Final Technical Report

WRT-1018: DAU Credential Development

Technical Report SERC-2020-TR-008

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INTRODUCTION

BACKGROUND

Given the evolving technologies relating to **Data Analytics** and **Artificial Intelligence and Machine Learning**, and evolving engineering practices relating to **Digital Engineering**, DAU has sponsored research to address DoD acquisition capabilities in each of these three **Areas of Strategic Importance (ASI)**. Results from this research are intended to inform the development of a program to provide the acquisition workforce micro-credentials for competencies in these areas.

Each ASI is rapidly evolving and will have a tremendous impact on the future of systems engineering. Therefore, it is necessary to determine the trajectories of technology development in each of these areas, how these will likely impact DoD acquisition professionals, and the competencies that they will need to meet these challenges. This research is intended to support DAU's creation of training curriculum around each of these areas, including capturing critical competencies via appropriate frameworks, along with associated **knowledge, skills, abilities and behaviors (KSABs)**, that are relevant to each of the three aforementioned ASIs for DoD acquisition professionals. KSABs are organized by the level of proficiency which they reflect; proficiency is the quality or state of KSABs, i.e. the depth to which an individual has achieved the competency.

AREAS OF STRATEGIC IMPORTANCE

Digital transformation is fundamentally changing the way work will be done across a wide range of government agencies, industries, and academia. Digital transformation 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 (Department of Defense, 2018). To support this transformation, DAU is creating curriculum around three ASIs: digital engineering (DE); artificial intelligence/machine learning (AI/ML); and data analytics (DA).

DIGITAL ENGINEERING

Digital Engineering (DE) is ''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. A DE ecosystem is an interconnected infrastructure, environment and methodology that enables the exchange of digital artifacts from an authoritative source of truth" (DAU, 2017).

The DE ASI provides elements critical to support acquisition in an increasingly digital environment of global challenges, dynamic threats, rapidly evolving technologies, and increasing life expectancy of our systems currently in operation. The US DoD must continue to practice systems engineering efficiently and effectively to provide the best advantage for successful acquisitions and sustainment. Digital engineering encompasses updates to systems engineering practices to take full advantage of the digital power of computation, visualization, and communication to take better, faster actions throughout the life cycle.

Artificial Intelligence/Machine Learning

Artificial Intelligence (AI)/Machine Learning (ML) systems are programs continuously evolving to behave differently based both on input data and statistical, logical, and knowledge-based inference to achieve competence, if not mastery, on tasks normally reserved for humans.

The AI/ML ASI provides an individual with the AI and ML knowledge necessary to select the appropriate area(s) within this competency to consider when building or procuring a specific system. For example, the individual will understand the areas necessary to support autonomous systems and those that are appropriate for prescriptive support systems. The AI/ML competency includes a general understanding of the necessary infrastructure to **support such systems the ways humans interact** with them (e.g., fully autonomous, symbiotic, or human-in-the-loop) and the social, ethical, privacy, and safety issues of this class of systems.

Data Analytics

Data Analytics (DA) is the science of analyzing raw data in order to make conclusions about that information (Investopedia, 2019). A data scientist—that is the professional using Data Analytics—works at the intersection of information technology, machine learning, statistics, and business.

The Data Analytics ASI provides an individual with the specific analytical knowledge necessary to select the appropriate area(s) to consider when building or procuring a specific system.

Description of Deliverables

Deliverable: Competency Frameworks

Three competency frameworks, one for each ASI, were developed (DE, AI/ML, and DA). Each of the competency frameworks includes a set of relevant KSABs organized by proficiency level. These frameworks were developed in coordination with WRT 1006 - Digital Engineering Competency Framework (DECF) and are consistent with the DECF. For additional information, see section: Coordination Activities with WRT-1006.

Deliverable: Sources of Education and Training

The original research scope included a requirement to identify sources of education and training for each area of strategic importance. Though this requirement was later eliminated from the research task (RT), much of the raw data from the effort had already been collected. This work involved a detailed market survey of available sources for training and education in the competency areas identified in each of the three ASI competency models. The sources included educational institutions, MOOCs, online resources and published materials. The relevance, availability, and in some cases, cost were noted. These results are delivered via SERC-2021-TR-009B and summarized in Appendix A: Results of Literature Search.[1]

DELIVERABLE: WEBINARS

This work resulted in the development of a webinar series consisting of three webinars for each of the three ASIs. Webinars were delivered on each of these subjects and made available to the DoD community. For each ASI, Webinars were delivered that sought to introduce the ASI, the current state of the ASI, and a look toward the future of the ASI. Each Webinar was developed and delivered by an ASI subject matter expert/thought leader. Feedback was collected from attendees and analyzed as input to improve the content for future education. For more information see section: Webinars.

DELIVERABLE: MENTORING

For each of the ASIs, mentoring and coaching were made available to DAU curriculum developers. Subject matter experts were also made available to participate in pilot course office hour sessions. For additional information, see section: Mentoring.

[1] Note that because this work was removed from the scope of the task, only the initial categorizations performed are included in the results.

RESEARCH OVERVIEW AND APPROACH

RESEARCH APPROACH

Initial research involved targeted literature searches focused on each of the ASIs and resulted in the identification of relevant bodies of knowledge, or subject areas, for each. Key word representations of the subject areas were then validated and perceived gaps in knowledge and experience were identified through a series of in-depth stakeholder interviews.

These series of stakeholder interviews were conducted by the research team and focused on gauging the current state of knowledge and practices within the DoD regarding three ASIs: DE, AI/ML, and DA. A total of fifteen interviews, each lasting approximately one hour, was completed. The interviewees were sourced from a broad set of organizations across the DoD, including a Federally Funded Research and Development Center (FFRDC), and represented a diverse set of roles and responsibilities within their organizations. The research team ASI Subject Matter Experts (SMEs) jointly conducted each interview with a single interviewee. An interview script was developed and used to facilitate the discussions and gain an understanding of each individual's current knowledge of each ASI, examples from within their organizations regarding the use of each ASI, and the prevalence of observed workforce ASI skills. Then, key words from the literature search were used to represent subject areas for each ASI and were presented and described. Interviewees were asked to validate each of the ASI subject lists, share their views regarding the relative importance of each subject, and identify observed gaps in workforce knowledge and capability for each subject. Finally, individuals were asked what gaps in their own knowledge of each ASI they would like addressed via focused education and/or training. Detailed notes were captured during these interviews, and this data was analyzed using natural language processing (NLP). The results were used to inform the development of competency frameworks for each of the ASIs.

KSABs were then developed using the competency frameworks established for each ASI. These KSABs were further refined within each framework using the roles of "Practitioner" and "Manager." Expert judgment was utilized to create the KSABs and assign them to the respective roles.

These results were initially submitted to DAU as the ASI Competency Models Report submitted on May 29, 2020.

LITERATURE SEARCH METHODOLOGY

The methodology employed for the literature search was similar across all ASIs. The general method for doing the literature search was:

1. Generate a list of search terms in the domain.

The search terms for compiling the available AI and ML courses were constructed in the following fashion. First, search terms were taken from the AI and ML chapter headings of the book Artificial Intelligence: A Modern Approach, Third Edition, by Russell and Norvig, which is consistently rated the top textbook in AI. After compiling this list, it was sorted in alphabetical order, then augmented and annotated by extracting key words from the most recent year of a popular weekly, commercially oriented AI newsletter—O'Reilly Artificial Intelligence Newsletter. Terms that appeared frequently were highlighted in the list, indicating to the course researchers that these should be given special emphasis. Finally, the research team reviewed the generated list and provided a consensus on the highlighted terms. This analysis netted 69 terms, 20 of which were highlighted and given special emphasis on the list. The search terms used are listed in Appendix C.

