32nd Annual INCOSE international symposium

hybrid event

Detroit, MI, USA
June 25 - 30, 2022

A collaboration among industry, government and academia

Digital Engineering Measurement Framework – v1.0a

Digital Engineering Measurement Framework - Project Overview and Timeline

2020

AIA EMC Project Plan

- Refined list of DE metrics serving as Key Performance Indicators for program execution, and model health
- Detailed descriptions of each metric, traceable to SE metrics, quality, & requirements volatility

Established collaborative WG (9/14/20)

(PSM, NDIA, INCOSE, AIA, SERC, Aerospace, OUSD R&E, …)

Objectives

- Define industry consensus measurement framework for DE, MBSE
- Align measures with business information needs for project execution and organizational performance improvement.

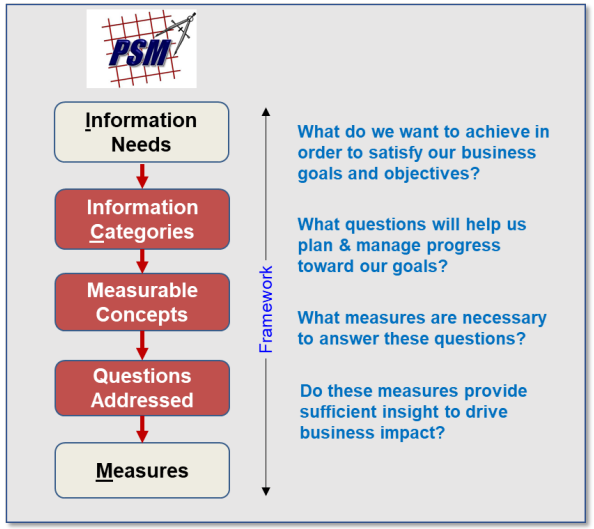
Leverage partner resources and assets

- Practical Software and Systems Measurement (PSM) Continuous Iterative Development Measurement Framework
- SERC / INCOSE / NDIA MBSE Maturity Survey
- SERC DE metrics research (SERC-2020-SR-003, SERC-2020-TR-002)
- Systems Engineering Leading Indicators Guide
- DoD Digital Engineering Strategy

2021

Follow PSM process to define DE measurement framework

- Aligned with ISO/IEC/IEEE 15939 measurement process standard



Team product development

- Front matter (concepts, terms, …)
- Information Needs (ICM Table)
- Measurement specifications

2022

Initial framework draft for review (Jan 2022) Publication release (May 2022)

Practical Software and Systems Measurement (PSM) Digital Engineering Measurement Framework

Version 1.0
May 18, 2022

Developed and Published by Members of:

Practical Software & Systems Measurement (PSM)
Systems Engineering Research Center
Aerospace Industries Association (AIA)
National Defense Industrial Association (NDIA)
International Council on Systems Engineering (INCOSE)
Department of Defense Research & Engineering
The Aerospace Corporation (AEROSPACE)

Unclassified: Distribution Statement A: Approved for Public Release; Distribution is Unlimited

Initial Measurement Specifications

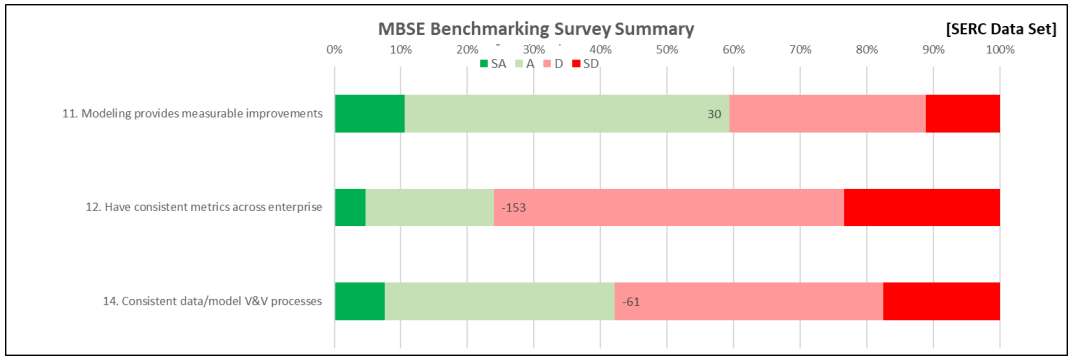
- Architecture Completeness and Volatility
- Model Traceability
- Product Size
- DE Anomalies
- Adaptability and Rework
- Product Automation
- Deployment Lead Time
- Runtime Performance

http://www.psmsc.com/DEMeasurement.asp

Lack of effective DE/MBSE measures has been an inhibitor to digital transformation

