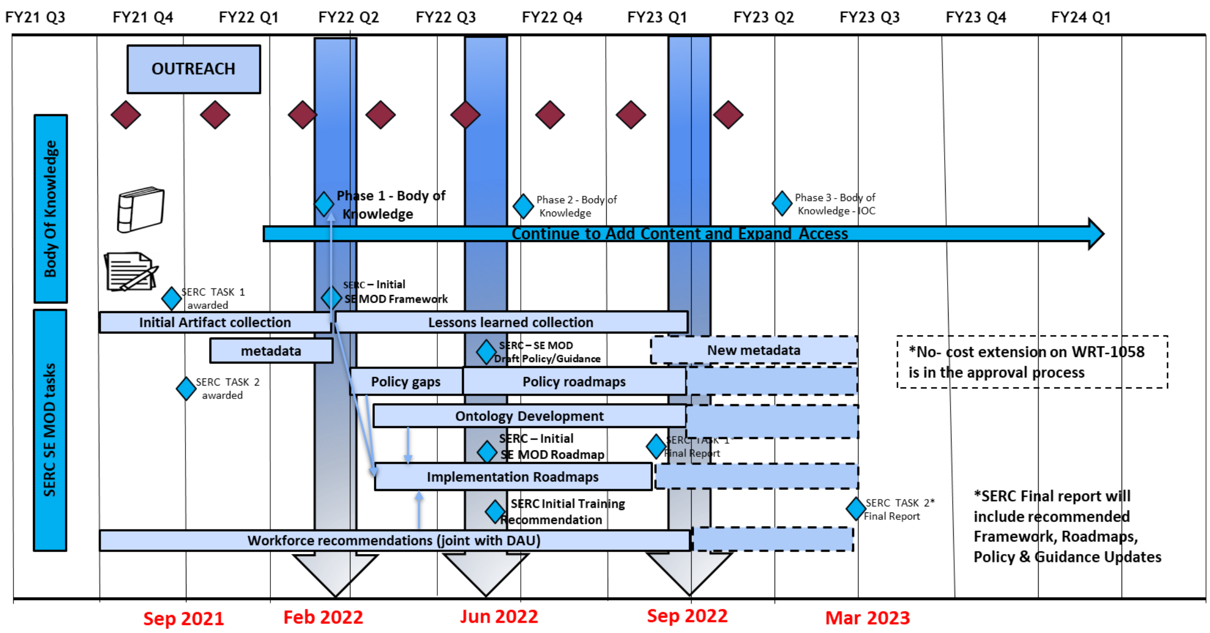

Figure 15. Full project schedule.

Major lines of effort include:

1. Lessons Learned: the research team led by student Kaitlin Henderson from Virginia Tech has compiled a database of over 600 lessons learned statements from open literature. This is currently in analysis. The lessons learned and source documents will form the next version of the SEModBoK metadata and references.

2. Ontology: the research team from Penn State is building an ontological model that integrates across three language sets: military capabilities, defense acquisition, and systems engineering lifecycle standards. This will serve as a secondary SEMOD integration framework across written policy and guidance.

3. Workforce: the project has teamed with the Defense Acquisition University (DAU) to collect a set of education and training artifacts derived from the lessons learned.

4. Policy analysis: the research team will complete recommendations for coverage of gaps and further focus area integration in the defense engineering policy and guidance.

5. Agile Digital Engineering: the research team will conduct a deeper analysis of the impact of agile methods and processes in modernized SE. As part of this, the full integration framework of Figure 5 will be iterated and described in detail for each relevant acquisition pathway.

6. Implementation roadmaps: as SE Modernization will be a long-term evolution, the research team will support the sponsor in development of a set of longer term implementation roadmaps.

In addition, this research identified two additional research areas that should be pursued:

1. ERI development: develop an exemplar reference implementation(s) establishing digital engineering practices and policies that provide a consistent, coherent, and controlled environment that is context-independent, scalable, and federated. This reference implementation would allow the department to demonstrate concepts relating to the authoritative source of truth in support of programs of record, along with joint experimentation initiatives. The ERI would establish a digital engineering environment to mature data standards and data exchange methodologies between applications baselining interface capabilities and becoming a reference implementation environment for demonstrating and transitioning digital engineering capabilities to program offices in the services. Modernization requires an ecosystem capable of capturing and retaining digital engineering artifacts using shared semantic data models (ontologies) between applications using data exchange, data product control, operational configuration, and traditional document production.

2. In the future, program managers must be able to navigate through government acquisition milestone processes and government procurement processes that are linked through data and models. Initial example acquisition artifacts are starting to be exchanged through the efforts of the government Digital Engineering Working Group, various digital engineering pilot projects, and a small set of acquisition programs of record. However, these are not standardized or widely distributed. There is a need to standardize on digital engineering relevant statement of work and contract language that would be useful for programs requesting to start applying digital engineering to new programs. There is also a need for models of the actual request for proposal and technical evaluation processes, and the changes to the contracting processes needed to manage the exchange of data and models at both the government levels and government to contractor interfaces. needs include:

    a. Define a sample acquisition flow for a defense program of record that begins with identification of a needed material solution through to the point of award to a contractor or contractor team. Consider the Major Capability Acquisition, Mid-Tier Acquisition, and Software Acquisition pathways.

    b. Prototype a digital Systems Engineering Plan and digital milestone approval workflow

c. Develop example models for Statement of Work and Technical Evaluation Criteria

d. Develop examples for model-based contracting and digital approaches to augment the traditional concept of Contract Data Requirements prior to contract award

e. Define criteria for validation and approval of these digital artifacts and processes.

8. Conclusion

Computer Aided Design (CAD) and Product Line Management (PLM) methods and tools gradually moved the physical design processes from highly manual to mostly seamless and efficient sets of data and workflow. This “Mechanical Engineering Modernization” took decades of evolution. SE Modernization is also going to be a long-term process.

This report summarizes the initial steps and pain points for the journey. The question “why modernize systems engineering” proved to be very difficult to answer originally. Different aspects of systems engineering such as mission integration, digital systems engineering, and agile systems engineering are evolving differently in different disciplines, creating organizational and process barriers in both engineering and acquisition. The primary goal of this phase of SE Modernization framework was to develop the integration framework that would bring these disciplinary and methodological views together. To do this we had to create a new mental model and set of visualizations that portray systems engineering in a different light. The basic process areas of systems engineering remain valid, but the lifecycle models and associated digital practices will look very different than the traditional underlying SE process in defense acquisition cycles.

9. Project Timeline & Transition Plan

All research in this report will transition directly into the companion WRT-1058 Systems Engineering Modernization Policy, Practice, and Workforce Roadmaps research task. Transition opportunities will be identified in that report.

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APPENDIX A: WORKSHOPS AND RELATED OUTCOMES

The research team conducted three formal workshops with government, industry and academia to gain insights. The workshops included:

1. Translating Digital Engineering into Pragmatic Impact
2. SE Modernization Strategy Session – conducted jointly with the International Council on Systems Engineering.
3. Digital Artifact Workshop – conducted jointly with DAU.

TRANSLATING DIGITAL ENGINEERING INTO PRAGMATIC IMPACT: STRATEGY TO IMPLEMENTATION: WORKSHOP SYNOPSIS

November 9, 2021 (Conducted on Zoom)

Workshop Motivation and Intent

Systems engineering (SE) modernization efforts through MOSA, Mission Engineering and SW Engineering are heavily dependent on the implementation and use of collaborative digital tools and processes. The government/defense industry is undergoing profound changes from traditional engineering requirements, design, development, integration, and verification methods based on documents and artifacts to a future based on digital models and cross-functional digital representations of system designs and end-to-end solutions. Many of the measurable benefits of Digital Engineering (DE) are associated with the use of both data and digital models as a community "source of truth" for all life cycle activities. The DoD Digital Engineering Strategy describes a foundation for enterprise stakeholders across government, industry, and academia to work on their respective digital transformation initiatives. This strategy has been well received, many pathfinders and pilots in the realization of this strategy have validated the approach, and industry and government are investing in the necessary transition. Questions remain with development of standard approaches and pathways to support this transition, while also addressing the resulting return on the investments, measurements and metrics to ensure impact and efficiency.

The intent of this workshop was practical with a view towards supporting the continued transition of the Digital Engineering strategy into a set of implementable and scalable pathways. With this in mind, we planned this workshop with selected and key stakeholders with the primary objective to:

Develop a baseline set of engineering and acquisition processes that are most likely to be impacted by the Digital Engineering transformation, with "start with these" style guidance. This could potentially lead to a pseudo-pareto listing of these processes in the order of impact magnitude, ROI, and difficulty.

A follow on intent is to leverage workshop results into the:

1. Development of sample flows of these processes in typical acquisition and engineering activities that can inform a starting workflow for the transition.
2. Development of a sense for any dependencies in the transition of these processes along with a degree of difficulty. The degree of difficulty could address dimensions such as talent development, infrastructure, data, and so on.

Workshop Attendees, Organization and Context

The workshop was kicked off by Ms. Phil Zimmerman articulating the intent of the workshop for the approximately 50 participants. In order to enhance the discussion and data collection, the participants were organized into five groups, with each group being moderated by a member of the SERC Research Council.

Group 1: Test and Evaluation (Laura Freeman, Virginia Tech)
Group 2: Mission Engineering (Dan DeLaurentis, Purdue)
Group 3: Agile and Security (Cliff Whitcomb, NPS)
Group 4: Systems Engineering/Program Management (Tom McDermott, Stevens)
Group 5: Leadership Perspective – Cross Functional (Phil Anton, Stevens)

As context for this workshop, the set of pain points developed by the Digital Engineering Working Group was shared with the Breakout Group Moderators. These pain points are summarized in Table 4.

Furthermore, the moderators and the participants were requested to think about the primary digital engineering metrics categories during the course of their discussions in the breakout sessions. There were enumerated as: a) Impact to Quality; b) Impact to Speed and Agility; c) Impact to Collaboration and Knowledge Transfer; and d) Impact to the Adoption of Digital Engineering.

Finally, a list of primary acquisition and engineering functions, as reflected in Figure 16. List of Primary Acquisition and Engineering Functions used as a Reference Baseline.Figure 16, was shared with the team as a reference baseline.

Table 4. DoD Digital Engineering Pain Points.

DE Area	Pain Point Title	Pain Point
Goal 1: Use of Models	**Standards**	Models are not consistently planned, developed or used across Services, engineering disciplines, domains, lifecycle phases, or programs
	Reference Models/ Reference Architectures	DoD lacks a concept of operations, reference models/ architectures to guide Digital Engineering implementation
	Modeling Practice	DoD lacks methodologies to use model-based approaches to perform lifecycle activities
Goal 2: Data & ASOT	**Data Exchange**	The DoD lacks digital representations providing alternative views to access, visualize, communicate and deliver data, information, and knowledge to stakeholders
	Authoritative Data	DoD lacks authoritative data sources that are accessible, understandable and trustworthy
	Decision & Visualization Framework	The DoD lacks a decision and visualization framework to communicate across decision makers and stakeholders.
Goal 3: Technology Innovation	**Digital Enterprise**	The DoD lacks an established digital engineering capability to develop and deploy digital engineering models for use in the defense acquisition process
	Engineering Practice Innovation	The DoD lacks mechanisms to implement Digital Engineering across R&E
	Pilots	The DoD lacks mechanisms to innovate rapidly, and to infuse advancements in technology to improve the engineering practice
Goal 4: Infrastructure and Environments	**Digital Ecosystem (Integrated Modeling Environment)**	An ecosystem does not exist to digitally collaborate across organizations, engineering disciplines, and lifecycle phases to rapidly discover, manage, and exchange models and data
	IT Infrastructure	The existing infrastructures were not designed for complex digital model-based engineering activities
	SW & Tools	The DoD lacks access to DE software and tools across the Enterprise
Goal 5: Culture and Workforce	**Policy, Guidance, and Plans**	The DoD lacks comprehensive policies, guidance, and plans.
	Talent Management	The DoD lacks recruiting, hiring and retention strategies for Digital Engineering.
	Leadership & Communication	The DoD lacks enterprise expectations, strategic direction, and prioritized investments across the enterprise
	Change Management	The DoD lacks enterprise accountability to measure, demonstrate and improve tangible results

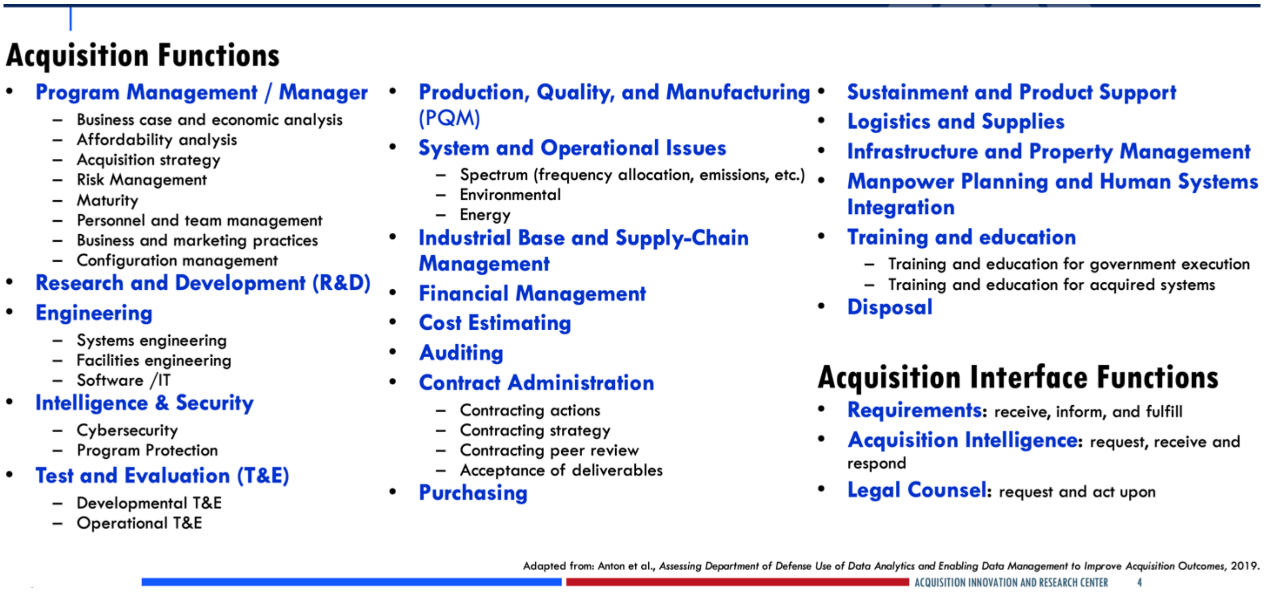


Figure 16. List of Primary Acquisition and Engineering Functions used as a Reference Baseline.

Primary outputs from the Systems Engineering, Requirements Engineering, and Program Management Session:

1. Need: Digital Engineering Environment: There is need to characterize a minimally viable DE infrastructure, to address the following that can have a significant impact on cost of implementing Digital Engineering:
   a) Dealing with multiple CAD environments, licensing costs, multiple heterogenous DE environments;
   b) Cost of tools across multiple contractors using different vendors, lack of interoperability, and (in the case of some vendors) the approach to tool licensing; lack of kernel/metadata compatibility;
   c) Inability to prescribe tools and interoperability across programs/contractors, prescribing data format is also a challenge;
   d) People don't always realize the power in the tools they already have, skills and experience and training is a barrier to expertise to make these types of choices;
   e) Data sharing and standards defining best tool combinations to work with each other are sparse at best.

2. Need: Develop a Portfolios of Reuse Opportunities: There is need to explicitly develop a portfolio of reuse opportunities within a program, and across a portfolio of programs. This would allow us to identify specific opportunities to impact development agility:
   a) Leverage an opportunity to cut quite a bit of time in program development (SOW, etc.);
   b) Leverage benefits from Data and Model reuse to evolving system versions, iterations;
   c) Assess traceability between contract documents and cross-referencing to contractor documentation, benefit in cost and time;
   d) Apply DE as early in the requirements definition as possible, building databases & tools entering acquisition, also architecture definition;
   e) Development of enterprise/mission reference architectures; a library of design patterns;

f) Information that is required by JCIDS is managed in different places – via Digital Engineering we have an opportunity to integrate it;
g) Generally getting information into computational space in a consumable data format benefits future use;
h) There is a need to trace from requirement to test results, very difficult today given speed of development, and DE is really needed to solve this problem;
i) Project portfolio and requirement portfolio management can benefit from data and models for individual systems.