2. Search the web using these search terms.

3. For each search term, compile a list of course offerings and determine their quality.

   The course offerings' quality was determined with four metrics: number of enrollees, average course rating, number of views and number of reviews. Not all courses had all 4 metrics. In those instances, the available metrics were reported, and often they were a sufficient indicator. As an example, the Machine Learning course offered by Stanford has over 14 million recent views as well as over 130,000 reviews.

Coordination Activities with WRT-1006

The DoD Digital Engineering Strategy (2018) included five goals for the Department's digital transformation. Goal 5 is to "transform the culture and workforce to adopt and support digital engineering across the life cycle" (DoD, 2018). In May 2019, the Office of the Undersecretary of Defense for Research and Engineering (OUSD (R&E)) funded a related task through the SERC (WRT-1006). This task was created in 2019 to develop a Digital Engineering Competency Framework (DECF) to support this goal.

Close coordination with work performed on WRT-1006 was vital to the success of WRT-1018. The DECF provides the foundation for the DE competencies described in this report. Likewise, learning from this task fed into updates in the DECF. This was accomplished through:

- Research team members who participated in both tasks (Drs. Nicole Hutchison and Jon Wade);
- Regular weekly reviews of 1006 findings and progress with the 1018 team;
- Reviews of the 1018 framework with the 1006 team; and
- Discussions of alignment with sponsors and SMEs.

Interviews

Interview Demographics/Organizations Represented

Interviewees represented a wide variety of roles and responsibilities from a diverse set of DoD and related organizations, including one FFRDC. The organizational roles represented included management as well as individual contributors. The levels of education across the sample included Bachelors, Masters, and multiple PhDs, and years of experience ranged from three to 35 years with an average of more than 18 years. Represented organizations and a subset of represented titles appear below.

Table 1: Represented Organizations

AFICC (Air Force Installation & Contracting Center)	F-35 Prognostics & Health Management (PHM) IPT
OSD OUSD Research & Engineering	Space Production Corps
OSD	Technical Staff Member to Commander, Naval Air Forces/Commander, Naval Air Force, US Pacific Fleet
USMAC Logistics Data Analysis Center	NIWC Atlantic - Engineering - 5.6
Defense Acquisition University	The MITRE Corporation
Naval Warfare Center	US ARMY PEO STRI (USA)
Naval Special Warfare Command	

Table 2: Subset of Represented Titles

Ops Research Analyst	Lead Systems Engineer
Director, Engineering Policy & Systems	Chief of Engineering
Data Specialist	Director, Analytics
Director, Engineering and Technology Center	Director, Data Science & Analytics
Force Data Scientist	Deputy G1
Manager, Systems and Mission Engineering	

Key Findings

In order to have a more accurate representation of the insights provided by the stakeholders, three groups were created based on the different points of view they provided in their interviews.

- Group 1: DAU Point of View
- Group 2: MITRE Point of View
- Group 3: All Other DoD Stakeholders Point of View
- Group 4: Aggregate Representation

The team applied Natural Language Processing (NLP) techniques to analyze the transcripts from the interviews. Using in-house NLP tools, the team extracted four types of information:

1. The most common words, visualized as a wordcloud
2. The words most commonly used together (n-grams and in this case bigrams)[2]
3. General text statistical information (number of words, entropy of the text; clusters with the main topics)
4. The relationships between words, represented as a semantic network.

Examples of these results can be found in Figures 1-4, below.

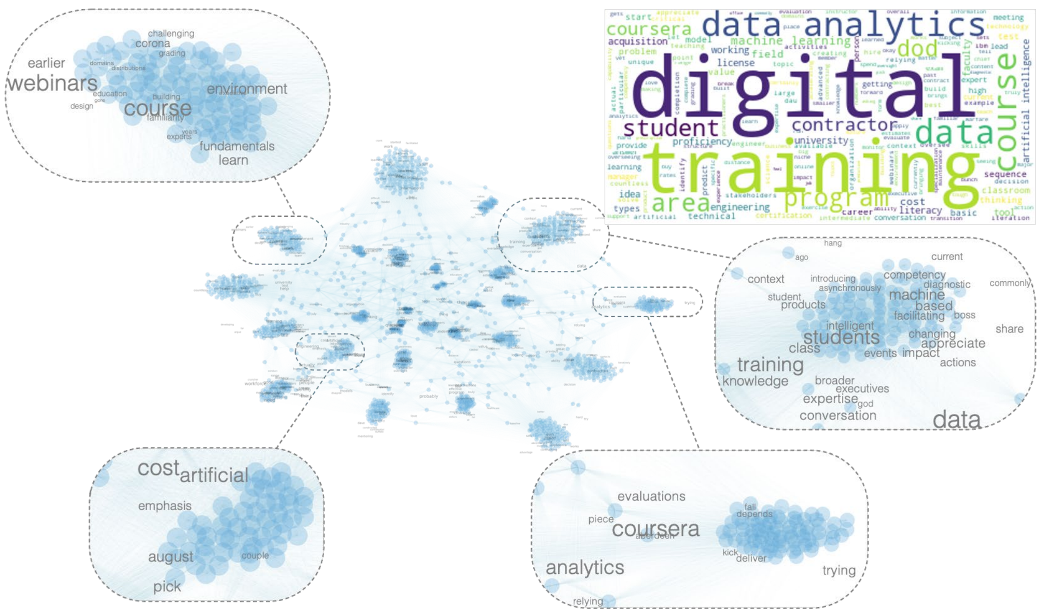

Figure 1: DAU Point of View

Data analytics seems to be the area of primary interest, in the proper context of digital engineering and digital literacy in particular.

[2] n-gram is a contiguous sequence of n words from a given sample of text or speech, with bigrams being composed by two words, as in "system engineering"

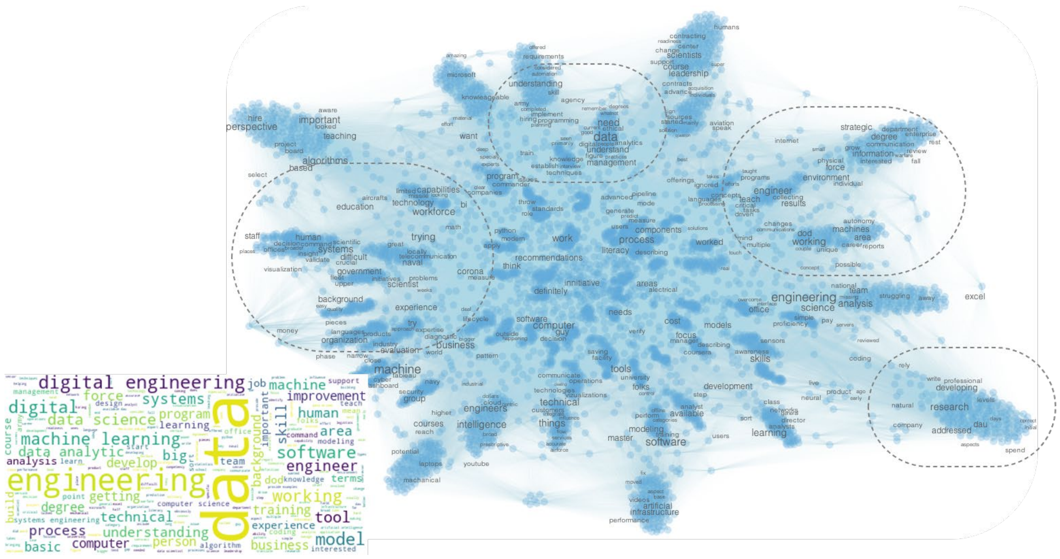

Figure 2: FFRDC Point of View

Data and engineering are the focus here. There is a need of applications in more advanced areas, such as machine learning.

