DON ME & Digital Enablers Landscape: Lexicon Assessment, Centrality Analysis, & Strategic Recommendations

Phase B Deliverable Report

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Executive Summary

Project Background

The Department of Navy (DON) aims to improve and formalize the application of Mission Engineering (ME) to transform the DON into a strategically agile organization that makes data-informed decisions to achieve priorities laid out in strategic naval priorities and objectives. Currently, however, the DON requires an enterprise-wide ME approach and enabling digital engineering (DE) disciplines for improved decision-making processes. The DON Office of Strategic Assessment (OSA) assigned Applied Research Laboratory for Intelligence and Security (ARLIS) and Virginia Tech Applied Research Corporation (VT-ARC) to explore foundational elements for an enterprise-wide ME approach. The team will develop, apply, and gather recommendations surrounding an Applied ME Process, capturing future-state needs along the foundational layers depicted in Figure 1[i], moving the DON toward an enterprise approach to ME.

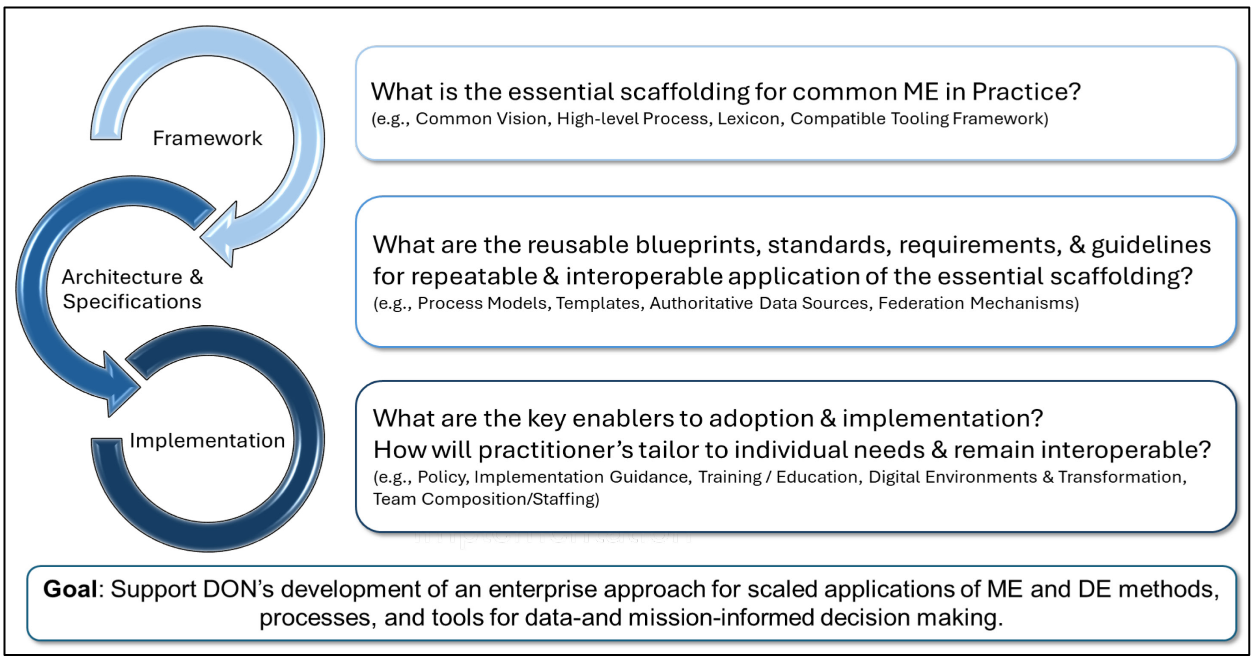

Figure 1 Macro Foundations for Developing an Applied ME Process (Updated)

Report Objective

This report provides a lexicon and centrality analysis that augments the previous report, *Landscape Analysis: Integrated DON Understanding of Mission Engineering Efforts & Digital Tools*, providing additional insights and strategic recommendations for key actions the DON and greater DoD should consider in an enterprise-wide approach for ME and DE. This report focuses on the following overarching objectives:

1. Assess the current state of lexicon across key ME and DE practitioner communities.
2. Capture strategic recommendations surrounding DON ME and DE capability, lexicon, and policy/guidance needs.

Keywords: Department Of Navy; DON; Mission Engineering; ME; Digital Engineering; Data-Driven Decision Making; Mission-Informed Decision Making; Decision Science; Strategic Agility; Portfolio Management; Strategic Decision Making; Enterprise Approach; Applied Mission Engineering

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[i] Updated since the previous report, *Landscape Analysis: Integrated DON Understanding of Mission Engineering Efforts & Digital Tools.*

Summary of Key Findings

This report provides a technical update on research conducted for the Department of the Navy (DON) by the Virginia Tech Applied Research Corporation (VT-ARC) and the University of Maryland Applied Research Laboratory for Intelligence and Security (ARLIS). This report's findings build upon the previous and provide strategic insights regarding the mission engineering (ME) and digital engineering (DE) adoption landscape. Updated insights include an evaluation of ME and DE lexicon inconsistencies across various sectors—including the Department of Defense (DoD), industry, academia, external government agencies—and within their colloquial usage as captured by Large Language Model (LLM) aggregations from publicly available sources. Furthermore, the team introduced additional centrality measures, building on previous knowledge graph analyses of ME and DE adoption within the DoD and broader communities. These expanded analyses reveal deeper patterns of influence and interaction, yielding further strategic and actionable recommendations summarized below. These recommendations – both strategic and tactical – form the roadmap to guide future implementation and efforts to incentivize and enforce the adoption of ME and DE within the DON and greater DoD.

Key Findings:

The following key findings reflect a synthesis of the comprehensive insights gleaned from lexicon analysis, expanded centrality analysis, and assessment of international lessons learned and best practices. Sections 2-4 expand on these findings.

1. ***Complex decision-making apparatus and dependencies necessitates ME and DE formalization and adoption:*** ME, enhanced by DE, is the key enabler to improving alignment and digital traceability between stakeholder seams to clearly align activities and decision making through a mission-focused approach.
2. ***Need for standardization and structured approaches:*** DoD emphasized the need for common frameworks and data environments – from the DoD DE Strategy (2018) to the DON's Digital Systems Engineering Transformation (DSET) Strategy (2020). These strategies stress formalizing the use of models, authoritative data sources, and integrated tools and processes across the enterprise into lifecycle activities. The standardization of ME and DE implementation across programs presents an opportunity to bridge stakeholder seams and enable cross-team synergy, reducing errors and aligning efforts toward the DON's and larger DoD strategic goals.
3. ***Cultural barriers present challenges to ME and DE adoption:*** Many stakeholders are reluctant to fully embrace new digital tools, often preferring the familiar legacy requirements management and traditional systems engineering approaches. The value of digital tools is only unlocked when available at an adequate scale, used broadly, and standardized across the DoD.
4. ***High Degree of Uniformity and Cross-Sector Alignment of DE Lexicon:*** DE terminology is more consistent across sectors (across Services, DoD, industry, academia, and open-source definitions) focused on digital models, integration across disciplines, authoritative data sources, and lifecycle management, with less divergence in wording than seen for ME. This cross-sector cohesion – driven by a DoD-wide strategy that enforces consistent terminology and vision – has accelerated DE adoption across the DoD.
5. ***Uneven Adoption and Lagging Alignment of ME Lexicon:*** DoD and its contractors use unique lexicons across their individual communities implementing ME. The focus on missions and warfighting outcomes is echoed within DoD, but different branches emphasize different aspects. The Navy, Air Force, Marine Corps, and Coast Guard all adopted ME in principle in their contexts– because the need to analyze missions existed – but they often did so in isolation and without a unified definition, resulting in differing practices. The lexicon analysis revealed some consistency across DoD documents, but noticeable divergence between DoD and non-DoD sources on certain ME concepts. ME does not have a singular driving DoD-wide strategy calling for uniformity and transformation like that of DE. ME is still in the process of laying the foundations toward achieving alignment.

To address these key challenges above, the team outlined the following broad recommendation areas:

1. ***Establish and Enforce a Common Lexicon for ME:*** DoD should formally adopt and enforce a unified set of ME definitions as outlined by the OUSD(R&E) Mission Engineering Guide and ensure all branches use this language.
2. ***Develop ME Strategy & Policy (Analogous to the DE Strategy):*** DoD should craft an ME Strategy that parallels the 2018 DE Strategy's role to set common goals for ME adoption, endorsed definitions, and objectives and ensure all stakeholders have a clear reference to guide implementation.
3. ***Ensure DE tools are accessible to ME practitioners***: There is a natural synergy between DE and ME – digital models and simulations can greatly enhance ME analyses. Using these tools will not only improve the quality of ME (as complex system of systems can be evaluated in silico) but will standardize and scale ME practices.

4. ***Strengthen Cross-Community Collaboration and Knowledge Exchange*:** Foster regular interaction among all of the Services, industry, and academia to accelerate lexicon and practice convergence.
5. ***Invest in Training and Cultural Adoption*:** The DoD should update curricula to cover the standardized definitions and methodologies for ME and DE. For DE, ensure that the workforce is trained not only in tools but in the underlying principles. For ME, training should focus on the interdisciplinary nature of the work – bringing together operators and engineers to learn the ME process, so that terms like "mission thread" or "capability gap" have a shared meaning.
6. ***Refine and Iterate Guidance*:** Treat strategies and guides as living documents. Regularly collect feedback on how terms and processes are implemented and interpreted in programs and exercises.
7. ***Capitalize on International Opportunities:*** Leverage best practices, lessons learned, and momentum of international allies and partners, through joint training and knowledge exchange opportunities, standards co-development, North Atlantic Treaty Organization (NATO) exercise opportunities, and international industry partnerships. Working closely with allies and partners, the DoD would not only gain efficiency and insight but also strengthen coalition warfighting capability and interoperability.

The team translated these recommendation areas into near and far-term actions that the DON can pursue toward improved ME and DE standardization and adoption. These include:

1. ***Establish a Unified ME and DE Lexicon Across the DON***: Develop a single authoritative lexicon, publish it as a DON reference document, and develop associated standards for enforcement. This will address the misalignments identified in the lexicon analysis and encourage proper use of digital tools and consistent processes. By eliminating semantic confusion, the DON will improve communication with industry partners and among its own teams, enabling more effective collaboration on complex mission-engineering efforts.
2. ***Standardize and Integrate DE Ecosystems Across the DON:*** Establish standardized DE ecosystems, define and publish common data/modeling formats, and enforce DE requirements in lifecycle activities. This will enable the DON to conduct holistic mission analyses, evaluating how well systems work together in a mission context (the essence of ME) using digital means. It also supports cross-sector (government-industry-academia) collaboration, aiming to have all key players "plugged into" the same digital ecosystem with agreed-upon standards.
3. ***Transform Workforce through Training and Education:*** Institutionalize a 3-tier certification/education program to ensure that ME and DE become mainstream skills across various levels of personnel. Reinforce the training through rotation/exchange programs and incentives. A trained workforce will drive adoption and scaling from the bottom up.
4. ***Embed ME and DE Requirements in Acquisition and Planning:*** Update document templates and guidebooks to require an explicit section on how ME and DE will be applied to "bake in" and enforce ME and DE practices rather than interpreted optional add-ons. Direct ongoing programs to perform an ME review at a major milestone to rapidly instill the practice of iteratively evaluating mission outcomes throughout the acquisition lifecycle.
5. ***Adopt Digital Twin and Simulation Environments for Mission-Centric Analysis:*** Launch a near-term digital mission model initiative to implement a common ME process, integrate digital mission models of various systems, and allow analysts to experiment with different configurations and tactics, serving as a quick-start initiative for the use of mission-level digital twins to inform decisions.
6. ***Leverage AI-Driven NLP Tools to Harmonize Terminology:*** Explore the use of an AI-driven tool to scan all new acquisition documents, operational and ME analyses, and warfighting concepts for the use of key ME and DE terms. Generate machine-driven suggestions for definitions or mappings of legacy terms to new lexicon, accelerating lexicon harmonization. Explore the use of AI-driven tools for mining lessons-learned databases and after-action reports to identify cases in which terminology mismatches contributed to any misunderstandings in past program health, exercises, or operations, providing real-world insights for lexicon improvements.
7. ***Conduct ME Pilot Programs and Wargames:*** Launch a series of pilot programs that integrate ME and DE into naval (and perhaps greater DoD and international level) exercises, simulations, and wargaming events to prove real-world value. Hands-on application in operational contexts will support broader adoption and refine the DON's methods.

Implementing these actions would enable the DON to accelerate ME and DE standardization and adoption. ME and DE will enable the DON to respond to threats more swiftly (through rapid scenario analysis and course-of-action modeling), integrate new capabilities or partners more smoothly (since common standards and models exist), and out-think adversaries by leveraging superior digital tools and mission understanding.

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Acquisition and Industrial Security (A&IS) Mission Area

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1 Introduction

1.1 Scaling Mission Engineering & Digital Engineering for Strategic Decision Making

Modern naval operations face complex, multi-domain challenges that demand more than traditional engineering and systems engineering approaches. The DON must integrate capabilities across air, sea, undersea, cyber, and space domains, often in real-time. Achieving this level of integrated, multi-domain capability poses significant challenges. The Naval Information Warfare Systems Command (NAVWAR) notes that leveraging technology at the pace of change and managing the growing interconnectivity of warfighting systems are two key challenges to Naval superiority (NAVWAR, 2023). The complexity of this challenge compounds when considering the multi-faceted and multi-stakeholder nature of the Department of Defense (DoD) acquisition system. Illustrated in Figure 2, critical interdependencies exist across an expansive stakeholder network made up of strategic leaders, the operational community, capability portfolio and program management personnel, and the fiscal community. Each stakeholder has a distinct focus, swim lanes, and related slices of the decision-making apparatus that makes up the greater SoS.

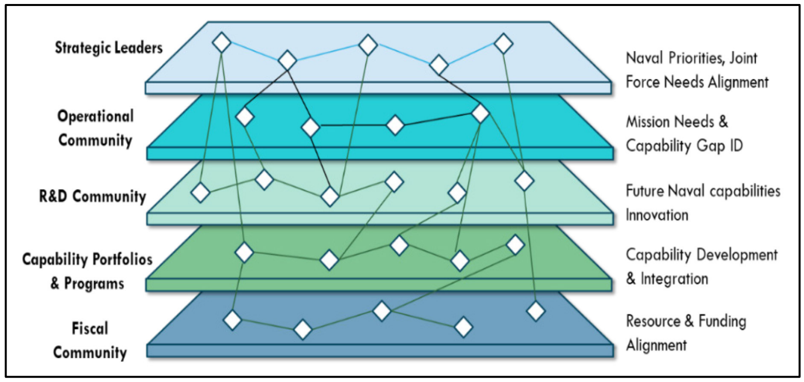

Figure 2: Illustrative Depiction of Stakeholder Decision Dependencies in Delivering Capabilities to the Warfighter

All stakeholders share a common goal: close capability gaps, meet the needs of the warfighter, and prepare a lethal Joint Force. Despite this, gaps exist across their organizational and technical seams arising from distinct responsibilities, priorities, funding, timelines, success metrics, lexicon, methodologies, and cultures. These gaps obfuscate the mission health awareness and the impact of actions across stakeholders– whether at the individual service level or across the services–and can create "valleys of death" that the overarching acquisition system struggles to overcome, as depicted in Figure 3. These gaps and seams limit the application and scaling of mission-and data-informed decision making for force design, investment prioritization, capability development, gap closure, mission impact assessments, and mission health tracking across stakeholders. ***ME, enhanced by DE, is the key enabler to improving alignment and digital traceability between stakeholders to clearly align activities and decision making through a mission-focused approach***. ME and DE are transformative and complementary disciplines capable of significantly reshaping the design and execution of modern military operations. By aligning high-level mission requirements directly with optimized solutions, ME and DE enhance both the lethality and efficiency of military capabilities, thereby ensuring that resources and strategies are precisely matched to desired mission outcomes – with specific measures of success, effectiveness, and performance. Together, ME and DE offer strategic advantages for the DoD, improving agility, interoperability, and mission effectiveness in an era of rapidly evolving threats.

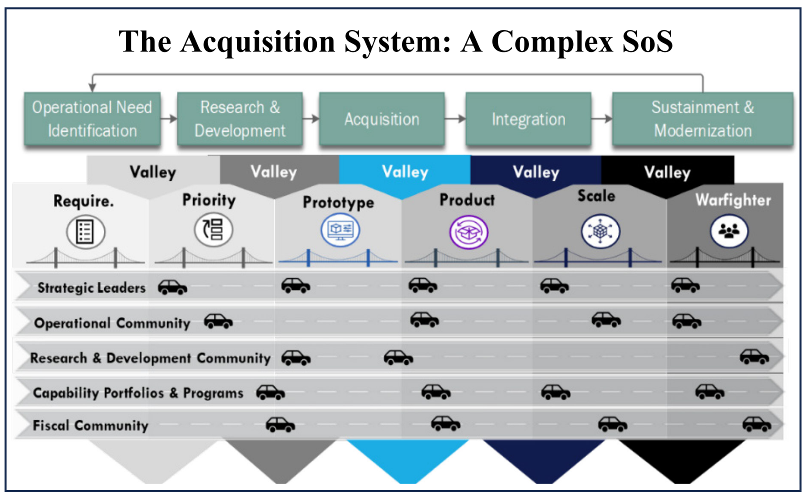

Figure 3: Illustrative Depiction of DoD's Acquisition System Organizational Seams

1.2 ME & DE Adoption Challenges

ME provides a mission-focused, threat-informed approach to identify the right mix of capabilities and ensure they work synergistically. Instead of evaluating a new system in isolation, ME examines how that system contributes to an entire mission thread, informing stakeholders about "building the right things, not just building things right." DE addresses the pace and complexity of this integration. Digital models and simulations allow engineers to iterate designs quickly, test systems of systems in realistic synthetic environments, and evaluate mission impacts before fielding hardware. ME defines what needs to happen for mission success and DE provides the digital means for how to get there efficiently. Despite these clear benefits, adoption has been inconsistent, particularly ME approach adoption. Factors contributing to inconsistent and delayed adoption are described below.

- ***Need for standardization and structured approaches:*** The DoD has emphasized the need for common frameworks and data environments – from the 2018 DoD Digital Engineering Strategy to the DON's own 2020 DSET Strategy. These strategies stress formalizing the use of models, authoritative data sources, and integrated tools and processes across the enterprise. The DoD highlights that without common standards and language among practitioners, the promise of ME and DE will be undermined by fragmented efforts across silos of excellence. If each service (or individual offices) uses a different definition for "mission thread" or employs incompatible tools, it becomes difficult to collaboratively analyze missions or reuse digital assets. Incentivizing and requiring the use of structured methodologies, with a structured minimum common product set, ensures that insights from ME analyses are repeatable and trusted, and that digital models developed by one team can be integrated and leveraged by another. The standardiz***ation of ME and DE implementation across programs presents a force-multiplier opportunity – bridging stakeholder seams and enabling cross-team synergy***, reducing errors, and aligning efforts toward the DON's and larger DoD strategic goals.

- ***The lack of a unified ME and DE lexicon***: The ME and DE landscape lacks a unified lexicon and taxonomy. Communities (requirements, engineers, testers, operators, industry) use terms like "Measure of Effectiveness" or "Digital Twin" in varying ways, assuming they are applying ME approaches, despite a lack of Mission-centric measures. A common misperception is that the use of DE enabling tools infers that the practitioner is doing ME. This is in part due to the varied adoption of lexicon across communities. Such terminology discrepancies impede communication and result in misalignment. An analysis of model-based engineering efforts within the DON found that while model-based systems engineering (MBSE) practices have grown, there is "a lack of organized mentoring and access to DE subject matter experts" and inconsistent knowledge management, including gaps in lexicon establishment (NAVWAR, 2023). ***Establishing and encouraging a unified ME and DE lexicon is essential to realize the strategic value and operational effectiveness envisioned by ME and DE initiatives***.

- ***Cultural barriers present challenges to adoption***: Despite top-level recognition of the importance of ME and DE, culturally, the defense acquisition community has been slow to move away from document-centric, legacy processes. Many engineers and program managers are reluctant to fully embrace new digital tools, often preferring the familiar legacy requirements management and traditional systems engineering based approaches. This has led to situations where digital models are underutilized or used in inconsistent ways, limiting their value, as their ***value is truly only unlocked when available at an adequate scale, used broadly, and standardized across the DoD***.

- ***Pockets of implementation across the DoD; lack of institutionalization***: Common across all services, the DON's implementation of ME and DE has been uneven. The Air Force and Army have each launched DE initiatives (e.g. Air Force's "Digital Campaign" and Army's modernization efforts with enterprise cloud modeling environments and digital engineering pathfinders, backed by policy that requires DE plans for programs). The Army and Air Force both have Futures Commands – with Space Force following suit standing up the Space Futures Command– establishing pockets of ME implementation. The Air Force activated the Integrated Capabilities Command (ICC) (Provisional) to accelerate force modernization and integration. The DON's 2020 DSET Strategy is in place, in addition to the DON's ME Technical Authority Board (ME TAB), Warfighting Integration Team, Naval Air Systems Command (NAVAIR) PMA 298, AI Task Forces, and Office of Naval Operations N9 driving progress in aspects of ME and DE. ***More work is needed to institutionalize DE across all levels, while also simultaneously institutionalizing ME as a beneficiary of this adoption***. Internationally, allied militaries are also modernizing – the UK is building a "Digital Backbone" for its forces, and NATO is moving toward data-driven, multi-domain mission integration. The DON must continue to build on best practices, overcome hurdles, and consolidate wins to fully leverage ME and DE for competitive advantage.

Effective integration of ME and DE is critical to achieving the DON's strategic vision of future force readiness and agility. By engineering missions holistically and leveraging DE, the DON can better align its capabilities to mission outcomes, reduce development timelines, and iterate faster than adversaries. The following sections of this report summarize detailed findings on how ME and DE terminology and concepts are currently understood and provides recommendations – both strategic and tactical – to overcome cultural and technical barriers toward improved adoption to fully realize a digitally-enabled, mission-focused force.

2 ME & DE Lexicon Analysis

This section provides a synthesis of key findings extracted from the team's ME and DE lexicon analysis aided by the internally developed LexiScope tool. This analysis explored semantic similarities and differences, definition clustering, conceptual relationships, and term frequency. The team incorporated these findings as part of the strategic drivers and recommendations laid out in Section 5.

2.1 Methodology Overview & Summary of Key Findings

To effectively gauge the current state of ME and DE adoption across the DON, Joint forces, and contractors, the team conducted a semantic-based lexicon analysis – examining how these communities define and use key terms. The team utilized the internally developed LexiScope, a natural language processing (NLP) tool, to compare ME and DE definitions sourced from the DoD, industry, and academia, and the open web over time. The team generated data-driven visualizations such as heatmaps highlighting semantic similarities and differences, dendrograms illustrating definition clustering, principal component scatter plots showing conceptual relationships, and word clouds emphasizing frequently used terms. This comprehensive analysis reveals areas of conceptual alignment and identifies gaps in understanding or emphasis. Aligning definitions across stakeholders is critical, as shared terminology reduces misinterpretations, minimizes duplicated efforts, and enhances coherence in key initiatives like mission thread analyses or digital twin development. The team contextualized these results within broader research and policy frameworks to draw strategic implications for the DON's ongoing digital transformation.

Emphasizing the importance of a unified lexicon underscores the recognition that consistent terminology is foundational to interoperability, whether between software systems, analytical models, or human teams operating across organizational boundaries. The DON has emphasized the necessity of a standardized lexicon to facilitate effective communication and interoperability across diverse communities, including requirements development, acquisition, and collaboration with industry partners. For instance, NAVWAR developed the Enterprise Architecture Integrated Dictionary, providing authoritative, validated terms and definitions adopted across various Navy systems commands. This standardized lexicon aims to eliminate ambiguity and ensure consistency, thereby preventing historical challenges in which differing terminologies led to integration failures. At the broader DoD level, initiatives like the DoD Mission Engineering Guide (MEG) explicitly aim to standardize terminology to foster stronger collaboration between the DoD and industry partners. The MEG provides clear guidance intended to enhance mutual understanding across complex engineering efforts. Although there has been some focus on common vocabulary and measurable reductions in ambiguity—as captured through the longitudinal lexicon analyses captured in this report—continued efforts remain vital to fully realize seamless collaboration.

Key findings derived from the comprehensive lexicon analysis are included below and further expanded on in the remainder of Section 2. The analysis demonstrated clear differences in the overall trends for adoption of ME versus DE, with notable contrast in cross-sector lexicon alignment.

High Degree of Uniformity and Cross-Sector Alignment of DE Lexicon:

The 2018 DoD DE Strategy set the stage for the Services, industry, and academic partners to coalesce around the DE concept. Trends extracted from the lexicon analysis included:

- ***DoD Lexicon:*** Each of the military services and OSD offices quickly aligned on core DE concepts (model-based engineering, digital twin/thread, digital transformation, digital modernization, etc.), leading to similar definitions and tight clustering across policy documents and strategies. The services developed service-level strategies pushing for alignment and implementation of such concepts.
- ***Industry, Academia, and Open-Source Lexicon:*** Industry (e.g. BAE Systems, IEEE, INCOSE, etc.) discuss DE in the same terms, aligning with ongoing trends in model-based systems engineering and Industry 4.0. Academia reinforces similar concepts through research on digital twins, lifecycle modeling, and cross-discipline integration. Additionally, open sources describe DE in line with the DoD strategy – emphasizing digital models, integrated data, and lifecycle use.
- ***A sense of a unified movement:*** the goals of the 2018 DE Strategy (e.g. formalize model use, establish an authoritative source, transform culture) are not limited to policy documents – they have been actively internalized by the community in a relatively uniform manner. The DON, Air Force, and Army are all implementing DE and digital transformation initiatives that use the same language (model-based systems engineering, digital twin, etc.), and industry is building tools and methods to support those goals.

DE terminology is more consistent across sectors focused on digital models, integration across disciplines, authoritative data sources, and lifecycle management, with less divergence[ii] in wording than seen for ME. This cross-sector cohesion – driven by consistent terminology and vision – has accelerated DE adoption across the DoD.

Uneven Adoption and Lagging Alignment of ME Lexicon:

In contrast to DE, ME adoption has been more uneven and is still maturing toward alignment. The concept of ME has been around in various forms for years (often under different names or without formal recognition), but it has not had a singular driving DoD wide strategy calling for uniformity and transformation like that of DE. Therefore, ME terminology has varied across sectors, with DoD branches each adding their flavor, industry and academia seeking broader conceptual framing, and open sources capturing the basics. Trends extracted from the lexicon analysis included:

- ***DoD Lexicon***: DoD and its contractors use unique lexicons across their individual communities implementing ME. The Office of the Under Secretary of Defense for R&E (OUSD(R&E)) defines ME as "the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects." The focus on missions and warfighting outcomes is echoed within DoD, but different branches emphasize different aspects. The Navy, Air Force, Marine Corps, and Coast Guard all adopted ME in principle in their contexts– because the need to analyze missions existed – but they often did so in isolation and without a unified definition, resulting in differing practices.
- ***Industry, Academia, and Open-Source Lexicon***: Federally Funded Research Centers (FFRDC) (e.g. MITRE, NDIA), and academia (e.g. SERC, INCOSE), recognize ME as an emerging extension of systems engineering focused on mission-level outcomes. These communities describe ME in generalized terms (e.g. an "interdisciplinary approach…to achieve desired mission outcomes"), which may differ slightly from each service's jargon (Dahman and Parasidis, 2024). Open sources (e.g., Wikipedia) reflect the DoD perspective of ME usually, but there can be variations or simplifications in those descriptions.
- ***Historical Cross-Sector Divergence:*** The team found that an academia/industry cluster of ME definitions formed separately from the service definitions. This shows that the defense industry and researchers developed a more standardized view (perhaps due to cross-pollination at conferences and via organizations like NDIA or INCOSE), whereas within DoD the alignment lagged behind.
- ***Recent Years Suggest Trend Toward Unification:*** OUSD(R&E) published the MEG in late 2020 to codify ME principles and "establish a set of common terms and definitions." This effort, along with the creation of an ME Community of Practice, is essentially doing for ME what the 2018 strategy did for DE – providing an authoritative reference that others can adopt. In contrast to the 2018 DoD DE Strategy or others like it (e.g., 2020 DoD Data Strategy) – which are issued by the Office of the Secretary of Defense (OSD) as enterprise-level guidance to all Services, Agencies, and Components and serve as a basis for future Directives, Instructions, and compliance frameworks – the MEG was developed by an individual office within OSD as a technical implementation framework. While the MEG is influential, the DoD lacks enterprise-level mechanism to drive alignment in vision and terminology.
- ***DoD at a turning point for ME Lexicon Alignment:*** The DON and other services are now moving to align with the OUSD's ME framework, which should improve consistency. As of now, the team's findings – particularly the lack of OSD-level strategy – indicate the alignment is not yet as tight as it is for DE. The DON and Army might use slightly different ME playbooks, and industry partners may not always know if ME means the same thing to one service as it does to another. In contrast to DE (used fairly consistently across sectors), ME terms still require clarification in practice. The trend, however, is toward convergence. With top-down pressure (e.g. the NDAA's mandate for mission integration and OUSD(R&E)'s guidance) and increased collaboration, the team expects the ME lexicon to coalesce similar to how DE's did. An OSD-level strategy or guidance would accelerate this trend.

In summary, DE shows a high degree of cross-sector alignment already, whereas ME is still in the process of laying the foundations toward achieving alignment. DE's adoption has been accelerated by a common vision and vocabulary from the start with OSD-level guidance, leading to broad acceptance in the DON and DoD at large. ME's adoption has been more fragmented, with pockets of advanced practice and understanding (SERC, NDIA, etc.) but also pockets of confusion or differing interpretations in the Services. This is partly due to the lack of OSD-level guidance. However, ongoing standardization efforts are driving cross-sector convergence. The research demonstrates that DE lexicon is anchored by concepts of digital models and authoritative data, while ME lexicon is anchored by mission context and SoS integration. Both

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[ii] The divergence recorded across sectors was ***minimal to moderate*** for DE – a largely aligned trend suggesting communities are pushing in the same direction (with perhaps differences in pace rather than fundamental concept).

domains have critical terms that need clear consensus on definitions (to avoid each organization reinventing them). These insights into terminology shape the recommendations for standardization and adoption.

Recommendations for Improving Standardized Adoption of ME and Continued Institutionalization of DE:

- **Establish and Enforce a Common Lexicon for ME (Following DE's Example):** The DON and DoD should formally ***adopt a unified set of Mission Engineering definitions*** as outlined by the OUSD(R&E) MEG and ensure all branches use this language. For instance, terms identified as central (like mission, mission thread, systems-of-systems, mission outcomes) should be clearly defined in doctrine and training. A concerted effort to disseminate "what is and is not ME" and the approved definitions will reduce confusion. This could involve updated Navy guidance documents that explicitly reference the DoD-wide definition of ME (similar to how all services reference the 2018 Digital Engineering Strategy for DE terminology).

- **Develop an ME Strategy & Policy (Analogous to the DE Strategy):** To drive home the importance of ME, the DoD should ***craft an ME Strategy*** that parallels the 2018 DE Strategy's role. This strategy would set common goals for ME adoption (e.g., "Institutionalize mission context in requirements and acquisition," "Develop tools and data environments for mission-level analysis," "Cultivate ME expertise in the workforce"). By having an OSD enterprise-level strategy, complete with endorsed definitions and objectives, all stakeholders will have a clear reference, much as they do for DE. This top-down approach helped DE achieve unity and would likewise signal leadership commitment to ME. It could also tie into policy – for example, updating acquisition policy to require mission-level engineering considerations (just as a new DoD Instruction now formalizes digital engineering in acquisition).

- **Leverage DE Infrastructure to Support ME**: There is a natural synergy between DE and ME – digital models and simulations developed under DE initiatives can greatly enhance ME analyses. The DON should also ensure that ***DE tools (modeling & simulation environments, digital twins, authoritative data repositories) are accessible for ME studies***. Using these tools will not only improve the quality of ME (as complex SoS can be evaluated in silico) but will also help standardize ME practices (teams using common digital environments will by necessity use common data and terminology). Notably, DoD's current ME methodology explicitly "applies digital model-based engineering approaches to assess how well a SoS achieves mission objectives…" thus, integrating DE and ME efforts is a force multiplier. As a recommendation, the DON could pilot ***mission-level digital twin models*** for key missions, thus marrying the concepts: this approach reinforces DE adoption (through a compelling use-case) and standardizes ME (through shared digital artifacts and language).

- **Strengthen Cross-Community Collaboration and Knowledge Exchange**: Fostering regular interaction among the Services, industry, and academia will accelerate lexicon convergence. The DON should actively participate in and perhaps ***lead the ME Community of Practice*** and similar working groups for DE, ensuring that lessons learned and terminology updates are shared widely. Joint workshops or tiger teams can be set up for ME on critical mission areas, including industry subject-matter experts and academic researchers alongside DoD personnel. Such forums help align vocabulary – for example, an NDIA-led working group could help translate an industry best practice into terms the Services can adopt, and vice versa. Additionally, the DON could sponsor knowledge exchanges (conferences, technical interchange meetings) specifically to reconcile differences in ME approaches among the Services. Over time, repeated collaboration will organically enforce a common language for both ME and DE across the defense ecosystem.

- **Invest in Training and Cultural Adoption**: Both ME and DE require not just agreement on paper but also understanding on the ground. The DON (in concert with DAU and educational institutions like NPS) should update curricula to cover the standardized definitions and methodologies for ME and DE. For DE, ensure that the workforce is trained not only in tools but in the underlying principles (so that terms like "authoritative source of truth" are clearly understood and implemented, not just buzzwords). For ME, training should focus on the interdisciplinary nature of the work – for example, bringing together operators and engineers to jointly learn the ME process, so that terms like "mission thread" or "capability gap" have a shared meaning across functional communities. A ***certification or qualification program in ME*** (similar to how Systems Engineering has level certifications) could be established to build a cadre of mission engineers fluent in the common lexicon. Culturally, leadership in the DON should highlight successes where ME and DE made a difference, as this reinforces adoption. When personnel see that using these practices (with the associated standard terminology) leads to better outcomes (e.g., quicker acquisition decisions, more effective capabilities for the warfighter), they will more rapidly embrace the concepts. This addresses the Strategy's goal of transforming culture for DE and similarly will build a proactive culture for ME.