3. Need: Develop a portfolio of data that are particularly hard to get and share access to: In order to allow a focused effort to get at the persistent issue of data sharing and access, this effort may be critical to the implementation to Digital Engineering:
   a) JCIDS data;
   b) Any activities that have classified material, particularly performance data; Tools are not operating at high side or flexibly across levels, access to tools; Much is still manual at the higher levels; There is a need to study organizations that have solved this issue (e.g., IAMD);
   c) Reuse of architectural models and data from program to program, system to system;
   d) There may be a large quantity and richness of available technical data but difficult it is often difficult to abstract or aggregate for higher level decision makers;
   e) Inability to look at and extract information across data sets without the manual process of compiling the data.

Primary outputs from the Test and Evaluation Session:

Reality: ROI with Digital Engineering will only be achieved if downstream organizations also adopt Digital Engineering, and refactor their practices and processes to leverage the models and data that represent the technical baseline – the authoritative source of truth.

1. Need: Governance to Leverage Reality: An adjudication authority is necessary for the following exemplar reasons:
   a. PM/PEO will own the authoritative source of truth – who makes ATEC/DTE&A/DOT&E adopt, if there are disagreements on the fidelity?
   b. Who tells the PM/PEO the authoritative sources is not good enough? Or causes a verification and validation of the digital models and data?
   c. There is a need to rethink governance between programs and oversight organizations.
2. Need: Assess and Review the Digital Engineering Investment Model: As an example, there are obvious efficiencies relating to test and evaluation that result from Digital Engineering. As an example, there is the possibility of reducing physical test resources along a tractable timeline in coordination with investments in the Digital Engineering infrastructure.
3. Need: Assess and Review what aspects of the TEMP can be Digitized: This is a specific effort focused on enhancing efficiency, leveraging information already developed in form of models and data, allowing sync-up between requirements and design changes, and the TEMP. There is a need to revisit and rethink the TEMP in the context of Digital Engineering.
4. Need: An Enterprise Level Model V&V Capability and Model DIDs: This will be critical to developing a level of trust in the models and the associated authoritative source of truth, it will be key to accepting models from the contractors, and to get other organizations (e.g., ATEC) to buy into leveraging digital models for virtual testing in lieu of physical testing. There is also a need to develop the equivalent of *DIDs for models – will allow:*
   a. Consistency in what we ask for in models and related data

b. When SE is engaged in contract language writing, quality is improved, DE should help to identify correct language
c. Ability to support technical decisions at the portfolio level

Primary outputs from the Agile and Security Session:

Activities with the most significant impact from Digital Engineering are likely to be:

1. Risk Management: Earlier identification, and perhaps more comprehensive identification of risks is possible, with consistency and transparency; this will also likely guide and focus risk-based prototyping. Identifying failure modes and risks early on in the process is a large benefit and can be done consistently and transparently. Can understand risk before development matures, reducing a need for as many prototypes.
2. Software Development: Software benefits significantly from a DE environment – allowing rapid software updates, enabling agile development and DEVSECOPS, leveraging auto-generated code, it makes software scans possible, allows M&S to augment T&E, helps with software safety 882e software safety standard impacts, and allows assessment how open our interfaces are (for MOSA approach), and supports the identification of major MOSA open aspects
3. Business Case and Economic Analysis: Currently, modeling and simulation implemented to accomplish trade studies and cost – benefit analyses is already done for most programs, but is not integrated and visible for use and understanding throughout the program lifecycle. The ability to maintain a connection to modeling and simulation done up front is a real value-add, rather than having to go back in time and find it if it is needed later in program development.
4. Configuration and Change Management: The DE environment will allow a more efficient, traceable, and transparent configuration and change management approach, with built in cost assessment. Consistency of CM due to integrated tools and built-in or designed-in traceability provides positive impact. Perhaps not as easy to implement if tools and data are not harmonized into a consistent environment. ROI is potentially good.
5. Sustainment and Product Support: This becomes possible in a manner that allows earlier design impact assessment and follow-on optimization of the support ecosystem, based on utilization.
6. Cybersecurity: This can be finally included earlier as part of the system design trade space. Easier to control flow of information and who holds the data (all kinds of data) so perhaps programs will be more secure. Better to know who owns the data. Could be trickier due to the need to know for various data, different environments, data storage across classification levels, risks of having everything in a cloud environment (prone to hacking). Can better define what the data looks like and how the system can respond – reduction of silos is a benefit.
7. Program Protection: Government is asking industry to protect what the government is asking them to develop and build. Government will build the model for industry to follow, so time to build involves some difficulty and has a cost to it up front.
8. Sustainment and Product Support: Condition-based maintenance, virtual trainers, PPMX, and these sort of meta-verse aspects become important here. Continuation of software development into the O&S phases should be considered – so implementing a “colorless” money format could benefit sustainment and support. Lots of types of data, activities, currently many different tools and approaches in these phases impacts difficulties in implementation. ROI is long term realization, with some strands or threads offering benefits early on from advanced and digital manufacturing.

Primary outputs from the Mission Engineering Session:

Reality: Digital Engineering can enable better gap analysis in the context of a "kill web" and targeted prototyping. It can also support enhanced portfolio based resource allocation and decision making, but is truly dependent on the transformation of the enterprise from a digital perspective.

1. Need: Leadership Engagement and Support: We truly need to go beyond the heros and the coalition of the willing to accelerate investment and gain the benefits from this through re-thinking the investment model for digital engineering and getting past the stove piped resources.
2. Need: The data and underlying models, shared in timely and appropriate fashion, necessary to support comprehensive ME analysis.

Activities with the most significant impact from Digital Engineering are likely to be:

1. Program Management and Manager;
2. Systems Engineering;
3. Test and Evaluation;
4. Gap Analysis and Prototyping;
5. System and Operational Issues (Spectrum; Energy; and Environment).

Primary Outputs from the Cross Functional Leadership Session:

Note that there is some return on investment (ROI) in the near term, mostly in better quality of the systems being acquired. The major ROI is in the long-term (e.g., a lot of cost avoidance). If you assess implementation based only on the near-term ROI, then DE investments will likely not rate high enough.

Also, if we had full DE implementation with physics-based modeling, implementation would be relatively modest effort for DT, but we are not mature enough yet in capability and capacity.

The best approach may be to focus on implementing DE for SE first.

Activities with the most significant impact from Digital Engineering are likely to be:

Top Tier:

- Systems Engineering, and re-thinking Design Reviews

Second Tier:

- System of Systems/Mission Engineering
- Sustainment and Product Support
- Training and education for operating the acquired systems
- Requirements setting and management. (Using DE to support requirements generation and management and mission engineering should identify issues early.)

Third Tier:

- Acquisition Strategy
- Risk Management
- Configuration Management
- Software engineering / IT
- Program Protection
- Test and Evaluation (T&E): Developmental and Operational
- Cyber-Security
- Assessing System and Operational Issues

- Cost Estimation
- Contract Administration and Purchasing (e.g., CDRL reduction and streamlining)
- Training and education for government execution

Fourth Tier

- Mission support

Negative Impact

- Legal Reviews. The highest “negative impact” may be to the Office of General Counsel (OGC) because it is hard to explain technical aspects of DE (there are very few lawyers in OGC with technical degrees).

Integration and mapping of workshop outcomes

The workshop served as an excellent initial realization of SE Modernization pain points. The outcomes of each breakout session were mapped into a relationship diagram as shown in Figure 17. As this diagram is overly complex, pain point areas are defined and summarized in the following slide images.

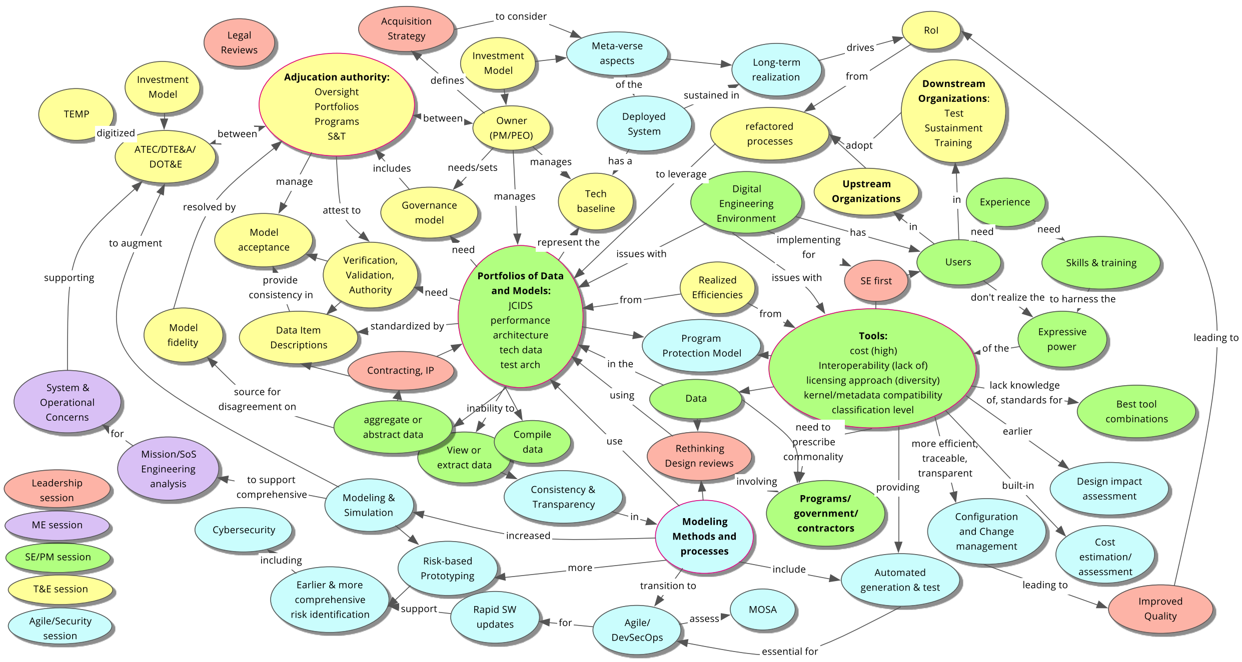
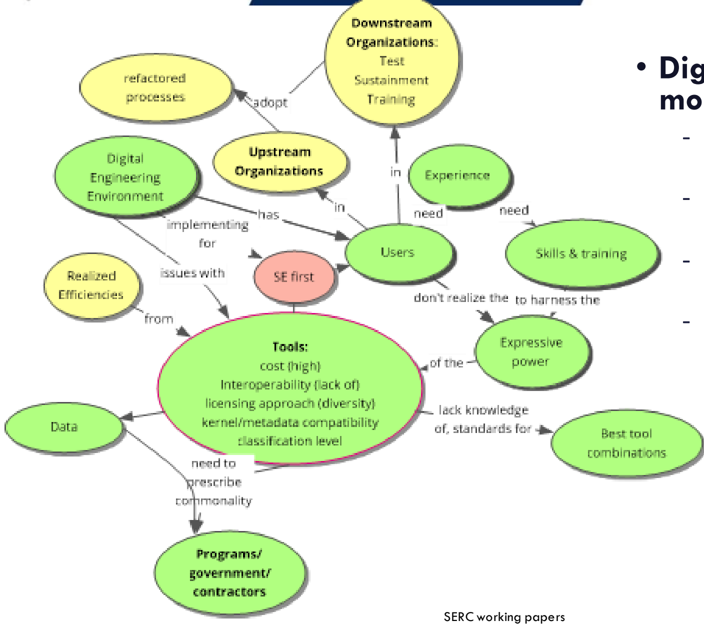


Figure 17. Mapping of workshop outputs.

SYSTEMS MAPPING



- **Digital** Tools will **drive SE modernization**
  - **But are evolving** and still not mature enough
  - Still learning how to best use them
  - Need to settle on best tool combinations
  - Need metrics for realized efficiencies

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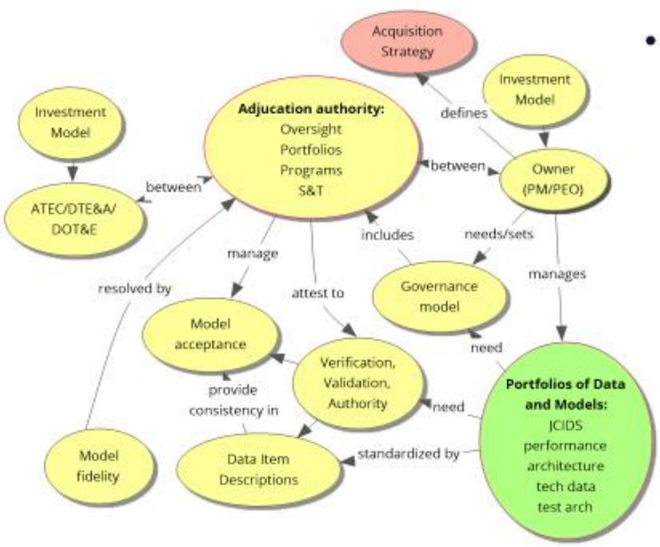
SYSTEMS MAPPING



- **Who owns the models and data?**
  - Reqs and Test will need to converge around models
  - Need governance model, V&V authority
  - Clarity on authority designation: portfolio manager, PM/PMO, Test

