Defense Business Board

Business Transformation Advisory Subcommittee

DBB FY24-03

Assessment of the Department of Defense

Creating A Digital Ecosystem

February 29, 2024

AN INDEPENDENT DBB REPORT - Assessment of DoD enterprise-wide digitalization as it affects engineering, development, acquisition, and lifecycle management.

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I. Preface

Tasking

The 2022 National Defense Strategy (NDS) requires the Department of Defense (DoD or "the Department") to continue to advance its commitment to modernization and innovation and to "build a resilient Joint Force and defense ecosystem." Creating an interoperable digital ecosystem, with common standards and requirements designed to harness the power of accurate, real-time data and shared between industry and DoD, is essential to achieving these requirements and to improving how the Department operates. Such a transformation will provide more efficient decision-making and risk analysis; more accessible simulation environments and advanced computing to streamline development activities; and a genuine transformation of the acquisition product lifecycle to boost warfighter capabilities more rapidly and effectively.

On July 31, 2023, the Deputy Secretary of Defense (DepSecDef) tasked the Defense Business Board (DBB or "Board"), through its Business Transformation Advisory Subcommittee ("Subcommittee"), to evaluate the need for lifecycle digitalization and to provide recommendations on creating a digital ecosystem with industry partners. Lifecycle digitalization is the integration of digital technologies, data, and systems throughout the product lifecycle (requirements, engineering, acquisition, and sustainment). This process involves incorporating and combining innovations such as collaborative data platforms, Artificial Intelligence (AI), predictive analytics, digital twins, advanced manufacturing, comprehensive lifecycle management, and automation.[1]

The Terms of Reference (ToR) for *Creating a Digital Ecosystem* ("Study" or "Report"), found in Appendix A, guided the full scope of the Subcommittee's research, interviews, and analysis to provide the recommendations to the Department outlined in this Study.

Approach and Methodology

The twelve-member Subcommittee, with support from the DBB staff, conducted a six-month Study. The team analyzed and synthesized data gathered from an extensive literature review and interviews with 58 individuals across 45 organizations. Discussions included perspectives, experiences, challenges, and best practices from senior government officials, private-sector C-level executives, and workforce leaders on the frontline of digital change initiatives.

The ToR directs the Subcommittee to address six relevant areas of investigation or assessment:

1. evaluate the current state of the Department's digitalization efforts (throughout the Study);
2. identify the challenges to implementation (Findings and Observations, Section IV);
3. review industry best practices (throughout the Study and Background, Section III);
4. provide recommendations (Section V; however, additional details, explanations, and key elements are provided in Appendix H);
5. suggest measures for success (Section VI); and
6. offer additional matters related to building a Defense Digital Ecosystem (throughout the Background, Findings, and Recommendations in Sections III, IV, and V).

The Subcommittee concluded the digitalization efforts taking place both in the Department of Defense and in the Defense Industrial Base (DIB) are rapidly evolving and enormously complex. The Subcommittee was quick to recognize an all-encompassing review of these activities would not be possible and focused its investigation on those areas that would directly impact and accelerate the development, acquisition, sustainment, and operations of our military forces.

Study Members and Signatures

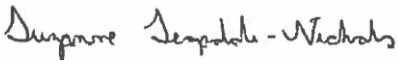
Mr. Stan Soloway serves as chair of the DBB Business Transformation Advisory Subcommittee. Mr. Soloway and Ms. Suzanne Leopoldi-Nichols, Subcommittee Co-Chair, led the *Creating a Digital Ecosystem* Study. Contributing members include Honorable Deborah James, Mr. Craig Albright, Mr. Joe Anderson, Mr. Anand Bahl, Mr. Greg Bowman, Ms. Marachel Knight, Mr. Oscar Munoz, Honorable Eric Rosenbach, General Joseph Votel, and Saf Yeboah Amankwah. Member biographies are found in Appendix C.

Ms. Cara Allison Marshall is the DBB Designated Federal Officer (DFO); Captain Chad Graham, US Navy, serves as a DBB Military Assistant and Alternate DFO; Mr. Matthew Ratcliff, US Air Force Digital Engineering Technical Advisor, serves as subject matter expert on special assignment to the DBB; and Janice McLaury, a contractor, serves as researcher, writer, and analyst. The DBB team served as primary support officials to this Study. Ms. Gwyneth Murphy, analyst, augmented Study efforts.

The Subcommittee members presented the Study findings and recommendations to the DBB at an open public meeting on February 29, 2024. After discussion and deliberations, the Board approved the Study with comments as documented in Appendix L. Briefing slides presented and approved at the meeting are found in Appendix B.

Signatures

Stan Soloway
Subcommittee Chair



Suzanne Leopoldi-Nichols
Subcommittee Co-Chair

Honorable Deborah James
Subcommittee Member
DBB Chair

Craig Albright
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Joe Anderson
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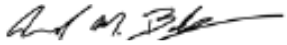

Anand Bahl
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Greg Bowman, JD
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Marachel Knight
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Oscar Munoz
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Honorable Eric Rosenbach
Subcommittee Member

General Joseph Votel
(US Army, Ret)
Subcommittee Member

Saf Yeboah Amankwah
Subcommittee Member

II. Executive Summary

Defense Digital Transformation

The immediate and rapid development of a Defense Digital Ecosystem must become a top national security priority if the United States is to maintain its military advantage over the pacing threat from adversaries, including the People's Republic of China (PRC or "China"), who are aggressively transforming their defense production processes. In this rapidly evolving threat environment, the establishment of a Defense Digital Ecosystem across weapon system development, acquisition, sustainment, and operations is essential to ensuring the agility and ability to deliver disruptive capability to the warfighter "at the speed of relevancy." To achieve this overarching goal, this Study examines multiple facets of digital transformation, including state-of-the-art technology; commercial best practices; organizational culture and training needs; and intellectual property and security requirements. This ecosystem must include a strong foundational architecture to support the software tools, training, communication, and interoperability required to enable the functional support of weapon systems throughout their lifecycles. A transformed digital ecosystem will also facilitate the exchange of real-time data across multiple platforms, organizations, and partners while maintaining strict access controls and cybersecurity. Furthermore, the users of such an ecosystem must possess the necessary expertise and competencies to develop, operate, and maintain it.

> For the purpose of this Study, digitalization is defined as the process of leveraging digitized data, digital tools, IT technologies, and talent to enable or improve processes[2] in a business operation[3].

Across the global economy, the rapid evolution and adoption of digital tools and strategies are transforming business, government, and organizational operations, from basic automation to complex integrated systems. In virtually every industry sector, companies are heavily investing in and highly prioritizing the management of these capabilities to enable the seamless, continual flow of data across programs and customers. Digitalization facilitates rapid product development and speed-to-market. Through real-time, enterprise-wide data sharing, visibility into supply chains and improved product support, program risks are reduced at both the front end and throughout the product lifecycle. In the competitive marketplace, the development of a comprehensive ecosystem is fast becoming a "coin of the realm."[4]

VinFast: Fully Digital Factory Accelerates Speed and Scale

VinFast, the Vietnamese car manufacturer, built a fully digital automotive factory in 21 months, 50% faster in time to market than usual, and easily scalable for future expansions. Utilizing the latest technology, VinFast designed digital twins of products, the production, and the performance of production and product, creating a "closed-loop" manufacturing system. Merging the virtual world with the real world, digital tools provide new insights; physics-based simulations with data analytics in a fully virtual environment; and faster more reliable results with fewer real prototypes. A high-performance digital infrastructure provides performance data of the real production and of the real product to be analyzed and fed back into the development cycle for improvements, optimization, and innovation at an early stage.[5] [6]

According to some experts the Subcommittee interviewed, the adoption of comprehensive digital strategies is the most profound change since the advent of cloud computing. Through scores of interviews with experts inside the Department and across both the defense and commercial

sectors, as well as a broad literature review, the Subcommittee has concluded the Department's ability to establish an interoperable digital ecosystem is essential and must be established as a top priority for national security. The Subcommittee's research indicates that while the Department is making real progress in its digital journey and the recognition of its importance continues to grow, DoD nonetheless significantly lags behind the commercial sector in the adoption of proven capabilities. Unfortunately, the Subcommittee learned the Department lags, or could soon lag, behind our adversaries, who are investing heavily in similar capabilities and appear to be fielding new capabilities at a more rapid pace than the US. When the PRC routinely fields new capabilities in half the time it typically takes the US and technology continues to move at an unprecedented pace,[7] the national security imperative becomes clear and the danger of inaction is vividly present.

> ***"Digital engineering must be addressed in the acquisition strategy, including how and when digital engineering will be used in the system life cycle and expected benefits of its use."***
>
> *~ DoDI 5000.97 Digital Engineering policy, December 2023*

The Subcommittee identified numerous centers of excellence where experimentation and pilot programs are facilitating digital ecosystems. Best practices have produced measurable and impactful results that offer a strong foundation to build a true transformation. DoD's issuance of its first Digital Strategy Directive in 2018[8], and the subsequent release of individual military Service ("the Services") strategies and policies, helped to catalyze meaningful progress and momentum. The recently released DoDI 5000.97 Digital Engineering policy[9] further complements this Study and provides a foundation for executing some of the Board's recommendations. However, the Board does not believe the directives in this policy can be executed under the current governance and funding structures available. As an Under Secretary of Defense for Research and Engineering (USD (R&E)) policy directive, it lacks the authority to compel other Office of the Secretary of Defense (OSD) entities and the Services to resource and support.

The Subcommittee also concluded, despite the increasingly robust internal knowledge and experiential base and the impressive groundwork to date, the Department's transformation initiatives are moving too slowly to meet international pacing threats nor the pace of technological advances. A wide array of industrial sectors are outpacing DoD and the DIB, including commercial automotive, aerospace, and advanced manufacturing, leaving DoD at serious risk of falling further behind faster than ever before.

A combination of longstanding bureaucratic inertia; a culture known to be highly risk-averse; workforce gaps; and resource availability present significant barriers to success. On a more basic yet critical level, DoD has yet to articulate a clear, cohesive vision to the Services and Components who must work collaboratively, or within a governance model, to help ensure success. Instead, as reflected in the majority of the Subcommittee's interviews, current efforts remain siloed, uneven, and limited at a time when they need to be significantly accelerated, focused, and cross-cutting.

Simply put, the Subcommittee's goal with this Report is to offer actionable recommendations we believe will help to align and build on the real progress already made and help the Department accelerate this critical transformation.

Accelerating and Scaling

As noted earlier, the pacing threats faced by the US dictate that the Department move expeditiously in its digital transformation. Transformations involve changes to impact virtually every aspect of the enterprise. They are sweeping in their scope and impact, and all actions taken in support of them must be aligned with bold and sweeping objectives. At the same time, the commercial sector has learned transformations also take time and must be underpinned by

practical and strategic objectives that deliver real value in the near term, even as the fuller benefits and effects come later. The same is true for DoD.

The leadership of the Department has already taken the critical first step in declaring, essentially, all new programs will be “born digital” and, as also noted earlier, valuable experimentation has already been accomplished and continues. For the transformation to be successful, however, it is essential, in keeping with proven best practices, DoD leads, organizes, and manages the initiative in a way to provide Department-wide clarity of vision, responsibilities, accountability, and support. Further, a true transformation must remain unyielding; DoD must first strategically identify, support, and incentivize high-impact digital initiatives likely to deliver near-term benefits, as well as establish new best practices that can be rapidly replicated in a broader transformation.

Finally, the Subcommittee’s recommendations are built upon a recognition that digital transformation will impact a wide array of functions and processes, including but not limited to engineering, tech infrastructure, contracting, sustainment and logistics, budget, legal, and personnel. As such, each functional community must actively be engaged in programs from the very start, as well as in workforce development initiatives so that the program roadmap accurately and proactively identifies potential barriers and ways to overcome them.

For all those reasons, the Subcommittee recommends the Deputy’s Management Advisory Group (DMAG), or a similarly scoped body, establish this transformation as its top priority. We further recommend the creation of an Executive Action Group which would be charged with execution responsibility. In addition, the Subcommittee is making a series of recommendations to help aggressively launch a Defense Digital Ecosystem.

In addition, while much of the Department's efforts to date center on ensuring new programs are "born digital," the Subcommittee strongly believes significant nearer-term performance improvements will result from reasoned yet aggressive efforts to "digitize" legacy systems, especially at the Component level. As demonstrated by the Collins case study, and insights the Subcommittee received from the automotive industry, focusing on already fielded products and systems can help alleviate supply chain risks; enable more rapid upgrades; and reduce overall sustainment costs. Not all legacy programs or components are logical candidates for digital transitions. Nonetheless, DoD must include, as part of its digital strategy, requirements for the Services to aggressively identify programs where digital tools can have a measurable impact.

Collins Aerospace: Digital Twin Solves Crisis

When faced with the crisis in Ukraine and the immediate sanctions imposed by the US and UN, Collins had to stop the import of a key heat exchanger for aircraft. By mining the company’s technical data performance metrics, it produced a digital twin of the component and accompanying aircraft systems. What would have taken six months or more to find and develop a new supplier, the team was able to complete it in one week with digitalization, avoiding any interruption in maintenance and operations.[10] [11]

Throughout its history, DoD has demonstrated an unparalleled ability to address crises rapidly and effectively, as demonstrated by the Department’s efforts to swiftly develop counter-IED technologies and, more recently, its extraordinary contributions to the response to the COVID pandemic, including the development of the vaccine. The Subcommittee believes comprehensive digital transformation initiatives are of the same level of importance. As noted earlier, a good deal of experimentation and piloting has already been done. Now is the time to accelerate the pace of wide-scale digital ecosystem adoption.

Observations, Findings, and Recommendations Summary

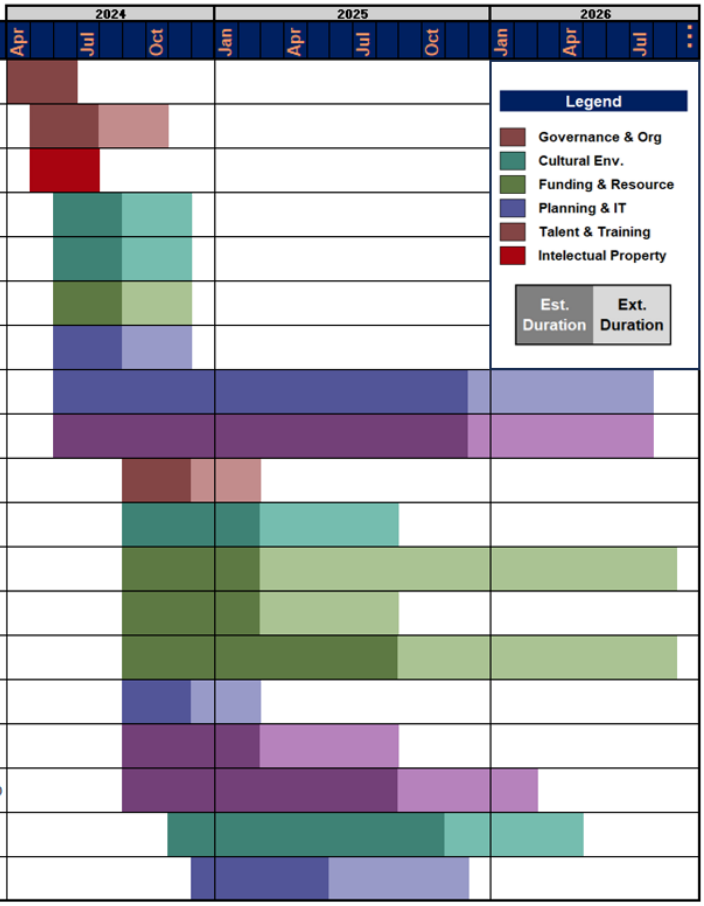
Detailed findings and recommendations are contained in the body of this Study; however, at a high level, several overarching observations informed our work:

Table 1: Findings and Recommendations

Themes	Findings and Recommendations
Governance & Organization	**Finding I**: *DoD Requires Centralized Authority to Advance Digitalization* **Recommendations**: • Assign Deputy's Management Action Group (DMAG), or similarly scoped body, as the leadership authority for developing the Defense Digital Ecosystem • Convene an Executive Action Group (EAG) to remove barriers to change • Expand and formalize industry participation in the development of solutions
Planning & IT Infrastructure	**Finding II**: *DoD's Lack of an Integrated Digital Ecosystem Creates Inefficiencies* **Finding III**: *DoD Lacks Digital Taxonomy for an Interoperable Digital Strategy* **Finding IV**: *DoD's Ability to Best Utilize Data is Constrained* **Recommendations**: • Develop a collaboration platform architecture and roadmap • Establish a common vision and taxonomy • Develop standards for data interface and interoperability • Require all functional stakeholders across the product lifecycle to participate in planning
Cultural Environment	**Finding V**: *DoD Culture is Risk Averse & Resistant to Change* **Recommendations**: • Establish a deliberate process based on proven change management techniques and principles • Actively address the institutional resistance to risk in a change management plan • Incentivize and reward personnel to adopt digital skills • All leaders at all levels must include digital skills objectives in performance evaluations
Talent & Training	**Finding VI**: *DoD Workforce is Not Adequately Prepared for a Digital Ecosystem* **Recommendations**: • Establish distinct digital ecosystem pathways for both military and civilian personnel to include clear opportunities for advancement and leadership • Develop a strategy to rapidly recruit highly specialized and in-demand technical disciplines • Expand and fund opportunities for critical skills development to close the gap between experienced workforce professionals and technically skilled "digital-doers"
Funding & Resourcing	**Finding VII**: *PPBE Process Obstructs Ability to Fund Foundational Initiatives* **Recommendation**: • Establish a centralized OSD Managed fund for the Services and Programs to effectively compete for resources that support and accelerate enterprise-wide digitalization
Intellectual Property	**Finding VIII**: *IP & Technical Data Rights Remain a Critical Concern* **Recommendations**: • Mandate regular progress reports from the Intellectual Property Cadre

Table 2: Recommendations Timeline

Recommendation	Timeframe	Owner
Assign DMAG (or similar) as the authority for developing the Digital Ecosystem	<3 months	DMAG
Convene an Exec Action Group to remove barriers to change	3-6 months	USD (R&E, A&S), CIO, CDAO
Mandate regular progress reports from the Intellectual Property Cadre	<3 months	USD(A&S)
Establish a deliberate change management process and plan	3-6 months	EAG
Address the institutional resistance to risk in the plan	3-6 months	DMAG, EAG, Services
Work with USD (Comptroller) to establish digital ecosystem as an investment priority.	3-6 months	USD (Comptroller)
Establish a common vision and taxonomy	3-6 months	USD (R&E, A&S), CIO, CDAO
Develop collaboration platform architecture and roadmap	18+ months	USD (R&E, A&S), CIO, CDAO
Establish distinct digital ecosystem pathways for both military and civilian	18+ months	USD (P&R)
Formalize Industry participation in the development of solutions	3-6 months	USD (R&E, A&S)
Incentivize and reward personnel to adopt digital skills	6-12 months	USD (P&R)
Establish a centralized fund and modify PPBE process to remove budget restrictions	6-24 months	USD (Comptroller)
Near-term: use current DoD authority to recover / reallocate funds	6-12 months	USD (Comptroller)
FY 25-26: pursue legislative action for a centralized DoD fund	12-24 months	USD (Comptroller)
Require all functions from across all stages of lifecycle to identify data needs	3-6 months	USD (A&S), Services
Expand and fund opportunities for critical skills development	6-12 months	USD (P&R)
Develop a strategy to rapidly recruit highly specialized technical disciplines	12-18 months	USD (P&R), CDAO
All include digital skills objectives in performance evaluations	12-18 months	USD (P&R)
Develop standards for data format and interfaces, standards to facilitate interop.	6-12 months	EAG, USD (R&E, A&S), CIO, CDAO



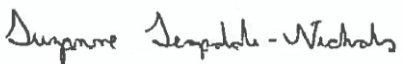
Final Comments

The DBB appreciates the Deputy Secretary's confidence in entrusting the Board with this important Study. We sincerely applaud the innovative and dedicated professionals within the Department, and especially leadership within the Services, who are working tirelessly to employ rapidly advancing technology and drive fundamental changes for the warfighter and to the way we keep our nation safe.

The full DBB approved the observations and recommendations contained within on February 29, 2024.

Respectfully submitted,

Mr. Stan Soloway
Subcommittee Chair



Ms. Suzanne Leopoldi-Nichols
Subcommittee Co-Chair

III. Background

Introduction to the Digital Imperative

One former senior defense official succinctly explained the potential power of a digital ecosystem, "Imagine a scenario where a weapon system is loaded with sensors designed to provide performance telemetry back to an operational unit equipped with a digital twin. The digital twin could then accurately model and integrate real-time performance with any emerging environmental and intelligence data to identify potential gaps in capability. Artificial intelligence could be designed to provide an array of solutions to rapidly optimize and overcome a wide variety of technical challenges." Reinforced by a digital ecosystem, they continued, "The operational unit would possess a system capable of countering emerging threats, in real-time conditions, and be able to adapt faster than a human could." The official summarized, "Now, imagine China has managed to achieve this before us. Simply put, the military organization who achieves 'symbiosis on the battlefield' will own the battlefield."

The aggressive and smart adoption of digital strategies has become essential to mission readiness and execution and, thus, the continued ability of the US to promote global security and defend democratic values. "We achieve deterrence by maintaining a highly ready, combat-capable force in the present and by modernizing the US military to sustain a dominant warfighting advantage in a future operating environment."[12] Today's digital imperative stands at the heart of fielding and sustaining a dominant warfighting advantage.

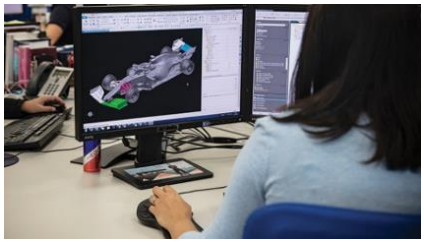
> ***"We can't predict the future. So, what we need is the right mix of technology, operational concepts, and capabilities — all woven together in a networked way that is so credible, flexible, and formidable that it will give any adversary pause."***
>
> *~ Secretary of Defense Lloyd Austin, April 30, 2021*

For the Department, the transformative nature of a digital ecosystem is no different. DoD has largely embraced the digital concept and pockets of excellence and experimentation have demonstrated the explosive potential to change everything from the battlespace to back-office operations. Moreover, digitalization is fast becoming the new Space Race.[13] Peer and near-peer competitors, especially the PRC, are investing substantial resources in the deployment of AI and digital tools – capabilities that, as many interviewees suggested, will likely be critical to battlefield dominance.

Executed across all stages of the acquisition lifecycle, from initial concept through retirement, a digital ecosystem is essential to the Department's ability to meet national security imperatives. This requires overcoming long-standing challenges, such as the pace at which new systems are fielded; DoD's siloed structure and processes; and ever-increasing supply chain instability. Across the few programs that have embraced digitalization, most have seen significant reductions from the historical average in the time required to meet acquisition milestones. These pathfinders have borne the brunt of the effort to evolve the new paradigm, and the Department is now able to take advantage of the lessons learned to rapidly scale them for more universal adoption.

More than automation, digitalization involves the seamless, continual interface and flow of data across programs, the Services, and DoD enterprise, creating a fluid exchange of information throughout the acquisition product lifecycle. Digitalization significantly improves system development cycle times and operating efficiencies; reduces errors; improves productivity; enables real-time data sharing; and ultimately, drives cost-effectiveness.[14] Further, a digital ecosystem, and its agile framework, enable the ability to resolve problems earlier than traditional program models, thus mitigating risk more effectively and rapidly. In so doing, it provides the foundation for a more agile, responsive acquisition lifecycle system, which is fundamental to the implementation of an effective digital ecosystem.

Formula-1 (F-1): Digital Data Revolutionizes Strategy



High-performance computing enables Formula-1 to run aerodynamic simulations to develop its next-generation car 70% faster than ever before -- creating a car that reduces downforce loss from 50% to 15%. By the time the prototype hits the wind tunnel for the first time, it already has thousands of hours of testing through digital simulations. The raw material for this evolution is data. The F-1 racer collects, analyzes, and leverages data and content to make real-time decisions. With 300 sensors on each race car generating and transmitting more than a million data points per second from car to pit, Formula-1 is genuinely a data-driven sport.[15]

Transformation of this magnitude requires a coalescing force of sustained leadership and assured continual investment; conversely, a failure to commit to the requisite structural and investment needs suboptimizes the Department's ability to face existential challenges and risks DoD falling dangerously behind competitors. Even during this Study, the Subcommittee observed notable progress, and momentum continues. And, as noted earlier, the Subcommittee sought to provide a set of recommendations that build on the significant progress made. Given the nature of the threat, the pace remains too slow and is hamstrung by historic bureaucratic rigidity; cross-functional and cross-organizational disconnects; and DoD's longstanding culture of risk aversion. These obstacles will only be overcome through a cohesive vision coupled with the creation of immutable institutional and policy changes designed to survive the inevitable military and civilian leadership changes and traditional bureaucratic inertia.

> ***"A standards-based open architecture framework, with broad collaboration and input from Industry, including startups, primes, and commercial entities, and government, is critical to accelerate innovation, enable true interoperability, and sustain technological dominance."***
>
> *~ Congressional Testimony of Jim Taiclet, President and CEO, Lockheed Martin*

The risks of failing to inculcate change throughout the system can be seen in the dilution or suboptimization of numerous reforms directed by Congress or instituted within DoD, over the last thirty years. As but two examples, the advent of the Mid-Tier Acquisitions (MTA) pathway was an important initiative to overcome barriers to speed and innovation but has yet to take hold to the degree possible and necessary. And, while the use of Other Transactions Authorities (OTA) skyrocketed due to Congressional direction and authority, the number of OTA prototypes that have successfully transitioned to production remains low. Although both MTAs and OTAs have demonstrated the ability to deliver capability faster and adapt more quickly to accessing new and evolving technologies, neither has experienced the broad application warranted.[16]

Notably, Congress continues to advocate for reform and change. Most recently, the FY 2024 National Defense Authorization Act directed DoD to rapidly review its requirements, policies, and practices with an eye toward the development of the very kind of digital ecosystem that is the focus of this Study.

The Pacing Threat

> **"For decades, China has been using the power of its authoritarian government to pursue civil-military fusion, the practice of intentionally using their commercial industry to augment and enhance their military and defense establishment, we must vigorously address it.**
>
> *~ Congressional Testimony of Jim Taiclet, President and CEO, Lockheed Martin*

Historically, Americans have built the best weapons in the world. However, some experts predict that American battlefield dominance may be at greater risk than ever as the pacing threats to the US appear to be moving faster in the development and fielding of new

capabilities. It is also clear that near-peer adversaries are swiftly evolving their digital capabilities.[17] For example, the PRC typically develops, tests, deploys, and refines new weapons systems in seven years; as compared to a 16-year average for DoD.[18] Much of this can also be attributed to a cultural bias around virtual technology.

One official further emphasized that when it comes to virtual testing, "Our culture in DoD promotes a risk-averse response to trusting emergent technologies. We tend to "trust the human," or better yet, we feel more comfortable if every step is demonstrated in a physical environment before allowing it to continue development, manufacturing, and operational deployment." The official continued, "China is the opposite. The PRC "trusts the machine" more than the human. In other words, it trusts the model more than the engineer or analyst and, therefore, can move faster." Further, China is not constrained by the layers of process and policy to which all DoD acquisition is subjected to, some of which is a necessity in a Democratic system but can also further complicate change. In short, the threat is very real and immediate, and this is not a race America can afford to lose. Now is the time to fully embrace and dramatically accelerate this transition.

