Systems Engineering Research Center (SERC)

A unique DoD UARC developing a Systems Research Network

Digital Engineering Research

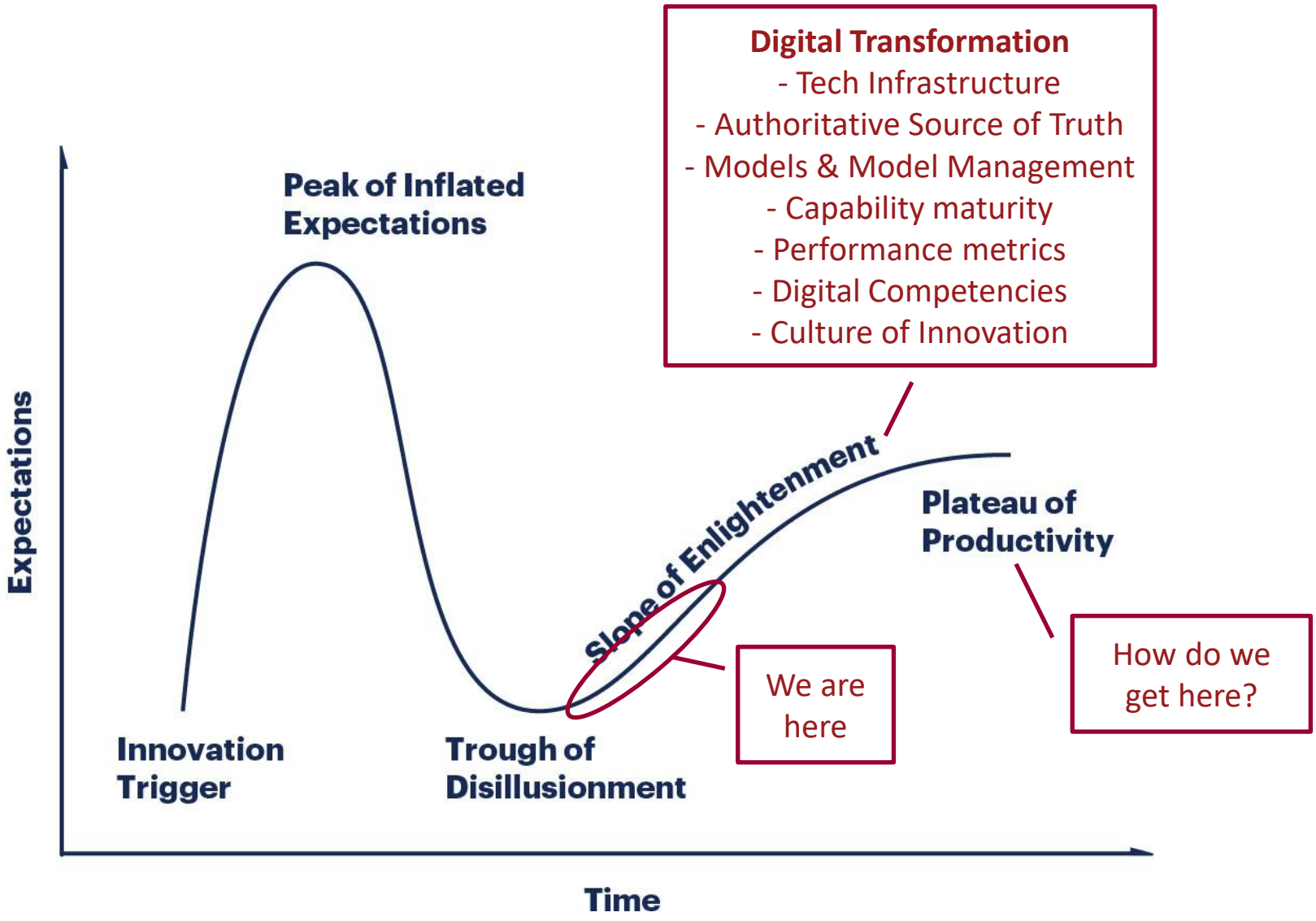
September 2020

This material is based upon work supported, in whole or in part, by the U.S. Department of Defense through the Systems Engineering Research Center (SERC) under Contract H98230-08-D-0171. The SERC is a federally funded University Affiliated Research Center (UARC) managed by Stevens Institute of Technology consisting of a collaborative network of over 20 universities. More information is available at www.SERCuarc.org

SYSTEMS ENGINEERING RESEARCH CENTER

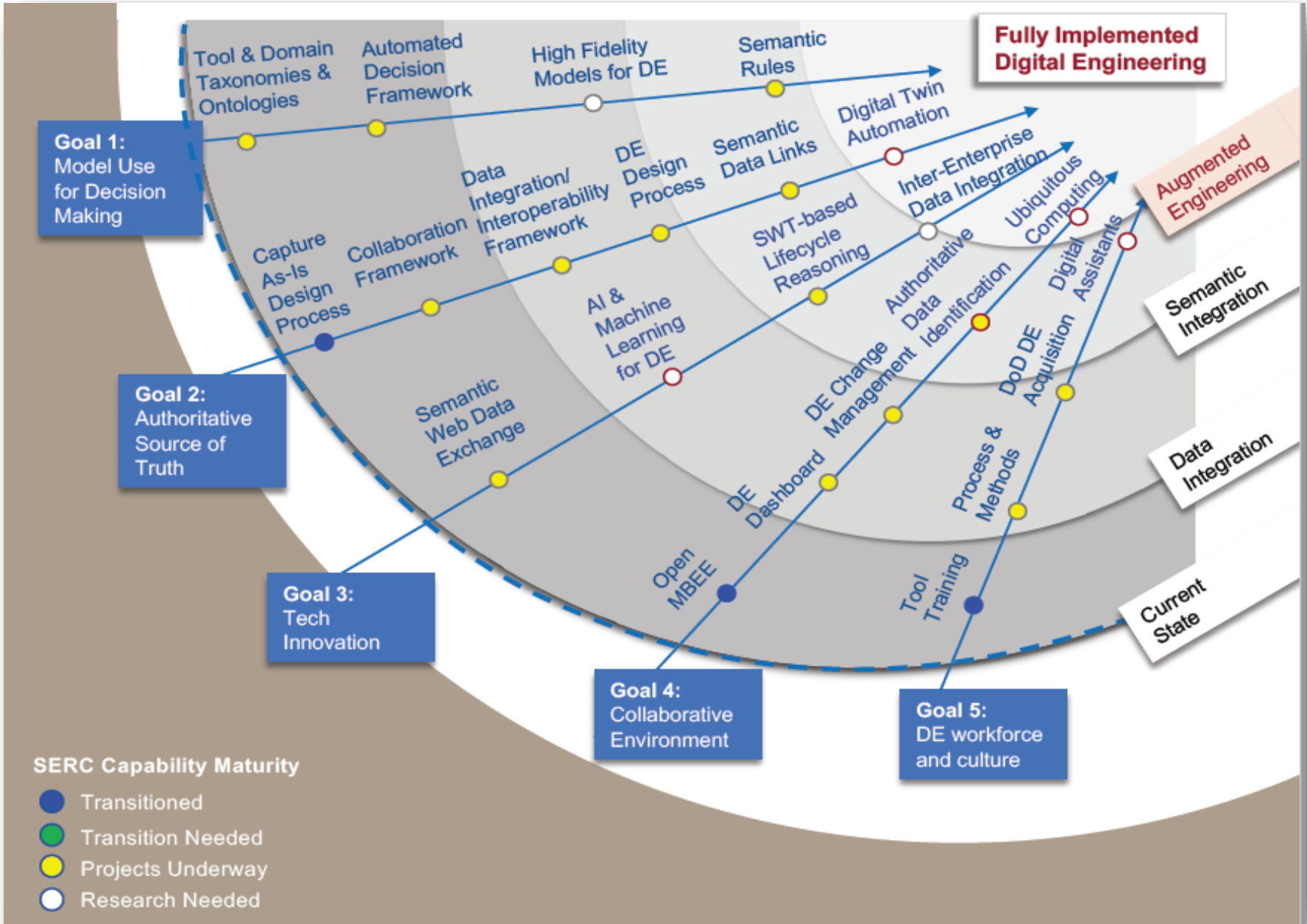
The Systems Research and Impact Network

Where is DE on the Gartner Hype Cycle?