- **Refine and Iterate Guidance Using Feedback:** Finally, as ME and DE practices mature, the DON and DoD should treat their strategies and guides as living documents. Regularly collect feedback on how terms and processes are implemented and interpreted in programs and exercises. If ambiguity in terminology is noted (for instance, if different groups still use a key term differently), update the official lexicon or provide examples to clarify. For DE, as new tech emerges (AI, new modeling tools), ensure the lexicon expands or adapts to include those in a controlled way so as not to splinter the community's understanding. For ME, as it becomes more widely practiced, gather case studies from each Service: do they all frame the mission problem the same way? If not, convene a working group to standardize the approach and terminology used in mission problem statements and analyses. By continuously ***measuring adoption and gathering lessons learned***, the DON can identify where inconsistencies remain and proactively address them – leading to ever tighter alignment. In essence, treat the lexicon itself as an asset to be managed. This continuous improvement loop will solidify both ME and DE standardization and ensure long-term, cross-sector adoption.

Overall, by implementing these recommendations–establishing common definitions, creating strategy/policy impetus, leveraging synergies, encouraging collaboration, investing in training, and iterating on guidance–the DON and the wider DoD can greatly enhance the standardization and adoption of ME and DE. The end state would be a workforce and community that speak with one voice on ME and DE, enabling more effective integration of mission-centric thinking with cutting-edge digital practices to deliver superior warfighting capabilities. The next five sections dive deeper into components of the lexicon analysis and key findings.

2.2 Semantic Heatmaps

As part of the comprehensive lexicon analysis, the team used the LexiScope tool to derive heatmaps visualizing the degree of similarity between definitions of key terms across sources (darker cells indicate higher similarity). The heatmap displays pairwise semantic similarities, with values ranging from 0 (no similarity) to 1 (high similarity). Brighter cells indicate closer alignment between sources, while darker cells reflect significant differences. The semantic similarity heatmaps illustrate how closely available definitions of ME and DE terms align across DoD components and aggregated open data sources using large language models. As expected, a clear pattern emerged in the analysis: definitions from the same community (e.g., multiple DoD sources) tend to cluster with high similarity (darker blocks), whereas cross-community comparisons (DoD vs. industry vs. academia) often show lighter shades indicating divergence. Figure 4, for example, highlights how specific measures associated with ME (i.e., Measure of Effectiveness) have highly divergent definitions.

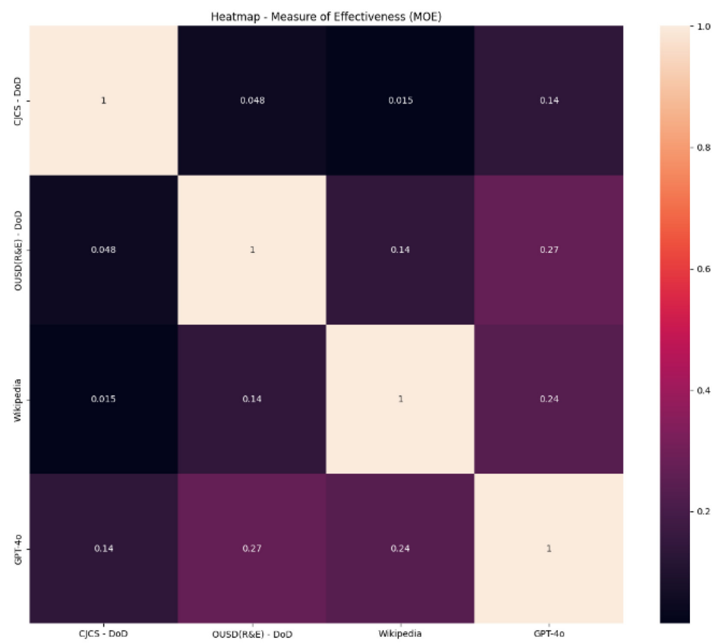

Figure 4: Semantic similarity heatmap for "Measure of Effectiveness" across communities

Official DoD definitions of **Mission Engineering** emphasize "deliberate planning…of operational and system capabilities to achieve desired warfighting mission effects." This is language that tends to cluster closely with other defense documents. Academic definitions, by contrast, frame ME as applying systems engineering to missions (treating the mission as the system of interest). This academic view shares more terminology with systems engineering literature and thus shows less similarity (lighter heatmap cells) when compared to the warfighter-centric DoD definitions. Industry sources often fall in between – for instance, a defense contractor may echo the DoD's focus on capabilities, while a commercial tech firm could use entirely different language for a term like "digital engineering," leading to a notable drop in similarity on the heatmap.

Overall, the heatmaps revealed strong consistency within DoD documents, but noticeable divergence between DoD and non-DoD sources on certain concepts. For example, as anticipated, definitions of "Concept of Operations (CONOPS)" from Navy and Joint publications showed high mutual similarity (common phrasing around mission scenarios, objectives, and execution), whereas a CONOPS definition from industry had a lower similarity score, indicating different terminology. Such findings suggest that within the DoD, a relatively unified understanding of core terms is emerging, thanks in part to shared doctrine and guidance, but when communicating with industry or academic partners, misalignment in language can occur. Another heatmap focusing on DE terms (like "Authoritative Source of Truth" and "Digital Engineering Ecosystem") showed that industry sources often emphasize the technological aspect (e.g. data management platforms, Product Lifecycle Management tools), while DoD sources emphasize the authoritative data and governance aspect. These nuances matter – if the DON says "authoritative source of truth" and intends a single validated data repository, but a vendor interprets it merely as a configuration management database, deliverables and expectations might diverge. The heatmap analysis underscores the importance of a common vocabulary: where the DoD has provided clear definitions (as in official glossaries and strategies), consistency is high; but where multiple interpretations exist, the DON should standardize the lexicon to avoid confusion.

The similarity heatmap for ME definitions depicted in Figure 5 reveals several differences between sources, but some alignment across select sources. Each cell compares the textual similarity of two source definitions (lighter colors indicate higher similarity). There is a **cluster of light-colored cells (high similarity ~0.9)** in one region of the matrix – highlighting an academic synthesis (INCOSE/IEEE/SERC) and a Defense Acquisition University (DAU) definition are almost identical (bright cells with values ≈0.95–1.0). This indicates that certain academic and training communities are using very similar language to define ME. The team also found a strong alignment between official Navy and OUSD(R&E)'s 2020 MEG definitions. Both emphasize mission outcomes achieved through integrating systems in an operational context. Naval sources echo the MEG's focus on warfighting outcomes and often explicitly start from the desired mission capability and work downward to systems. In contrast, many other cells are dark (low similarity <0.3), especially when comparing definitions across the individual military branches. Additionally, the DON's ME definition has low similarity with the academic/industry definitions (dark blocks), meaning the DON's wording diverges significantly from those sources. Overall, the heatmap shows **pockets of high similarity and broad areas of divergence**. A few groups (e.g. the SERC/MITRE/NDIA cluster) agree strongly on what ME means, but cross-comparisons between, say, the Air Force and an academic source or between OUSD(R&E) and Wikipedia are much darker, highlighting the **inconsistency of the ME lexicon across sources**.

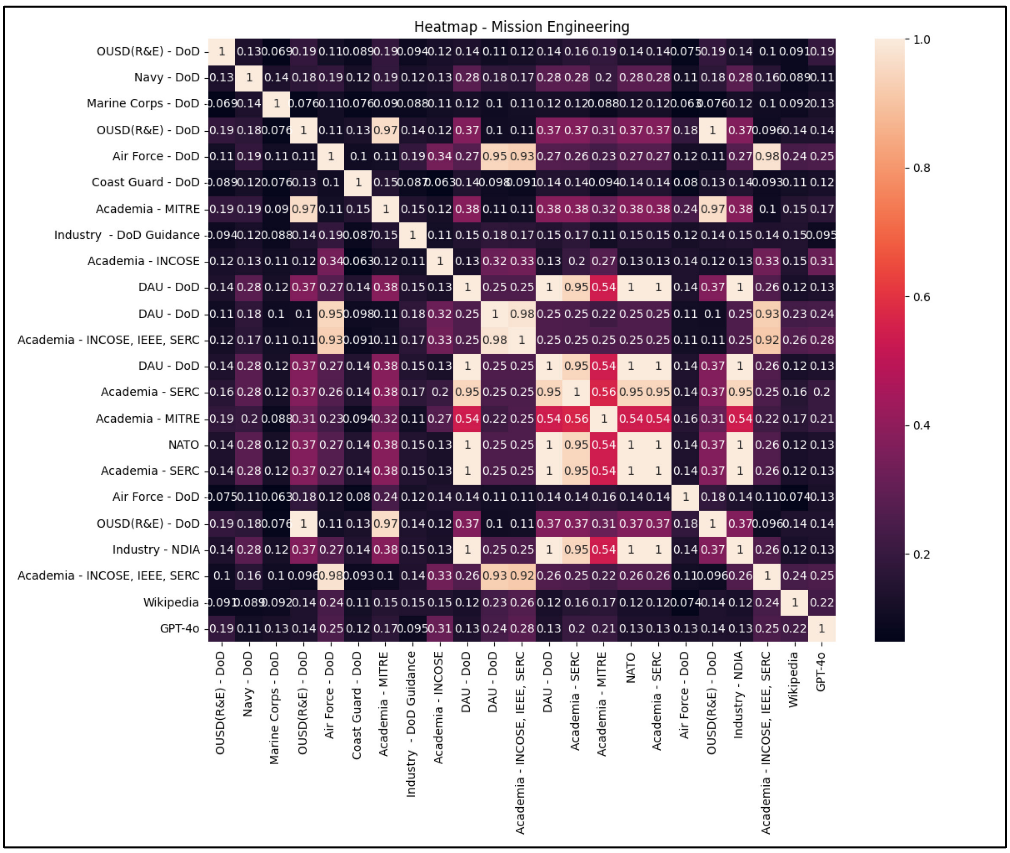

Figure 5: Semantic Similarity Heatmap for Mission Engineering

The DE similarity heatmap shown in Figure 6, on the other hand, is **much warmer overall**, indicating greater consensus. Most DoD-to-DoD comparisons are medium to light colored (values in the 0.5–0.8 range), showing that the Army, Navy, Air Force, OUSD, etc., all describe DE in a similar way. The DON's and Air Force's definitions of DE overlap significantly in content (many shared terms about models, data and lifecycle), yielding a moderately high similarity score. The DoD's official definition of DE – "an integrated digital approach using authoritative sources of system data and models as a continuum throughout the development and life of a system" – has been widely adopted across the services. Even industry and academic entries are fairly aligned with DoD definitions – indicated by warm colors when comparing the OUSD(R&E) definition to an IEEE or university definition, for example. There are a few outliers: one cell corresponding to a particular industry definition (BAE Systems) is darker against others, suggesting that BAE's phrasing emphasized something unique (perhaps a specific use-case) not present in other definitions. Also, the FY20 NDAA (Congressional) reference to digital engineering has somewhat lower similarity to others – not surprisingly, a legal text frames DE differently than technical descriptions. Early open descriptions of "digital engineering" sometimes equated it to digital tools in engineering or specific concepts like digital twin technology, without covering the full lifecycle approach. Consequently, the heatmap might show a modest drop in similarity for open-source DE definitions versus the authoritative definition. However, importantly, **no major "cold spots" divide the DE heatmap** the way they do in the ME heatmap. Overall, the heatmap suggests that ME and DE are understood rather uniformly within the core defense community, with only peripheral sources showing conceptual drift.

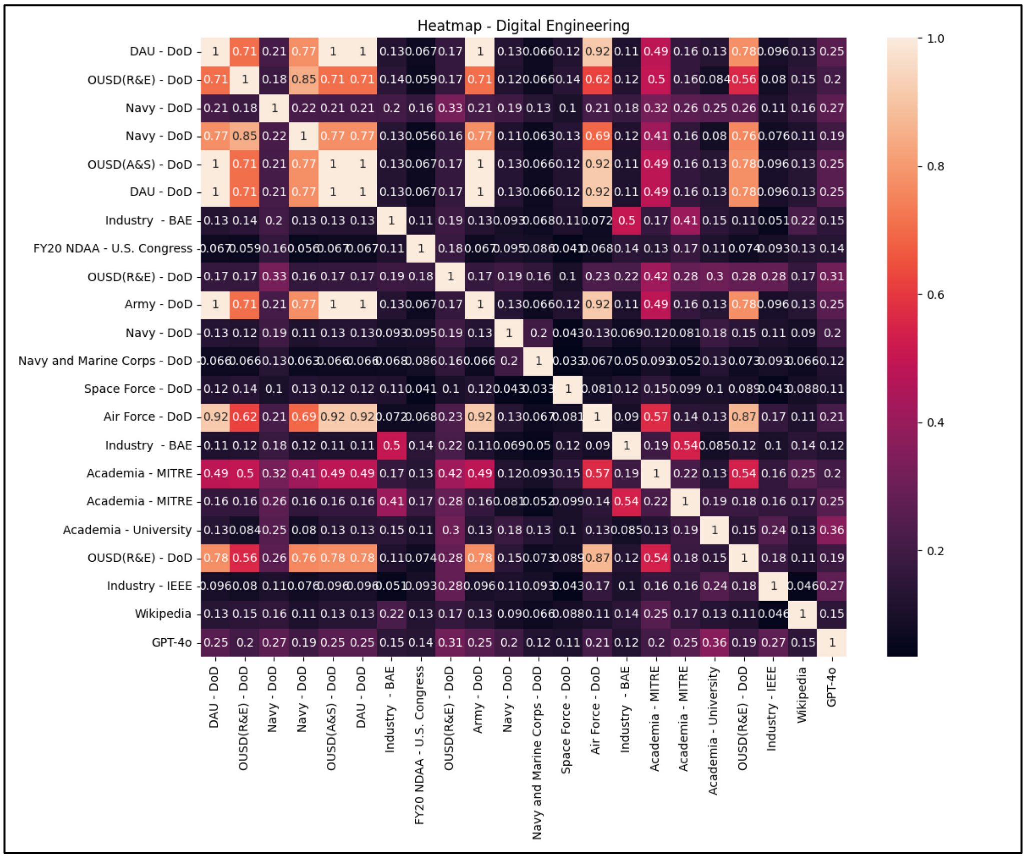

Figure 6: Semantic Similarity Heatmap for Digital Engineering

2.3 Clustering & Dendrogram

As another means to investigate lexicon similarity across sources, the team developed dendrograms that group definitions creating a hierarchical clustering of how various organizations describe a concept. A striking observation from these dendrograms is the formation of clusters that correspond to the source domain. Definitions from within the DoD cluster tightly together for many terms, indicating a shared interpretation, while definitions from academic or commercial sources form separate branches. The dendrogram analysis offers a visual hierarchy of how terms group, shedding light on each term's semantic "family." Items that cluster together have more similar definitions.

For ME terms, the dendrogram depicted in Figure 7 confirms that ME is tightly coupled with other mission-centric terms and systems engineering concepts. ME appears in a cluster alongside terms such as "Mission Analysis," "Mission Thread," and "Mission Architecture," as well as near the broader node of "Systems of Systems Engineering." This clustering reflects that those terms share a lot of vocabulary and themes with ME definitions. Its proximity to systems engineering in the dendrogram underscores that many definitions frame ME as an application or extension of systems-of-systems engineering principles to mission-level problems. We also see ME linking with the concept of Mission Integration Management (MIM) – not surprisingly, since DoD documents identify ME as a key technical element enabling MIM in portfolio decisions. In contrast, terms like "Concept of Operations (CONOPS)" and "Scenario" might form a neighboring cluster, indicating that while related (they set the stage for mission engineering by defining operational context), they are distinct enough to form their own subgroup.

Diving deeper into the two clusters in the ME dendrogram (Figure 7), one cluster (purple in the figure) groups a mix of **military branch definitions and open-source entries**. The Navy, Air Force, Marine Corps, and Coast Guard definitions, along with the Wikipedia entry and a GPT-4 generated definition used in the analysis, all appear on the same broad branch. This suggests these definitions, while not identical, share enough common ground (e.g. generic references to "mission" and "capability") to be loosely related. However, the **branch distances within that purple cluster are still relatively large**, implying that even among themselves the services might use different wording or emphasis in ME (they cluster together largely because they are equally dissimilar to the other cluster). In stark contrast, the second cluster contains the **academic and industry-aligned definitions**, and these are tightly knit. In the orange/green sub-branches, entries from SERC, MITRE, NDIA, and a combined INCOSE/IEEE source sit very close to each other (short branch lengths). This tight grouping means that these sources use nearly the same language – essentially a cohesive mini-lexicon for ME. Interestingly, the Defense Acquisition University's definition joins this cluster as well, indicating that DoD training materials have adopted the academia/industry phrasing (likely to teach a standard concept). The clear separation between the two clusters indicates **lexicon fragmentation**: one cluster represents a more **unified, "systems engineering" view of ME** (common in academia/industry), while the other is a **scatter of service-specific interpretations**. The lack of a single, cohesive cluster including all sources points to why practitioners have struggled with ME – different communities use different definitions for terms in practice.