From Piloting to Accelerating

Senior leaders within the Department, and especially across the Services, have begun to respond to the imminent threat with direction, development, and issuance of digital strategies. Digital engineering pilot programs have all consistently identified the extraordinary impacts of digitalization as a catalyst for broad change, reduced total cost of ownership, increased speed to deployment, and predicted dramatic improvements in system sustainment.[19]

Air Force B-21: Digitalization Delivers Major Weapons System in 8 Years

Born digital, the B-21 was developed using digital engineering and digital tools, which enabled the team to iterate designs, test faster, fail quicker, solve problems before they become issues, reduce overall risk, and deliver an upgradeable weapons platform relevant for the next 30-50 years. Digitalization enabled the B-21 to go from design to flight in 8 years.[20] [21]

Nonetheless, DoD as an enterprise continues to move too slowly in the adoption of these proven strategies, lags well behind the commercial industry in digital transformation and, as noted, risks falling dangerously behind key adversaries. Similarly, several interviewees with experience in both the defense and the commercial sectors indicated that even within some core companies in the DIB, there are vastly different paces of adoption between the defense and commercial sectors.

> ***"In the relentless pursuit of innovation, we recognize that digital transformation is not just a choice, it's a necessity. It's more than just the adoption of technology; thriving requires a fundamental shift in our mindset and processes, and this is particularly relevant in the context of aerospace and defense."***
>
> *~ Tony Hemmelgarn, President & CEO, Siemens Digital Industries Software*

The creation of a digital thread, integrated across the acquisition lifecycle, is highly complicated and challenging to envision. Despite being well ahead of DoD, private industry is far from seamlessly and consistently achieving its own fully functioning digital ecosystems. The difference, though, is that almost every major industry, driven by the need to be first and the best, has made the transformation a top priority and is committing to invest resources, time, and leadership in developing and executing a digital strategy. Moreover, contrary to the traditional DoD culture, several executives interviewed also argued that "failures" experienced along the way were both expected and provided valuable lessons in driving success. In their experience, a digital strategy done right, much like agile software strategies, means one fails faster and more rapidly adjusts, thereby, reducing broader program risks.

Digitalization played a major role in the COVID pandemic, where companies were required to rapidly respond to dramatic changes in their ability to operate. One senior industry executive noted COVID was a catalyst for enormous change; the imperative to rapidly adopt digitalization, including digital twinning, enabled the company to reduce time to market from an average of two years to as little as two months.[22] Clearly, crises are in no way desirable, but they do produce opportunities for learning and changing what can be normalized to improve routine operations. The same was true for earlier events, like the Counter-IED initiative. In those cases, the Department proved it could rapidly adapt, adjust, and meet major challenges. Digital transformation is no different.

The time for experimentation has passed, and the time to normalize and accelerate has arrived.

The Subcommittee concluded the time is not only right, but the need is clear, for the Department and, in particular, the Office of the Secretary of Defense, to fully commit to the creation of the requisite structures, practices, policies, and processes to enable the rapid evolution of a digital ecosystem across the Defense enterprise. Conversely, the failure to make the necessary strategic investments and to exercise the sustained leadership needed for success puts risk on mission effectiveness, warfighter preparedness, and national security.

Digital Ecosystem

In 2018, the defense acquisition community initiated a digital ecosystem strategy to bring together people, processes, and products into an interoperable exchange of data, information, and communications. The radical change from a paper-based, or 'analog', operation to a data-centric one driven by authoritative and up-to-date sources became known as the "a single source of truth." Leaders, engineers, buyers, comptrollers, technicians, maintenance personnel, and customers would be able to rapidly iterate, analyze, and make decisions.

"We've built a digital ecosystem that focuses on program execution, bringing together employees, customers, and partners into an integrated environment, so they can seamlessly work together. This accelerates design, integration, testing, and deployment across programs, helping us to deliver with quality, speed, and efficiency…. increasing the number of programs that are operating in this ecosystem…. today, we have over 100 active programs. We're also investing in and advancing the technologies and digital systems in our factories."

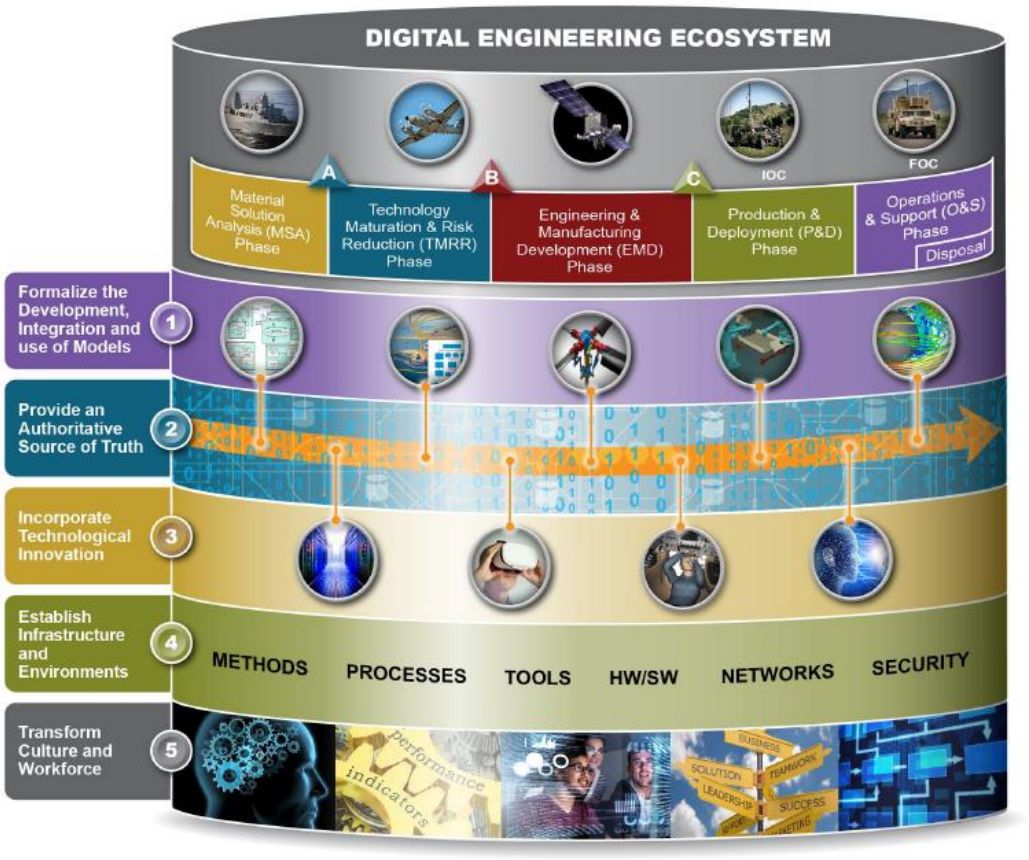
~Kathy J. Warden, Chair, CEO & President
Northrop Grumman Corporation

The "digital ecosystem" concept includes a holistic end-to-end integration of the acquisition product lifecycle, which begins with a user need and continues through research and development, test, manufacturing, sustainment, and continuous iteration to maintain effectiveness and operational availability. Each of these phases, when adopting a digital posture, does not fundamentally change purpose or meaning but does affect the underlying processes and tools used to perform the primary function.

Bye Aerospace, Inc: Dial In and Iterate to a 99% Solution

With digital tools, Bye Aerospace, Inc. can either do the same number of iterations in less time or can do more iterations in the same amount of time – the company is doing both. Shrinking the electric-propulsion aircrafts' product development time and doing more iterations in the same timeframe enables a quicker time to market with the right plane. "With a typical program, you get two iterations. If you're doing a very good job, you get three. With the [enterprise software] solutions, you can iterate on a weekly basis, so being able to dial in and iterate to a 99 or 100% solution to your requirements is the biggest advantage." [23]

Graphic 1: DoD Digital Engineering Ecosystem Concept [24]



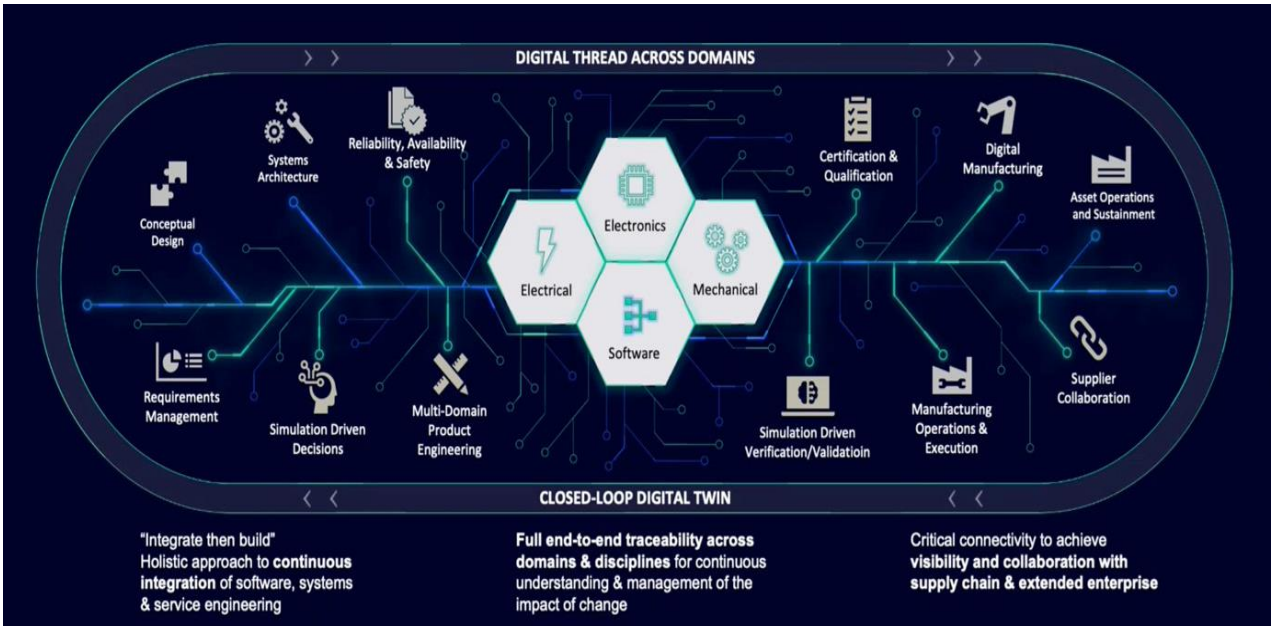
Technological Advantage

The drive for agility, flexibility, and rapid increases in "time of need" capacity led to a pivotal industrial advancement -- the integration of the "digital twin" into requirements development, engineering, acquisition, manufacturing, testing, innovation, and lifecycle management.

A fully realized digital twin is a hyper-accurate virtual representation of a physical item that relies on continuous improvement and simulation, allowing the twin to behave as if it were in the physical world. Several commercial companies provide cloud-based platforms for design and simulation, enabling teams to collaborate seamlessly regardless of geographical location. This enhances flexibility and dramatically accelerates innovation cycles within manufacturing operations. Although rudimentary digital simulations and mathematical models have existed for many years, the ability to create true, physics-based digital twins has advanced exponentially in the last decade due to breakthroughs in high-performance computing, hardware, and virtual reality technology.

Thereafter, the digital twin reflects the product's performance and allows operational data to support rapid innovation, applications of artificial intelligence, predictive maintenance, and even real-time changes in product use. The linking of several digital twins, such as the product, processes, and performance, is called the "digital thread" which, among other things, provides continuity throughout the entire lifecycle.

Graphic 2: Digital Twins Used to Create a "Cross Domain Digital Thread." [25]



The Next Digital Evolution: The Industrial Metaverse

Additionally, global manufacturers and software makers are developing an even broader digital ecosystem concept called the "**Industrial Metaverse**." This metaverse is not focused on games or social content applications; rather, it is the next evolutionary step of advanced manufacturing. According to the World Economic Forum, it is "a persistent 3D platform implemented across an organization, value chain, and product life cycle, serving as a digital reflection of an entire organization in its operational environment. In its combinatory nature, it integrates processes, materials, machines, and people in a bidirectional flow between real and virtual worlds."[26]

Simply put, the Industrial Metaverse is the convergence of technologies that, when used in combination, can create an immersive virtual / physical industrial environment. As it evolves, the metaverse will be able to connect multiple digital ecosystems into a never-before-seen immersive system accessible by innovators from around a company or around the world.

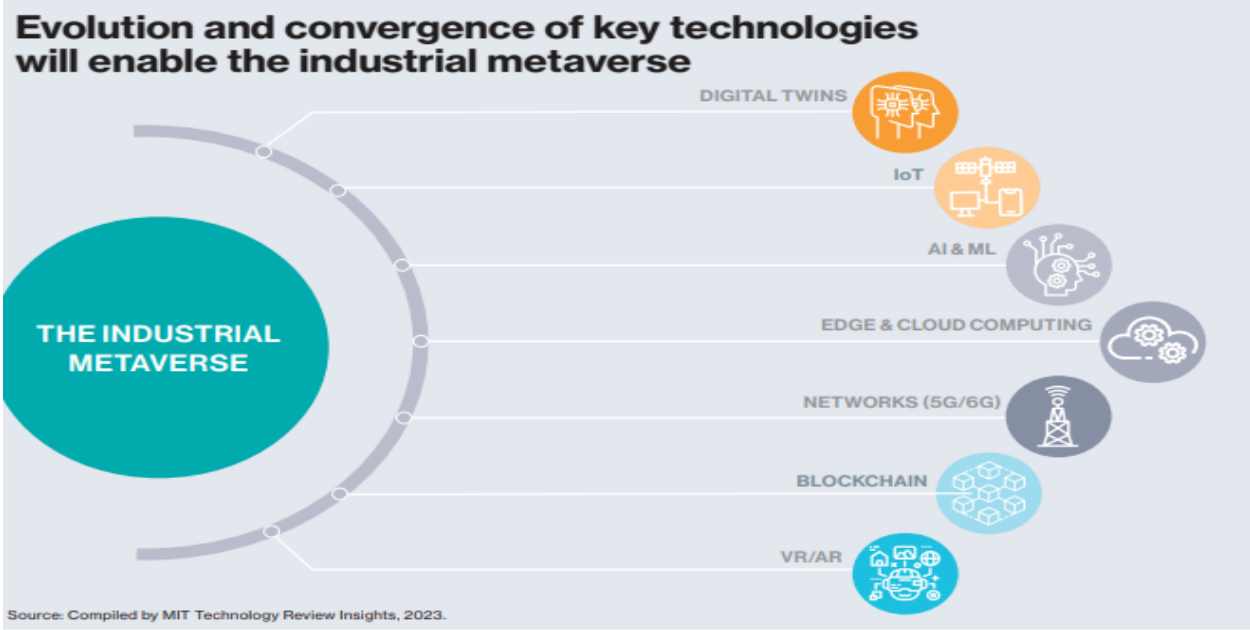
Multinational technology companies are investing billions in creating this capability, which promises to improve speed, scale, innovation, and cost at levels only imaginable.[27]

Toyota TILT Lab: Digital Innovation Disrupts and Improves Traditional Methods

The shift towards digitalization in the manufacturing engineering world provides new opportunities to improve processes and to produce better products -- innovative solutions disrupt and improve traditional methods. To reduce the high cost and long lead times of physical prototypes, Toyota created the TILT Lab -- a place where team members are encouraged to 'tilt' their conventional thinking on its axis and to help them see concepts through to prototypes.[28]

The TILT Lab is a restriction-free sandbox allowing any idea, utilizing any software and/or technology to quickly flow through its Proof-of-Concept process, increasing team members' skills and innovation with the overarching idea that digitalization helps achieve sustainability.

Graphic 3: Industrial Metaverse and Technological Convergence[29]



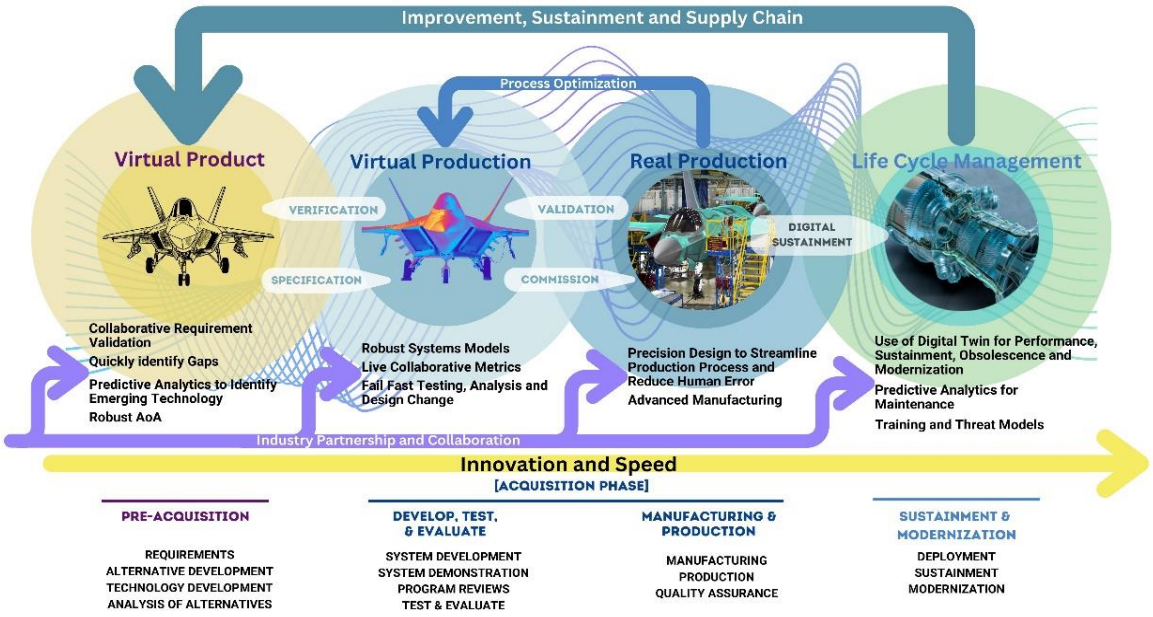
These advancements have not only transformed traditional manufacturing methods, but have also paved the way for more agile, efficient, scalable, and innovative production. However, challenges persist in adopting and fully harnessing the potential of digital manufacturing. These include concerns about data security, the need for upskilling the workforce to operate new technologies, and the initial investment required for implementation. These same concerns exist in the development and realization of a digital ecosystem.

Digitalized DoD Lifecycle

In 2023, the Air Force Materiel Command, under the command of General Duke Z. Richardson, adopted the Digital Materiel Management[30] concept to provide a common alignment of lifecycle activities, functions, and practices. The common threads uniting the digital ecosystem are models, data, and infrastructure serving to integrate program management, contracting, engineering, logistics, financial management, and test and evaluation.

As the largest complex organization in the world, this is particularly problematic for the Department and the Services, given the institutionalized processes and practices surrounding funding, contracting, program management, engineering, testing, and sustainment that have been in place for decades. As Gartner researchers discovered, "Despite the hype about digital transformation, it is rare for a traditional enterprise to fully transform. Wholesale attempts to do so often fail."[31] In fact, McKinsey found, "Seventy percent of complex, large-scale change programs do not reach their stated goals. Common pitfalls include a lack of employee engagement, inadequate management support, poor or nonexistent cross-functional collaboration, and a lack of accountability."[32] One senior leader commented, "There are very few industries that have succeeded in digital transformation. It's hard for everyone. The fact that DoD struggles does not indicate that it is not doing its job."

Graphic 4: Four Major Phases of Acquisition in Digitalized Product Lifecycle



Continuity between digitalized design and process threads provides DoD the capacity for continuous improvement, enables faster response to warfighter needs, and can maximize operational availability. A fully digitalized product lifecycle is realized throughout the four major phases of acquisition:

1. *pre-acquisition phase* -- digital models are used to rapidly develop innovative alternatives for warfighter capabilities and prepare for solicitation;
2. *develop, test, and evaluate phase* -- designs are fully modeled and optimized virtually before prototype testing;
3. *manufacturing and production phase* -- digital design data is used to streamline processes, take advantage of advanced manufacturing techniques, and reduce human error; and
4. *sustainment and modernization phase* -- capabilities utilize product lifecycle management systems for maintenance support, monitoring critical supply chains, and providing continuous operational feedback.

Air Force LGM-35A Sentinel: Virtual Models Modernizing Real Weapons Systems

The Sentinel program was an early adopter of digitalization. From the beginning, the concern was that investment in generating a digital twin would incur costs and thereby introduce risk. However, the program realized the benefits of collaborative virtual design iteration made it possible to predict how changes could impact cost and enable decision-making earlier in the acquisition process… thereby reducing research and development risk.[33]

Best Practices

Throughout its review, the Subcommittee was impressed by the professionalism and initiative of the Services and of the Department leadership interviewed to recognize challenges and to foster ways to improve innovation and modernization of the Defense forces. Many of these Department initiatives have adopted digitalization best practices from industry.

Today, digital technologies have revolutionized private-sector manufacturing and maintenance across multiple sectors of the economy. From requirements development, design, prototyping, and testing to acquisition, supply chain management, manufacturing, logistics, and long-term life-cycle management, digitalization has improved quality, speed, scalability, and end-user affordability. The adoption and integration of digital technologies into every phase of an organization's operations and throughout the product lifecycle has streamlined operations and driven "persistent innovation" to protect a company's market position and prevent competitive disruption. In recent years, there have been exceptional advances in industries ranging from aviation, space, and defense to automotive, energy, and consumer goods. According to Gartner, a US management consultancy, 91% of businesses are engaged in some form of digitalization.[34]

> ***87% of senior leaders say digitalization is a priority; moreover, 89% already adopted a digital-first business strategy or are planning to do so.***
>
> *~ Gartner*

This is not merely turning analog processes into digital (i.e., making paper drawings into digital artifacts), rather it is the breaking down of organizational, process, and production silos using an open digital ecosystem and access to a common set of data. Implementing such a complex, end-to-end, digital ecosystem is not a quick implementation for industry. Many have found that a rapid and/or piecemeal approach to this transformation will likely result in an expensive failure.

Recognizing this complexity, DoD leaders and industry partners have conducted tightly focused pilots across several DoD programs (supporting both new and legacy systems) by implementing digital best practices in their strategy, technology, production, and sustainment operations. For example, the following:

- The **Shipyard Infrastructure Optimization Program** in which the Navy is using state-of-the-art digital modeling, simulation, and collaboration tools with an industry partner, Siemens, to create the largest digital twin of an industrial facility in history. This once-in-a-century investment is using these tools to help modernize and optimize the four aging naval shipyards into new modern facilities that will serve our nation for decades. It will drive the ability to rapidly simulate multiple real-world scenarios for ship maintenance, overhauls, and battle damage repairs leading to exceptional efficiency and readiness gains; thus, returning ships to the fleet faster than ever before.[35]

- The **B-21 Raider** in which the US Air Force and its industry partner, Northrup Grumman, developed and built the nation's next long-range strategic bomber digitally from the very beginning of the program. Together, the Service and Northrup simulated thousands of designs for the aircraft before selecting the prototype and production model. The all-digital open architecture will not only make the production faster and more scalable, but it will also make the aircraft more adaptable and sustainable as the Original Equipment Manufacturer (OEM) and the Air Force innovate together to meet both emerging threats and logistical requirements.[36] [37]

- The US Army's **XM30 Combat Vehicle Program**, in which two OEM teams, General Dynamics Land Systems and American Rheinmetall Vehicles, are replacing the aged M2 Bradley Infantry Fighting Vehicle (IFV), using a "born digital approach." The Bradley program began in 1963, but the first systems were not fielded until 1981. The Army's leadership recognizes that today's threat environment cannot sustain such long development and initial production timelines. Accordingly, the Army is requiring the prototyping OEM teams use an integrated digital environment to enable accelerated development, selection, acquisition, production, fielding, and sustainment of the XM30.[38] [39]

Moreover, the Subcommittee commends the US Air Force for its Digital Acceleration Task Force, which along with the US Army and industry partners, seeks to create the initial framework of a Digital Materiel Management ecosystem. This nascent effort seeks to accelerate the delivery of capability to the warfighter by transforming disparate programmatic lifecycle activities into the seamless and efficient connectivity of data and models, coupled with secure access to this information throughout the full lifecycle of the system. In other words, it is seeking to create "digital threads" across multiple domains and missions.

IV. Findings & Observations

Governance & Organization

Finding I: DoD Requires Centralized Authority to Advance Digitalization

DoD requires a centralized authority to compel, oversee, and finance the Services to consolidate or participate in the advancement of comprehensive digitalization.

Observations:

Acquisition leaders are not incentivized to adopt long-term transformation efforts, nor to promote continuity of these efforts through multiple changes in organizational leadership. The typical tenure of a program manager (PM) is approximately three years, regardless of the complexity of the system being acquired. The pressure to demonstrate accomplishments is all too often focused on the completion of a discrete program objective (e.g., a milestone, key test, or review), or a short-term change initiative. Further, leaders are hesitant to take on broad initiatives that would have to be transitioned to an incoming leader. Several of the Subcommittee interviewees concurred that digitalization efforts do not provide quantifiable, measurable metrics of success until minimum viable products are achieved, or capability maturity levels are attained, which often require more than a three-year leadership assignment. Without buy-in from the incumbent or a clear incentive, broad initiatives are either stalled or abandoned based on varying priorities and competing demands of the program.

Department and Service leaders do not have a common vision for digitalization and are inconsistent in how they communicate up, down, and horizontally. Although there are efforts in progress across DoD to embrace digitalization and the larger digital transformation, most of these efforts are stovepiped to a specific midlife upgrade, new program, or new service. The US Air Force has demonstrated the most cohesive and structured effort to date through the Digital Transformation Office, Digital Acceleration Task Force, and with the overt support of executive leadership. To a lesser extent, the Army, Navy, and OSD are all also contributing to the digitalization of the defense ecosystem but none, including the Air Force, have the authority or resources to guide these efforts into an integrated, compatible, or interoperable environment. Since the release of the 2018 DoD Digital Engineering Strategy and subsequent 2020 Navy and USAF Strategies, (the Army strategy has not been released at the time of this study), there has not been a consistent enterprise-wide effort to create a comprehensive Defense Digital Ecosystem. The current level of effort consists of voluntary participation in communities of interest and digital practice forums, self-funded digital tools and environments limited to a specific program, and a wide array of definitions and terminology between Industry, the Services, and the so-called “Fourth Estate.”

The Department does not have a centralized authority, empowered with resources, to adroitly enable digital initiatives in a cohesive and coordinated process. Transitioning to a digital ecosystem for development, procurement, acquisition, and sustainment of military systems will require a shift in business operations and cultural practices within the Department, the Services, and the defense industrial base. Consistent themes were noted from interviews that questioned, “What unity of effort is underway and who is leading this mission to create a digital ecosystem within DoD? What happens if we do not move forward with data standards to facilitate an interoperable digital ecosystem for the Joint Force and DoD as an enterprise-wide strategy?” Changing DoD’s prevailing risk-averse culture and inefficient business processes is essential for the success of any enterprise-level digital initiative; and, the only way to make such critical changes across large disparate organizations is a top-down, empowered central authority focused on this transformation. In a previous DBB Study, *Improving the Business Operations Culture of*

DoD, the Board noted the need for a high-level appointee to report directly to the Deputy Secretary of Defense to focus solely on business transformation, with authority to institute enterprise-wide reform across the Services.[40]

Planning & IT Infrastructure

Finding II: DoD's Lack of an Integrated Digital Ecosystem Creates Inefficiencies

The lack of an integrated digital ecosystem, coordinated between the Department and Industry partners, creates critical inefficiencies leading to lengthened and misaligned design cycles, excessive procurement timelines, and a lack of insight into critical indicators of reliability, supply chain interruptions, and mission support.