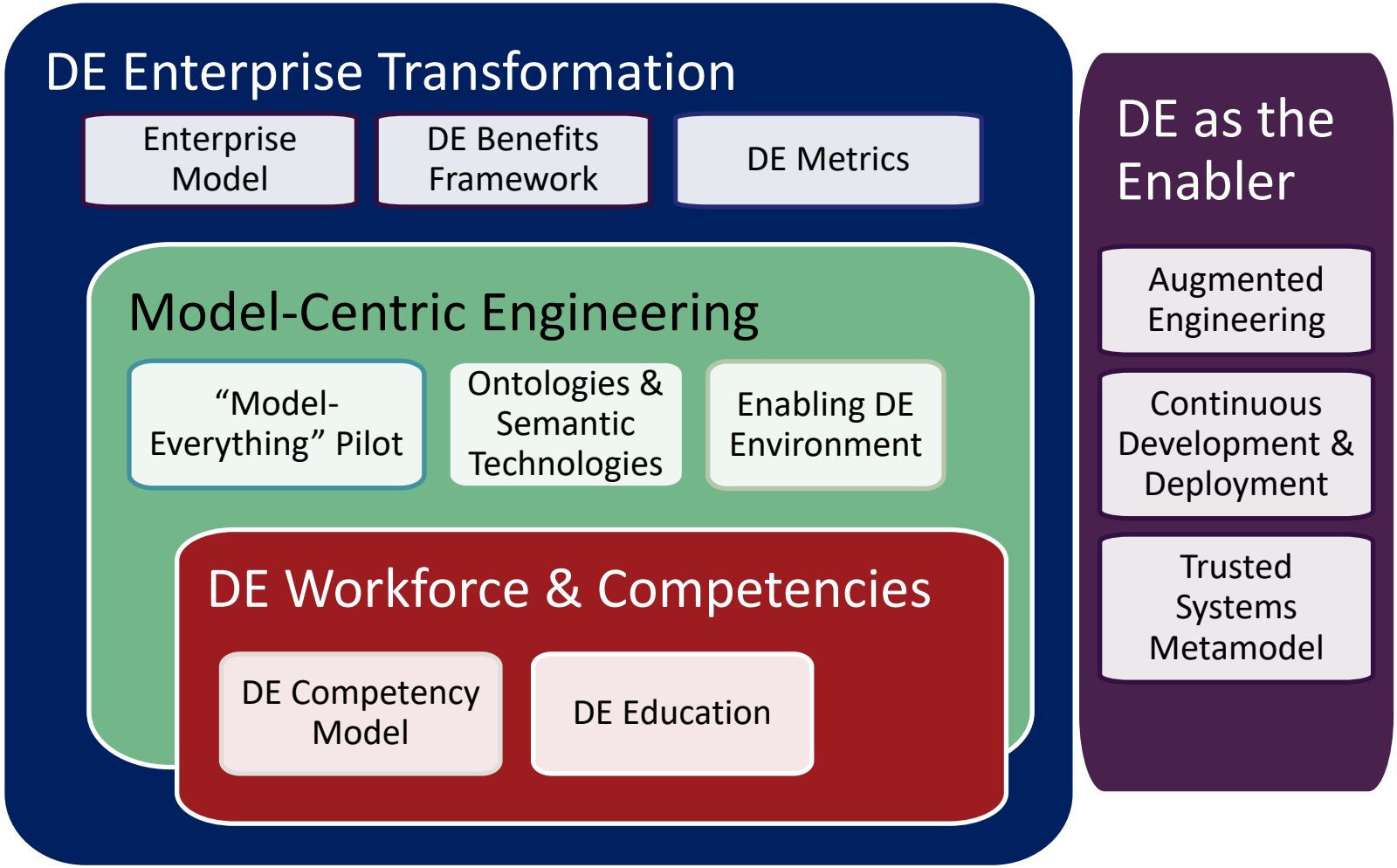


SYSTEMS ENGINEERING RESEARCH CENTER

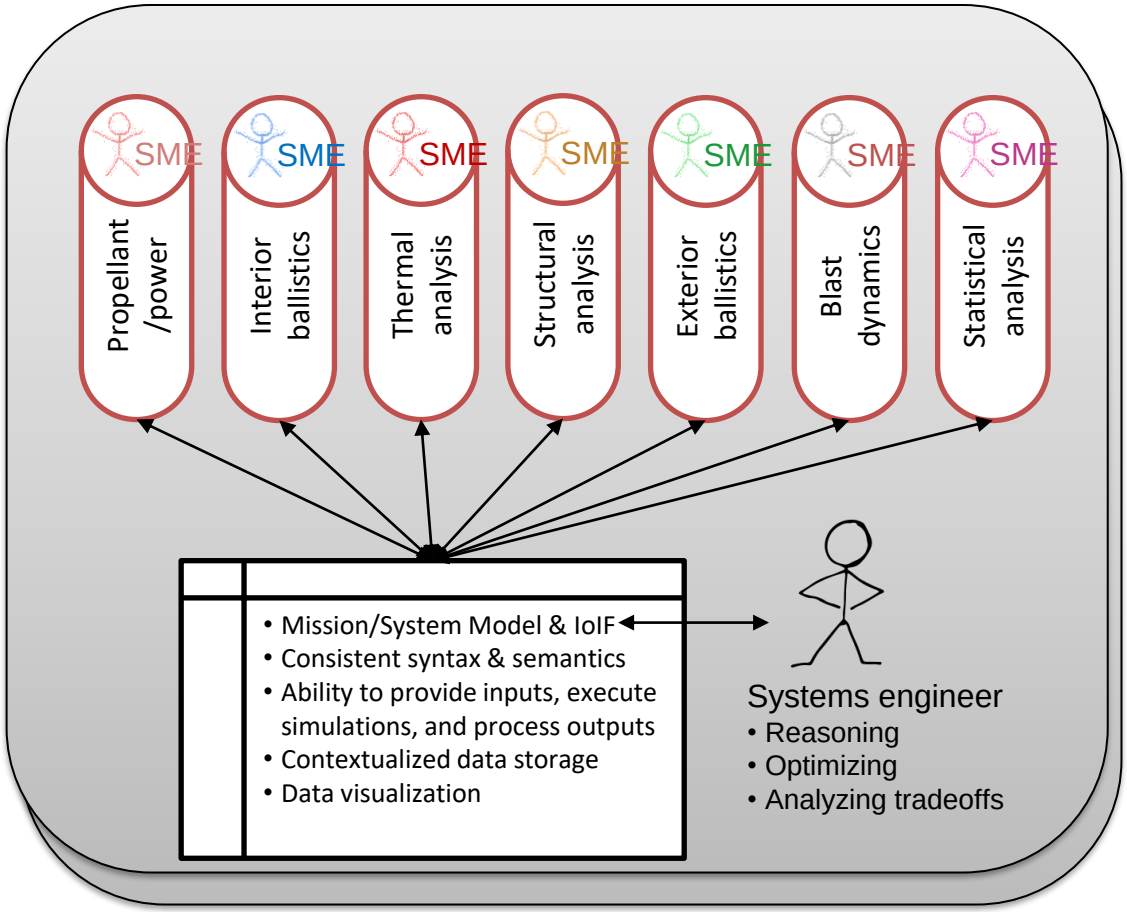
Digital Engineering Roadmap – the Enabler



SERC Digital Engineering Research



Aspirational High-level Research Vision, facilitated by Digital Engineering



Strategic/mission-level decision-maker
- Setting requirements & objectives
- Exploring tradeoffs
- Adjusting requirements & objectives based on capability information

SYSTEMS ENGINEERING
Research Center

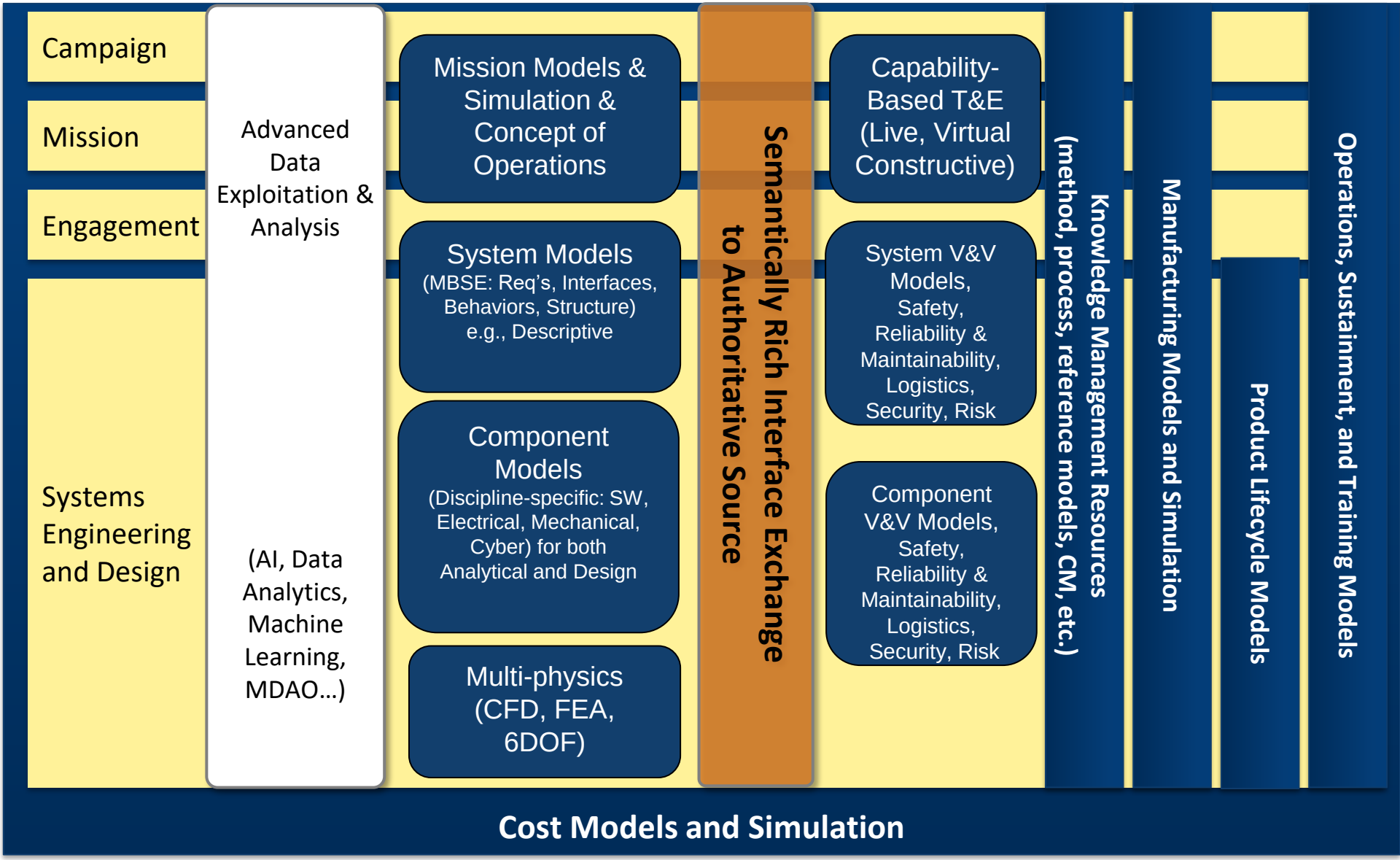
Enabling Concepts – Not an Exhaustive List