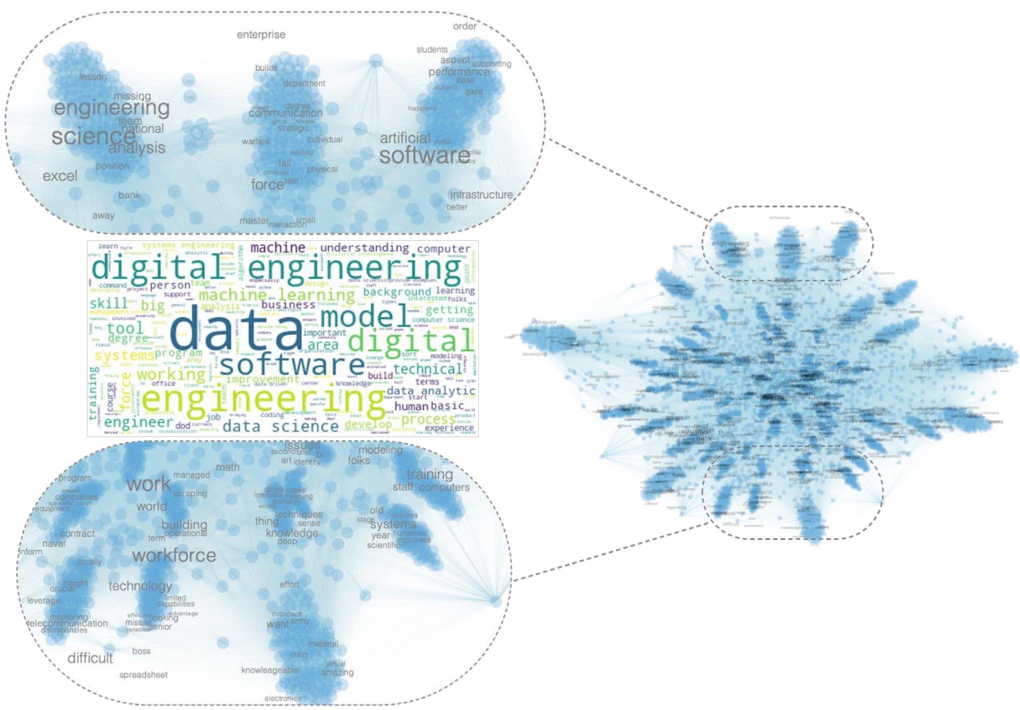

Figure 3: DoD Practitioners Point of View

There is an interest in learning more about data and analytics, with a focus on technical aspects such as data engineering. Expanding knowledge of computer software and machine learning, as a means to improve processes and operations, is important. Logistics of training the workforce is also important.

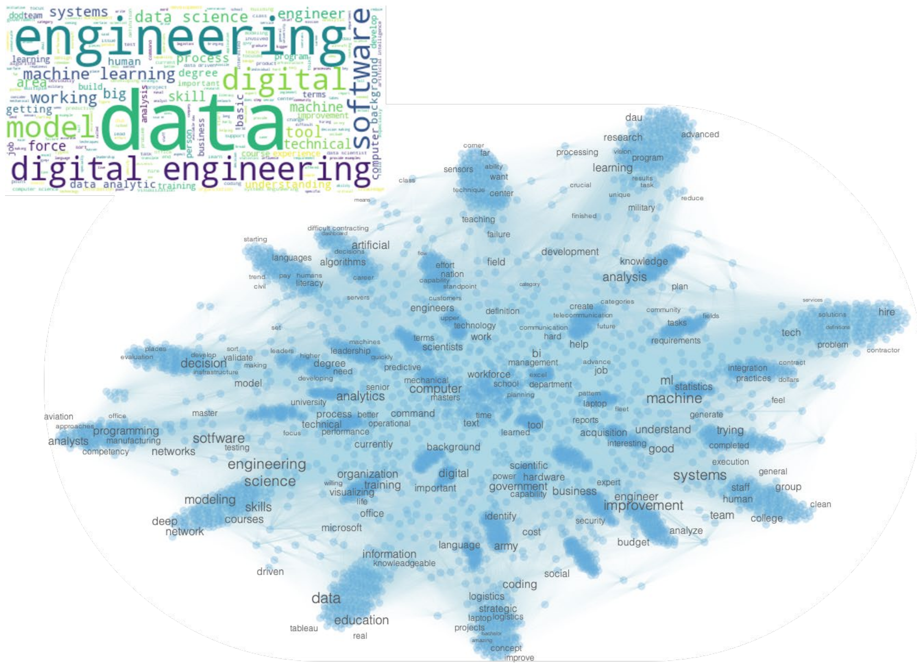

Figure 4: Aggregate Point of View

Data engineering is the primary focus. The large relevance of data reveals a need to address data-related issues across different applications. Machine learning and data science/data analytics seem to have similar relevance.

COMPETENCY FRAMEWORKS

This section provides an overview of the three competency frameworks for each of the ASIs, including an overview of KSABs. The full list of KSABs can be found in SERC-2021-TR-009A.

DECF FRAMEWORK (WRT-1006) INFLUENCE

The frameworks developed as part of this research were coordinated with the research for WRT-1006, the Digital Engineering Competency Framework (DECF). As outlined in the DECF:

> Data is the foundation on which digital engineering is built. Data is required to support and build models and simulations. These models are used to develop systems and support programs, creating a set of digital artifacts that support a variety of engineering, programmatic, and contractual uses. This all occurs in a digital environment, a carefully structured collection of data and supporting software. Ideally, successful digital engineering approaches should lead more consistently to the development of successful systems. (Hutchison et al. 2021)

This logic provides the structure for the DECF and is illustrated in Figure 5.

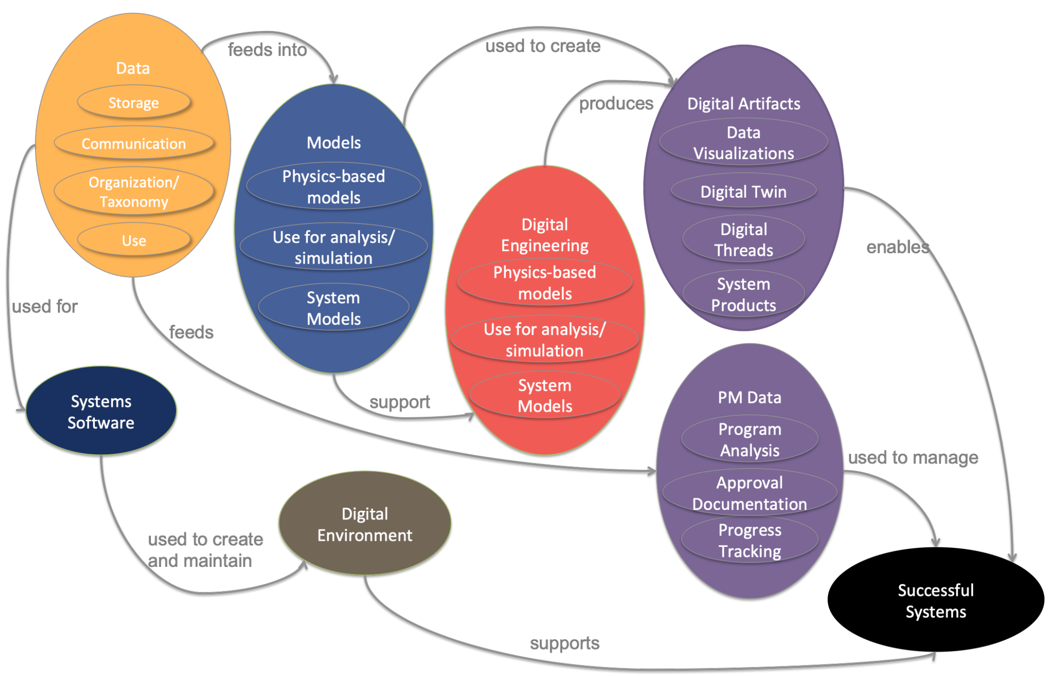

Figure 5. Context for the Digital Engineering Competency Framework (DECF)

Based on this conceptual framework, DECF v. 1.1 contains five main competency groups as illustrated in Figure 6.