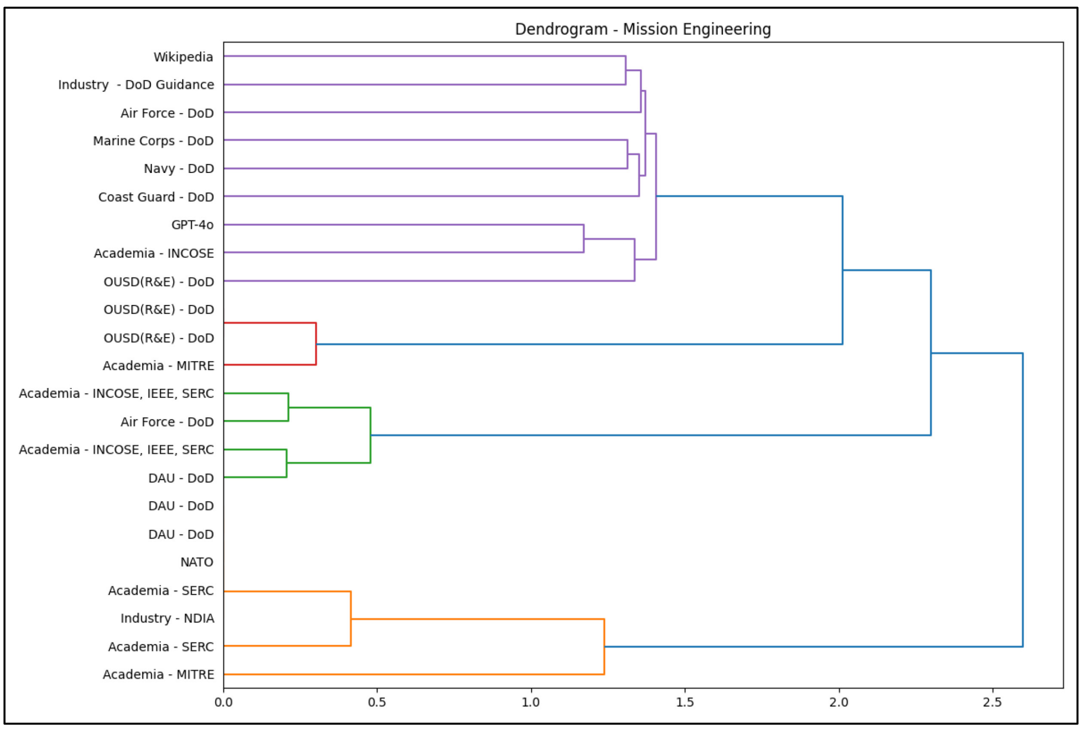

Figure 7: Hierarchical clustering of ME Definitions Illustrates Lexicon Split

For DE terms, the dendrogram depicted in Figure 8 shows DE embedded in a cluster of digitally-focused engineering terms. Notably, "Digital Thread" and "Digital Twin" are clustered very close to DE. This makes sense: a digital thread (the framework connecting data and models across the lifecycle) and digital twin (virtual replicas of physical systems) are often key enablers or components of DE initiatives. The definitions of DE frequently mention creating an ecosystem of tools and models – essentially describing a digital thread – and the use of virtual models – essentially digital twins – so semantically they overlap significantly. The DE cluster also likely incorporates "Model-Based Systems Engineering (MBSE)," since DE encompasses and builds upon MBSE practices. The dendrogram likely places MBSE as a bridge node, linking traditional systems engineering with the newer DE paradigm. This indicates that texts discussing DE often include MBSE concepts, reflecting that DE is an evolution of model-based approaches with greater integration and scope.

The DE dendrogram has **two key clusters worth noting**: a mission-centric cluster (with ME at its center) and a digital-centric cluster (with DE at its center). The separation between these clusters on the dendrogram highlights that, while both terms include the word "engineering," their contexts differ. Despite this separation, it is worth noting points of contact: for example, the term "Digital Mission Engineering" is emerging at the intersection of the two clusters, shown in NATO and industry discussions linking mission threads with digital modeling. This implies a convergence of the ME and DE domains in future concepts, something the DON might capitalize on.

One **dominant cluster** (highlighted in orange) contains most of the official DoD sources (i.e., the Army, Navy, Air Force definitions, the OUSD(R&E) strategy definition, the OUSD(A&S) perspective, and DAU's materials). The branch distances among these are small, which means all sources use similar language for DE. This indicates that the DoD's foundational definition of DE from the 2018 DE Strategy has been consistently adopted and reflected in both training and guidance documents. There is a secondary cluster (green branch) that includes a few of the more atypical sources. Notably, an **industry example (BAE Systems)** and an **academic perspective** fall into this cluster, along with a joint "Navy and Marine Corps" document and the NDAA reference. These outliers cluster together not necessarily because they all agree with each other strongly, but because each is somewhat different from the main cluster. That said, this secondary cluster is not extremely distant; many mention the key concepts of models, data, and lifecycle, so they are **moderately similar to the primary cluster**. The dendrogram overall shows **better lexicon cohesion for DE**: sources connect under one big tent (the blue linkage) at a reasonably low distance. In practical terms, this means the **Navy, Air Force, Army, industry, and academia are all speaking roughly the same "language" for DE**, with only slight dialects, showing cross-sector alignment on terminology.

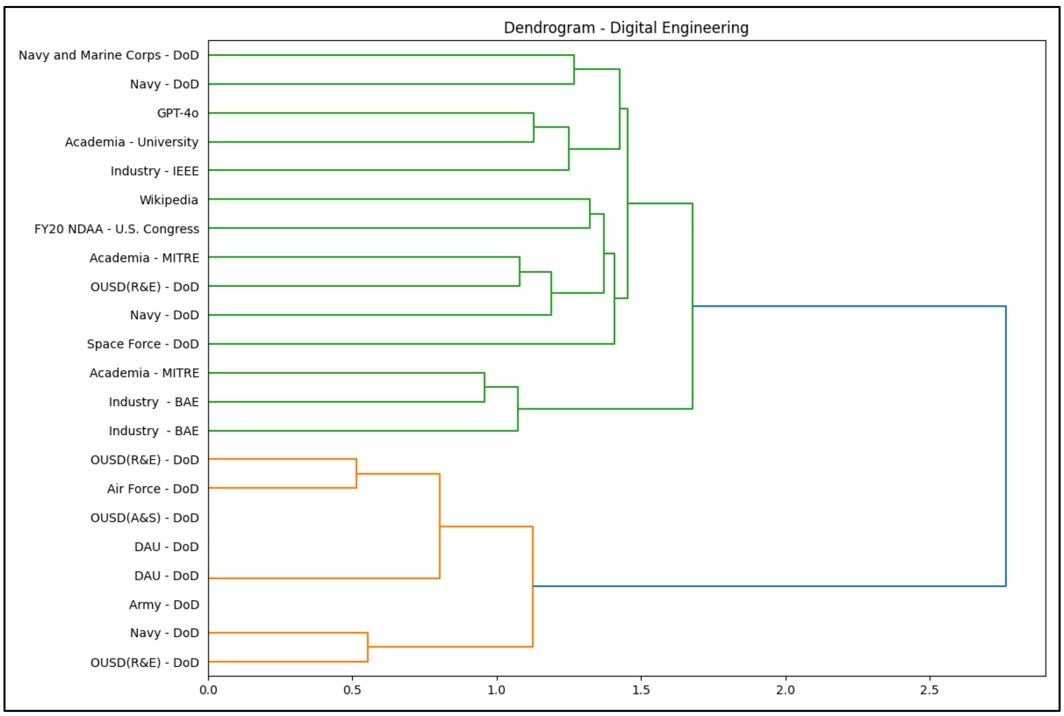

Figure 8: Digital Engineering dendrogram Shows a Story of Lexicon Unity

2.4 Principal Component Analysis (PCA) Scatter

The team also developed PCA scatter plots using the LexiScope tool to reduce the complex semantic space of definitions into two principal components for visualization. Each point on these plots represents a specific definition of a term, and points that cluster together indicate semantically similar definitions. The scatter plots essentially mirror the dendrogram findings but provide a more intuitive "map" of the landscape of meanings.

The team found that definitions of terms like "Mission Engineering" and "Digital Engineering Ecosystem" from DoD sources clustered in one region of the plot, whereas definitions from academic journals or industry guides were plotted farther apart. This dispersion suggests that while the DoD definitions share common language (likely influenced by official policy documents), other communities might emphasize different facets. For instance, an academic definition of "Mission Engineering" might stress the analytical process and theory, whereas a defense contractor's definition might stress capability integration for a customer's mission. The PCA visualization makes these differences apparent through a visual gap between clusters. From a Navy perspective, the goal would be to narrow these gaps over time, bringing points closer through collaborative efforts on terminology. The scatter plots also help identify "bridge" definitions – cases where a defense industry source has adopted the DoD's definition verbatim (plotted in the DoD cluster). Such bridges are positive signs of convergence. Overall, the PCA results reinforce the insight that sector-specific language still exists: the DON and DoD have some internal alignment, but aligning externally (with academia, industry, and allies) will require deliberate outreach and standardization.

Diving deeper, the ME scatterplot depicted in Figure 9 shows definitions from Navy and DoD sources tightly grouped, indicating they share very similar language and framing. This is represented on the left side of the plot (negative principal component axis), showing a cluster of points represents definitions from sources like the **Navy, Marine Corps, Air Force, Coast Guard, Wikipedia, and even the GPT-4 draft**. These points are relatively spread out but occupy the same general quadrant, indicating these definitions share some baseline terms but each has its own nuance. They are not all on top of each other, which tells us that, say, the Navy and Air Force definitions still differ – but collectively, they inhabit a part of the space distinct from the rest.

On the upper-right of the plot, by contrast, the points for **Academia/Industry sources (e.g. "Academia – SERC", "Industry – NDIA") tightly cluster together** – essentially overlapping in some cases. This tight cluster corresponds to the common lexicon used by research and industry groups for ME. In the ME scatterplot, one or two points sit somewhat between the extremes. The MITRE definition (an FFRDC perspective) appears a bit closer to center, hinting that it might bridge terms between the purely academic view and the DoD usage. The distance between this academic/industry cluster and the cluster of service definitions is noticeable; there is a gap in the plot, reflecting the **conceptual gap between how, for example, SERC talks about Mission Engineering versus how an individual Service might**. The spread is still moderate – all these points likely fall within the same quadrant – signifying that no community's definition is wholly inconsistent with another, but the academic and industry points exhibit a bit more variance. Overall, **ME has high coherence among defense stakeholders, with outsiders gradually converging as the term becomes more standard,** confirming there is **no single "center of gravity" for all ME definitions**. Instead, there are essentially two centers – one around the academic/NDIA consensus, and another looser center around the DoD usage. **This dispersion underscores the lack of unity in lexicon**.

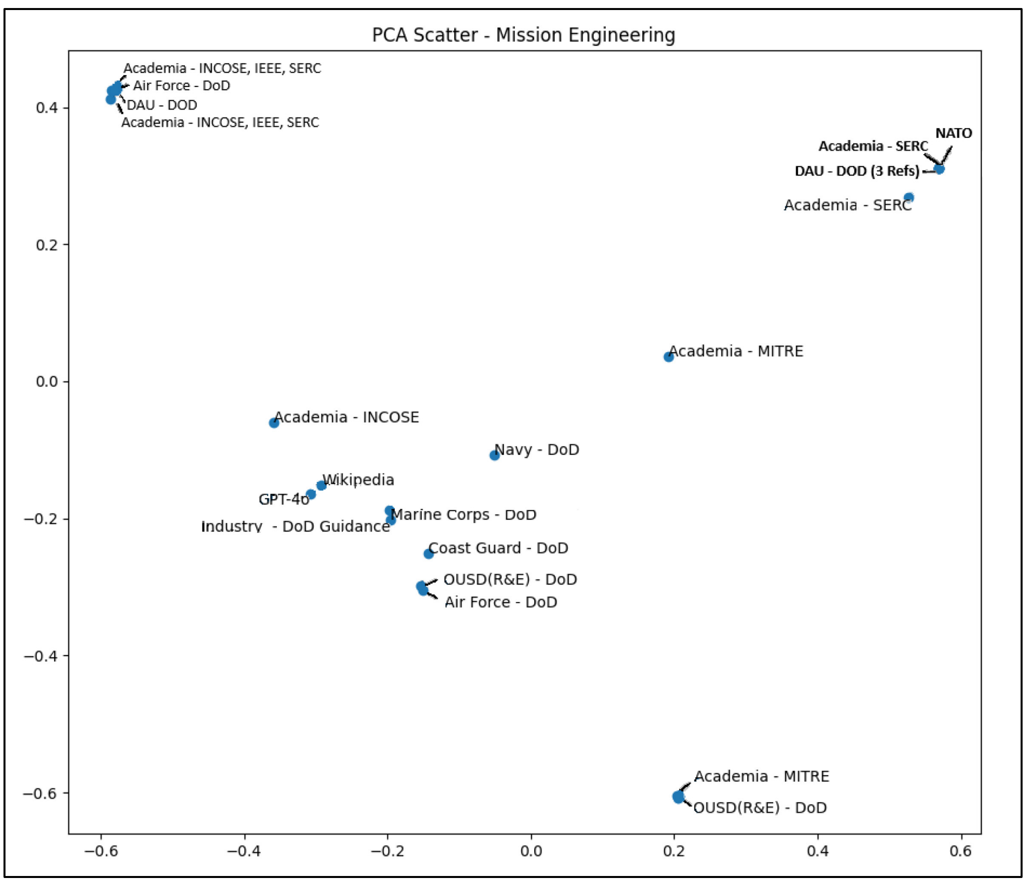

Figure 9: PCA Scatterplot for ME Term Definitions

For DE, the PCA plot depicted in Figure 10 shows a tighter clustering for most points. Since the DoD's 2018 DE Strategy has been broadly communicated and adopted, definitions from OSD, the military services, and defense industry leaders all include common pillars (use of models, end-to-end digital thread, etc.). This is shown by large number of points on the plot – representing the **Army, Navy, Air Force, OUSD(R&E), OUSD(A&S), and DAU definitions** – clustering very near one another around the center-right of the plot. This implies the existence of a **central reference definition** that all of these have adopted. Even academia tends to use the same core ideas (often referencing the DoD strategy as a guiding document). As one example of alignment observed, the DoD strategy's five goals include formalizing the use of models as authoritative data and transforming the workforce culture – themes echoed by industry publications and standards bodies (e.g., the Institute of Electrical and Electronics Engineers, or IEEE, Systems Council discussions on DE). Thus, their textual data align closely.

There are a few points that fall outside the core cluster. The **BAE Systems definition**, positioned somewhat above the main cluster, includes some different terms (perhaps emphasizing "product lifecycle" or specific industry practices) that make it semantically distinct. An **academic entry (university)** and the **Space Force** definition appear slightly to the left of the main group, suggesting a slight difference in phrasing or emphasis. However, even these outliers are relatively close to the central cluster compared to what we saw with ME. The overall density of points in one region of the PCA plot means that **most definitions of DE share a common core vocabulary and concept set**. Additionally, the PCA analysis **underscores that the DONs's understanding of DE is in lockstep with broader DoD and industry**, which is a positive sign for joint efforts. Meanwhile, **for ME, the Navy/DoD cluster is distinct but not isolated** – indicating an opportunity to further socialize the ME concept with industry partners so that they fully grasp and use the term in the same sense as the DON. The PCA analysis for DE thus reinforces that **DE has a cohesive, central lexicon**.

