The Digital Engineering Competency Framework (DECF): Critical Skillsets to Support Digital Transformation

Nicole Hutchison, nicole.hutchison@stevens.edu; and **Hoong Yan See Tao,** hseetao@stevens.edu

ABSTRACT

In the US, the Department of Defense (DoD) is engaging in major digital transformation efforts to modernize the defense workforce, particularly the engineering acquisition workforce to ensure that the workforce remains technically competent. This effort was kicked off with the publication of its *Digital Engineering Strategy* in 2018. Digital engineering is necessary to update and support systems engineering practices to maintain a competitive advantage in data analytics, data science, computation technology, modeling, and simulation. The DoD envisions successful digital engineering transformation through the modernization of the way the Department designs, develops, delivers, operates, maintains, and sustains systems. One of the key aspects of this transformation is developing a digital engineering competency model to develop and sustain the workforce. In 2019, the DoD tasked the Systems Engineering Research Center (SERC) with the creation of a "Digital Engineering Competency Framework (DECF)" as part of its critical digital transformation and workforce development modernization efforts. Though created in the context of the US DoD, the DECF is not intended to be a defense- or US-centric and instead provides a foundation for any individual or organization looking to embark on digital transformation. This paper provides an overview of the DECF and its potential relationships with other competency frameworks.

INTRODUCTION

In early 2022, Ms. Stephanie Possehl, former Acting Deputy Director for Engineering Office of the Under Secretary for Defense (Research and Engineering) (OUSD(R&E)), wrote about the Engineering and Technical Management (ETM) vision for the US DoD's future. This vision included taking disparate but related career fields – Engineering (ENG), which includes systems engineers; Production, Quality, and Manufacturing (PQM); and Science and Technology Management (S&TM) – and replacing them with a new ETM functional area. This workforce encompasses the largest acquisition body in the DoD. With more than 72,000 members, it is nearly 40% of the defense acquisition workforce (Possehl 2022).

WHAT IS DIGITAL ENGINEERING?

DAU defines DE as "an integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal." In plain language, this means that digital engineering uses authoritative data and models to support the design, development, operation, maintenance, and retirement of systems. The strategic vision is to "securely and safely connect people, processes, data, and capabilities across a digital enterprise … using technologies such as advanced computing, big data analytics, artificial intelligence, autonomous systems, and robotics to improve the engineering practice." (DoD 2018) In the broader context, this also implies a transition to digital acquisition.

Though models and simulation are not new to the discipline of SE, DE represents a transformation from systems that are formally document-based to systems that rely on native models and data. "Digital transformation" is the term describing this transition from traditional, document-heavy, and event-driven acquisition and engineering approaches to a data- and model-driven approach that improves transparency and integration and allows improvements in existing processes. Full digital transformation requires both **digitization and digitalization**. Digitization is generally the easier of the two to tackle; moving from a physically printed document as the baseline to a PDF is a simple example of digitization. Digita-