- **Descriptive models**
  - They have a formal syntax and semantics reflected with a graphical language
  - They represent Structure, Behavior, Interfaces, Requirements and related Interactions
  - They can characterize different levels of abstraction – Mission, System, Subsystem where different types of methods usually apply
  - They can generate "documents/specifications" based on stakeholder-relevant views
- **Modeling Methods and Methodology**
- **Ontologies and Semantic Technologies enabler for interoperable AST**
  - Provides a means to link data across all domain (like the Internet)
  - Provides semantics to support Knowledge Representation, which is an enabler for AI
  - **Interoperability and Integration Framework (IOIF)**
- **Enabling Digital Engineering Environment**
- **Multi-Disciplinary Design Analysis and Optimization**
  - Enabling Technologies for Tradespace Analysis
- **Modeling Pattern (s)** characterizes "integrated" interplay of three related aspects
  - Target system (Sub-System 1)
  - "Designing" system – processes, methods, models, tools and computing infrastructure (Sub-System 2)
    - Model of the Target system is actually part of System 2
  - "Evolving" system – encapsulates both Target and "Designing" system (System 3)
  - There are continuous dynamics that influence all three systems

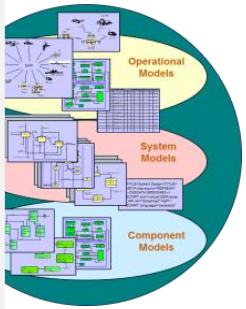
How do we know if an organization has adopted Digital Engineering?

- It has a documented business strategy for use of models/digital artifacts and top-down executive level support for Digital Engineering transformation
- It has established a "tech stack" for a Collaborative Integrated Modeling Environment (IME) and the associated Authoritative Source of Truth (AST)
  - Well defined model management processes. This includes methods, methodologies, tools and licenses, a model curation activity, and model exchange practices
  - Established model quality assurance (validation, issue tracking, and improvement)
  - Established means for linking descriptive system models with discipline specific models
  - Established procedures in place for conducting model and modeling reviews directly in the IME and AST across disciplines and across customers/suppliers
  - Established means for generating stakeholder role-specific views directly from the AST
- Established policies and procedures for using models/digital artifacts for contracting and contract deliverables (including procedures for dealing with data rights and IP rights)
- Established workforce development based on modeling methods using case studies in business relevant domains of interest

Reference Architecture for an IME in support of Digital Engineering



Formalizing the Reference Architecture



Element 1

Element 2

Element 3

Element 4

Operational Models

Other Business Models
Personnel, support, training, etc.

SoS Level

User Capability Model (aka Mission Model)

System Model is Authoritative Requirements Source (e.g. Gov't Specification)

User

Acquisition Agreement

System Model

Initial System Model

Final System Model

Main Contract

Acquirer

System Level

Functional Baseline

Sub-System 1 Model

Sub-System 2 Model

Sub-System n Model

Sub Contracts

Developer

Sub-System Level

Allocated Baseline

Discipline-Specific Models (Mechanical, Electrical, SW)