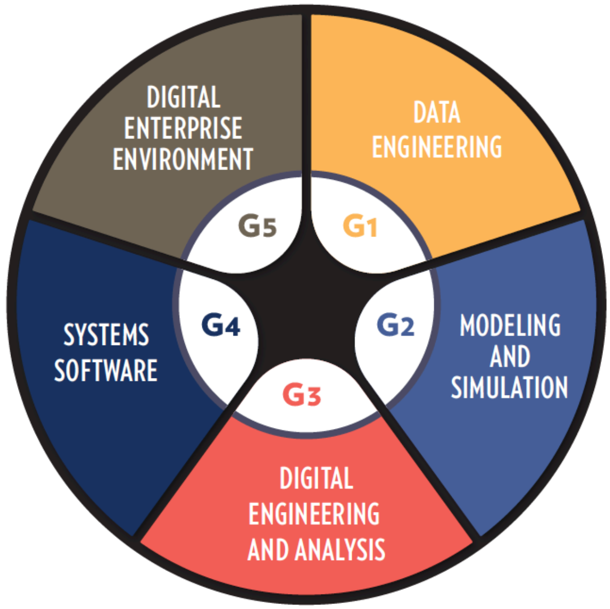

Figure 6. DECF Competency Groups

These five competency groups, along with a foundation of general digital competencies, comprise the DECF. Competency groups provide a logical structure for the individual competencies, making the DECF easier for users to understand and utilize. The groups in Figure 6 are intended to provide a holistic perspective of all the skills required to provide value in a digital environment.

The DECF begins with the data foundations that are required for an effective digital environment ("Data Engineering"). The competency groups constitute the means by which digital engineering takes full advantage of the digital power of computation, visualization, and communication to take better, faster actions throughout the life cycle. These competency groups can be seen as supporting the four elements of John Boyd's OODA loop: Observe, Orient, Decide, and Act (Wade et al., 2020). Data Engineering provides the means by which to observe, ensuring that data is acquired, curated, compressed, secured, and prepared. Next, Modeling and Simulation provides the ability to orient this data to describe and understand a phenomenon of interest. Decision Making utilizes analysis tools and techniques to make appropriate decisions. Finally, Engineering Methods are used to transform these decisions into engineering actions.

Micro-Credentialing Framework Overview

This section provides an introduction into the three competency frameworks for DE, AI/ML, and DA. Table 3 illustrates the relationships among the three competency frameworks. DE both structures the application of the other competency frameworks and provides the prerequisites (software and digital literacy) for understanding them.

Table 3: Relationship of the three competency frameworks

Digital Engineering	Artificial Intelligence/Machine Learning	Data Analytics
Digital Engineering and Analysis (G3)	Digital Engineering	
	Social & ethical issues and implications	Diagnostic, Predictive and Prescriptive analytics
	Human-computer interaction	Exploration, mining and visualization
	Action execution patterns	Data driven systems: Bottom-up machine learning
Modeling and Simulation (G2)	Natural Text Processing - NLP	
	Algorithm and modeling for Knowledge representation	
	Learning patterns	
Data Engineering (G1)	Data engineering: collecting, transmitting, preparing & organizing data	
Systems Software (G4)	Computer Science	
Digital Literacy - Foundation		

Another way to view relationships within the Competency Frameworks is through the use of a Sankey Diagram, as seen below in Figure 7. The Sankey Diagrams are a type of flow diagram emphasizing the major transfers or flows within a system. We used it to represent the logical relationships between the different competencies. In this case, it depicts the flow from the Digital Literacy Foundation through each ASI showing competencies common to each: Digital Literacy Foundation on the left side of the diagram flows through the DE competencies into AI/ML, DA, and competencies common to both AI/ML and DA. This visualizes the connections of the different competencies and the dependencies present. For example, AI/ML and DA – which share some competencies - have their unique competencies coming from the common root of Digital Engineering and Analysis, representing once again their logical proximity.

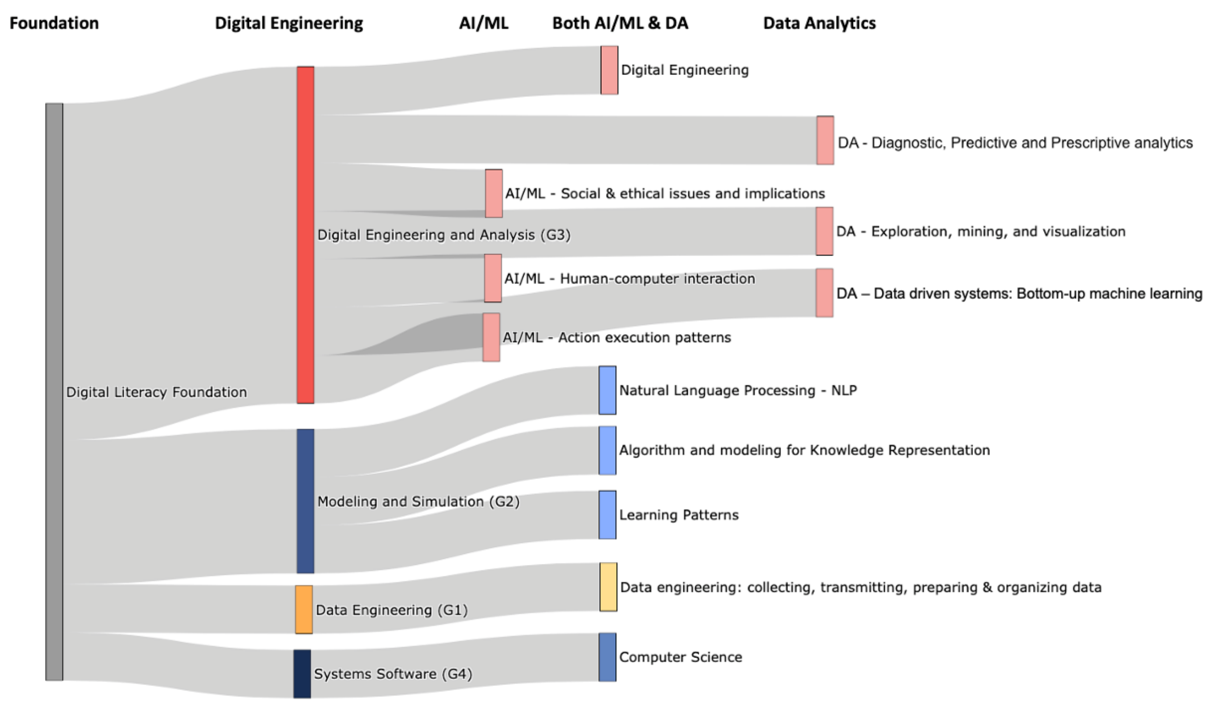

Figure 7: Sankey Diagram of Competency Frameworks

The following three subsections provide tabular representations of each framework. While every role is likely to require some competencies from each of the groups, no role should require expert proficiency in all of the competencies in each group. The specific competency, proficiency levels, and KSABs required for an individual are dependent upon the role(s) performed.

Proficiency levels are the level to which a competency is attained. The definitions of proficiency levels that influenced these frameworks align with the Helix framework (Pyster et al. 2018), as illustrated in Table 4.