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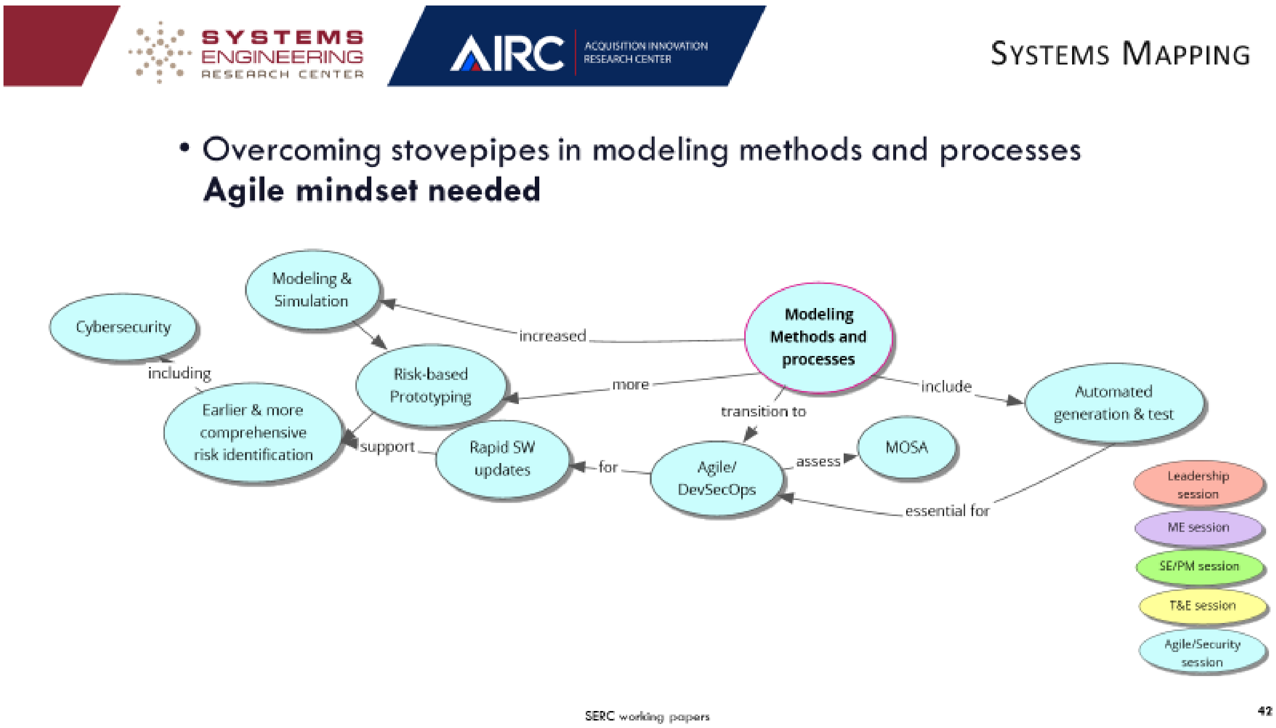
SYSTEMS ENGINEERING RESEARCH CENTER
AIRC ACQUISITION INNOVATION RESEARCH CENTER
SYSTEMS MAPPING
• Overcoming stovepipes in modeling methods and processes
Agile mindset needed
Modeling & Simulation
Cybersecurity
including
increased
Modeling Methods and processes
Risk-based Prototyping
more
include
Automated generation & test
transition to
Earlier & more comprehensive risk identification
support
Rapid SW updates
for
Agile/ DevSecOps
assess
MOSA
essential for
Leadership session
ME session
SE/PM session
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Agile/Security session
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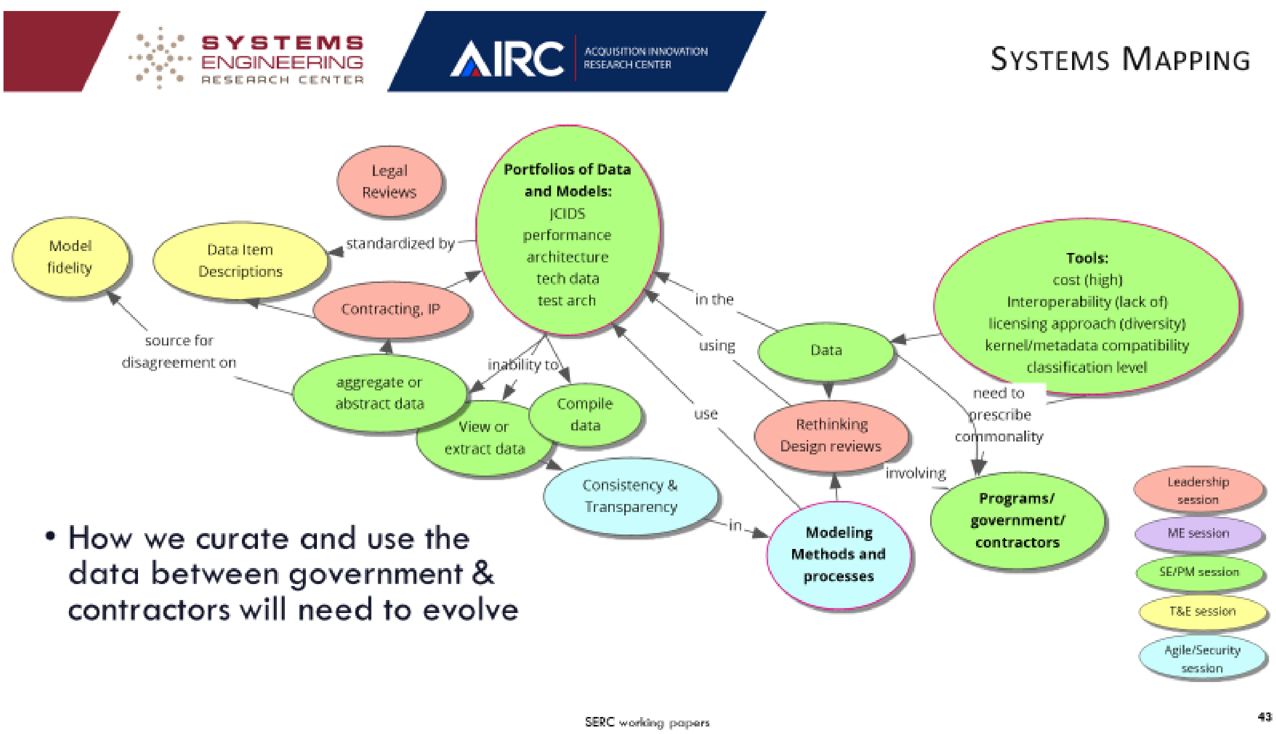
SYSTEMS ENGINEERING RESEARCH CENTER
AIRC ACQUISITION INNOVATION RESEARCH CENTER
SYSTEMS MAPPING
Legal Reviews
Portfolios of Data and Models: JCIDS performance architecture tech data test arch
Model fidelity
Data Item Descriptions
standardized by
Contracting, IP
Tools: cost (high) Interoperability (lack of) licensing approach (diversity) kernel/metadata compatibility classification level
in the
using
Data
source for disagreement on
inability to
aggregate or abstract data
Compile data
View or extract data
use
Rethinking Design reviews
need to prescribe commonality
involving
Consistency & Transparency
in
Modeling Methods and processes
Programs/ government/ contractors
• How we curate and use the data between government & contractors will need to evolve
Leadership session
ME session
SE/PM session
T&E session
Agile/Security session
SERC working papers
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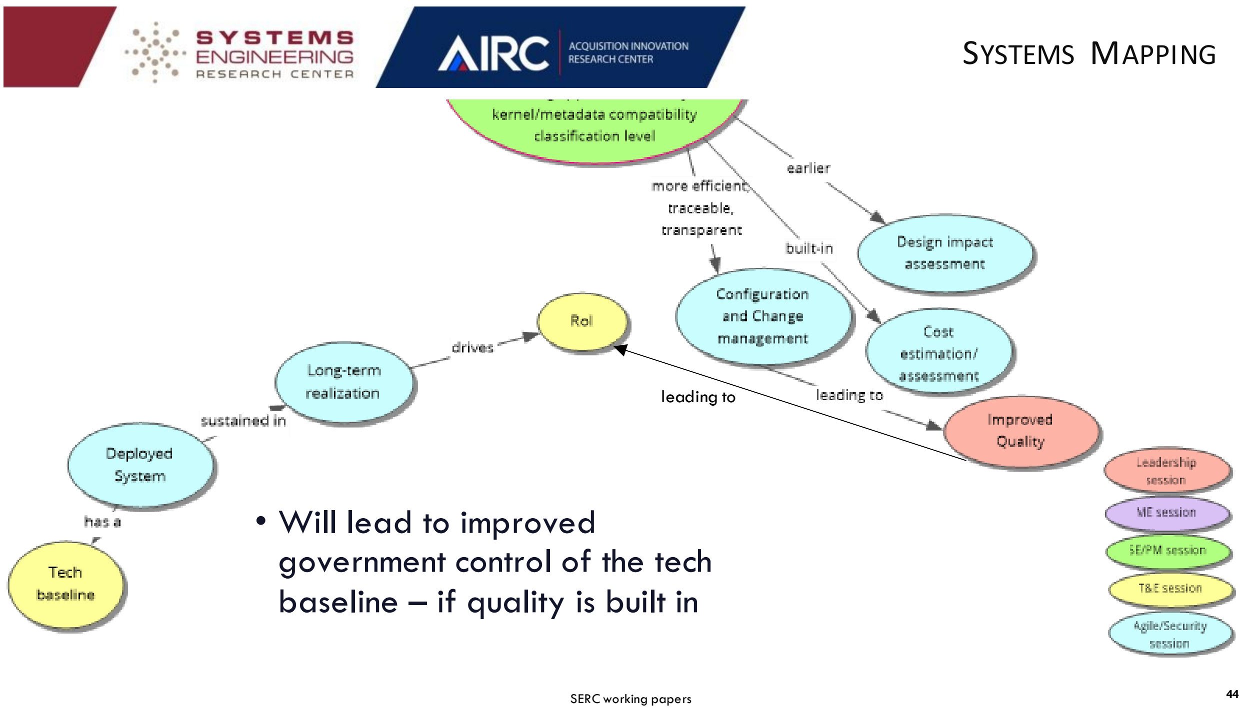


SYSTEMS ENGINEERING MODERNIZATION: WHAT DOES A FULLY DIGITAL, AGILE, AND MODEL-BASED SE PROCESS LOOK LIKE?

January 28, 2022 (Conducted in hybrid form at the INCOSE International Workshop Los Angeles CA and on Zoom)

Workshop Motivation and Intent

Systems Engineering is in the midst of several transformational changes that dramatically affect traditional practices. First among these is the digital transformation but following pretty closely is speed and agility. Combining these imperatives with software-driven technology shifts like artificial Intelligence creates an era of dynamic change for the typical systems engineer. For example, methods and guidance related to at least five SE practices – model-based engineering, agile software, mission and systems-of-systems engineering, modeling & simulation, and portfolio management – all have strong interrelationships but rather independent bodies of knowledge. Today's systems engineers need more integrated guidance. What does a fully digital, agile, and model-based SE process look like?

As stated in the upcoming INCOSE Vision 2035, "The future of systems engineering is model-based, leveraging next generation modeling, simulation, and visualization environments powered by the global digital transformation, to specify, analyze, design, and verify systems." The competitive environment for systems engineering is increasingly focused on speed, adaptability, and agile methods. Many products today create stable platforms and realize value from continuous capability delivery. However, systems engineering has traditionally focused on platform and related product delivery, implying a much stronger need to integrate mission and SoS analyses and portfolio management into the SE process. These are all precursors to future complex and adaptive systems challenges like intelligence and security. Each of these focus areas promote the idea that changes to culture and mindset are necessary to achieve success.

The US Department of Defense recently started an initiative to "Modernize SE to support the delivery of capability to meet mission needs" which implies current practices are insufficient or at least insufficiently integrated to meet their rapidly evolving mission environments. Is there a strong need to "modernize"? What focus areas should we tackle first? How are emerging and relevant practices integrated into SE discipline? How should the overall practice of systems engineering shift over time? These are all questions that must be addressed by INCOSE.

The goals of this session are to: (1) document the current state of SE with respect to evolving markets and methods, (2) identify focus areas for INCOSE that we should address with respect to evolving practice, (3) develop a set of prioritized actions or perhaps simple roadmaps, and (4) recommend/Identify key enablers that are essential to a modern approach to SE (for example reference architectures, SoS collaboration environments, etc.). The outputs of this session will be provided to various working groups to drive future INCOSE products and events.

The primary outputs of the session are summarized in Figure 18.

What is the Current State?	How do we increase collaboration & knowledge sharing?	What is the Future State?
Lack bridging/integration of engineering and other competencies (science, safety, software, security, programmatics)	Leaders not managers, need to recognize this is a digital transformation linking SE and other disciplines through data	Seamless interoperability and integration of all engineering disciplines
Hard to create collaboration, continuously, in digital environments, funding is a barrier	SE job is to communicate! Funding allocations don't promote collaboration	Continuous engineering across the globe – communicating seamlessly and remotely
Lack of governance approaches for data and models, still paper CM/DM mindset	Apply automation, remove drudge work, focus on build	Digital twin(s) that is holistic for a system over its entire life cycle
Historical approaches dominate, lack change momentum	Recognize limits of the digital technologies, build incrementally & continuously	Greater (digital) integration of SE and other disciplines including project management
Engineers lose dynamic content as the design progress, artifacts become more static, stale	Learn from SW how to build iterative, collaborative teams	The equivalent of a DevOps revolution cutting across disciplines & lifecycle
Need to move away from a static view of the system toward model-based reviews, Big shortage of experienced practitioners	Training and exposure for everyone	"How to model" is a core competency for more than just the engineering community
Need to know when we change things, are not breaking something else, not seeing full scope Lack a digital process flow handbook(s), a digital workflow with traceability to domains	Interoperability standards, tools, clouds, data across boundaries, norms for working together Recognize limits of the digital technologies, build incrementally & continuously	Tool maturity: more open, interoperable, usable, standardized

Figure 18. INCOSE January Strategy Session summary.

Detailed collected statements from the Strategy Session are captured below:

What is the Current State of Systems Engineering in DoD?

1. Mission/SoS/system complexity overwhelming existing process, need to transform at scale
2. A singular focus on "system" is obsolete, need Mission/SoS views throughout the process
3. Too many templated, over-specified pass-fail requirements, need to reflect the important model relationships
4. Too much focus on verification over validation, use, sustainment – poor definition of business <-> product
5. Lack standard ontologies/data models
6. Lack of standard processes between SE and engineering domains (no interoperability)
7. Lack bridging/integration of engineering and other competencies (science, safety, software, security, programmatics).
8. Lacking agility, need to refactor traditional processes, need agility to master rapid change
9. Need to move away from a static view of the system toward model-based reviews
10. Programs often many missing models, particularly operational/business contexts, didn't examine all options
11. Need to know when we change things, we are not breaking something else, not seeing full scope
12. Lack of governance approaches for data and models, still paper CM/DM mindset
13. Engineers lose dynamic content as the design progress, artifacts become more static, then stale
14. Historical approaches dominate, lack change momentum, need to work through impacts to people & culture
15. Requires government/contractor collaboration, lack of established processes and norms
16. Lack a digital process flow handbook(s), a digital workflow with traceability to domains
17. Hard to create collaboration, continuously, in digital environments; funding allocations can be a barrier
18. Big shortage of experienced practitioners
19. Too much focus on new technologies/products over how we engineer things

How do we increase collaboration & knowledge sharing?

1. DoDI 5000.88: "Collaboratively perform", "make data and artifacts available"
2. SE job: communicate! How can we help? You won't have to wait on us…
3. Leaders not managers, need to recognize this is a transformation, many maturity levels
4. Funding allocations don't promote collaboration, need portfolio strategies
5. Interoperability – new to SE: standards, tools, clouds, data across boundaries, new norms for working together
6. Recognize limits of the digital technologies, build incrementally & continuously
7. Government/contractor boundaries, disciplinary boundaries – people learn by copying others' strategies, not enough examples yet
8. Training and exposure for everyone
9. Learn from SW how to build iterative, collaborative teams
10. Apply automation, remove drudge work, focus on build, learn from DevOps transformation

What is the future state of SE?

1. An idealistic vision for SE Mod is needed for graduates to go into the workforce looking toward seamless interoperability and integration of all engineering disciplines
2. Continuous engineering across the globe – communicating remotely is key – some engineering disciplines do this well today but not integrated at the system level
3. Greater (digital) integration of SE and project management
4. Digital twin that is holistic for a system over its entire system development life cycle
5. The equivalent of a DevOps revolution cutting across disciplines & lifecycle – leaders have joined the quality with speed and consistency bandwagon
6. "How to model" is a core competency for more than just the engineering community
7. Not getting dragged down by data loss/data impedance
8. Tool maturity: more open, interoperable, usable, standardized…
9. Digital tools improve the SE practice and number of programs/organizations doing SE

June 28, 2022 (Conducted in hybrid form at the INCOSE International Symposium Detroit MI and on Zoom)

Follow-on Workshop Motivation and Intent

The strategy session at the INCOSE International Workshop in January 2022 discussed the concept and need for SE Modernization, resulting in a summary set of current state and future state attributes of modernized SE reflected in the table at the bottom of this page. Linking to these themes we would like to explore SE Modernization around three mental models: SE as a seamless data-driven activity; SE as continuous and agile across any life cycle; and SE as enabled by evolution of digital tools. The attached readahead provides additional information on the development of these mental models by the Systems Engineering Research Center (SERC).
In this follow-on workshop we focused on SE Modernization as a digital transformation. Attendees were asked to be prepared to discuss these questions:

1) Can you provide concrete examples of progress toward this future state: seamlessly shared and authoritatively managed data used across disciplines?
2) What are the top 2 barriers to enabling digitally iterative design?
3) What aspects of tool integration prevent you from realizing the vision of seamless data exchange? What 2 tool features would you change for data exchange?

The primary integrated output of this session was the need for and initial definition of the Exemplar Reference Implementation discussed previously.

The detailed collected notes from the workshop, by question, are below. Pain point related comments are highlighted in red text.

Q1: Can you provide concrete examples of progress toward this future state: seamlessly shared and authoritatively managed data used across disciplines?