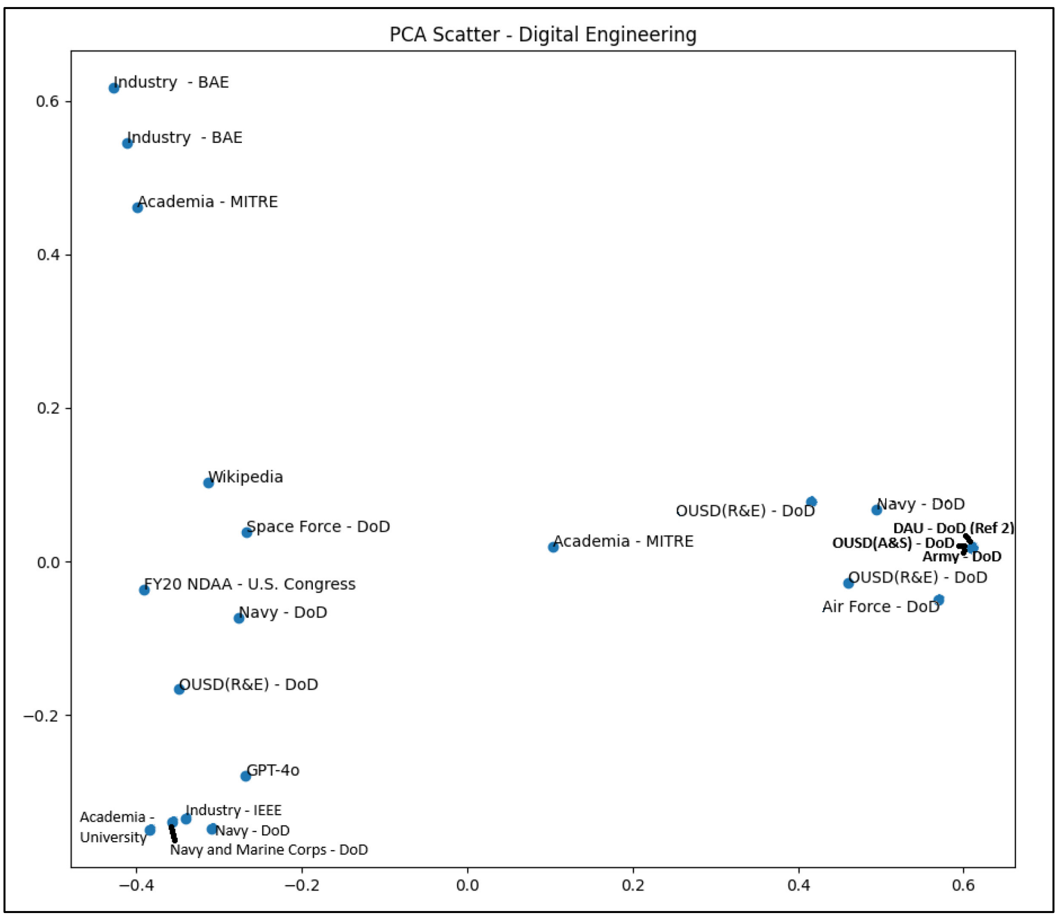

Figure 10: PCA scatter for DE Term Definitions

2.5 Word Cloud Analysis

The team also leveraged LexiScope-derived word clouds as part of this lexicon analysis to highlight the most frequent and prominent words used in definitions, offering a quick snapshot of what each community emphasizes. For example, the word cloud for "Measure of Effectiveness (MOE)" depicted in Figure 11 shows words like "mission," "objectives," "results," and "outcome" as dominant – reflecting that most definitions link MOEs to mission-level outcomes and the achievement of objectives. Notably absent are technical performance terms, underscoring that MOEs are about operational success. In contrast, the word cloud for "Measure of Performance (MOP)" had prominent terms such as "system," "performance," "quantitative," "speed," and "payload," aligning with the idea that MOPs are technical performance metrics (e.g., speed, range, reliability). By comparing these, it is apparent why confusion can arise: one person's "effectiveness" is another's "performance," depending on context. Another revealing example is the word cloud for "Concept of Operations" (CONOPS) Military definitions of CONOPS often highlight terms like "mission," "commander," "scenario," "execute," and "environment," indicating a narrative of how an operation will be conducted. An industry definition might instead highlight "system, users, functionality," framing it more like an early concept document for system design rather than an operational plan. Such differences in emphasis become apparent in word clouds.

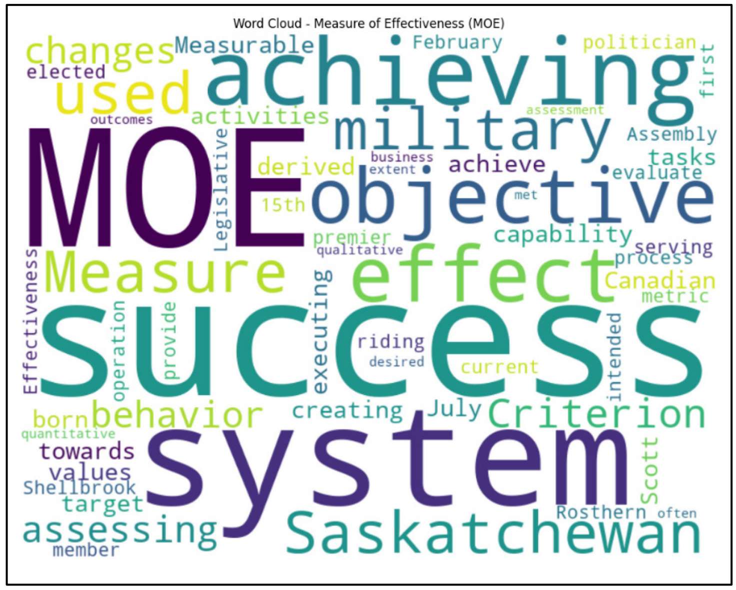

Figure 11: Word Cloud for "Measure of Effectiveness (MOE)" Across DoD, Industry, and Academic Definitions

Encouragingly, **some terms showed fairly universal language** – the word cloud for "Authoritative Source of Truth (ASoT)" was dominated by words like "data," "model," "single," and "source" across both DoD and industry definitions, indicating **broad agreement that it refers to a single repository of trusted data**. This suggests that where the concept is inherently technical and has been popularized (in this case through the DE community and INCOSE), alignment is easier to achieve. On the other hand, terms that mix operational and technical context (like MOEs, or "Mission Thread") showed more varied language. The takeaway for the DON is that **word choice matters – consistently using and enforcing the preferred terms (and definitions) in documentation and training will shape the broader community's language over time**.

The ME definitions word cloud shown in Figure 12 brings out the prevalent terminology. Common prominent words included "mission," "engineering," "capability/capabilities," "operational," "systems," and "outcomes." This aligns with official definitions that describe ME as engineering focused on achieving mission outcomes with a given set of systems and capabilities. In Navy and OSD texts, phrases like "desired mission outcomes" or "mission effects" appear frequently, explaining why "outcomes" or "effects" show up big in the word cloud. Likewise, the inclusion of "systems of systems" in some definitions (particularly those influenced by the academic definition "application of SoS engineering in an operational context") means the word "systems" is heavily featured. The word cloud also shows process words like "analyzing," "integrating," "planning" – reflecting that ME is often defined as a series of actions or an interdisciplinary process.

The ME word cloud also shows the presence or absence of certain terms across communities: for instance, the word "interdisciplinary" appears in the DoD guide definition of ME (highlighting that it spans multiple domains of expertise), but not all sources use that term. Some industry or Navy sources implicitly understand ME as interdisciplinary but describe it more in terms of outcomes and systems; hence "interdisciplinary" might be smaller or only present in a subset of word clouds. Another term, "SoS," might be explicit in academic definitions (as noted above) but less so in the DON's lay descriptions – again a slight inconsistency in terminology. However, those latter terms are smaller, suggesting not every definition explicitly uses them. Additionally, the words **"data"** and **"model"** are not prominent here, showing that ME's vocabulary is less about technical enablers and more about mission components and processes.

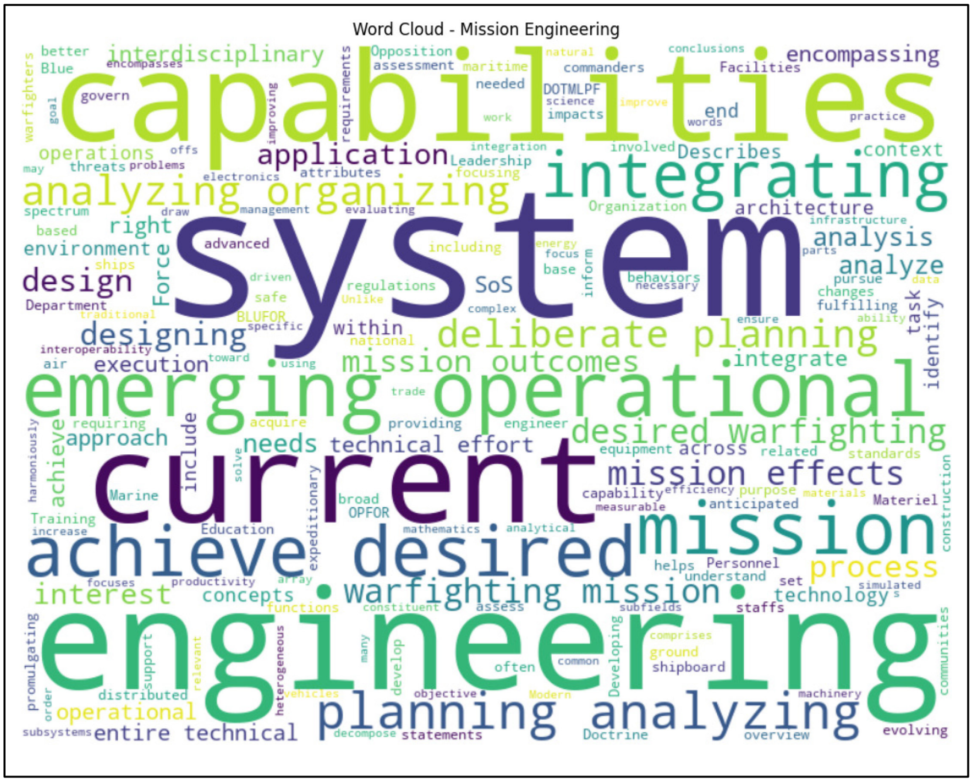

Figure 12: Aggregated Word Cloud for ME Definitions Across Sources

The DE word cloud depicted in Figure 13 unsurprisingly highlights words like “digital,” “models,” “data,” “authoritative source,” “enterprise,” “integrated,” and “lifecycle.” These reflect the core tenets of DE as per DoD guidance. Words like “model,” “data,” “virtual,” “simulation,” and “toolchain” might also appear, since DE involves virtual modeling and simulation tools connected across a project. Terms like “lifecycle,” “continuum,” “across,” “activities,” “processes,” highlight the idea that DE spans **all stages of a system’s life** (from concept to disposal) and connects activities across traditionally siloed disciplines. Another important word is **“product”** – DE is sometimes described as treating digital models themselves as a key product of the engineering effort (not just by-products). In contrast to ME, the DE word cloud is more about technology, methods, tools, and process integration (appearance of terms like digital, model, tool, data, software, infrastructure) while the ME word cloud emphasized mission and operational integration (terms like mission, capability, outcome). The dominating presence of terms like “digital,” “model,” “integrated,” “authoritative,” “lifecycle” shows a fairly uniform understanding and consistent lexicon – everyone talks about creating **integrated digital models as authoritative data sources throughout the lifecycle**.

Some open-source definitions framed DE narrowly as “using digital technology in engineering” without the nuance. In those cases, broad terms like “technology” or “software” could appear, but in the curated DoD/industry definitions such generic terms are less emphasized than specifics like “models” or “lifecycle integration.” The word clouds therefore highlight that the DON and DoD have been using very specific language for DE (e.g., “authoritative source of truth”) that should be carried into how the workforce and contractors discuss it, to avoid dilution of meaning. For ME, the word cloud suggests a need to ensure terms like “mission threads,” “effects,” and “operational context” remain central in usage, and that all communities eventually include those concepts when they use the term “mission engineering.” Any omissions or differences flagged by the word clouds (such as one community not mentioning “SoS” when others do) point to **areas to clarify in education and documentation**.

In summary, the ME word cloud emphasizes mission-focused integration of systems and capabilities, with the lexicon revolving around operational effects, systems engineering actions (plan, analyze, integrate), and the handling of current/emerging capabilities in an operational mission context. In contrast, **the DE word cloud centers on digital models, data integration, and lifecycle approach**, indicating a lexicon that is technology and process-oriented. This confirms a **conceptual difference**: the DE discourse is focused on transforming **how** engineering is done (via digital means), whereas the ME discourse is about **what** is being engineered (missions and capabilities).

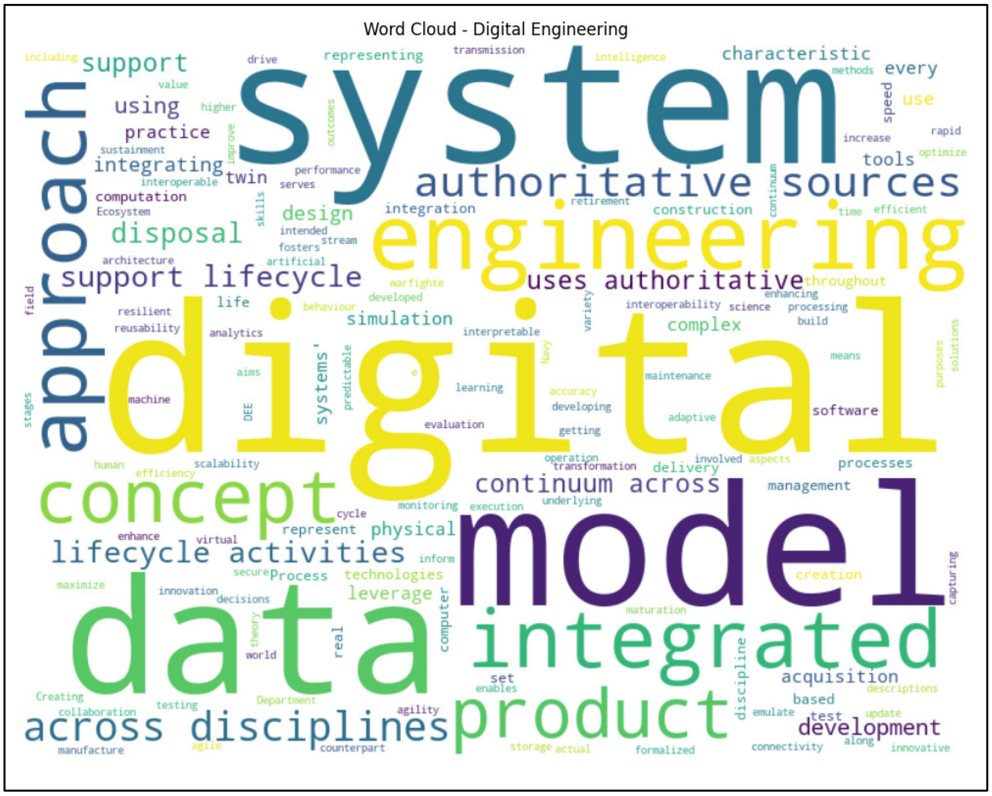

Figure 13: Aggregated Word Cloud for DE Definitions Across Sources

2.6 Comparative Insights Across Lexicon Analysis Findings

Correlating the LexiScope findings with broader DoD digital transformation efforts reveals both progress and remaining gaps. On one hand, the DON and DoD have produced a variety of guidance documents, strategy papers, and glossaries that push toward common definitions. The clustering of DoD definitions is evidence that these efforts (such as the OUSD(R&E) MEG and the 2018 DoD DE Strategy) are taking hold internally. Indeed, the DON's 2020 DSET Strategy explicitly calls for establishing a common "authoritative knowledge source" and refined lexicon as a foundation for enterprise-wide adoption. This aligns with recommendations from experts: **having a single, shared vocabulary and repository of models is essential to break down silos**. This report's lexicon analysis underscores this – **wherever definitions varied, this analysis highlights areas where such governance is either lacking or not yet effective.** On the other hand, the persistence of divergent clusters and terminology outliers observed through the LexiScope tool indicates that **more work is needed to operationalize these standards across all stakeholders**. It is not enough to publish a glossary; the terms must be reinforced through usage in standardized processes, contracts, training, requirements and acquisition documents, and tools. The DON has recognized this in practice. For example, NAVWAR reports that many of its teams have been "resistant or slow to adopt new engineering practices," and it identified the need for better community knowledge sharing and lexicon consistency as part of ongoing DE transformation efforts. The heatmaps and word clouds put a finer point on inconsistencies to address.

Another insight from combining the lexicon analysis with literature is the role of interoperability across sectors. The differing language between DoD and industry suggests a potential hurdle when the DON collaborates with contractors or academia on ME and DE initiatives. This is echoed in policy discussions – DoD's 2020 Data Strategy and DE policies stress making data "visible, accessible, understandable, linked, trustworthy, interoperable, and secure" (VAULTIS) across the enterprise. If terminology is part of the data (for instance, model metadata, or documentation in model-based systems engineering tools), then semantic differences are a form of technical debt. They can cause mismatches in model integration or misinterpretation of analysis results. For example, if one model calls an MEtric an "MOE" and another a "KPP" (Key Performance Parameter), an integrator might not realize they should be aligned. **Achieving technical interoperability has a linguistic component**.

Academic research also supports this notion; studies on ME adoption have discussed integration challenges when combining frameworks and data from different domains, noting that common ontologies can aid in bridging those gaps. The lexicon analysis dendrograms, which effectively visualize an ontology gap, bolster the case for **investing in a Navy-wide ME ontology or lexicon project**.

The team's findings reveal that while the DoD and DON communities are coalescing around certain ME and DE concepts, inconsistencies remain, particularly in cross-sector contexts. The DON's current efforts (as seen in strategic documents and pilot projects) are pushing in the right direction, but **a more concerted push is needed to standardize terminology and ensure all stakeholders – military, civilian, and international – have a shared understanding of key terms**.

3 Updated Centrality Analysis

In addition to examining definitions through the comprehensive lexicon analysis, the team updated and refined the ME and DE knowledge graph and performed expanded centrality analysis, building on the previous report, *Landscape Analysis: Integrated DON Understanding of Mission Engineering Efforts & Digital Tools*. Different centrality measures capture various aspects of a node's role in a network, whether it be its ability to spread information, act as a bridge between different parts of the network or maintain connections to other influential nodes. This section details the expanded centrality measures and analysis performed against the updated and refined ME and DE knowledge graphs. The team incorporated these findings as part of the strategic drivers and recommendations laid out in Section 5.