Table 4. Proficiency Levels (adapted from Pyster et al. 2018, used with permission)

#	Level	Level Description
1	**Awareness**	Individual has common knowledge or an understanding of basic techniques and concepts. Focus is on learning rather than doing.
2	**Basic**	Individual has the level of experience gained in a classroom or as a trainee on-the-job. Individual can discuss terminology, concepts, principles, and issues related to this proficiency, and use the full range of reference and resource materials in this proficiency. Individual routinely needs help performing tasks that rely on this proficiency.
3	**Intermediate**	Individual can successfully complete tasks relying on this proficiency. Help from an expert may be required from time to time, but the task is usually performed independently. The individual has applied this proficiency to situations occasionally while needing minimal guidance to perform it successfully. Individual understands and can discuss the application and implications of changes in tasks relying on the proficiency.
4	**Advanced**	Individual can perform the actions associated with this proficiency without assistance. The individual has consistently provided practical and relevant ideas and perspectives on ways to improve the proficiency and its application and can coach others on this proficiency by translating complex nuances related to it into easy-to-understand terms. Individual participates in senior-level discussions regarding this proficiency and assists in the development of related reference and resource materials.
5	**Expert**	Individual is known as an expert in this proficiency and provides guidance and troubleshooting and answers questions related to this proficiency and the roles where the proficiency is used. Focus is strategic. Individual has demonstrated consistent excellence in applying this proficiency across multiple projects and/or organizations. Individual can explain this proficiency to others in a commanding fashion, both inside and outside their organization.

ASI: DE

The categories discussed in the DECF section above are used in the DAU competency framework ASI: DE. The DAU competency framework includes a subset of the broad work done in the DECF effort. Descriptions of the Competency Groups and their constituent competencies are outlined in Table 5.

Table 5: Digital Engineering Competency Framework

ID[3]	Competency Title	Competency Description
G1	Data Engineering	Apply knowledge on how to acquire, curate, compress, secure, and prepare data resulting from a digital engineering environment. Create or support data-focused processes. Data could originate from modeling and simulation, or from sensors in the physical world.
G2	Modeling and Simulation	Use of digital models to describe and understand phenomena of interest from initiation of the effort through the entire life cycle maturation. Model literacy—understanding what models are and how they work—is required to move into more advanced skills, from the ability to build a model using appropriate tools, standards, and ontology to creating a modeling environment.
G3	Digital Engineering and Analysis	Apply traditional engineering methods and processes in a digital environment. Create new engineering processes and methods for a digital environment. Create digital artifacts throughout the project or system lifecycle. Use engineering methods, processes, and tools to support the engineering and system lifecycle.
G4	Systems Software	Apply technical knowledge in various software or coding languages to create, support, and maintain applications. This includes the abilities to understand, apply, problem solve, create, and critique software in pursuit of particular learning and professional goals.
G5	Digital Enterprise Environment	Use the foundations of data, modeling, and software to create and maintain the digital enterprise. This requires creating the environment in which digital engineers, discipline and domain engineers, program managers, and decision-makers work.

ASI: AI/ML

AI/ML was considered by many of the stakeholders interviewed as a foundational area for their work. The core interest was in the artificial intelligence and machine learning technology necessary to enable and do data analytics. This includes not only the AI and ML techniques such as knowledge representation and supervised learning but also the enabling infrastructure such as data transport, storage and representation. There is a strong emphasis on monitoring the use of the data and inferences from the data to ensure ethical and privacy preserving systems.

[3] The ID coincides with the competency groups in the DECF for easier referencing.

Table 6: Artificial Intelligence and Machine Learning Competency Framework

Number	Competency Title	Competency Description
1	Learning patterns	Apply knowledge of the types of Machine **L**earning to identify the machine learning patterns, such as supervised, unsupervised, and reinforcement learning, that are appropriate for the target data.
2	Action-execution patterns	Apply knowledge of Artificial Intelligence and of the system domain and problems to be addressed to suggest the appropriate tools and techniques for systems ranging from autonomous agents to predictive support systems.
3	Data Engineering: collecting and organizing data	Apply knowledge of formal data modeling, data representation, data storage, networking, and transport to address the collection, organization, representation, and secure storage of the data.
4	Algorithms and modeling for Knowledge Representation	Apply appropriate models of knowledge representation and related algorithms to represent information and knowledge harvested from data, and support inferential methods to use that data, information, and knowledge.
5	Computer science	Apply base knowledge of computer science theory, tools, languages, and life cycle to support the artificial intelligence and machine learning systems.
6	Human Computer Interaction	Apply knowledge of user-centered design, social media, and human attention, perception, and retention to enhance synergies and build symbiotic interactions between humans and intelligent systems.
7	Social and Ethical Issues and Implications	Apply knowledge of the social and ethical implications of artificial intelligence and machine learning systems to build ethical and privacy preserving systems.
8	Natural Text and Language Processing	Apply knowledge of Natural Language Processing (NLP) and Natural Text Processing to prepare, understand, modify, and build systems-extracting actionable information from text using formal approaches.

ASI: DA

DA was considered by many of the stakeholders interviewed as one of the most critical and upcoming areas. The core interest was on data, the foundation of any digital transformation. Once there is an availability of data large enough to be representative of the target domain, the next step is to get immediate meaning out of it; this is where DA plays its role.

Data Analytics/Data Science shares foundational competencies with DE and specific competencies with AI/ML, as illustrated in Table 3 above.

The distinctive element of Data Analytics is its being entirely data driven and consequently employing bottom-up processes.

Table 7: Data Analytics Competency Framework

Number	Competency Title	Competency Description
1	Learning patterns	Apply knowledge of the types of data representation and Machine Learning to represent data behavioral patterns as learning patterns, such as supervised, unsupervised, and reinforcement learning.
2	Computer science	Apply base knowledge of computer science theory, tools, languages, and life cycle to support data-driven systems, such as in Data Analytics.
3	Data Engineering: collecting and organizing data	Apply knowledge of formal data modeling, data representation, data storage, networking, and transport to address the collection, organization, representation, and secure storage of the data.
4	Exploration, mining and visualization	Apply knowledge of data manipulation, patterns detection and ergonomic visualization to create actionable storylines from data.
5	Data-driven systems: Bottom-up machine learning	Combine the knowledge of Data Analysis and Machine Learning to create systems based on data patterns.
6	Algorithms and modeling for data-driven systems	Apply knowledge of bottom-up modeling to represent information and knowledge harvested from data, and support inferential methods to use that data, information, and knowledge.
7	Diagnostic, Predictive, and Prescriptive Analytics	Use the knowledge harvested from data and from the related models, exploration, mining and visualizations to create systems able to diagnose, predict, or prescribe cases or behaviors.
8	Natural Text and Language Processing	Apply knowledge of Natural Language Processing (NLP) and Natural Text Processing to prepare, understand, modify, and build systems-extracting actionable information from text using formal approaches.

Knowledge, Skills, Abilities, and Behaviors (KSABs)

KSABs were created for each ASI addressed in this research task. These were provided to DAU and are included in SERC-2021-TR-009A as a spreadsheet. Table 8 gives statistics related to the number of KSABs identified for each ASI.

Table 8: KSAB Statistics

	DE	AI/ML	DA
Practitioner	71	46	60
Manager	57	15	18
Total	**74**	**48**	**62**

Overlap with DECF Framework (WRT-1006)

The notional overlap between the DAU frameworks for the ASIs (DE, DA, and AI/ML) and DECF v. 1.1 is illustrated in Figure 8, below.