1. Mike Spatz MIT: MIT developed connector-ware to run through various analysis codes (finite element), and coupled to MBSE models. Enabled by writing “one end of” the code. Talks available, but maybe not paper
    a. developed connectware, cadware, thermal performance combined — Coupled to MBSE models - modify requirements on other side
    b. We are trying to get magic draw coupled and it is more painful
    c. They won’t change it for us*
    d. We have connected MBSE to FTK, PLM, and FEA. And it works
2. Curtis Potterfield from Boeing: Approach that connects electrical design to the signal model. Has approach, looking for software that implements it.
3. Network design layout takes interface connections
    a. We have practical implementation
    b. Main artifacts
    c. Box to box
    d. Design info to the architectural model
4. Steven Dam - Missile Defense agency: Matlab with Innoslate and STK, working with NASA “break the ice” challenge with ANSYS/CAD toolset. Working on high-energy laser test bed. Portfolio management office working on naval secured power testbed, set of PMOs to use for naval resilient power Automated ships.
    a. We are doing a lot of this now

   b. We found you need to be careful in MBA research
      i. To not be fully seamless
      ii. Need test points
      iii. "Garbage in garbage out"
      iv. Don't have the true physics to model this, not all the physical understanding exists to model these systems.
      v. I.e. used Artificial Viscosity
      vi. TOM - one model for everything is not necessarily the idea
      vii. Need to calibrate the model to experimental data.
   c. Videos, webinars all on website
   d. Q: are you using these tools to dev requirements, concepts, systems, etc?
   e. A: ALL of it
5. Mark Petrotta "The N^2 problem", the exponential explosion of tool interconnections/interoperations. Problems with differences in modeling styles. Having a curated list of modeling artifacts helped to address startup friction. Incentivized reuse of models. Comment on ASOT: may mislead people into assuming a centralized service.
   a. everything talking to each other issues
   b. 2 SysML models.. a lot of work, impedance mishmash of styles
   c. Movement against centralization — not our intent…
   d. "Asot" and ideas imply centralization but…
   e. Inventory discovery: curated list of model assets and digital artifacts very helpful
   f. Addressing what is out there/ registering
   g. An index of available assets helped to know what is out there
   h. Encourages multiple utilizations or longevity for models/reuse characteristics
   i. Stepping up the level to index the digital assets
   j. ASOT - authoritative for whom?
6. Lessons learning
   a. What represents the milestones? We can prioritize the types of data as you go down this architecture… need higher fidelity because of cross-product communication
   b. If we can look at the adaptive reference framework and requirements we can prioritize data. (may have missed some of the chains of steps). Currently, there are a lot of assumptions about what will be reused. Concern about where the money will come from for curation of data/prototypes. The data has to be captured within a database, which needs to be flexible enough to store arbitrary data.
7. Common domain problem — would be helpful to have a strategy or guide
8. OMFV - how to build our data architecture? Bc we can't export everything
   a. Having to make a lot of assumptions about what could be reused
9. We can only control so much —
10. when program runs out….. budget/funding issues!
11. Need to be able to capture and curate the data in a DB tool
12. We have storage for artifacts
13. Tie it to decisions, what was there, crack what is going on and determine what is [needed]
14. Bill Fetech, Mitre – Synched DOORs to Cameo via data hub which acted as source of truth (automatic or manual)
15. Bill Fetech, Mitre – Process model synch with these instantiations
16. Laura Hart, LM – Same integration of DOORs to Systems Models via DataHub. Various system tool vendors. Implementation of OSLC also applied.
17. Laura Hart, LM – Jazz environment synchronization, change requests, defect reports, etc. integrated. Required complicated upfront planning. Was a homogeneous environment. (Rational tool suite)
18. Robert Raygan, DAU - AFSOC - MC130 Amphibious Capability (MAC) AFRL 6.2 funded Rapid Prototyping with flying prototype in two years. Multiple subcontractors collaborating with operations in virtual environments through SysML and other models.
19. William(GTRI)- We have also synched data between Cameo and DOORS using DataHub
20. Bill Fetech - MITRE - Prototype syncing Siemens Team Center and DOORS
21. Example. Raytheon IRAD 'Lighthouse' Programs POC. James Teaff

a. Lighthouse provides authoritative sources of data models to also feed other areas (i.e., supply chain, product line engineering, SW ENG and SW factories)
b. Considered pathfinders and are considered Digital Engineering Ecosystem pilots
c. Realize the digital thread with a set of actively linked data stores, database of SysML and UML models
d. All tools are linked together, where data models are all tied together
e. Change propagation – changes are propagated with the ability to conduct change impact analysis

22. Navy Combat System Configuration Control Board has a single repository;
    a. Navy moving toward public-subscribe in the future (API) implementation and Common Data Repository
    b. In the Navy, Enterprise/corporate funding has been applied to host authoritatively managed data (Shipboard Combat Systems); DODAF like artifacts; manage who can change the data; configuration control board approvals
23. MBSE Demonstration (Alan Dianic) get to SRR w/o traditional artifacts. "Model-based SE Phase 1" @ Chantilly customer. Integration with DOORS to analysis framework. M&S to determine buildability. Effort to process models to generate required text-based documents. Survey of industry; Ford does model-based requirements in model only, down to component specs. Requires tools and models that can map to each other. A common ontology would be helpful.
24. L3 Harris (Sundar Thyagarajan). MBSE digital engineering across the board (Eng'g disciplines only for now). Customer driving need for MBSE. Requirements driven. DOORS or other tools used (Data Hub to Cameo). Focus is on model-driven milestone tools.
25. Not seeing much seamless sharing. Why? Security, IP, data ontologies are pain points.
26. AFRL WeaponOne. (Troy Snow) Digital Agile Open pilot.
27. PEO Weapons Digital Acquisition & Sustainment Office – (DASO) (Troy Snow). Gov't Weapons Reference Architecture was developed. Follows Dr. Roper's tech stack concept.

Q2: What are the top 2 barriers to enabling digitally iterative design?

1. Computational approaches are limited by the necessity to do at least occasional physical testing, usually some physics you are unsure about.
2. Steven Dam - do testing to make sure your model makes sense
3. Can especially be a problem when wanting to understand "a generation ahead".
4. need to understand the regional validity!!
5. But it is not documented ! ** agreement between parties** Lack of documentation about model assumptions.
6. Tom - data is referenced by model, not putting data into the model Important not to put data in the model (hardcoding?).
7. coming from software - Data best as something like a config file. Should not have headers in model saying how the data is computed in model —- should be separate "data" file explaining the data
8. Pain points - lack of domain signal
9. Idk what I should be preserving for data??
10. Even if I know what should be prioritized — how to structure, keep over time?
11. How to prioritize which data is worth retaining, and lack of data architecture.
12. Value lies in comparing differences in new data vs reference data.
13. context of looking at holistically or as a group?
14. Many people looking over a large group — who owns the data, who uses it?
15. Ref architecture for MOSA -
16. Pattern people work - potential answer is when a digital program learns something it should/could feed back into the program
17. Not preserving the entirety of that Instance, but an extraction of the original?
18. Q: example? A: i.e. microwave self protect system prototype
19. Air Force may have done something similar but you make more and more of your architecture across disparate systems the same I.e. dependencies, etc.
20. Like a wiki where people can decide to reuse

21. Comment - I don't think there is a place to put that data
22. A lot of data is stored in different domains
23. When you have shared data, does it become authoritative when you pull it into your program or before?
24. Comparison between Git and Wiki in terms of the speed and gravity of immediate change commits.
25. our community needs some sort of way to accept into "stacks"
26. Cost of being wrong
27. (referring to Git still) not allowed to commit into Master branch - but would be development branch
28. You know what the output is supposed to be with software
29. It is one thing when you are building something.. but is another thing when socio-technical stuff is involved and it could be [unpredictable output]
30. DARS? **A GOOD BAD EXAMPLE* DARS originally an architecture repository, became instead a registry because of access control issues(?). Everyone's AV1s were supposed to go in DARS, but they couldn't go in , no one knows how to use it - was supposed to be a report/summary of what they did - classification issues - how to get to it
31. if you are using a feedback process - people can choose what aspects to use
32. Model curation in defense is an issue with long times required to find models.
33. Organization learning systems - challenge everywhere
34. People check off boxes - too many
35. How to acquire org. Knowledge
36. But even more so how do you apply it?
37. Potential issues with checklists
38. potential one-off issues that become hard design rules or inaccessible data.
39. Historical data also helpful for knowing how to bound assumptions about future systems, but requires strategy.
40. Problems extend beyond tools.
41. NASA gold rules….cost it takes to go through all those checks
42. how much data do we store? — Ans: enough to make those distinctions
43. this idea predisposes that there is a higher level of strategic intent that all of our systems have — branch of same tree — all hungry for CONTEXT - to make "healthy" assumptions, bc it will take time to implement
44. Easier if we can have confidence in our assumptions
45. Knowing what the priorities are would be helpful
46. Technologies necessary to evaluate
47. We need strategy and guidance
48. JCIDS staff - supposed to come from them
49. mystery area, of how the circles connect
50. mostly PowerPoint [for communication] – lots of design by powerpoint in defense.
51. Navair as an example
52. How do I derive a system
53. Disconnect between JCIDS process and the acquisition process pathways….. policy level work to make that more seamless
54. I.e tool focus…but a lot
55. Current organizational structures get in the way of this
56. Ability of human beings to summarize and reuse the Mass amount of data?
57. Collaborative environments that have all the tools. Air Force experience is with stovepipe platforms. More than tools, also includes the configurations of the tools.
58. Classification of models and migration between levels and compartmentalizations/access
59. Willingness to share methodology and design for concerns of IP, etc.
60. Stakeholder collaboration and learning curve for implementation (customer base as well as partners). More than a contracting and tiering issue.
61. Culture is risk adverse and change reverse
62. Contracting and business process not designed to enable iterative development and delivery
63. Functional Area training & tools incompatibility (eg. PM, Business System, Engineering, Sustainment, etc.)

64. Industry lacking MOSA implementation
65. Non standard data models and interfaces
66. Lack of standardization for model based methods across the enterprise
67. Program/Project Managers (PMs) There is a need to move towards Product Line-based Management vs. Project Management
68. Transition from defining/developing an end-product to transitioning to a DevOps Team
69. AGILE- SCRUM adoption required: static deliverables no longer useful in addressing today's complexity
70. Managing Runaway Requirements
71. There is a need to manage running (runaway) requirements
72. Consider 'Is there a limit to how fast to how fast we are iterating?'
73. Mindset of developers requires consideration
74. Bear in mind 'how stable' requirements are
75. Identification of 'what job(s) need to be done' is needed
76. Cost Control is a challenge in the design of the iterations (TM)
77. The quickly changing language associated with the technology (LP)
78. Language between Sys Eng and SW Engineers (TM)
79. Integrated Product Teams (IPTs) that aren't really integrated (SEs, SW Eng, and Specialty Eng)
80. No common ontologies for system-level interoperability.
81. I/F between models and between levels of models not well defined. Hand off from system level models to lower level models not matured.
82. DoD has not issued guidance on how to enable digitally iterative design on programs. Industry is developing approaches.
83. Workforce transformation & culture change is needed
84. Impediments/ discontinuities in the tool chain and development environments. Emphasis is on getting things done and not on this required continuity. This is an Enterprise-level issue.

Q3: What aspects of tool integration prevent you from realizing the vision of seamless data exchange? What 2 tool features would you change for data exchange?

1. Inoslate designed for tool integration (company formed out of frustration from the lack of interoperability of tools)
    a. Based on SQL database, has security and authorization features.
    b. How can we bring design engineering space and tools together - to do exactly that
    c. Open standards
    d. Open API
    e. Cloud computing - interaction
    f. Need a way to interact and work together "network centricity"
    g. Iron bank, containerized, Secure
    h. We are a MOSA
    i. Sequel server database is our bottom layer
    j. The openness is what is great to get to their data without being locked out by vendors
2. never going to happen long term… get rid of the idea that data has to move from tool to tool, then the default is just to have access to the data
3. Q: to exchange all data?? What data is needed.. Some sort of strategy
4. Data may forever be stranded due to tools changing, occasionally with breaking changes.
5. OSLC connection/use is not full issue, how the data and what data is needed must be identified for information exchange. (Not a magic solution, configuration and pre-definition is needed)
6. Tool licensing restrictive on use of certain tools, especially if off shore (ITAR)
7. For SE, SysML should mandate consistency with UAFML
8. No equivalent (SysML like) framework standard for managing requirements
9. Standard implementation of reference architectures and reference models
10. Integration of Val/Ver for sim based verification
11. Holistic Product Line Variation Management & Version Management
12. Need holistic product line variation management and version management for all the data in the digital thread

13. Interoperability with Others
14. When we specify requirements and operate SE skills we do not put sufficient focus on interoperability with others, and forward interoperability with future systems. we tend to myopically focus on the thing, not the relationships
15. Contractual Obligation
16. Use of DE and other practices should be specified in the contract if you want to get it done
17. Digital Trinity
18. Use of DE, MOSA, and AGILE necessary to enable operation in a total immersive environment
19. Fit-for-Use
20. Models should be fit for use
21. Rules-based
22. Models should be rules-based
23. Aspects of tool integration that prevent you from realizing the vision of seamless data exchange:
24. Vendor/Tool Lock prevent progress; The movement of data between tools needs to be streamlined.
25. MS Products – Current Tools have rudimental exchange.
26. VISIO is an example of a fairly interoperable tool (TM)
27. Two tool features you would change for data exchange:
28. The Exchange of Graphics is very limited
29. Tools that support language interoperability (e.g., 2 names for 1 object)
30. Common Data Scheme names
31. Common renaming of objects/components
32. Aspects of tool integration that prevent you from realizing the vision of seamless data exchange:
33. Problems achieving bi-directional traceability between tools. e.g. DOORS and Cameo
34. Proprietary data formats often make data exchanges fail. Many times this is an IP management issue. Lack of interoperability between different vendor products.
35. Lack of standards on APIs that tie tools together
36. Two tool features you would change for data exchange:
37. Standardize data interfaces among tool and tool vendors. Government would need to drive this
38. Non-technical user experience needs to be part of operating the tool. Different classes of users? For example: Architects, Modelers, Reviewers.

Summary: what is really needed is a set of data interoperability and exchange reference implementations that good be starting places for programs to build their SE Modernization journeys. A representative starting place is perhaps found in OSLC and OpenMBEE. This is a recommendation and a roadmap drafting activity for the SE Mod project - Can the gov't team start up a strong community working activity?

SYSTEMS ENGINEERING PRACTICES, WORKFLOWS & DIGITAL ARTIFACTS IN A DIGITAL ACQUISITION THREAD

February 22, 2022 (Conducted on Zoom, jointly with DAU)

Workshop Motivation and Intent

DoD and academia SE practioners will engage in open discussion and facilitated breakout groups during the workshop. Participants will support identification of systems engineering processes and digital artifacts most likely to be impacted by Digital Engineering transformation (e.g., establishment of technical baselines), and determine what if any policies/guidance are impediments or those that need updating to fully implement the Digital Engineering Strategy. Also, an assessment of what skills/competencies the SE workforce will need to perform their SE functions will be discussed.

PURPOSE OF THE WORKSHOP: The intent of this workshop is to develop an understanding of digital artifacts and impacts to the systems engineering workflow using model based acquisition processes. This effort will also provide insights into gaps existing in current workforce skills, policy & guidance that are essential to implementing a Digital Acquisition thread. This workshop is one of several workshops, surveys, and information sessions that will provide an understanding of which digital artifacts support SE Workflow. An additional goal is to support DAU Development of a Pilot as an exemplar for a SE Digital Acquisition thread.

EXPECTED OUTCOMES:
1. Develop a baseline set of systems engineering processes most likely to be impacted by digital artifacts (e.g., SEP and other documents) and data-driven practices in Digital Engineering transformation.
2. Identify and explore existing gaps in SE Workflow associated with digital artifacts with an emphasis on SE Modernization Focus Areas and enablers.
3. Detect dependencies associated with the transition of these processes along with the relative degree of difficulty. The degree of difficulty will address dimensions such as talent development, infrastructure, data, and so on.
4. Develop an understanding of the updated or new skill sets and SE Competencies

Our goal is to use the outcomes of this workshop to support the continued understanding of the impacts of how the transition of the acquisition community embracing Digital Transformation will have on SE practices and related artifacts. We will use the outcomes to further understand and:
1. Refine or expand our current set of pain points.
2. Develop common areas of focus for our follow on workshops.
3. Understand the gaps in workforce practices & related skills.

Summary outcomes from the workshop are presented in Figure 19.

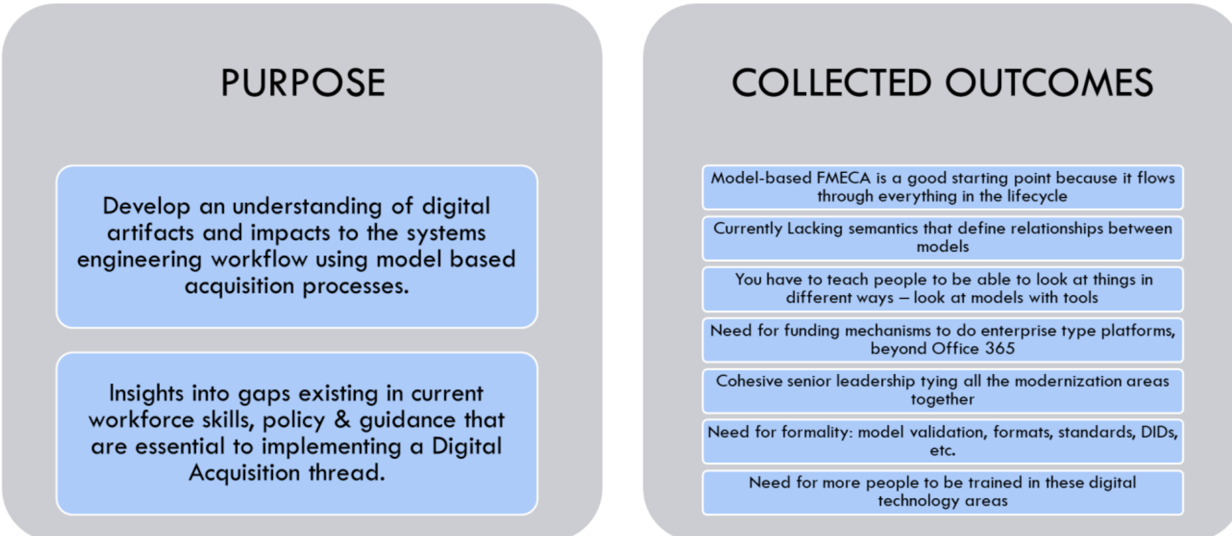


Figure 19. Summary outcomes from the Digital Artifact workshop.

Detailed comments are captured below. Pain point related comments are highlighted in red text.

Q1. Across a full digital acquisition thread, from initial concept definition to sustainment, what are the primary digital artifacts that are needed to allow different acquisition functions to collaborate around models and data?