3.1 Knowledge Graph Update

The team employed a knowledge graph methodology to organize and structure relevant data, interdependencies, and adoption trends surrounding the ME and DE landscape. The team leveraged a Neo4j database for the ME and DE landscape, populating the knowledge graph with ME and DE-related publications from OpenAlex. The updated knowledge graph includes additional datasets such as DoD and service-specific policy documents and Justification Book entries that reference ME or DE pulled from Advana's Gamechanger knowledge base. The knowledge graph approach enabled the capture and visualization of key relevant entities and tools; investigation of how tool nodes relate to the ME and DE disciplines; and assessment of how entities and disciplines evolve over time. The resulting knowledge graph can serve as a living framework, with the capability of continuously integrating new data sources to capture and track key entities and relationships as ME and DE disciplines continue to evolve over time. Alongside this report, the team delivered the software program and database files associated with the ME and DE knowledge graph, visually depicted below in Figures 14-16, pertaining to key technical tools and key contributors/thought leaders found.

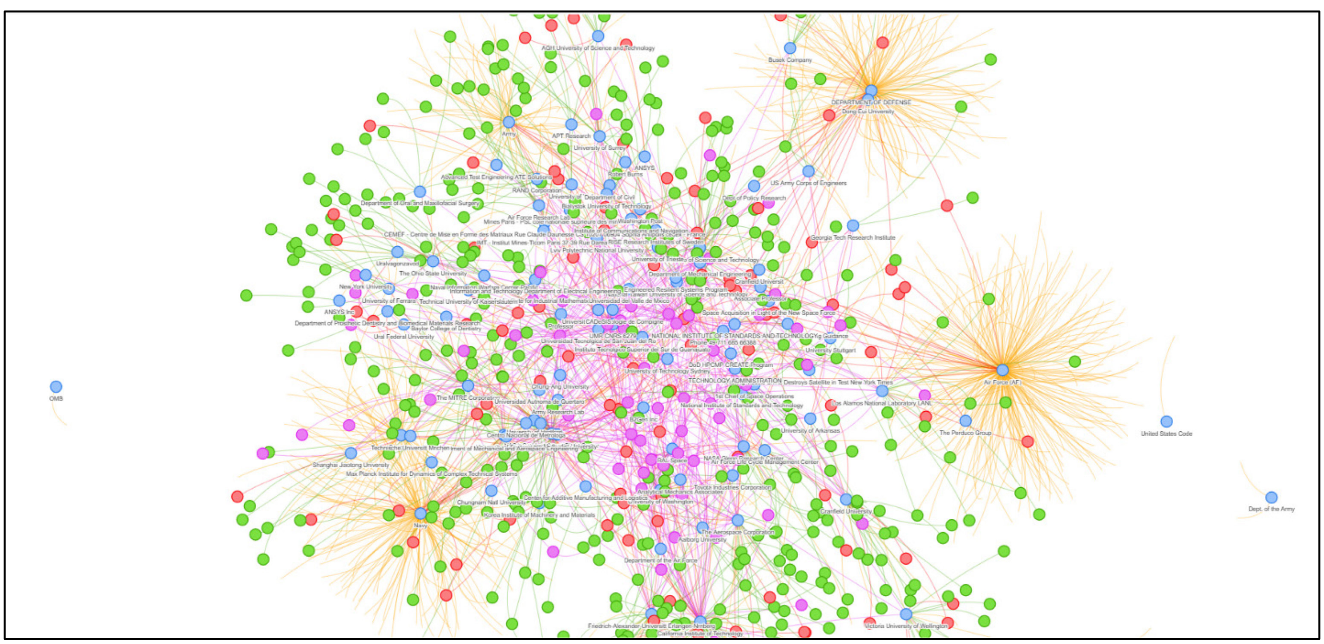

Figure 14: Knowledge Graph for ME and DE

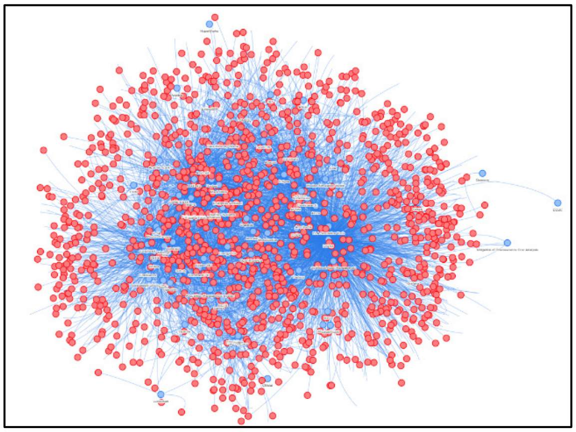

Figure 15: Isolated Knowledge Graph for ME and DE Technical Tools

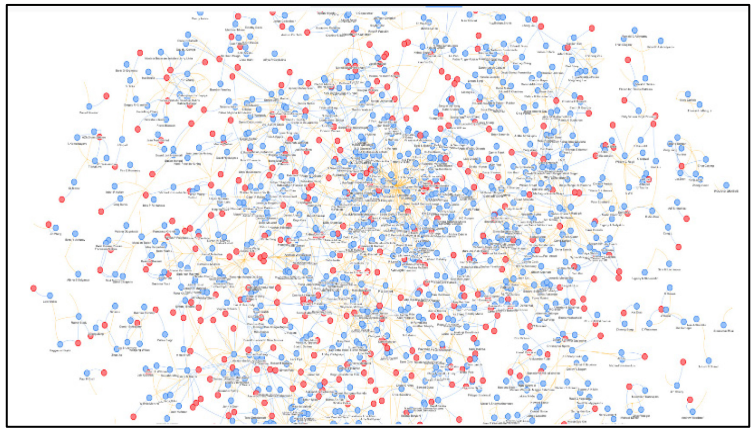

Figure 16: Isolated Knowledge Graph for Key Contributors and Thought Leaders in ME and DE

3.2 Closeness Centrality

Th team updated the previous closeness centrality analysis given additional data. This measure captures how close a node is to all other nodes in the network on average. The fundamental idea is that nodes with higher closeness centrality can quickly reach other nodes via the shortest paths, making them key players. Mathematically, closeness centrality C(x) is the inverse of the sum of shortest path distances from a node xxx to all other nodes in the graph:

$$C(x) = \frac{N-1}{\sum_y d(y,x)}$$

where:

$N = represents\ the\ total\ number\ of\ nodes\ in\ the\ graph, and$

$d(y,x) = denotes\ the\ shortest\ parth\ length\ between\ nodes\ x\ and\ y$

In this report’s context, a publication with high closeness centrality is semantically or referentially well-connected to all other major works – it covers themes common to many others or is cited across disparate subtopics. Despite the inclusion of additional datasets, the top 5 articles by closeness centrality did not change from the previous analysis. They are listed below:

1. "Transforming Systems Engineering through Digital Engineering" (Closeness: 4.639)
2. "Towards Developing Metrics to Evaluate Digital Engineering" (Closeness: 4.619)
3. "Transforming System Engineering" (Closeness: 4.282)
4. "Application of Model-Based Systems Engineering Concepts" (Closeness: 4.192)
5. "Analyzing Mission Impact of Military Installations" (Closeness: 4.216)

Scores ranging from 4.2 to 4.6 indicate strong connectivity.

These are key cornerstone articles of either ME or DE, and these articles are at the center of the evolving ME and DE landscape. The first four articles are general articles relating to topics within DE and systems engineering. The fifth article is more topic specific, discussing how ME is used in military installations. Throughout the landscape review, many similar and application-specific papers appeared, where DE and ME played a role in the application space. Seeing these different topic areas indicates the growing pervasiveness of DE and ME in many different fields of study.

3.3 Betweenness Centrality

The team performed betweenness centrality analysis to investigate how often a node appears on the shortest path between other nodes in the network. A node with high betweenness acts as a crucial bridge or intermediary connecting different clusters of the network that would otherwise be far apart. In the ME and DE landscape context, a high-betweenness article or organization could link together two distinct communities (e.g., a paper that connects the academic research cluster and the military practitioner cluster through a common citation). Betweenness highlights nodes that control information flow or integration between subdomains. For instance, if ME and DE were largely separate circles, a paper that discusses how DE enables ME could appear with high betweenness, as it sits at the juncture of those two circles. Such nodes are often key to a network, and where – if removed – the network would fragment, indicating their role in maintaining the cohesion of knowledge across subfields. Mathematically, betweenness centrality is calculated as:

$$C_B(v) = \sum_{s \neq v \neq t} \frac{\sigma(s,t|v)}{\sigma(s,t)}$$

where:

$\sigma_{s,t}$ = *the total number of shortest paths from nodes* ***s*** *to node* ***t****, and*

$\sigma_{s,t}(v)$ = *the number of those paths that pass through* ***v***

The sum is taken over all possible pairs of nodes, meaning that nodes appearing in higher quantities of shortest paths get higher scores. The higher the score for a node, the more likely it acts as a bridge between a wide range of nodes. This is illustrated in Figure 17.

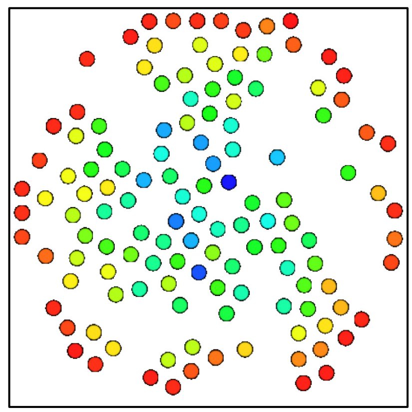

Figure 17: Nodes with High Betweenness Centrality (Blue) at the Crossroads of Various Clusters

Betweenness centrality is useful in identifying bottlenecks, key intermediaries, and points of vulnerability. A node with high betweenness centrality plays a strategic role in maintaining connectivity and can influence interactions by controlling access between different groups. These nodes are critical to consider, especially in allocating resources across entities for specific fields of research. The five most critical nodes according to betweenness centrality are listed below:

1. "Analysis of standards for lifecycle management of systems for US Army" (Betweenness: 170,265)
2. "Neural-Parareal: Self-Improving Acceleration of Fusion MHD Simulations Using Time-Parallelisation and Neural Operators" (Betweenness: 75,299)
3. "Engineering Curriculum in Support of Industry 4.0" (Betweenness: 67,492)
4. "Early Validation and Verification of System Behaviour in Model-based Systems Engineering: A Systematic Literature Review" (Betweenness: 38,325)
5. "Model-Based Systems Engineering in Concurrent Engineering Centers" (Betweenness: 34,943)

High-betweenness centrality papers within the ME and DE knowledge graph serve as vital bridges and strategic drivers of innovation and integrative concepts, connecting otherwise isolated communities and disciplines. These influential works provide critical insights by linking military operational requirements, industry best practices, and academic research innovations. Leveraging these pivotal papers, preserving these key organizations, and keeping them engaged in study can drive effective policy development, targeted research investments, strategic workforce training, and robust digital infrastructure for ME and DE initiatives within the DoD.

Informed by the betweenness centrality analysis, the team compiled **recommendation areas the DoD should pursue**:

- ***Standards and Interoperability:*** Establish formal policies mandating lifecycle data standards across DoD acquisitions, informed by the NIST paper titled *Analysis of standards for lifecycle management of systems for US Army (*Betweenness: 170,265). This paper highlights interoperability through standards like ISO 10303 STEP, PLCS, and EIA-836, ensuring seamless technical data exchange between the Army and OEMs. By institutionalizing these standards, DoD can enhance mission readiness and improve the effectiveness of digital engineering implementations.

- ***Research and Innovation:*** Prioritize and fund research in advanced modeling and simulation methods that leverage artificial intelligence for accelerated analysis, referencing *Neural-Parareal: Self-Improving Acceleration of Fusion MHD Simulations Using Time-Parallelisation and Neural Operators* (Betweenness: 75,299). This paper shows how integrating neural networks with traditional high-performance simulations significantly boosts computational efficiency, directly supporting mission-driven engineering where rapid scenario evaluations are critical.

- ***Workforce Development:*** Invest in modernized engineering curricula that integrate DE competencies as informed by *Engineering Curriculum in Support of Industry 4.0* (Betweenness: 67,492). This paper emphasizes the need for an updated, industry-relevant educational approach, integrating multiphysics simulations, digital twins, and collaborative digital design methods. Adopting these practices in defense educational institutions will build a digitally fluent workforce essential for effective ME and DE adoption.

- ***Policy Integration and Early Validation***: Update and enforce DoD policies to require early-stage model validation and verification (V&V) processes as outlined in *Early Validation and Verification of System Behaviour in Model-based Systems Engineering: A Systematic Literature Review* (Betweenness: 38,325). This systematic review identifies significant gaps and diverse methods in early V&V practices, underscoring the necessity of formalizing these processes to reduce downstream risk and ensure mission success from early design phases.

- ***Infrastructure and Collaborative Environments***: Establish concurrent engineering centers leveraging Model-Based Systems Engineering (MBSE) methodologies inspired by the paper titled *Model-Based Systems Engineering in Concurrent Engineering Centers* (Betweenness: 34,943). This paper illustrates how integrated MBSE environments facilitate rapid collaborative decision-making and system integration, significantly reducing design cycle time. Investing in such digital infrastructures will enable agile, collaborative ME processes critical for responsive capability development.

Implementing these targeted recommendations, grounded in insights from high-betweenness centrality papers, will profoundly strengthen the DoD's capability in mission-centric DE. By embracing interoperability standards, funding innovative research, modernizing workforce training, formalizing robust early-stage validation processes, and investing in advanced collaborative infrastructures, the DoD will foster a cohesive ME and DE ecosystem. Ultimately, this strategic approach ensures greater operational agility, reduces lifecycle costs, and enhances the military's ability to respond swiftly and effectively to emerging threats.

3.4 Eigenvector Centrality

The team performed eigenvector centrality analysis to assess a node's influence based on the number of connections and the quality (centrality) of those connections. In our analysis, eigenvector centrality helps identify nodes (especially organizations or seminal publications) that are connected to many other influential nodes. For example, an organization like OSD might have high eigenvector centrality because it sponsors or is referenced by many key initiatives in ME and DE. Likewise, a foundational document cited by other central documents will score highly. Eigenvector centrality often aligns with intuitive influence – it finds the hubs that are connected to other hubs. In the ME and DE knowledge graph, nodes with high eigenvector centrality represent core frameworks or authorities (e.g., important strategy documents, major research studies, leading institutions). Eigenvector centrality builds upon other centrality measures by considering *not just how many connections a node has, but also how the importance of those connections.*

Eigenvector centrality is computed as follows:

$$C_E(v) = \frac{1}{\lambda} \sum_{u \in N(v)} C_E(u)$$

High eigenvector centrality papers serve as linchpins in the ME and DE knowledge graph, connecting diverse yet pivotal concepts across the landscape. These influential works bridge policy, technical, and operational domains – for example, the DoD's **2018 DE Strategy** spans multiple disciplines and stakeholders, encouraging innovation in how systems are built, tested, and sustained while also reshaping workforce practices. Similarly, OUSD(R&E)'s **MEG** links mission outcomes with systems engineering decisions, ensuring operational context drives technology solutions. The connective role these documents play with high-centrality measures should inform where to focus on in terms of policy directives, research investments, workforce development, and technology adoption across ME and DE initiatives. They effectively illuminate "what matters most," helping decision-makers prioritize efforts that will have broad, cross-cutting impact on the Department's digital transformation. The top papers by eigenvector centrality are listed below:

1. "Towards Developing Metrics to Evaluate Digital Engineering" (Eigenvector: 59.64)
2. "Transforming Systems Engineering through Digital Engineering" (Closeness: 40.36)
3. "Transforming System Engineering" (Closeness: 30.91)
4. "Analyzing Mission Impact of Military Installations" (Closeness: 23.64)
5. "Assessment of Joint All Domain Command and Control Requirements and the Use of Live, Virtual, and Constructive Capabilities for Training" (Closeness: 20.82)

These articles largely overlap with those found in the closeness centrality, with the exception of the fifth paper. This reinforces that these articles fall at the center of the knowledge graph.

Informed by the eigenvector centrality analysis, the team compiled **recommendation areas the DoD should pursue**:

- ***Institutionalize mission-driven DE in DoD strategy and guidance:*** Adopt and enforce policies that embed ME and DE principles at all levels, as emphasized by high-centrality strategy documents. For instance, the DoD **2018 DE Strategy** outlines five goals to transform engineering – promoting model-based methods, enterprise integration of data, and a culture shift in training. Likewise, the **MEG** highlights mission-level analyses to inform requirements, acquisition, and research and development decisions. Building on these insights, the DoD should update governance (directives, instructions, guides) to require model-centric planning and mission-context analysis in capability development. This ensures that technology investments and acquisitions are consistently aligned with mission outcomes and that top-down support is in place for enterprise-wide DE adoption. The papers collectively highlight the critical need for policy-driven integration of digital tools and methods, advocating for mandates requiring digital model utilization, cross-functional integration, and an authoritative source of truth to streamline DoD's acquisition and engineering processes.

