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Measuring the RoI of Digital Engineering: It's a Journey, Not a Number

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ABSTRACT

Since publication of the Department of Defense (DoD) Digital Engineering Strategy in 2018, Digital Engineering (DE) and Model-Based Systems Engineering (MBSE) have become a central digital transformation strategy for the entire acquisition community. At this point, the services and program management offices are still struggling to quantify the value of this DE transformation. Research conducted by the Systems Engineering Research Center (SERC) in collaboration with a government/industry Digital Engineering Measures Working Group created the first formal measurement framework for this transformation. Program offices desire a quick and aggregated answer to the question “What is the return on investment for my DE transformation?” but they must first do the work to create the bottoms-up detailed measures and measurement strategy that will allow them to attain that answer over time. The new DE Measurement Framework, published through Practical Software and Systems Measurement (psmsc.com), provides a starting point for this journey.¹

MOTIVATION

Digital Engineering (DE) and model-based systems engineering (MBSE) approaches are two components of enterprise digital transformation that have great promise to improve the efficiency and productivity of engineering activities, particularly for complex engineered systems. Organizations perceive and have cited many benefits of this transformation, but there has been little attention on formally measuring these benefits (Henderson and Salado 2021). Systems engineering as a discipline has long had difficulty providing quantifiable evidence of its value (Honour 2004); DE transformation provides an opportunity to better measure its value. Transitioning from a document-based to a model-based approach is expensive, and organizations want to know if the effort and cost to adopt MBSE is worth it.

THE BENEFITS OF DIGITAL ENGINEERING

The SERC engaged with government and industry subject matter experts (SMEs) to develop a set of metrics that should be employed to best show the value of DE and MBSE. Since there are many potential benefits, we developed a causal model based on performance measurement literature to systematically decide on which metrics should be prioritized, then worked with the community of SMEs to refine that model into the set of potential measurement specifications described in the DE Measurement Framework. Our research indicated: 1) DE and MBSE have measurable benefits; 2) DE/MBSE measures can be defined and tracked, and are extensions to well-known software measures; and 3) DE/MBSE measures primarily support the systems engineering process and can provide data-driven quantitative assessment of systems engineering benefits, given an appropriate measurement framework.

Previous SERC research on benefits and metrics in DE surveyed both literature and the MBSE community to broadly collect potential measures associated with benefits and adoption indicators (SERC SR-001 2020; SERC TR-002 2020). The survey results and initial DE Metrics report remain available on the SERC website: <https://sercuarc.org/results-of-the-serc-incose-ndia-mbse-maturity-survey-are-in>. The earlier surveys were used to narrow down a set of eight direct benefits and measurement strategies associated with DE measurement, as described in Table 1.

¹ PSMSC is an initiative sponsored by the DoD and U.S. Army to provide Project Managers with the objective information needed to successfully meet cost, schedule, and technical objectives on programs.

Direct Benefits	Definition	Measurable benefits
Higher level support for Automation	Use of tools and methods that automate previously manual tasks and decisions	Greater process automation, increased use of tools, increased efficiency, reduced cost
Early verification and validation (V&V)	Moving tasks into earlier development phases that would have required effort in later phases	More discrepancies found in reviews, earlier defect resolution, reduced rework
Strengthened testing	Using data and models to increase test coverage in any phase	Increased defect detection and resolution before fielding, reduced rework
Better accessibility of information (ASOT)	Increasing access to digital data and models to more people involved in program decisions	Increased number of users in the tools, run-time performance of the infrastructure, reduced lead time
Increased traceability	Formally linking requirements, design, test, etc. through models	Greater design correctness and completeness, better able to track product design sizing, reduced volatility and increased stability
Multiple viewpoints of model	Presentation of data and models in the language and context of those who need access	Increased number of users in the tools, greater design correctness, increased efficiency
Reusability	Reusing existing data, models, and knowledge in new development	Better data and model reuse, reduced effort, reduced lead time
Higher level of support for Integration	Using data and models to support both the integration of information and system integration tasks	Reduced number of product iterations before release, reduced release cycle time

Table 1. Direct and measurable benefits of DE/MBSE

REALIZING THE BENEFITS

DE is fundamentally about increasing stakeholder involvement in the engineering development and related program management processes. There are two primary drivers of stakeholder involvement: 1) the organization has to create the environment for and measure actual use of the digital tools; and 2) the organization has to develop the associated digital project methods and processes. Many of the other benefits of a digital transformation will be lost if artifacts must be produced and activities must be conducted outside of the digital environment and related models. This leads to a measurable adoption strategy as follows:

- Methods, processes and tools must be standardized across the project or organization
- The workforce must be trained on and work inside of the tools and associated models
- The organization must measure both the internal and external use of the tools and user experience
- Organizations need to get serious about conducting reviews “in the model”
- Organizations need to get serious about modeling and using reference architectures and reusing them across portfolios
- Tool vendors must get serious about increasing automation and inter-operability in their tools

However, adoption measures are the foundation. Real returns will accrue when the quality and timeliness of the product improve through the use of DE and MBSE. We found a set of base quality and cycle time measures that are common to most digital transformation activities and well described in the software community. These lead to a measurable product definition and development strategy as follows:

1. DE/MBSE should reduce errors throughout the system definition and design phase. Measuring defects/errors and resolving these earlier in the development processes is important and can be supported by the digital tools. Errors should not persist from one phase to the next.
2. DE/MBSE will improve functional completeness and correctness of the underlying description of the design. Programs and organizations need to develop the ability to quantify and analyze functions in a digital systems model. The DoD acquisition community should put more effort in defining models associated with decomposition of capabilities, functions, and requirements, then measuring the peer review, simulation, and test of those models.
3. Programs and organizations need to measure the efficiency gained in model-based review artifacts. Leading indicators of efficiency are associated with the number of review discrepancies/actions and decision signoffs or approvals at the review. To achieve RoI, the DoD must be serious about conducting technical reviews in the models, as the DoD DE Strategy states.
4. Reduced cost, which is the ultimate measure of return, is a lagging indicator dependent on all these other indicators. Reduced cost should be evaluated across programs in the enterprise, but more leading indicators such as defects and effort also require tracking within a program or project and must be measured to derive cost benefits. Unfortunately, this means the RoI answer is a journey, not a number.

We have found there are only a small handful of DoD programs that have started this measurement journey. Programs must begin collecting data on these base measures before the RoI answer can be realized.

MEASURING DIGITAL ENGINEERING ACTIVITIES

In today's systems, engineering creates not only the product itself, but also the digital data and models that define and then support the product over its life cycle. Because DE and MBSE processes help to define the capabilities of the eventual system, the measures can serve as useful leading indicators for other product-related measures such as operational integration, evaluation, and support. DE/MBSE can also produce independent products in support of delivered data, hardware, and software products such as digital twins or other model- or simulation-based executable systems.

The benefits of DE and MBSE are associated with intangible products, defined in software, even though much of the purpose of DE/MBSE is to improve tangible products. Thus, measurement of DE and MBSE is primarily a software measurement activity. Because of this, the DE Measurement Working Group selected the PSM framework as a baseline measurement specification approach. PSM defines an information-driven measurement process focused on the technical and business goals of any organization, and allows specification of measurement goals, information, and indicators (Jones, et al. 2001). The original PSM guide to software measurement was published in 2001. In 2020, an extension to the guidance published covering additional measurement concepts associated with software and system continuous iterative development (CID). The CID framework directly applies to DE and MBSE in the use of evolving models as the primary source of knowledge about a system and its life cycle. The DE measurement framework further extends the PSM base framework and the CID framework to cover DE/MBSE measurement concepts. Programs should use all three of these measurement frameworks in their measurement journeys.

Version 1.0 of the DE Measurement Framework was published May 18, 2022. The framework can be downloaded at <https://www.psmc.com/DEMeasurement.asp>. The development of the framework was a community effort sponsored by the SERC, the Aerospace Industries Association (AIA), the International Council on Systems Engineering (INCOSE), the National Defense Industrial Association (NDIA), and PSM.

Programs should begin using the measurement specifications in the framework immediately, and report their experience to the community. It is expected that this measurement framework will evolve over time as additional experience and lessons learned are collected and published. The elusive RoI number will not be predictable until enough programs start to measure and quantify the details of their processes and compare these measures from program to program.

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Tom McDermott is a leader, educator, and innovator in multiple technology fields. He currently serves as Deputy Director and Chief Technology Officer (CTO) of the Systems Engineering Research Center (SERC) at Stevens Institute of Technology in Hoboken, NJ, as well as a consultant specializing in strategic planning for uncertain environments. He studies systems engineering, systems thinking, organizational dynamics, and the nature of complex human socio-technical systems. He teaches system architecture concepts, systems thinking and decision making, and the composite skills required at the intersection of leadership and engineering. He has over 30 years of background and experience in technical and management disciplines, including over 15 years at the Georgia Institute of Technology and 18 years with Lockheed Martin.

Tom's professional accomplishments in this position come from a combination of servant leadership, systems thinking, and heuristic knowledge of complex system architectures. His long-term research goal is to develop methods and tools that support better systems thinking in the management and engineering domains and enable more rapid development of system knowledge. His current research activities focus on innovation models, strategic foresight techniques, system data analytics, and modeling and simulation of policy implications in current and future complex systems.

Tom is a graduate of the Georgia Institute of Technology, with degrees in Physics and Electrical Engineering. He developed his career in the defense electronics industry, culminating in a leadership position with Lockheed Martin as Chief Engineer and Program Manager for the F-22 Raptor Avionics Team. Tom was GTRI Director of Research and interim Director from 2007-2013. During his tenure the impact of GTRI significantly expanded, research awards doubled to over \$300M, faculty research positions increased by 60%, and the organization was recognized as one of Atlanta's best places to work as well as one of the nation's leaders in employee development. He also has a visiting appointment in the Georgia Tech Sam Nunn School of International Affairs. Tom is one of the creators of Georgia Tech's Professional Masters degree in Applied Systems Engineering and lead instructor of the "Leading Systems Engineering Teams" course.



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