Observations:

The Department has institutionalized and relies upon, outdated data-exchange practices to communicate both internally and with contractors, thereby further driving risk to meeting requirements, cost, and schedule. Although many, varied tools exist to execute a digital transformation in private and public sectors alike, they are yet to be used consistently or in a coordinated manner. The continued dependency on legacy, paper-based processes, also known as analog methods, to manage data, in both industry and government, significantly suboptimizes digitalization initiatives. The Subcommittee observed a clear absence of an electronic digital ecosystem between DoD and partners, including vendors, suppliers, customers, the defense industrial base, and supporting organizations.

Volvo CE: Digital Thread Rallies Legacy Systems

Volvo Construction Equipment (CE) is a leading international manufacturer of premium construction equipment, supplying products and services to more than 180 countries around the world. Like DoD, in-house legacy systems and processes had become more costly and complex with an IT landscape that had become overly cumbersome, resulting in siloed and manual paper-based processes. Increasingly, it became too difficult to manage software and hardware dissimilarities across legacy systems, so Volvo CE digitalized its processes -- providing an authoritative source of information across engineering, operations, supplies, and customers by leveraging open architecture and integration with other enterprise systems -- establishing a digital thread.[41] [42]

The Department does not have a centralized resource for open application program interface standards for use by software vendors for interoperability. The lack of common standards for interfaces and interoperability creates an immediate hindrance to moving forward with establishing a digital environment in which all can collaborate. The lack of real-time electronic interchange leads to lengthened design cycles, creating inefficiency with counterproductive back-and-forth processes. Ultimately, this method of communication runs the risk of delivering products to market that do not meet the original intended purpose.

Not having an end-to-end digital environment, to collaborate with trusted suppliers, negatively impacts time to the warfighter. DoD is not prepared to design, procure, or improve upon critical capabilities at a speed that maintains relevancy and ensures warfighter dominance. Relying on numerous back-and-forth manual email exchanges or paper processes leads to ever-lengthening requirements development, production, and deployment timelines. Infrequent check-ins versus using more agile real-time collaborative systems and processes also hinder results. The Department does not have adequate insight into the tier 2 and tier 3 supplier base to

understand timely indications of supply chain or logistics interruptions impacting operational availability. The lack of a digital environment impacts the reliable delivery and sustainment of critical programs across DoD.

Flex: Digitalizing Saves the Supply Chain[43]

The Coronavirus pandemic shut down the world's manufacturing center in China, disrupting supply chains and underscoring the hazards of a globalized economy. Faraway factories once celebrated for delivering lower costs, now seemed a fatal vulnerability. For Flex, a Singapore-based manufacturer with 100 facilities in 30 countries, the consequences were most acute. Some of its 21 factories in China stayed closed for weeks, and a plunge in trans-Pacific air travel created obstacles for manufacturers to move goods and people.

Flex factories suddenly were either producing too many parts or not producing at all. The crisis peaked when factories faced shortages of 8,000 individual items — roughly five times what Flex dealt with on a typical day. If the shortfalls of electronic components, such as memory chips, connectors, and LCD panels, were not quickly resolved, production would grind to a halt.

In response to the dire situation, production specialists re-created an entire ventilator assembly line in Mexico from copying US images captured on a virtual reality system. Supply chiefs at a California command center tracked the status of 16,000 suppliers and more than one million individual parts using data analytics tools. Near real-time information on every .0005-cent screw to each integrated circuit costing hundreds of dollars was provided in a single cohesive view of the multinational operation. Real-time data enabled Flex to filter its supply chain by specific locations, not just the country of origin, to make rapid, targeted decisions.

Business workflows play a crucial part in any organization to make it possible to scale and maximize growth, communication, product development, and efficiency; process inefficiency is one of the biggest threats companies face.[44]

Process inefficiencies can cost 30% of a company's annual revenue and waste 26% of an employee's workday.
~ Forbes, 2023

The lack of necessary digital tools hampers DoD's ability to:

- collaborate directly with partners; shorten the development cycle for requirements; and ensure requirements are understood across all parties before development begins;
- ensure traceability of the requirement through to testing and qualification;
- utilize the requirements, electronic specifications, and design artifacts for use in long-term sustainment;
- create digital twins to enable more predictive analytics through the product lifecycle; and
- use electronic bills of materials to better distinguish top-to-bottom requirements to sustain programs long-term and model single-source supply risks.

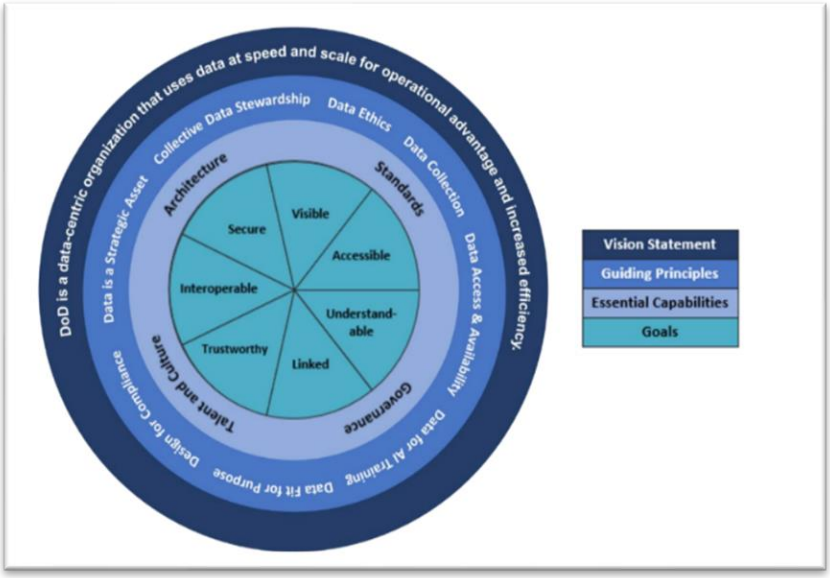
The Department has not kept pace with Industry in the employment of modern digitalized processes and practices, which has resulted in protracted acquisition timelines. As new digitized tools, technologies, and processes have been introduced into an end-to-end lifecycle from design through sustainment, DoD has not kept pace with Industry. Previous DBB Studies, four listed in Finding VI, have continued to highlight the impact on DoD's culture and workforce from a lack of investment in technology modernization,[45] business operations innovations,[46] and workforce development and training.[47] [48] Public and private senior executives interviewed noted talent is concerned about job security, training, transferring knowledge, collaborating, and program control; while the Department as a whole breeds risk aversion.

Finding III: DoD Lacks Digital Taxonomy for an Interoperable Digital Strategy

The lack of a consistent digital taxonomy makes it difficult to effectively develop, communicate, and execute an interoperable digital strategy.

Observations:

Graphic 5: 2020 DoD Data Strategy Framework[49]



In the 2020 DoD Data Strategy, the Department recognized data as a 'strategic asset,' stating "data in DoD is a high-interest commodity and must be leveraged in a way that brings both immediate and lasting military advantage. As DoD shifts to managing its data as a critical part of its overall mission, it gains distinct, strategic advantages over competitors and adversaries alike."[50] The Data Strategy Framework included standards as an essential capability, noting, "… Given the diversity of DoD systems, these standards should be applied at the earliest practical point in the data lifecycle, and industry standards for an open data architecture should be used wherever practical."[51]

A lack of common taxonomy has stalled the development of cohesive department-wide strategies and standards for data interface requirements and tool integration. No enterprise-wide taxonomy has been defined or adopted and there are a wide variety of definitions for digitalization, digital transformation, digital engineering, and cloud communications. There are examples of progress toward developing common standards, but they appear to be disconnected and isolated. The Air Force is making great strides through its Integrated Digital Environment (IDE), which consists of a collection of data, models, and tools for collaboration, analysis, and visual representation of work activities. This includes guidance for the use of the data, models, and tools in conjunction with processes and procedures to ensure results.[52] Another positive example is the Department of Navy's (DON) effort to prioritize the development of glossaries, terminologies, and Model-based Systems Engineering (MBSE) schemas. As a senior government official noted, "Vernaculars (for technical language and glossaries) are key to building coordinated capabilities and communicating interfaces." For the Department to be successful in building cohesive data threads, these efforts and others must be properly aligned.

The Department and the Services do not have a common understanding of what is meant by "digital transformation" and other key enabling terms, each promulgating its own definitions. However, because DoD has failed to define data standards across the Department, including the most fundamental definition of what is meant by "digital transformation," the lack of consistency in taxonomy affects the Department's ability to transform the entire digital lifecycle / ecosystem. While there are positive examples of both digitizing (i.e., converting an item / element to electronic form) and digitalization (the use of connected data to drive outcomes), digital transformation has different meanings in different communities and Components; there is no standard to guide the various pilots. As such, the varied tools that exist to execute a digital transformation are rarely used in a consistent and coordinated manner.

For example, “digital engineering” and “digital transformation” are interchanged in their applications at the beginning of the lifecycle: pre-acquisition, development, testing, and evaluation. Others use the same terms generically to refer to the application of digital technology at any phase including sustainment. DoD needs to provide clarity such that appropriate focus is placed across the full lifecycle. Inconsistent taxonomy also adversely affects the Department’s ability to develop common interface requirements and standards to guide enterprise tool compatibility and integration. One interviewee noted, “Interoperability is far too complex, and engineering models must be sustainable.”

Finding IV: DoD’s Ability to Best Utilize Data is Constrained

DoD has access to massive amounts of data; however, its ability to capture, analyze, and apply insights is far too limited and is often constrained by possessive information practices and insufficient experience.

Observations:

The Department and the Services do not have standards to recognize the full extent of their data nor have adequate means to store and share data. In 2021, DoD deployed ADVANA as its data platform for advanced analytics. Although it is a great start, its adoption has been slow. In 2022, the Department established the Chief Digital and Artificial Intelligence Office (CDAO), responsible for accelerating DoD's adoption of data, analytics, and AI, to better enable decision advantage from the boardroom to the battlefield.[53] The deployment of ADVANA and the creation of the CDAO position are positive signs DoD is committed to using its data assets. Ultimately, a lack of data standards and definitions hinders the ability to realize the full potential of data; common standards are required to enable integration, analytics, and data-driven decisions.

> ***“Digitalization makes all the difference in capability to operate at the scope and scale and degree of global integration over distances.”***
> *~ senior government official*

The Department and the Services have not invested in enabling a secure and federated data management strategy to capitalize on data assets that support cross-cutting data-driven decisions. As noted in the Acquisition with Digital Engineering paper “…, the vision in DoD Data Strategy (conceived separately from Digital Engineering) of “a data-centric organization that uses data at speed and scale for operational advantage and increased efficiency”[54] is not yet sufficiently captured into engineering or acquisition and sustainment policy and guidance. Program offices need additional guidance in various areas to effectively define workflow and enable data-supported decisions within the engineering, acquisition, and sustainment activities.”[55]

An area of grave concern is that the lack of intellectual property / data rights to technical data has adversely affected the Department’s access to and use of strategic data. When intellectual property (IP) / data rights are not secured during initial contracting, obtaining such rights afterward becomes nearly impossible or prohibitively expensive. It is also worth noting that ignoring securing data up-front has an unrecognized impact on sustainability, which is the most expensive phase of a platform or capability. The Subcommittee repeatedly heard, “Sustainment OM&N (Operations, Sustainability, and Maintenance) is the largest cost of the lifecycle of any system, and retrofitting a system is difficult.” A focused effort on obtaining the “correct” data up-front is needed, and data needs to be actionable. The lifecycle thread and securing critical data depends on contractors at the Acquisition phase, including design engineers as well as manufacturing and sustainment engineers. A senior DoD official noted, “We don’t get the data we need because we don’t know what to ask for in the contracting phase.”

BASF Digital Transformation Safeguards Chemical Company's Sustainability

BASF digitally transformed to ensure longevity and sustainability in uncertain and unpredictable environments, such as political turmoil, climate impacts, and energy market disruptions. BASF's digital transformation was the foundation for its virtual plant, ensuring the flow of real-time data over the entire lifecycle of facilities and production processes. The first step was to integrate data and interconnect existing software tools with a well-established process control system, plant engineering tools, and simulation software -- creating a virtual operation and a universal flow of data across BASF's facilities. The second step was to merge data with a digital simulation, creating a real-time virtual plant, or digital twin, to test ideas. Digital process twin technology uses state-of-the-art mathematical techniques to analyze and optimize process design and operation, reduces development time, and enables design and test processes virtually before using valuable raw materials in a real production plant.[56]

Data owners do not have an incentive to share, interconnect, or curate their data, nor do they trust the Department to use it properly. Where data exists within the Department, it is not connected / integrated, and there is no incentive for data sharing or interoperability. It is constrained by legacy stovepiped security and IT infrastructure and, therefore, is difficult to utilize effectively or at all. Data should be treated as a strategic asset -- shared, connected, and integrated across the Services and Agencies to maximize decision-making for business operations and warfighting alike. Lastly, the ability to move up and down classification levels or across programs does not exist. The lack of movement makes it extremely hard to move end-to-end visibility to a program, platform, or theater. In summary, DoD has the desire to use data as a strategic asset, but the Department lacks the taxonomy, standards, integration, and sometimes IP rights to execute its vision.

Cultural Environment

Finding V: DoD Culture is Risk Averse & Resistant to Change

DoD Culture is programmatically risk-averse and resistant to transformational change, especially without leadership or resourced support.

Observations:

The Department must overcome a cultural and institutionalized paradigm in which personnel at all levels are unduly burdened to account for failures rather than encouraged to take contemplated risks potentially leading to rapid innovation. A risk-averse culture is understandable, given DoD's accountability for taxpayer dollars and the criticality of its mission. However, accountability often results in public admonishment for any perceived or actual failure, resulting in a DoD culture that stifles innovation, initiative, and a forward-leaning risk posture.

A tendency to acquiesce to the "Frozen Middle" is obstructing progress toward the adoption of digital tools and technologies. The term 'frozen middle' is used when an organization becomes 'stuck in its ways' at the middle management levels. In DoD, the 'frozen middle' is the personnel layers that delay or avoid change to remove risk from the process, thereby preventing substantial progress as a result. Bureaucratic processes and turf battles in middle management consistently contribute to strangling innovative ideas.[57] In several Subcommittee interviews, it was opined, that the 'frozen middle' amplifies a

> ***"Industry is outpacing the Department; DoD is slow and risk averse, resulting in obsolescence issues."***
> *~ senior Industry executive*

risk-averse culture that the Pentagon desperately needs to shed. Without "thawing" this mid-tier leadership group by enabling them to take prudent risks, the Department will not be able to achieve more innovation and modernization. Simply put, the current system, is postured to appease mediocrity rather than challenging leaders and rewarding bold initiatives despite the Department's commitment to the contrary.

Department personnel are not incentivized to adapt their skills, processes, or practices to successfully perform and participate in an ever-evolving, state-of-the-art digital ecosystem. Many senior executives expressed this concern. Coupled with DoD's organizational inertia, this lack of incentive threatens the Department's ability to rapidly respond to China's ever-developing and growing threat. DoD continues to fall behind in adopting new technologies and tools for an agile and advanced digital workforce, which stifles the speed, scale, and adoption of new warfighter capabilities. Senior officials noted that because program managers are not incentivized, they often choose to reduce short-term risk and cost by *not* introducing new digital tools or processes into programs, using the established path of least resistance.

Risk 'Failing Forward' Incentivizes Innovation

During the 2018 Air Warfare Symposium, Air Force Chief Master Sergeant Kaleth Wright addressed the need to eliminate the frozen middle -- to free airmen to innovate, to incentivize innovation and free-thinking, and to encourage suggesting new ideas to change the culture from risk averse. Being innovative involves help from leadership to get to yes.
"We have so many bright airmen in our ranks waiting to provide ideas and innovative concepts… also waiting to be disruptive. Here is the problem, this is representative of what we call the frozen middle. The boss likes to say there is a long line of airmen waiting to tell us how to do things better, but there is even a longer line waiting to tell them no. This is one of the most pressing challenges we have to innovation; some of it is steeped in tradition while some of it is steeped in our culture, but we must figure out a way to get past this frozen middle. We must be comfortable with taking risk…. Comfortable with failing forward."[58]

Talent & Training

Finding VI: DoD Workforce is Not Adequately Prepared for a Digital Ecosystem

DoD workforce is not adequately prepared to transition to a digital ecosystem and is faced with a significant gap between experienced workforce professionals and technically skilled "digital doers."

Observations:

The Department currently lacks the full scope and depth of workforce skills to enable an accelerated transition to a digital ecosystem. There is an abject need to significantly upskill workforce capabilities beyond traditional engineering, acquisition and logistics competencies; critical skill development is key to the talent strategy needed to accomplish an effective digital workforce. Past DBB Studies indicate DoD is well aware of the critical need to identify, recruit, and retain digital doers and the challenges it faces in competing with private Industry.[59] [60] Finding qualified technology talent for developing a digital ecosystem is also difficult for Industry, making the Department's lag even more disconcerting.

A Hamstrung Workforce

"DoD Acquisition workforce is subject to a bureaucratic culture of excessive compliance and oversight, a challenging environment for innovation. Creative problem-solving and measured risk-taking are not often rewarded, and too few individuals with an Industry background agree to take senior leadership roles at DoD."

~ Atlantic Council; Scowcroft Center for Strategy and Security

Change from within is hard but necessary to evolve, innovate, modernize, and keep pace with competitors in any arena. DoD is no different, especially given it is one of the largest organizations in the world, with 3.4 million Service members & civilians on 4,800 sites in more than 160 countries,[61] and given the wave of retirement eligibility is nearing 30% of the federal workforce in 2024.[62] Although transferring knowledge and experiences within DoD is challenging, it is essential. Interviews with defense officials expressed optimism and confidence that DoD leadership understands that it needs to provide the necessary resources, develop specialized talent, and implement management processes to effectively reskill its existing workforce. A seasoned leader, with a strong background in product development and traditional engineering, shared an anecdotal best practice used in his current organization. In that unit, an engineer savvy in digital technology is paired with a seasoned procurement analyst with a history of DoD best practices. Together, the partnership mutually transfers knowledge and covers essential skills, from technology to software development, hardware requirements, data analytics, internal processes, procurement practices, and more during the lifecycle.

Talent management and procurement capabilities need to work in tandem to best support real-time decision-making, which is necessary for cross-functional digital operations to effectively accelerate the procurement process. The skills challenge within DoD is too often viewed through a limited lens, i.e., "digital doers" include more than digital engineering, software development, and cyber security experts. Digital skills for procurement personnel are essential to turn digital strategies into effective contracting actions and long-term, affordable, sustainment programs. The same is true for military and civilian personnel across the functional spectrum, including but not limited to supply chain management and logistics. Unfortunately, to date, none of the Services' digital strategies have fully addressed this crucial component of the digital ecosystem lifecycle, even though execution is highly dependent on the capabilities of the procurement workforce.

Keeping Pace in the Great Power Competition: *In 2022, China's defense spending increased by 7.1% – the fastest pace since 2019. In addition, President Xi publicly emphasized securing tech and high-quality talent as high-priority steps to modernize China's military during the next five years. To ensure these efforts succeed, Chinese leadership has developed a "multi-pronged strategy for growing its science and technology talent pool." Industry experts are already taking notice, projecting that by 2030, China will be firmly ahead of the U.S. in AI.*

~ Harvard Business Review

Recruiting new talent is vital and will continue to be a challenge in a highly competitive marketplace for a tech-savvy workforce. It is widely recognized the Department and Industry are in competition with each other to attract and retain employees with specialized technical skills and experience, and both are in competition with the broader marketplace for talent as well. Unfortunately, DoD does not have a clear

Gap in Pay: *A 2022 review found federal salaries lag corporate counterparts by 22.47% on average. The Federal Employees Pay Comparability Act of 1990 sought to eliminate the gap by authorizing the full pay raise necessary to reduce the delta down to 5%. However, since 1994, no Administration has fully adopted the pay adjustment the law allows. This upward adjustment would come at a current cost of $19.2 billion.*

~ The Washington Post

pathway to acquire the talent it needs in this domain. This is a continued theme throughout DBB Studies, including:

- Improving the Business Operations Culture of the Department of Defense, FY2024;
- Building a Civilian Talent Pipeline, FY2023;
- Recommendations to Improve IT User Experience Within DoD, FY2023; and
- Strengthening Defense Department Civilian Talent Management, FY2022.

> ***"The digital engineering workforce does not exist within DoD to implement fully, from Requirements through Sustainment."***
> *~ senior government official*

Civilian and military job classifications, career paths, and recruitment have not kept pace with the emergence of niche technical disciplines and specializations. This concern was repeatedly emphasized in the Subcommittee's interviews with both private and public executives. A common theme was DoD has atrophied technical talent, including advanced engineering skills over the last several decades, in part due to intentional outsourcing, coupled with the use of "total systems performance-type contracts." One senior government official noted, DoD has not developed technical career paths nor clear definitions of the knowledge, skills, and abilities for various specialty fields necessary to support defense acquisitions that are model-based and data-centric outside of the research organizations. He continued, "If legacy civilians are not able to work with digital, they will not be ready to work on new systems…. This is one reason it takes so long to field systems and why the results are not very good but accepted anyway; fixing issues later in the process, that could and should be fixed much earlier, costs time and money."

Moreover, without career pathways that provide clear considerations for advancement and leadership opportunities, it is even more difficult to attract or retain qualified talent. Several senior military officials expressed concern there is not yet, within any Service, a clearly defined and promotable "digital military operational specialties" (d-MOSs). As a result, they sometimes face reluctance from active-duty personnel assigned to digital missions who are concerned the assignment will negatively impact career paths and promotability.

> ***"The digitalization workforce needs to know contracting, technical programming, and engineering; they need to work together to interface from the very beginning and throughout the lifecycle."***
> *~ senior government official*

Defense organizations are developing digital training and education opportunities but lack the ability to ensure the training is utilized and applied as broadly as needed. The Defense Acquisition University (DAU) and other Service-level educational institutions have begun to implement and offer new courseware focused on building the key skills associated with doing business in an increasingly digital marketplace. DAU cannot be expected to change the workforce trajectory on its own. One Air Force senior leader stated, "Younger talent is hungry to learn and use digital in their everyday work, but the tools are not ready." It was noted that when training was provided to build the needed skills, talent relied on a particular software or tool; however, the educational investment was lost when the student returned to their workplace and realized they did not have the tools necessary to effectively apply their new knowledge.

Other training and certification requirements still dominate the school's curricula. The Department adopted the "Back-to-Basics" program to educate engineering and technical management personnel in acquisition-coded positions, and DAU is in the process of offering courses to address digital engineering. Additional educational resources have been made available to the workforce, including the "Digital University," subscriptions to commercial learning programs, and establishing

community of practice knowledge repositories. Yet, while acquisition personnel are required to maintain their existing proficiencies and achieve a minimum of 80 continuous learning points every two years, the continuing education each individual pursues is almost entirely elective and sometimes hard to acquire. The effort to develop "digital skills" typically requires a much larger and more intentional investment from both the learner and the employer than the minimum currently required and the current resources available.

Funding & Resourcing

Finding VII: PPBE Process Obstructs Ability to Fund Foundational Initiatives

The Program Planning Budgeting and Execution (PPBE) process obstructs the ability for the Department and the Services to fund foundational digital transformation initiatives.

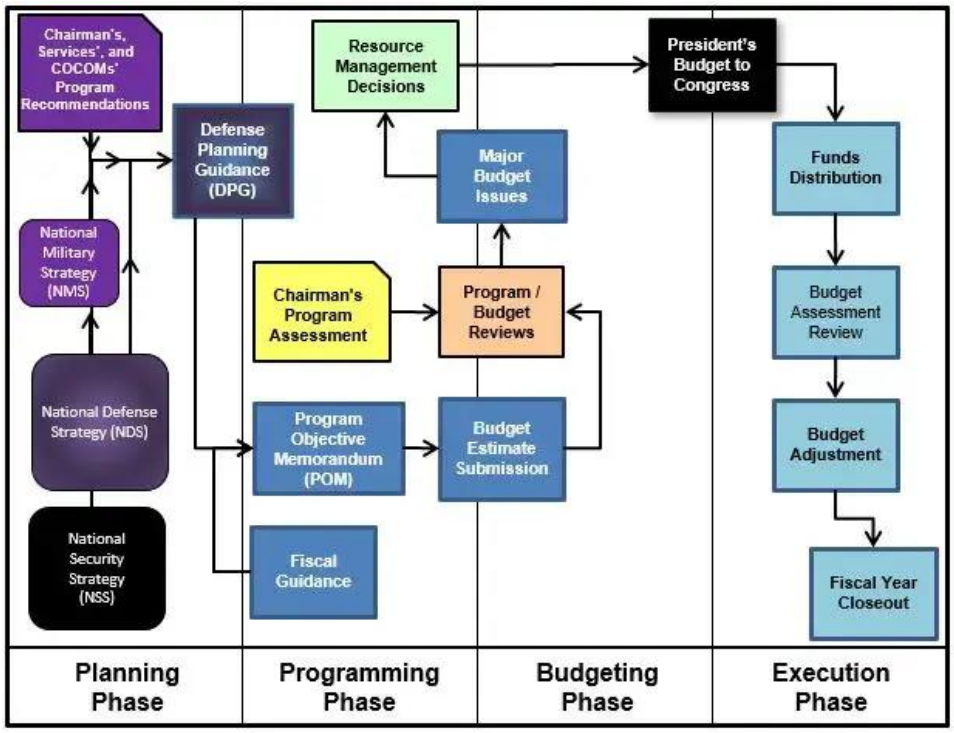
Observations:

DoD budget process is siloed and does not support cross-cutting, end-to-end, horizontal requirements and lacks the ability to rapidly adjust to implement digital capabilities. It is well known that Federal budgeting and acquisition authorities drive the Department to operate in distinct silos (often based on the restrictions associated with the so-called "color of money" funding a particular activity). This results in the Services and Agencies having the ability to meet immediate, annual requirements and to focus on design and development processes of systems; but it stymies adequate consideration of long-term sustainment, integration, and full-rate production needs. For example, supply chain requirements for parts obsolescence are not considered early enough in the budgeting and acquisition phase of the lifecycle.

Near-peer adversaries are developing the ability to bring innovative, disruptive capabilities to the battlefield with incredible speed. Once this capability is manifested into a threat, it will take enormous effort and time for DoD to overcome a pacing threat's momentum for change.

Business cases that show return on investment for infrastructure and sustainment are difficult to build and are often only able to show cost avoidance. There exists a dichotomy within the Department in which the development of a digital ecosystem is recognized as one of the highest priorities, and yet large-scale efforts continue to be unfunded year after year. Budget requests for digital investments are typically based on cost avoidance justifications and are difficult to uphold in program budget reviews, favoring cost savings, military hardware acquisition, and operational availability. The benefits and Return on Investment (ROI) of implementing a digital capability within the acquisition product lifecycle are typically not recognizable within the first two to three years or, in some cases, well into sustainment. Each year, the PPBE process relies on the Program Objective Memorandum (POM) to communicate a statement of need in the programming phase, but it is limited in ROI foresight to be within the five-year Fiscal Year Defense Program (FYDP) cycle.

Graphic 6: SecDef PPBE Process[63]



Investments in digital capabilities are typically on a program-by-program basis, often only affordable by new, well-funded programs, and ignore sustainment and legacy systems. These well-funded programs are unable to support efforts involving an investment in cross-cutting capabilities that include multiple programs or functional areas, and the proposed efforts do not survive the review process. This makes the scaling of successful pilot programs into a shared, centralized capability next to impossible. One official commented, "The PPBE process promotes a tendency to purchase "stuff" and not interfaces." Ultimately, the rationale for investing in these capabilities is inherently non-corporeal and is meant to address an intangible threat from a future adversary. The PPBE process does not support rapid horizontal-change requirements that are, for example, cross-cutting between OSD (R&E) and OSD (A&S) for end-to-end lifecycle capability investments.