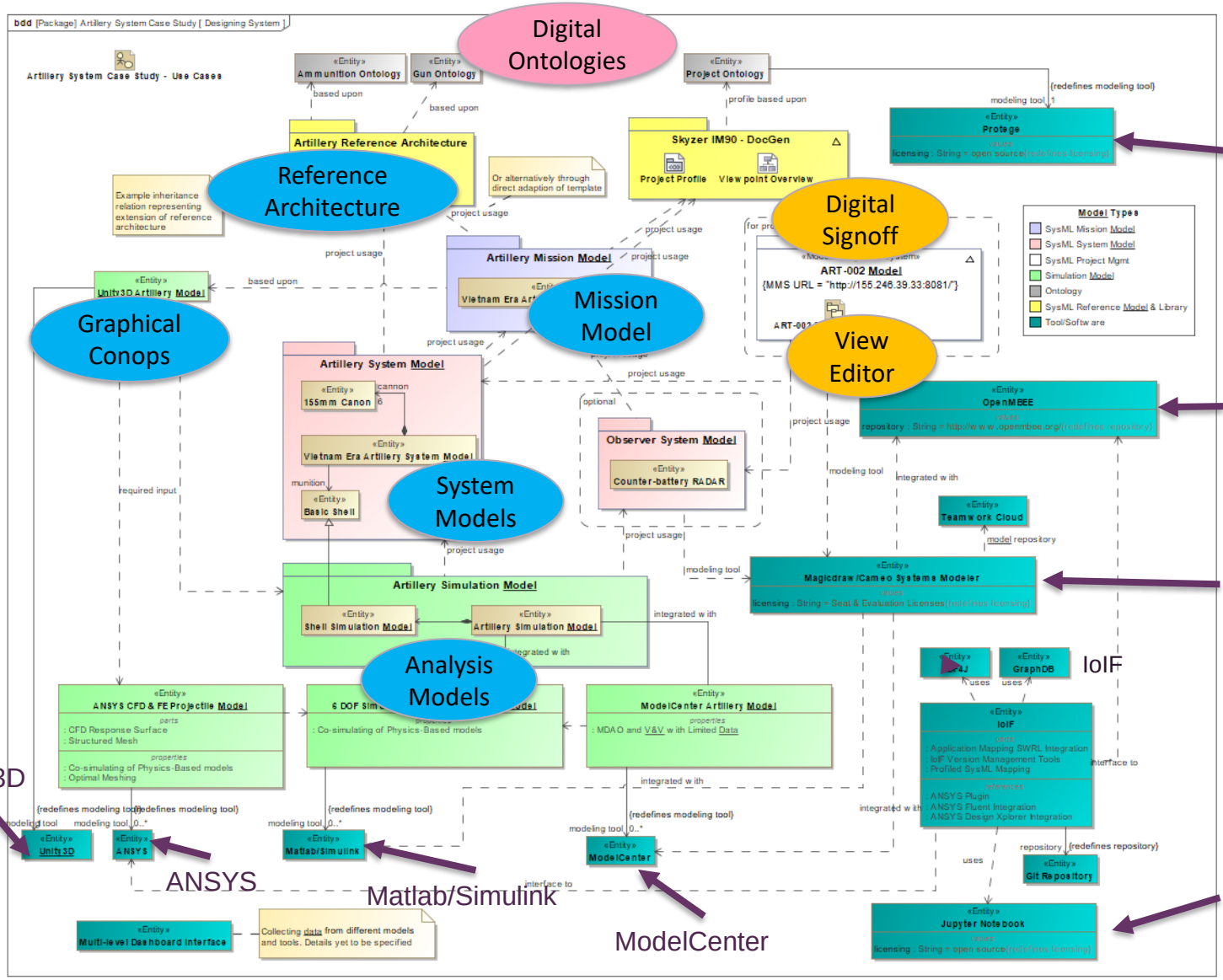
Component 1 Model

Component 2 Model

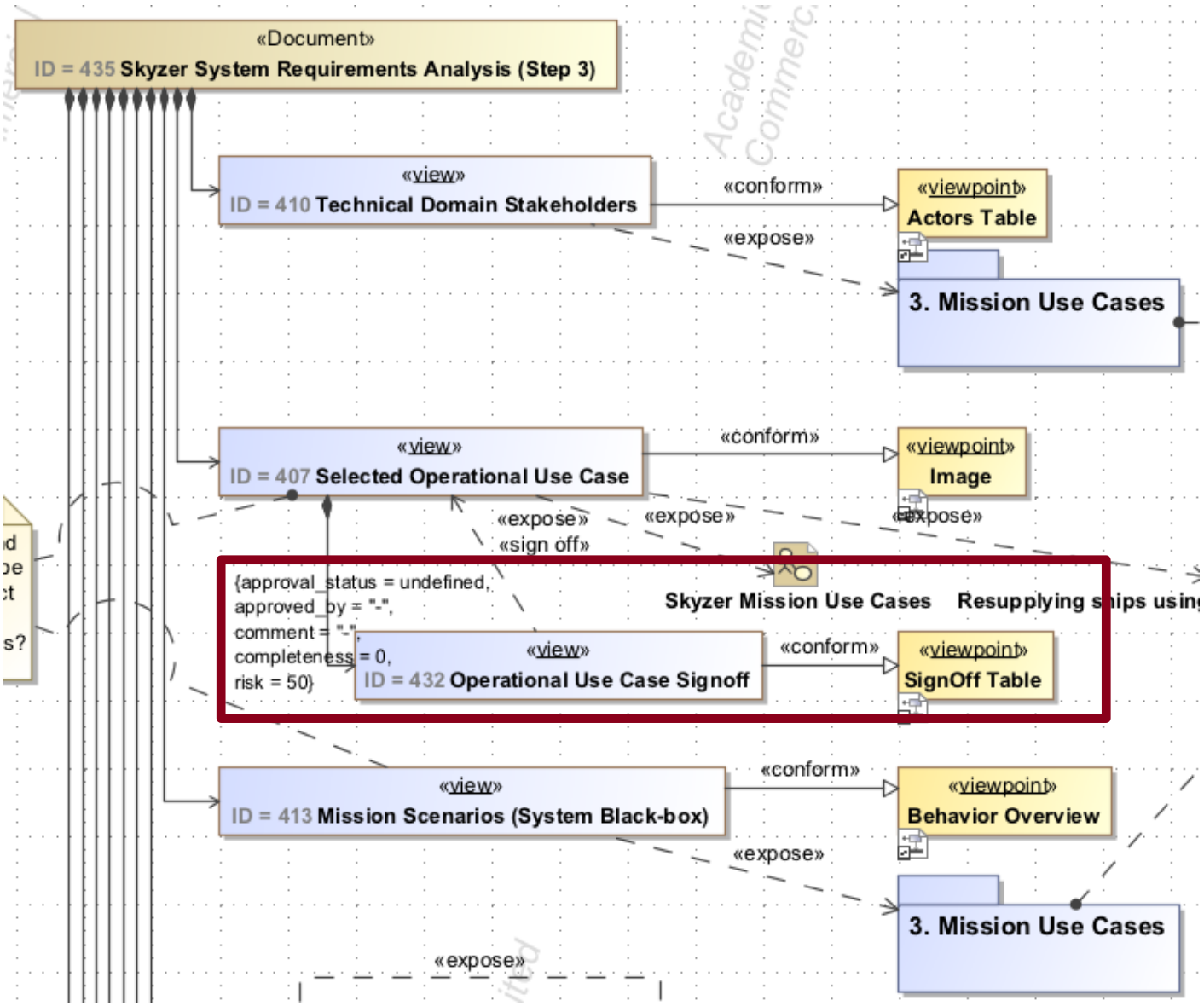
Component n Model

Sub Contractors

Example Reference Architecture "Full Stack"

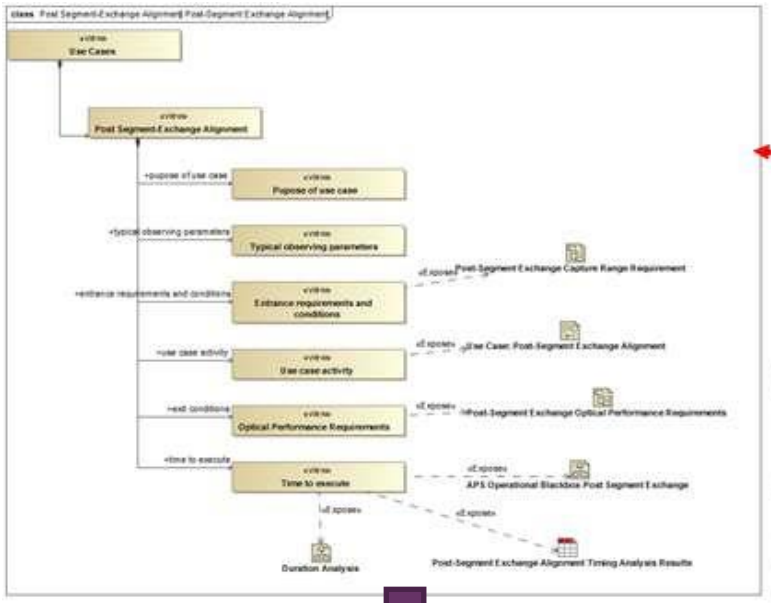


Digital Signoff Are Placed in View Hierarchy With Model Artifacts that Should be Exposed



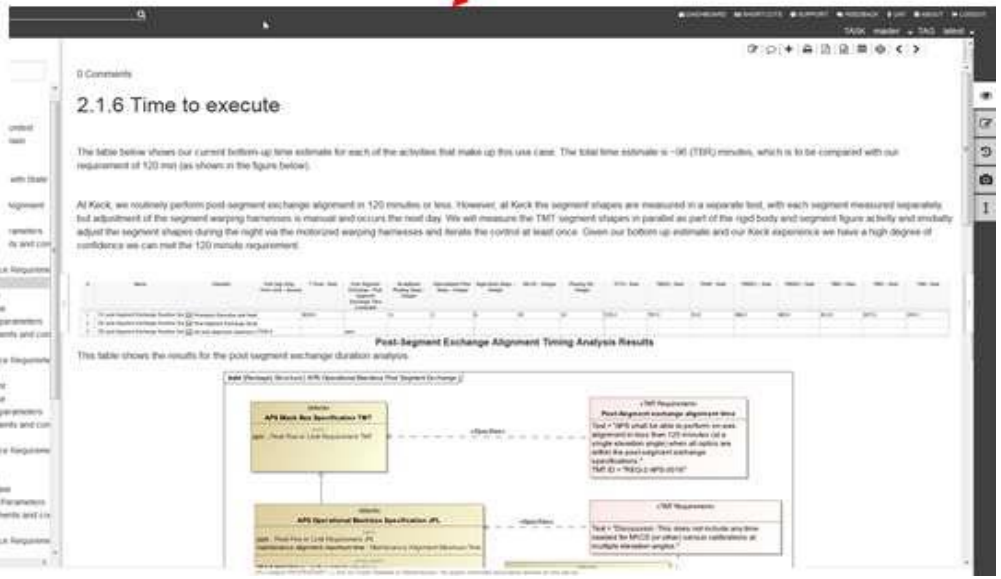
Leverage Capabilities of OpenMBEE as Part of Integrated Modeling Environment