- ***Digital Engineering Adoption:*** Accelerate adoption of model-based engineering practices through success story dissemination and workforce upskilling. The knowledge graph's central nodes underscore the need to expand DE practices across programs and communities. A notable example is the USS Gerald R. Ford (CVN-78) design, which used a full-scale 3D product model to uncover efficiencies and saved the Navy an estimated $4 billion in lifecycle costs. DoD should replicate and scale such successes by MBSE approaches in programs and sharing case studies that demonstrate clear ROI. Equally important is cultivating the human capital for DE: high-centrality policy guidance calls for comprehensive training and education for the DoD workforce in DE tools and principles. Investing in workforce development (through DAU curricula, certification programs, and workshops) will foster a culture that embraces data-driven, model-centric decision making. These steps will drive broader acceptance of DE, ensuring that the methodology is not isolated in pilot projects but becomes standard practice across the DoD.

- ***Prioritize Training, Research, & Innovation that advances DE capabilities:*** Enhance DoD's training strategies through comprehensive integration of Live, Virtual, and Constructive (LVC) capabilities, as indicated by the *Assessment of Joint All Domain Command and Control Requirements and the Use of Live, Virtual, and Constructive Capabilities for Training* (Eigenvector: 20.82). This work outlines the strategic importance of robust LVC environments to ensure realistic, scalable training scenarios that accurately represent complex multi-domain operations. By prioritizing investments in integrated training environments, the DoD can significantly enhance preparedness and operational effectiveness in a cost-effective, scalable manner. Additionally, insights from the central literature stress that keeping pace with evolving threats and complex missions requires continuous innovation in engineering methods. DoD should direct research funding toward areas that high-centrality sources identify as game-changers – for example, developing more powerful modeling & simulation techniques, mission-level digital twins, and AI-enhanced engineering tools. The **DoD's 2018 DE Strategy** explicitly calls for rapid incorporation of technological innovations (advanced computing, big data analytics, artificial intelligence, autonomous systems, etc.) to build an end-to-end digital enterprise. By heeding this advice, the DoD can create more realistic mission simulations, predictive analytics for design trade-offs, and autonomous support tools that streamline engineering processes. Focused investment in these areas (in collaboration with academia and industry) will ensure the DoD's

ME and DE capabilities remain state-of-the-art – enabling faster iteration, better-informed decisions, and the agility to out-innovate adversaries.

- ***Establish common standards and metrics to guide and measure ME/DE implementation:*** High-centrality papers highlight that standardization and measurement are critical for enterprise-wide success. On the standards side, the DoD should create an **authoritative source of truth** for models and data by enforcing common ontologies, data formats, and model quality criteria. The DE Strategy notes that formalizing modeling "formalisms" (syntax, semantics, lexicons, etc.) is necessary to orchestrate work across teams and ensure all stakeholders adhere to shared modeling rules. This means adopting open standards and interoperability protocols so that tools and models can seamlessly exchange information across the Services and contractors. Equally important is implementing robust **metrics**. Top-ranked research on MBSE and DE (with high eigenvector centrality) recommends an MEasurement framework to assess the value and benefits of DE. Following this guidance, the DoD should define key performance indicators for DE implementations – for example, reductions in design cycle time, fewer integration defects, improved requirements traceability, and increased stakeholder collaboration. DoD should establish robust evaluation frameworks for DE initiatives as emphasized by *Towards Developing Metrics to Evaluate Digital Engineering* (Eigenvector: 59.64). This paper underscores the importance of systematic measurement to assess the effectiveness and maturity of DE processes, recommending the implementation of clear, standardized performance indicators across programs to consistently quantify benefits such as reduced lifecycle costs, improved collaboration, and faster iteration times.

- ***Invest in a unified digital engineering ecosystem and shared toolsets:*** High-centrality strategy documents stress that current program-specific engineering systems are often isolated and hard to integrate, presenting a barrier to effective ME and DE. Moving to a modern infrastructure that offers a consolidated, secure, and collaborative environment is imperative to connect engineers, data, and tools across the enterprise. The DON and greater DoD can expand on efforts already underway – for example, leveraging the **Joint Mission Environment Test Capability (JMETC)** and other DoD-funded DE platforms as common resources. Programs should be incentivized to explore and tap into enterprise solutions where possible for shared modeling software, computing infrastructure, data repositories, and networks at multiple classification levels. In addition, the DoD should continue to enhance infrastructure for ME analysis (such as distributed simulation environments that incorporate operational scenarios). By pooling investments into joint tools and cloud-based secure environments, DoD stakeholders can collaborate in real-time, access authoritative data sources, and avoid redundant expenditures. A unified infrastructure will enable smoother implementation of standards, better configuration control of models, and more efficient scaling of best-of-breed tools across projects. The *Analyzing Mission Impact of Military Installations* study (Eigenvector: 23.64) illustrates how mission-focused modeling can significantly improve operational decision-making and strategic planning for installations, highlighting the value of infrastructure capable of integrating diverse operational data sets into mission-impact assessments and predictive analytics.

Implementing the above recommendations will have a powerful strategic impact on the DON and DoD's ME and DE efforts. By acting on insights from the most influential (high-centrality) knowledge graph nodes, the DoD can create a virtuous cycle that strengthens ME and DE adoption. Adopting robust evaluation metrics, instituting transformative policies, developing mission-centric infrastructures, and integrating advanced training environments collectively address foundational challenges. These targeted actions will foster enhanced interoperability, operational readiness, and cost-efficiency, ultimately enabling the DoD to maintain superior mission outcomes and strategic advantage in an increasingly complex threat landscape.

In the near term, aligning policy and culture with digital practices will break down silos and encourage collaboration across programs and organizations – outcomes highlighted as critical benefits in the eigenvector centrality analysis (e.g. improved cross-stakeholder collaboration and shared understanding). Over the longer term, the DoD can expect reduced inefficiencies if it implements common standards and interoperable tools, as well as enhanced mission outcomes due to more rigorous mission-driven analyses and faster technology insertion into warfighting systems. Ultimately, leveraging these high-centrality insights positions the Department to build an agile, digitally-enabled engineering ecosystem.

4 Augmenting the Landscape Analysis: International Allied Progress

The push for ME and DE transformation and adoption is not isolated to the DON or DoD – U.S. allies and partners have similar digital transformation efforts. Comparing approaches and progress internationally provides valuable perspectives and best practices that can inform Navy strategy, as well as opportunities for collaboration to mutually enhance capabilities. This section explores efforts underway across allies and partners. The team incorporated these findings as part of the strategic drivers and recommendations laid out in Section 5.

4.1 NATO & Allied Approaches

NATO as an alliance has recognized the importance of digital transformation to enable future operations. By 2030, NATO's digital transformation initiative aims to facilitate Multi-Domain Operations with a focus on effective connectivity, data interoperability, and decision support.[iii] Central to NATO's approach is developing a digital-ready workforce and digitally enabled processes, as outlined in its Digital Transformation Implementation Strategy (NATO Allied Command Transformation [ACT], 2022). This mirrors the DON's emphasis on people, process, and technology, but at a coalition level – NATO must ensure that 30 nations' forces can interoperate both technically and semantically. To that end, NATO employs frameworks like the NATO Architecture Framework (NAF) to guide common mission architecture development. NAF provides standardized methods for developing mission thread descriptions and system architectures that all members can use. For example, NATO's Federated Mission Networking (FMN) initiative defines standards and profiles so that different nations' command-and-control systems can plug into a shared mission network rapidly. The U.S. Navy, as part of the alliance, benefits from and contributes to these efforts. Ensuring that the DON's ME and DE practices align with NATO standards (where applicable) will contribute to smooth joint operations.

Allies such as the United Kingdom, Canada, and Australia have also launched their own DE and mission-oriented programs. The UK's Ministry of Defence, for instance, published a Digital Strategy for Defence that highlights the creation of a secure, singular "Digital Backbone" to enable data sharing across the armed forces (UK Ministry of Defence [MoD], 2021). This backbone concept is essentially the UK's version of an authoritative data environment, aimed at breaking down silos between services (Royal Navy, Army, Royal Air Force) and with industry. The UK is also heavily investing in digital twins and model-based support for procurement; as noted, its Defence Equipment & Support organization claims DE will "revolutionise" procurement, getting equipment from concept to frontline faster through extensive use of virtual testing (UK Defence Equipment & Support [DE&S], 2023)). Australia likewise is moving aggressively: the Australian Department of Defence released a Digital Engineering Strategy 2024 committing to streamlined, data-driven processes and increased use of virtual simulation to meet the Australian Defence Force's needs (Australian Department of Defence, 2024). The strategy explicitly calls for integrating people, processes, tools, and data across a model-based enterprise, very much resonant with U.S. objectives. Canada has been pursuing strong model-based systems engineering adoption in defense procurement and participates in NATO initiatives to maintain interoperability.

In summary, allied nations share common themes: the need for integration, speed, and agility through digital means; a focus on data as a strategic asset; and the importance of training and culture in making it happen. They also face similar challenges such as legacy systems and workforce upskilling. For the DON, this means there is a community of like-minded militaries from which to learn and with whom to cooperate.

4.2 Lessons Learned & Best Practices

The DON and DoD should gather lessons learned and best practices from international partner initiatives. This section describes several overarching themes as a starting point. One key lesson from international efforts is the **importance of top-down vision combined with bottom-up implementation**. Allies have often framed their DE transformations in terms of high-level national strategy (e.g., Britain's Defence Digital Service leading the charge, Australia's ambitious plan tied into defense industry policy). This top-level endorsement provides air cover for change. The DON has something similar in the DSET Strategy and the DoD-wide mandates but reinforcing it continuously (as NATO's senior leaders do by stressing the "urgency" of digital transformation) will help maintain momentum. Another lesson is in how allies manage standardization. NATO's example shows that developing agreed-upon reference architectures and data standards greatly eases integration –

[iii] NATO Allied Command Transformation. (2023). Empowering NATO's Multi-Domain Operations Through Digital Transformation. Retrieved from https://www.act.nato.int/article/empowering-nato-mdo-through-digital-transformation/NATO ACT+1NATO ACT+1

the DON could emulate this by creating reference architectures for common mission types and urging all internal stakeholders to align to them, allowing for lower-level tailoring that maintains interoperability through the common top-level framework.

Additionally, allies highlight **iterative experimentation as imperative**. The UK and Australia often start with pilot projects or "pathfinders" (for instance, the UK's RAF did a Project ASTRA which included DE pilots for future combat air). These allow testing new methods on a small scale. The U.S. Army had launched similar DE pathfinder pilots in their push for digital transformation aligning with the DoD DE Strategy.[iv] The team's recommendation for Navy to pursue similar pilots echos this approach and are validated by allies' successes – starting small and proving value.

Workforce and cultural change are other areas to heed lessons. Allies have launched initiatives like the UK's Digital Academy for Defence and Australia's partnerships with universities and industry to cultivate skills. This reiterates that training is not solved by one-off efforts; it requires sustained programs. An interesting best practice is in collaborative development: AUKUS (the trilateral pact between Australia, UK, US) Pillar II is targeting joint development of advanced capabilities – inherent in that is the need for shared DE approaches so that a design in Australia can be handed off to the U.S. seamlessly. This is one initiative to keep in mind as the DON designs its DE ecosystem, with coalition interoperability a key consideration from the start (e.g., adopt standards that allies are also using, such as coherent use of UML/SysML models or even common tool environments where appropriate).

Furthermore, allies have found **success in engaging industry early and deeply**. The UK, for instance, works closely with major defense contractors through its Engineering Delivery Partner programs to ensure industry is co-driving digital transformation. The DON could expand its collaboration with industry beyond compliance to include co-development of methods (perhaps through consortia or public-private initiatives on digital engineering standards).

One final area of lessons learned pertains to **measuring adoption and maturity through clear milestones and metrics.** NATO and allies set clear metrics and milestones surrounding their digital transformation initiatives (NATO's lines of effort, Australia's phased implementation methodology). The DON should likewise track metrics like percentage of programs using model-based engineering, time savings in development due to digital practices, or number of personnel certified in ME and DE disciplines – this echoes NATO's focus on concrete outcomes by set dates.

4.3 Collaborative Opportunities

Aligning ME and DE goals among allies and partners opens up many opportunities for collaboration that would benefit the DON. These opportunities are outlined below.

- **Joint Training and Knowledge Exchange**: The DON could invite allied experts (from NATO ACT, or the UK's Defence Digital Service, for example) to share experiences and solutions, and reciprocate by sharing lexicon analysis findings or Navy-developed tools. This could take the form of multinational workshops or embedding liaison officers in each other's DE teams.

- **Standards Development**: Working through groups like NATO's Science & Technology Organization or the multinational armaments cooperation forums, the DON can help drive co-development of international standards for things like mission thread data formats, model exchange protocols, or even shared lexicon entries for coalition operations. A tangible step might be to propose a NATO Standardization Agreement (STANAG) for ME terminology and processes, ensuring that, say, a "Concept of Operations" or "Mission Thread" means the same (and is documented the same way) across navies. This would greatly aid combined operations.

- **NATO Exercises as ME and DE Testbeds**: The DON can also leverage NATO exercises as a testbed for ME and DE implementations. For instance, during the international maritime exercise Rim of the Pacific (RIMPAC) or a NATO exercise like Formidable Shield, the DON could partner with allied participants to jointly use digital ME tools to plan and analyze the exercise scenario. This not only improves the exercise outcomes but also demonstrates interoperability of tools and models. On the DE side, sharing of digital models and tools can be a huge force multiplier. The DON could collaborate with the Royal Australian Navy or Royal Navy to develop a common digital twin of a shared platform (e.g., an AUKUS submarine concept or a coalition task force model). By pooling modeling

[iv] Army Directive 2024-03 (Army Digital Engineering). (2024). Retrieved from https://armypubs.army.mil/epubs/DR_pubs/DR_a/ARN40932-ARMY_DIR_2024-03-000-WEB-1.pdf

effort, each navy gains a richer, validated model set to use. There is precedent in projects like the F-35 program, where partners share simulation data for the joint mission rehearsals.

- **International Defense Industry Partnerships**: Additionally, collaboration can extend to industry partnerships across countries. Many large defense companies operate in multiple allied nations; the DON can encourage these companies to create common DE deliverables that all customers can use. For example, a U.S. and UK joint team could develop a library of reference models for missile defense that both navies use in their ME. This type of collaboration would also benefit the DON's Wartime Acquisition and Sustainment Support Plan (WASSP) activities; incorporating ME into WASSP efforts ensures that allied force supplies and logistics support the combined mission.

- **Actively Participate/Engage in AUKUS Pillar II**: Lastly, AUKUS Pillar II, which covers advanced technologies like AI, autonomy, quantum, etc., will require joint modeling and simulation. The DON's active engagement and participation there will ensure that the ME aspects (how those technologies fit into missions) are considered jointly.

In conclusion, by working closely with allies and partners, the DON gains efficiency and insight while also strengthening coalition warfighting capability. Technical and semantic interoperability are both critical for future joint combined operations – and ME and DE collaboration address both while ensuring acquisition and operational activities support the mission. Such cooperation ensures that in a future crisis, U.S. Navy assets and those of its allies can plug and play seamlessly, having been engineered from the outset to a common understanding of the mission and using compatible digital tools.

5 Strategic Recommendations for the Department of Navy

The DON can accelerate its adoption of ME and DE by pursuing a two-tiered approach: (a) high-level strategic actions that institutionalize ME and DE across the enterprise, and (b) actionable near-term opportunities that can be implemented to facilitate the building of momentum. The team derived the following recommendations through a synthesis of all findings covered. They offer a roadmap that is strategic yet actionable – combining broad initiatives with concrete steps.

5.1 Recommended Strategic Actions

Recommendation 1: Establish a Unified ME and DE Lexicon Across the Navy

These actions directly address the misalignments identified in the lexicon analysis and is supported by experts who argue that clear lexicons and taxonomies encourage proper use of digital tools and consistent processes. By eliminating semantic confusion, the DON will improve communication with industry partners and among its own teams, enabling more effective collaboration on complex mission-engineering efforts.

Table 1: Recommendation - Establish a Unified ME and DE Lexicon Across the Navy

Action	Impact
Develop and institutionalize a single, authoritative lexicon (unified vocabulary) of ME and DE terms to be used in all DON organizations. Curate definitions from joint doctrine, DON guidance, and industry standards.	• Ensure everyone – from systems engineers at NAVSEA to warfighters at Fleet commands – interprets and uses key terms the same way • Ensures ME and DE in practice is consistent through common vocabulary
Publish the unified vocabulary as a DON reference document. Make accessible to all DON organizations via an online knowledge portal. Expand access to DoD and Allies and partners, in longer term.	• Ensure awareness and accessibility to the authoritative lexicon
Develop mandates and associated standards for use and enforcement of the unified vocabulary in requirements documents, training curricula, contracts, etc.	• Enforces that everyone uses the key terms consistently • Ensure wide and expansive use across all research and development, engineering, acquisition, operations, and sustainment

Recommendation 2: Standardize and Integrate DE Ecosystems

These high-level actions enable the DON to conduct holistic mission analyses, evaluating how well systems work together in a mission context (the essence of ME) using digital means. It also supports cross-sector (government-industry-academia) collaboration, aiming to have all key players "plugged into" the same digital ecosystem with agreed-upon standards.