> ***"Program-centric Acquisition Defining requirements, securing budgets, and acquiring capabilities are done for hundreds of individual programs. DoD invests a significant percentage of its funds in complex major systems for which prime contractors offer closed, propriety solutions. This impedes interoperability and responsiveness to changes in operations, threats, and technologies. Open-system architectures with well-defined interface control documents are rarely adopted, constraining the ability to insert innovative technology."***
>
> ~ Atlantic Council; Scowcroft Center for Strategy and Security

While "digitization" and "digital transformation" are stated as top goals of DoD's leadership, current funding streams, policies, and prioritization do not adequately support that primacy. Investment in digital capabilities is typically on a program-by-program basis and, often, only those that are well-funded can afford them.

Intellectual Property

Finding VIII: IP & Technical Data Rights Remain a Critical Concern

Ongoing debates over intellectual property and technical data rights represent significant barriers to the creation of an effective, efficient digital ecosystem.

Observations:

Conflicts over the ownership and sharing of IP are a key barrier to the establishment of an integrated digital strategy. As has been true with several government reforms, policies, and practices, defining the ownership and sharing of intellectual property is among the most critical factors in enabling broad reform; opening the door to innovation; and expanding the Department's access to the full scope of capabilities available in the marketplace. While this Study is not intended to "solve" longstanding debates over IP concerns, a broad consensus on several key points emerged from both within the Department and across the private sector, which included concerns over security, long-term costs, and a degree of mutual distrust.

The government's lack of forward IP planning often leads to significant cost increases and spares delays. Because the government frequently does not consider lifecycle IP and technical data needs in its program planning and development, the issue too often arises in times of crisis (e.g., supply chain disruptions) or changed market conditions (parts obsolescence). The failure to address these issues at the front end of the process can lead to vendor lock and difficult, often protracted, negotiations over what is, or is not, "proprietary." This leads to significant delays in parts availability and substantial unplanned costs. The responsibility for negotiating IP contract clauses typically falls to the contracting officer, who may or may not have adequate visibility into actual program needs and associated dynamics. Consequentially, many legacy programs are in favor of digitalization but find themselves in a position where obtaining technical data is cost-prohibitive. It was apparent IP and data reform are being considered for new programs, but a holistic approach is needed, particularly for legacy capabilities requiring support for more prolonged periods of time.

In a digital environment, IP can and should far more frequently center on performance and interface standards. Within the current DoD data rights provisions is authority for DoD to obtain IP that does not threaten a company's core IP but is, instead, focused on minimal access to data and then for only limited purposes, such as required for operations, maintenance, installation, and training (OMIT). In a digital environment, OMIT could well play an increasingly crucial role, particularly as digital models focus more on interfaces and performance rather than detailed manufacturing or process specifics. While not a solution to broader, complex IP and technical data rights issues, these provisions do open the door to a more robust ability to pursue and access alternative solutions when circumstances warrant.

V. Summary of Recommendations

Digital Ecosystem Governance & Organization

The Department of Defense is the largest employer in the United States, with over 180,000 employees in acquisition-coded positions and on the frontlines of developing digital ecosystems within the Department and the Services. Large, interoperable networks of distributed data, systems, and people require leadership and collaboration to ensure efforts are coordinated and to provide strategic guidance and resources. Today, those functions remain largely siloed and disconnected.

The Subcommittee makes the following recommendations to unify the "digital-doers" and capitalize on their great work.

1. **Assign the Deputy's Management Action Group (DMAG), or similarly scoped body** with like charter and membership, **as the** central **leadership authority for developing the Defense Digital Ecosystem** across the Services, ensuring compliance with enterprise-wide digital strategies and instructions to defragment current Department efforts. The DMAG, or similarly scoped body, would be responsible for finalizing the Departmental vision, ensuring implementation efforts are all aligned and focused on the stated goals and vision, serving as a champion for resources and other support and incentives. This recommendation for placing responsibility in a senior centralized authority is in line with a recommendation provided in the DBB's November 2023 Study, *Improving the Business Operations Culture of DoD*. In that Study, the DBB recommended the creation of a position to lead a "small office of formally trained and educated strategists, business analysts, data scientists, project managers, change management specialists, and IT transformation managers that focuses solely on business transformation, with authority to institute enterprise-wide reform across the Services and reportable to the Deputy Secretary of Defense." [64]

   Accountability: DMAG, or similarly scoped body, or as assigned
   Time Frame: <3 months

2. **Convene an Executive Action Group (EAG) to remove barriers to change**. Co-chaired by the USD (A&S) and USD (R&E), the EAG would be tasked to lead the execution of a Department-wide digital strategy; coordinate across DoD Components; and identify and remove barriers to implementing an enterprise-wide digital ecosystem. Efforts would include collaboration and coordination with the Services, the DIB, and non-traditional business associations. The EAG will report directly to the DMAG, or similarly scoped body, as its primary Governance Supporting Tier Forum.

   Accountability: Executive Action Group (USD (R&E), USD (A&S), DoD CIO, CDAO)
   Time Frame: 3-6 months

3. **Expand and formalize industry** (both the DIB and non-traditional enterprises) **participation in the development of solutions** to critical policy and other barriers to the creation of the digital ecosystem, including but not limited to, IP policy, standards development, etc.

   Accountability: USD (R&E), USD (A&S)
   Time Frame: 3-6 months

Digital Ecosystem Planning & IT Architecture

Interoperability and automation are key objectives of a digital ecosystem, but they do not come easy; it requires time, effort, and resources to make it happen. The "digital-doers" have been working to coordinate with each other, industry experts, and standards organizations to form communities of interest and to discuss ideas, workarounds, and find solutions using whatever resources they can pull together. The time to grow these efforts and codify them has arrived.

The Subcommittee believes the following recommendations will significantly impact making a Defense Digital Ecosystem a reality.

4. **Develop collaboration platform architecture and roadmap** for all suppliers to use to digitalize requirements management, design & development, testing, production, operations, and sustainment, throughout the lifecycle. Some parts of DoD, like the Air Force Digital Materiel Management initiative, are already progressing in this direction using the Digital Building Codes. We propose adopting similar interoperable platforms to drive cross-industry/DoD collaboration and speed up program cycles to stay competitive. These architectures must address requirements management, design platform(s), a Product Lifecycle Management platform, a digital twin of systems, data analytics and visualization tools and the hosting environment required for interoperability.

   Accountability: Executive Action Group (USD (R&E), USD (A&S), DoD CIO, CDAO)
   Time Frame: 18+ months

5. **Establish a common vision and taxonomy** across the Department, the Services, various Chief offices, the DIB, and non-traditional enterprises. The current decentralized transformation efforts will be accomplished more effectively once a common language, set of guidelines, and best practices are developed to communicate intent, focus areas, technical needs, and areas of responsibility. Refresh the vision annually with new industry tools, processes, and best practices.

   Accountability: Executive Action Group
   Time Frame: 3-6 months

6. **Develop standards for data interface and interoperability within and across the digital ecosystem(s) throughout the Department and the DIB.** Technical interface standards among the "digital-doers" are essential to accelerate change; establishing a baseline for a common digital language, with clear expectations and data requirements, is a critical first step.

   Accountability: Executive Action Group
   Time Frame: 6-12 months

7. **Require all functional stakeholders from and across the product lifecycle (e.g., contracting officer, engineers, designers, logisticians, manufacturers, sustainers, operators, etc.) to participate in the digital ecosystem planning for program design and development.** Understanding and defining the end-state requirements at the beginning of the program will support all stages of the lifecycle; safeguard the acquisition process; and ensure sustainment and performance data are connected via digital threads. Progressive efforts must include expertise from all phases of the Acquisition process to account for interrelated processes, data needs, and information flows.

   Accountability: USD (A&S), Service Acquisition Authority
   Time Frame: 3-6 months

Digital Ecosystem Culture

Organizational culture is largely considered a combination of shared values, attitudes, and expectations that influence the behavior of the workforce. It affects how people experience an organization and helps guide and inform the actions of all team members. Cultural alignment is foundational to any organization, and it falls upon leaders to institute those cultural elements designed to promote success. DoD has developed some of the most effective leaders in the world and has always risen to the challenge when faced with a crisis. Now is the time for leadership to drive cultural change with clear direction and a singular intent.[65]

> ***"[Digital Transformation] feels like you're doing a continuous thing, but it's actually fiercely discrete."***
> *~ Dr. William Roper*

> ***"Organizations that follow a change management strategy are more than 6x likely to meet their digital transformation goals."***
> *~ Mendix.com*

The following Subcommittee recommendations are intended to guide and adjust the workforce culture to accelerate the adoption of a digital ecosystem, empowering fervent talent while dethawing the frozen middle with specific performance incentives, communication, and education.

8. **Establish a deliberate process based on proven change management techniques and principles**, including milestones and tollgates. A DoD formal change management plan must include a focus on driving culture change which is required with large transformational efforts, including a clear vision; leadership; governance; performance metrics and accountability; workforce incentives; and funding.[66]

   Accountability: Executive Action Group
   Time Frame: 3-6 months

9. **Actively address the institutional resistance to risk in the change management plan**. To overcome resistance, the Department's leadership must actively and explicitly incentivize and support program managers and frontline workers who, while pursuing change, are assuming reasonable risk.

   Accountability: DMAG, or similarly scoped body, Executive Action Group, Services
   Time Frame: 3-6 months

10. **Incentivize and reward personnel to adopt digital skills** and to take on digital initiatives, including Department-wide award programs recognizing outstanding performance in the pursuit of innovation and accelerating the digital ecosystem.

    Accountability: USD (P&R)
    Time Frame: 6-12 months

11. **All leaders at all levels must include digital skills objectives in performance evaluations**. Providing a mixture of positive encouragement and valued incentives with clear expectations for advancement will assist in overcoming workforce uncertainty, risk aversion, and inertia. Including digital objectives in yearly performance plans and assessments has proven to have a profound effect in driving adoption, encouraging re-skilling of the workforce, and accelerating transformation across the Department.

    Accountability: USD (P&R)
    Time Frame: 12-18 months

Digital Ecosystem Talent / Training

The digital world requires digital skills. As an Air Force Senior Officer said, "There will always be room for legacy work, but the majority of the workforce will be doing their day-to-day jobs in a digital environment and using new digital skillsets." A variety of unique skills and expertise has always been needed to support the mission of DoD, but using digital tools requires an expansion of that knowledge. Tools, infrastructure, and software systems all mean nothing if the Department does not have the talent to use them.

In consideration of the research, best practices, and incredible work the Department is doing in building digital knowledge and resources, the Subcommittee recommends the following actions be taken to exploit these activities and build a world-class workforce.

12. **Establish distinct digital ecosystem pathways for both military and civilian personnel to include clear opportunities for advancement and leadership**. Civilian personnel career pathways must be associated with a combination of education, training, functional expertise, and practical experience. Within the Services, a clearly defined and promotable ***digital military operational specialties*** (MOS) will enable the recruitment and retention essential to developing the uniformed Services' digital capabilities.

    Accountability: USD (P&R)
    Time Frame: 18+ months

13. **Assign OSD Personnel & Readiness (OSD (P&R)) in collaboration with CDAO to develop a strategy to rapidly recruit highly specialized and in-demand technical disciplines** that support digital modernization initiatives. The strategy shall include a plan to address how best to exploit recruitment incentives, special pay options, and other authorities essential to lessening the gap with the private sector for in-demand jobs.

    Accountability: USD (P&R), CDAO
    Time Frame: 12-18 months

14. **Expand and fund opportunities for critical skills development to close the gap between experienced workforce professionals and technically skilled "digital-doers."** Like Industry, DoD must combine focused education with on-the-job training and foster working collaborations. Invest in and develop the digital ecosystem workforce through multiple opportunities, including upskilling, reskilling, mentorships, internships, workforce development, education, and training.

    Accountability: USD (P&R)
    Time Frame: 6-12 months

Digital Ecosystem Funding

"Going Digital" is not a clear and direct process for any organization. Attempting to learn while finding pathways to success requires flexibility and speed to adapt to an ever-changing landscape. The Services and individual programs have made tremendous progress, despite very limited resources. However, for transformation to scale, discrete, assured funding is essential. Digital transformation fundamentally changes the way large organizations perform their work; the larger the organization, the larger the need for dedicated and agile resources.

The Subcommittee provides the following recommendation as a recognition of the need to accelerate digital transformation as a national defense imperative.

15. **Establish a centralized OSD Managed fund for the Services and programs to effectively compete for resources to support and accelerate enterprise-wide digitalization**. The Department needs to prioritize the establishment of the Defense Digital Ecosystem as a strategic investment. This is the way a large, diverse, private sector enterprise would go about this challenge to enable the implementation of cross-cutting and horizontally integrated digital transformation initiatives. Providing a general fund to resource digital change will assist the rapid scaling of universal capabilities; promote the adoption of digital initiatives throughout the lifecycle; and provide the flexibility to adjust, adapt, and focus needs without the process restrictions of the PPBE.

    Accountability: USD (Comptroller)
    Time Frame: 6-24 months

Digital Ecosystem IP

Creating an interoperable, interconnected, and functioning digital ecosystem built on data requires partnership, clear expectations, and mutual trust. The Department, the Services, and Industry are working diligently to ensure data can be shared, protected, and remain mutually valuable. No issue attracts more concern or attention than the way companies handle their IP and technical data. The Subcommittee recognizes the Department already has several initiatives, through the Under Secretary of Defense Acquisition & Sustainment National Defense Industrial Strategy and the USD (A&S) IP Cadre, exploring options and generating solutions.

The following recommendation is provided to ensure the continued departmental efforts to resolve IP issues affecting the digital ecosystem continue.

16. **Mandate regular progress reports from the Intellectual Property Cadre to the DepSecDef through the DMAG,** or similarly scoped body, highlighting advances in DoD IP developments and outstanding issues with firm timelines for solution development. All efforts to address IP and tech Data rights should include early collaboration with a cross-section of industries and experts from the defense and commercial sectors. Accountability for execution must include clear objectives for all functional elements and metrics to measure effectiveness and impact on cost and operational availability.

    Accountability: USD (A&S)
    Time Frame: <3 months

VI. Measuring Progress in the Digital Ecosystem: Key Performance Indicators (KPIs)

The transition to a digital ecosystem is not merely a vertical shift within the individual Services; it spans the entire Department of Defense. To ensure bold advancements in digital transformation, DoD must adopt a holistic perspective, encompassing all Services and programs. The establishment of a robust digital ecosystem necessitates monitoring and evaluation through well-defined Key Performance Indicators.

Three Steps to Assess Digital Ecosystem Progress

To accelerate the digital ecosystem journey within DoD, a systematic approach is essential. First, **cataloging initiatives** become paramount — each Service and DoD needs to document digital ecosystem projects. By prioritizing the top three to five impactful endeavors, efforts will be channeled more effectively. Second, **tracking progress** ensures transparency and agility. Regular updates allow for course corrections when needed, ensuring alignment with strategic goals. Lastly, the **development of a comprehensive dashboard**, both at DoD and within the individual Services or departments, acts as a guiding compass. This dashboard, populated with digital ecosystem-focused KPIs, steers DoD's transformation journey toward success.

Five C-Level Digital Ecosystem KPIs[67]

Key aspects of the Department's digital ecosystem include: metrics such as pervasiveness of digital native programs, leadership engagement, talent retention, budget allocation, and Return on Investment. These factors collectively shape DoD's journey toward digital excellence.

1. **Digital Native Programs (New & Legacy):** The percent of new programs designed as digital native, and the percent of legacy programs transformed to digital. The target is 100% for new and 50% for legacy, but also recognizes that transformation is a journey and starting at a lower percentage and increasing over time indicates progress.
2. **Leaders' Time Devoted to Transformation**: Incorporating digital ecosystem efforts into performance evaluations ensures leadership engagement. The percentage of leaders' time or resources dedicated to digital transformation reflects organizational commitment.
3. **Attracting and Retaining Technical Talent**: The success of any digital ecosystem hinges on talent. Measuring the number of top technical professionals (such as data scientists and specialists) attracted, promoted, and retained provides insights into the ecosystem's health.
4. **Budget Allocation for Transformation**: DoD's commitment to digital transformation must be reflected in budgetary resources. Tracking the percentage and dollar amount allocated to digital initiatives (including change management, applications, and infrastructure) provides a tangible measure of commitment.
5. **Return on Digital Ecosystem Investment**: Measured in dollars, time, and percentage, ROI quantifies the benefits derived from digital projects relative to their costs. The formula is straightforward: ROI = (Project Benefit / Project Cost) × 100. Project Benefits focuses on speed, inventory reduction, asset reallocation, and resource rationalization from investing in a particular process change, application, or infrastructure.

Second-Level Digital Ecosystem Program KPIs

The inclusion of **second-level KPIs** is pivotal in the Department's quest to establish a robust digital ecosystem. While the proposed C-level metrics provide a high-level overview, these detailed KPIs are required to delve deeper into specific aspects. Organized around the five cornerstones outlined in this Digital Ecosystem Study, each group of metrics serves a distinct purpose. By tracking progress within these themes — whether it's supplier alignment, program efficiency, leadership engagement, or talent retention — DoD accelerates its digital transformation journey. These granular KPIs act as navigational beacons, guiding DoD toward digital excellence and resilience.

	KPI	Measurement
Governance & Organization -- to promote inclusion and accelerate change.		
1	**Digital Ecosystem Progress Review Frequency**	# of instances reviewed and discussed (DMAG and EAG)
2	**Industry Partner Participation**	# of industry partners involved in development
3	**Digital Native Programs**	% of new programs designed as digital native
4	**Digital Transformation of Legacy Programs**	% of legacy programs transformed to digital
Planning & IT Infrastructure -- to establish an ecosystem necessary to share data across the supply chain.		
1	**Supplier Certification and Alignment**	% of suppliers certified and aligned to DoD platforms - in total and by Prime Tier 1-3
2	**Electronic Program Requirements**	% of requirements loaded into a management platform
3	**Bills of Materials (BOMs) Management**	% of BOMs loaded into a PLM environment
4	**Digital Twin Systems Deployment**	Number of Digital Twin systems in use
5	**New Program Development Cycle Time**	Average time for new program development
Cultural Environment -- to increase risk tolerance and speed.		
1	**Leaders' Time Devoted to Transformation**	Percentage of leaders' time or resources
2	**Digital Skills Development Objectives**	% of performance plans focusing on personal digital skills
Talent & Training -- to increase workforce readiness.		
1	**Top Technical Talent Attraction, Promotion, and Retention**	# of data scientists and specialists retained
2	**Training Completion for New ACAT 1 Programs**	% of resources completing training within 90 days of program establishment
3	**Training Completion for High-Priority Legacy Programs**	% of resources trained for programs with components at risk
Funding & Resourcing -- to commit and deploy necessary resources.		
1	**Budgetary Resources for Digital Ecosystem**	Amount of budgetary resources defined/committed
2	**Projected Cost Growth Variance**	Variance from approved business case
3	**Return on Digital Ecosystem Investment (ROI)**	ROI = (Project Benefit / Project Cost) × 100

Digital Ecosystem KPI Summary

In summary, the move toward digital excellence requires a panoramic view, collaborative efforts, and a vigilant eye on KPIs. By embracing these principles and vetting and implementing KPIs similar to those listed above, DoD can navigate the digital landscape with purpose and precision.

VII. Impacts

The impacts of an accelerated enterprise-wide digital transformation are many and have implications for all facets of a program's life and virtually all functional components of the Department and the Services. While those impacts are tangible and documentable, not all lend themselves to traditional, objective measurement. Nonetheless, taken as a whole, they create a foundation for the Department to transform in historic ways.

Battlefield Superiority

No priority is more important to the Department than its ability to control the battlefield and bring consistently superior capabilities to the fight. The goal is and always has been to establish and maintain military dominance.

As noted in this Study, while DoD continues to field extraordinary capabilities, its superiority is being challenged in ways not seen in decades. A comprehensive digital ecosystem represents the Department's best and most achievable path toward ensuring a battlefield advantage remains unchallenged. And there could be no greater or more important impact to ensuring national security than maintaining the battlefield advantage and equipping the warfighter.

Reduced Program Cost, Risk, and Cycle Times

In keeping with the theme of maintaining the battlefield advantage, there can be no question that significantly reducing cycle times is essential. Given the always limited resources available, so too is the ability to control cost and, importantly, cost growth. Done right, those outcomes will emanate from a digital transformation. Agile program management strategies and model-based systems engineering, including for test and evaluation, combine to reduce costs and development cycle times. Moreover, because testing is more continual, problems and failures are identified and mitigated far earlier than is the case in traditional program models. This reduces risk and, as a corollary, cost, and ultimate cycle time. Finally, these impacts, as noted in this Report's recommendations, can be measured and tracked in ways to allow for continuous learning.

Enhanced Sustainment Performance

Too often lost in the discussion of digital ecosystems is its enormous impact on sustainment, including for legacy systems. The use of digital tools enables far more effective and timely data collection and analysis covering every aspect of a system's performance and use, thereby facilitating more efficient and effective sustainment planning. Beyond that, the digital ecosystem provides the Department with far greater market flexibility to deal with parts obsolescence or diminished manufacturing supply. Likewise, contemporary digital tools enable greatly improved supply chain visibility both to identify and manage supply chain risks and to more accurately and timely track supplies, in transit or at rest, than is currently the case.

Workforce and Cultural Transformation

It is widely understood the Department, like many other institutions, faces a range of workforce challenges, not the least of which is transforming a workforce optimally prepared for the challenges of the 21st Century. As outlined in this Study, one critical component in establishing an effective digital ecosystem is an investment in workforce development, including reskilling current talent in almost every function and developing talent acquisition and management strategies to enable the Department to better compete for talent (see *DBB Report on Talent Management)*. Looked at another way, the development of the digital ecosystem can be the catalyst to an unprecedented transformation of DoD workforce and, with it, the very culture of the Department.

Expand Competition

Finally, while the Department and the nation have long been exceptionally well-served by the world's most effective defense industrial base, it is also true that expanding that base and increasing competition are both desirable and necessary. Digitalization is the key to achieving this goal. Among other things, the use of digital tools, open-systems architecture, integrated data sharing, etc., create significantly expanded opportunities for competition at both the system and component level and by both the Department and its principal primes. That expanded competition will also be of great importance to supply chain risk management strategies.

VIII. Conclusion

When the Subcommittee began its work on this Study, it quickly became apparent the topic was not only broad and complex but also subject to numerous interpretations and definitions. Thus, the first objectives were to develop practical definitions and a common perspective. That it took real time to do so is emblematic not only of the complexity involved but also of why the Department has, at times, struggled to do the same. Yet, over the six months of study, as the Subcommittee's thinking and perspectives evolved and solidified, it became evident the same was happening in and across increasing parts of the Department.

The Subcommittee has been greatly heartened by the notable progress being made and the important foundations being laid for a meaningful transformation. In relatively short order, real progress has become evident and is to the credit of those leaders and their teams who have recognized the fundamental importance of moving forward. The challenge now is to accelerate that progress and to institutionalize the evolving changes. Much of this Study is therefore focused on steps the Subcommittee has determined as necessary to ensure DoD rapidly and effectively moves forward to meet the realities and pace of both technology and the threats we face.

That is why this digital transformation must be identified as a top national security priority, on par with other major challenges the Department has so effectively met. Such a designation, accompanied by sustained leadership and oversight at the highest levels of the Department, is necessary to ensure all Components of the Department are working at speed and in unison to the same common vision. It is also an essential element for ensuring all Components receive the appropriate and necessary resources to support efforts, as well as the kind of "risk absorption" leaders must provide in any innovative and forward-leaning organization. And, in the end, a well-executed digital transformation strategy will also catalyze a wide range of impacts and benefits to the Department, including but not limited to the kind of transformational culture change to stand the Department in good stead for the unknown challenges of the future.

The landscape within the Department and outside of it is already rich with the learnings and lessons of an array of pilots and experimentation as well as real-world applications. The global realities dictate time is not on the United States' side. Fortunately, utilizing the lessons learned, DoD is in a position to dramatically accelerate this foundational shift. There is no time to waste.

IX. Table of Appendices

Appendix A: Terms of Reference (ToR)

DEPUTY SECRETARY OF DEFENSE
1010 DEFENSE PENTAGON
WASHINGTON, DC 20301-1010

JUL 31 2023

MEMORANDUM FOR DEFENSE BUSINESS BOARD

SUBJECT: Terms of Reference — Creating a Digital Ecosystem

To "build a resilient Joint Force and defense ecosystem," as outlined in the 2022 National Defense Strategy, the Department must continue to advance its commitment to modernization and innovation, and that includes modernizing its business systems. Creating a common digital ecosystem — one shared between industry and the Department of Defense (the Department) — has the potential to vastly improve how the Department does business. Specifically, a digital ecosystem designed to harness the power of accurate, real-time data can aid in faster and more efficient decision-making and risk analysis. There are already examples within the Department where digital ecosystems, which can enable more accessible simulation environments and advanced computing, are streamlining development activities. Furthermore, applications of the digital ecosystem for supply chain visualization, manufacturing, and other processes could also transform the Department's business enterprise.

Given the opportunities digital ecosystems present, I direct the Defense Business Board (the Board), through its Business Transformation Advisory Subcommittee (the Subcommittee), to evaluate and provide recommendations on creating a digital ecosystem with industry partners. Specifically, the Board, through its Subcommittee, will:

- Evaluate the current state of the Department's enterprise-wide digitalization as it affects engineering, development, acquisition, and lifecycle management.
- Examine the best-in-class business practices of private-sector engineering, manufacturing, maintenance, and lifecycle management companies as they relate to digitalization.
- Identify the benefits and challenges to implementing a digital ecosystem across the Department, including: cultural changes, implications to vendor management, security, contracting, technology, and budget requirements.
- Provide recommendations and case studies to support the Department's adoption of a common digital ecosystem across all services to support more rapid, accurate, and affordable development, deployment, and sustainment of military-specific innovations for both hardware and software.
- Identify metrics to measure the success of adoption.
- Address related matters the Board determines relevant to this task.

I direct the Subcommittee to submit its independent recommendations to the full Board for its thorough consideration and deliberation at a properly noticed public meeting, unless it must be closed pursuant to one or more of the exceptions found in title 5, U.S. Code, section 552b(c). The Board will provide its findings and recommendations to me no later than February 29, 2024.

In conducting its work, the Board and its Subcommittee have my full support to meet with Department leaders. The Board staff, on behalf of the Board and the Subcommittee, may request the Office of the Secretary of Defense and Department Component Heads to timely furnish any requested information, assistance, or access to personnel to the Board and the Subcommittee. All requests shall be consistent with applicable laws; applicable security classifications, DoD Instruction 5105.04, "Department of Defense Federal Advisory Committee Management Program," and these Terms of Reference. To support the effort, the United States Air Force will provide a full-time detailee to the Office of the Secretary of Defense/Office of the Director of Administration and Management (OSD/ODA&M) to support the Board's work on this study. The detailee shall be a professional from the Office of the Assistant Secretary of the Air Force for Science, Technology, and Engineering with knowledge of and experience in digital systems engineering. The detailee will remain until the study is approved.

Material provided to the Board becomes a permanent part of the Board's record. Components are reminded all data/information provided is subject to public inspection unless the originating Component office properly marks the data/information with the appropriate classification and Freedom of Information Act exemption categories before the data/information is released to the Board. The Board has physical storage and electronic storage and communications capability on both unclassified and classified networks to support receipt of material up to the Secret level. Each Component should remember that Board members, as special government employee members of a Department of Defense Federal Advisory Committee, will not be given any access to the Department network, to include the Department email systems.