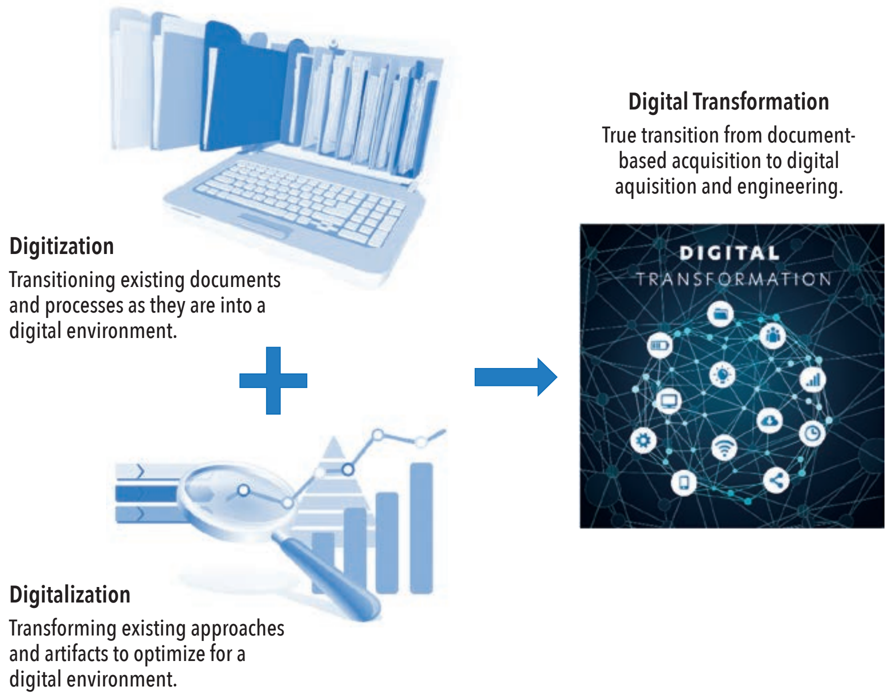

Figure 1. Digital Transformation Requires the Combination of Both Digitization and Digitalization. (Hutchison, See Tao, and Long – used with permission)

lization requires not that existing processes and artifacts be translated into an electronic environment but that these be reviewed to determine where they can and should be updated to improve effectiveness, efficiency, and transparency in a digital environment. It is only with thoughtful consideration of both aspects that any organization can achieve true digital transformation.

WHY DOES THE COMMUNITY NEED A NEW FRAMEWORK?

Beginning in 2020, the SERC team – comprised of researchers from the Stevens Institute of Technology, the Naval Postgraduate School, and the Georgia Tech Research Institute – worked with industry and government to understand critical skills for current and envisioned future DE skillsets. This included an analysis of existing competency frameworks such as:

- DAU Engineering Project Management competency models (DAU 2016a and 2016b)
- INCOSE *Systems Engineering Competency Framework* (INCOSE 2018)
- MITRE *Systems Engineering Competency Model* (MITRE 2007)
- NASA "Systems Engineering/Project Management Combined Competency Model" (NASA 2020)
- Helix *Atlas* Proficiency Model (Hutchison et al. 2020)
- IEEE *Software Engineering Competency Model* (IEEE 2014)
- US Department of Labor *Engineering Competency Model* (US Department of Labor 2017)
- SERC *Mission Engineering Competency Framework* (Vesonder et al. 2018)
- US Department of the Navy *Systems Engineering Career Competency Model* (SECCM) (Whitcomb et al. 2017)

The team started by developing a model of the existing competency frameworks, capturing each individual knowledge, skills, abilities, and behaviors (KSABs) statement from each model, and then reviewing to remove duplicates.

These competency frameworks provide insights into the SE, programmatic, general engineering, software, and modeling and simulation aspects of DE. A core take-away, though, was that none of these were sufficient to cover the space. For example, Helix and the INCOSE framework discuss MBSE, but neither reflects how general SE skills would need to change to reflect an environment where digital approaches had become "business" as usual. This, therefore, became a core focus for the DECF work: updating the existing KSABs from these models to reflect work in a DE environment. The corollary to this was to add DE skills that were not covered in any of the existing competency frameworks.

THE LOGIC BEHIND THE DECF

The initial competency work resulted in over 1,000 KSABs. Even after clean-up, there are hundreds of individual skills required for DE. Note that no one individual is expected to have each of these KSABs, but a team performing DE must collectively have coverage across the breadth of the competencies. This number is too large for any individual to be able to grasp easily. The team, therefore, began exploring different mental models to explain the core facets of DE in a rationale way. These were reviewed with stakeholders in government, academia, and industry, and iterated over time. Figure 2 shows the final mental model for portioning the DE space in a way that is intended to be easily understandable. This provides the basis for the DECF structure:

- The foundation of DE is data. Understanding data storage, usage, sharing, security, and management are critical aspects of creating a DE process and environment that will provide a common backbone for DE work.