Table 2: Recommendation – Standardize and Integrate DE Ecosystems Across the Navy

Action	Impact
Establish standardized DE ecosystems and ***embrace mission thread analysis as a core practice***. Ensure standards include interoperability with industry tools. As part of this, build upon existing DoD guidance such as DoDI 5000.88 (requiring programs to develop DE and maintain an authoritative source of truth for systems).	• Strengthen cross-sector interoperability • Enforces open standards and non-proprietary formats to ensure no single vendor's software becomes a roadblock
Define, publish, and adopt common data formats, modeling standards, and tool integrations. This should include reference architectures for common mission types and reference frameworks to drive common digitally based ME architecture development. For example, the Navy should define standard architectures for "digital twins" of its ships, aircraft, and mission scenarios, so that different program offices and contractors can contribute to and draw from these digital models seamlessly.	• Enable practitioners to easily share and federate models, data, and simulations across DON and DoD stakeholders
Leverage a "digital thread" approach, where data flows through design, testing, deployment and sustainment.	• Connect traditionally siloed disciplines
Enforce requirements surrounding these standards and provide enabling infrastructure to support adoption of the requirements, such as cloud-based model repositories accessible to Navy, Marine Corps, and industry engineers with proper access controls.	• Enforce practitioners to share and federate models, data, and simulations across Navy and DoD stakeholders • Ensure ME analyses have latest, authoritative data

Recommendation 3: Transform Workforce through Training and Education

DON leadership recognized the need for digital transformation; the 2020 DSET Strategy calls for transforming the culture and upskilling the workforce to adopt and support DE across the lifecycle. Pockets of expertise exist (e.g., NAVSEA and NAVAIR have MBSE leads, some warfare centers have ME leads and pilots), but the DON needs a comprehensive push institutionalize competency. By creating a pipeline of trained professionals, the DON ensures that ME and DE become mainstream skills. A trained workforce will drive change from the bottom up, applying the techniques in their everyday work and championing the benefits across the fleet. Investing in training and education underpins all other recommendations – it is the enabler that makes new processes and technologies effective.

Table 3: Recommendation – Transform the Workforce through Training and Education

Action	Impact
Expand and institutionalize ME and DE training across all levels of Navy personnel, ***establishing certification programs***. Training should cover not just definitions, but also methodologies (mission thread development, model-based systems engineering, data analytics) and tools (simulation software, model curation platforms).	• Build a digitally fluent workforce of skilled users and leaders who understand ME and DE concepts, tools, and policies • Ensure personnel use common processes and toolsets, reducing risk of inconsistent process or tool usage
Develop and implement a 3-tier education program to include ***basic exposure*** for all officers and acquisition professionals (e.g. inclusion of ME/DE modules in Naval education like the Naval War College and DAU courses), ***specialized training*** for systems engineers and program managers (perhaps an ME/DE qualification similar to how DAWIA certifications work for acquisition), and ***advanced training*** for practitioners who will become the new subject matter experts.	• Ensure skilled users and leaders at various levels who understand ME and DE vocabulary, concepts, methodologies, tools, and policies • Ensure personnel use common processes and toolsets, reducing the risk of inconsistent process or tool usage
Reinforce training and workforce development through rotations and exchange programs with industry (to learn best practices), workshops under the Navy's Systems Engineering Transformation Working Group, and incentives for attaining proficiency (awards, career advancement tied to digital engineering skills).	• Provide adequate incentives for personnel to pursue training opportunities, decreasing organizational and cultural barriers • Increase/accelerate rate of adoption across all personnel levels

5.2 Actionable Near-Term Opportunities

Recommendation 4: Embed ME and DE Requirements in Acquisition and Planning

The DON should incorporate ME and DE implementation requirements into DON acquisition, capability, and experiment planning documents. Existing DoD policy lays the groundwork: DoDI 5000.88 (Engineering of Defense Systems) mandates programs produce DE Implementation Plans and use digital models as a technical baseline. The DON should enforce mandates and go a step further to ensure the same mandates pertain to ME implementation (e.g., every program's DE plan should address how the program will evaluate system's performance in a mission context, not just in isolation).

Table 4: Recommendation – Embed ME and DE Requirements in Acquisition and Planning Across the Navy

Action	Impact
Update document templates and guidebooks to require an explicit section on how ME and DE will be applied, including within capability development plans, systems engineering plans, and test plans. For example, any new program could be asked to articulate its mission context (what mission threads it supports and what mission-level outcomes define success) and how digital models will be used in development and testing. This does not require new legislation – it can be implemented through internal directive by Secretary of the Navy or Assistant Secretary for Research, Development & Acquisition (ASN RDA).	• "Bake in" and enforce ME and DE practices rather than interpreted optional add-ons • Signals to stakeholders the value of mission-focused, model-based approaches; incentivizing and enforcing the practices • Builds a portfolio of programs that consistently use DE artifacts and mission thread analyses, greatly facilitating integration, oversight, and will over time enable mission health tracking
Direct ongoing programs to perform an ME review at a major milestone(s) (for instance, before Milestone B or C)	• Rapidly instill the practice of iteratively evaluating mission outcomes throughout the

to instill the practice of iteratively evaluating how well the system contributes to a mission-level effect. Leverage modeling and simulation, existing exercises, and field activities where possible to realize efficiencies.	acquisition lifecycle, improving alignment of systems to warfighter needs

Recommendation 5: Adopt Digital Twin and Simulation Environments for Mission-Centric Analysis

The DON should establish standardized "digital twin" architectures and simulation environments to model Navy and Marine Corps platforms and missions, and use them to conduct ME analyses that reduce operational risk. The below includes actionable next steps that seek to leverage existing technology across Navy labs and warfare centers. This recommendation area is about uniting and standardizing existing efforts under an ME perspective.

Table 5: Recommendation – Adopt Digital Twin and Simulation Environments for Mission-Centric Analysis

Action	Impact
Launch a near-term digital mission model initiative. This initiative would select key mission areas – for example, anti-submarine warfare, carrier strike group air defense, or amphibious operations – to develop digital mission models that mirror real-world operations. These models would seek to implement a common ME process (which the team is currently developing for DON), integrate digital mission models of various systems (ships, aircraft, sensors, weapons, networks), and allow analysts to experiment with different configurations and tactics.	• Standardized methodologies (building on existing Navy simulation frameworks such as the Naval Integrated Modeling Environment and using common data models) will quick-start the use of mission-level digital twins to inform decisions • In practice, implementation will dramatically reduce operational risk by uncovering integration issues or unintended consequences in silico, rather than in field
Incorporate allies and partner best practices as part of the near-term initiative/pilot and actively participate in allies and partner opportunities where they arise. The UK's Defence Equipment & Support has demonstrated that creating a digital twin of equipment and virtually testing it "thousands of times" can speed up delivery and optimize capability for the front line. Likewise, the DON can revolutionize its testing and evaluation by shifting much of it to the digital domain.	• Ensure the DON's push for ME and DE does not occur in isolation • Incorporate valuable perspectives and best practices captured internationally, saving time and resources • Make use of opportunities for collaboration to mutually enhance capabilities
Charter a near-term pilot project to develop a digital twin for a critical mission (e.g., Ballistic Missile Defense patrol) in partnership with an industry team, thereby not only getting a useful analysis tool but also learning the process to replicate for other missions.	• Conduct a quick-start approach to digital twins to explore and showcase the power of DE in a mission context, building confidence and support for broader adoption

Recommendation 6: Leverage AI-Driven NLP Tools to Harmonize Terminology

To harmonize terminology for a unified lexicon surrounding ME and DE, the DON should utilize artificial intelligence (AI) and NLP tools. As demonstrated by the team's approach to lexicon analysis through the LexiScope tool, NLP can be a powerful ally in parsing large volumes of text in Navy documents and knowledge bases to flag inconsistencies in language. Implementing such tools is relatively low-hanging fruit, as the algorithms can be adapted from existing commercial NLP platforms. It also visibly demonstrates the Navy's commitment to digital solutions for its transformation.

Table 6: Recommendation – Leverage AI-Driven NLP Tools to Harmonize Terminology

Action	Impact
Explore the use of an AI-driven tool to scan all new acquisition documents, operational and ME analyses, and warfighting concepts for the use of key ME and DE terms (leveraging terms in the unified lexicon) and alert staff to any deviations or undefined terms. For example, if a draft requirements document uses the term "Measure of Success" in an inconsistent way as compared to the approved lexicon (perhaps it should use "Measure of Effectiveness" instead based on the context), the tool would flag it for clarification.	• Ensure stakeholders consistently use terms • Alleviate burden of manual review • Generate machine-driven suggestions for definitions or mappings of legacy terms to new lexicon, accelerating lexicon harmonization • Enforce/institutionalize common lexicon, preventing regressions into old jargon • Familiarize personnel with AI-driven analytics, paving way for broader uses in line with DON's digital transformation goals
Explore the use of AI-driven tools for mining lessons-learned databases and after-action reports. AI could identify if terminology mismatches contributed to any misunderstandings in past program health and performance (cost, schedule, performance), exercises, or operations, providing real-world insights for lexicon improvements.	• Understand impact of mismatched lexicon and areas for further improvement through unified lexicon

Recommendation 7: Conduct Quick-Win ME Pilot Programs and Wargames

The DON should launch a series of pilot programs that integrate ME and DE into naval exercises, simulations, and wargaming events to prove real-world value. Hands-on application in operational contexts will support adoption and refine the DON's methods, gradually. The DON could select an upcoming fleet exercise or wargame and inject an ME team into the planning process. Over time, the practice of including a "ME cell" in exercises could become routine. This would improve outcomes of the exercises and ingrain ME and DE into the DON's operational DNA, ensuring these approaches are actively informing warfighting capabilities and outcomes. Conversely, this also ensures those conducting ME are adequately incorporating operational user and warfighter perspectives into ME activities. These pilots would be relatively low-cost because they leverage existing exercises and modeling tools; they mainly require a dedicated effort to integrate them.

Table 7: Recommendation – Conduct Quick-Win ME Pilot Programs and Wargames

Action	Impact
Launch a pilot that leverages DE tools to model different courses of action associated with a chosen mission(s) and identify the optimal set of capabilities or tactics to achieve the exercise objectives. During execution, they could also rapidly evaluate data collected using digital models, providing feedback to commanders in near-real-time.	• Demonstrate how ME and DE contribute to operational decision-making, not just acquisition • Capture exemplars of ME and DE in action, to scale up or repeat across the fleet • Quick pilot projects that yield lessons learned, identify gaps, and train personnel
Partner with entities like the OUSD(R&E) Rapid Defense Experimentation Reserve (RDER), inserting ME and DE methods to test emerging technologies in mission contexts. The DoD has used DE to support ME activities in RDER. The Navy could leverage this in its own mission-focused digital experimentation events. A concrete example could be a ***"digital twin wargame***," where key stakeholders run a virtual counterpart using standard ME and DE methods tools, then compare results.	• Success stories gathered from Navy and greater OSD pilots would demonstrate the value of applied ME and DE – when leadership and operators see that an ME analysis prevented a potential failure, informed a critical decision, or uncovered a new tactic, it builds buy-in

6 Conclusion & Future-State Considerations

The adoption of ME and DE is not just a technical endeavor, but a strategic imperative for the DON. This report highlighted that while the DON and DoD have made important strides in digital transformation surrounding ME and DE – defining key terms, formulating strategies, and starting pilot projects – there remains a clear need for greater unity and acceleration of these practices across communities. Standardizing ME and DE terminology across the DON will lay the foundation for all other standardization and collaboration efforts. Likewise, integrating the DON's DE efforts under an enterprise ecosystem with authoritative data and shared models will ensure that the wealth of information and analysis generated through standardized processes is accessible and usable by anyone who needs it, from system designers to operational planners. These steps, combined with a concerted push in training and culture, will address many of the adoption gaps discussed in this report and the previous – confusion about terms, inconsistent tool usage, and resistance to change.

By implementing the strategic and actionable recommendations covered in this report and summarized below, the DON can achieve tangible improvements.

- **Near-term institutionalization of a unified lexicon and ME/DE requirements** in acquisition activities and plans will eliminate inconsistent practices and align new projects with mission-focused thinking.

- **Quick wins like recommended pilots and AI-based document checks** will demonstrate cost and time savings, building further momentum and lessons learned.

- **Longer term, high-level workforce transformation and fully interoperable data environments** will yield a DON that is faster and more agile in capability development. When DE is fully woven into the fabric of DON acquisition and operations, the time to field new technologies will shrink – models and simulations will validate designs much earlier and pinpoint the right solutions for mission needs. When ME is fully woven, it will ensure that those solutions are the right ones by continuously aligning system capabilities to operational outcomes.

Implementing these recommendations would provide a multitude of impacts. In operational terms, a DON embracing ME and DE in standardized practice will be able to respond to threats more swiftly (through rapid scenario analysis and course-of-action modeling), integrate new capabilities or partners more smoothly (since common standards and models exist), and out-think adversaries by leveraging superior digital tools and mission understanding. Another critical impact is on interoperability and joint combined effectiveness. As noted in the international comparisons, modern conflicts will be fought by coalitions and across domains; having a standardized approach to ME means the DON can plug into Joint and Allied mission analyses with minimal friction. DE will further allow the Navy to contribute to and draw from a joint digital thread of operations (for instance, linking an Air Force sensor model with a Navy weapon system model in a combined simulation). This kind of synergy is only possible when organizations adopt common standards – exactly what the DON will achieve internally with a unified approach, and externally through collaboration. The result is a force that can truly act as part of an integrated all-domain team, a key goal of concepts like Joint All-Domain Command and Control and Distributed Maritime Operations.

To ensure sustained progress, the DON should treat ME and DE adoption as an ongoing journey, establishing metrics and governance to monitor implementation. Regular reviews (perhaps annual "ME and DE Effectiveness" forums) can assess these metrics, share best practices, and update policies as needed. NAVWAR's strategy calls for annual execution plans with explicit goals and metrics to guide enterprise-wide DE implementation – a practice that should be emulated DON-wide. Leadership involvement will remain crucial: senior leaders should continue to champion ME and DE in public forums and internal communications, keeping the momentum high and signaling that this is the new normal for how the DON does business. Additionally, as technology evolves (AI, cloud, edge computing, etc.), the DON's ME and DE approaches should evolve in tandem, continually integrating new tools that can enhance mission analysis or digital modeling. The recommendations in this report lay out the next steps, but the DON should remain adaptive – learning from each initiative, scaling what works, and pivoting from what does not.

In conclusion, ME and DE offer the DON a powerful dual promise: **the ability to engineer for mission success** and the **ability to do so with greater speed, insight, and efficiency**. By unifying the lexicon, strengthening data and model infrastructure, investing in people, and seizing quick wins, the DON can accelerate the adoption. The payoff will be a DON that not only keeps pace with the rapid changes of the 21st-century security environment, but one that leads – leveraging its digitally empowered, mission-focused ethos to maintain maritime superiority and to confidently orchestrate missions that protect the nation's interests. The roadmap outlined here is both ambitious and attainable; with sustained commitment, the DON's adoption of ME and DE will transform how it fights and wins in the years to come.

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Acronyms

AI	Artificial Intelligence
ARLIS	Applied Research Laboratory for Intelligence and Security
CONOPS	Concept of Operations
DAU	Defense Acquisition University
DE	Digital Engineering
DoD	Department of Defense
DON	Department of Navy
DSD	Decision Science Division
DSET	Digital Systems Engineering Transformation
FFRDC	Federally Funded Research Center
FMN	Federated Mission Networking
FY	Fiscal Year
ICC	Integrated Capabilities Command
IEEE	Institute of Electrical and Electronics Engineers
INCOSE	International Council on Systems Engineering
JMETC	Joint Mission Environment Test Capability
KPP	Key Performance Parameter
LLM	Large Language Model
LVC	Live, Virtual, and Constructive
MBSE	Model-Based Systems Engineering
ME	Mission Engineering
ME TAB	ME Technical Authority Board
MEG	Mission Engineering Guide
MIM	Mission Integration Management
MOE	Measure of Effectiveness
MOP	Measure of Performance
NAF	NATO Architecture Framework
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVWAR	Naval Information Warfare Systems Command
NDAA	National Defense Authorization Act
NDIA	National Defense Industrial Association
NLP	Natural Language Processing
OSA	Office of Strategic Assessment
OSD	Office of the Secretary of Defense
OUSD(R&E)	Office of the Undersecretary of Defense for Research and Engineering
PCA	Principal Component Analysis
R&D	Research and Development
RIMPAC	Rim of the Pacific
SERC	Systems Engineering Research Center
STANAG	NATO Standardization Agreement
VAULTIS	Visible, Accessible, Understandable, Linked, Trustworthy, Interoperable, and Secure
VT-ARC	Virginia Tech Applied Research Corporation
WASSP	Wartime Acquisition and Sustainment Support Plan

References

The team reviewed a large number of publications and DoD strategies that influenced this work. Those central to findings included in this report are cited below and some are annotated additionally as footnotes throughout this report when directly cited for a key statement or finding.

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