The Board and the Subcommittee will operate in conformity with and pursuant to the Board's charter; title 5, U.S. Code, chapter 10 (commonly known as the "Federal Advisory Committee Act"); title 5, U.S. Code, section 552b (commonly known as the "Government in the Sunshine Act"); and other appropriate federal statutes, regulations, and policy. The Subcommittee and individual Board members do not have the authority to make decisions or provide recommendations on behalf of the Board nor report directly to any federal representative. The members of the Subcommittee and the Board are subject to certain Federal ethics laws, including title 18, U.S. Code, section 208, governing conflicts of interest, and the Standards of Ethical Conduct regulations in 5 C.F.R., part 2635.

Thank you in advance for your cooperation and support to this critical undertaking to inform subsequent decisions on how the Department addresses national security challenges in the coming decades.

cc:
Senior Pentagon Leadership
Directors of Defense Agencies
Directors of DoD Field Activities
Advisory Committee Management Officer, DA&M

Appendix B: DBB Presentation Slides to the Board

FY 2024 Assessment of the Department of Defense

Creating a Digital Ecosystem

Business Transformation Advisory Subcommittee

February 29, 2024

Contents

- Terms of Reference
- Subcommittee Membership
- Digital Ecosystem Background
- Impacts
- Findings and Recommendations
- Conclusion & Closing Comments

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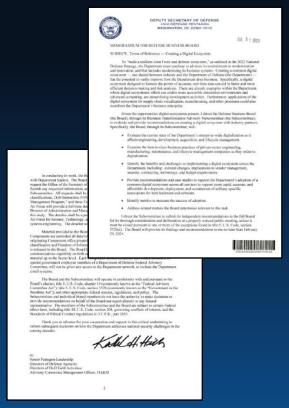
Terms of Reference

- **Evaluate the current state** of DoD enterprise-wide digitalization as it affects engineering, development, acquisition, and lifecycle management.
- **Examine the best-in-class business practices** of private-sector engineering, manufacturing, maintenance, and lifecycle management companies as they relate to digitalization.
- **Identify the benefits and challenges** to implementing a digital ecosystem across the Department, including cultural changes, implications to vendor management, security, contracting, technology, and budget requirements.
- **Provide recommendations** and case studies to support DoD adoption of a common digital ecosystem.
- **Identify metrics** to measure the success of adoption.
- **Address related matters** the Board determines relevant to this task.

Based on the enormous complexity of this topic, the Subcommittee decided to limit its investigation to acquisition and lifecycle management of military capability.



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Business Transformation Advisory Subcommittee

DBB Staff

Cara Allison Marshall
Designated Federal Officer

CAPT Chad Graham
Navy Military Representative

Matthew Ratcliff
USAF Subject Matter Expert

Janice McLaury
Research Lead and Writer/Editor

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Background
The Digital Ecosystem

What is a Digital Ecosystem?

- The injection of digital technologies into every phase of a program's lifecycle, enabling innovation at "the speed of relevance"
- All stakeholders see, iterate on/analyze same data ("single source of truth")

The Digital Twin

- Integrated into requirements, development, manufacture, engineering, test, and lifecycle management
- Post fields, the "twin" reflects actual product performance and enables rapid innovation, predictive maintenance, AI applications, etc.

Multiple "twins" linked together (e.g., product performance and processes) is called the Digital Thread.

Background
A National Security Imperative

Digitalization is transforming every industrial sector.

- Many consider it the most significant technological evolution since cloud.
- Gartner estimates 90% of companies engaged in some degree of "digitalization."
- 87% of top execs call it a top priority.

It is the new Space Race – and a National Security Imperative.

- THE pacing threat is the PRC: investing massive sums in digital capabilities; also fielding new systems in 7yrs vs. 16yr average in U.S.
- PRC has the advantage of not being "burdened" by the bureaucratic layers inherent (and often appropriate) in a democracy.

This places an even greater premium on DoD's ability to transform process, culture, and people.

"Whoever achieves symbiosis on the battlefield, controls the battle."

Impact
The BLUF

Superior Capabilities, Better Decisions, and Better, More Efficient System Performance

- Battlefield Superiority
- Reduced Program Cost, Risk, and Cycle Times
- Enhanced Sustainment Performance
- Workforce and Culture Transformation
- Expand Competition

Background
The Transformation Has Begun, But…

- The DoD has begun the transition.
- First digital directives issued in 2018; followed by additional USD (R&E) guidance, Service-specific plans and policies
- Numerous promising experiments and pilots
- However:
- The pace is not adequate to meet the threat
- There is no common understanding/vision/taxonomy across the Deptartment
- The risk-averse nature of DoD culture inhibits rapid forward movement
- Pilots, planning remains siloed, limited
- Workforce gaps are known/recognized, but strategies to address are lacking
- Funding lacking for critical initiatives
- Continued focus on “experimentation” risks ignoring lessons/insights already learned
- Significant tech questions–capabilities, processes–remain unaddressed

Findings and Recommendations
Governance & Organization

Finding

DoD Requires Centralized Authority to Advance Digitalization

Observations

- Acquisition leaders are not incentivized to adopt long-term transformation efforts, nor promote continuity.
- Leaders do not have a common vision for digitalization and are inconsistent in how they communicate.
- The Department does not have a centralized authority, empowered with resources, to adroitly enable digital initiatives.

Recommendations

- Assign DMAG (or similar) as the authority for developing the Defense Digital Ecosystem
- Convene an Executive Action Group to remove barriers to change
- Expand and formalize Industry participation in the development of solutions

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Findings and Recommendations
Planning & IT Infrastructure

Finding

DoD's Lack of an Integrated Digital Ecosystem Creates Inefficiencies

Observations

- Outdated data-exchange practices to communicate with suppliers further drives risk.
- Lack of end-to-end digital environment to collaborate negatively impacts time to market and sustainment .
- Lagging behind industry in the prioritization and investment in modern digital tools, processes and practices

Recommendations

- Develop a set of collaboration and data exchange platforms to enable real time interaction with DoD suppliers
- Require use of the platforms to ensure data is available through full lifecycle of the program from ideation to sustainment

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Findings and Recommendations
Planning & IT Infrastructure

Finding

DoD Lacks Digital Taxonomy to Create an Interoperable Digital Strategy

Observations

- A lack of common taxonomy has stalled the development of data interface requirements and tool integration.
- No common understanding of what is meant by "digital transformation" and other key enabling terms and definitions

Recommendations

- Establish a common vision and taxonomy, including a schedule to routinely review and update

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Findings and Recommendations
Planning & IT Infrastructure

Finding

DoD's Ability to Best Utilize Data is Constrained

Observations

- No standards that define data format and interfaces to adequately access, store, or share their data
- Not invested in enabling a federated, yet integrated data management strategy to support data-driven decisions
- Data owners do not have an incentive or means to share, interconnect, or curate their data, nor do they trust each other to use it properly.

Recommendations

- Require all functional stakeholders across the product lifecycle to participate in planning to identify data needs
- Develop standards for data format and interfaces, standards must be designed to facilitate interoperability

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Findings and Recommendations
Cultural Environment

Finding

DoD Culture is Risk Averse & Resistant to Change

Observations

- Personnel held to account for failures and resistant to take on calculated innovation risks
- The "Frozen Middle" is obstructing progress toward the adoption of digital tools and technologies.
- Personnel are not incentivized to adapt their skills, processes, or practices to successfully participate in a digital ecosystem.

Recommendations

- Establish a deliberate change management process and plan
- Address the institutional resistance to risk in the plan
- Incentivize and reward personnel to adopt digital skills
- All include digital skills objectives in performance evaluations

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Findings and Recommendations
Talent & Training

Finding

DoD Workforce is Not Adequately Prepared for a Digital Ecosystem

Observations

- Lacks the full scope and depth of workforce skills to accelerate transition to a digital ecosystem
- Civilian and military job classifications, career paths, and recruitment have not kept pace with new technical disciplines and specializations.
- Digital training and education opportunities lack the ability to ensure the training is utilized and applied as broadly as needed.

Recommendations

- Establish distinct pathways for both military and civilian for advancement and leadership
- Develop a strategy to rapidly recruit highly specialized and in-demand technical disciplines
- Close the skills gap between experienced professionals and skilled "digital-doers

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Findings and Recommendations
Intellectual Property

Finding

IP and Technical Data Rights Remain a Critical Concern

Observations

- Conflicts over the ownership and sharing of Intellectual Property is a key barrier to a digital strategy.
- A proactive IP planning approach can result in significant cost savings and prevent delays in spares procurement
- Digital IP can and should center on performance and interface standards.

Recommendations

- Mandate regular progress reports from the Intellectual Property Cadre to the DepSecDef through the DMAG

Findings and Recommendations
Digital Ecosystem Funding

Finding

PPBE Process Obstructs an Ability to Fund Foundational Initiatives

Observations

- Budget process does not support end-to-end (enterprise wide) horizontal requirements and lacks the ability to rapidly adjust
- Investments in digital capabilities are typically on a program-by-program basis and ignore sustainment and legacy systems.
- Digital investments are more likely in big or new programs than in small or legacy programs.
- Current funding requests often lack sufficient detail on cost savings, return on investment, and the risk of failing to act.

Recommendations

- Work with USD (Comptroller) to establish digital ecosystem as an investment priority.
- Establish a centralized fund and modify PPBE process to remove budget restrictions
  - *Near-term*: use current DoD authority to recover / reallocate funds
  - *FY 25-26*: pursue legislative action for a centralized DoD fund

Key Performance Indicators

	KPI	Measurement
Governance & Organization -- to promote inclusion and accelerate change.		
	1 Digital Ecosystem Progress Review Frequency	# of instances reviewed and discussed (DMAG and EAG)
	2 Industry Partner Participation	# of industry partners involved in development
★	3 Digital Native Programs	% of new programs designed as digital native
★	4 Digital Transformation of Legacy Programs	% of legacy programs transformed to digital
Planning & IT Infrastructure -- to establish an ecosystem necessary to share data across the supply chain.		
	1 Supplier Certification and Alignment	% of suppliers certified and aligned to DoD platforms - in total and by Prime Tier 1-3
	2 Electronic Program Requirements	% of requirements loaded into a management platform
	3 Bills of Materials (BOMs) Management	% of BOMs loaded into a PLM environment
	4 Digital Twin Systems Deployment	Number of Digital Twin systems in use
	5 New Program Development Cycle Time	Average time for new program development
Cultural Environment -- to increase risk tolerance and speed.		
★	1 Leaders' Time Devoted to Transformation	Percentage of leaders' time or resources
	2 Digital Skills Development Objectives	% of performance plans focusing on personal digital skills
Talent & Training -- to increase workforce readiness.		
★	1 Top Technical Talent Attraction, Promotion, and Retention	# of data scientists and specialists retained
	2 Training Completion for New ACAT 1 Programs	% of resources completing training within 90 days of program establishment
	3 Training Completion for High-Priority Legacy Programs	% of resources trained for programs with components at risk
Funding & Resourcing -- to commit and deploy necessary resources.		
★	1 Budgetary Resources for Digital Ecosystem	Amount of budgetary resources defined/committed
	2 Projected Cost Growth Variance	Variance from approved business case
★	3 Return on Digital Ecosystem Investment (ROI)	ROI = (Project Benefit / Project Cost) × 100

★ Top C-Level Metrics

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Conclusions

- Digital transformation is complicated.
- "Going Digital" needs to be a National Security Priority.
- Cross-cutting leadership is required.
- Notable progress is being made.
- Time to scale-up is now.

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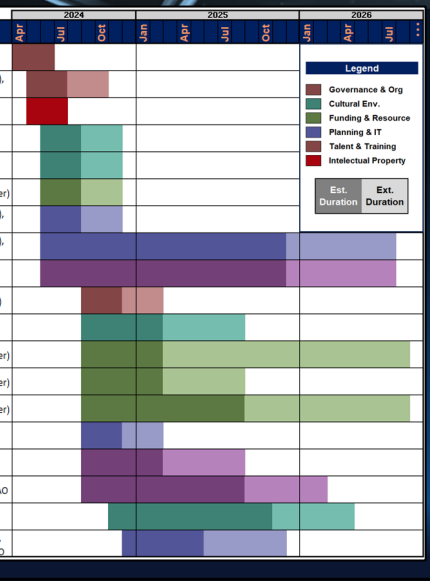
Summary of Recommendations
Timeframes

Recommendation	Timeframe	Owner
Assign DMAG (or similar) as the authority for developing the Digital Ecosystem	<3 months	DMAG
Convene an Exec Action Group to remove barriers to change	3-6 months	USD (R&E, A&S), CIO, CDAO
Mandate regular progress reports from the Intellectual Property Cadre	<3 months	USD(A&S)
Establish a deliberate change management process and plan	3-6 months	EAG
Address the institutional resistance to risk in the plan	3-6 months	DMAG, EAG, Services
Work with USD (Comptroller) to establish digital ecosystem as an investment priority.	3-6 months	USD (Comptroller)
Establish a common vision and taxonomy	3-6 months	USD (R&E, A&S), CIO, CDAO
Develop collaboration platform architecture and roadmap	18+ months	USD (R&E, A&S), CIO, CDAO
Establish distinct digital ecosystem pathways for both military and civilian personnel	18+ months	USD (P&R)
Formalize industry participation in the development of solutions	3-6 months	USD (R&E, A&S)
Incentivize and reward personnel to adopt digital skills	6-12 months	USD (P&R)
Establish a centralized fund and modify PPBE process to remove budget restrictions	6-24 months	USD (Comptroller)
Near-term: use current DoD authority to recover / reallocate funds	6-12 months	USD (Comptroller)
FY 25-26: pursue legislative action for a centralized DoD fund	12-24 months	USD (Comptroller)
Require all functions from across all stages of lifecycle to identify data needs	3-6 months	USD (A&S), Services
Expand and fund opportunities for critical skills development	6-12 months	USD (P&R)
Develop a strategy to rapidly recruit highly specialized technical disciplines	12-18 months	USD (P&R), CDAO
All include digital skills objectives in performance evaluations	12-18 months	USD (P&R)
Develop standards for data format and interfaces, standards to facilitate	6-12 months	EAG, USD (R&E, A&S), CIO, CDAO



Approach and Methodology

Study Scope and Purpose

This Study addresses the needs of the Department and challenges faced in the development of an integrated digital ecosystem to respond to our near-peer adversaries at the speed of relevance. The Subcommittee focused on the personnel, tools, resources, and partnerships that accelerate adoption of digital technologies throughout the acquisition lifecycle that bring disruptive capabilities to our warfighters.

Data & Literature Review

Research included case studies, technical analysis, DoD policies, editorials, academic papers, and other related subject matter studies and reports.

Focus Groups

The Subcommittee conducted 58 interviews over the course of the Study. Participants included senior military and civilian members of the armed forces, industry executives, and subject matter experts.

Appendix C: Business Transformation Subcommittee Members' Biographies

DEFENSE BUSINESS BOARD

THE HONORABLE DEBORAH LEE JAMES

CHAIR, DEFENSE BUSINESS BOARD and FORMER SECRETARY, U.S. AIR FORCE

From December 2013 through January 2017, Deborah served as the 23rd Secretary of the United States Air Force with responsibility for 660,000 military and civilian personnel and a budget of nearly $140 billion. She was the second woman to ever lead a military service in the United States.

Prior to this role, she served as President of SAIC's Technical and Engineering sector, a $2 billion, 8,700-person enterprise. Earlier in her career, Deborah held other P&L positions and worked in the Legislative Branch of government and the Department of Defense (DoD).

Deborah has deep expertise in strategic planning, risk management, public policy, cyber security, space, logistics, and innovation. Deborah is a proficient speaker on business and government topics, including issues in national security and world affairs, politics in Washington, business transformation leadership, mergers and acquisitions, cost reduction strategies, and diversity and inclusion.

She is an accomplished keynote speaker and enjoys working one-on-one as an Executive Mentor with C-suite level professionals, sharing her expertise and providing advice on team building, organizational change management, partnering with the Federal Government, and transformational technology. Deborah is the author of the new book, *Aim High: Chart Your Course and Find Success* and periodically appears on *MSNBC, CBS*, and other national news programs. Finally, Deborah serves on various for-profit and non-profit boards of directors. Deborah became the Chair of the Defense Business Board upon her appointment in 2021.

Previous Experience

- 23rd Secretary of the United States Air Force
- SAIC, President, Technical and Engineering Sector
- SAIC, Executive Vice President, Communications and Government Affairs
- SAIC, General Manager, Command and Control Business Unit
- Business Executives for National Security (BENS), Executive Vice President and Chief Operating Officer
- Vice President, United Technologies, International Operations, and Marketing
- Assistant Secretary of Defense, Reserve Affairs, DoD
- Armed Services Committee, U.S. House of Representatives

Education

- Columbia University, School of International & Public Affairs - MIA, International Affairs
- Duke University - AB, Comparative Area Studies

Today's Affiliations

- Member, Board of Directors: Textron, Unisys, Noblis, Systems & Technology Research, Atlantic Council, PenFed Foundation
- Advisor: Beacon Global Strategies LLC, Leanln.org, Massachusetts Institute of Technology, Lincoln Laboratory, Ursa Major Tech, SOSi
- Executive Mentor, ExCO Leadership
- Senior Advisor, Center for Strategic and International Studies

DEFENSE BUSINESS BOARD

STAN SOLOWAY

PRESIDENT & CEO, CELERO STRATEGIES, LLC

Stan Soloway is President & CEO of Celero Strategies, LLC, a full-service strategic consultancy focused on the federal market. Celero Strategies is Soloway's latest step in a career during which he has become widely regarded as one of the nation's leading experts on the federal market, the factors and dynamics that drive it, and how to translate that expertise into meaningful strategies and action. With Celero Strategies, Soloway's goal is to combine two core passions: helping good companies bring innovative solutions to government and helping government significantly improve its performance and delivery of service. Stan is a Fellow of both the National Academy of Public Administration (where he also serves as Vice Chair of the Board of Directors) and of the National Contract Management Association.

Prior to founding Celero Strategies in January 2016, Stan served for 15 years as the President & CEO of the Professional Services Council (PSC), the largest and most influential national association of government technology and professional services firms. While at PSC, Soloway was the industry's leading voice, policy strategist, and resource for both government and the private sector. He regularly testified before Congress, was a prolific writer, appeared often on radio and television, and was routinely sought out by both corporate and government organizations to discuss current market trends, dynamics, and strategies. He has also been a contributing author for books published by Cambridge University, Harvard Law School, and the University of Pennsylvania, and in 2021 co-authored *Other Transactions at 60: Hitting Their Stride or Hitting the Wall*? which was published by the IBM Center for the Business of Government.

Stan was the recipient of the 2016 Consumer Electronics Show (CES) Government Technology Leadership Award and was named the IT Industry Executive of the Year in 2013 by Government Computer News. He has been cited as one of the 100 Most Influential Business Leaders in Washington (*Washington Business Journal*) and one of the 100 Most Influential Figures in National Defense (*Defense News* and *Gannett*). He is a four-time winner of the Federal 100 Award for his Leadership in Federal Information Technology and is a Principal at the Partnership for Public Service where he serves as a Senior Advisor to Government Executives (SAGE).

During the second half of the Clinton Administration, Stan served as the Deputy Undersecretary of Defense and was responsible for wide-ranging reforms to defense acquisition and technology policy and practices, and broader department-wide re-engineering. In recognition of his leadership in the Department, Stan was awarded both the Secretary of Defense Medal for Exceptional Public Service and the Secretary of Defense Medal for Distinguished Public Service.

As a passionate believer in the importance and value of public service, Stan also served from 2007 to 2013 as a Senate-confirmed member of the Board of Directors of the Corporation for National and Community Service (now known simply as AmeriCorps). Earlier in his career, he provided public policy and public affairs consultancy for nearly 20 years. He also co-produced the acclaimed PBS television series *"Great Confrontations at the Oxford Union."* He is a graduate of Denison University, where he was elected to the National Men's Leadership, National Journalism, and National Political Science Honorary Societies.

DEFENSE BUSINESS BOARD

SUZANNE LEOPOLDI-NICHOLS

CHIEF GLOBAL BUSINESS SOLUTIONS OFFICER
WPP (FORMER)

Suzanne is an expert on Next-Gen Shared Services (NGSS) and Global Business Services (GBS). She is a seasoned executive leader with an extensive background in transforming and optimizing GBS organizations across various industries. With more than two decades of experience, Suzanne has established herself as a strategic visionary, driving change, innovation, and operational excellence. Having led over 17,000 employees on six continents, Suzanne possesses a deep understanding of diverse cultural nuances and of navigating complex global operations. Her GBS experience spans a vast array of functions, including brokerage, customer service, call centers, finance, human resources, information technology, legal, marketing, procurement, payroll, real estate, and world-class sales support.

Suzanne has held key leadership positions in renowned companies, including WPP Plc., United Parcel Service (UPS), Archer Daniels Midland Company, and American Greetings. In these roles, she led initiatives to create world-class GBS organizations, streamline operations, and drive significant cost savings.

During her tenure as Chief GBS Officer at WPP Plc., she was tasked with building a robust GBS framework from the ground up. By implementing transformative strategies and governance frameworks, she empowered cross-functional teams to identify and achieve significant savings while driving sustainability initiatives and reducing indirect procurement spend.

Prior to her role at WPP Plc., Suzanne served as President of Global Business Services at UPS, the world's largest package delivery company. She reengineered the GBS organization, leading to a substantial decrease in customer churn and unlocking considerable transformation run rate savings.

Before UPS, she held the position of Global Head of Shared Services at Archer Daniels Midland Company, where Suzanne led the development and implementation of strategic, operational, and tactical plans for Global Shared Services centers. Through her leadership, the team achieved sizable Selling, General, and Administrative (SG&A) savings and fostered a culture of continuous improvement.

Suzanne is an Advisory Board member at IQPC's Shared Services and Outsourcing Network (SSON) and is a Founding member of The GBS Board. Suzanne and her teams won multiple awards for their work in GBS, including:

- SSON's Top 20 Most Admired Shared Services
- IAOP inducted Suzanne into their Leadership Hall of Fame
- APA's Prism Award for Overall Best Practices in Management, Process, and Technology

DEFENSE BUSINESS BOARD

CRAIG ALBRIGHT

SENIOR FINANCE EXECUTIVE, XEROX CORP (FORMER) and EXECUTIVE ADVISOR

Craig Albright is a seasoned finance executive with extensive CFO experience and more than 25 years of senior roles in finance, strategic planning, business intelligence, and consulting. He has a demonstrated capability as a trusted advisor - having partnered with over 20 leadership teams - and as a leader of high performing teams, to assess, transform, and drive growth results.

Craig spent 19 years at Xerox in a broad range of senior roles. Most recently, Craig served as Finance Executive for Xerox Global Cash Center and as Chief Financial Officer (CFO) for Xerox Americas, the largest division of Xerox Corp, a global leader in office and production print technology and related solutions. Previous roles at Xerox included CFO of Commercial Excellence overseeing financial planning for global technology, service, and software offerings; CFO Xerox Europe during the Eurozone crisis; VP Finance, Large Enterprise Operations & Global Document Outsourcing; VP Finance, North America Managed Print Services; VP Finance, Xerox Global Services; and Director Corporate Strategy Integration & Business Intelligence working with the Executive Committee on setting the corporate agenda and leading strategic planning. Craig joined Xerox in 2004.

Prior to joining Xerox, Craig was a Senior Manager at Marakon Associates, a management consulting firm specializing in value-based management and advising Fortune 500 clients on issues relating to business strategy, performance improvement, and organizational design. Craig began his career at Deloitte as a Business Analyst in 1992.

Craig earned his MBA in Finance & Strategic Management from Wharton and his BS in Mathematics from the University of Chicago.

DEFENSE BUSINESS BOARD

JOSEPH B. ANDERSON, JR.

CHAIRMAN & CHIEF EXECUTIVE OFFICER
TAG HOLDINGS, LLC

Mr. Joseph B. Anderson, Jr., born in Topeka, Kansas, graduated from the United States Military Academy at West Point with a Bachelor of Science in Math and Engineering. Subsequently, he received two Master's degrees from the University of California, Los Angeles. Mr. Anderson attended the Army's Command and General Staff College and is a graduate of the Harvard Advanced Management Program. Mr. Anderson received an Honorary Doctor of Management from Kettering University and an Honorary Doctor of Commercial Science from Central Michigan University. In May 2016, Mr. Anderson received the Distinguished Graduate Award from The United States Military Academy at West Point honoring him for his lifetime of achievement.

During his military career, Mr. Anderson commanded troops as an Infantry Officer in the 82nd Airborne Division and served two tours of duty with the 1st Cavalry Division in Vietnam. In addition to Troop Commander, Mr. Anderson served as Aide-de-camp to two general officers and was an Assistant Professor in the Department of Social Sciences at West Point. Mr. Anderson and the infantry platoon he commanded in Vietnam were subjects of the highly acclaimed documentary film *The Anderson Platoon*. The documentary has been shown in more than 20 countries and has won several awards to include the Oscar of the Academy Awards and an Emmy. Mr. Anderson's military awards include two silver stars, five bronze stars, three Army Commendation Medals, and eleven Air Medals. While in the Army, Mr. Anderson was selected to be a White House Fellow and worked as Special Assistant to Secretary of Commerce, Juanita Kreps for one year. After the assignment, Mr. Anderson continued to work for Secretary Kreps until he joined General Motors.

Following his service with the U.S. Army, Mr. Anderson began his business career with General Motors and served as a Plant Manager and Business Unit Director. He was appointed General Director, Body Hardware Business Unit, Inland Fisher Guide Division, General Motors Corporation, a business unit with 7,000 employees and revenue of $1 billion. After 13 years of service, Mr. Anderson resigned to become President and CEO of a privately held company, Composite Energy Management Systems Incorporated. He acquired a controlling interest in another privately held company, Chivas Products, Ltd, and held the position of Chairman of the Board and CEO. Currently, Mr. Anderson is the majority owner, Chairman, and CEO of TAG Holdings, LLC which owns several manufacturing service and technology-based companies based in North America, serving a variety of industries including automotive, heavy equipment, aerospace, and defense.

Mr. Anderson currently serves on the Board of Directors of Business Leaders for Michigan, Michigan Aerospace Manufactures Association (MAMA), and Wynnchurch Capital Advisory Board and is on the Modular Assembly Innovations Board of Managers. His community involvement includes Chairman of the Board of the National Recreation Foundation and Horizons Upward Bound Advisory Board; Mr. Anderson has served on the Boards of Directors of several New York Stock Exchange companies. He is immediate Past Chairman of the Federal Reserve Bank of Chicago-Detroit Branch and is also a Past Chairman of the U.S. Department of Commerce Manufacturing Council.

DEFENSE BUSINESS BOARD

ANAND BAHL

CHIEF INFORMATION OFFICER
MICRON TECHNOLOGY, INC.

Anand Bahl is Chief Information Officer at Micron Technology, Inc., where he oversees the Global Technology teams. His leadership guides manufacturing and engineering solutions, enterprise applications and analytics, global security, infrastructure and operations, and other business-facing IT services and capabilities. Anand is focused on driving an enterprise-wide digital transformation at Micron to enable speed at scale.

He has more than 20 years of international and domestic experience in both IT and Finance in the chemical, textile, and technology industries. Immediately prior to joining Micron in July 2018, Anand led Vivint Smarthome's Finance and Supply Chain IT organization. He has also held various IT and Finance leadership positions at Symantec, Advanced Micro Devices, Koch Industries, and Dow Chemical (Rohm & Haas).

