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14. ABSTRACT

This report surveys the state of the current digital-engineering (DE) tool landscape, with specific emphasis on applications relevant to the U.S. Department of Defense (DoD). The request originated from an inquiry seeking to understand the state of DE tools without disclosing personally identifiable information. The study excludes areas that have been heavily analyzed in prior literature, such as artificial intelligence (AI)/machine learning and application life-cycle management, and instead focuses on a wide range of DE capabilities, including model-based systems engineering; modeling, simulation, and analysis; digital twin; and product life-cycle management. Sources for this research included generative AI platforms, vendor websites, and government documentation. The DoD is accelerating DE adoption, necessitating the development of DE ecosystems and tools that are both interoperable and accreditable for production use. A detailed taxonomy of capability groups is presented alongside a curated list of representative tool vendors and offerings. The report further outlines examples of integration that demonstrate emerging interoperability trends. This analysis aims to support organizations navigating the evolving DE landscape and evaluating solutions suitable for operational use within defense and mission-critical environments.

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TI Research

A chief service of the DoDIAC is free technical inquiry (TI) research limited to four research hours per inquiry. This TI response report summarizes the research findings of one such inquiry. Given the limited duration of the research effort, this report is not intended to be a deep, comprehensive analysis but rather a curated compilation of relevant information to give the reader/inquirer a "head start" or direction for continued research.

Abstract

This report surveys the state of the current digital-engineering (DE) tool landscape, with specific emphasis on applications relevant to the U.S. Department of Defense (DoD). The request originated from an inquiry seeking to understand the state of DE tools without disclosing personally identifiable information. The study excludes areas that have been heavily analyzed in prior literature, such as artificial intelligence (AI)/machine learning and application life-cycle management, and instead focuses on a wide range of DE capabilities, including model-based systems engineering; modeling, simulation, and analysis; digital twin; and product life-cycle management. Sources for this research included generative AI platforms, vendor websites, and government documentation. The DoD is accelerating DE adoption, necessitating the development of DE ecosystems and tools that are both interoperable and accreditable for use in production. A detailed taxonomy of capability groups is presented alongside a curated list of representative tool vendors and offerings. The report further outlines examples of integration that demonstrate emerging interoperability trends. This analysis aims to support organizations navigating the evolving DE landscape and evaluating solutions suitable for operational use within defense and mission-critical environments.

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1.0 TI Request

1.1 Inquiry

What is the current state of the digital-engineering (DE) tool landscape, with a focus on application to the U.S. Department of Defense (DoD)?

1.2 Description

The inquirer asked for a comprehensive assessment of the current DE tool landscape for use within the DoD. This includes identifying and analyzing a subset of the range of commercial, open-source, and government-off-the-shelf (GOTS) tools across key DE capability areas, such as model-based systems engineering (MBSE); modeling, simulation, and analysis (MS&A); product life-cycle management (PLM); digital twin; and digital thread. One typically used example was chosen to highlight each capability. The objective is to understand how these tools support the DoD's evolving requirements for digital transformation, integration, and enterprise-wide traceability throughout the systems engineering life cycle—from concept development to sustainment. The study also examines tool interoperability, scalability, and suitability for use in secure, accreditable environments in alignment with DoD acquisition practices. Additionally, it highlights trends in the digital-engineering ecosystem (DEE), such as tool consolidation, and best practices for implementing DEEs within defense contexts. The goal of this inquiry is to inform stakeholders, including program offices, acquisition teams, and engineering leadership, on the current state of DE tools and to provide insights to guide tool selection, integration, and future capability development within the DoD.

2.0 TI Response

This report has been systematically crafted by examining the context of most of the DE space, excluding areas that have been covered extensively in the past, including artificial intelligence (AI)/machine learning (ML) and application life-cycle management (ALM). Research was conducted using generative AI platforms, vendor websites, and government documentation.