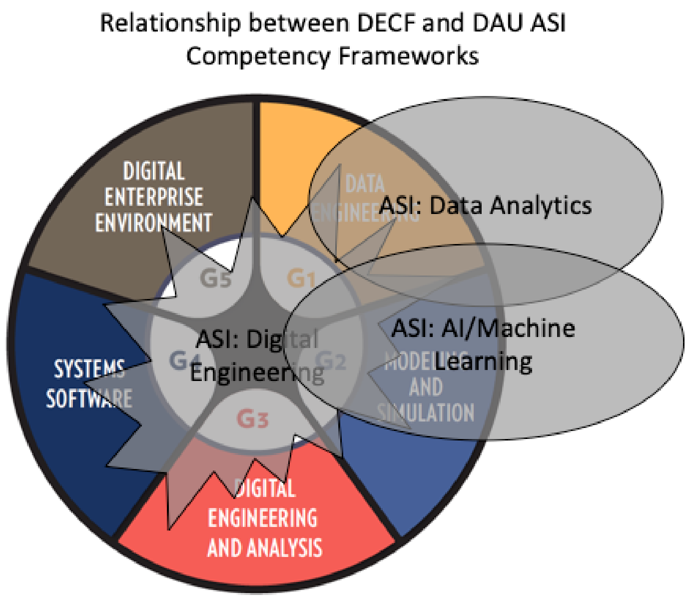

Figure 8. Digital Engineering Competency Framework (DECF) v. 1.1.

Each of the competencies/KSABs in the ASI: DE framework is contained within the DECF; i.e. this is a subset of the DECF model specifically relevant and within the scope of DAU curriculum. Generally, lower proficiency levels – those that may more likely be attained through training rather than those that require extensive practical experience to develop – are reflected in the DAU framework. The competency frameworks for both DA and AI/ML are related to the digital engineering competencies and some of them overlap with the DECF, specifically in the "Data Engineering" and "Modeling and Simulation" competency groups. However, the purpose of the DECF is different than the ASI micro-credentials DAU has created. Therefore, while there is overlap with the DECF, there are also many KSABs in DA and AI/ML that go into more depth than anything contained within the DECF.

SUMMARY OF FINAL DELIVERABLES

SOURCES OF EDUCATION AND TRAINING

The Literature Search Methodology provided above directed the search for sources of education and training. While the marketplace research was removed from the project scope, an overview of the preliminary findings is found in Appendix A, and a detailed list of resources is available in SERC-2021-TR-009B.

WEBINARS

WRT-1018 delivered a series of three webinars for each of the ASIs in accordance with the following framework:

Webinar 1: ASI Introduction
Webinar 2: ASI State of Practice
Webinar 3: ASI Example of Recent Application/Future Vision

These webinars were publicly available and recorded for future use by DAU. The presentation slides and recordings are located at https://sercuarc.org/dau-webcasts.

Table 9 below provides an overview of the webinars (title, presenter, date delivered, and number of individuals who attended the webinars live). Further details can be found in Appendix D: Webinar Details.

Table 9: Digital Readiness Webinar Series

Category	Date	Presenter	Attendance
Digital Engineering	**Digital Readiness: Age of Digital Engineering**		
	July 9, 2020	Dr. Jon Wade, University of California San Diego	Attendance: 803
	Digital Readiness: Drivers, Challenges, Opportunities		
	July 16, 2020	Mr. Troy Peterson, SSI	Attendance: 281
	Digital Readiness: Surrogate Pilot Experiments		
	July 23, 2020	Dr. Mark Blackburn, Stevens Institute of Technology	Attendance: 278
AI/ML	**Digital Readiness: AI/ML, The thinking system quest**		
	Aug 20, 2020	Dr. Gregg Vesonder, Stevens Institute of Technology	Attendance: 182
	Digital Readiness: AI/ML, Finding a doing machine		
	Aug 27, 2020	Dr. Gregg Vesonder, Stevens Institute of Technology	Attendance: 171
	Digital Readiness: AI/ML, Common Sense prevails?		
	Sept 3, 2020	Dr. Gregg Vesonder, Stevens Institute of Technology	Attendance: 418
Data Analytics	**Digital Readiness: The World of Data**		
	July 30, 2020	Dr. Carlo Lipizzi, Stevens Institute of Technology	Attendance: 305
	Digital Readiness: Data and the World: State of Practice		
	Aug 6, 2020	Dr. Carlo Lipizzi, Stevens Institute of Technology	Attendance: 475
	Digital Readiness: Data for the upcoming world: Horizon scanning		
	Aug 13, 2020	Dr. Carlo Lipizzi, Stevens Institute of Technology	Attendance: 179

MENTORING

Researchers were made available to curriculum developers within DAU to provide mentorship and guidance to them during curriculum development. This mentoring effort, in conjunction with the KSABs provided, was intended to support the creation of micro-credentials within DAU. The focus of the effort was primarily on Data Analytics, which was the most developed area within the DAU program.

In addition to mentoring provided to DAU by researchers on the team, office hours were setup as an extension of the mentoring effort. This allowed researchers to provide guidance to pilot students of the micro-credential program, feedback on the micro-credential program as designed, and continued support for DAU faculty administering the program.

CONCLUSION

Evolving technologies relating to **Data Analytics (DA)**, **Artificial Intelligence and Machine Learning (AI/ML)**, and evolving engineering practices relating to **Digital Engineering (DE)** have necessitated a response from DAU to ensure the appropriate and effective learning collateral is made available to the DoD workforce. To this end, DAU has initiated targeted research to address this need. Each of these three knowledge clusters is an Area of Strategic Importance (ASI) for DAU and is the focus of this research task, WRT-1018.

Initial research on this task included a comprehensive literature search and analysis for each ASI, resulting in key terms representing relevant sub-topics for each area. Additionally, a series of interviews were conducted with a number of practitioners and other stakeholders. These interviews and subsequent analysis aided in the identification of observed critical gaps, from each interviewee's point of view, in DoD acquisition workforce capabilities. Moreover, literature search and interview results helped to inform the development of focused competency frameworks for each ASI along with relevant Knowledge, Skills, Abilities and Behaviors (KSABs) for each. These frameworks and KSABs were aligned with work performed under WRT-1006 that resulted in the development of the Digital Engineering Competency Framework (DECF).

The DA framework has already begun to and will continue to inform the development of curriculum and/or in the identification of current available academic and commercial offerings to provide micro-credentials in these competencies for the defense acquisition workforce. DAU will begin implementing the AI/ML and DE frameworks into curricula in 2021.

Original research scope included a requirement to identify sources of education and training for each area of strategic importance. Though this requirement was later eliminated from the RT, much of the effort had already been completed resulting in the raw data of the search results. This work involved a detailed market survey of available sources for training and education in the competency areas identified in each of the three ASI competency models.

In the case of DA, mentoring was provided to the DAU curriculum developer. Additional mentoring resources were offered for DE and AI/ML curriculum development.

Finally, a key set of WRT-1018 deliverables was the development and delivery of a series of three webinars for each ASI. These webinars were made publicly available by DAU.

FUTURE RESEARCH

The SERC is continuing research relevant to the DAU micro-credentialing task reported here. This research includes metrics around digital engineering, continued work on DE competencies, and a DAU-sponsored task that includes the development of a modeling and simulation environment to support the curriculum in the three ASIs as well as other areas. (See Figure 9)