Model Development Kit/DocGen
View and Viewpoint Hierarchy



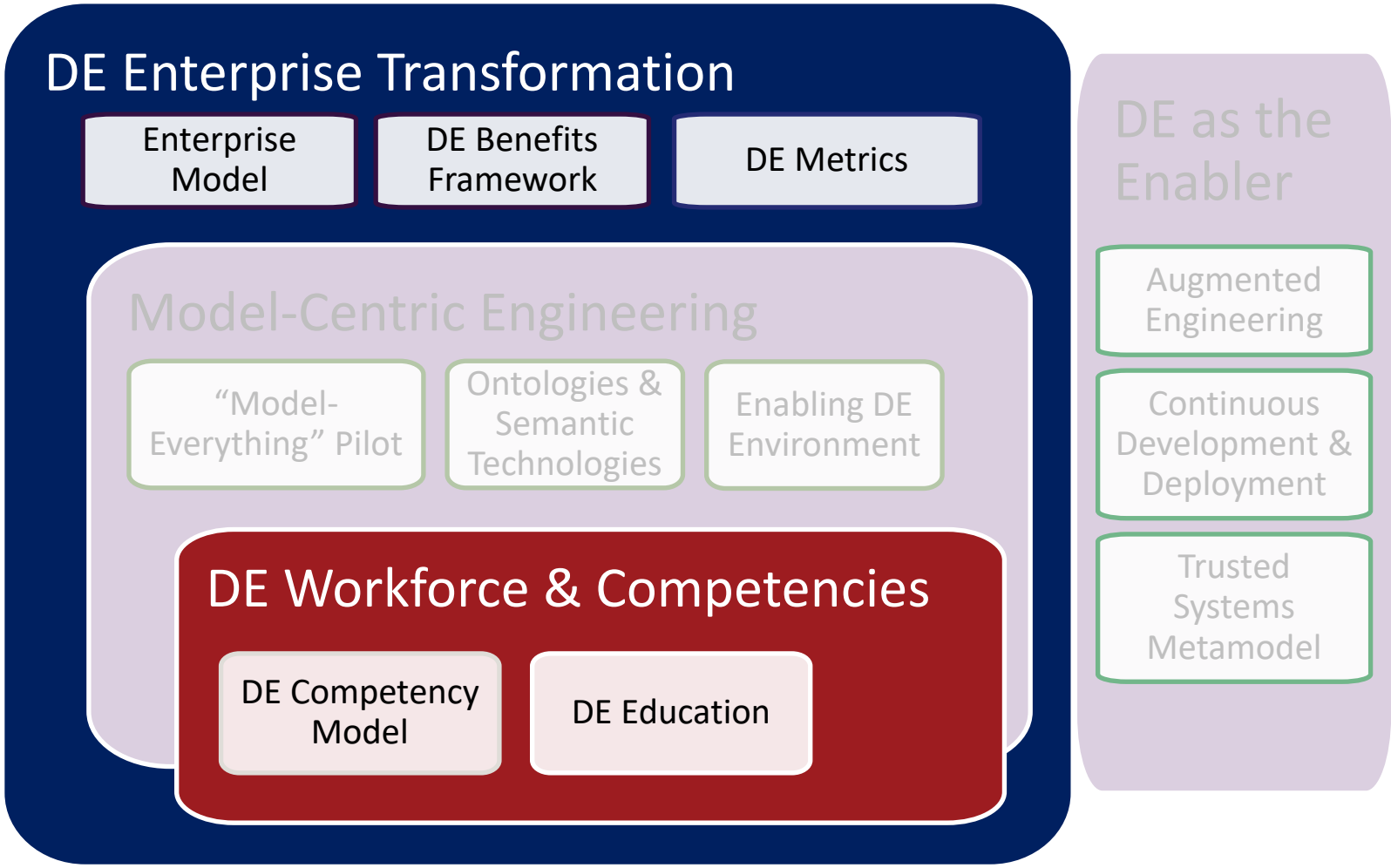
Model Management System

View Editor



Visualization in View Editor (allows edits to be pushed back into model)

SERC Digital Engineering Research



Summary DE Success Measures Framework

Models are used to inform enterprise and program decision making	An enduring, authoritative source of truth is used over the lifecycle	Use technological innovation to improve engineering practices	Infrastructure and environments support improved communication and collaboration	Transform culture and workforce engineering across the lifecycle

Quality:
- Reduce Errors/Defects
- Improve System Quality
- Improve Traceability
- Reduce Cost

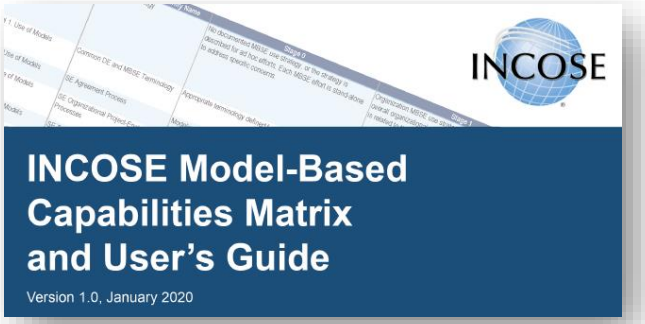
Knowledge Transfer:
- Better access to information
- Better communication/ info sharing
- Collaboration

Velocity/Agility:
- More Reuse
- Improve Consistency
- Increase Efficiency
- Support Integration
- Reduce Time

User Experience:
- Manage Complexity
- Improved System Understanding
- Automation

Adoption:
- Methods/Processes
- Roles/Skills
- Training/Tools
- Leadership support
- Change Mgmt Process
- Resources

INCOSE Model-Based Capabilities Matrix



- Released January 2020 by INCOSE
- Framework for assessing organizational maturity

Model-Based Capability Stages	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4
Tools & IT Infrastructure					
Collaboration	E-mail, telecom.	System Model File Exchange.	Various organizations working on different parts of model. Full model integrated by a single organizations.	Partial On-line, real-time collaboration amongst distributed teams	On-line, real-time collaboration amongst distributed teams
Disparate Database/Tool interoperability	None	Tool-to-Tool, ad hoc interoperability	Partial Federated Database Management System (FDBMS)	Main tools interoperable. Supporting tools interact through file transfer.	Fully Federated w/ standard "plug-and-play" interfaces. Data is interchanged among tools
Inter-Database/Tool Data Item Associations	Databases/tools are independent	Inter-Database/Tool Data Item associations defined	Inter-Database/Tool Data Item associations defined, captured, managed	Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable	Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable where changes in one data source alerts owners of other data sources of intended updates
User IF, Viewpoint/Views	N/A	Doc Gen	UI draws from Model app	UI draws from multiple models/DBs	UI supports Interrogation; multiple configs

Download Results

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

June 8, 2020 – Summary Report Task Order WRT-1001: Digital Engineering Metrics Supporting Technical Report SERC-2020-SR-003

View the DE Metrics Summary Report (June 8, 2020)

March 19, 2020 — Benchmarking the Benefits and Current Maturity of Model-Based Systems Engineering across the Enterprise Results of the MBSE Maturity Survey / Part 1: Executive Summary

View the SERC-2020-SR-001 report on the results of the MBSE Maturity Survey

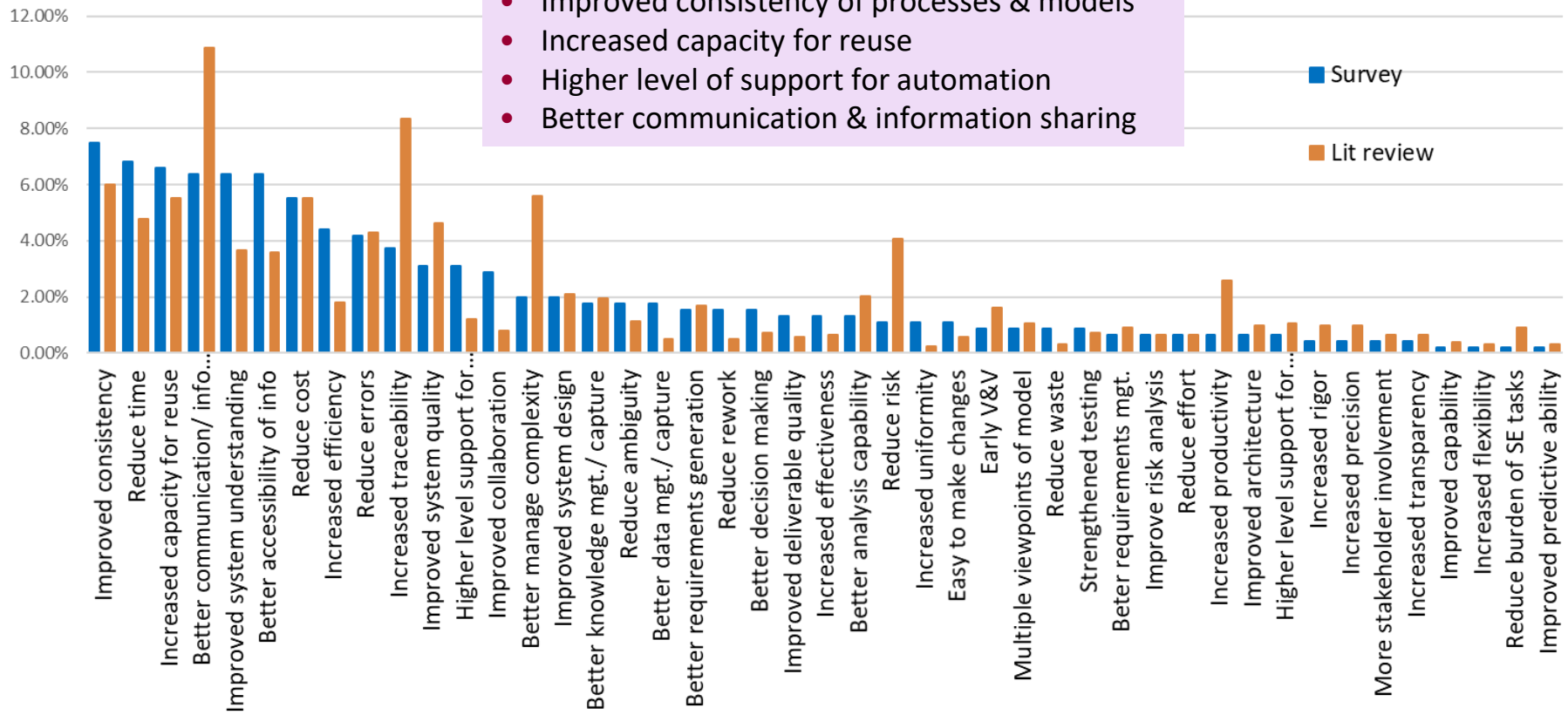
June 8, 2020 – Task Order WRT-1001: Digital Engineering Metrics Technical Report SERC-2020-TR-002

View the Digital Engineering Metrics Full Technical Report

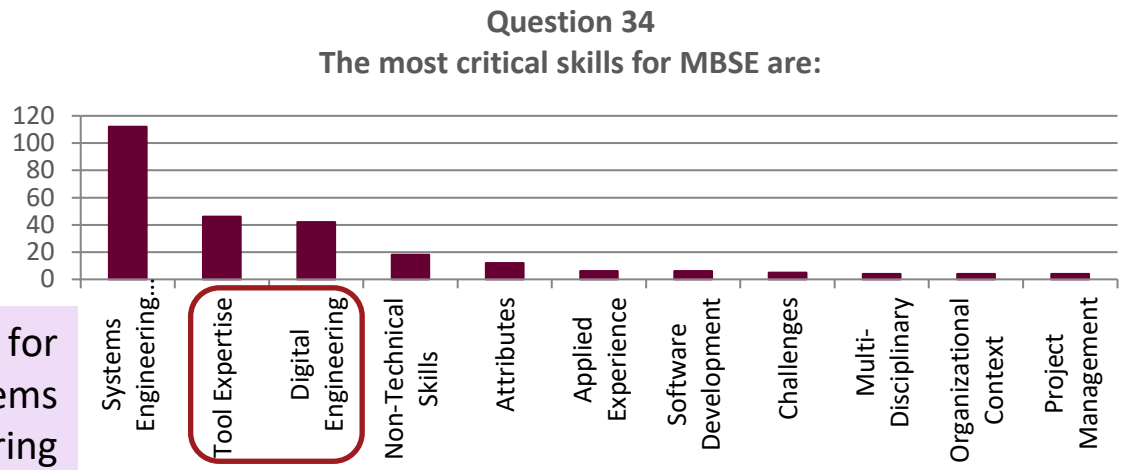
Top Cited DE Benefits Areas from Literature and Survey Results

Key metrics:

- Increased traceability
- Reduced defects/errors
- Reduced time
- Improved consistency of processes & models
- Increased capacity for reuse
- Higher level of support for automation
- Better communication & information sharing

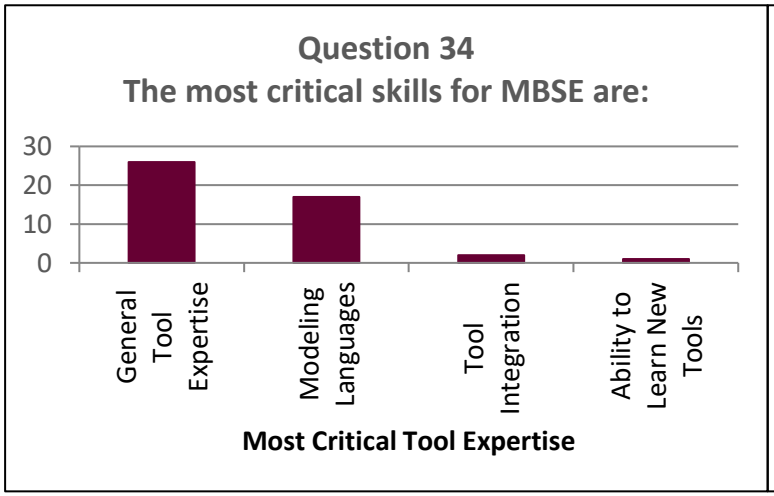


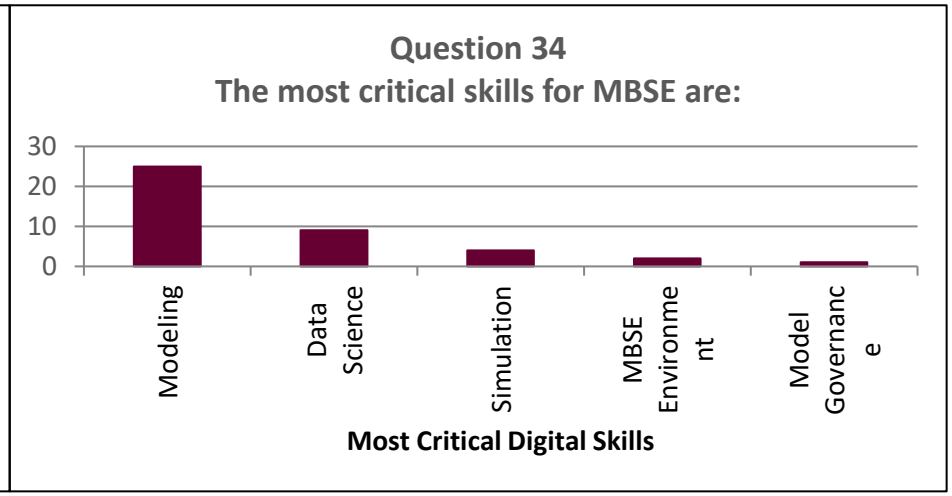
Survey Results linking Critical Skills to transformation



DE is no cure for poor systems engineering

DE requires new digital data and tool competencies



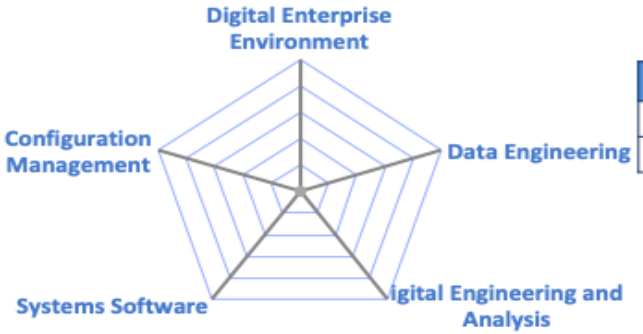


Digital Engineering Competency Framework (DECF)

There are 5 competency groups and 22 competencies identified for the DECF

1. Digital Enterprise Environment		
Digital Enterprise Environment Development	1	Digital Environment Development
Digital Enterprise Environment Management	2	Management
	3	Communications
	4	Planning
Digital Enterprise Environment Operations and Support	5	Digital Environment Operations
	6	Digital Environment Support
Digital Enterprise Environment Security	7	Digital Environment Security

5. Configuration Management	
22	Configuration Management

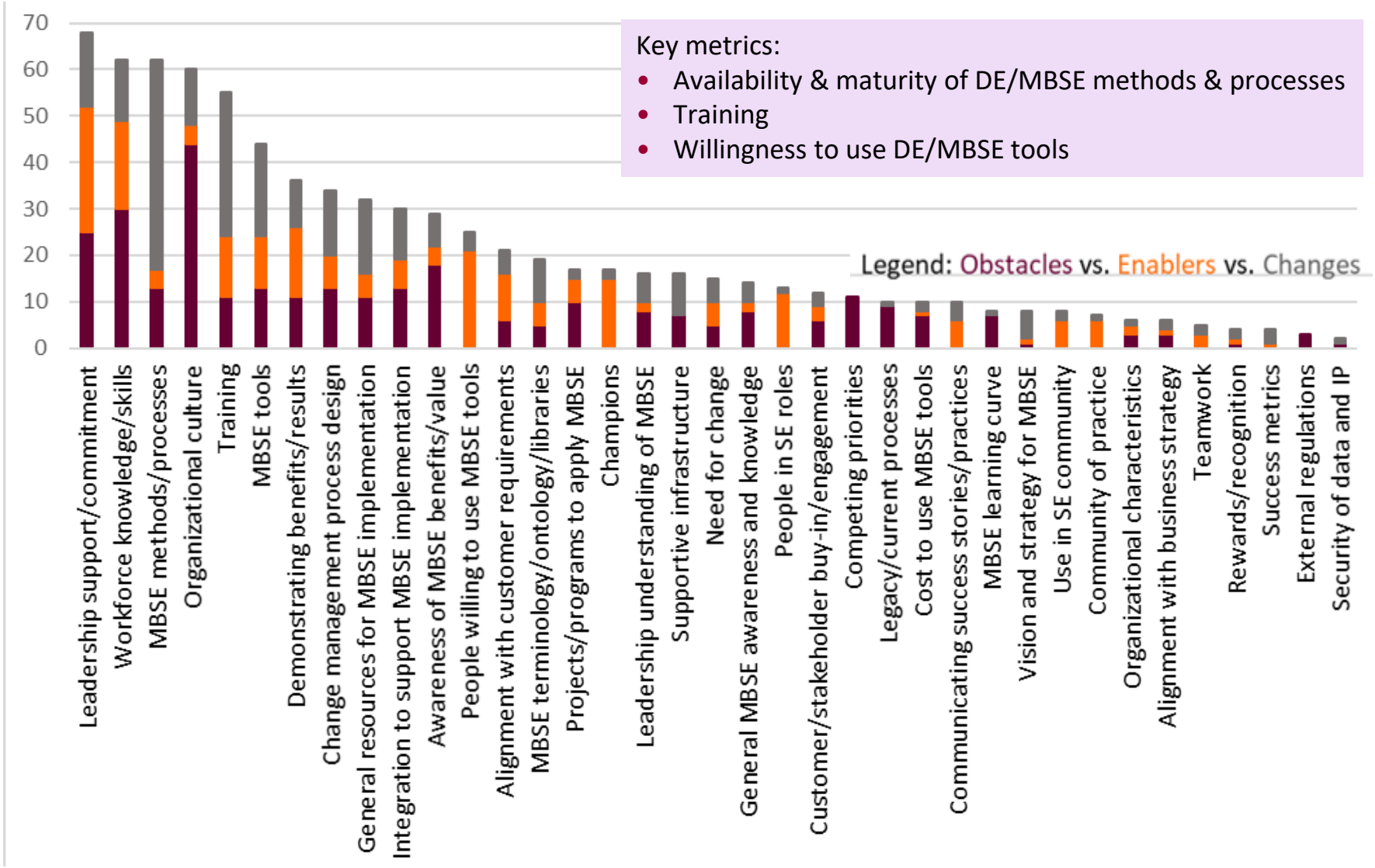


2. Data Engineering	
8	Data Governance
9	Data Analytics

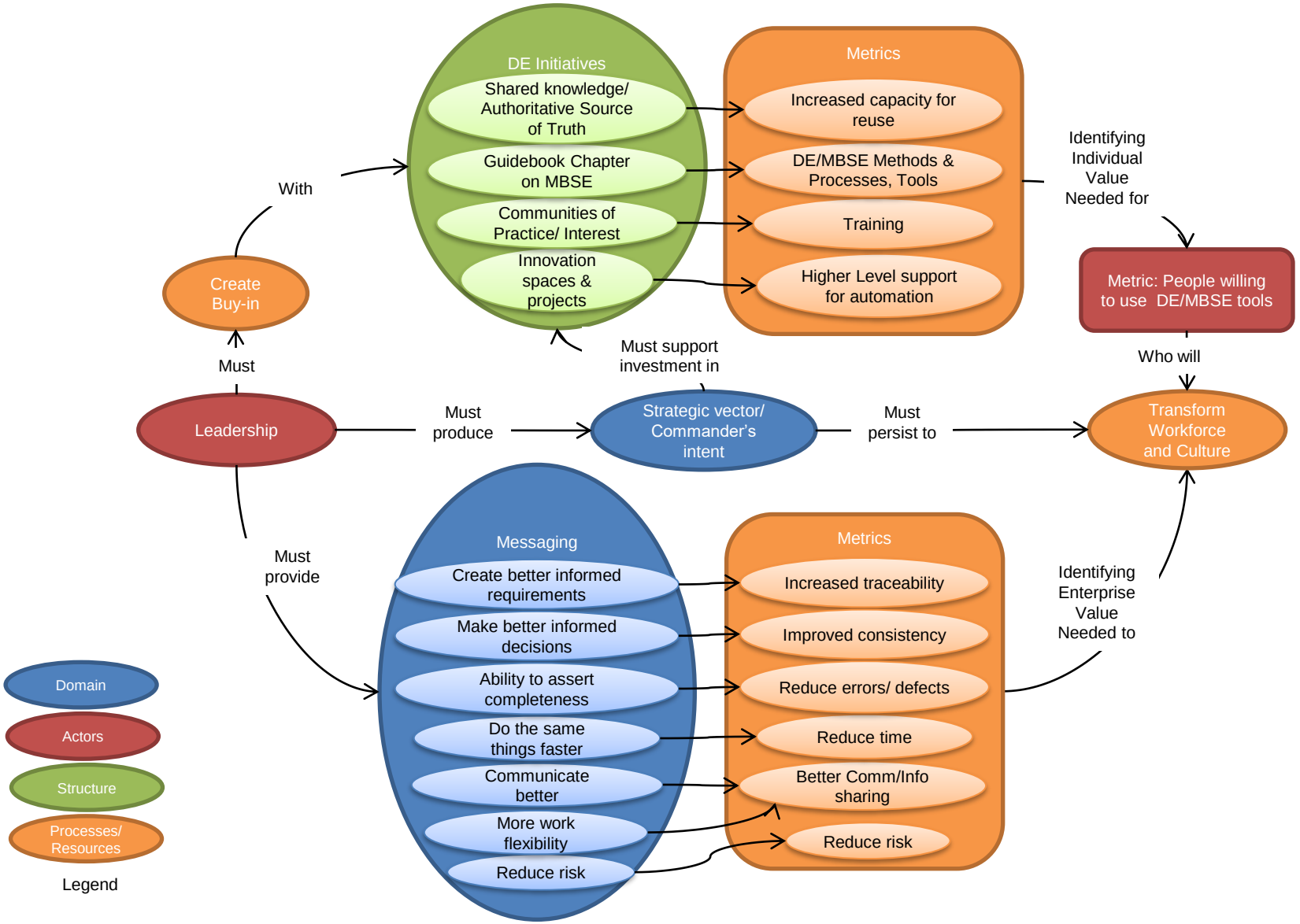
4. Systems Software	
20	Software Construction
21	Software Engineering

3. Digital Engineering and Analysis		
Modeling, Simulation, and Analysis	10	Modeling, Simulation, and Analysis
Coaching and Mentoring	11	Coaching and Mentoring
Systems Engineering	12	Model-Based Systems Engineering Process
	13	Digital Architecting
	14	Digital Requirements Modeling
	15	Digital Verification
Systems Engineering Management	16	Digital Model-Based Reviews
	17	Project Management
	18	Organizational Development
	19	Digital Engineering Policy and Guidance

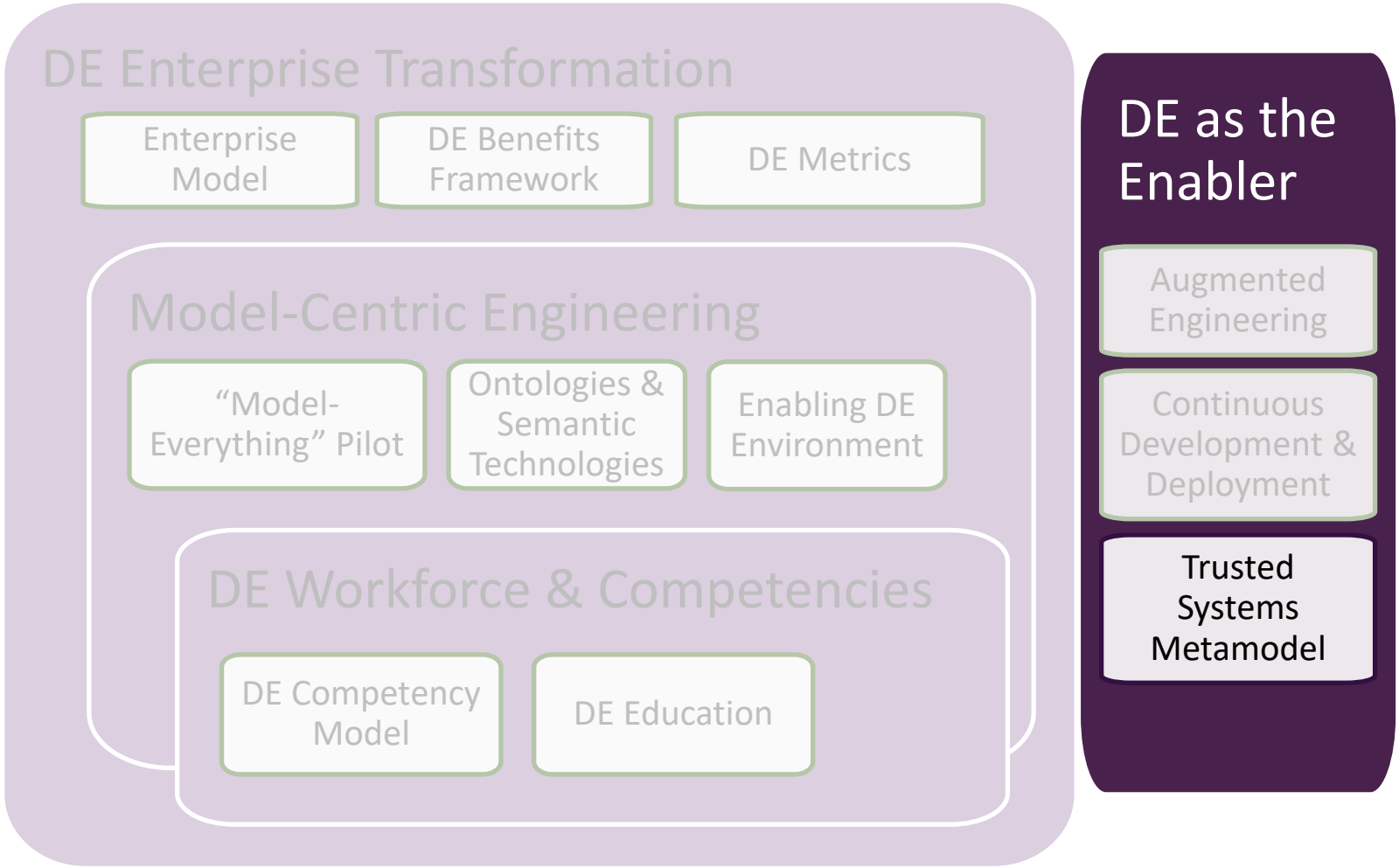
Comparing Obstacles vs. Enablers vs. Changes



Obstacles, Enablers, Changes: linking leadership and metrics to transformation



SERC Digital Engineering Research



Standard DE Methodology for Designing Safety/Security into a Mission/Systems Model

System Model

Assurance Model (STPA)

System Aware Model (Resilience modes and Sentinel patterns)

Threat Model

DE as the Enabler

Trusted Systems Metamodel

MISSION AWARE

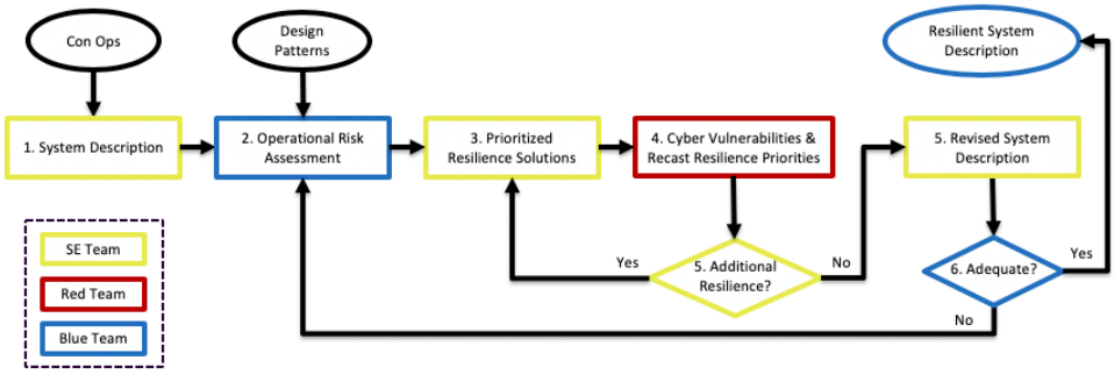
Project: ART-004: Pipeline - Metrics Project
Contact: Tim Sherburne
Powered By GENESYS. Generated 14 February 2020.

Folders | Packages

DOC.2 CSRM

- CSRM
  - 1-System
    - Architecture
    - Behavior
  - 2-Risk
  - 3-Resilience
  - 4-Cyber

Cyber-Security Requirement Methodology (CSRM)



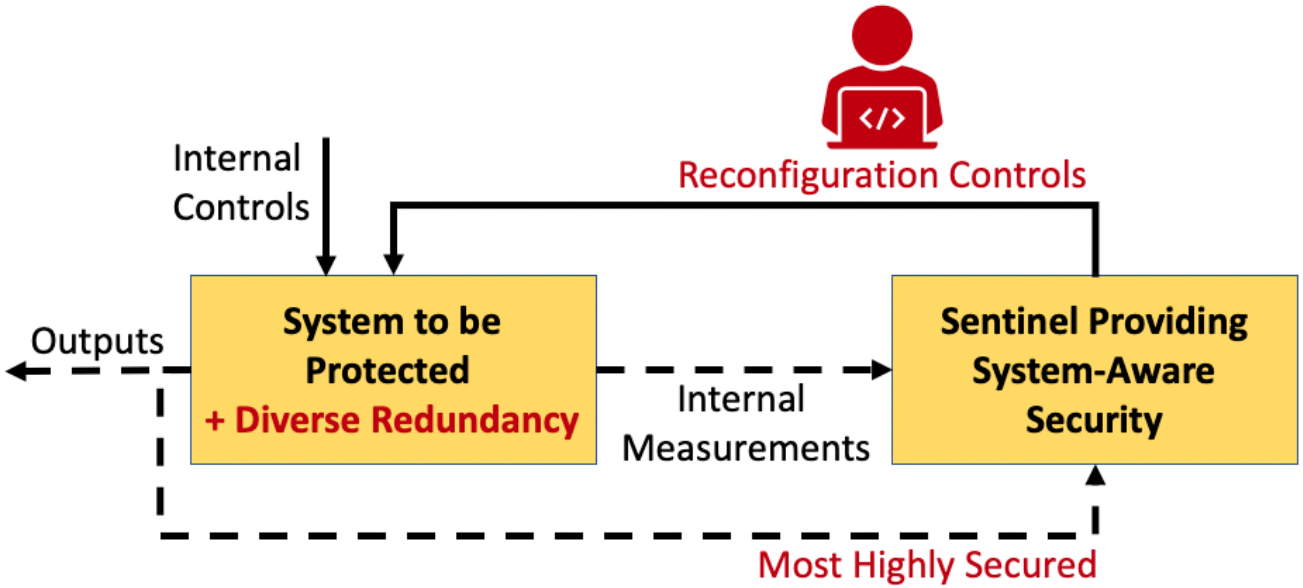
Select "Packages" -> "CSRM" to navigate model per CSRM Steps
NOTE: click package icon to expand section

Project: ART-004: Pipeline - Metrics Project

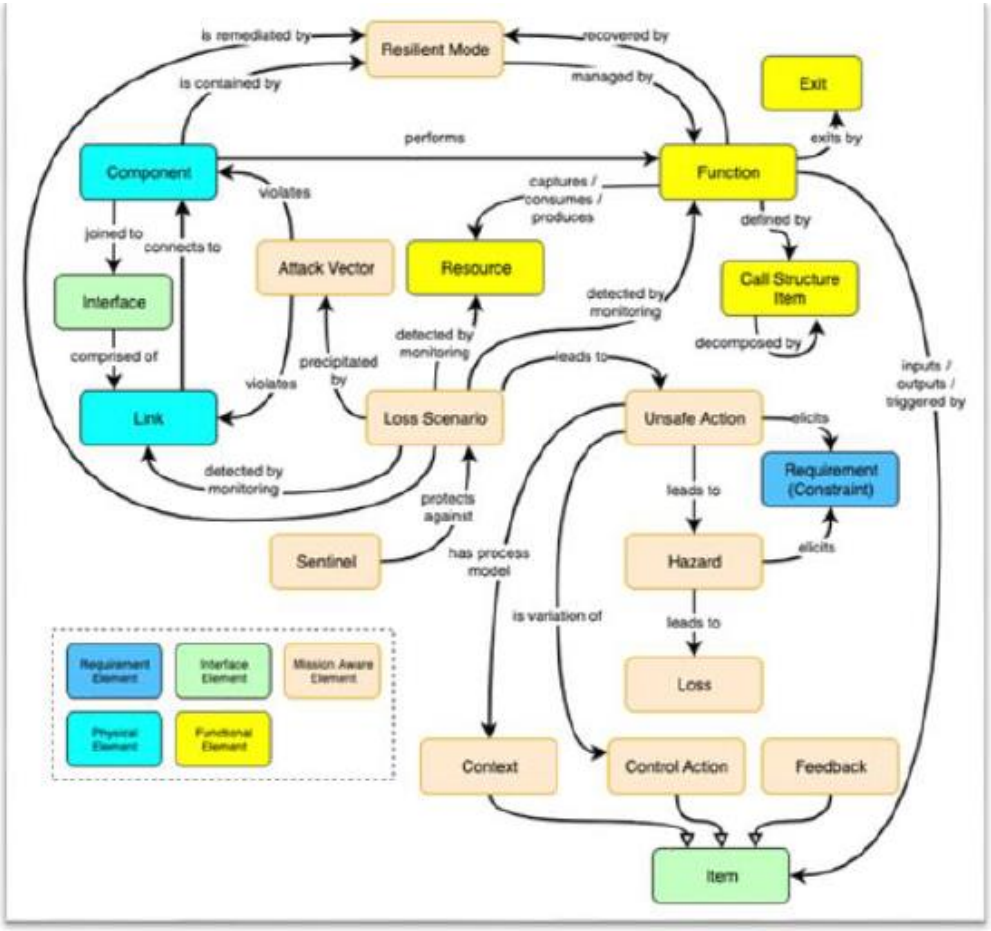
Mission Aware Cyber Resilience

- System design for **Resilient Modes**: distinct and separate methods of operation of a component, device, or system based upon common resilience design patterns such as diverse redundancy.
- System monitoring via a **Sentinel** design: another design pattern responsible for monitoring and reconfiguration of a system using available Resilient Modes.

SERC has demonstrated the effectiveness of these patterns in live red team testing of UAVs, Automobiles, 3D printers, and Military armament



Mission Aware Standard MBSE Meta-Model



MISSION AWARE

CSRM Steps:

1. System Description
   - Component, Link
   - Function, Exit, Resource, Call Structure, Control Action, Feedback, Context
2. Risk Analysis
   - Loss, Hazard, Unsafe Action
3. Resilience Solutions
   - Resilient Mode
4. Cyber Vulnerability Assessment
   - Loss Scenario, Attack Vector
5. Iterate Resilience Solutions (Metrics)
6. Iterate Vulnerability Assessment

https://github.com/coordinated-systems-lab/ma-mbse-metamodel

Questions and Discussion