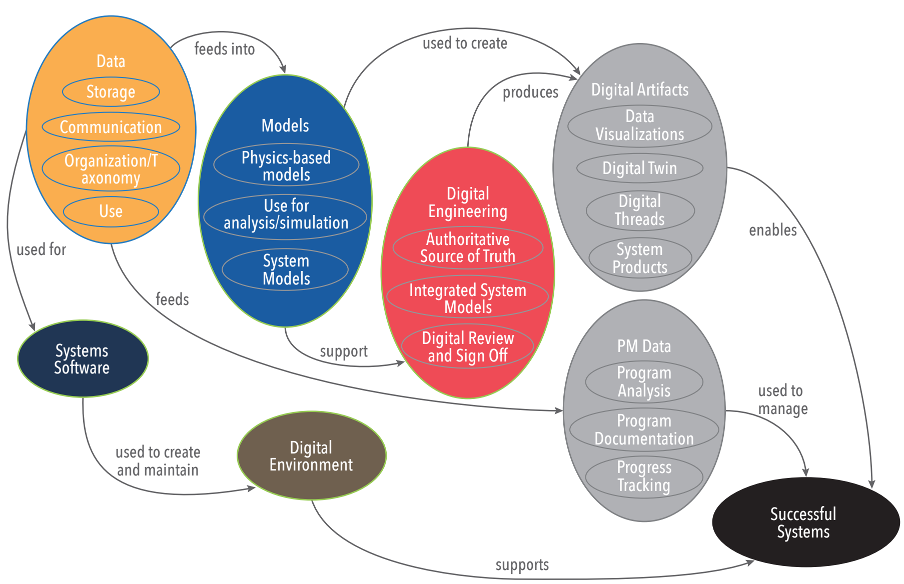

Figure 2. Logical model of the core aspects of digital engineering

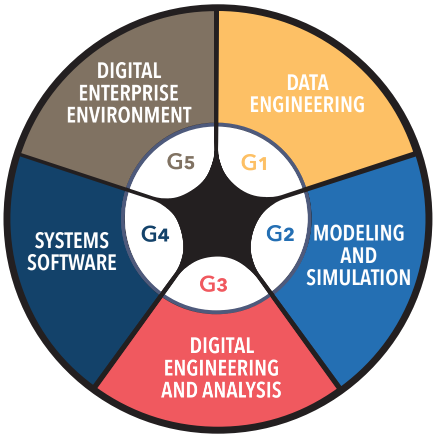

Figure 3. Digital Engineering Competency Framework (DECF) v. 1.1 Overview (SERC 2018)

- Data is the foundation for building models. Models in this sense mean abstractions of a system; simplifications that use data to create as realistic a representation of the system as necessary. Models are used for analysis and simulation, which create additional data and provide better insight into the system.
- Models provide the foundation for DE activities. Here, "DE" encompasses the systems engineering activities conducted in the digital environment as well as the acquisition-related activities.
- Digital engineering produces a variety of digital artifacts that are utilized by a variety of stakeholders and can be used throughout the system lifecycle. For example, a digital twin can be used in the development, but there are also examples of digital twins of operational systems that feed real-time data into the digital twin to allow predictive analysis. One example of this is the US Navy's Military Sealift Command, which uses data from ships in theater to better predict preventive maintenance needs. (Systems Engineering Research Center 2022)
- In addition to the "engineering" context, DE should represent an integrated environment that uses authoritative data for all aspects of a program. Therefore, the PM aspects of a system should be integrated into the data flows.
- Data also feeds into the software aspects of a digital environment. There are two facets of systems software that are important in the DE context. The first are the principles of software engineering that will feed the processes and approaches used in a digital environment. The second is the software of the digital environment itself – the tools that support DE activities.

Table 1. Individual Competencies in the DECF (Hutchison et al. 2021, used with permission)

G1 DATA ENGINEERING			
S1	Data Engineering	C1	Data Governance
		C2	Data Management
G2 MODELING AND SIMULATION			
S2	Modeling and Simulation	C3	Modeling
		C4	Simulation
		C5	Artificial Intelligence/Machine Learning
		C6	Data Visualization
		C7	Data Analystics
G3 MODELING AND SIMULATION			
S3	Digital Systems Engineering	C8	Digital Architecting
		C9	Digital Requirements Modeling
		C10	Digital Validation and Verification
		C11	Model-Based Systems Engineering Processes
S4	Engineering Management	C12	Digital Model-Based Reviews
		C13	Project and Program Management
		C14	Organizational Development
		C15	Digital Engineering Policy and Guidance
		C16	Configuration Management
G4 SYSTEMS SOFTWARE			
S5	Systems Software	C17	Software Construction
		C18	Software Engineering
G5 DIGITAL ENTERPRISE ENVIRONMENT			
S6	Digital Enterprise Environment Development	C19	Digital Environment Development
S7	Digital Enterprise Environment Management	C20	Management
		C21	Communications
		C22	Planning
S8	Digital Enterprise Environment Operations and Support	C23	Digital Environment Operations
		C24	Digital Environment Support
S9	Digital Enterprise Environment Security	C25	Digital Environment Security