Anand received a Master of Business Administration in Finance and Operations and a Master's of Inorganic Chemistry from Vanderbilt University.

DEFENSE BUSINESS BOARD

GREGORY L. BOWMAN

CHIEF STRATEGY OFFICER & SENIOR VICE PRESIDENT SIEMENS GOVERNMENT TECHNOLOGIES, INC.

Gregory L. Bowman is the Senior Vice President of Corporate Development & Chief Strategy Officer of Siemens Government Technologies (SGT), Inc., the separate but affiliated U.S. government arm of technology powerhouse Siemens. With project teams across the U.S. and internationally, SGT is a cleared provider of Siemens products, technologies, and software to solve some of the most complex government challenges in energy, automation, and digitalization.

At SGT, Mr. Bowman has served as Director of Large Integrated Programs (OCONUS); Deputy/Chief Operating Officer of Energy & Infrastructure; and Vice President of Strategy, Growth, and Partnerships. In his current role, he is focused on driving strategic growth by leveraging innovations from across the Siemens global portfolio to support U.S. government customers around the world.

Prior to joining SGT, Mr. Bowman served in the U.S. Army for more than 25 years — culminating his career as the Strategic Military Law and Policy Advisor/Legislative Counsel to the Secretary of the Army. Chosen to establish that position, he served two Secretaries and two Acting Secretaries of the Army for over seven years.

A graduate of Longwood University, Mr. Bowman was commissioned in the Army in 1990, graduated summa cum laude in Pre-Law, and was recognized as the Distinguished Military Graduate. Following graduation, he was selected for the "Educational Delay" Program to attend the University of Virginia School of Law. He received his Juris Doctorate in 1993; later received a Master's of Military Law and Government Contracting (Honor Graduate) from the U.S. Army Judge Advocate General's Legal Center & School; and a Master's of Military Arts and Sciences (Strategy) from the U.S. Army Command & General Staff College. He is a member of the Virginia State Bar and is admitted to practice law before both the Supreme Court of Virginia and the Supreme Court of the United States.

Mr. Bowman's military positions included Strategic Military Law and Policy Advisor and Legislative Counsel, the Secretary of the Army; Legislative Counsel, Office of the U.S. Army Chief of Legislative Liaison; Deputy Staff Judge Advocate, U.S. Army Armor Center and Fort Knox, Kentucky; Military Personnel Law Attorney, Administrative Law Division, Office of The Judge Advocate General; Senior Legal Advisor, Government Support Team (1st Armored Division-Baghdad); Military Member Judicial Review Committee of Iraq; and served as the first Administrator/Amicus Central Criminal Court of Iraq.

DEFENSE BUSINESS BOARD

MARACHEL KNIGHT

SENIOR TECHNOLOGY & OPERATIONS EXECUTIVE, AT&T (and BOARD DIRECTOR, MARVELL TECHNOLOGY, INC.

Marachel Knight retired from AT&T Communications after a 25+-year career in technology, engineering, and operations. During her tenure with AT&T, Marachel held technology SVP roles spanning research and development, architecture, planning, engineering, operations, and construction. She successfully orchestrated a mobility and broadband transformation to achieve billions of dollars in new revenue while optimizing operating efficiencies and reducing costs. Under her leadership, AT&T became the first US telecommunications company to build a standards-based 5G network and earned the distinction as the nation's fastest wireless network. Marachel's areas of expertise include technology architecture and development, technology operations, engineering, network construction, service realization and program management, P&L, business operations, capital and expense budget management, and project management. Marachel is recognized as a top business and technology executive by *Women Who Make America, The Network Journal, Black Enterprise, Fierce Wireless,* and *Diversity Woman Media*, and she holds two patents for telecommunications systems innovations.

Since 2020, Marachel has served on the Board of Marvell Technology, Inc. (NASDAQ: MRVL), a $5.5B data infrastructure semiconductor solutions provider and developer of the industry's first 3nm data infrastructure silicon. She also serves on the Defense Business Board, an independent advisory body providing the Secretary/Deputy Secretary of Defense and Department of Defense (DoD) leaders with private sector perspective on business management issues. Since joining the Board in 2022, she has advised on innovation and transformation business practices and co-authored two study reports, *Recommendations to Improve IT User Experience within DoD* and *Creating a Digital Ecosystem*.

Additionally, Marachel served on the Business and Community Advisory Council of the Federal Reserve Bank of Dallas from 2021 to 2023, and she has held Board Member and Chair roles at several industry/professional/academic associations and nonprofits, including the National Action Council for Minorities in Engineering, 5G Americas, and Next Generation Mobile Networks. Throughout her career, Marachel has been an advocate for women in tech. At AT&T, she Co-founded and later acted as a National Advisor for their Advocates for Women in Technology employee resource group.

Marachel earned her Master's in Information Networking from Carnegie Mellon University and her Bachelor's in Electrical Engineering from Florida State University. She holds Professional Engineer (P.E.) and Project Management Professional (PMP) designations. A lifelong learner, Marachel completed Stanford Directors' College at Stanford Law School in 2022, MIT's Crisis Management and Business Continuity program in 2023, and Cornell Tech Board Institute: Navigating Emerging Technologies and More in a Complex World in 2023.

DEFENSE BUSINESS BOARD

OSCAR MUNOZ

RETIRED CHAIRMAN, PRESIDENT & CEO
UNITED AIRLINES

Oscar Munoz served as CEO of United Airlines before becoming Executive Chairman of the Board, until retiring in May 2021. During his tenure as CEO, United achieved a rapid turnaround, delivering industry-leading operational reliability as well as sustained financial success, with stock value increasing 54%.

Mr. Munoz was credited with reestablishing United's relationship of trust with its own employees and the customers and community whom it serves. Those efforts earned support and praise from United's largest employee unions and resulted in increasing levels of satisfaction. Under Mr. Munoz' leadership, United sustained an impressive record for leveraging its logistical resources and expertise to benefit communities across the United States and around the world, partnering with federal and local entities in order to deliver vital supplies and personnel to where they were needed most – especially during the Covid-19 pandemic.

Mr. Munoz established United, one of the largest carriers by volume, as the Aviation Industry's prime leader toward achieving an environmentally sustainable future, making historic investments in biofuel technology, next-generation efficient aircraft, and seeding innovators on the electrical aviation frontier. As Executive Chairman, Munoz seized a primary role in helping marshal the global response to the pandemic – partnering with government and administration leaders in support of employees overseeing recovery efforts.

Previously, Oscar served as President and Chief Operating Officer of the North American rail-based transportation supplier CSX Corp. A decade of excellent financial performance, including a boost in operating income of nearly 600%, earned CSX recognition from Most Honored Companies by Institutional Investor.

Oscar previously served as Chief Financial Officer and Vice President of Consumer Services at AT&T Corporation. He also served as Senior Vice President of Finance and Administration for U.S. West; Regional Vice President of Finance and Administration for Coca-Cola Enterprises; and finance positions at PepsiCo.

Currently, he serves on the Board of Directors of CBRE as well as Univision. He is an Independent Trustee on Fidelity's Equity & High-Income Funds Board and sits on Salesforce's Global Advisory Board, as well as the Board of Archer Aviation, a leading Urban Air Mobility company and developer of all-electric vertical take-off and landing ("eVTOL") aircraft. He is a member of the Board of Trustees for the Brookings Institution and is a Trustee of the University of Southern California, where he earned his undergraduate degree in Business. He also received an MBA from Pepperdine.

As a first-generation college graduate from an immigrant family, he and his wife, Cathy, founded Pave It Forward, a foundation that raises scholarship funds for first-generation students. The first Latino to run a major U.S. airline, Hispanic Business magazine twice named Oscar one of its 100 Most Influential Hispanics.

DEFENSE BUSINESS BOARD

THE HONORABLE ERIC ROSENBACH

SENIOR LECTURER & DIRECTOR, DEFENSE, EMERGING TECH & STRATEGY PROGRAM
HARVARD KENNEDY SCHOOL

The Honorable Eric Rosenbach is a Senior Lecturer at the Harvard Kennedy School and is the Director of the Defense, Emerging Technology, and Strategy Program at the Belfer Center for Science and International Affairs. Previously, he co-led the Belfer Center with former Secretary of Defense Ash Carter. Rosenbach currently serves on the Secretary of State's International Security Advisory Board and on the Deputy Secretary of Defense's Defense Business Board.

Rosenbach teaches graduate courses in policy development, strategy execution, and international security. He also teaches two online courses for HarvardX on managing cyber risk and public sector strategy execution.

Rosenbach previously held several senior level appointee jobs in government. As the Chief of Staff to the Secretary of Defense from 2015-2017, Rosenbach was one of the senior-most leaders in the Department of Defense. He served as Secretary Ash Carter's closest strategic advisor on key policy initiatives, such as the war to defeat ISIS, the "rebalance" to Asia, and the effort to check Russian aggression. Rosenbach also led the Department's efforts to improve innovation by forging and managing key initiatives such as the Defense Digital Service and the Defense Innovation Unit.

Before serving as Chief of Staff, Rosenbach was the Senate-confirmed Assistant Secretary of Defense for Global Security and Homeland Defense. His diverse portfolio as Assistant Secretary included cyber, space, countering the proliferation of weapons of mass destruction, antiterrorism, continuity of government, and defense support to civil authorities. Earlier, Rosenbach served as Deputy Assistant Secretary for Cyber Policy.

Rosenbach previously served as National Security Advisor for then-Senator Chuck Hagel and as a professional Staff Member on the Senate Select Committee on Intelligence, where he led oversight of Intelligence Community counterterrorism programs. A former Army Intelligence Officer and Commander of a Telecommunications Intelligence unit, Rosenbach led a team that worked closely with the NSA to provide strategic intelligence in direct support of commanders in Bosnia and Kosovo.

Rosenbach has published widely and authored several books, including *Confronting Cyber Risk: An Embedded Endurance Strategy*. The *LA Times* called his book *Find, Fix, Finish*, co-authored with Aki Peritz, "an important volume in the secret history of a nasty war."

As a Fulbright fellow, he conducted research on privatization programs in Eastern Europe. He holds a Juris Doctor from Georgetown, a Master of Public Policy from the Harvard Kennedy School, and a Bachelor of Arts from Davidson College.

DEFENSE BUSINESS BOARD

GENERAL JOSEPH L. VOTEL
U.S. ARMY (RET)

FORMER COMMANDER, U.S. CENTRAL COMMAND and U.S. SPECIAL OPERATIONS COMMAND

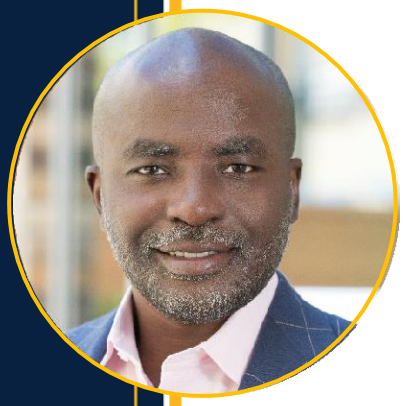
General Joseph L. Votel is a retired U.S. Army Four-Star officer and the former Commander of the U.S. Central Command – responsible for U.S. and coalition military operations in the Middle East, Levant, and Central and South Asia. During his 39 years in the military, he commanded special operations and conventional military forces at every level. His career included combat in Panama, Afghanistan, and Iraq. Notably, he led a 79-member coalition that successfully liberated Iraq and Syria from the Islamic State Caliphate. He preceded his assignment at CENTCOM with service as the Commander of U.S. Special Operations Command and the Joint Special Operations Command.

Following his retirement from military service, General Votel served as the President & CEO of Business Executives for National Security (BENS). He is a member of the Board of Trustees of Noblis Corporation and a Strategic Advisor for Sierra Nevada Corporation and AGI, Inc. Votel is a Board Director with AeroVironment; Minnesota Wire; DC Capital Partners; and Helix Decision Science and a member of the Government Advisory Board for Insight Partners. He a non-resident Distinguished Fellow at the Middle East Institute and the Distinguished Chair of the Combating Terrorism Center at West Point.

General Votel is a member the Executive Boards at Freedom House and the UPenn Center for Ethics and the Rule of Law (CERL). He is a member of the Advisory Board for Spirit of America. Votel is a current member of the Defense Business Board and the Council on Foreign Relations.

Votel was recognized with the Distinguished Military Leadership Award from the Atlantic Council; the U.S. – Arab Defense Leadership Award from the National Council on U.S. - Arab Relations; the Patriot Award from the Congressional Medal of Honor Society; the SGT James T. Regan Lifetime Achievement Award from the "Lead the Way" Foundation; and the Freedom Award from the Intrepid Sea, Air and Space Museum.

Votel is a 1980 graduate of the United States Military Academy and earned Master's degrees from the U.S. Army Command and Staff College and the Army War College. He is married to Michele; and they have two grown sons, a daughter-in-law, and two grandchildren. The Votels reside in Lake Elmo, Minnesota.



DEFENSE BUSINESS BOARD

SAFROADU YEBOAH-AMANKWAH

SENIOR VP & CHIEF STRATEGY OFFICER
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Safroadu “Saf” Yeboah-Amankwah is Senior Vice President and Chief Strategy Officer (CSO) at Intel Corporation. Yeboah-Amankwah leads Intel’s Global Strategy Office, including Intel Capital, and works with the executive team on developing and driving growth-oriented strategies.

Yeboah-Amankwah joined Intel from McKinsey & Company, where he was most recently a Senior Partner and Global Head of the Transformation Practice for the Telecom, Media, and Technology (TMT) practice, based in Washington, D.C. He was also the Global Lead of Client Capabilities for the TMT practice.

Previously, he served as Managing Partner for South Africa and Head of McKinsey’s TMT and Digital practice for Africa.

Yeboah-Amankwah received both his Bachelor’s and Master’s in Electrical Engineering and Computer Science from the Massachusetts Institute of Technology. He is a former Board member of the United Negro College Fund.

During his time in Africa, Saf was one of McKinsey’s experts on doing business in Africa, leading the firms work in digital and telecommunications across Africa. While in that role, he supported the turnaround of a leading local telecom operator and led a three-year transformation program at one of Africa’s largest retail banks. He also supported a global private-equity firm in turning around an Africa multinational, focused on the agricultural value chain. His other efforts helped a high-tech multinational develop a growth strategy for its African operations that led to a 3X improvement in sales, and he co-led a three-year transformation for one of the largest telecom OEMs, encompassing operations in North America, Europe, and Asia.

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Appendix E: Disclosures

This Study, DBB FY 24-02, *Creating a Digital Ecosystem*, is a product of the Defense Business Board. The DBB's recommendations herein are offered as advice and do not represent DoD policy.

The Secretary of Defense established the DBB in 2002 to provide the Secretary and Deputy Secretary of Defense with independent advice and recommendations on how "best business practices" might apply to the overall management of DoD. DBB's members, appointed by the Secretary of Defense, are senior corporate leaders with demonstrated executive-level management and governance expertise.

DBB members possess a proven record of sound judgment in leading or governing large, complex organizations and are experienced in creating reliable and actionable solutions to complex management issues guided by proven best business practices. All DBB members volunteer their time to this mission.

Authorized by the Federal Advisory Committee Act of 1972 (5 U.S.C. § 10) and governed by the Government in the Sunshine Act of 1976 (5 U.S.C. § 552b, as amended), 41 CFR 102-3.140, and other appropriate federal and DoD regulations, the DBB is a federal advisory committee whose members volunteer their time to examine issues and develop recommendations and effective solutions to improve DoD management and business processes.

Appendix F: Acronym List

AI	Artificial Intelligence
ARTS-V3	Advanced Radar Threat System-Variant
BOMs	Bills and Materials
CDAO	Chief Digital and Artificial Intelligence Office
CEO	Chief Executive Officer
CIO	Chief Information Officer
CERP	AF B-52, Commercial Engine Replacement Program
d-MOSs	Digital Military Operational Specialties
DAU	Defense Acquisition University
DBB	Defense Business Board
DFO	Designated Federal Officer
DIB	Defense Industrial Base
DMAG	Deputy's Management Action Group
DoD	Department of Defense
DON	Department of Navy
DMM	Digital Materiel Management
DSD	Deputy Secretary of Defense
EAG	Executive Action Group
EMD	Engineering and Manufacturing Development
F-1	Formula-1
FOC	Full Operational Capacity
KPI	Key Performance Indicators
FY	Fiscal Year
FYDP	Fiscal Year Defense Program
IDC	International Data Corporation
IDE	Integrated Digital Environment
IFV	Infantry Fighting Vehicle
IP	Intellectual Property (Data Rights)
IFV	Infantry Fighting Vehicle
LRIP	Low-rate Initial Production
MBSE	Model-based Systems Engineering
MOM	Manufacturing Operations Management
MOS	Military Operational Specialty
NIAR	National Institute of Aviation Research, Wichita State
MTA	Mid-Tier Acquisition
NDS	National Defense Strategy
NDIS	National Defense Industrial Strategy
NGAD	Next Generation Air Dominance
OEM	Original Equipment Manufacturer
OM&N	Operations, Sustainability, and Maintenance
OMIT	Operations, Maintenance, Installation, and Training
OSD	Office of the Secretary of Defense
OSD (A&S)	Office of the Secretary of Defense for Acquisition & Sustainment
OSD (P&R)	Office of the Secretary of Defense for Personnel & Readiness
OSD (R&E)	Office of the Secretary of Defense for Research & Engineering
OTA	Other Transactions Authority
PLM	Product Lifecycle Management
PM	Program Manager
PMSE	Program Model-based Systems Engineering

POM	Program Objective Memorandum
PPBE	Program Planning Budget and Execution
PRC	People's Republic of China
PTES	Protected Tactical Enterprise Service
PTS	Protected Tactical SATCOM
R&D	Research and Design
ROI	Return on Investment
SSC	Space Systems Command
TD	Technical Data
TIA	Totally Integrated Automation
ToR	Terms of Reference
USD (A&S)	Under Secretary of Defense for Acquisition & Sustainment
USD (P&R)	Under Secretary of Defense for Personnel & Readiness
USD (R&E)	Under Secretary of Defense for Research & Engineering

Appendix G: Glossary of Definitions

Authoritative Source of Truth	the reference point for models and data across the system lifecycle that provides traceability as the system evolves, capturing historical knowledge and connecting configuration-controlled versions of models and data.[68]
Deputy's Management Action Group	formerly DAWG, the Deputy's Management Action Group meets at the discretion of the Deputy Secretary of Defense to provide advice and assistance to the DepSecDef on matters pertaining to DoD enterprise management, business transformation, and operations and to strategic-level coordination and integration of planning, programming, budgeting, execution, and assessment activities of the Department.[69]
Digital Ecosystem	an interconnected infrastructure, environment, and methodology (process, methods, and tools) used to store, share, access, analyze, visualize, and interoperate evolving systems' data and models.[70]
Digital Engineering	the process of utilizing and integrating digital models and underlying data to create, modify, test, evaluate, assemble, and experiment in a virtual world before bending metal in the physical world for a program or system.[71]
Digital Model	a digital (i.e., in an electronic form, able to be read and manipulated by computer) representation of an object, phenomenon, process, or system. The representation can include form, attributes, and functions and may be depicted visually or described via mathematical or logical expressions.[72]
Digital Thread	an enterprise-level analytical framework designed to connect authoritative data and digital models across a system's lifecycle (i.e., product, processes, and performance) to provide decision-makers the capability to access, integrate, and transform data into actionable information, including a feedback loop.[73]
Digital Transformation	the definition can vary depending on the function or role of an organization. In general, it is the process of adoption and implementation of digital technology to create new or modify existing products, services, and operations by the means of translating business processes into a digital format.[74]
Digital Twin	a hyper-accurate real-time digital/virtual representation of a physical object. It integrates all data, sensor information, simulations, and models of the physical object, which are generated throughout its design, development, testing, manufacturing, operation, and service and sustainment.[75]
Digitalization	the process of leveraging digital technologies and digitized data to enable or improve processes[76] (e.g., computer files, connected data elements for a product, a configuration and all dependencies to move to a digital business operation[77]).
Digitization	the process of converting paper-based documents (e.g., text or visual aids) into digital form to be processed by a computer.[78]

Lifecycle Digitalization	the integration of digital technologies, data, and systems throughout the lifecycle (requirements, acquisition, and sustainment). This process involves incorporating innovations like collaborative platforms, AI, predictive analytics, digital twins, and automation.[79]
Model-based Systems Engineering	an innovative approach to system engineering utilizing models as a central tool to design and manage complex systems. In MBSE, a model represents the entire system or specific aspects, serving as a visual representation of requirements, behavior, structure, and more.[80]
Red Team	an ad-hoc organizational element designed to provide an independent capability to fully explore alternatives in plans and operations in the context of the operational environment and from the perspective of adversaries.[81]

Appendix H: Additional Details to Support Recommendations

Governance & Organization

1. **Assign** the **Deputy's Management Action Group (DMAG)**, or similarly scoped body with like charter and membership, **as the** central **leadership authority for developing the Defense Digital Ecosystem** across all the Services, ensuring compliance with enterprise-wide digital strategies and instructions to defragment current Department efforts. The DMAG would be responsible for finalizing the departmental vision, ensuring implementation efforts are all aligned and focused on the stated goals and vision, serving as a champion for resources and other support and incentives.

   Transformational change requires sustained, enterprise-wide leadership support with ruthless prioritization and focus by the most senior members of the leadership team. This does not yet exist within DoD for the creation of the digital ecosystem, which all interviewed agree is a core national security imperative. While the recent USD (R&E) Instruction, DoDI 5000.97 "Digital Engineering," is helpful and effectively sets forth some of the functional responsibilities necessary for a transition to digital engineering, it does not, nor can it, set forth the requisite structure of leadership and accountability. The highest levels of DoD leadership must lead the charge, including the Secretary; the Deputy Secretary; Under Secretaries for Acquisition, Research, Development and Sustainment; Service Secretaries and the Joint Chiefs of Staff; the Service Vice Chiefs; and Chief Information Officers. The DMAG, or similarly scoped body, is comprised of all of the appropriate OSD and Service officials and, therefore, the Subcommittee agrees it is the most logical entity to oversee and drive change of this magnitude.

   Provide leadership and accountability for efforts to:

   - construct an enterprise-level digital ecosystem capability as a top management and national security priority;
   - serve as the overarching leadership body to guide its execution and unify efforts across DoD enterprise;
   - establish metrics (recommended KPIs in Section VI) and hold appropriate functional organizations accountable for meeting appropriate targets;
   - serve as the champion for requisite funding and other resources; and
   - avoid establishing a dedicated office or "chief" to drive this level of transformational change.

2. **Convene an Executive Action Group (EAG) to remove barriers to change**. Co-chaired by the USD (A&S) and USD (R&E), the EAG would be tasked to lead the execution of a Department-wide digital strategy; coordinate across DoD Components; and identify and remove barriers to implementing an enterprise-wide digital ecosystem. Efforts would include collaboration and coordination with the Services, the DIB, and non-traditional business associations. The EAG will report directly to the DMAG, or similarly scoped body, as its primary Governance Supporting Tier Forum.

   - The Executive working group will serve as the Supporting Tier Forum for topics requested by or presented to the DMAG, or similarly scoped body, for decision. Membership should include the following principals: USD (A&S), USD (R&E), CIO, CDAO, Service Acquisition Executives (without delegation), and OSD / Service Digital Transformation Principals.

- Mission:
    - Set and monitor policy for the acceleration of creating a digital ecosystem capability enterprise-wide.
    - Identify, elevate, or resolve ecosystem issues related to infrastructure and architecture to include: hardware, software, networks (including cloud services), tools, and workforce.
    - Monitor, evaluate, and report on implementation progress throughout the Department.
    - Work with each of the Services to establish formal offices and task forces, similar to the Air Force Digital Transformation Office and Digital Acceleration Task Force, to centralize communication, find solutions, remove barriers, and collaborate on joint efforts.
    - Coordinate across the Department to develop enterprise-wide solutions to common barriers.
    - Promote and oversee ecosystem pilot programs, experiments, and initial implementations of digital ecosystem efforts throughout DoD and the Services and provide leadership for scaling of successful initiatives.
    - Provide funding to support enterprise-wide solutions/and oversee the execution of DoD central Digital Ecosystem fund if approved.
- The success of this recommendation will be apparent by the measurable adoption and acceleration of an enterprise-wide Defense Digital Ecosystem capability that supports digital engineering, acquisition, and sustainment. This will be measurable through a reduction in time from requirements to production, an overall reduction in program risk, increased operational availability, and warfighter readiness.

3. **Expand and formalize industry** (both the DIB and non-traditional enterprises) **participation in the development of solutions** to critical policy and other barriers to the creation of the digital ecosystem, including but not limited to, IP policy, standards development, etc.
    - USD (A&S) and USD (R&E)
    - Build a public/private partnership – a coalition of Industry (DIB and Non-Traditional) C-Suite Level executives to include the Assistant Secretaries (OSD); Under Secretaries of the Services; DAFAs; and other interested parties. Hold quarterly or semi-annually brainstorming sessions, resulting in action items to:
        - define common [Industry] standards, definitions, set of metrics, data format, interoperable tools, and recommendations;
        - advise on policy and practices to accelerate an interoperable digital ecosystem for all and provide resources (e.g., if DoD mandates all new programs must be born digital, then provide free software licenses to subcontractors, at a certain level, to help all necessary players adopt practices, driving speed of adaptation); and
        - provide recommendations on where to apply centrally-mandated funding for the most impact on creating a digital ecosystem.
    - Success for this recommendation would be a coalition / ad hoc group of OSD as well as Service and DAFA leaders partnered with C-Suite Industry leaders, all working towards the establishment of a trusted, interoperable ecosystem designed to enable collaboration and development of DoD weapons systems.

Planning & IT Infrastructure

4. **Develop collaboration platform architecture and roadmap** for all suppliers to use to digitalize requirements management, design & development, testing, production, operations, and sustainment throughout the life cycle. Some parts of DoD, like the Air Force Digital Materiel Management initiative[82], are already progressing in this direction using the Air Force Digital Building Codes[83]. We propose adopting similar interoperable platforms to drive cross-industry/DoD collaboration and speed up program cycles to stay competitive. These architectures must address requirements management, design platform(s), a Product Lifecycle Management platform, digital twin of systems, data analytics and visualization tools, and the hosting environment required for interoperability.

    - Each Service and organization with acquisition authority will develop a platform architecture and roadmap for implementation to support digitalizing the program lifecycle.
    - A collaborative environment will include the key architecture components below:
        - Requirements Management/Design Platform: Electronically input all program requirements into a requirements management platform. Collaborate with all suppliers in the early stages, including the pre-design stage, and require a firm interlock before moving to design and development to ensure alignment. Manage early design and modeling requirements, within the same system for end-to-end traceability, to avoid rework, and to reduce cycle times. Using a requirements management platform will also enable the Department to provide visibility and share requirements across programs.
        - Product Lifecycle Management Platform: Load all program Bills of Materials (BOMs), including technical and design specifications, into a joint PLM environment to serve as an authoritative source of truth to document and adjust them throughout the lifecycle from idea to obsolescence. This ensures scalability, parts production longevity, and continuity and helps understand sourcing / supply constraints.
        - Digital Twin Systems: Utilize detailed information from PLM and design systems to create robust digital twins for predictive maintenance and enhanced AI / ML capabilities.
        - Data Analysis and Visualization Tools: Integrate data from core platforms (i.e., requirements, PLM, and digital twin platforms) and field performance into visualization tools for insightful analysis.
    - Successful implementation of this recommendation is the creation of a collaborative, interoperable environment that allows industry and DoD to contribute to the development and sustainment of a product throughout its entire lifecycle with common software tools, enabling coordination of efforts, continuity of information, and continuous curation of product data.