1. M Gangl - We are working on this heavily in the Air Force
    a. From operational to acquisition to testing and sustainment.
    b. We have an activity right now we have the new weapons center people – global strike command.
    c. ISR sensors – working requirements in Doors. Also developing mission conops and description and using that model to link behavioral and structural to acq programs that are providing platforms that support that.
        i. CAMEO Licenses, SysML models
        ii. Further down the line working with Siemens
        iii. Working operational analysis and tradespace using AFSIM and STK
        iv. Variety of programs
2. Walt T: specialty engineering – instantiating into DE, assuming a program is already doing that.
    a. FMECA is a good starting point because it flows through everything in the lifecycle
    b. Model-based FMECA, have a whole list of lessons learned and challenges – interoperability, access (live or CM controlled)
    c. multi-level security
    d. Have a paper in IEEE shortly
3. M Gully – SysML model, Cad models, SW Source Code, CCA Design Models (multiple but notably a schematic), VHDL Models
    a. SysML models consists of many views. But SysML gives “hooks” to link in other digital artifacts. It’s the starting point.
4. Tracee Gilbert: https://www.incose.org/incose-member-resources/working-groups/transformational/digital-engineering-information-exchange
5. Walt T: DE into all R&M. Making assumption that program is already going down DE path with viewpoint.
    a. FMECA
    b. Flows through lifecycle starting with engineering.

6. Allan D: SysML doesn't include semantics. Need relationships between models, need some work to have common semantics. That can undermine or complicate things.
    a. logical data model that fits what one program is doing versus another
    b. definition of a reference architecture is a difficult thing that is fit for purpose
    c. How can we create a unifying approach to defining these logical models?
    d. Extent to which the process bureaucracy drives engineering – artifacts in paper or on the wall
    e. need to transform how we are used to consuming data to looking at the models and analyses
    f. works well when it works continuously
    g. if they don't see specific views or analyses (traceability) they get uncomfortable
7. Gully: Models have to be built with common design methodology but the language itself is semantically rich, if you're using the language as intended, then you are a long way down the road. The tools don't force you to adhere to construct of language.
    a. Assumptions are made
8. Walt: Need Gerber or ODB++ files along with the BOM for PCB design.
    a. https://www.vse.com/blog/2019/10/29/gerber-files-explained-understanding-their-role-in-pcb-manufacturing/
    b. https://www.vse.com/blog/2019/10/29/gerber-files-explained-understanding-their-role-in-pcb-manufacturing/
9. Walt: With FMECA, we have list of lessons learned. Some of the outcomes were model interoperability between prime and subs. Access was a big area (live or version control). Big challenge was integrating subsystems and multiple levels of security that have to be dealt with. There's still a lot of things in traditional tools that need to interface with SysML model.
    a. Will have paper shared in IEEE on this
10. M Gangl: When we get to mech and electrical CAD products we in the DAF are trying to figure out what details we really need. Getting the whole tech package may be difficult and costly. So what is really needed for sustainment and dealing with DMS really needs to be planned.
11. M Blackburn: NAVAIR – tech models linked together – at component level, used semantic tech for interoperability. Brought it into descriptive models, but didn't want all the info. Had metadata.
    a. NAV sys model, formalizes structural analysis and behavioral analysis that allows them to go through different levels of reqs.
12. Allan: Extent to which process bureaucracy drives engineering
    a. Paperwork – working with them to walk through model. We need to transform from the way we used to consume text-based data and being able to look at model with tools that can help us with analysis. How reqs are integrated.
    b. Creating an environment that will allow us to do this digital instead of manually once and for all
    c. You have to teach people to be able to look at things in different ways – that is part of the education process and demonstration on how it can be more efficient and effective
13. Gangl: Behavioral model of software for mission CONOPS, written to execute behaviors. Tool tested performance and validation of reqs which was fed back into behavioral model.
    a. Use case on how to use MBSE models and T&V code without having to do flight tests

Q2. What are the primary barriers to sharing the data and information as it transitions across stages of the acquisition process?

1. Interoperability
2. M Gangl: Lack of funding mechanisms within AF to do enterprise type platforms. Limits sharing.
3. Greg H: Requirements management- Putting reqs directly into model instead of Doors. Looking at education to educate various PMs in reqs process and being able to share those resources across various programs to help prevent recreating the wheel.
4. Mark B: Same with NAVAIR.
5. Walt T: For the MBE FMECA SOW we are requesting access to models and data via pre-defined views in the MBE FMECA Profile DID (SysML Version)

   a. We hosted the XML file and human readable files on the DSPO ASSIST database....it was successful during the pilot with programs and industry.
   b. Requesting access frequently
   c. When you are between versions, they don't want govt to access the models
   d. Contract language is "toughest nut to crack"
6. Mark: Config Management is more text oriented, we should use the term "model management. EVM can be done differently, more continuously. Government needs to have some approach to get to the contractor information in their environment, need to be able to ask for these.
7. M Gully: Resonate with the lack of enterprise tools. At this point we've taken it as an assumption that we won't have a common set of enterprise tools for the Army so we're diverting attention to looking at standards for data formats/data exchange IAW the DAU Digital Thread definition of a framework
8. R Raygan: AF research lab included open systems architecture as a model
9. Interface with contractors challenges
10. Mark: web-oriented view of model information, rendering that contractor can provide, need to be able to ask for those kind of things in the future
11. Gangl: Looked at Cameo collaborator as a way to allow people to view and make comments, without making changes to the actual model
    a. need Guide to managing view accesses between gov and contractor
    b. need Guide to managing contract language for digital engineering
12. Gully: This is a complicated problem. Which data do I need to own? Access? What does govt need to acquire vs see and review?
    a. Aware of IP Cadre, but within HQ and program office, the ability to consume all of the information is an overload. That's a challenge in itself. Deep dive in a bunch of different subjects.
    b. You can go and find specific things – need the senior leader elevator speech that seems to relate all of these together.
    c. Programs are having to use single use CDRLs to acquire any kind of models – must apply for this because existing CDRLs are obsolete for this. Paperwork reduction act is hard to get through.
13. Matt E: Behind the "8 ball". Not holistically working in synchronized fashion.
    a. Grace: MOSA implementation, using DE will help identify opportunity where MOSA concept can be applied. Each PM is taking shot figuring out what is good for particular program, but not holistic. Still long ways to go.
    b. ASOT: Each PM thinks authoritative
14. E. Fallon: Potential general pain point to go along with the lack of cohesive senior leader tying all of the modernization areas together are showing the value of using the digital environment. Organizations need to see that the cost of the modernization is worth it and not just another requirement being levied on their already tight budgets.
    a. What is the digital environment replacing, not supplementing, in the acquisition process

Q3. What new acquisition related functions need to be developed in this thread?

1. Gully: model validation
   a. If we are going to accept the model then we have to understand how we will evaluate it that model and if it is valid to begin with
   b. Looking at paperwork reduction and impact that is having on models
2. Raygan: What does DE thread look like? How much can be updated?
   a. https://www.dau.edu/aafdid/Pages/about.aspx
3. Hill: procurement of resources and how to better streamline that process
   a. Procurement process can be a barrier
4. Allan: How information to gov is delivered and what does that look like
   a. Get acceptance to DE moving forward: CDRLs. How do they have to evolve to capture delivery but also the expression in data environment that expresses maturity for the system that is being defined
5. Mark: Simulated source selection

6. Gully: probably need to start avoiding the boilerplate CDRL language, "Contractor Format Acceptable" . Worked fine for documents but not for models
7. Walt: Yes, that is exactly what we "did" with the MBE FMECA Profile Data Item Description (SysML version.

Q4. What are the primary gaps in role definition, skills, and training?

1. Greg: Training in reviewing models and artifacts, becoming comfortable in that environment.
2. M Tucker: Same hurdle in DE: being aligned with defining baseline. Digital Twin. Definition varies from person to person, so before training people on how to use it and integrate it, we have to get aligned definitions.
    a. Create a digital engineering 101 brief
    b. Have a community of practice with monthly meetings and working groups
3. Raygan: DAU ETM-1020/2020 Digital Literacy foundation and practitioner
    a. New curriculum
    b. 1070/2070
    c. We tried to make it a point to very specifically define things like digital twin, thread, etc.
    d. Have a DE workshop
4. Gully: Not sure it's a gap in training; more of a need for more people to be trained in some new technology areas (MBSE, Data [integration/analytics/transformation], cloud migration). We've found that there is usually some training available but it's not necessarily known, can sometimes require additional funding, and there's a natural delay to get a majority of an organization as large as the DoD re-trained.
5. Tracee: AIAA Digital Twin Position Paper https://www.aiaa.org/docs/default-source/uploadedfiles/issues-and-advocacy/policy-papers/digital-twin-institute-position-paper-(december-2020).pdf
6. Bruce: training our work force is important, due to retention. We seem to have a lot of DE turnover in the Navy
    a. Lots of reasons for retention issues (Will have to think). The class envir is definitely a roadblock.

APPENDIX B: INITIAL CITED AND RELATED REFERENCES

This is the listing of the initial 51 documents selected for the SEModBoK prototype. Asset number, Asset Name, and Abstract are the first three metadata fields.

Resource Asset Number	Resource Asset Name	Resource Abstract
N/A	Digital Engineering Strategy	The ODASD(SE) developed this strategy in cooperation with stakeholders across government, industry, academia. It is a living document and will continue to evolve to support the Department's continuing need to provide critical capability to the warfighter as quickly as possible. The strategy is intended to guide the planning, development, and implementation of the digital engineering transformation across the DoD. Initiatives focus on policy/guidance, pilots, implementation, and tools. The strategy promotes the use of digital representations of systems and components and the use of digital artifacts to design and sustain national defense systems.
N/A	Defense Acquisition Guidebook, Chapter 4 Life Cycle Sustainment	The Defense Acquisition Guidebook (DAG), Chapter 4, provides guidance for Program Managers (PMs) and Product Support Managers (PSMs) to develop and execute successful sustainment strategies, and to document those strategies in a Life Cycle Sustainment Plan (LCSP) that aids program management, communication, and collaboration with critical stakeholders.
DoDD 5137.02	Under Secretary of Defense for Research and Engineering	Establishes the position, responsibilities and functions, relationships, and authorities of the USD(R&E). Authorizes the USD(R&E), as a Principal Staff Assistant (PSA) reporting directly to the Secretary of Defense, to promulgate DoD policy within the responsibilities, functions, and authorities assigned in this issuance.
N/A	Memorandum for Secretaries of the Military Departments - Digital Engineering Strategy	This memo announces the approval of a Digital Engineering Strategy to modernize the DoD's engineering and acquisition practices. The Strategy sets a new vision for the way we conceive, build, test, field, and sustain our national defense systems. It also transforms how we must train and shape the workforce to use digital engineering practices.
N/A	Digital Engineering Strategy Memorandum	This is a follow-on memo to the 6/25 memo on the planned Digital Engineering Stategy. It further elaborates on the intentions of the strategy and contents. The strategy describes the "what" is necessary to foster the use ofdigitaJ engineering practices. Industry, Services, and Agencies are working to develop the "how" - the implementation steps necessary to apply digital engineering in each enterprise, at the level that makes sense to that organization.
N/A	Memorandum for the Acquistion Enterprise: Guidance for	Implementing the Department of the Air Force's transition to Digital Acquisition involves artful execution of the "Digital Building Code." The tabs in this memorandum provide the first iteration of the Department's Digital Building Code, and also introduce the initial version of the e-Program Criteria Scorecard used by the Service Acquisition Executive

Resource Asset Number	Resource Asset Name	Resource Abstract
	E-Program Designations	(SAE) to assess a program for an e-Program designation.
Army Directive 2019-29	Enabling Readiness and Modernization Through Advanced Manufacturing	This directive establishes policy and assigns responsibilities for the employment of advanced manufacturing methods and materials in all capability areas where the Army has an interest. Advanced manufacturing will fundamentally change the way the Army designs, delivers, produces, and sustains materiel capabilities. It will enable the Army to modernize systems while simultaneously enhancing readiness.
N/A	DoD Digital Modernization Strategy	The Digital Modernization Strategy provides a roadmap to support implementation of the National Defense Strategy lines of effort through the lens of cloud, artificial intelligence, command, control and communications and cybersecurity. The strategy also highlights two important elements that will create an enduring and outcome driven strategy. First, it articulates an enterprise view of the future where more common foundational technology is delivered across the DoD Components. Secondly, the strategy calls for a Management System that drives outcomes through a metric driven approach, tied to new DoD CIO authorities granted by Congress for both technology budgets and standards.
N/A	United States Navy and Marine Corps Digital Systems Engineering Transformation Strategy	This Navy and Marine Corps Digital Systems Engineering Transformation Strategy specifies activities necessary to enhance engineering acquisition practices within our enterprise. The strategy aligns with Department of Defense Digital Engineering Strategy goals, shifts how they work from traditional document-centric activities to digital-centric activities, and informs designers, developers, managers, and technical authority stakeholders with continuous access to authoritative data.
N/A	US Army Digital Engineering Implementation	Outlines the Army's vision and implentation strategy, current initiatives, but also challenges it.
N/A	Naval Digital Engineering Implementation Overview	Aligned with DoD, Naval and Digital Strategies. Breaking Framework up into 4 Elements: 1.) I&I Work – Develop ICTBs which inform CDDs 2.) Instantiate System Spec in SysML 3.) Decompose and Allocate rapidly, and instantiate subsystem design in models 4.) Accelerate design-to-manufacture release thru continuous interaction with Single Source of Truth

Resource Asset Number	Resource Asset Name	Resource Abstract
NA	Systems Engineering Digital Engineering Fundamentals (Including Models and Simulations)	Provides 8 steps that programs should follow to include systems engineering and digital engineering approachs.
NASA-HDBK-1004	NASA Digital Engineering Acquisition Framework Handbook	This NASA Technical Handbook provides guidance for establishing NASA's digital engineering acquisition framework that includes Data Requirements Descriptions (DRDs) and contractual language for the Statement of Work (SOW) in support of a digital engineering environment (DEE). A DEE will modernize how the Agency conceptualizes, designs, develops, delivers, operates, and sustains systems. A DEE will help enable collaborative digital engineering while integrating stakeholders with authoritative decentralized sources of data and models seamlessly across organizations and disciplines supporting life-cycle activities from concept through disposal. Digital engineering is the integrated digital approach that utilizes authoritative sources for product and system data and associated models collaboratively across all product-involved disciplines supporting life-cycle activities from conceptualization through disposal (Pre-Phase A through F). A DEE enables the interconnected data, people, processes, and technology used to store, access, analyze, and visualize evolving systems' data and models to address the needs of enterprise-wide stakeholders. It provides information referencing topics such as model-based definitions (MBD) (annotated 3D CAD models), model-based analyses (MBA), model-based systems engineering (MBSE), model-based enterprise (MBE) (aiding manufacturers to integrate system, service, product, process, and logistics models across the manufacturing/support enterprise), product data and life-cycle management (PDLM), and general guidance to adapt the methods needed to implement digital engineering product/data acquisition requirements maximizing model representations.
AD1113155	Enabling Digital Engineering (DE) in the Joint Capability Integration and Development System (JCIDS)	Digital Engineering DE is a term defined and used by the Office of the Deputy Assistant Secretary of Defense for Systems Engineering OUSDSE to encompass model based engineering but also its environment. The concept of using models in engineering to support acquisition are not new but the concepts of using DE across the system or service life cycle to enhance engineering effectiveness is new. DE also encompasses integrated models to enhance engineering activities with the intent of improving engineering to provide the end productservice more efficiently. This report will examine selected government acquisition documents to see if they contain barriers to DE, are silent on DE, or have features that enable or promote DE.

Resource Asset Number	Resource Asset Name	Resource Abstract
N/A	Air Force Materiel Command Digital Campaign	The *Air Force Materiel Command Digital Campaign* is an AFMC coordinated effort to move the activities of our enterprise, government and industry, to modern digital capabilities and processes. The desired end state is a collaborative, integrated digital environment that guides, orchestrates, and delivers the means for each individual across the enterprise to access the data, functions and elements needed to do a his or her job in a purely digital manner. This includes all functions, from acquistion to sustainment and beyond, not just engineering. The goal is to deliver capabilities to our Air and Space Force at ever increasing speed and efficiency by designing, sustaining, and modernizing them in an integrated digital environment.
N/A	Bending the Spoon: Guidebook for Digital Engineering and e-Series	This companion guide to *There is No Spoon* will equip you for those value judgments and help you pursue spoon-bending results for both digital engineering and *e*-Series. Specifically, it goes deeper on the modeling and infrastructure requirements to effect several tenants of *There is No Spoon*: "eCreating before Aviating" and owning and furnishing the tech stack. must that replaces, automates, or truncates formerly real-world activities. e-Series, engineering principle right up front: Digital Engineering must achieve a measure of authoritative virtualization that replaces, automates, or truncates formerly real-world activities.
GAO-20-590G	Agile Assessment Guide: Best Practices for Agile Adoption and Implementation	This GAO Agile Guide is intended to address generally accepted best practices for Agile adoption, execution, and control. The best practices center on Agile adoption, execution, and control. They developed each best practice in consultation with a committee of IT and program management specialists and organization executives across government, private industry, and academia.
OUSD(A&S) AAP IPMD	Agile and Earned Value Management: A Program Manager's Desk Guide	Integrating Agile and EVM together can improve traceability and visibility for project outcomes. Proper planning and scheduling relying on both techniques provides integration and coordination, promoting best practices for project management. With practice, integrating EVM and Agile has led to more success preparing for and managing the Integrated Baseline Review (IBR). This document is intended as an informative resource for Department of Defense (DoD) personnel who encounter programs on which Agile philosophies and Earned Value Management (EVM) are applied.