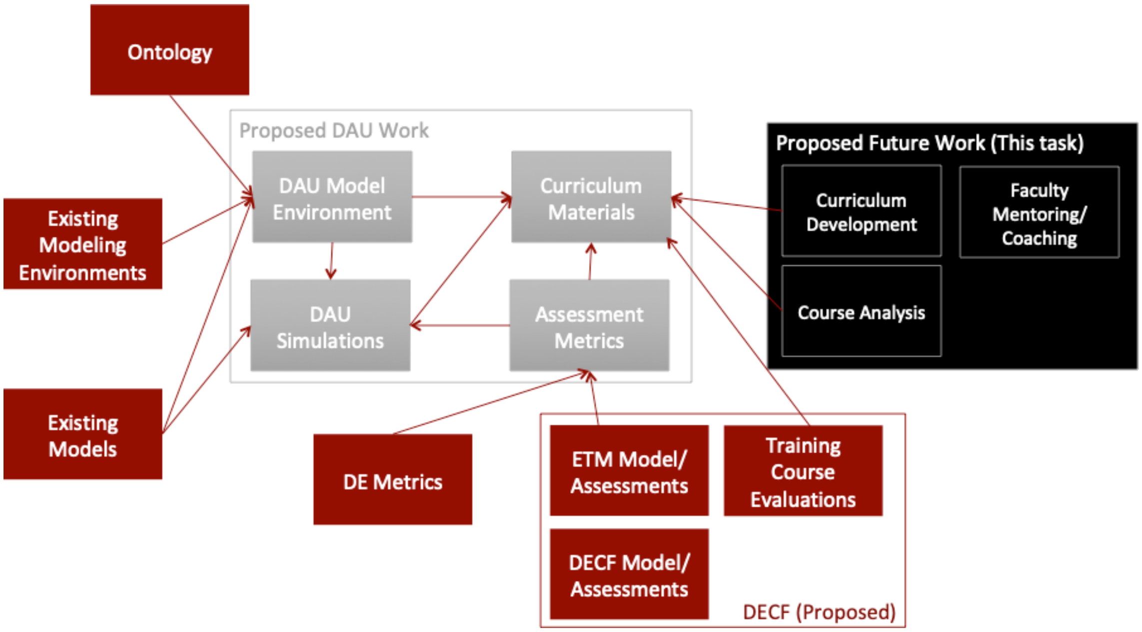

Figure 9. Positioning of Proposed Future Work

The team proposes the following continuation work based on the ASI micro-credentialing task:

- Curriculum development
  - Continue supporting course development mentoring with DAU/other government developers
- Faculty mentoring/coaching
  - Participate in pilot courses and in "office hour" student sessions
  - Develop capstone projects with students (like our SYS 800) under our supervision
- Course Analysis
  - Provide data analysis/recommendations from student feedback from initial courses
  - Model ASI Frameworks and perform analysis of selected related courses/curriculum (from list of courses resulting from 1018 course curriculum education/training sources)
  - Identify and assess practitioners/managers from across the DoD to create a workforce assessment/gap analysis with respect to the ASI competency frameworks

    - Provide periodic assessments of the course offerings (AI/ML and Data Analytics are in a continuous evolution)

- Community Building

    - Identify current DoD work being performed (in each ASI), identifying relevant experts and knowledge sources for boarder leverage and synergies and identify relevant state of the practice tools, methods and processes for each ASI

    - Provide quarterly webinars on topics from each of the 3 ASIs

These proposed activities will build upon the foundation of this task as well as support and create synergies with other SERC tasks in the digital engineering space.

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APPENDIX A: RESULTS OF LITERATURE SEARCH

In addition to the information provided in this appendix, a spreadsheet is provided as SERC-2021-TR-009B.

The results are broken into six different modes, as listed in Table 10 below.

Table 10: Modes of Instruction Included in Search Results

MOOC Courses	Massive Open Online Courses are from sites like Coursera and EdX. These courses can be offered from a variety of different providers, including large corporations like IBM as well as traditional universities. However, they share the same platform. Note that EdX does not give ratings for its courses, so they will be listed at the bottom. The courses are sorted primarily by ratings and secondarily by number of ratings for easier viewing.
Traditional University Courses	These are traditional university courses. They would be taken directly from universities as opposed to a MOOC platform like the courses mentioned above.
Books	These are books addressing relevant topics. Ratings were taken from Amazon
Articles	Articles using the Medium platform use "Claps" to indicate quality. These are similar to likes on other platforms, but individual readers can "clap" multiple times. Thus, it is a unique indication of quality. Only two articles shared "Number of View" values.
Podcasts	Ratings for these podcasts were collected from Apple Podcasts.
Videos	YouTube videos. Number of views and number of likes are included.

489 resources were collected during the search process, and they are broken up in the six modes as shown in Table 11 below.

Table 11: Statistics for Modes of Instruction Included in Search Results

Delivery Medium	MOOC	University	Article	Book	Podcast	Video
# of Resources in List	213	128	34	9	3	102
% of Total	43.56%	26.18%	6.95%	1.84%	0.61%	20.86%

APPENDIX B: INTERVIEW SCRIPTS & KEY QUESTIONS

Demographic Questions

- Briefly describe your background, education level, and years of experience.
- Briefly describe your organization and its mission.
- Describe your role within the organization.
- What is your span of influence?
- Do you consider your role to be technical, non-technical, mixed?

DIGITAL ENGINEERING

Overview

- In your own words, what is Digital Engineering?
- Do you use digital engineering approaches in your work? Please provide examples.
- How does your organization use digital engineering? Please provide examples.

Competencies

- Of the skills you may have identified as important for Digital Engineering, which ones do you think are most common in the current workforce?
- Are there critical skills you look for when selecting Digital Engineering knowledgeable individuals?
- Why are these skills important from your perspective?

Key Words

For each topic below, do you believe the DoD workforce knowledge is: “About Right”, “Needs Improvement”, or “Not Critical/Important”?

- Digital Literacy
- Software Literacy
- Data Engineering
- Modeling
- Decision Making
- Engineering Processes

Future Directions

- What gaps in your own knowledge of Digital Engineering would you like to address?
- Would you and/or your team be interested in training in Digital Engineering?

ARTIFICIAL INTELLIGENCE/MACHINE LEARNING

Overview

- In your own words, what is Artificial Intelligence and Machine Learning?
- Do you use Artificial Intelligence and Machine Learning in your work? Please provide examples.
- How does your organization use Artificial Intelligence and Machine Learning? Please provide examples.

Competencies

- Of the skills you may have identified as important for Artificial Intelligence/Machine Learning, which ones do you think are most common in the current workforce?
- Are there critical skills you look for when selecting Artificial Intelligence/Machine Learning knowledgeable individuals?
- Why are these skills important from your perspective?

Key Words

For each topic below, do you believe the DoD workforce knowledge is: "About Right", "Needs Improvement", or "Not Critical/Important"?

- Learning Patterns
- Action Execution Patterns
- Data Engineering: Collecting and Organizing Data
- Algorithms and Modeling for Knowledge Representation
- Computer Science
- Human-Computer Interaction
- Social and Ethical Issues and Implications
- Natural Text Processing – NLP (Natural Language Processing)

Future Directions

- What gaps in your own knowledge of Artificial Intelligence and Machine Learning would you like to address?

- Would you and/or your team be interested in training in Artificial Intelligence and Machine Learning?

DATA ANALYTICS

Overview

- In your own words, what is Data Analytics/Data Science?
- Do you use data-driven systems and/or approaches in your work? Please provide examples.
- How does your organization use Data Analytics/Data Science? Please provide examples.

Competencies

- Of the skills you may have identified as important for Data Analytics, which ones do you think are most common in the current workforce?
- Are there critical skills you look for when selecting Data Analytics knowledgeable individuals?
- Why are these skills important from your perspective?

Key Words

For each topic below, do you believe DoD workforce knowledge is: “About Right”, “Needs Improvement”, or “Not Critical/Important”?

- Learning Patterns
- Computer Science
- Data Engineering: Collecting and Organizing Data
- Exploration, Mining, and Visualization
- Data-Driven Systems: Bottom-up Machine Learning
- Algorithms and Modeling for Data-Driven Systems
- Diagnostic, Predictive, and Prescriptive Analytics
- Natural Text Processing – NLP (Natural Language Processing)

Future Directions

- What gaps in your own knowledge of Data Analytics would you like to address?
- Would you and/or your team be interested in training in Data Analytics?

APPENDIX C: SEARCH KEYWORDS

Digital Engineering

- Data Management
- Data Modeling
- Data Engineering
- Digital Collaboration
- Digital Literacy
- Digital Communication
- Model Usage
- Model Development
- Model Exploration
- Model Curation
- Software Literacy
- Engineering Processes.