The vision is that if DE is implemented effectively, systems will be developed more effectively and efficiently, which will result in a higher percentage of successful systems.

The DECF v.1.1 has five main competency areas, which align with the discussion of the logic model of DE: data engineering; modeling and simulation; DE and analysis;

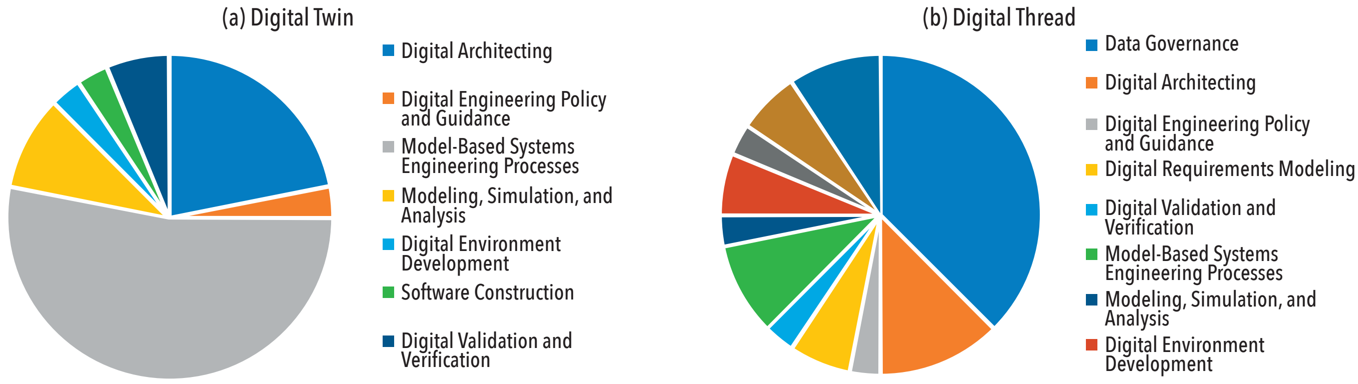

Figure 4. Distribution of digital twin- and digital thread-related KSABs throughout the DECF competencies.

systems software; and digital enterprise environment. (Hutchison et al. 2021)

Note that the full DECF can be downloaded from the SERC website, https://sercuarc.org/decf-review/.

The DECF v.1.1 contains six hundred fifty-nine (659) KSABs divided between these five competency areas. Each area contains individual competencies as shown in Table 1.

The KSABs within each competency are specifically targeted to digital engineering. Therefore, a broad competency area like "Communication" has a relatively low number of KSABs related to digital engineering, while a specific competency like "Model-Based Systems Engineering Processes" that is intrinsically linked with digital engineering has a higher number of KSABs.

The KSABs are distributed across five proficiency levels of the workforce: **Awareness**, **Basic**, **Intermediate**, **Advanced**, and **Expert**. At the Awareness and Basic levels, the KSABs represent wide-ranging fundamentals within a competency area. At the Advanced and Expert levels, the KSABs include the practice of detailed methods that make up the various applications of the competency area. The DECF is built to be a general framework that can be used to create specific competency models that are customized, so the KSABs cover the span of potential DE practices, even if all these practices are not utilized within every organization.

The competency list may be surprising in that expected items appear missing. Where are things like digital twins, threads, and artifacts? The simple answer is that these will integrate throughout the DE environment – and therefore, they are woven throughout the DECF instead of being stand-alone competencies themselves as shown for digital twins and digital threads in Figure 4. This illustrates that a number of competencies are required to implement or create these well.