DoD Instruction 5000.97 [1] has recently emphasized the use of DE tools, methods, and best practices, pushing the DoD to adapt quickly to incorporate DE into legacy and new weapon, mission, and information technology systems. This accelerates the development and integration of products into entire enterprises and systems of systems. The need for DEEs has emerged to enable the DoD to seamlessly adopt DE. While there is the cloud-native landscape

website, there is currently no DE tool landscape website. Many organizations are using the same tools in this area but have not surveyed the full competitive landscape or ensured the tools are a fit for the needed use cases. Additionally, these tools must be in a state where they can be accredited to operate in DoD production environments. With the introduction of software factories, software development embraced options and interoperability to avoid vendor lock, while emphasizing security with development, security, and operations. Similar rigor needs to be applied to the DE space as adoption grows.

The Defense Acquisition University defines DE as "an integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support life-cycle activities from concept through disposal" [2]. This is a very broad definition and includes Cloud, AI/ML, and ALM, but these tech stacks are covered extensively elsewhere. For this survey, test management is considered part of ALM, though it technically overlaps both DE and ALM. The focus of DE is on the capability groups detailed in Table 1, with the systems and product life cycle in mind.

DE capabilities have been around in various forms for decades, starting with numeric models and simulation, but, within the past decade, these have been collected under the banner of DE and integration between the tools is beginning to emerge.

2.1 DE Market

The work done by DoD contractors to develop custom tools needed to fit niche needs is not included in this technical report, as these are not generally available to the broader community. Table 2 provides a nonexhaustive list of DE tool vendors in the market.

It should be noted that the DE space has consolidated over the past few years with examples such as the Synopsys acquisition of Ansys (who previously acquired AGI and Phoenix Integration), Dassault's acquisition of No Magic, and Keysight's acquisition of SCALABLE Network Technologies. Additionally, this list (Table 2) does not include startups or small businesses, as they have not yet entered the DoD space in significant numbers and tend to focus on Cloud, AI/ML, or ALM applications.

Table 1. DE Capability Groups

Capability Group Name	Acronym	Description
Requirements Management	RM	The capturing, managing, and tracing of system requirements throughout the development life cycle
Model-Based Systems Engineering	MBSE	A formalized approach to system design using models, often the Systems Modeling Language (SysML)/Unified Modeling Language (UML), as the primary artifacts for architecture, analysis, and verification
Model-Based Enterprise Architecture	MBEA	A strategic modeling of organizational capabilities, processes, systems, and technologies using frameworks like the U.S. Department of Defense Architecture Framework (DoDAF), Unified Architecture Framework (UAF), and the Open-Group Architecture Framework
Modeling, Simulation, and Analysis	MS&A	The use of computational tools to simulate system behavior, physical dynamics, and mission outcomes for analysis, optimization, and decision support
Numeric Analysis	N/A	A focus on designing and analyzing algorithms, or methods, to find approximate but accurate numerical solutions to mathematical problems
Digital Thread	N/A	An end-to-end digital connectivity of life-cycle data across tools, models, and stakeholders to maintain context and traceability from concept to sustainment
Digital Twin	N/A	A real-time, virtual representation of a physical system or asset that mirrors behavior, integrates sensor data, and supports prediction and optimization; usually involves AI/ML that process data from the real twin to improve the digital twin
Product Life-Cycle Management	PLM	The management of product information, workflows, and life-cycle states from concept through retirement, integrating engineering, manufacturing, and supply chain
Product Data Management	PDM	A focus on managing model files (e.g., CAD), part libraries, revisions, and metadata associated with product design and collaboration
Geospatial Information System	GIS	Technology for collecting, analyzing, and visualizing spatial and geographic data for mapping, planning, and decision-making
Augmented Reality/Virtual Reality	AR/VR	The use of AR/VR to visualize, train, or simulate system behavior and environments in immersive formats
Additive Manufacturing	AM	The design, simulation, and production of parts through three-dimensional (3-D) printing and other additive processes, enabling complex geometries and rapid iteration
Computer-Aided Design	CAD	Tools for creating, modifying, and optimizing two-dimensional (2-D) and 3-D geometry for mechanical and structural components during product development

Capability Group Name	Acronym	Description
Computer-Aided Engineering	CAE	Simulation-based tools for analyzing structural, thermal, fluid, and multiphysics behavior of designs; includes finite-element analysis (FEA), computational fluid dynamics (CFD), and motion analysis
Electronic Design Automation	EDA	Tools used for design, simulation, and verification of electronic circuits, integrated circuits (ICs), and printed circuit boards, including Hardware Description Language modeling, synthesis, and layout