Resource Asset Number	Resource Asset Name	Resource Abstract
N/A	Building an Agile Force: The Imperative for Speed and Adaptation in the US Aerospace Industrial Base	The imperative to grow agile force structure means that the Air Force can no longer tolerate extended developmental timeframes. The need for speed-to-field, quantity, and the continuing acceleration of technology and processing power means that capability advancements and insertion should be delivered through new aircraft. Retrofitting weapon systems through sustainment and modernization will not be enough. The aerospace industry must not just keep pace but outpace America's adversaries in fielding new and innovative capabilities. Adaptation is the advantage, and speed is the new offset. The Air Force must change its buying behavior—in essence, create more competition—if it is to revitalize both the defense aerospace industry and its own force design. In this strategic approach, the U.S. aerospace industry must increase its speed-to-field and integrate new capabilities. This will enable the Air Force to rapidly connect, command, and create advantageous new force compositions.
19-03715-2	Modernizing DoD Requirements: Enabling Speed, Agility, and Innovation	This paper proposes a three-pronged approach to reforming the requirements process. First, the DoD should refine what it means by "requirements." Defining enduring, enterprise-level requirements within major mission areas allows for management at the portfolio level, improving alignment across systems and enabling more flexibility and innovation at lower levels. Next, the DoD should establish an Adaptive Requirements Framework that parallels the new Adaptive Acquisition Framework and provides new pathways for generating and validating requirements. Finally, the DoD should rethink how programs progress through each of the new pathways.
	Mission Engineering Guide	This guide describes the foundational elements and the overall methodology of Department of Defense (DoD) Mission Engineering (ME), including a set of ME terms and definitions that should be part of the common engineering parlance for studies and analyses, building upon already accepted sources and documentation from the stakeholder community in the Office of the Secretary of Defense (OSD), Joint Staff, Services, and Combatant Commands. This document: Describes the main attributes of DoD ME and how to apply them to add technical and engineering rigor into the ME analysis process; Enable practitioners to formulate problems, and build understanding of the main principles involved in performing analysis in a mission context; and Provide users with insight as to how to document and portray results or conclusions in a set of products that help inform key decisions.
DODI 5000.88	Engineering of Defense Systems	In accordance with the authority in DoD Directive (DoDD) 5137.02 and the guidance in Section 133a of Title 10, United States Code (U.S.C.), this issuance establishes policy, assigns responsibilities, and provides procedures to implement engineering of defense systems.

Resource Asset Number	**Resource Asset Name**	**Resource Abstract**
SERC-2018-TR-106	SERC Technical Report on Mission Engineering	This report provides the results of a 16-month study on mission engineering conducted by SERC. Supported by a literature review of mission engineering and related areas such as systems of systems and capability engineering, the research team has interviewed 32 individuals who are or have been mission engineers. The views of the mission engineering workforce provide a crucial perspective on the emerging area of mission engineering, in particular, the skillsets which characterize mission engineering competencies. The DoD has defined 'mission engineering', but there is a range of differing views of the definition and scope of mission engineering and its relationship to systems engineering among current practitioners. The differences in views are reflected in this report, including perspectives from US organizations outside the DoD as well as non-US organizations. It should be noted that mission engineering is an emerging discipline and this report reflects the current state of its maturity.
10 U.S.C. 144; 2446, Sec 805	Modular Open System Approach in Development of Major Weapon Systems	Title 10 U.S.C. 2446a.(b), Sec 805 states that MOSA is the preferred method for the implementation of open systems, and it is required by United States law. A major defense acquisition program that receives Milestone A or Milestone B approval after January 1, 2019, shall be designed and developed, to the maximum extent practicable, with a modular open system approach to enable incremental development and enhance competition, innovation, and interoperability.
N/A	Employment of Open Systems Architecture Contract Guidebook for Program Managers, Version 1.1	The Department of Defense Open Systems Architecture (OSA) Contract Guidebook for Program Managers, Version 1.1 is to be used by the acquisition community for incorporating OSA principles and practices into the acquisition of systems or services. The Guidebook contains background information on OSA and provides contract language to capture the benefits of an open architecture and an open business model to increase opportunities for competition and improve access to innovation. All acquisition professionals are directed to become familiar with the referenced Guidebook and implement its principles and practices. This includes enforcing OSA wherever applicable and effectively managing data rights over the entire life cycle of the product.

Resource Asset Number	Resource Asset Name	Resource Abstract
N/A	Modular Open Systems Approaches for our Weapon Systems is a Warfighting Imperative	For the past several years, each of the Services has been developing, demonstrating, and validating common data standards through a cooperative partnership with industry and academia. This work has resulted in the establishment of Open Mission Systems/Universal Command and Control Interface (OMS/UCI), Sensor Open Systems Architecture (SOSA), Future Airborne Capability Environment (FACE) and Vehicular Integration for C4ISR/EW Interoperability (VICTORY) among other standards. They determined the continued implementation of these standards, and further development of Modular Open Systems Approach (MOSA) standards in areas where we lack them is vital to our success. As such, MOSA supporting standards should be included in all requirements, programming and development activities for future weapon system modifications and new start development programs to the max imum extent possible. In an effort to formalize the approach to MOSA, Service Acquisition Executives will publish specific implementation guidance for our acquisition prograns.
AFPD 63-1/20-1	Integrated Life Cycle Management (MOSA instruction)	Purpose of AFI 63-101/20-101, Integrated Life Cycle Management, contains directive overarching processes and procedures required to deliver and sustain warfighting capabilities. Integrated Life Cycle Management governs all aspects of infrastructure, resource management, and business systems necessary for the successful acquisition of systems, subsystems, end items, and services to satisfy validated warfighter or user requirements. The management of systems throughout their lifecycle involves a multi-functional collaborative effort among the requirements, acquisition and sustainment, test, information operations, and intelligence communities. Details on key acquisition and sustainment activities can be found in the body of this document, referenced supporting documentation, or by using the AF Acquisition Process Model tool.
	Air Force Data Rights Guidebook	Authored by the Air Force Intellectual Property Cross-Functional Team chaired by SAF/AQ and SAF/GCQ, "...this publication is intended to equip Air Force acquisition personnel to handle common issues encountered in the realm of intellectual property (IP) acquisition under the Defense Federal Acquisition Regulation Supplement (DFARS), particularly those issues surrounding rights in technical data and computer software. It is intended to complement rather than substitute for other Department of Defense (DoD) guidebooks on data rights. While those guidebooks may present basic information and considerations for planning and acquisition, this publication presents recurring issues that acquisition personnel can expect to face in the format of frequently asked questions. Each issue or question is followed by a suggested plan for dealing with that issue.

Resource Asset Number	Resource Asset Name	Resource Abstract
70-3	Army Acquisition Procedures (MOSA Instruction)	This pamphlet provides dis- cretionary guidance on materiel acquisition management. It is to be used with DODD 5000.01, DOD I 5000.02, and AR 70–1. It contains information relevant to research, development, and acquisition, and life cycle management of Army materiel to satisfy approved Army requirements. This revision adds clothing and individual equipment in- formation and procedures for Configuration Steering Boards. It replaces type classifica- tion and materiel release information and updates acquisition program baseline, ter- minology, and organizational information.
	Defense Acquisition Guidebook 3-2.4.1 Modular Open Systems Approach	An open systems design is a design approach for developing an affordable and adaptable open system. It derives inputs from both the technical management processes and technical processes undertaken within the systems engineering and other life-cycle processes, and in turn impacts these processes. The open systems design strategy should be implemented as part of the program's overall technical approach and becomes an integral part of the program's Systems Engineering Plan (SEP) and a summary in their Acquisition Strategy.
	Open Systems Joint Task Force (OSJTF) Program Manager's Guide to a Modular Open Systems Approach (MOSA) to Acquisition (2004)	The Open Systems Joint Task Force (OSJTF) has developed a set of indicators that have been incorporated as MOSA implementation questions in an assessment tool called MOSA PART; which is a DoD adaptation of the Program Assessment and Review Tool (PART) originally prepared by the Office of Management and Budget. MOSA PART may either be used for self- assessment by program managers, or be utilized by acquisition executives to recognize when an acquisition program is following MOSA. When MOSA indicators are taken into account and adhered to by an acquisition program, there can be a level of confidence that such program has effectively implemented MOSA.
20-S-1275	Modular Open Systems Approach (MOSA) Reference Frameworks in Defense Acquisition Programs	This document is intended to guide engineering staff and decision makers in common ways to recognize and use MOSA elements to support the technical performance and sustainment of acquisition systems.
DoDD 5000.59	DoD Modeling and Simulation (M&S) Management	Reissues Reference (a) to update policy and responsibilities for DoD M&S management. Establishes the DoD M&S Steering Committee (M&S SC). Authorizes the development of DoD Publications as needed and continues to authorize consistent with DoD 5025.1. This Directive applies to all M&S tools, data, and services developed, used, or managed by or on behalf of the DoD Components after the effective date of this Directive.

Resource Asset Number	Resource Asset Name	Resource Abstract
DoDI 5000.61	DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A)	Establishes policy, assigns responsibilities, and prescribes procedures for the VV&A of models, simulations, distributed simulations, and their associated data.
DoDI 5000.70	Management of DoD Modeling and Simulation (M&S) Activities	Implements DoD M&S management activities of DoD Directive (DoDD) 5000.59 pursuant to DoD Directive 5134.0. Assigns responsibilities for the DoD Modeling and Simulation Steering Committee (M&S SC). Establishes the Director, DoD Modeling and Simulation Coordination Office (M&SCO), as the focal point for coordinating all matters related to DoD M&S, with the advice and recommendation of the M&S SC, and as Secretariat for the M&S SC. Extends discovery metadata policy consistent with DoD Instruction 8320.02 to those DoD M&S tools, data, services, data assets, models, and simulations (hereinafter collectively referred to as "M&S assets") that are key. Authorizes the publication of the DoD M&S Glossary
MIL-STD-3022	Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulations	This standard was developed by the Modeling and Simulation Coordination Office in coordination with the Military Departments. It establishes templates for the four core products of the Modeling and Simulation Verification, Validation, and Accreditation processes. The intent of this standard is to provide consistent documentation that minimizes redundancy and maximizes reuse of information. This promotes a common framework and interfacing capability that can be shared across all Modeling and Simulation programs within the Department of Defense, other government agencies and allied nations.
N/A	DoD Verification, Validation, and Accreditation (VV&A) Recommended Practices Guide	MSE supports the various DoD- and Service-level Communities by producing standardized VV&A documentation and meeting net-centric architecture requirements for sharing, discovering, and retrieving VV&A information within the Global Information Grid (GIG) enterprise. The guide MSE provides the standardized VV&A documentation templates formalized in the DoD Standard Practice Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulations (MIL-STD-3022). Also provided is the VV&A Recommended Practices Guide which is intended to facilitate the application of DoD-specified directives and guidelines, and to promote the effective application of VV&A.
N/A	DAU T&E Community of Practice	This Community serves as a platform to connect T&E practitioners from across multiple career fields, offering them a chance to talk, share, and acquire knowledge about key T&E topics.

Resource Asset Number	Resource Asset Name	Resource Abstract
DoDI 4245.14	DoD Value Engineering Program	Implements section 1711 of title 41, United States Code and Office of Management and Budget Circular No. A-131 by establishing policy, assigning responsibilities, and defining authorities for the effective administration of the DoD VE Program. Implements the reporting requirements. Establishes and maintains the VE Executive Steering Group. Establishes and maintains the VE Management Advisory Group.
41 U.S.C. 1711	Value Engineering	Each executive agency shall establish and maintain cost-effective procedures and processes for analyzing the functions of a program, project, system, product, item of equipment, building, facility, service, or supply of the agency. The analysis shall be- (1) performed by qualified agency or contractor personnel; and (2) directed at improving performance, reliability, quality, safety, and life cycle costs.
NO. A-131	Value Engineering	This Circular provides guidance to support the sustained use of value engineering (VE) by Federal Departments and Agencies to reduce program and acquisition costs, improve performance, enhance quality, and foster the use of innovation. Agencies should maintain policies and procedures to ensure VE is considered and integrated, as appropriate, into the planning and development of agency programs, projects, activities, as well as contracts for supplies and services, including performance based, architect-engineering, and construction contracts.
FAR Part 48	Value Engineering	This part prescribes policies and procedures for using and administering value engineering techniques in contracts. Contracting activities shall send contractor-submitted Value Engineering Change Proposals (VECPs) to the appropriate technical personnel for review. Technical personnel shall conduct a comprehensive review of VECPs for technical feasibility, usefulness, and adequacy of the contractor's estimate of cost savings; make a written report; and recommend acceptance or rejection to the contracting officer. The designee authorized to grant exemptions from value engineering provisions in appropriate supply, service, architect-engineer and construction contracts is set forth in CAM 1301.70.

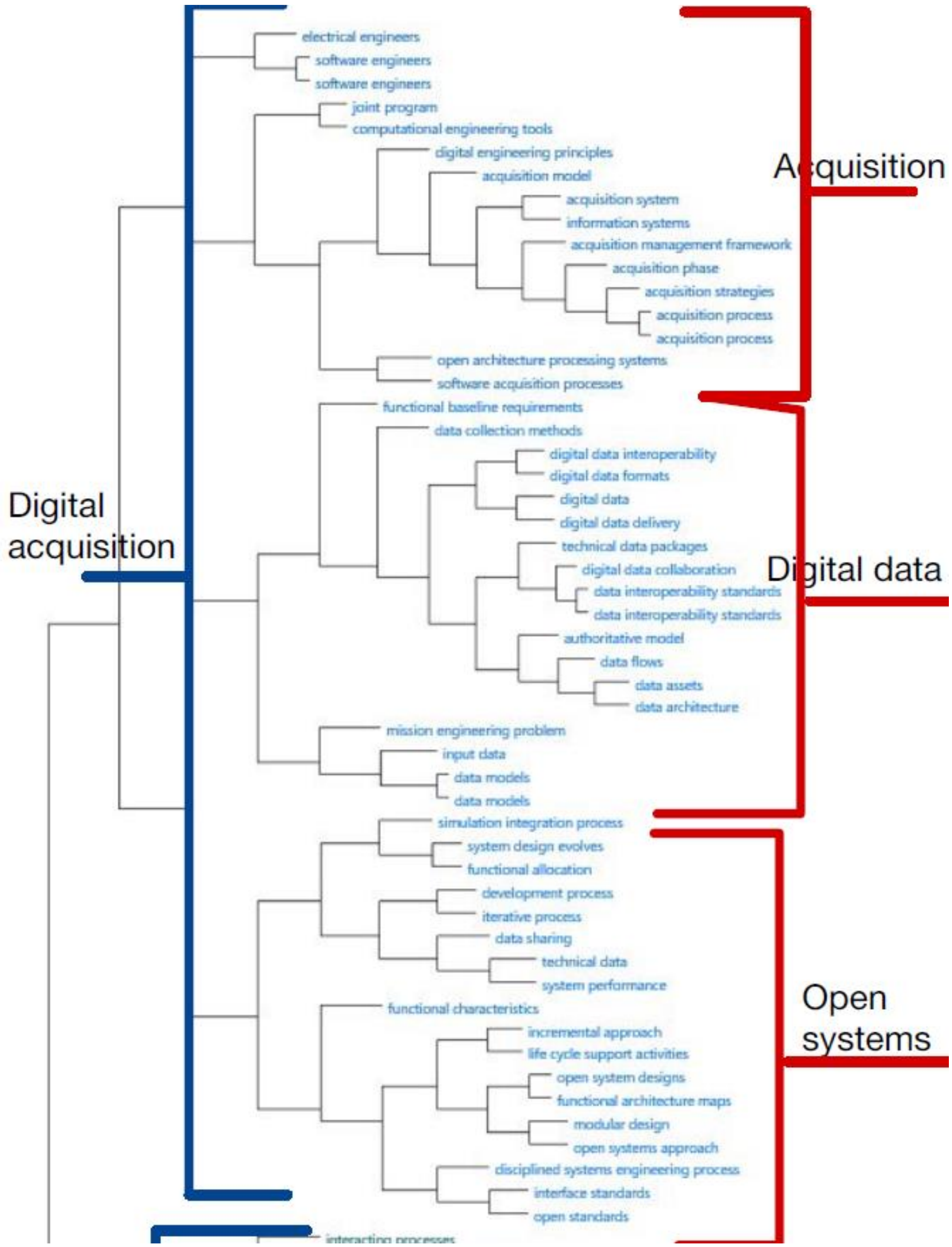
Resource Asset Number	Resource Asset Name	Resource Abstract
	Capital Programming Guide, Appendix 7, Value Management	The value management methodology (also known as value analysis, value engineering, value planning, etc.) should be considered for use in the Planning and Budgeting, Acquisition, and Management-In-Use Phases of capital programming. The value methodology uses a systematic job plan to identify essential functions necessary to accomplish an activity, analyze those functions, and generate alternatives to secure them at their greatest worth on a life-cycle benefit-to-cost basis. By following the process defined in the job plan, the use of the value methodology will facilitate the selection through evaluation and analysis of the "best value" alternative for those functions. The process provides plans and actions to acquire and implement the selected alternatives. The IPT may employ the use of the value management methodology in several ways including a professional value management specialist as a member of the team, using team leaders trained in the value management methodology, or using value specialists (either agency employees or industry consultants) to perform studies.
SD-24	Value Engineering: A Guidebook of Best Practices and Tools	This publication shows how VE can be an effective mechanism for generating cost savings or cost avoidance for contractors and the U.S. Government, gives details on the basics of the VE methodology, discusses how to establish a VE program, describes best practices for applying VE on government contracts, and provides an overview of the benefits of a strong VE program.
	(DAU) Continuous Learning Module CLE 001, Value Engineering	Value Engineering (VE) is recognized as an effective technique for reducing costs, increasing productivity, and improving quality-related features of systems, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life cycle cost consistent with required performance. It is DoD policy to use VE to make a significant contribution toward greater economy in developing, acquiring, operating, and supporting the products necessary to fulfill its mission. This module provides an overview of VE from both the acquirer and contractor perspective; how VE can be applied and implemented; and how VE Engineering Change Proposals (ECPs) can be effectively used.