Substantiated by DoD SERC research

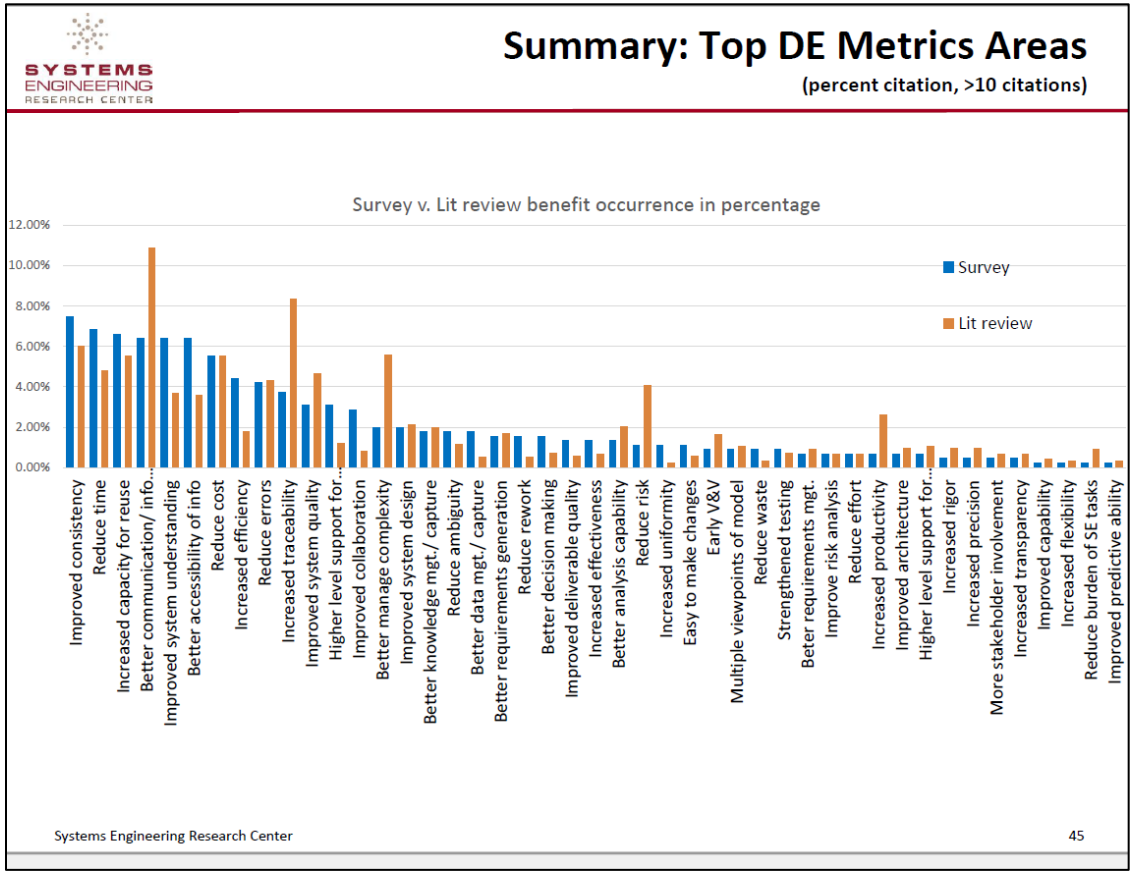
Benchmarking the Benefits and Current Maturity of Model-Based Systems Engineering across the Enterprise (SERC-2020-SR-001)



Category	Question title	SERC MBSE Questionnaire	Survey Score	SA	A	D	SD	Chart	Calculated Score
Model Metrics	11. Modeling provides measurable improvements	Modeling activities in our organization provide measurable improvements within and across projects.	30	18	83	50	19		30
	12. Have consistent metrics across enterprise	We have consistent metrics across our program(s)/enterprise that include our modeling activities.	-153	8	33	90	40		-153

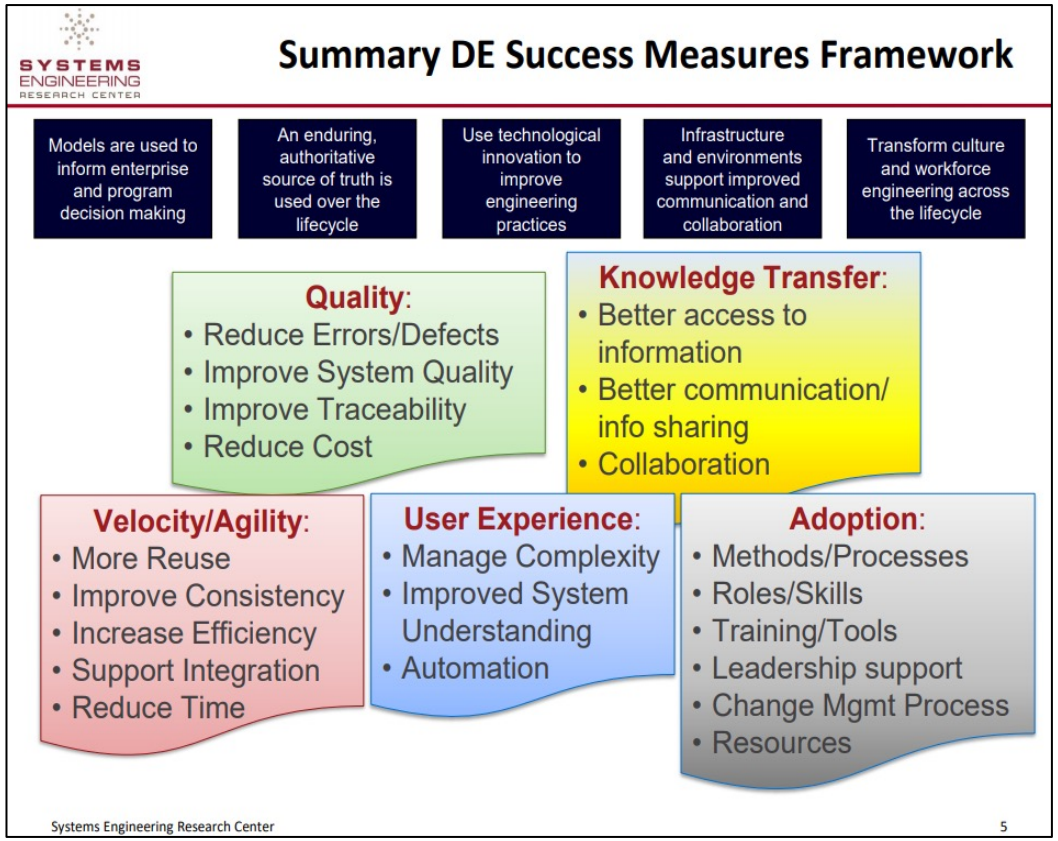
https://sercuarc.org/results-of-the-serc-incose-ndia-mbse-maturity-survey-are-in/

Summary Report Task Order WRT-1001: Digital Engineering Metrics Supporting Technical Report (SERC-2020-SR-003)
Task Order WRT-1001: Digital Engineering Metrics Technical Report (SERC-2020-TR-002)



Success Measures and Benefits of Digital Engineering Transformation

Research from DoD SERC and Virginia Tech helped inform the DE Measurement Framework



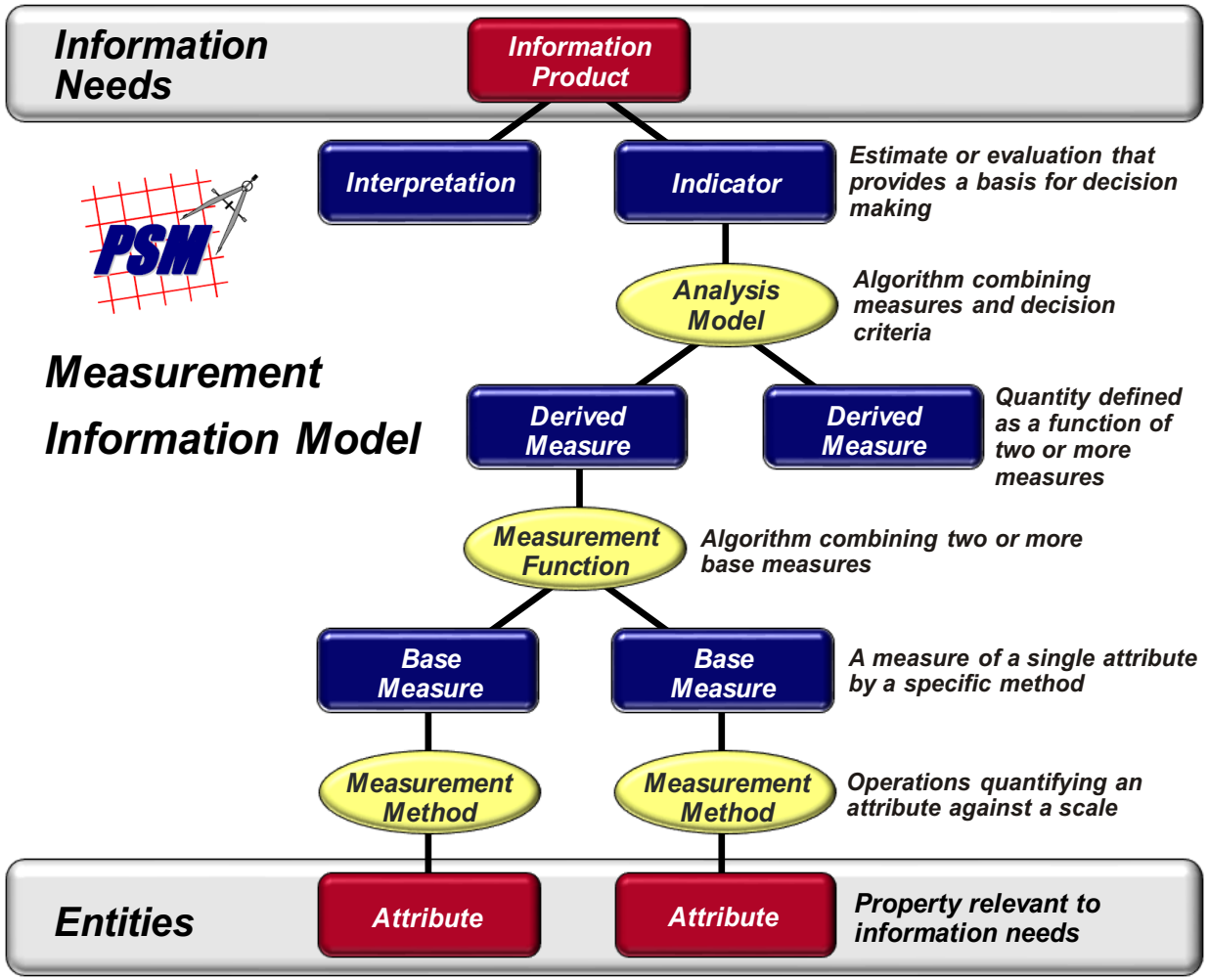
Primary Benefits	Description	Secondary Benefits and Measures
Higher level support for automation	Use of tools and methods that automate previously manual tasks and decisions	8.6 Product Automation 8.7 Deployment Lead Time
Early Verification and Validation (V&V)	Moving tasks into earlier developmental phases that would have required effort in later phases	8.4 DE Anomalies 8.5 Adaptability and Rework 8.7 Deployment Lead Time
Reusability	Reusing existing data, models, and knowledge in new development	8.4 DE Anomalies 8.5 Adaptability and Rework 8.7 Deployment Lead Time
Increased Traceability	Formally linking requirements, design, test, etc. via models	8.7 Deployment Lead Time 8.8 Runtime Performance
Strengthened Testing	Using data and models to increase test coverage in any phase	8.1 Architecture Completeness and Volatility 8.2 Model Traceability 8.3 Product Size
Better Accessibility of Information (ASoT)	Leveraging an Authoritative Source of Truth (ASoT) to increase access to digital data and models to increase the involvement of stakeholders in program decisions	8.7 Deployment Lead Time 8.8 Runtime Performance
Higher Level of Support for Integration	Using data and models to support integration of information and to support system integration tasks	8.6 Product Automation 8.2 Model Traceability
Multiple Model Viewpoints	Presentation of data and models in the language and context of those that need access	8.1 Architecture Completeness and Volatility 8.7 Deployment Lead Time

PSM measures are derived from business information needs

Based on objectives and issues from the project or enterprise levels

- *Objective* - a project goal or requirement
- *Issue* - an area of concern that could impact the achievement of an objective, including risks, problems, and lack of information

Measures should provide insight into project or enterprise information needs to support decision-making



PSM Practical Software and Systems Measurement, www.psmsc.com

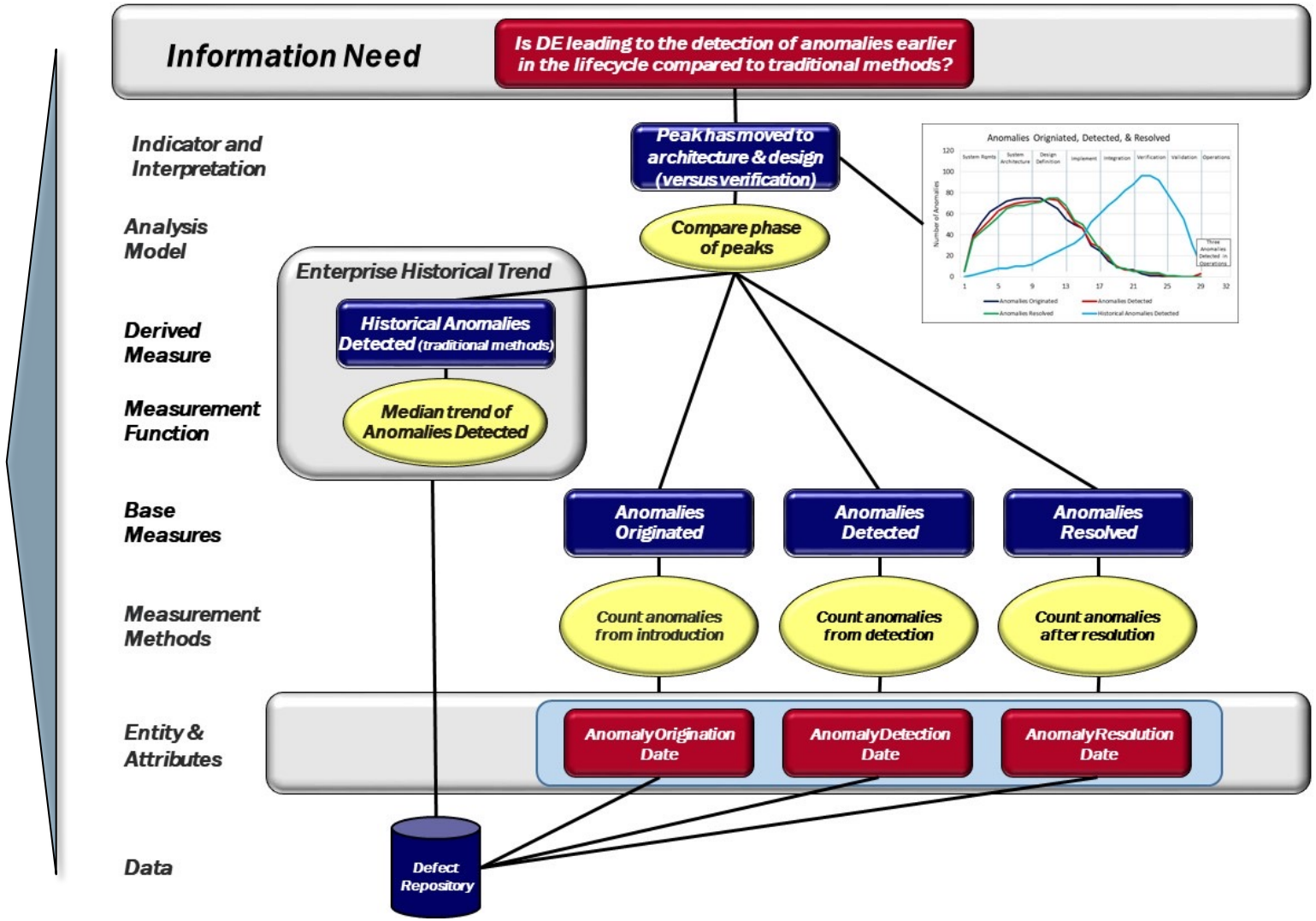
See Framework for more information

DE Measurement Framework ICM Table (Excerpt)

Information Categories	Measurable Concepts	Project Information Needs	Enterprise Information Needs	Potential Measures	Notes (Guiding Objectives)
Product Quality	Functional Correctness	Are we finding and removing anomalies early in the life cycle using models and shared information? Is the quality of the product in question adequate for the product to be used in subsequent phases or activities?	How many anomalies were released (escaped) to operations? Is the use of DE leading to the detection of anomalies earlier in the lifecycle compared to traditional methods or projects)? Has the detection curve shifted to the left?	DE Anomalies *	For digital engineering focus on the defects for modeling and simulation (including drawings).
Product Quality	Functional Correctness	How much rework effort is spent maintaining planned or unplanned changes to DE work products across the life cycle?	How much is rework reduced through use of DE? Can changes to work products be implemented more efficiently and with less effort in a DE environment relative to traditional methods?	Adaptability and Rework * Acceptance of Completed Work Products (Model Elements, Artifacts) Rework or Rework Defects	Completion of work products requires defined acceptance criteria. Rework is required when the acceptance criteria are not met.
Product Quality	Functional Correctness	What traceability gaps or defects exist in the digital model? Does model traceability support change impact assessments (requirements, design, compliance)?	Is architectural traceability improved using digital engineering methods relative to traditional approaches?	Model Traceability * Traceability Anomalies	
Process Performance	Process Effectiveness	How many released, validated system definitions/analyzed elements were functionally correct, but returned for rework?	Is the organization learning how to reduce the number of defects released to operations?	Model Element DE Anomalies	

Example Measurement Information Model – Anomalies

Digital engineering measures and indicators are specified in a structured template aligned with the PSM Measurement Information Model



Example Measurement Specification (Excerpts)

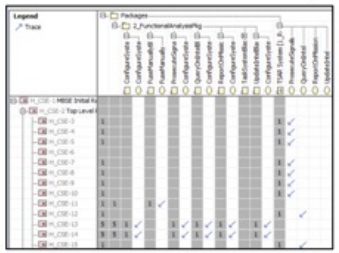
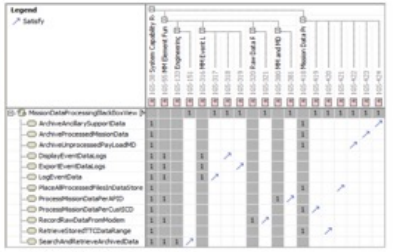
8.2 MODEL TRACEABILITY

Description / Definitions / Measures (Base, Derived)

Measure Introduction	
Description	The usefulness and quality of a digital model depends on the completeness and integrity of the relationships among model elements. Traceability between elements, such as requirements allocation and flow down to architectural, design, and implementation components, assures that the system solution is complete and consistent. Gaps in bi-directional traceability between the artifacts of two models or might indicate where further analysis or refinement are needed. This might further apply to traceability gaps within a single model, when there is no implicit traceability between artifacts of different design stages. The prerequisites of any traceability measurement are agreed-upon, a priori guidelines and definitions, e.g., what model elements and relationships shall be traced, that apply to the specific DE model of the system. *Note:* While traceability might be applied to any model elements of interest that shall be defined a priori, functional architecture completeness always explicitly focuses on functions, requirements, and the associated hierarchy. Traceability reports and analyses might be facilitated by digital modeling tools. The traceability concepts and indicators in this specification are representative examples of more general traceability mappings and reports across the development life cycle, such as: • Traceability between stakeholder needs, system requirements, and allocated or derived requirements at each level of the system hierarchy • Traceability and flow down of requirements to the logical or physical solution domain (e.g., design, implementation, integration, verification, validation) • Allocation and traceability of performance measures or parameters, such as Measures of Effectiveness (MOEs) or Key Performance Parameters (KPPs) • Traceability of system interfaces
Relevant Terminology	Model Element: Modeling constructs used to capture the structure, behavior, and relationships among system model components (See 2.2.2 Model Element) Source Element: The *a priori* base model elements defined per DE model from which other model elements shall be derived from or allocated to, e.g., a stakeholder needs. Destination Element: The model elements defined per DE model that shall be derived from or allocated to the Source Elements. Traceability Gap: One or more model elements defined per DE model that shall be traced, but that have not yet been derived or allocated to Source Elements. Note: For enhanced traceability concepts refer to the advanced topic discussion.

Information Need and Measure Description	
Information Need	What is the extent of achieved traceability coverage from Source Elements, e.g., requirements, down to the logical or physical solution domain? What is our progress in completing the digital model? What traceability gaps exist?
Base Measure 1	Model Elements Traced [integer] "Number of model elements in a 1... n source/destination element relationship(s) as defined in an agreed upon, *a priori* guideline.
Base Measure 2	Model Elements Not Traced [integer] Number of model elements not in any 1... n source/destination *element relationship as* defined in an agreed upon, *a priori* guideline.
Derived Measure 1	Total Model Elements = Model Elements Traced + Model Elements Not Traced [integer] Total number of model elements *Note:* As defined in an agreed upon, a priori guideline (See Base Measure 1 and Base Measure 2).

Indicator(s) and Interpretation

Indicator Specification	
Indicator Description and Sample	Model Traceability can be depicted using visual or tabular summaries of the relationships among model elements. The specific indicators may depend on the model elements for which traceability is being measured, and the built-in reports and analyses provided by the digital modeling tool. For example, traceability among model elements might be implemented by showing requirements derivation and model traceability coverage of stakeholder needs into system and component requirements. Representative example indicators used to assess traceability dependencies among selectable model elements (e.g., requirements, use cases, activities, logical architecture and design, physical design, interfaces, parameters, measures of performance) are depicted in Figure 8.2-1. Here, mostly 2-dimensional matrices containing model specific model elements of interest are utilized. Alternatively, the relationship between model elements might be depicted as flow down. With respect to Figure 8.2-1 (bottom left), a specific use case is linked to related actions via an activity diagram.  Traceability Between Model Elements (Dependency Matrix)  Relationships to Problem or Solution Domain («satisfy» or «refine» Matrix)

Analysis Guidance

Analysis Model	Projects and organizations shall define the objectives, constraints, and criteria for establishing traceability among applicable model elements. This is typically guided by a model schema, metamodel, or blueprint that constrains traceability to meet the model's purpose. Review and analyze traceability dependencies among model elements to assess the completeness, adequacy, quality, and integrity of the digital model. The analysis may vary according to the types of specific model elements selected, but general guidelines may include: • Each source (parent) model element (Model Element 1) should be traceable to one or more allocated or derived destination (child) model elements (Model Element 2). • Each destination (child) model element (Model Element 2) should be derived from, or refine, a parent requirement or model element (Model Element 1). • Determine if the set of linked dependencies are, in aggregate, sufficient to adequately implement the parent requirement or model element.
Decision Criteria	In case a desired model traceability coverage (Derived Measure 2), e.g., 70%, of model elements of interest has not been met, the team shall specifically address these gaps. To validate whether the system meets stakeholder needs, at minimum, the system requirements should be traceable to these stakeholder needs. Model elements that do not satisfy requirements, might be obsolete and shall be evaluated. Again, the prerequisites of any decision making are agreed-upon, a priori guidelines and definitions, e.g., what model elements and relationships shall be traced, that apply to the specific DE model of the system

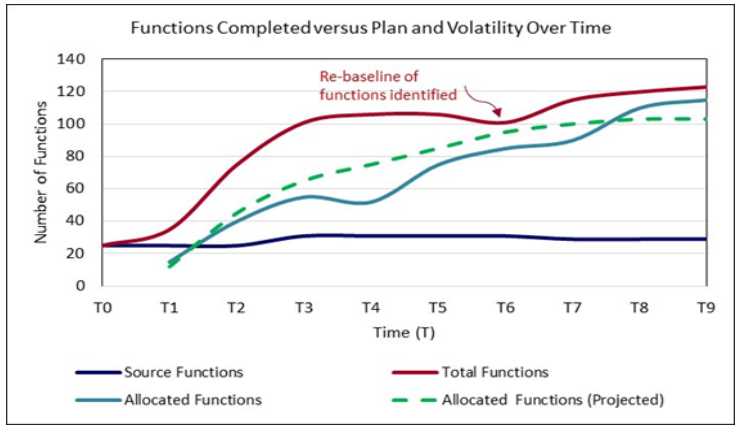
Additional Information and Guidance

Additional Analysis Guidance
Implementation Considerations

Information Category
Measurable Concept
Relevant Entities
Attributes
Data Collection Procedure
Data Analysis Procedure

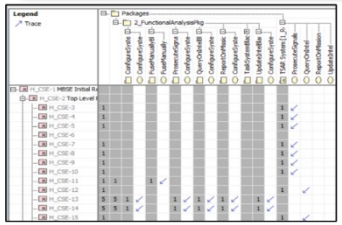
Digital Engineering Measurement Framework – Example Indicators

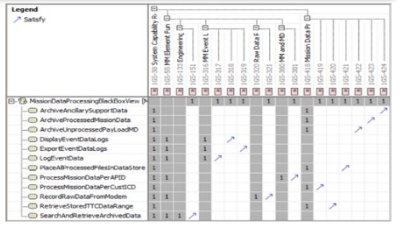
Architecture Completeness and Volatility

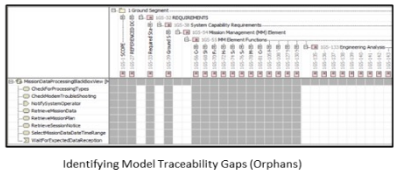


Is the architecture complete to proceed with design?

Model Traceability

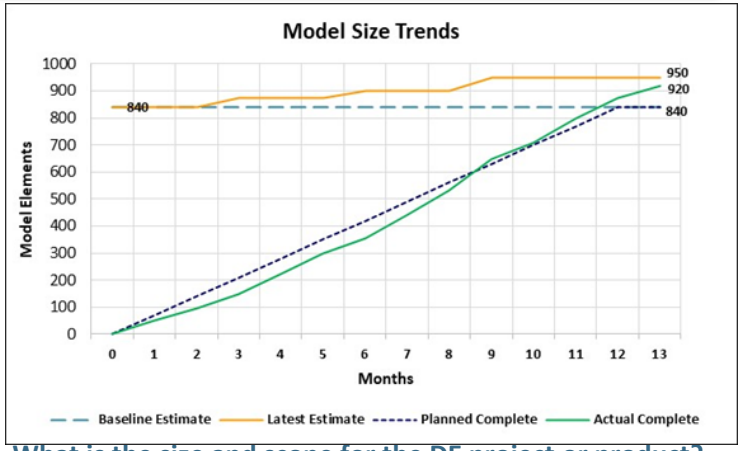






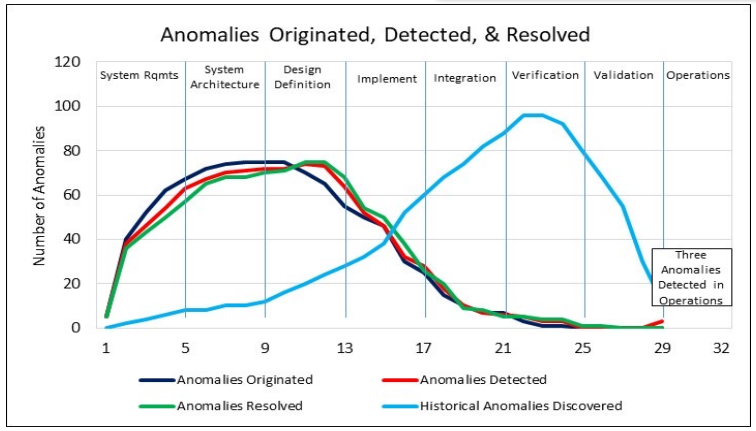
What is the traceability and coverage of model elements?

Product Size (Model Elements)

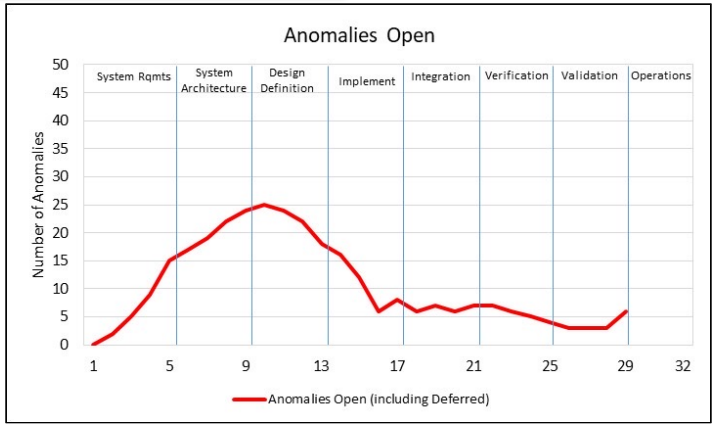


What is the size and scope for the DE project or product?

DE Anomalies

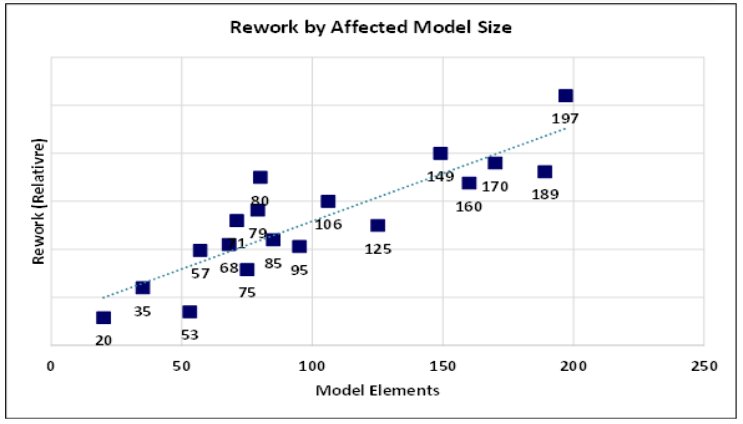


Are we finding and removing anomalies earlier using DE?



Is product quality adequate to be used in subsequent phases?

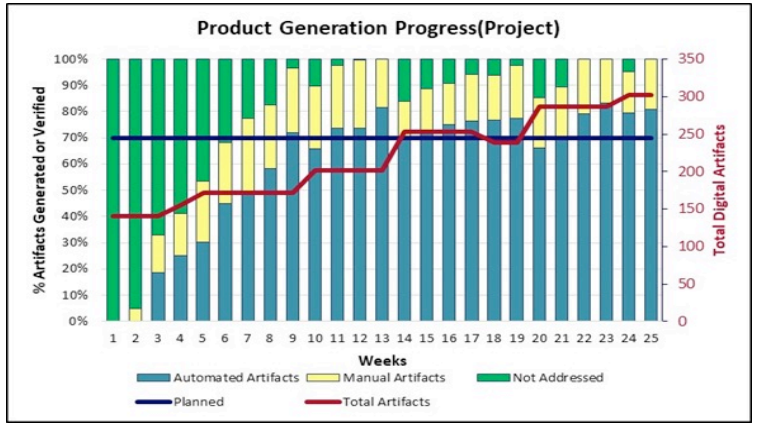
Adaptability and Rework



How much rework is for planned and unplanned changes?

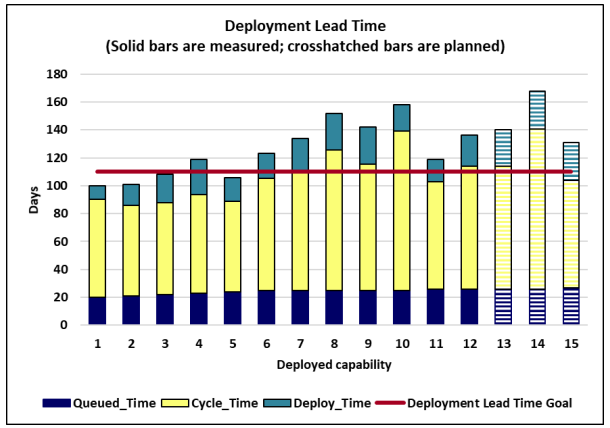
Digital Engineering Measurement Framework – Example Indicators

Product Automation



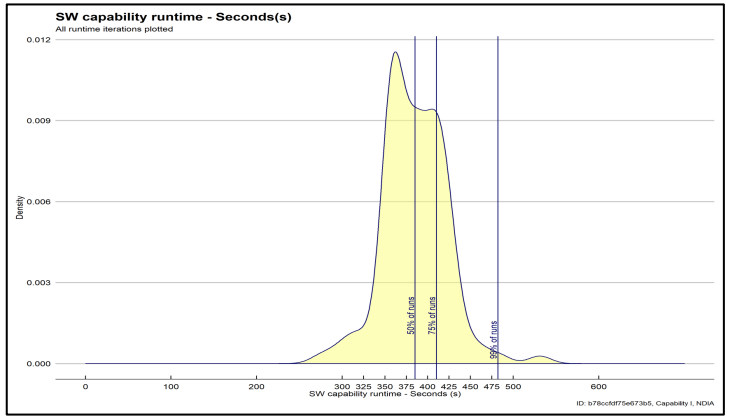
What percentage of artifacts are automatically model-generated?

Deployment Lead Time



How long does it take to deploy an identified capability?

Runtime Performance



What is the likelihood performance will meet operational needs?

Excerpts only from DE measurement specifications. Some specs have multiple sample indicators. See framework Section 8 - Measurement Specifications for details.

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Much appreciation to the many individuals and organizations that supported development of the V1.0a Digital Engineering Measurement Framework!

What hurt our heads?

- *How many different dialects are there?*
- *What is Digital Engineering?*
- *What is different about Digital Engineering?*

Where do we go from here?

- *DE measures for the enterprise*
- *Measure breadth of usability and user experience with digital tools*
- *Measure return on investment*
- *Measure additional productivity indicators related to velocity and agility*
- *Measure additional indicators that isolate new value to the enterprise through DE, in areas such as quality and knowledge transfer*
- *Measure enterprise and personnel process adoption*
- *Measure usability and user experience with digital tools*
- *Supportability and maintainability measures (impact assessment agility)*
- *Measures for security*
- *Identify typical digital artifacts*
- *Specify leading indicators*

Or do we take a Systems Thinking perspective?

Summary – Digital Engineering Measurement Framework v1.0a

- Lack of common measures and established best practices have inhibited digital transformation
- The v1.0a release of the DE Measurement Framework establishes an initial consensus from our partners as a starting point to advance a discussion across industry – some measures are conceptual

This initial DE measurement framework proposed by our team of representative stakeholder experts is intended to help projects and enterprises establish an initial path toward a measurably effective transition and implementation of digital engineering methods. It is but the first steps along this path, it will be a long and challenging but rewarding journey, and our industry will learn, iterate, and evolve as we go. We hope enterprises across a variety of application domains will find this initial measurement guidance useful to assess the effectiveness of their respective digital engineering transformation initiatives.

- Help us improve it! Participate in reviews, provide comments and suggestions, pilot the measures proposed, and participate in the future evolution of this framework
- Contact our team leads to get further involved

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