Table 2. DE Vendors

Company	Country	Capability Focus Areas
Altair [3]	United States	CAE, MS&A
Ansys [4]	United States	CAE, EDA, MBSE, MS&A, Digital Twin
Aras [5]	United States	PLM, Digital Thread
Autodesk [6]	United States	PLM, CAD, MS&A, AM
Cesium [7]	United States	GIS, MS&A, Digital Twin
Dassault [8]	France	PLM, CAD, MBSE, MBEA, Digital Twin
Epic [9]	United States	AR/VR, MS&A
Esri [10]	United States	GIS, Digital Twin
IBM [11]	United States	RM, MBSE, MBEA, ALM, AI/ML
Intercax [12]	United States	MBSE, Digital Thread
Jama [13]	United States	RM, ALM, Digital Thread
Keysight [14]	United States	EDA, MS&A, Digital Twin
Mathworks [15]	United States	MS&A, Numeric Analysis, AI/ML
NVIDIA [16]	United States	AI/ML, MS&A, Digital Twin
PTC [17]	United States	PLM, CAD, ALM, AR/VR, MBSE, Digital Twin
Siemens [18]	Germany	PLM, CAD, MS&A, MBSE, Digital Twin
Sparx Systems [19]	Australia	MBSE, MBEA
Synopsis [20]	United States	EDA, MS&A, ALM
Unity Technologies [21]	United States	AR/VR, MS&A

2.2 DE Tool Landscape

The landscape of DE tools is vast and growing, with hundreds of tools for the DoD to choose from across these categories. This space, unlike AI/ML or ALM, is mostly made up of commercial-off-the-shelf (COTS) vs. free/open-source software (FOSS) due to the unique capabilities and domain knowledge required. Additionally, a wide array of GOTS software has been developed, especially in the MS&A capability group. The technology landscape provided in Table 3 provides a nonexhaustive sampling of tools for each capability. Note, this does not suggest an entry is the "best tool" for each capability but is one that is commonly used in the DoD, alongside a limited set of FOSS tools. While FOSS tools are provided, they may not be appropriate for DoD applications.

2.3 DE Tool Integration Examples

While the ALM and AI/ML space is thinking integration first, the DE space is catching up in this regard. Given the emphasis on the need for DEEs, this is critical. This section highlights a couple brief examples of this integration.

2.3.1 Intercax Syndeia

Intercax Syndeia provides connectivity between models for traceability, central management, and dashboards. For example, it integrates Cameo with Jira, such that the design diagrams from SysML or UML can be shared with developers in tickets and tickets can be traced to the SysML model.

2.3.2 Ansys ModelCenter

ModelCenter enables interoperability between MS&A tools, as well as between MBSE and MS&A tools, while providing data analysis and trade-study capabilities.

Table 3. DE Tool Landscape Sample

Capability Group	Capability	Vendor	Tool	Description
AM	Design for AM and AM Simulation	Autodesk	Netfabb Simulation	A complete toolchain for 3-D printing, from model preparation to simulation and support structure generation
AR/VR	AR/VR: Game Engine	Epic	Unreal Engine	A real-time, 3-D creation platform widely used for simulation, gaming, and virtual environments
CAD	CAD COTS	PTC	Creo	The product design and development, supporting parametric modeling and simulation
CAD	CAD FOSS	The FreeCAD Team	FreeCAD	A parametric, 3-D CAD modeler designed for product design, mechanical engineering, and architecture
CAE	CFD	Ansys	Fluent	A tool used to model fluid flow, heat transfer, turbulence, and chemical reactions in complex geometries
CAE	Electromagnetic (EM) and Antennas	Ansys	HFSS*	A high-frequency EM simulation tool used for radio frequency (RF) and antennas
CAE	FEA	Altair	OptiStruct	A structural analysis and optimization solver with focus on advanced composites
Digital Thread	Digital Thread: Interface and Metadata	Intercax	Syndeia	A platform that leverages AI to automate digital thread creation across DE capability groups
Digital Thread	Digital Thread: Cosimulation	Ansys	ModelCenter	A model integration, orchestration, and optimization platform designed to connect and automate diverse MS&A tools across the life cycle
Digital Twin	Digital Twin	NVIDIA	Omniverse Digital Twins	Photorealistic, physics-based virtual replicas allowing users to simulate, predict, and optimize system behavior in a virtual environment
EDA	EDA: RF Design	Keysight	PathWave System Design (SystemVue)	An RF system simulation tool used for wireless system design and verification