Six additional foundational competency areas were identified as vital enablers for digital transformation and digital practices in general but are not necessarily "DE competencies". The researchers included them in the DECF but separated them from the five main competency areas. These competencies were deemed important to include in the DECF but also should be clearly separated from the five main DECF competency areas. The foundational competencies are identified as: digital literacy; DE value proposition; DoD policy/guidance; coaching and mentoring; decision making; and software literacy. Though this is a US DoD-focused set, these can easily be made more generic:

- General digital literacy (SFIA Foundation 2018): for most systems engineers, it is probably safe to assume a baseline understanding of operating in a digital world. However, when the aperture expands to include individuals across acquisition, this assumption may not hold true. General comfort with working digitally must be established for DE to be successful.
- DE value proposition: digital transformation is a long journey and will require a lot of work. If the workforce does not understand why they should go through this challenging process, it will require even more effort to make the transition. Regardless of the organization, making the value proposition for DE clear is a necessary step for embracing digital transformation.
- Policy and guidance: clear understanding of the organization's strategy and approach to DE. Without a clear vision for what this can be — hopefully linked to the value proposition — it will be an uphill battle for the workforce to make this transition.
- Software literacy: like general digital literacy, having a basic understanding of the major tools being used within the organization's DE context is a core competency on which the rest of DE work will be built.
- Decision-making and mentoring and coaching are general skillsets that are not specific to DE — however if these skills are not firmly established in the workforce, the gap will hinder the implementation of DE.

USING THE DECF

The DECF has contributed to several activities to support digital transformation in the DoD. The OUSD(R&E) has worked on creating a meta-model for engineering and technical management (ETM) competencies. Competencies from the DECF influenced the ETM model, particularly the inclusion of foundational digital literacy.

Partially, as a result of the DECF work, OSD has tasked the Defense Acquisition University (DAU) with developing a credential around DE. DAU is prioritizing its efforts to rapidly develop ETM credentials and other training materials to support this. Part of this effort includes DAU's partnership with SERC to develop a Simulation Training Environment for Digital Engineering (STEDE). Eventually, ETM certificates and credentials should have digital components that are consistent with the Department's goals for the ETM workforce. These goals are founded on competencies from the DECF, and the DAU approach is intended to provide a bridge between training and practical application of these skillsets. The STEDE is an ongoing research effort that continues to build upon the DECF. The results will be published on the SERC in Spring 2023. ■

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ABOUT THE AUTHORS

Dr. Nicole Hutchison is a Principal Investigator (PI) and research engineer at the Systems Engineering Research Center (SERC). Her primary work through the SERC has been in human capital development research. This has included the development of competency frameworks for systems engineering (the Helix project), digital engineering, and mission engineering. Currently, Dr. Hutchison is the PI for the Simulation Training Environment for Digital Engineering (STEDE), a project that is developing realistic models to be used in training the DoD acquisition workforce in a way that builds hands-on digital engineering skills. She previously served on the BKCASE research team, which resulted in the development of the Guide to the Systems Engineering Body of Knowledge (SEBoK). She is currently the Managing Editor for the SEBoK and the Lead Editor for the "Enabling Systems Engineering" section of the SEBoK. Before joining the SERC, she spent 5 years working for Analytic Services, Inc., supporting the US Departments of Defense, Homeland Security, Health and Human Services, and Justice. She holds a PhD in systems engineering from Stevens and is a Certified Systems Engineering Professional (CSEP) through INCOSE.

Dr. Hoong Yan See Tao is a Research Project Manager for the Systems Engineering Research Center (SERC). She is also a researcher on a current SERC research task titled "DAU Digital Engineering Simulations" and the Co-PI of the Defense Data Grand Prix. Previously, Yan was a SERC Research Associate and Postdoctoral Fellow where she conducted research in mission engineering, digital engineering, and performed project management roles with several human capital development and systems engineering and systems management transformation projects. Yan graduated with a Ph.D. in Systems Engineering at Stevens Institute of Technology in 2017. Yan was the President of the INCOSE Student Division at Stevens in 2013. Yan received her B.S. and M.S. in Electrical Engineering from the University of Texas at El Paso (UTEP). At UTEP, she worked in the Research Institute for Manufacturing and Engineering Systems and was the team leader for two NASA and Texas Space Grant Consortium design challenges.