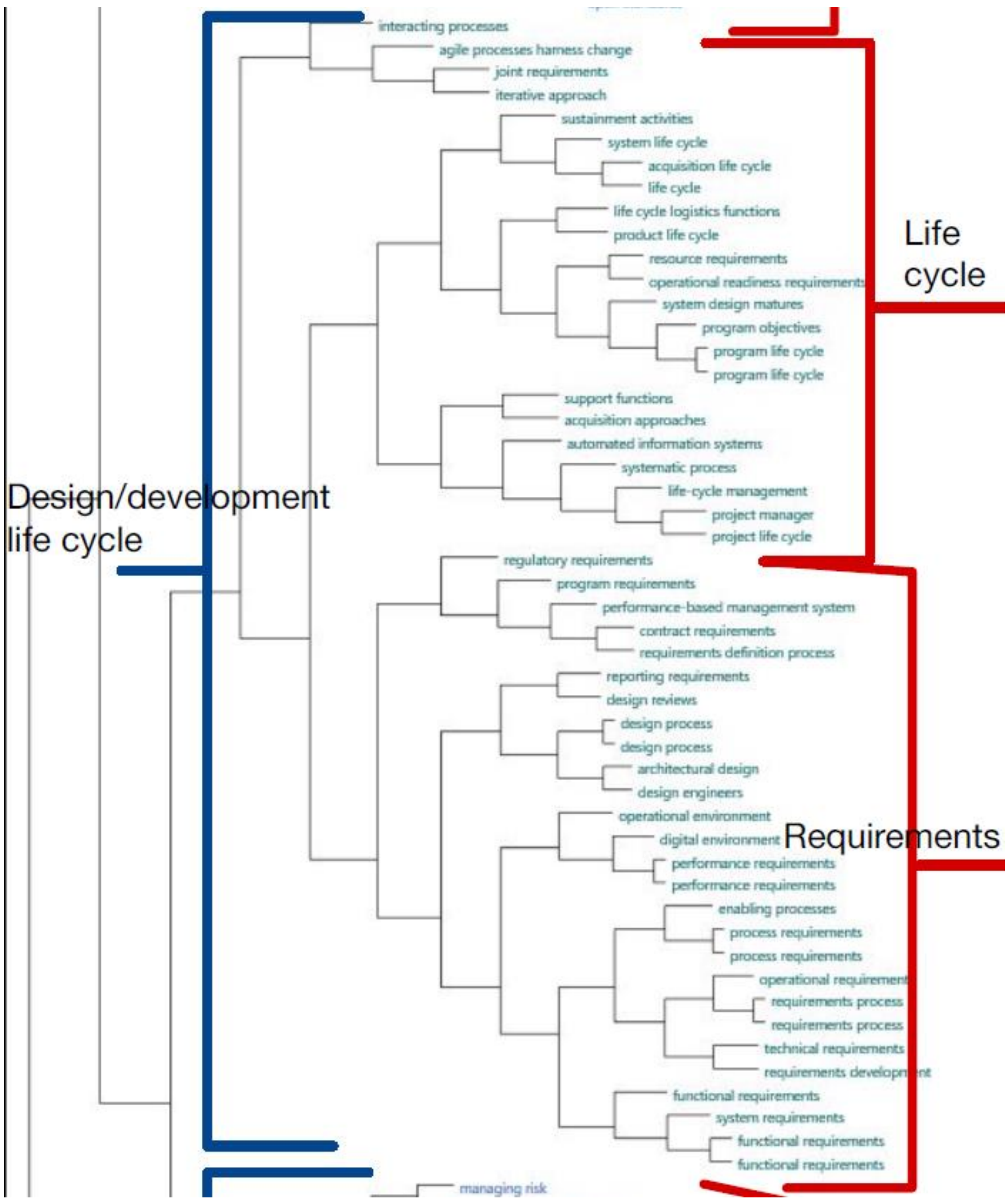
Resource Asset Number	Resource Asset Name	Resource Abstract
DODI 5000.87	Operation of the Software Acquisition Pathway	Programs executing the software acquisition pathway are not subject to the Joint Capabilities Integration and Development System (JCIDS), and will be handled as specifically provided for by the Vice Chairman of the Joint Chiefs of Staff, in consultation with Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)) and each service acquisition executive. Programs using the software acquisition pathway will demonstrate the viability and effectiveness of capabilities for operational use not later than 1 year after the date on which funds are first obligated to develop the new software capability. New capabilities will be delivered to operations at least annually to iteratively meet requirements, but more frequent updates and deliveries are encouraged where practical. Programs will require 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. The DODI 5000.87 replaces the interim policy, and completes the set of the new 5000 series instructions for each pathway of the Adaptive Acquisition Framework, along with a new DoD Directive 5000.01 and DoDI 5000.02 on the overarching acquisition system and AAF.
	Employment of Open Systems Architecture Contract Guidebook for Program Managers	The Department of Defense Open Systems Architecture (OSA) Contract Guidebook for Program Managers, Version 1.1 is to be used by the acquisition community for incorporating OSA principles and practices into the acquisition of systems or services. The Guidebook contains background information on OSA and provides contract language to capture the benefits of an open architecture and an open business model to increase opportunities for competition and improve access to innovation.
	DAU Software Community of Practice	The Information Technology (IT) Community of Practice (CoP) is focused on improving the performance of the DoD IT/SW Workforce. This community is here to support your IT/software acquisition needs. IT/Software has rapidly become the critical component to DoD's success on and off the battlefield. This community is focused on collaborating with the IT/software Acquisition workforce to ensure we engineer, design, develop and sustain world-class IT/software acquisition practices. This community touches on all aspects of IT/software acquisition for the improvement of better, faster, cheaper software solutions for all DoD personnel.
	Agile Software Acquisition Guidebook	This guidebook provides PMs with information on developing acquisition strategies for Agile software development. This guide will also support all other members of the program team by providing an understanding of Agile practices. Whiile this guidebook offers actionable information, it focuses primarily on the principles and good practices of an Agile software development approach through the lens of an acquisition strategy.

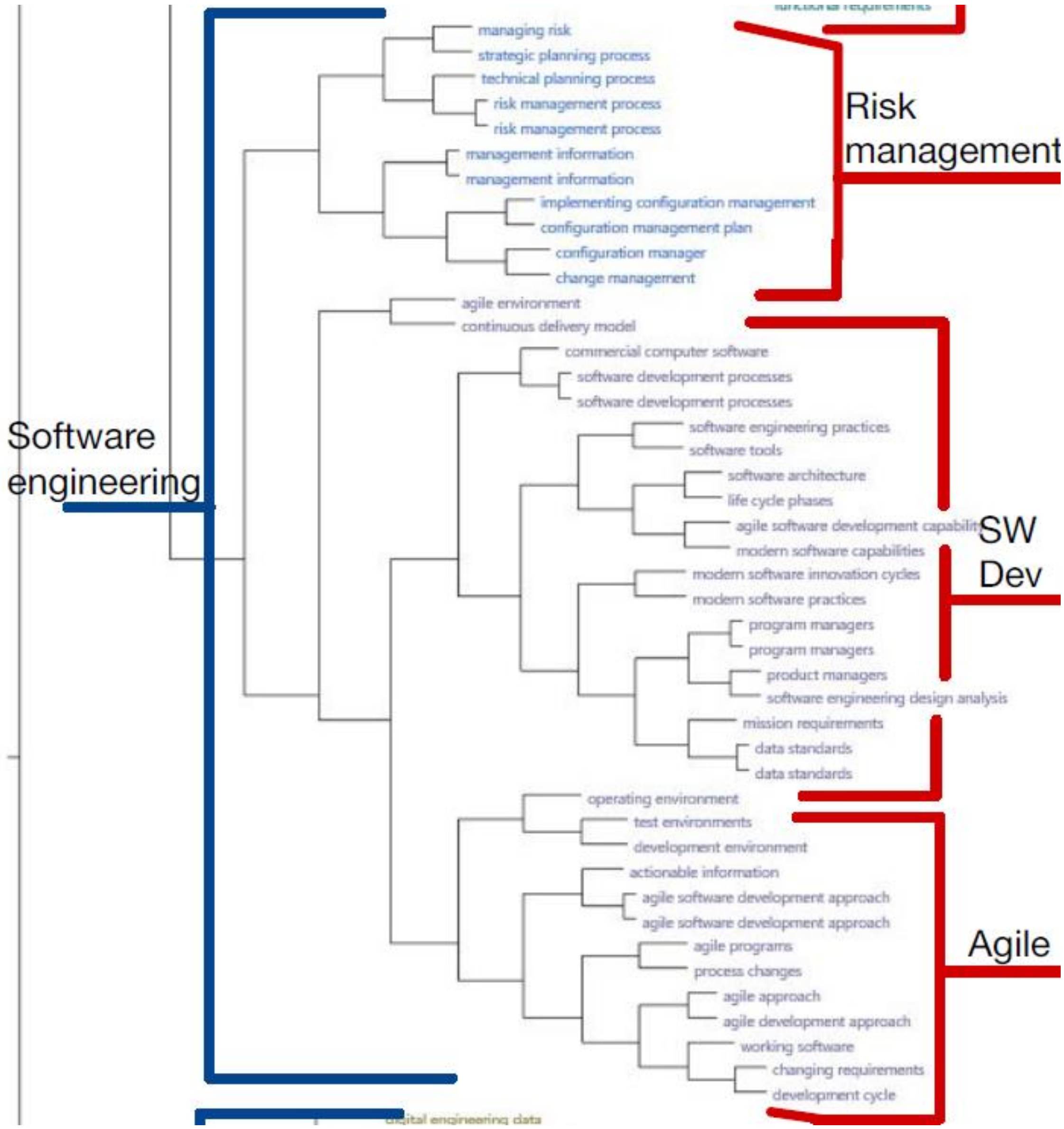
Resource Asset Number	Resource Asset Name	Resource Abstract
	Software is Never Done: Refactoring the Acquisition Code for Competitive Advantage	This report emphasizes three fundamental themes. 1) Speed and cycle time are the most important metrics for managing software. 2) Software is made by people and for people, so digital talent matters. And 3) Software is different than hardware (and not all software is the same). The main report provides an assessment of the current and desired states for software acquisition and practices, as well as a review of previous reports and an assessment of why little has changed in the way DoD acquires software, with emphasis on three fundamental themes. The report's recommendations are broken into four lines of effort, with a set of primary rec- ommendations provided for each (bold), along with additional rec- ommendations that can provide further improvements. Each rec- ommendation is accompanied by a draft implementation plan and potential legislative language.
	Report to Congress on FY20 NDAA Section 862(b)(1)(B) Software Development and Software Acquisition Training and Management Programs	This report is a continuation of efforts initiated after the publication of the 2018 Defense Science Board (DSB) report titled "Design and Acquisition of Software for Defense Systems", the 2019 Defense Innovation Board (DIB) report titled "Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage", also known as the Software Acquisition and Practices (SWAP) report, and the August 2020 initial report submitted to congressional defense committees in response to FY20 NDAA section 862(b). This report complements other ongoing congressional efforts related to software and workforce development: (1) Sec. 230. Policy on Talent Management of Digital Expertise and Software Professionals; (2) Sec. 255. Department-wide Software Science and Technology Strategy; (3) Sec. 256. Artificial Intelligence Education Strategy; and (4) Sec. 800. Authority for Continuous Integration and Delivery of Software Applications and Upgrades to Embedded Systems. Ultimately, the goal of the actions initiated by the response to FY20 NDAA section 862(b), as described in this final report, is to ensure that the defense workforce has the necessary training and tools to anticipate the demands of an ever-changing digital environment. This report and its accompanying appendices describe the approach developed by A&S and its partners to meet the requirements established under FY20 NDAA section 862(b). This includes the identification of software training, the development of an initial software competency menu, the incorporation of software competencies in existing DoD workforce requirements, the identification of potential career paths, and the creation of a training implementation plan to validate course curriculum and delivery for software acquisition professionals.

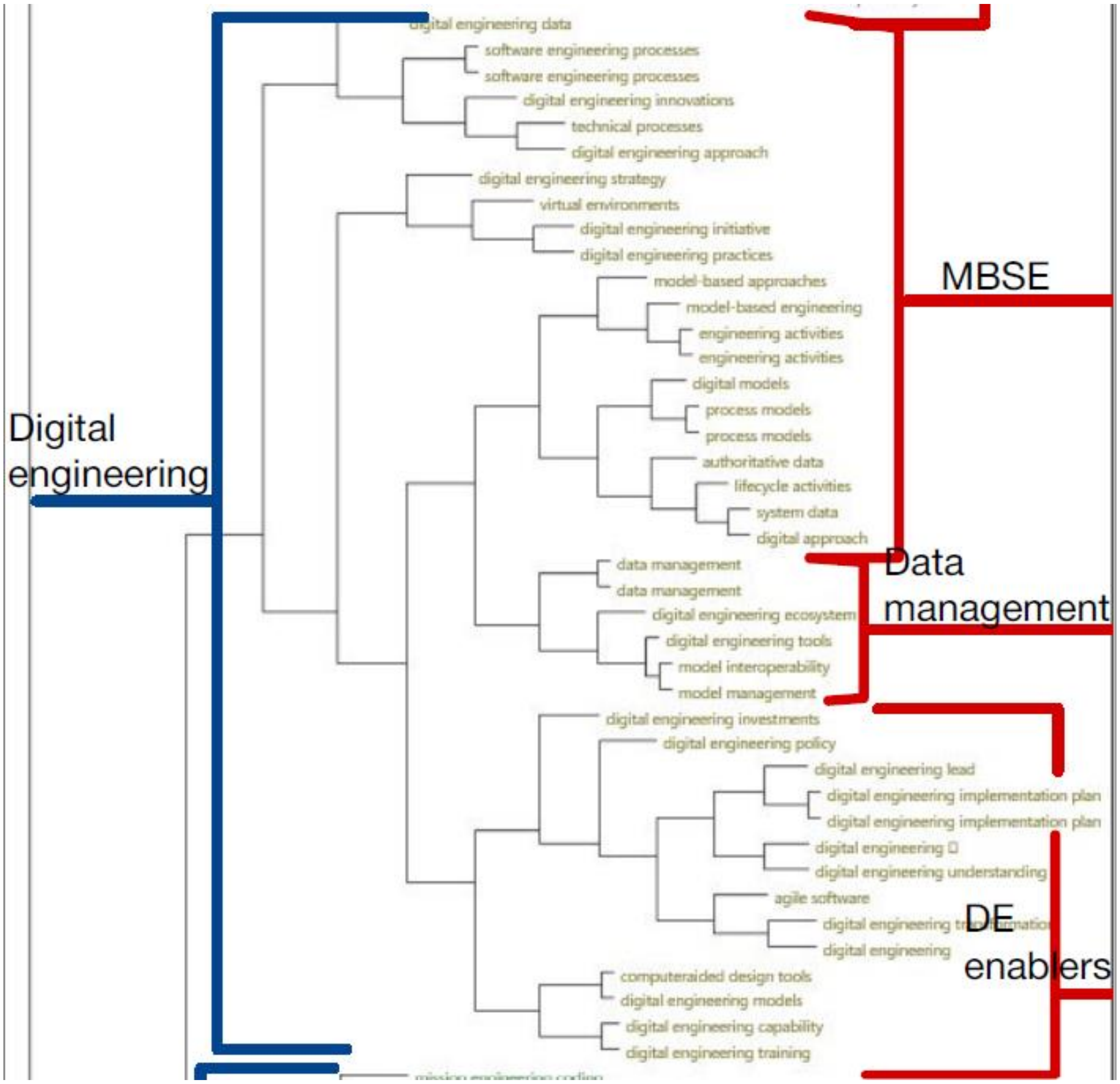
APPENDIX C: EXAMPLE KEYWORD CLUSTERING

This clustering of keywords related to the SEMOD focus areas was completed by student Loveday Glandon from the University of Alabama-Huntsville. In these diagrams there is a high level topical organization to the left and sub-topic organizations to the right. In the "Digital Acquisition" topic area there is pretty good coverage of all the four focus areas into lower level clusters. In all the other topic areas some of the focus areas are fully missing from the textual guidance.

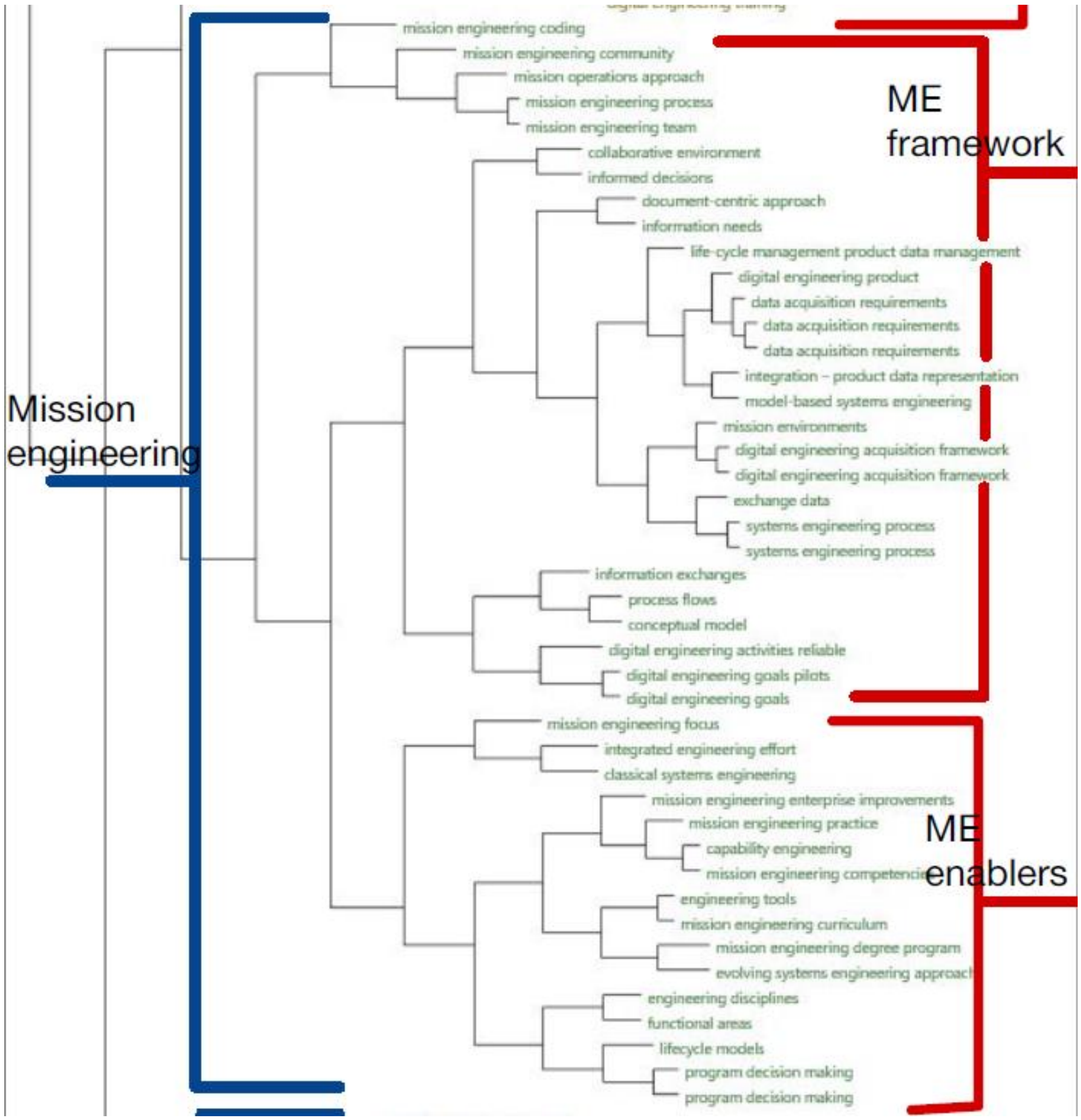


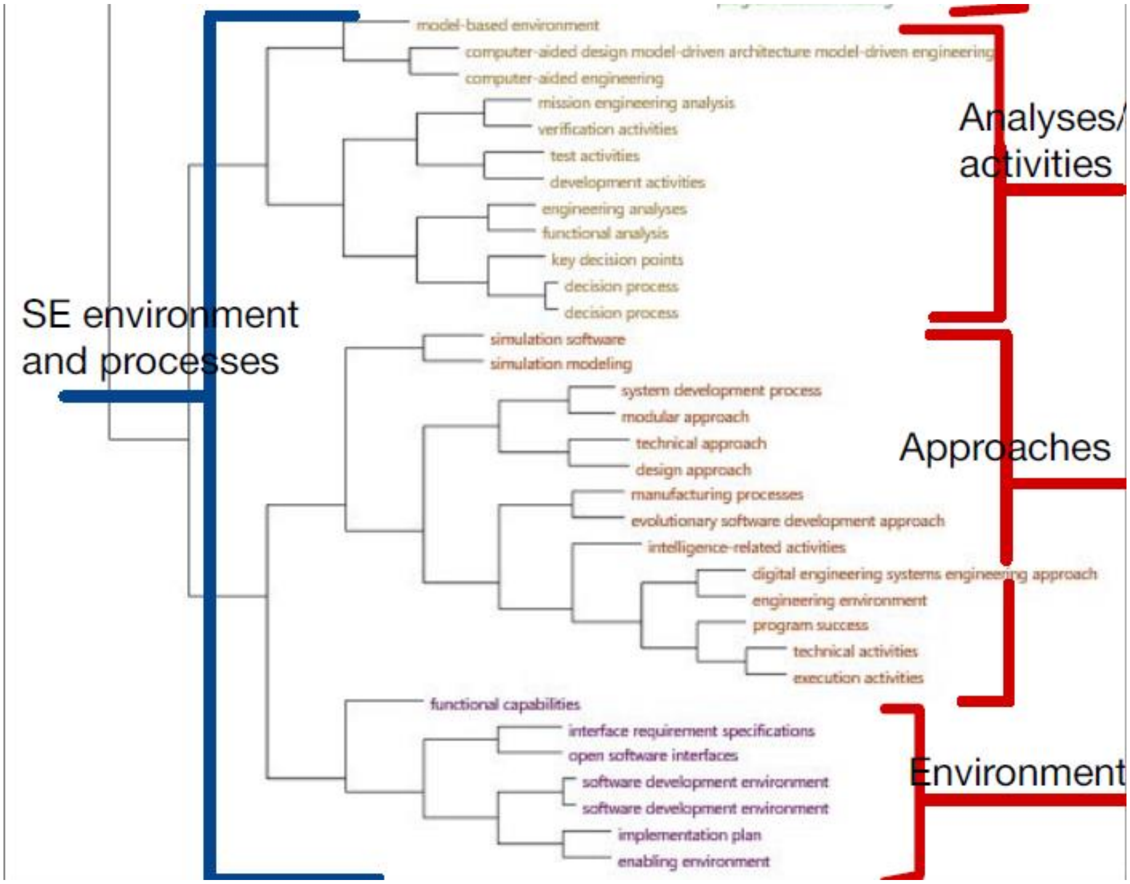

interacting processes
agile processes harness change
joint requirements
iterative approach
sustainment activities
system life cycle
acquisition life cycle
life cycle
life cycle logistics functions
product life cycle
resource requirements
operational readiness requirements
system design matures
program objectives
program life cycle
program life cycle
support functions
acquisition approaches
automated information systems
systematic process
life-cycle management
project manager
project life cycle
regulatory requirements
program requirements
performance-based management system
contract requirements
requirements definition process
reporting requirements
design reviews
design process
design process
architectural design
design engineers
operational environment
digital environment
performance requirements
performance requirements
enabling processes
process requirements
process requirements
operational requirement
requirements process
requirements process
technical requirements
requirements developm
functional requirements
system requirements
functional requirements
functional requirements
managing risk
Life
cycle
Design/development
life cycle
Requirements


managing risk
strategic planning process
technical planning process
risk management process
risk management process
management information
management information
implementing configuration management
configuration management plan
configuration manager
change management
agile environment
continuous delivery model
commercial computer software
software development processes
software development processes
software engineering practices
software tools
software architecture
life cycle phases
agile software development capability
modern software capabilities
modern software innovation cycles
modern software practices
program managers
program managers
product managers
software engineering design analysis
mission requirements
data standards
data standards
operating environment
test environments
development environment
actionable information
agile software development approach
agile software development approach
agile programs
process changes
agile approach
agile development approach
working software
changing requirements
development cycle
Software engineering
Risk management
SW Dev
Agile



digital engineering data
software engineering processes
software engineering processes
digital engineering innovations
technical processes
digital engineering approach
digital engineering strategy
virtual environments
digital engineering initiative
digital engineering practices
model-based approaches
model-based engineering
engineering activities
engineering activities
digital models
process models
process models
authoritative data
lifecycle activities
system data
digital approach
data management
data management
digital engineering ecosystem
digital engineering tools
model interoperability
model management
digital engineering investments
digital engineering policy
digital engineering lead
digital engineering implementation plan
digital engineering implementation plan
digital engineering
digital engineering understanding
agile software
digital engineering
computeraided design tools
digital engineering models
digital engineering capability
digital engineering training
Digital engineering
MBSE
Data management
DE enablers


Mission engineering
ME framework
ME enablers
mission engineering coding
mission engineering community
mission operations approach
mission engineering process
mission engineering team
collaborative environment
informed decisions
document-centric approach
information needs
life-cycle management product data management
digital engineering product
data acquisition requirements
data acquisition requirements
data acquisition requirements
integration – product data representation
model-based systems engineering
mission environments
digital engineering acquisition framework
digital engineering acquisition framework
exchange data
systems engineering process
systems engineering process
information exchanges
process flows
conceptual model
digital engineering activities reliable
digital engineering goals pilots
digital engineering goals
mission engineering focus
integrated engineering effort
classical systems engineering
mission engineering enterprise improvements
mission engineering practice
capability engineering
mission engineering competencie
engineering tools
mission engineering curriculum
mission engineering degree program
evolving systems engineering approach
engineering disciplines
functional areas
lifecycle models
program decision making
program decision making



APPENDIX D: POTENTIAL DIGITAL ARTIFACTS

This is a list of end item artifacts extracted from the combined set of policy and guidance documents compiled by student Zach Schaber from Stevens Institute of Technology. This list was compiled in response to the question “what digital artifacts might form the authoritative source of truth?” It is included here as a useful reference.

Document Description	Phase
Draft Capability Development Document (CDD)	MSA
Request for Proposal (RFP)	MSA
Acquisitiong Strategy (AS)	MSA
Systems Engineering Plan (SEP)	MSA
RAM-C Report	MSA
Test & Evaluation Master Plan (TEMP)	MSA
Analysis of Alternatives Report (AoA Report)	MSA
Program Protection Plan (PPP)	MSA

Information Assurance Strategy (IA Strategy)	MSA
Life-Cycle Sustainment Plan (LCSP)	MSA
Component Cost Estimate (CCE)	MSA
Concept of Operations/Operational Mode summary/Misssion Profile (CONOPS/OMS/MP)	MSA
Architectures, system digital artifacts (models, simulations, etc.)	MSA Output
Results of Market Research	MSA Output
Manufacturing and Quality (M&Q) Plans	MSA Output
Interdependencies/Interfaces/MOAs	MSA Output
Initial Life Cycle Mission Data plan (LMDP)	MSA Output
Draft System Performance Specification	MSA Output
Prototyping Strategy	MSA Output
Value Engineering results	MSA Output
Informated advice to the Security Classification Guide (SCG)	MSA Output
Early Operational Assessments (EOAs)	MSA Output
Statement of Work (SOW)	MSA Output
Contract Data REquirements Lists (CDRLs)	MSA Output
Source-Selection Criteria	MSA Output
Spectrum Supportability Risk ASsessment	MSA Output
Acquisition Strategy	MSA Output
Development Request for Proposal Release	TMRR
System Requirements Review (SRR)	TMRR
System Functional Review (SFR)	TMRR
Preliminary Design Review (PDR)	TMRR
Draft CDD	TMRR Input
CONOPS/OMP/MP	TMRR Input
ADM	TMRR Input
PPP	TMRR Input
SEP	TMRR Input
RAM-C Report	TMRR Input
Reliability Growth Curves (RGCs)	TMRR Input
Trade-off Analysis results	TMRR Input
Digital Engineering Ecosystem Planning	TMRR Input
Digital Artifacts	TMRR Input

System Safety Engineering and Management Planning	TMRR Input
Informed advice to ADM	TMRR Output
Preliminary system design	TMRR Output
Updated SEP	TMRR Output
Updated IMP	TMRR Output
Updated IMS	TMRR Output
Updated RAM-C Report	TMRR Output
Updated RGC	TMRR Output
Updated PPP	TMRR Output
Trade-off Analysis Results	TMRR Output
ESOH Analyses	TMRR Output
Assessment of Technical Risk	TMRR Output
Manufacturing Readiness	TMRR Output
Consideration of Technology issues	TMRR Output
TRA Plan	TMRR Output
Updated Life Cycle Mission Data Plan	TMRR Output
Updated System Performance Specification	TMRR Output
System Preliminary Design including functional baseline and allocated baseline	TMRR Output
Architectures, System Models and Simulations	TMRR Output
Prototyping Strategy and results of TMRR Prototyping Activities	TMRR Output
PDR Assessment	TMRR Output
Informated Advice to APB	TMRR Output
Informed advice to Affordability and Resource Estimates	TMRR Output
Informed Advice to Acquisition Strategy	TMRR Output

Informed advice to LCSP	TMRR Output
Informed Advice to DMSMS Management Plan	TMRR Output
Initial Information Support Plan (ISP)	TMRR Output
Informed advice to TEMP	TMRR Output
Early DT&E Assessments	TMRR Output
Informed advice to draft and final Development RFP	TMRR Output
Informed advice for the spectrum supportability Risk Assessment	TMRR Output
Informed advice for Waveform Assessment Application	TMRR Output
Critical Design Review (CDR)	EMD
Test Readiness Review (TRR)	EMD
System Verification Review (SVR) / Functional Configuration Audit (FCA)	EMD
Production Readiness Review (PRR)	EMD
Initial Operational Capability (IOC)	P&D
Full Operational Capability (FOC)	P&D
Post Implementation Review	P&D
FRP	P&D
VOLT Report	P&D Input
LCSP	P&D Input
DMSMS Management Plan	P&D Input
TEMP	P&D Input
ISP of Record	P&D Input
Updated FRP DR and.or FDDR	P&D Output
HSI Analyses	P&D Output
Informed advice to TEMP	P&D Output
OT&E Assessments	P&D Output
Draft and Final RFPs for Production and SE Support	P&D Output
Informed advice for Spectrum Supportability Risk Assessment	P&D Output
ADMs associated with Milestone C and FDDR	O&S Input
Trade-Off analysis results	O&S Input
system safety hazard analysis updated	O&S Input

End-User Feedback and trouble reports	O&S Input
Spectrum Supportability Risk assessment	O&S Input
Parts and Diminishing Manufacturing Sources and Material Shortages (DMSMS) Risk analysis	O&S
Disposal Plan?	O&S
Lessons Learned	O&S
Archive Data	O&S
Safe, sustainable, and reliable system that meets operational needs	O&S Outputs
Assessment of technical risk	O&S Outputs
Interdependencies/Interfaces/MOAs	O&S Outputs
ISP of Record	O&S Outputs
In-Service Performance and Failure Data	O&S Outputs
Value Engineering Results	O&S Outputs
Validated Models and Simulations representing the fielded System	O&S Outputs
Engineering Change Proposal (ECP) Packages	O&S Outputs