Capability Group	Capability	Vendor	Tool	Description
EDA	EDA: Physical Design	Synopsys	IC Compiler II	A place-and-route physical design tool used in digital IC implementation
GIS	COTS GIS	Esri	ArcGIS	A tool used for mapping, spatial analysis, and data management
GIS	FOSS GIS	QGIS Foundation	QGIS*	A tool used for geospatial data analysis, cartography, and map creation
MBSE	SysML Editor COTS	Dassault	Cameo Systems Modeler	An SysML-based MBSE tool used for system modeling and architecture
MBSE	SysML Editor FOSS	Obeo, CEA List	SysON	A web-based modeling tool designed for creating and editing SysML v2 models on an interoperable platform
MBSE	MBSE Configuration Management	Dassault	Teamwork Cloud	A model repository and version control server that supports collaboration for Cameo Systems Modeler
MBEA	UAF/UPDM* Editor	Sparx Systems	Enterprise Architect	A comprehensive modeling tool from Sparx Systems for enterprise architecture, including UAF and UPDM*
MS&A	GOTS Wargaming	PEO STRI*	OneSAF*	A simulation tool for generating synthetic entities and battlefield behavior
MS&A	COTS Mission Modeling	Ansys	STK*	The precision simulation of satellites, aircraft, and other assets with trade studies and propagation effects
MS&A	GOTS Mission Modeling	Air Force Research Laboratory	AFSIM*	A simulation framework for mission modeling oriented at U.S. Air Force use cases
MS&A	COTS Network Emulation	Keysight	EXata	A network emulator for representing battlefield communications and cybereffects
Numerical Analysis	Numerical Analysis COTS	Mathworks	MATLAB*	A numerical computing and programming environment widely used for algorithm development and simulation

Capability Group	Capability	Vendor	Tool	Description
Numerical Analysis	Numerical Analysis FOSS	FOSS	Jupyter, Matplotlib, SciPy, NumPy, Scikit-learn*	N/A (Can use Anaconda from Anaconda Inc. for startups)
PDM	PDM	Ansys	Minerva	A data management tool primarily used for Ansys models
PLM	PLM	Siemens	TeamCenter	Configuration management and data governance
RM	RM	IBM	DOORS NextGen*	A tool that defines, manages, and traces requirements across engineering life cycles

Note: UPDM = unified profile for DoDAF and Ministry of Defense Architecture Framework (MODAF); QGIS = quantum geographic information system; PEO-STRI = U.S. Program Executive Office Simulation, Training, and Instrumentation; HFSS = high-frequency simulation software; OneSAF = One Semi-Automated Forces; STK = systems toolkit; AFSIM = Advanced Framework for Simulation, Integration, and Modeling; MATLAB = Matrix Laboratory; Jupyter = Julia, Python, and R; Matplotlib = MATLAB, plot, and library; SciPy = scientific Python; NumPy = numerical Python; Scikit-learn = SciPy Toolkit; DOORS NextGen = dynamic object-oriented requirements system next generation.

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Biography

Alexander J. Matthews is the chief architect at NextGen Federal Systems, with 16 years supporting the intelligence community and U.S. Department of Defense, developing solutions, and providing services for complex weapon/mission systems, applications, and enterprise platforms as a technical lead, model-based systems engineering (MBSE) subject matter expert (SME), platform engineering SME, and application developer. Lately, he has focused on digital engineering/MBSE initiatives across NextGen programs, to include developing cosimulation capability; enabling rapid mission engineering for the XM30 mechanized infantry combat vehicle; applying MBSE to processing, exploitation, and dissemination modernization; and collaborating with a large prime to win a $3.5B mission system with a unique digital mission engineering approach.