SYSTEMS ENGINEERING RESEARCH CENTER

Digital Engineering Metrics

Sponsor: OUSD(R&E)

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11th Annual SERC Sponsor Research Review

November 19, 2019

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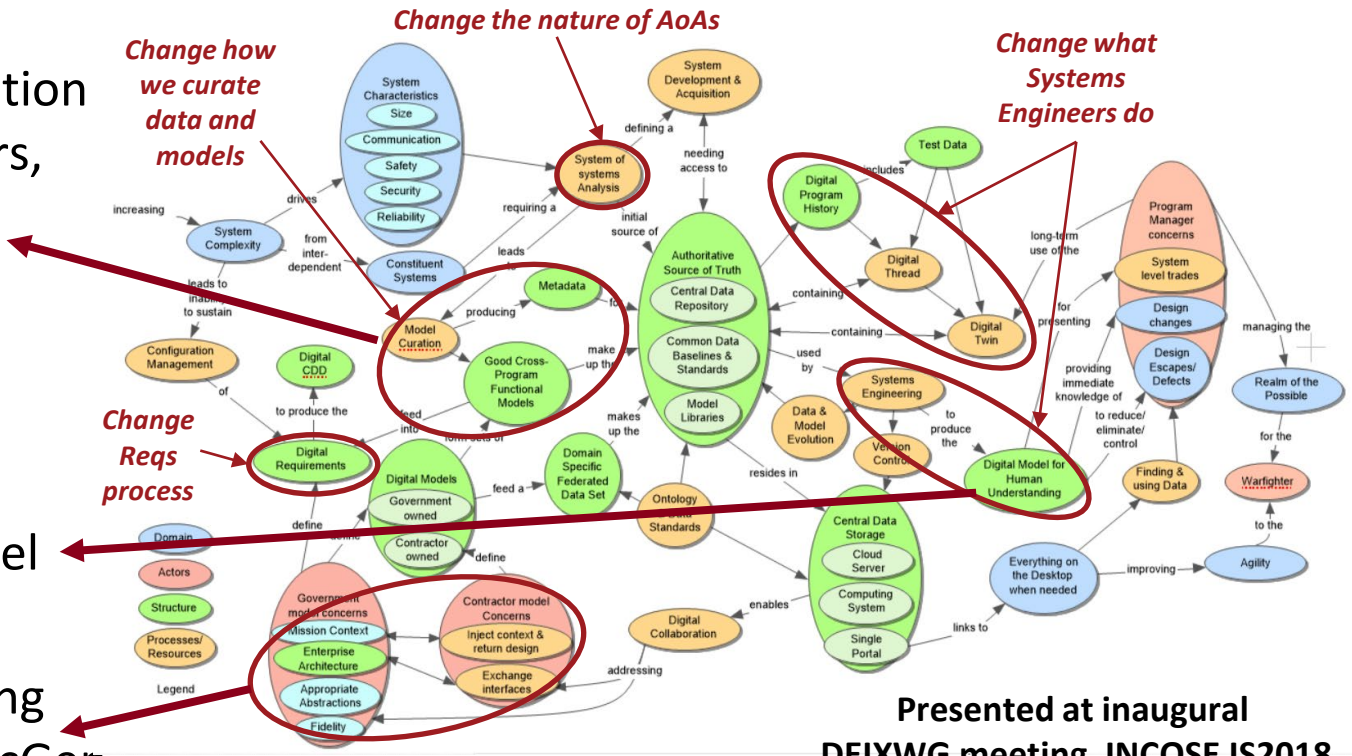
Enterprise Modeling of the DoD Digital Information Exchange Process

- 2018: SERC Project RT-182 conceptually modeled the 5 goals of the DoD DE Strategy to identify necessary acquisition enterprise changes
- 2019: Addressing multiple OUSD/RE research priorities:
  - DE Metrics (WRT-1001), determine critical ROI measures and improved SE value indicators
  - Model Curation (WRT-1009), curation practices, enablers, and technical innovation opportunities
  - DE Workforce (WRT-1006), DE competency model for DAU
  - DE Policy – building a model using DocGen



Presented at inaugural DEIXWG meeting, INCOSE IS2018

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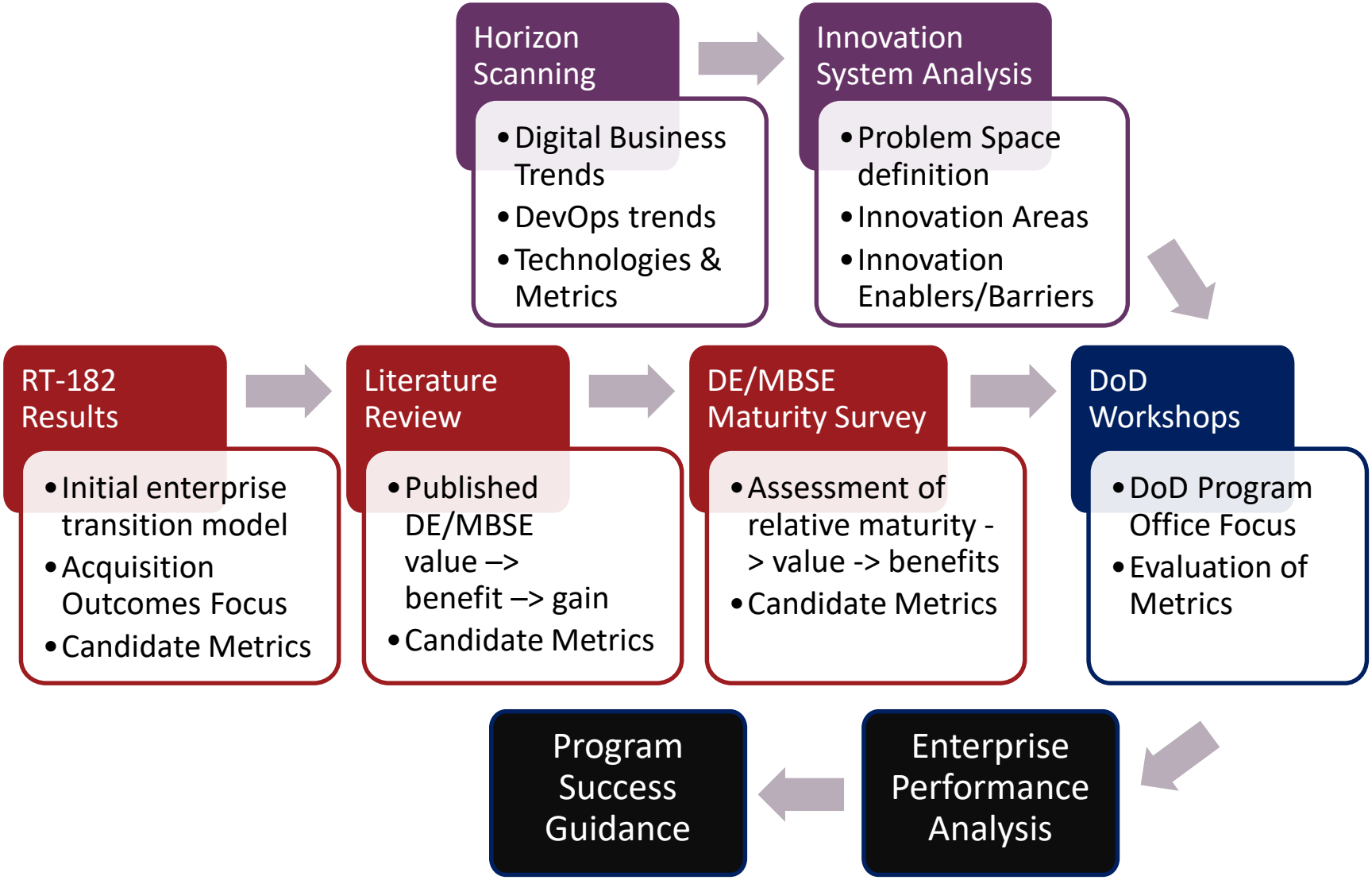
WRT-1001 Digital Engineering Metrics Project Guiding Questions

- If you had a "**Program Office Guide to Successful DE Transition**" what would that look like?
  - —Extend previous SERC work on DE enterprise transformation to the program office level.
- How can the **value and effectiveness** of DE be described and measured?
  - —Determine appropriate metrics for evaluating the benefits of DE transformation.
- Are there **game-changing methods and/or technologies** that would make a difference?
  - —Analyze the DE Innovation System (methods, processes, and tools) to identify gaps and challenges and potential paths for innovation.
- Can we describe an **organizational performance model** for DE transformation?
  - —Generalize the data and results.

WRT-1001 DE Metrics Project Activities



DoD Digital Engineering Strategy

STRATEGIC MANAGEMENT SYSTEM

Digital Engineering (DE) Vision: Modernize how the Department designs, develops, delivers, operates, and sustains systems.

DE Mission: Securely and safely connect people, processes, data, and capabilities across an end-to-end digital enterprise.

ENDS	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
WAYS / INITIATIVES	Formalize the planning for models to support engineering activities and decision making across the lifecycle	Plan and develop the authoritative source of truth	Infuse technological innovations to enable the end-to-end digital enterprise	Develop, mature, and use digital engineering IT infrastructures	Improve the digital engineering knowledge base
	Formally develop, integrate, and curate models	Govern the authoritative source of truth	Make use of data to improve awareness, insights, and decision making	Develop, mature, and use digital engineering methodologies	Lead and support digital engineering transformation efforts
	Use models to support engineering activities and decision making across the lifecycle	Use the authoritative source of truth across the lifecycle	Advance human-machine interactions	Secure IT infrastructure and protect intellectual property	Build and prepare the workforce
MEANS	**Process, Methods, Tools, Technology, People**				

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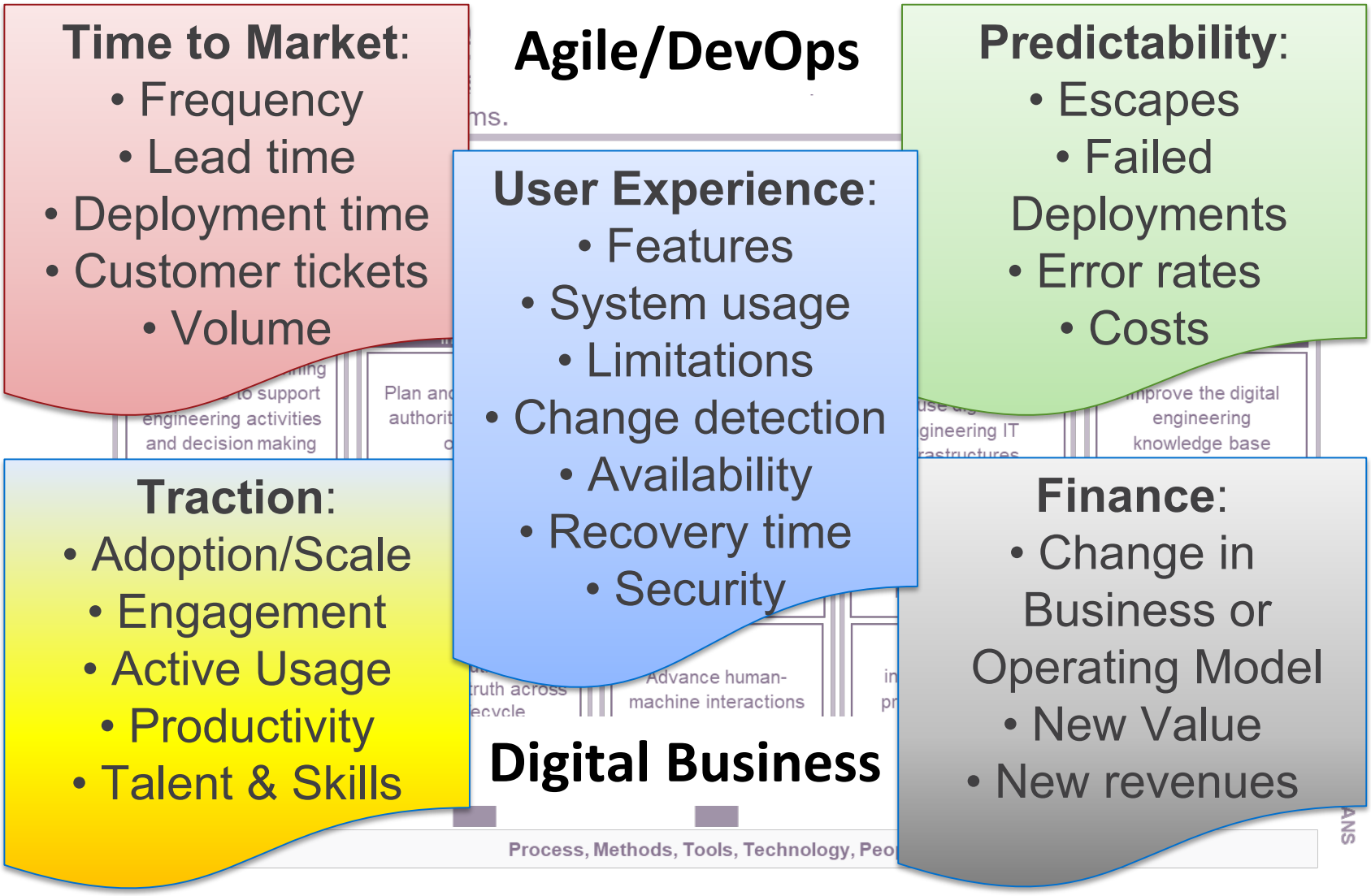
Focus: Enterprise Transformation Measures

- Gartner: "*Select just 5 to 9 metrics to track, report and act on. The value of a metric lies in its ability to influence business decision making*."

https://www.gartner.com/smarterwithgartner/how-to-measure-digital-transformation-progress/

- The best metrics:
  - —Have a defined and defensible causal relationship to a business outcome
  - —Work as a leading, not lagging, indicator
  - —Address a specific defined audience – in a way they can understand
  - —Drive action when they change from green to yellow to red
- There are no universal metrics – must be enterprise specific
- