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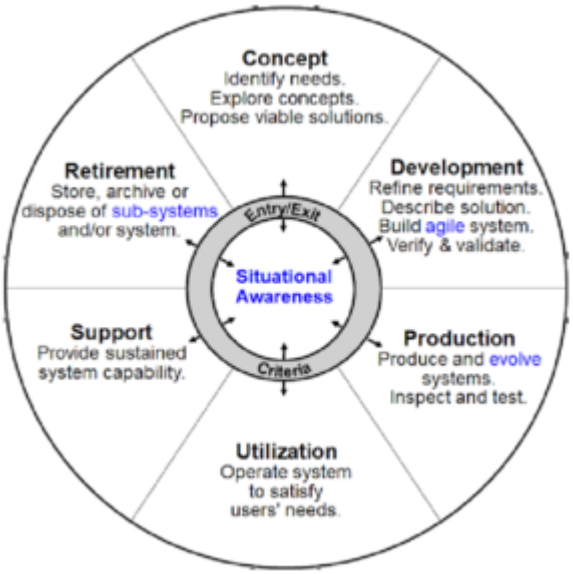
The First Industrial Revolution in the late 18th and early 20th centuries was marked by a transition from production by hand to machine production through the use of steam or water power. The Second Industrial Revolution from the late 19th to the early 20th centuries built upon the progress generated by the increased use of electricity as well as the railroad and telegraph networks that allowed people and concepts to move quickly. The Third Industrial Revolution of the late 20th century was a shift from mechanical and analogue electronics to digital electronics and was characterized by sweeping changes resulting from digital computing and digital communication technologies. During WWI and WWII, the U.S. Department of Defense (DoD) was a leader in technological innovation and use. Famously, a program in the Defense Research Projects Agency (DARPA) paved the way for the modern internet, which has dramatically transformed society.

Throughout the digital revolution, the DoD has moved from being a technological leader during WWII to a slower adopter of digital and computational technologies today. Defense programs that currently utilize digital acquisition and engineering approaches often have to extract technical and programmatic information from their modeling environments to “print out” deliverables in paper form, given the current constraints in the acquisition system.



Digital transformation in the DoD requires an overhaul of two primary elements: engineering and acquisition. In 2018, the Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)) published a *Digital Engineering Strategy*. This outlines the vision for digital engineering (DE) and five goals of the transition to a digitally based engineering and acquisition approach (DoD 2018). The DoD defines DE as "an integrated digital approach that uses authoritative sources of system data and models a continuum across disciplines to support lifecycle activities from concept through disposal" (DoD 2018). The primary goals of the *Digital Engineering Strategy* are illustrated at left.

Digital transformation is fundamentally changing the way acquisition and engineering are per-formed across a wide range of government agencies, industries, and academia. It is characterized by the integration of digital technology into all areas of a business, changing fundamental operations and how results are delivered in terms of new value to customers. It includes cultural change centered on alignment across leadership, strategy, customers, operations, and workforce evolution.

In the DoD, digital transformation involves transition from traditional acquisition and engineering approaches, which are heavily document- and event-driven, to a model-based approach that improves transparency and integration and allows improvements in existing processes. Full digital transformation requires both **digitization** and **digitalization**. Digitization – the simple transfer of existing processes into a digital environment – is generally the easier of the two to

tackle. The example of programs having to “print out” expected documents from models is an example of digitization. Digitalization does not require 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. The distinction is important because digitization is the easier of the two and can result in some initial quick wins; however digitization in itself is not enough. Without continuing to push for digitalization and making improvements to harness the power of digital approaches and workflows, the Department will not achieve its objectives for digital transformation.

As the DoD transitions to digital engineering, there is a need to develop and maintain an acquisition workforce that is literate in model-based approaches, competent in digital models, methods, and tools, and understands digital artifacts across the acquisition lifecycle. Recently, the Systems Engineering Research Center (SERC) developed a competency framework to support this workforce.

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Contents

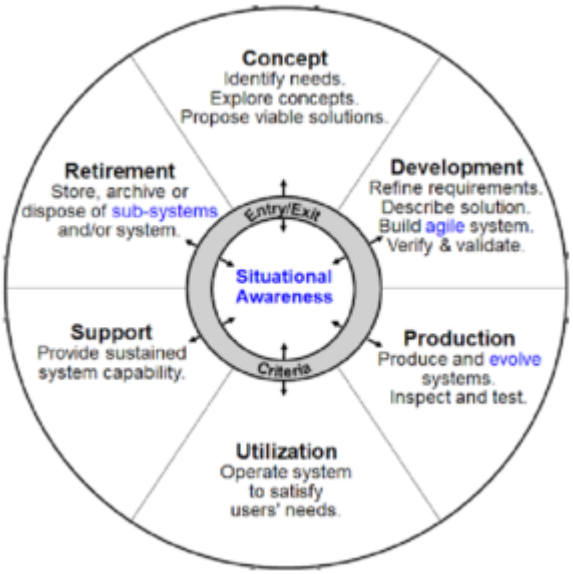
Digital Engineering Competency Framework (DECF)

A capable workforce is key to realize the intent of the digital engineering strategy. In 2019, the DoD tasked the SERC with defining the critical knowledge, skills, abilities, and behaviors (competencies) required to implement digital engineering approaches; highlighting

the competencies that are most critical for the DoD acquisition workforce; and providing the basis for ensuring the acquisition workforce has the appropriate competencies to work within the envisioned digital environment.

In 2021, the SERC published the Digital Engineering Competency Framework (DECF) version 1.1 (Hutchison 2021). The DECF conceptualizes digital engineering as being built on a foundation of digital data. Data is used to create models and those models are used to support the processes associated with digital engineering and the other acquisition functions. From the digital engineering activities, artifacts are generated – some focused on the system and some at the program level and higher. All of these are supported by modeling and simulation suites and require an integrated digital environment.

The DECF competency groups (below) align with the major activities in this context.



Competencies around the creation and use of digital and PM artifacts (e.g.,digital twin, digital thread, etc.) are interwoven throughout the competency groups, as they touch on each area. The DECF framework also assumes a foundation of basic digital competencies, shown in the table (below right).

Though they were created for different purposes, the DECF framework also aligns well with the Skills Framework for the Information Age (SFIA), which is a multi-national effort that outlines a “global skills and competency framework for the digital world." (Honour 2010) This indicates that the DECF, created for a DoD

context, is likely to have a wider applicability.

The final dimension for any competency model is that of proficiency: the level of attainment for a particular competency. The DECF utilizes typical strata for proficiency: awareness, basic, intermediate, advanced, and expert. For those familiar with Bloom's taxonomy, an "awareness" proficiency equates to "knowledge" – the ability to, for example, recite a specific definition. "Basic" equates to "understanding" – not just knowing a definition, for example, but being able to explain that definition using different terminology to different stakeholders. The "expert" proficiency is the equivalent of "synthesis" and "evaluation" – meaning having enough skill and depth of knowledge to be able to generate new concepts or appropriately assess when certain approaches and techniques are most appropriate.

FOUNDATIONAL DIGITAL COMPETENCIES	
F1	Digital Literacy
F2	Digital Engineering Value Proposition
F3	DoD Policy/Guidance
F4	Coaching and Mentoring
F5	Decision Making
F6	Software Literacy

Digital Competencies For Acquisition

Though the primary intent behind the development of the DECF was focused on digital engineering, the competencies also address aspects of the broader acquisition transformation. This is easiest to understand by starting with the foundations, but each group has competencies that are required by anyone working in the digital engineering and acquisition environment, regardless of role. The following is a discussion of the critical competencies and considerations that are generalized across the acquisition workforce.

- **Foundations** - There is a basic level of digital literacy required for anyone who works in a digital engineering and acquisition environment. Digital literacy is the ability to navigate this environment – to comfortably

find the information needed and understand the basic functionality of the software required for their role in the environment. Because this represents a shift in the fundamental workflow of many roles, it is critical that the value proposition for digital transformation be clearly articulated. The initiative will not succeed unless a sufficient percentage of the workforce sees the possibilities and they are willing to put in the work to learn new tools, processes, and approaches. Likewise, it is important that anyone in the Defense acquisition workforce be familiar with the existing policy and guidance around digital engineering.

Some training around this level of digital literacy has already been developed at the Defense Acquisition University (DAU). However, the most effective way for individuals to build digital literacy is to engage with the environment and "see" how their current function will be executed in this context. (Digitization) **In order to do this effectively, all training, regardless of role, should at least incorporate a simulated digital environment.** Contracting courses should demonstrate how models can be used for baseline "documentation" for a contract. Program Management (PM) courses should demonstrate how information can be leveraged to better understand risks, earlier; and how the PM tool kit could be translated into a digital dashboard for better program management and execution.

- **Environment** - The environment in which digital engineering and acquisition happens is critical to success. This has been a challenge in the Department. Currently, most program offices are trying to set up their own digital environments. The Services are creating guidance around the creation of digital environments and processes for digital engineering and acquisition, recommended tools, etc., but these are not currently being reviewed at a DoD level for interoperability. **To improve the current status around digital environments, the Department must create some clear guidance, including best practices, proven tools, and mechanisms for support.**

For most acquisition personnel outside of engineering, digital literacy about the particulars of their digital environment should be sufficient. However, for those that must oversee or develop these environments, there is a need for more in-depth training on tool

interoperability, guidance on security and resilience, and discussion with industry around proven approaches at the Department as well as Service level. Leaders in the Department must also provide guidance on how and when processes should be updated to take advantage of the power of a digital environment (digitalization) and when the current artifacts in a digital form need to be maintained (digitization).

- **Data Engineering** includes data governance, data management, data analytics, and data visualization. **Everyone who works in the digital environment will need to understand the basic rules by which data is managed, structured, and controlled for that environment.** Higher-order engineers and IT specialists will need to work with acquisition personnel to design the formal management approaches for data assets as well as the digital analysis and visualization approaches needed to improve the decision-making processes. Wherever the Department can provide insights into data approaches that best support decision makers, this will provide a great benefit and reduce the burden on program offices.
- **Digital Engineering and Analysis** includes systems engineering and engineering management that constitute how digital engineering takes full advantage of the digital power of computation and communication to take better, faster actions throughout the acquisition lifecycle. All acquisition personnel, regardless of role, should be familiar with the strategies, policies, standards, and guidelines for establishing an authoritative source of truth (ASOT), maintaining baseline control of models, and how and why changes can appropriately be made throughout the lifecycle. There are also considerations based on role: program managers should understand the relationships between the engineering models and the program models; contracting officers must understand how a flexible but controlled digital baseline can be used instead of a more static document; and logisticians should understand how changes in the mission and operational level models will impact the assumptions made about maintenance and supply. Engineers and test and evaluation personnel will need to have more depth in this area.
- **Modeling and Simulation** in the digital enterprise

environment is the process of creating and analyzing a digital prototype of a physical model to predict its performance in the real world. Individuals in engineering and test and evaluation will need to know how to create and modify models; however, all acquisition personnel will require model literacy: how to read and navigate a model and understand the assumptions and simplifications that have gone into it. Again, training that incorporates exposure to these concepts on models that are most relevant to an individual's role will be highly beneficial and improve not only understanding about a particular model but build the ability to learn about and understand models in general.

Recommendations

At the very least, all acquisition professionals require the foundational competencies and will require an awareness or basic proficiency in competencies across the DECF. Depending on an individual's role, higher proficiency levels may be required. The table below is the recommended **minimum** level of competency that individuals in the main functional areas, as defined by the DAU, should have. These are listed by the competency subgroups of the DECF (one level of granularity below the figure shown above). For ease of reading, the proficiency levels are abbreviated: awareness (A); basic (B); intermediate (I); advanced (D); and expert (E).

Recommended Minimum Competency Levels Across Roles

Competency Subgroup	ETM	T&E	LOG	PM	CO	IT
Digital Literacy	D	D	I	I	B	D
Digital Engineering Value Proposition	B	B	B	B	B	B
DoD Policy and Guidance	B	B	B	B	B	B
Digital Enterprise Environment Development	I	B	A	A	A	I
Digital Enterprise Environment Management	I	B	A	B	A	I
Digital Enterprise Environment Operations and Support	I	B	A	B	A	I
Digital Enterprise Environment Security	I	B	B	B	B	I
Data Engineering	A	A	A	A	A	B
(Digital) Systems Engineering	I	B	B	B	B	I

(Digital) Engineering Management	I	B	B	B	B	I
Modeling and Simulation	I	I	B	B	B	I
Systems Software	B	B	B	A	A	B

Conclusion

We live in a digital world. Keeping up with the pace of change has been a consistent challenge across government organizations for years. Digital transformation is a critical step in modernizing the acquisition system and enabling the Department to more rapidly and effectively meet the needs of the warfighter. However, digital transformation will fail unless all individuals across the acquisition workforce have a fundamental understanding of what digital transformation is; why it is important; and the role that they play in making it successful. The Department must push to ensure that everyone has a solid grounding in digital literacy and rapidly provide opportunities for members of the acquisition workforce to build their skills in understanding and using data; navigating and making decisions based on models; and managing workflows in the digital environment. Finally, this digital transformation is also a key enabler for other initiatives in the Department, such as a focus on agile, lean, or DevOps approaches.

About the Author

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 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, 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 has previously served on the BKCASE research team, which resulted in the development of 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 has helped to plan and conduct exercises in Emergency Management, helped run the Louisiana Family Assistance Center following Hurricanes Katrina and Rita, and served 10 years in emergency medicine. She holds a PhD in systems engineering from Stevens as well as a master's degree in Biohazardous Threat Agents and Emerging Infectious Disease from Georgetown University. Dr. Hutchison is an active member of the International Council on Systems Engineering (INCOSE), currently serving on as the INCOSE Events Portfolio Manager and on the INCOSE Certification Advisory Board. She holds her Certified Systems Engineering Professional (CSEP) credential.

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