



DIGITAL ENGINEERING

Recommendations for the U.S. Department of Defense

INTRODUCTION

Digital Engineering (DE) has received considerable attention in both industry and government as a tool to reduce acquisition timelines and costs, allow for more rapid systems upgrades, and streamline maintenance and upgrades. Specific to Department of Defense (DoD) system development, DE may be defined as the integration of data provided across industry and government engineering disciplines through the use of commercially and DoD-developed tools to support lifecycle activities from concept development through disposal.

The following will offer an overview of the evolution of digital engineering (DE) in systems design, development, and testing from an engineer's viewpoint, and will also offer observations on how the DoD might best take advantage of DE to accelerate force modernization developments and transitions. Going beyond DE as a marketing tool, this paper outlines specific areas of practice unique to DoD where DE can support better outcomes.

The DE challenge for DoD is attaining knowledge-based integration of data sufficient to answer lifecycle questions, including:

- How do the currently fielded systems or those under development support near-term missions?
- What is the performance and cost impact of replacing a subsystem in a legacy system?
- How do design decisions today impact system sustainment and operations availability?

AVAILABLE TOOLS

There is a wide range of DE-relevant tools available today. Examples of commercial tools used in industry and the DoD include Dynamic Object-Oriented Requirements System (DOORS) for system requirements, Air Force standard mission analysis tool (AFSIM), Satellite Toolkit (STK), and Matrix Laboratory (MATLAB) for system performance and mission simulations, and Altium Designer, PADS (PowerPCB), OrCAD, Collaborative Model-Based Systems Engineering (CAMEOTM), and RAPSODY for system design and development. DoD developed tools include modified commercial tools for unique mission requirements and individual Service mission maintenance and sustainment tools such as Planned Maintenance System Management Information (PMSMIS) (Navy), Standard Army Maintenance System-Enhanced (SAM-E) (Army), and Tactical Interim CAMS and REMIS Reporting System (TICARRS) (Air Force).

DIGITAL ENGINEERING – CURRENT PRACTICE

Digital engineering (DE) is a rapidly changing system engineering discipline that integrates tool-produced data sets into common environments, processes, and methods to make effective engineering and program decisions. DE is currently used to varying degrees in technology transition, product design, development, and lifecycle management by industry to compete in the commercial and government marketplace. DoD has only recently considered accelerating DE principles to support the new system modernization

efforts including the 804 series of hypersonic prototypes and the ground-based strategic deterrent (GBSD) program. In practice, DE seeks to enhance the efficacy of engineering practice across all life cycle phases and results in reduced errors in both hardware and software products. This paper explores the barriers that exist before the DoD can realize the full benefits of DE and provides specific recommendations for acquisition and engineering approaches, processes, cultural and structural support techniques to overcome those barriers. By fully embracing and implementing DE across the DoD, the Department will be better positioned to meet the peer competition goals defined in the National Defense Strategy ([NDS](#)).

DE tools and techniques are, by their nature, continuously improving and foundational to engineering practice. Engineering in a digital environment takes advantage of the continuous advances in computer and data processing technologies that in turn lead to increasingly more sophisticated performance, design and analysis tools which can readily incorporate common standards and interfaces. There are limits to DE-developed tools; to understand these one must understand causality as it is applied in engineering practice. *Causality* in engineering is defined as the influence and understanding by which one event, process, state, or object contributes to the production of another event, process, state, or object; in essence the cause is partly responsible for the effect, and the effect is partly dependent on the cause. In practice, causality manifests when unknowns drive engineering design uncertainty. Therefore, to be successful, all engineering developments, be they bridges, semiconductor devices, or complex spacecraft, must fully understand all causes and their subsequent impacts on the designs and their relation to well-understood and defined functions or missions. This foundational concept of engineering practice is the basis of all research and development across industry and drives the effort to continuously improve DE tools and techniques in use today.