AI/ML and Digital Analytics

- AdaBoost
- Apache Spark (tool)
- Bayesian Classifier
- Binary Classification
- Boosting
- Bots
- Collaborative Filtering
- Classifiers
- Clustering
- Continuous Markov Chains
- Convolutional Neural Network
- Data Bias
- Data integration, preparation and management
- Data Science
- Data Sets
    - Labeling
    - Transforming
    - Structuring
- Data Visualization
- Decision trees
- Deep Learning
- Dimensionality reduction
- Discriminator

- Ensemble methods
- Ernie NLU (natural language understanding, Baidu) GAN – Generative Adversarial Networks Hadoop(tool)
- Hidden Markov Models
- Hierarchical Clustering
- K nearest neighbor
- Learning Vector Quantization
- Machine Learning
- Map Reduce
- Monte Carlo simulation
- Multi Dimensional Scaling
- Nauta(tool)
- Neural Network
- NLP, Natural Language Processing
- Optimization
- Overfitting
- PCA – Principal Components Analysis
- PyTorch (tool)
- R (tool)
- Recurrent Neural Networks
- Regression, linear, multiple
- Reinforcement learning
- Sci-Kit learn (tool)
- Semi-Supervised Learning
- Stochastic gradient descent
- Supervised Learning
- SVM - Support Vector Machine
- Tensor Flow
- Underfitting
- Unsupervised Learning
- Vector Quantization
- Data Collection
- Data Cleaning
- Text Mining
- Text Vectorization
- Predictive Analytics
- Prescriptive Analytics
- Descriptive Analytics
- Data-driven Decision Making
- SQL
- Relational Databases
- non-Relational Databases

- Data Engineering
- Data Structures
- Entity-Relationship Models
- Network Analysis

APPENDIX D: WEBINAR DETAILS

Webinar video and presentation slides are available at the following link:
https://sercuarc.org/dau-webcasts

DIGITAL ENGINEERING

WEBINAR 1: DIGITAL READINESS: AGE OF DIGITAL ENGINEERING

Date: July 9, 2020
Presenter: Dr. Jon Wade, University of California San Diego
Attendance: 803

Abstract
The digital transformation is fundamentally changing the state of practice across a wide range of government agencies, industries and academia. As the DoD transitions to digital engineering, there is a need to develop and maintain an acquisition workforce and culture that is competent in digital engineering practices, tools, and outputs across the acquisition lifecycle. DoD 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. Digital engineering impacts how engineers perform their job functions, the tools required, the products delivered, and the interaction and sharing of data either locally or distributed. In order to succeed in digital engineering, deliberate efforts to develop new competencies for education and training of the DoD workforce must be implemented. This presentation describes digital engineering, its potential impact, the necessary methodological transition and the skill sets that will be essential for its support.

WEBINAR 2: DIGITAL READINESS: DRIVERS, CHALLENGES, OPPORTUNITIES

Date: July 16, 2020
Presenter: Mr. Troy Peterson, SSI
Attendance: 281

Abstract
This presentation will outline some of the fundamental drivers for Digital Transformation, why Digital Engineering is the key to the broader Digital Transformation, as well as share some best practices, lessons learned, and activities underway to help pave the path forward for Digital Engineering.

WEBINAR 3: DIGITAL READINESS: SURROGATE PILOT EXPERIMENTS

Date: July 23, 2020
Presenter: Dr. Mark Blackburn, Stevens Institute of Technology
Attendance: 278

Abstract
This Webcast provides an overview of the NAVAIR Systems Engineering Transformation (SET) Surrogate Pilot Experiments and discusses how these experiments provide implementation examples that align with the goals of the DoD Digital Engineering Strategy. It provides an overview to set the context of the SET Framework concept and Functional Areas.

The Webcast discusses enabling technologies for Digital Engineering examples that support the objectives of the SE Transformation. The Webcast starts with our efforts to formalize the artifacts for the NAVAIR Systems Engineering (NAVSEM) method using View and Viewpoints for automatically generating a "specification" directly from the model using DocGen.

The Webcast will also show the models that are online and provide information on the All Partners Network (APAN.org) where additional details about approach, models, presentations and results can be accessed.

ARTIFICIAL INTELLIGENCE/MACHINE LEARNING

WEBINAR 1: DIGITAL READINESS: AI/ML, THE THINKING SYSTEM QUEST

Date: August 20, 2020
Presenter: Dr. Gregg Vesonder, Stevens Institute of Technology
Attendance: 182

Abstract
Artificial Intelligence and Machine Learning (AI/ML) have had a fascinating evolution from 1950 to the present. This talk sketches the main themes of AI and machine learning, tracing the evolution of the field since its beginning in the 1950s and explaining some of its main concepts. These eras are characterized as "from knowledge is power" to "data is king.”

WEBINAR 2: DIGITAL READINESS: AI/ML, FINDING A DOING MACHINE

Date: August 27, 2020
Presenter: Dr. Gregg Vesonder, Stevens Institute of Technology
Attendance: 171

Abstract
In the last decade Machine Learning had a remarkable success record. We will review reasons for that success, review the technology, examine areas of need and explore what happened to the rest of AI, GOFAI (Good Old Fashion AI).

WEBINAR 3: DIGITAL READINESS: AI/ML, COMMON SENSE PREVAILS?

Date: September 3, 2020
Presenter: Dr. Gregg Vesonder, Stevens Institute of Technology

Attendance: 418

Abstract
Will there be another AI Winter? We will explore some clues to where the current AI/ML may reunite with GOFAI (Good Old Fashioned AI) and hopefully expand the utility of both. This will include extrapolating on the necessary melding of AI with engineering, particularly systems engineering.

DATA ANALYTICS

WEBINAR 1: DIGITAL READINESS: THE WORLD OF DATA

Date: July 30, 2020
Presenter: Dr. Carlo Lipizzi, Stevens Institute of Technology
Attendance: 305

Abstract
Data Analytics is the science of analyzing data to convert information to useful knowledge. This knowledge could help us understand our world better, and in many contexts enable us to make better decisions. To make this goal more attainable is the steep decrease of costs to gather, store, and process data, along with a growing motivation for the use of empirical approaches to problem solving.

Data Science - that is the overall umbrella where Data Analytics are studied and applied - is the study of the generalizable extraction of knowledge from data. Being a data scientist requires an integrated skill set spanning mathematics, statistics, machine learning, databases and other branches of computer science along with a good understanding of the craft of problem formulation to engineer effective solutions.

This presentation describes Data Analytics and Data Science, its potential impact, the necessary theoretical and practical elements to implement it and a set of case studies of application.

WEBINAR 2: DIGITAL READINESS: DATA AND THE WORLD: STATE OF PRACTICE

Date: August 6, 2020
Presenter: Dr. Carlo Lipizzi, Stevens Institute of Technology
Attendance: 475

Abstract
Data science is becoming an integral part of everything we do each day. Initially an exclusive domain of large corporations, data science is now at the personal level, with applications from domotics to wearables. What is adding value to our activities and what is just subtracting time? What are the technologies and approaches behind the most valuable solutions?

Data is market per se. Companies are investing in harvesting, curating, tagging data, generating a huge market, and serving sectors from marketing to security to intelligence. How can we benefit from the current increasing data availability and from the synergies between the different sources?

This presentation addresses the above questions, providing a picture of the general state of practice.

Webinar 3: Digital Readiness: Data for the upcoming world: Horizon scanning

Date: August 13, 2020
Presenter: Dr. Carlo Lipizzi, Stevens Institute of Technology
Attendance: 179

Abstract
Future cannot be predicted, but in science there is a high level of consistency over time. Data Science today is a steppingstone for an even more informed and complex way of living and doing business, with a continuous integration of sources and media, creating semantic synergies, pushing the boundaries of convenience, value and privacy.

This presentation scans the major trends in Data Science, starting from the current emerging trends, extrapolating scenarios.