5. **Establish a common vision and taxonomy** across the Department, the Services, various Chief offices, the DIB, and non-traditional enterprises. The current decentralized transformation efforts will be accomplished more effectively once a common language, set of guidelines, and best practices are developed to communicate intent, focus areas, technical needs, and areas of responsibility. Refresh the vision annually with new industry tools, processes, and best practices.

- Consistent with the recommendations outlined in the *Building a DoD Data Economy* study conducted by the Defense Innovation Board (DIB), we recommend that DoD Chief Digital and Artificial Intelligence Office (DoD CDAO) lead the effort to establish a common data vision and taxonomy.
- DoD CDAO should convene a team made up of the responsible leaders across the Department, the Services, various Chief offices, the DIB, and non-traditional enterprises to deliver a written vision and language ("data dictionary") to be used consistently in the development, sharing, and interoperability of data. This team should:
  - meet weekly (*consider using agile methodology*) to ensure progress is being made;
  - provide monthly status reports to the DMAG, or similarly scoped body / Executive Action Group; and
  - meet at least quarterly to review needed updates once the initial taxonomy is delivered.
- Data is the foundation of a digital ecosystem. To maximize its benefits, clear definitions must first be established so communication is effective, and interoperability is established.

6. **Develop standards for data interface and interoperability within and across the digital ecosystem(s) throughout the Department and the DIB.** Technical interface standards among the "digital-doers" are essential to accelerate change; establishing a baseline for a common digital language, with clear expectations and data requirements, is a critical first step.
   - DoD CDAO to work with CTOs and CIOs to establish data interface standards and interoperability.
   - DoD CDAO to convene a team to define standards and test interfaces.
   - Given the amount of data available across the Department, it is imperative that standards be defined to allow broad access and use.
7. **Require all functional stakeholders from and across the product lifecycle (e.g., contracting officer, engineers, designers, logisticians, manufacturers, sustainers, operators, etc.) to participate in the digital ecosystem planning for program design and development.** Understanding and defining the end-state requirements at the beginning of the program will support all stages of the lifecycle; safeguard the acquisition process; and ensure sustainment and performance data are connected via digital threads. Progressive efforts must include expertise from all phases of the acquisition process to account for interrelated processes, data needs, and information flows.
   - DoD OSD (A&S) to work with OSD (R&E) and the Services.
   - Establish minimum viable functional participation in the development of the ecosystem and prioritize activities that will lead to near-term and measurable returns on investment.
     - The formal practice of Systems Engineering requires the consideration of the entire lifecycle to develop, resource, and deliver capabilities that can be sustained.
       - This is especially true for building the foundations of a successful ecosystem that will provide services to each of the functional disciplines, managers, and operators. In such an endeavor, *the developers of the system are the users of the system* (and vice versa), and the user base is larger than what is normally considered when executing the individual phases of acquisition.

        - Integrated Product Teams must include decision-makers from research, development, test, manufacturing, operations, and sustainment if a viable ecosystem is to be realized.
    - In several interviews, the Subcommittee recognized that rather than starting with product design, a best commercial practice is to start with a deep understanding and mapping of the customer / user experience and then work backward to identify those current processes or practices that can or do inhibit significant change and innovation.
        - In the context of the Department and this Study, the development of data continuity across the lifecycle must begin with a similar approach. Sustainment, supply chain logistics, funding, and contracting practices must all be assessed at the front end to effectively map the path to rapid "delivery to market" and continual improvements in performance and operational availability.
            - From there, the dependencies on supply chain insight, product data, maintenance, operations, and others can be systematically addressed, digitalized, and modernized.
        - While ultimately the interdependency of the lifecycle phases is asynchronous, this process will continue to evolve as the program matures, is fielded, upgraded, supported, and ultimately retired.
- Supply Chain modernization is an opportunity to demonstrate the benefits of digitalization and to identify clear and specific data element needs that can be developed further over time - backward along the lifecycle, introducing more customers and data needs as it goes. To do this, the Department and the Service participants must change their approach to develop a viable "digital thread" from a perspective of a 'push' from development to a 'pull' from sustainment.

Cultural Environment

8. **Establish a deliberate process based on proven change management techniques and principles**, including milestones and tollgates. A DoD formal change management plan must include a focus on driving culture change which is required with large transformational efforts, including a clear vision; leadership; governance; performance metrics and accountability; workforce incentives; and funding.

    - The Secretary and Deputy Secretary must lead this effort and include the Under Secretaries for Acquisition, Research, Development, and Sustainment; Service Secretaries and Service Under Secretaries for Acquisition, Research, Development, and Sustainment; and the Joint Chiefs of Staff and the Service Vice Chiefs. The DMAG, or similarly scoped body, can serve as a quarterly reviewing body reporting directly to the Deputy Secretary.
    - Objectives:
        - Engage private-sector leaders to discuss approaches to culture change in large organizations.
        - Quantitatively measure the current values related to development, acquisition, and sustainment of Department capabilities.
        - Select a culture change approach to which the Department leadership can agree and then intentionally align it with strategy, resources, and structure.

- Ensure broad stakeholder engagement and participation in the change process.
- Employ a Department-wide communication strategy to promulgate culture change values and objectives across the force.
- Develop a system to highlight, reinforce, incentivize, and reward actions in the Department that support the creation of a digital ecosystem.
- Be prepared to manage emotional responses to the culture change.

- Success in creating a digital ecosystem will primarily depend on leaders who embrace change and new, novel approaches to how we develop, acquire, and sustain military capabilities and can articulate to the workforce and stakeholders why this is a necessary evolution for the Department of Defense.

9. **Actively address the institutional resistance to risk in the change management plan**. To overcome resistance, the Department's leadership must actively and explicitly incentivize and support program managers and frontline workers who, while pursuing change, are assuming reasonable risk.

   - This Secretary and Deputy Secretary must lead this effort and include the Under Secretaries for Acquisition, Research, Development, and Sustainment; Service Secretaries and Service Under Secretaries for Acquisition, Research, Development, and Sustainment; and the Joint Chiefs of Staff and the Service Vice Chiefs. The Executive Action Group, as discussed in recommendation 6, can take the lead on this recommendation and serve as a quarterly reviewing body reporting directly to the Deputy Secretary.
   - Objectives:
     - Identify and understand resistance issues;
     - Review and streamline decision authorities;
     - Set challenging, achievable, engaging, and measurable goals;
     - Articulate acceptable levels of risk for high-gain, high-value programs that support Departmental priorities and strategies;
     - Create a system to acknowledge and reward risk-taking that results in big wins for the Department; and
     - Be prepared to address resistance through communication strategies, changes in organization, policy, and leadership, or removal of those who cannot embrace new approaches.
   - Key to orchestrating effective change is embracing and supporting risk-taking by subordinate leaders who are actively engaged in pursuing programs that directly support Department priorities and strategy.

10. **Incentivize and reward personnel to adopt digital skills** and to take on digital initiatives, including Department-wide award programs recognizing outstanding performance in the pursuit of innovation and accelerating the digital ecosystem.

    - This effort must be led by the Under Secretary of Defense for Personnel and Readiness (USD (P&R)) answering to the Deputy Secretary of Defense. Critical to success in this recommendation is gaining the collaboration and support of the Service Assistant Secretaries and uniformed Personnel and Readiness Chiefs.

- Objectives:
    - Establish a high-level steering committee consisting of the leaders identified above, answering to the Deputy Secretary, that is charged with assessment, planning, execution, and reporting on progress toward the goal of a digitally enabled workforce.
    - Review the 2023 DBB study on *Building a Civilian Talent Pipeline* Study to identify applicable recommendations and action to support the adoption of digital skills.
    - Assess required skills and current inventory of unique skills necessary to support a digital ecosystem.
    - Pursue relationships with academic and industry organizations to provide opportunities for skill development and appropriate certification.
    - Develop a strategy for marketing requirements, identifying resources for re-training, education, and certification.
    - Create a program that provides financial and other incentives for DoD workers to become certified in specific, high-demand digital skills.
- A digital ecosystem will not be optimized without human talent trained and enabled with the skills necessary to operate effectively. In addition to bringing into the Department young, innovative digital natives the Department must have an aggressive and forward-looking program to re-train and educate the current workforce on necessary skills.

11. **All leaders at all levels must include digital skills objectives in performance evaluations**. Providing a mixture of positive encouragement and valued incentives with clear expectations for advancement will assist in overcoming workforce uncertainty, risk aversion, and inertia. Including digital objectives in yearly performance plans and assessments has proven to have a profound affect in driving adoption, encouraging re-skilling of the workforce, and accelerating transformation across the Department.

    - The Secretary and Deputy Secretary must direct this effort, with the support of the Service Secretaries and Chiefs of Staff. The USD (P&R) at OSD and in each of the Services will be responsible for promulgating policy and direction for implementation.
    - Objectives:
        - Convene a high-level working group answering to the USD (P&R) to identify specific performance objective(s) with metrics and determine which levels of leadership throughout the Department should include this in their performance evaluations.
        - Assess private-sector best practices and consider a pilot program in one Service or a limited number of Programs.
        - Issue Department-wide guidance for adoption and execution.
        - Design a mechanism to assess progress and effectiveness.
    - Establishing responsibility and accountability in leadership at multiple levels will ensure the implementation of digital ecosystem objectives across the Department of Defense.

Talent & Training

12. **Establish distinct digital ecosystem pathways for both military and civilian personnel to include clear opportunities for advancement and leadership**. Civilian personnel career pathways must be associated with a combination of education, training, functional expertise, and practical experience. Within the Services, a clearly defined and promotable ***digital military operational specialties*** (MOS) will enable the recruitment and retention essential to developing the uniformed Services' digital capabilities.

    - The Secretary and Deputy Secretary must direct this effort, and the USD (P&R) must develop it.
    - Develop technical career paths for individuals dedicated to digital engineering.
        - Create a clearly defined digital military operational specialty (MOS) for specialized skills that include the unique needs for managing data within a shared environment throughout the lifecycle (e.g., data curation, API programmer, and cloud storage maintainer.
        - Define the digital skills for fully qualified digital professionals.
        - Assure the Defense Acquisition University has a program and place to support such digital qualifications.
        - Review the plans and processes taking place in the Cyber domain for the development of talent career pathways and coordinate to expand these efforts to include digital engineering and data management disciplines.
    - Current active-duty personnel sometimes resist digital missions, concerned that the assignment will impact career paths and promotability.
    - Once the Department has institutionalized acquisitions in digital ecosystems, these fields may no longer be necessary as this work would be the "new norm" after 10-15 years; however, to accelerate the development of an ecosystem(s), the establishment of these specialties will enable recruitment and retention of these in-demand skillsets.

13. **Assign OSD Personnel & Readiness (OSD (P&R)) in collaboration with CDAO to develop a strategy to rapidly recruit highly specialized and in-demand technical disciplines** that support digital modernization initiatives. The strategy shall include a plan to address how best to exploit recruitment incentives, special pay options, and other authorities essential to lessening the gap with the private sector for in-demand jobs.

    - The Secretary and Deputy Secretary must direct this effort, and the Service Secretaries and the USD (P&R) must direct it.
    - Objectives:
        - Formalize a recruiting function specifically focused on building talent pipelines to attract, recruit, train, develop, and retain a comprehensive digital workforce.
        - Integrate, and or modify existing, DoD HR activities to source, assess, cultivate, and formalize the digital talent required from both within the Department and new hires.
        - Deliver critical skills development and training and implement a skill-tracking system to capture current and future employee competencies.
        - Establish a Digital Brand and address the value proposition for talent operating in the digital ecosystem. This declaration of intent must include both an identity of its own

as well as programs linked to academic and private-sector organizations, emphasizing opportunities and value associated with collaborations.

- Remove legal, policy, and organizational impediments that prevent bringing the highest quality people into DoD digital ecosystem and pursue initiatives to address competitive pay, incentives, and onboarding processes.
- Identify factors that will allow DoD to compete in a highly competitive marketplace with industry.

- The Department currently lacks the full scope and depth of workforce skills to enable an accelerated transition to a digital ecosystem and does not become a clear pathway to acquire the talent it needs.

14. **Expand and fund opportunities for critical skills development to close the gap between experienced workforce professionals and technically skilled "digital-doers."** Like Industry, DoD must combine focused education with on-the-job training and foster working collaborations. Invest in and develop the digital ecosystem workforce through multiple opportunities, including upskilling, reskilling, mentorships, internships, workforce development, education, and training.

    - The Deputy Secretary should task the Defense Acquisition University to implement and offer new coursework focused on building the key skills directly associated with doing business in an increasingly digital marketplace.
    - Objectives:
        - Assure the funding and resources are available for DAU to implement new programs.
        - Partner seasoned employees with digitally skilled talent to advance the skills of both.
        - Expand DAU and other available courseware focused on building the key skills associated with a digitalized environment.
        - Require program offices to conduct organization team training exercises at the outset of any digital initiative (new programs or legacy) to ensure alignment and organizational maturity necessary for success.
    - Civilian and military job classifications have not kept pace with the emergence of niche technical disciplines and specializations. Training, while expanding, is not yet nearly as broad or broadly available as it needs to be. And too much training is focused on the individual rather than the organization.

Funding & Resourcing

15. **Establish a centralized OSD Managed fund for the Services and programs to effectively compete for resources to support and accelerate enterprise-wide digitalization**. The Department needs to prioritize the establishment of the Defense Digital Ecosystem as a strategic investment. This is the way a large, diverse, private-sector enterprise would go about this challenge to enable the implementation of cross-cutting and horizontally integrated digital transformation initiatives. Providing a general fund to resource digital change will assist the rapid scaling of universal capabilities; promote the adoption of digital initiatives throughout the lifecycle; and provide the flexibility to adjust, adapt, and focus needs without the process restrictions of the PPBE.

- The Undersecretary of Defense (Comptroller) / Chief Financial Officer, or other suitable delegate, tasked by the Deputy Secretary of Defense, will be the primary owner of a centralized fund for initiatives proposed to the Deputy Secretary of Defense or Comptroller for funding. Funding awards will be made based on the review of and recommendations from a digital fund sub-committee consisting of the Comptroller and Executive Action Group.
- A Centralized digital fund for the Services and digital programs to compete with resource programs.
    - Identify Digital Ecosystem as an investment priority.
    - Establish a general fund and target investment level to resource digital change and Modify PPBE process to alleviate "color of money" restrictions. While we recommend this approach, this may have to be done in an installment fashion:
        - (a) use current DoD authority to recover funds and then re-allocate according to initiative prioritization.
        - (b) over time, FY 2025 – FY 2026, given the amount of funding necessary, pursue legislative action for a centralized DoD fund.
    - Establish ROI objectives for Digital Ecosystem investments and work with DoD partners to track.
    - Specify guidelines and incentives to promote the adoption of digital initiatives throughout the lifecycle:
        - born digital programs; retire legacy systems; and / or reduce maintenance cost.
        - programs that span full lifecycles (alone or with other initiatives).
        - systems that can talk across components / systems.
        - initiatives that enable rapid scaling of universal capabilities.
    - Ensure requests have clear business case returns in dollars and timeframe and a quarterly reporting loop tied to ongoing funding.
    - Encourage test and learn – pilot programs across the Services and be tolerant of risk.
- Innovation requires investment. Establishing a centralized fund is required to break away from cycles of investing in silos and fractional solutions across DoD. A centralized fund is imperative to improve agility and accelerate the rapid scaling of universal digital ecosystem capabilities. The success of this recommendation will be measurable through KPIs such as: (1) # of qualified digital initiatives; (2) % of annual DoD budget spent on qualified digital initiatives. See KPI section for additional KPI recommendations.

Intellectual Property

16. **Mandate regular progress reports from the Intellectual Property Cadre to the DepSecDef through the DMAG,** or similarly scoped body, highlighting advances in DoD IP developments and outstanding issues with firm timelines for solution development. All efforts to address IP and tech Data rights should include early collaboration with a cross-section of industries and experts from the defense and commercial sectors. Accountability for execution must include clear objectives for all functional elements and metrics to measure effectiveness and impact on cost and operational availability.

Appendix I: Key Performance Indicators

Table 1: C-Level KPIs to guide DoD's digital ecosystem journey, ensuring a holistic view and effective progress monitoring

		KPI	Description	Measurement	Purpose
C-Level KPIs to Guide Digital Ecosystem Progress	1	**Return on Digital Ecosystem Investment (ROI)**	Quantifies benefits (e.g., speed, cost avoidance, cost efficiencies) relative to costs	ROI = (Project Benefit / Project Cost) × 100	Assess project effectiveness
	2	**Budget Allocation for Transformation**	Reflects commitment to digital initiatives	Percentage and dollar amount allocated	Gauge resource dedication
	3	**Speed of Capability Development**	Measures time to build digital capabilities	Average time for tool, app, or infrastructure enhancement	Indicate agility and progress
	4	**Leaders' Time Devoted to Transformation**	Incorporates digital efforts into evaluations	Percentage of leaders' time or resources	Evaluate organizational commitment
	5	**Attracting and Retaining Technical Talent**	Vital for ecosystem success	Number of top technical professionals	Monitor talent acquisition and retention

Table 2: Second Level Digital Ecosystem KPIs to ensure DoD makes progress on key themes and continuous monitoring.

		KPI	Description	Measurement	Purpose
Governance & Organization *Goal: to promote inclusion and accelerate change.*	1	**Digital Ecosystem Progress Review Frequency**	Regular assessment and discussion	# of instances reviewed and discussed (DMAG and EAG)	Monitor progress and alignment
	2	**Industry Partner Participation**	Collaborating for ecosystem solutions	# of industry partners involved in development	Foster external expertise and innovation
	3	**Digital Native Programs**	Embracing digital from inception	% of new programs designed as digital native	Drive modernization and efficiency
	4	**Digital Transformation of Legacy Programs**	Adapting existing programs	% of legacy programs transformed to digital	Balance continuity and innovation
Planning & IT Infrastructure *Goal: to establish an ecosystem necessary to share data across the supply chain.*	1	**Supplier Certification and Alignment**	Ensuring collaboration across the supply chain	% of suppliers certified and aligned to DoD platforms measured in total AND by Prime / Tier 1-3 supplier.	Encourage participation and track impact
	2	**Electronic Program Requirements**	Efficient management of program requirements	% of requirements loaded into a management platform	Enhance transparency and streamline processes
	3	**Bills of Materials (BOMs) Management**	Technical and design specifications integration	% of BOMs loaded into a PLM environment	Improve product development efficiency
	4	**Digital Twin Systems Deployment**	Leveraging digital replicas for insights	Number of Digital Twin systems in use	Enhance maintenance and performance monitoring
	5	**New Program Development Cycle Time**	Accelerating program creation	Average time for new program development	Meet targets and reduce time-to-market
Cultural Environment *Goal: to increase risk tolerance and speed.*	1	**Leaders' Time Devoted to Transformation**	Incorporates digital efforts into evaluations	Percentage of leaders' time or resources	Evaluate organizational commitment
	2	**Digital Skills Development Objectives**	Enhancing leaders' capabilities	% of performance plans focusing on personal digital skills	Foster continuous learning and growth
Talent & Training *Goal: to increase workforce readiness.*	1	**Top Technical Talent Attraction, Promotion, and Retention**	Measuring talent impact	# of data scientists and specialists retained	Ensure a skilled workforce
	2	**Training Completion for New ACAT 1 Programs**	Enhancing skills for critical programs	% of resources completing training within 12 months or 90 days of program establishment	Align workforce with program needs
	3	**Training Completion for High-Priority Legacy Programs**	Addressing risk and obsolescence	% of resources trained for programs with components at risk	Mitigate operational shortfalls
Funding & Resourcing *Goal: to commit and deploy necessary resources.*	1	**Budgetary Resources for Digital Ecosystem**	Allocation for change management, apps, and infrastructure	Amount of budgetary resources defined/committed	Drive transformation initiatives
	2	**Projected Cost Growth Variance**	Monitoring program cost changes	Variance from approved business case	Control program costs effectively
	3	**Return on Digital Ecosystem Investment (ROI)**	Quantifies benefits relative to costs	ROI = (Project Benefit / Project Cost) × 100	Assess project effectiveness

Appendix J: Case Studies

Northrop Grumman Case Study: Digital Ecosystem Brings Employees, Customers and Partners into an Integrated Environment
Driving Quality, Speed, and Efficiency

VinFast Case Study: Fully Digital Factory Accelerates Vehicle Manufacturer into Fast Lane
Unprecedented Speed and Scale Launches First-Ever Vietnamese Car in Record Time

BASF Case Study: Digital Transformation Safeguards Chemical Company's Sustainability
Political Turmoil, Climate Impacts, and Energy Market Disruptions Affect Global Supply Chain

Flex Case Study: Digitalization Saves the Supply Chain
Digital Technologies Replaced Hands-on Interaction During Covid Crisis

Toyota Case Study: Innovative Solutions Disrupt and Improve Traditional Methods
TILT Lab: Ahead of Its Time in a World of Digitalization

Collins Aerospace Case Study: Digital Twin Solves Crisis
Digital Model Rapidly Speeds Up Delivery

Bye Aerospace, Inc. Case Study: Dials In and Iterates to a 99% Solution
Digital Tools Enable Single Modification to Aircraft Model to Morph All Related Activities

Volvo CE Case Study: Accelerates Digital Thread to Improve Legacy Systems
Real-time Data Fosters Seamless Product Lifecycle

NIAR Case Study: Engineering Digital Twins to Create Predictive Behaviors
Digital Twin Program Leads to Sustainment Support & Life Extension

United States Navy Case Study: US Navy's Shipyard Infrastructure Optimization Plan (SIOP)
Major Modernization Effort Underway, Utilizing Digital Twins

Joint Strike Fighter F-35 Case Study: Model-based Systems Engineering Produces Results
Empowering F-35 Digital Engineering Transformation

A-10 Case Study: Air Force Digitized Wing Data into 3D CAD on Legacy Aircraft
Major Modernization Effort Underway, Utilizing Digital Twins

Air Force B-21 Case Study: Digitalization Delivers Major Weapons System in 8 Years
Digitally-designed Bomber, the B-21, Intended to Penetrate Today's Air Defense

T-7A Case Study: Advanced Pilot Training System, Poster Child for Digital Engineering
Air Force Establishes Precedent for Digital Infrastructure

Air Force LGM-35A Sentinel Case Study: Virtual Models Modernizing Real Weapons Systems
Sentinel ICBM Using Digital Twinning at Every State of Program Lifecycle

Northrop Grumman Case Study: Digital Ecosystem Brings Employees, Customers and Partners into an Integrated Environment
Driving Quality, Speed, and Efficiency

Northrop Grumman (NG) Corporation is a leading global aerospace and defense technology company. With over 100,000 employees and an annual revenue of nearly $40 billion, it is one of the world's largest weapons manufacturers and military technology providers. From air, space, and cyber to land and sea, the company is focused on multiple domains and innovative production of some of the most advanced systems in the world.

To facilitate this, NG has implemented a large-scale digital transformation: including an integrated digital ecosystem; advanced digital engineering tools; AI enabled operations; AR/VR systems; and extensive automation. Moreover, the focus is heavily on a "digital culture" from the leadership-level and across the entire company to foster rapid adoption and innovation. Of note, is the company's implementation of a comprehensive digital ecosystem.

Kathy J. Warden, Chair, Chief Executive Officer and President of Northrop Grumman noted its transformative impact, "We've built a digital ecosystem that focuses on program execution, bringing together employees, customers, and partners into an integrated environment, so they can seamlessly work together. This accelerates design, integration, testing, and deployment across programs, helping us to deliver with quality, speed, and efficiency. We're increasing the number of programs that are operating in this ecosystem. And today, we have over 100 active programs that are doing so. We're also investing in and advancing the technologies and digital systems in our factories."[84]

The environment is being used across all parts of Northrop Grumman, including satellite programs, aircraft development, sensor programs, missile programs, and many other initiatives. "This solution is helping us connect our product development capabilities directly with the customer's mission, "Dr. Chris Orlowski, Director of Digital Engineering at Northrop Grumman explains, "Because as our customers face a continuously changing operational environment, we're supporting them, so they are best prepared to adapt, transform, and respond with speed ahead of any emerging threats." [85]

NG's integrated digital environment allows different players to access critical information they need when they need it. From systems engineers, analysts, and designers to manufacturers, supply chain managers, and the end-customer, every stakeholder can collaborate with the same data in real-time.

VinFast Case Study: Fully Digital Factory Accelerates Vehicle Manufacturer into Fast Lane
Unprecedented Speed and Scale Launches First-Ever Vietnamese Car in Record Time

VinFast is targeting to become South East Asia's leading passenger vehicle manufacturer and a remarkable new player in the global automotive industry. The Vietnamese car manufacturer built a fully digital automotive factory in 21 months, 50% faster in time to market than usual, and easily scalable for future expansions.

Utilizing the latest technology, VinFast designed digital twins of products, the production, and the performance of production and product, creating a closed-loop manufacturing system. The comprehensive digitalization process combines Product Lifecycle Management (PLM) software, Manufacturing Operations Management (MOM), and an integrated digital operations center for manufacturing across all phases. This coupled with Totally Integrated Automation (TIA) for all automation, including robots, conveyors, presses, and milling machines, creates a holistic approach -- resulting in increased speed and flexibility in development; ensuring high global standards in production; optimizing the manufacturing process; and ensuring the entire plant is future-proof for further expansions and new business models.

Merging the virtual world with the real world, digital tools provide new insights, physics-based simulations with data analytics in a fully virtual environment, and more reliable results faster with fewer real prototypes. A high-performance digital infrastructure provides performance data of the real production and of the real product to be analyzed and fed back into the development cycle for improvements, optimization, and innovation at an early stage.[86]

BASF Case Study: Digital Transformation Safeguards Chemical Company's Sustainability
Political Turmoil, Climate Impacts, and Energy Market Disruptions Affect Global Supply Chain

Headquartered in Ludwigshafen, the world's largest chemical production site spanning ten square kilometers, BASF digitally transformed to ensure longevity and sustainability in uncertain and unpredictable environments, such as political turmoil, climate impacts, and energy market disruptions. BASF's digital transformation was the foundation for its virtual plant, ensuring the flow of real-time data over the entire lifecycle of facilities and production processes. With more than 111,000 employees around the world and with 39,000 of those at headquarters, BASF has relied on digitalized work processes to optimize measures and apply ideas faster and on a digital twin to meet the challenge of adapting plants constantly to changing ambient conditions.

"Imagine you're an optimization engineer and your goal is to improve yields or energy efficiency. You're analyzing the plant's historical data, you see oscillations or other problematic behavior, and you want to know the reason why," said Matthias Roth, Senior Automation Manager, Advanced Process Control BASF. "It could be changed ambient conditions, changes in raw materials, but also changes in equipment, in parameters that are implemented in the automation system. You need access to all this information."

The first step was to integrate data and interconnect existing software tools, with a well-established process control system, plant engineering tools, and simulation software, creating a virtual operation and a universal flow of data across BASF's facilities. The second step was to merge data with a digital simulation, creating a real-time virtual plant, or digital twin, to test ideas. With digital devices everywhere and with the ability to change parameters to measure flow, a full picture of what is implemented in a plant was easy to create – from the DCS level down to the field level with installed sensors and actuators. Digital process twin technology uses state-of-the-art mathematical techniques to analyze and optimize process design and operation, reduces development time, and enables design and test processes virtually before using valuable raw materials in a real production plant.