Figure 1.0 depicts the current limitations of DE as applied to a typical complex electronic system/mission development. When a design is at the technical precision sufficient to be implemented into a system, the DE tools and techniques (hardware and software) used to design electronic devices from the semiconductor level through subassemblies are very mature, resulting in low levels of hardware/software errors. At the subsystem level, DE tools and techniques are less precise and require optimization for the specific implementation, requiring specific engineering efforts to ensure integration into the end system. At the complex system and mission level the many system performance unknowns create a high level of design uncertainty requiring the development of system and mission-specific DE tools and techniques to be able to meet the desired end performance.

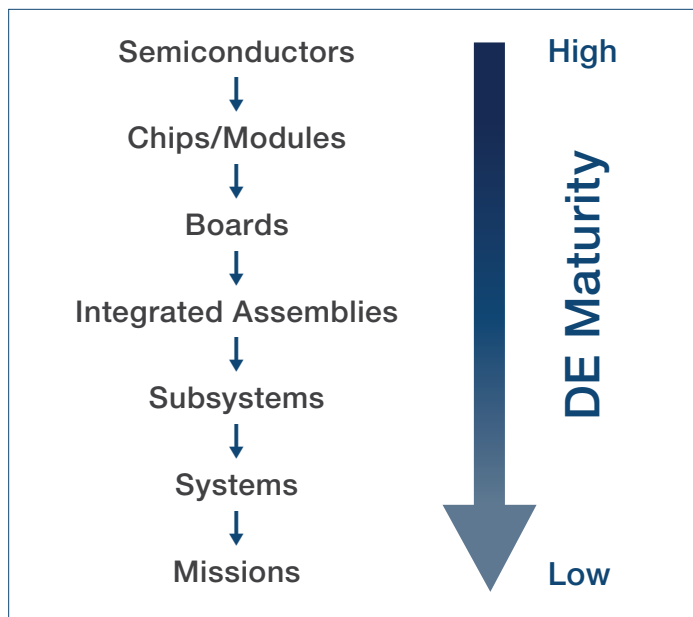


Figure 1.0 Digital Engineering Maturity in Electronic Systems Development.

In commercial markets, strong industry competition drives major investments in DE system/mission-level tools. However, for DoD requirements the system and mission aspects are driven by competition between nation states that require DoD engineering leadership and investments in maturing DoD system and mission specific DE tools. To address a rapidly modernizing China threat, developing DoD owned dynamic mission understanding through DE tools and techniques are paramount to successfully fielding competing capabilities.

CURRENT DOD ENGINEERING STRUCTURE, POLICIES, AND PRACTICES

As evidenced in the recent pandemic crises, the U.S. has shown, again, that we continue to lead the world when it comes to having innovative technologists and researchers. To ensure strong leadership, the DoD research and technology enterprise is governed and directed by numerous boards, panels, interest groups, research agencies/centers, and laboratories. In comparison, especially since the end of the Cold War, the DoD engineering enterprise lacks similar strong governance boards, panels, and oversight groups.

For decades, engineering strategy has not been coordinated across the whole department but rather exists mostly as isolated communities across the Services, diluting the Department's engineering expertise and authority. In addition, the Department has had challenges transferring emerging technologies into real system and mission capabilities at the pace of our nation's peer competitors. Therefore, an understanding of the current state of engineering practice within DoD is critical to develop solutions to these challenges and how DE can be applied to meet them.

Starting in the 1960s, the DoD began embracing management principles that emphasized program management at the expense of

valuing engineering leadership and technical judgement, and cost control at the expense of technical innovation. That trend has only strengthened with time. Today, this philosophy permeates throughout DoD development organizations. Consequently, engineering capabilities, authorities, practices, and policies vary significantly across the Services and Combatant Commands, which results in uneven performance on programs and limits the Government's ability to hire and retain the top engineering expertise required to advance DE principles into the modernization programs.

OPPORTUNITIES TO ACCELERATE DOD MODERNIZATION THROUGH DIGITAL ENGINEERING

The acceleration of DoD modernization efforts to field dominant system and mission capabilities against peer adversaries can be readily supported through the enterprise development and use of DE tools and techniques across the Services. The critical DE enterprise requirements include:

1. **Providing continuous evaluation of a system's ability to address the changing threat/mission.** The threats are changing constantly, and DoD must be able to continually evaluate current and future systems and their capabilities to meet the evolving threats. A DE environment will facilitate the necessary integrated cross-service and dynamic mission analysis that is required to support the requirements development and approval processes on an ongoing basis.
2. **Reducing design implementation errors to improve the quality of DoD design reviews (SRR, PDR, CDR, TRR, etc.).** A digital engineering environment will improve the quality and completeness of data produced by industry in support of formal design reviews in a format such that the government has high confidence in the system's demonstrable mission capabilities by the CDR.
3. **Removing barriers for continuous technology transition into systems.** A Government-owned DE with substantiations of all systems under development and using common standards and interfaces will readily interface with DoD service and joint mission DE capabilities to rapidly identify specific technology insertion mission benefits.
4. **Supporting the ability of the Government to be the system integrator and maintainer.** A Government-owned DE approach will create uniform architectural and system standards and requirements for all development programs such that any Government or Industry provider can integrate and maintain the delivered capability.

The best approach for DoD to accelerate DE requirements across the joint force is to introduce and emphasize the importance of engineering management, staff development, and engineering practice that already occurs in private industry. The rapid advancement in space capabilities by small start-up businesses including lower cost to orbit as well as new space services in high-speed

communications, sensing, and on-orbit servicing are all possible to advances in DE. To achieve these rapid advances for DoD requires a close integration of the engineering disciplines across the Services that includes mission development, prototypes, and system design, test, training, and fielding under a unified governance model led by senior engineering professionals. For over 65 years, the Defense Science Board (DSB) has been providing technical analyses and reports to help govern DoD's technology investment strategy but by charter does not represent DoD engineering practice. Drawing from this experience, it is proposed that the process of realizing the desired NDS would benefit significantly from the creation of a Defense Engineering Board (DEB) under the U.S. Secretary of Defense, to lead technology transition and system development and exercise real engineering authority.

A Defense Engineering Board (DEB), with the following structure and authorities, will achieve the benefits of DE and accelerate DoD technology developments and mission insertion:

- **Defense Engineering Board (DEB) Chairman:** A proven highly experienced engineer with a fixed 6-year term assignment for continuity, vetted through a rigorous government and industry supported certification process.
- **Staffing:** A mix of industry and government engineers on limited term non-acquisition assignments to foster new ideas and innovations in DoD engineering.
- **Responsibilities:**
 - Supervise all DoD engineering policies and practices, including the Office of the Secretary of Defense (OSD) and the Service engineering organizational structures for the purpose of ensuring that engineering practices and capabilities are consistent across the DoD enterprise,
 - Provide a matrix engineering reporting and ombudsman structure across DoD,
 - Address the hiring and retention policy and regulatory barriers to allow better cross-utilization of government and industry engineering skills,
 - Develop innovative pilot programs and projects to be implemented consistently across the Services that demonstrate DE goals and concepts, and
 - Provide engineering assessments of programs and OSD/ service engineering organizations as assigned by DoD and U.S. Congress.

This proposed DEB structure and authorities would provide DoD and Congress with a technically competent, comprehensive, clear approach and generate the supporting metrics to be able to measure progress of the department's enterprise engineering capabilities and its ability to meet the goals of the modernization goals of the National Defense Strategy (NDS).

SUMMARY

To achieve better outcomes requires real change in engineering practice in DoD with leveraging Digital Engineering (DE) as paramount. DE comprises the essential tools, techniques, and processes used by industry in technology transition, product design, development, and lifecycle management to compete in the commercial marketplace. DE can be a powerful tool for DoD as it addresses the National Defense Strategy (NDS) requirements. The development of DoD-specific mission/system DE tools and techniques is needed to accelerate the current pace of force modernization and is only possible by improving enterprise engineering practice across the joint force. To enable a DoD cross-enterprise engineering approach requires engineering governance and supporting authorities as envisioned by the creation of a Defense Engineering Board (DEB); one that comprises the best engineering talent our nation has to offer and one that is closely integrated with industry engineering innovation

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