The digital twin accessed across all facilities allows BASF to optimize production processes and minimize resource use and development time to meet current challenges, including high energy prices and the high cost of raw materials.[87]

Flex Case Study: Digitalization Saves the Supply Chain
Digital Technologies Replaced Hands-on Interaction During Covid Crisis

Less than a year after becoming CEO of Flex Ltd., Revathi Advaithi faced one of the most serious threats in the company's half-century history. The novel Coronavirus pandemic shut down the world's manufacturing center in China, disrupting supply chains and underscoring the hazards of a globalized economy. Faraway factories once celebrated for delivering lower costs, now seemed a fatal vulnerability.

For Flex, a Singapore-based manufacturer with 100 facilities in 30 countries, the consequences were most acute. Some of its 21 factories in China, where the Coronavirus outbreak prevented millions of workers from reaching their jobs, stayed closed for weeks. Additionally, a plunge in trans-Pacific air travel created obstacles for manufacturers who depended heavily on airlines to move goods and people.

As the pandemic reshaped global demand, Flex factories suddenly were either producing too many parts while others were not producing at all. The crisis peaked in February when Advaithi learned Flex factories faced shortages of 8,000 individual items — roughly five times what Flex dealt with on a typical day. If the shortfalls of electronic components such as memory chips, connectors, and LCD panels were not quickly resolved, production would grind to a halt.

In response to the dire situation, production specialists re-created an entire ventilator assembly line in Mexico from copying US images captured on a virtual reality system. Using a wall-size, touch-screen display, supply chiefs at a California command center tracked the status of 16,000 suppliers and more than 1 million individual parts using a data analytics tool. Near real-time information on every .0005-cent screw to each integrated circuit costing hundreds of dollars was provided in a single cohesive view of the multinational operation. Real-time data enabled Flex to filter its supply chain by specific locations, not just the country of origin.

With global travel nearly impossible, digital technologies were substituted for the hands-on interaction the virus had stifled. Zoom meetings became vital to coordinate actions happening thousands of miles away, soaring from 63,000 in December to 226,000 in April. By early May, Flex had redeployed hundreds of remote workers, accelerated production of medical gear required to fight the pandemic, and made its way to a narrow profit.[88]

Toyota Case Study: Innovative Solutions Disrupt and Improve Traditional Methods
TILT Lab: Ahead of Its Time in a World of Digitalization[89]

"The TILT Lab is a restriction-free sandbox allowing any idea, utilizing any software and/or technology to quickly flow through its Proof-of-Concept process, increasing team members' skills and innovation with the overarching idea that digitalization helps achieve sustainability."

~ Mark Kuzniarski, analyst, Digital Intelligent Manufacturing Engineering Group at Toyota

The shift towards digitalization in the manufacturing engineering world provides new opportunities to improve processes and to produce better products -- innovative solutions disrupt and improve traditional methods. To reduce the high cost and long lead times of physical prototypes, Toyota created the TILT Lab -- a place where team members are encouraged to 'tilt' their conventional thinking on its axis and to help them see concepts through to prototypes.

The TILT Lab offers everything from 3D printing, augmented reality, and virtual reality technology to lasers. The Lab enables teams to bring their wildest ideas to life. Once proven, TILT Lab creations may be applied at Toyota plants to improve processes or solve challenges. Specific needs center around validation related to product integration and manufacturing process. Keeping with one of Toyota's core principles of Kaizen – a quest for continuous improvement – combining these technologies helps identify and resolve issues with one voice months earlier by blurring the lines between design, engineering, and manufacturing from working together at every phase.

Equipped with virtual prototyping capabilities, specifically using virtual reality to conduct immersive product reviews or experience virtual assembly processes, Toyota accelerated the company's innovative approaches and shared the results with Toyota Motor Corporation, R&D in Michigan, and Manufacturing facilities across North America. The main outcome is the inclusion of Design, Engineering, and Manufacturing early in the design phases gives Toyota the confidence to validate processes for new products with physically reliable scaled virtual versions of engineering accurate data, whether for process validations or design reviews.

As part of Toyota's continuous digital transformation, virtual prototyping allows employees to innovate safely and quickly, delivering the highest-quality products to market while consuming fewer resources.

Collins Aerospace Case Study: Digital Twin Solves Crisis
Digital Model Rapidly Speeds Up Delivery[90]

Around the world, the COVID-19 pandemic, the war in Ukraine, natural disasters, and economic uncertainty have disrupted supply chains, causing shortages, delays, and budget issues for everything from fighter jets to uniforms for the Department. The volatility of the global geopolitical uncertainty is expected to continue, so the future requires more end-to-end military readiness – a resilient, battlefield-ready defense enterprise.

Collins Aerospace utilized a single source of supply in Russia to make heat exchangers for every commercial and military aircraft the company serviced. When Russia invaded Ukraine in February 2022, within 12 hours, Collins Aerospace went from 100% to 0% capacity because of their decision to act quickly and sell both Russian facilities, leaving no capacity or production capability.

Facing the very likely scenario that 30 aircraft a month would be grounded until heat exchanger production resumed, Collins Aerospace leveraged its younger workforce with digital engineering skills to develop a digital twin of its heat exchangers used in all supported aircraft. Within one week, using data collected through flight operations and a customer response center, the company created a digital twin of the power management thermal system, a digital model, for the Boeing 787 and 777 and Airbus 350 airplanes. Afterward, the company worked with airlines on projections for servicing planes; the team was 97% accurate on performance. Collins Aerospace worked fast to establish operations in the United Kingdom and the US. Then, it worked with airlines to propose and execute accelerated repairs without grounding a single plane. Without digitalization, the process would have taken six months for each model.

"Culture is one of the hardest things to overcome, and we were fortunate a crisis drove us to think differently about how to solve problems. Change comes in crisis or in planning, and planning enables a more strategic, well-thought-out solution," declared Collins Aerospace's senior executive. He continued, "The four phases of a well-planned digital ecosystem are to digitalize the product lifecycle; utilize data as a strategic asset; drive operational excellence; and strengthen the source and security of data."

Bye Aerospace, Inc. Case Study: Dials In and Iterates to a 99% Solution
Digital Tools Enable Single Modification to Aircraft Model to Morph All Related Activities[91]

Bye Aerospace, Inc.'s two-seat eFlyer-2 training aircraft's electric-propulsion system changes the opportunity with electric aircraft. Two aircraft projects are well underway in the Federal Aviation Administration (FAA) FAR 23 standards and certification process, ranging from ready-to-purchase to research and development.

The eFlyer 2 is an all-composites airplane with advanced aerodynamics, a vast flying range, and the latest in avionics. It has a low part count, yet it is a robust system, which makes it a durable aircraft. Using five software programs, including 3D software, Bye Aerospace is able to harness capabilities for product data and end-to-end management, analysis, testing and certification, and computational fluid dynamics. The software enables Bye Aerospace to more or less morph, or rubber band, design into the next design and into the design beyond that. The advantage is it is not only a physical change or a modeling change, but it also has the analysis resources linked to that one source of truth, which is the model. So, with modifications to the model, all the other related activities also morph with the aircraft.

Agility in the design process is based on wave linking; the ability to create a top-down structure where something as simple as a shape can be broken down into pieces and passed down to the people responsible for designing those pieces to add detail. Then, with wave linking, designs are easily passed on to other designers for changes, without meetings to communicate changes. It is easy to open an assembly to see changes, made by others, linked to the design and how those changes affect the overall design as a whole.

Further, with digital tools, Bye Aerospace can either do the same number of iterations in less time or can do more iterations in the same amount of time – the company is doing both. Shrinking the electric-propulsion aircrafts' product development time and doing more iterations in the same timeframe enables a quicker time to market with the right plane. "With a typical program, you get two iterations. If you're doing a very good job, you get three. With the [enterprise software] solutions, you can iterate on a weekly basis, so being able to dial in and iterate to a 99 or 100% solution to your requirements is the biggest advantage.

Volvo CE Case Study: Accelerates Digital Thread to Improve Legacy Systems
Real-time Data Fosters Seamless Product Lifecycle

Headquartered in Sweden, Volvo Construction Equipment (CE) is a leading international manufacturer of premium construction equipment. Leveraging more than 180 years of construction expertise and the knowledge of over 14,000 employees, it supplies products and services to more than 180 countries around the world.

Like DoD, in-house legacy systems and processes became more costly and complex and IT landscape had become cumbersome with no less than four different product data management systems. With decades-old IT, the legacy systems required significant investment - resulting in siloed and manual paper-based processes. Increasingly, it became too difficult to manage software and hardware dissimilarities across legacy systems, so Volvo CE digitalized its processes, providing an authoritative source of information across engineering, operations, supplies, and customers by leveraging open architecture and integration with other enterprise systems -- establishing a digital thread.

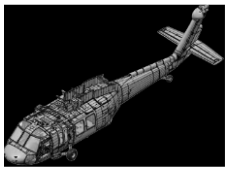
Establishing a digital thread around parts-centric documentation resulted in smoother handovers, reduced duplicate data across systems, increased collaboration throughout the organization and, ultimately, enabled software-driven product lifecycle management. Additional benefits of traceability and real-time data visibility included:

- ***cross-functional design engineering** – unifying engineering tools;*
- ***virtual development and configuration management** – utilizing one global process with common data;*
- ***product preparation** – fact-based feedback significantly reduced human errors and increased interactions between designers and manufacturing engineers during development and identified issues in early phases;*
- ***engineering change management** – utilizing one system to execute analysis on a single source of information enables designers to quickly validate the impact of development changes; and*
- ***concurrent engineering** – ensuring a single authoritative source of truth enables collaboration in one shared system.*

A common language fosters communication and collaboration. Volvo CE's digital thread enabled capturing and retaining product knowledge more efficiently and potentially use real-time 3D data throughout the entire product lifecycle.[92]

NIAR Case Study: Engineering Digital Twins to Create Predictive Behaviors
Digital Twin Program Leads to Sustainment Support & Life Extension

Established in 1985, the National Institute for Aviation Research (NIAR) at Wichita State University (WSU) provides research, testing, certification, and training for aviation and manufacturing technologies. Placed fourth among all US universities that perform aerospace R&D, WSU's activity is driven by more than 1,100 employees in 20 laboratories. A significant accomplishment at WSU-NIAR is the establishment and growth of the Digital Twin Program, leading to sustainment support and life extension for aircraft such as the F-18 Hornet, B-1 Lancer, UH-60 Black Hawk helicopter, F-16 Viper, and M113 armored personnel carrier.



Preparing the U.S. Army for "Born Digital" Platforms: UH-60L Blackhawk Digital Twin. *In 2021 and 2022, the project completed the disassembly, scanning, modeling of 4,994 structural parts, and in 2023, Global Finite Element Models (GFEM) enabled 3-D computer-aided drawings. Prior to GFEM, aircraft drawings were two-dimensional blueprints, drawn to scale, on a flat piece of paper, with each measurement of every angle, thickness, and material type. Now, digital standards use computer-generated representations of the parts, rotatable so engineers or vendors contracted to build the product better understand designs / engineering. As a result, the Army was able to create the process of establishing a digital twin. Additionally, flight simulators are digital twins and benefit training personnel in unpredictable flying conditions, multiple scenarios, muscle memory, and confidence in abilities to operate complex aircraft at significantly reduced costs and risk to human lives. Additional NIAR feats include:*

Resolving a Clearance Issue During New Ejection Seat Development: **F-16 Digital Twin Use.** *US Air Force leveraged F-15 developed ejection seat model with NIAR developed F-16 3D cockpit models.*

Generating manufacturing quality CAD models using engineering drawings and retired airframes: **F-18 C & D Digital Twin.** *NIAR demonstrated capability and then industrialized the process for other legacy airframes and ground vehicles.*

Working several programs to address digital twin legacy systems: **230 F-18 C/D; 5,000 M-113 Armored Personnel Carrier; 800 AH-64 D Helicopters; 45 B-1B Bomber Aircraft; 2,135 UH-60 L/M/V Helicopters; T-38 Wing; 2,500 C-130 Hercules Aircraft; 939 F-16 Viper Aircraft; 1,800 F100 Engines; and 500 T-38 Wing Aircraft.**

NIAR is engineering digital twins to create predictive behaviors of physical assets models, including finite elements, computation fluid dynamics, weapons trajectory, external loads, and systems. The goal is to validate engineering models against real world and physical test data, flight ground test, ground test, and wind tunnel data.[93]

United States Navy Case Study: US Navy's Shipyard Infrastructure Optimization Plan (SIOP)
Major Modernization Effort Underway, Utilizing Digital Twins

As part of a major shipyard infrastructure optimization and modernization project, the US Navy's Shipyard Infrastructure Optimization Plan is using digital modeling and simulation tools to improve the layout of facilities, reconstruct dry docks, modernize infrastructure, build industrial plant equipment, and boost productivity. Digital twins of four shipyards are created to maximize yard configuration, reduce overhaul time, and improve logistics.

The term "digital twin" is often considered a digital representation of a product or asset and how it behaves or is manufactured. While that is often true, one of the overlooked factors of a true digital twin is the process by which an asset is sustained. In this case, simulation software provides the ability to simulate, visualize, analyze, and optimize production, systems, and processes, including material flow, resource utilization, and logistics for all levels of plant planning, from global facilities and local plants to specific production lines.

Dry docks are the shipyard's foundational building blocks where everything is built out from them. The objective is to bring vital, centuries-old infrastructure into the modern era. The digital twins of depot facilities are being used to monitor operations and status during the maintenance cycles, including aircraft carriers, submarines, and aircraft. Such models can be used to quantify the spend for improvements and provide a clearer understanding of the return on repair or improvements for both facilities and processes. Building out a digital process model lays out the most optimized shop floor in future buildings, providing an enormous benefit to the shipyard workforce by allowing real-time evaluations and streamlined processes. Digital efforts are aiding in identifying choke points and making fluid adjustments.[94] [95]

Joint Strike Fighter F-35 Case Study: Model-based Systems Engineering Produces Results
Empowering F-35 Digital Engineering Transformation

The Joint Strike Fighter, F-35, continued to be in low-rate initial production (LRIP) for almost two decades to correct technical problems and is yet to be approved for full operational capability (FOC).[96] *The F-35 is the most advanced fighter jet in the world. Stealth technology enables it to avoid enemy detection. Advanced avionics, weapons, sensors, and networking capabilities enable it to do more than any other aircraft in history, tilting the balance of air power against adversaries. As a result, it is one of the most complicated weapon systems ever built, making it extraordinarily challenging to respond to new requirements of rapidly advancing threats.*

In 2018, Model-based Systems Engineering (MBSE) transformed critical development practices and digitized prior paper-based approaches to engineering, enabling the sharing of data and digital models on multiple classification levels and empowering essential engineering processes (requirements, design, verification, certification, and compliance) to transpire in a single set of federated models. This resulted in a better understanding of the impacts of new capabilities; access to real-time web access to engineering tools; and the ability to perform digitized technical reviews. Further, new capabilities were born digital [97]

In December 2023, Representative Wittman, R-VA, chairman of the House Armed Services Committee's Tactical Air and Land Forces panel declared, "… If you have six test beds, you can fly the aircraft and do things simultaneously, so the learning curve gets a lot faster." It is critical to focus early on software in program development, and the Pentagon must change its mindset. He continued, "For years, the Pentagon has been a hardware-centric organization. In today's world ... software needs to be at the forefront, then hardware needs to follow."[98]

A-10 Case Study: Air Force Digitized Wing Data into 3D CAD on Legacy Aircraft
Major Modernization Effort Underway, Utilizing Digital Twins

Digitalization is a Revolution Not a Transformation. The A-10 Thunderbolt, a single-seat, twin-turbofan, straight-wing, subsonic attach aircraft, received a new lease on life with new wings, despite repeated efforts from the Air Force brass to retire it. The A-10 was manufactured by Fairchild Republic Corporation between 1975 and 1984 before the company ceased production.

Popular among pilots for its 'get home' effectiveness, the A-10's mission is ground attacks against tanks, armored vehicles and installation, and close air support of ground forces. Also known as the Warthog, the Flying Gun, and Tankbuster, the high-survivability and versatile military aircraft flew extensively during Operation Desert Storm; in support of NATO operations in response to the Kosovo crisis; and in Operation Enduring Freedom in Afghanistan and Operation Iraqi Freedom.[99]

During Operation Iraqi Freedom, cracks were identified in the wing of the A-10 aircraft. The original OEM for the A-10 was no longer in existence nor was the original equipment, so original data for the A-10 was delivered to the Air Force program office, where it was digitized into 3D CAD models to re-wing the fleet. During downwind operations in the Middle East, digital models were created to analyze data within weeks to address the operational capability quickly using digital tools.[100]

The purpose of the wing swap is to extend the life of the A-10 to continue the valuable mission it contributes to the Air Force. The real cost and time savings were the return to flight and extended service of critical air power. Enhancing durability and efficiency, a new set of wings extends the A-10's flying life to 10,000 hours. Every time a jet is down, it severely impacts flying hours, student pilot training, and instructor pilot training, especially for the 357th Fighter Squadron which is the only unit training A-10 pilots. A new set of wings added 7.3 thousand hours back into the flying program, placing three jets back into the working system of completing missions, sorties, and countless training requirements. Additionally, digital transformation dropped the downtime from 2,000 hours to maintain the aircraft to 700 hours. [101]

With a new set of wings, an upgraded A-10 will be put back into the system, saving the Air Force $12 million and equipping another close air support weapon for the next fight.[102]

Air Force B-21 Case Study: Digitalization Delivers Major Weapons System in 8 Years
Digitally-designed Bomber, the B-21, Intended to Penetrate Today's Air Defense

Born digital, the B-21 was a digitally designed bomber -- meaning traditional means of designing aircraft on paper, CAD files, and clay models were abandoned to embrace the new era of digital engineering.

Using computer modeling and data enabled engineers to run component tests on computer simulations rather than building real-world equivalents, saving time and money. Developers then created an entire computer-simulated aircraft, known as a "digital twin," to run tests. Digital engineering and digital tools enabled the team to iterate the designs, test faster, fail quicker, solve problems before they became issues, reduce overall risk, and do more testing before flying the actual airplane. In a digital environment, thousands of designs are considered before selecting the final design, and every team member, regardless of physical location, connected to a virtual room to share information in real-time.

Air Force Chief of Staff Gen. Charles "CQ" Brown proclaimed the digital engineering revolution is "going to change the way we do things here in the future." He continued, "All these new digital engineering techniques will upend the way future programs are developed. There just aren't as many "test points" needed, which speeds the process up."

The all-digital open architecture enables the aircraft to be more adaptable in the future, and as missions change and threats evolve, the Air Force will be able to perform upgrades to the electronic systems to counter adversaries' radar or sensor improvements and to keep the Raider relevant and in operation post-production. The ability to swap out both software and hardware creates flexibility in the most advanced aircraft today and for the next 30 to 50 years.[103]

T-7A Case Study: Advanced Pilot Training System, Poster Child for Digital Engineering
Air Force Establishes Precedent for Digital Infrastructure

T-7A (Advanced Pilot Training System) – The Advanced Pilot Training System (APT) T-7A Red Hawk, the poster child for potential digital engineering, is replacing Air Education and Training Command's fleet of T-38C aircraft, a workhorse training fighter and bomber pilots. The T-7A supersonic advanced jet trainer and associated training devices are a game changer and provide advanced training capabilities and mission systems. The aircraft is designated eT-7A prior to delivery, identifying it as a digitally engineered aircraft.

From the beginning, advanced manufacturing and digital modeling tools were used to improve design and tests. Instead of sending aircraft models to a wind tunnel for early testing, the program used high-speed computing, shortening the usual concept-to-design process by nine months. With digital designs, program engineers and production and flight teams collaborated and anticipated programs earlier, reducing the need for rework and saving costs. In fact, virtual models and 3D tools reduced assembly hours up to 80% and halved the time needed for software development.[104]

These results, along with similar wins to install new wings on the A-10 attack aircraft a year ahead of schedule and optimize and refine Sentinel's design early in the acquisition process, are due to the 2018 Pentagon push to modernize acquisition and sustainment process by establishing a digital infrastructure, formalizing model-based systems engineering across the Services, and promoting innovation. Siloed organizational constructs and funding processes made it difficult to transfer lessons learned from programs like T-7A to the Air Force's broader portfolio. Not all acquisition offices have funding for necessary software, and inflexible policies make it harder to transition.

In 2020, the Air Force launched a grassroots initiative, Digital Campaign, to build momentum to implement change, it lacked a full-time, dedicated team. As a result, the Air Force created the Digital Transformation Office to address necessary operational shifts while working to unify the Service's digital integration efforts. In late 2023, the Air Force announced it is considering a new armed variant of the T-7A Red Hawk, dubbed F-7, which could replace older F-168 fighter jets potentially.[105]

Air Force LGM-35A Sentinel Case Study: Virtual Models Modernizing Real Weapons Systems

Sentinel ICBM Using Digital Twinning at Every State of Program Lifecycle

At every stage of the program lifecycle, the Air Force-managed modernization of America's ground-based nuclear missiles emerged as a testbed for the use of digital twins -- virtual models of real weapons systems. Digital twinning uses software models of real components or systems to guide designers developing plans for a prototype; it is also used to determine how to manufacture the real thing, replace parts, minimize fuel consumption, and conduct maintenance more efficiently.

Eight years ago, the LGM-35A Sentinel Intercontinental Ballistic Missile System (ICBM), originally named the Ground Based Strategic Deterrent (GBSD) program, began using digital twinning. Early on, the concern was that design choices made to maximize capabilities might introduce cost and schedule risk. The digital environment, however, enabled multi-disciplinary engineering models in line with research and design cost models to examine a trade space where different capabilities and ways to achieve them could be costed against each other, especially in the research and development phases. Digital engineering tools made it possible to predict how choices would cost out and enabled earlier decisions in the acquisition process that have huge, positive implications later.

Throughout the entire process, digital twinning is beneficial – from an early conceptual design frame at the onset of a program to the engineering and manufacturing development (EMD) phase, where prototypes often are built to the first flight itself and transitioning into sustainment.

Digital twinning and digital engineering mean a million things to a million people, but it can also mean a million different things within a single program or a single program office, depending on the lifecycle. For example, the digital tools the Air Force program used for the new Sentinel ICBM enabled it to scan and assess six billion different system designs to best balance capabilities with cost. As part of Space Force's commitment to being a digital-first Service, it focused on developing an entire digital ecosystem, including acquisition, training, doctrine, red teaming, and force design.[106]

Appendix K: Pockets of Success Vignette[107]

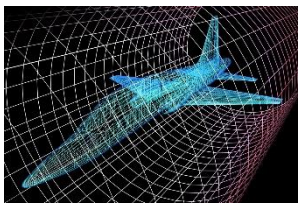
Software Example - **The F/A-18** is the first aircraft to incorporate a digital multiplexer (MUX) bus architecture for the whole flight system. The architecture enables the computer controlling the aircraft to transfer data between systems quickly and more efficiently. As a result, the F/A-18 can support the most advanced avionics software suite currently available, known as the digital control-by-wire flight control system. The software acts as a digital co-pilot in the F/A-18 Hornet and provides incredible computer-assisted handling qualities and maneuverability, making it easier for the pilot to concentrate on operating the weapons system during a mission. Upgrading the computer system is easy and inexpensive, and advanced electronics make it relatively easy to learn to fly and remain evasive while still acquiring targets.

Radar Example - The Air Force awarded four digital engineering contracts for system design, analysis, validation, and verification against a subscale prototype of the **Advanced Radar Threat System-Variant 3 (ARTS-V3)**. Using digital designs cut costs by one-tenth compared to a full-scale system, enabling multiple vendors to build for a "digital fly-off."

Digital Engineering Example - Having fully embraced digital engineering, the **B-52 Commercial Engine Replacement Program (CERP)** rapid prototyping project conducted a "digital fly-off" between power plants (engines), using modeling and simulation to compare fuel efficiency, maintenance requirements, and performance. Digital artifacts for MBSE and 3D analysis were received in the competitive proposals to perform rapid, accurate assessments and have helped maintain the program's schedule and anticipate future integration issues.

Contracting Example - **The Contracting Information Technology (CON-IT)** system replaced aging legacy contract writing and management systems with a single contract management system to provide interoperability across the Air Force contracting. In partnership with the Department of Agriculture, the program uses agile acquisition practices to develop, deploy, and enhance contract information capabilities faster and with less risk. In FY21, CON-IT awarded 57%, or $15.6 billion of obligated dollars, of Department of Air Force contract actions throughout the year.

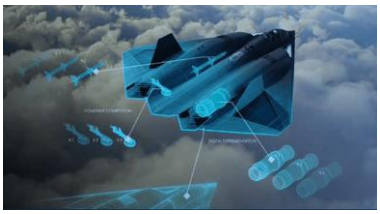
OMS Architecture Example - **The F-15EX** is designed to replace the F-15C/D fleet and augment the aging F-15 fleet. The Open Mission Systems (OMS) architecture is the most significant difference, enabling rapid insertion of the latest aircraft technologies. The F-15EX has fly-by-wire flight controls, an advanced cockpit system, a new electronic warfare system, and the latest-available F-15 mission systems and software capabilities. Looking to the future, the F-15EX incorporates provisions for fiber optic cabling for a high-speed avionics service bus to enable an OMS computing environment.



Battlespace Environments/Acquisition Lifecycle Example - The Department of Air Force (DAF) relies on **Modeling & Simulation (M&S)** capabilities to develop virtual ranges permitting threat-representative environments and provide the means to test and train in high-fidelity, operationally realistic battlespace environments. In FY21, multiple phases of the acquisition product lifecycle utilized M&S; the **Space Force's PTES program used Digital Twins and M&S** to enable a rapid user requirement feedback loop in operationally relevant scenarios resulted in 43% of requirements significantly rewritten, saving an estimated six-year total schedule. Using high-performance computing resources, The Air Force Research Laboratory (AFRL) evaluated common and less expensive flares on F-35, reducing the logistical burden and costs of $1 billion over the fighter's lifetime while still maintaining effectiveness.[108]

Digital Engineering Example - The Air Force's digital engineering-based **Next Generation Air Dominance (NGAD)** fighter is designed to outpace threats to air superiority. Development is using digital engineering and manufacturing, open system architectures enabled through a government reference architecture, and agile software through containerization to break vendor lock and increase competition in the industrial base by reducing barriers to entry.

Satellite Example - **Protected Tactical SATCOM (PTS)** will provide advanced satellite communication capabilities. Using Digital engineering to increase speed and agility, PTS will enable an unprecedented understanding of system performance before any hardware is built or tested. Providing continuous insight for early problem resolution will help to deliver warfighting capability rapidly and affordably. Digital engineering, as compared to a conventional acquisition program, delivered three years earlier the prototype.



Space Example - Space Systems Command (SSC) is using a complex **MBSE approach for MILSATCOM acquisitions** for the Protected Tactical Enterprise Service (PTES). PTES enables government ownership of MBSE-developed models of system-level requirements and test verification strategies, while, at the same time, enabling Industry to maintain IP of lower-level designs and test sub-systems. Interface agreements enable rapid decision-making through data sharing, interoperability, and collaboration between the program office and the prime contractor.

Cyber Example - **Unified Platform (UP)** fulfills the need to fuse cyber data from multiple sources and classification levels across the Services and is a central component of US Cyber Command's Joint Cyber Warfighting Architecture. The centralization of data allows decision analytics to produce mission-relevant information for 133 Cyber Mission Force teams and Service-specific cyber elements. The scalability and interoperability of this architecture enable quick cyber responses, execute real-time defensive cyber operations, expand new mission sets, integrate innovative technologies, and exploit emerging opportunities.[109]

Digital data needs to be actionable…. If certain planes fly in Japan during the Japanese Cherry Blossom blooming season, the pollen clogs the filter system and creates issues. Using real-time data, digital simulation discovered the issue.

~ Senior Industry Executive

Appendix L: Public Comments

No public comments provided.

Appendix M: Study Citations & End Notes

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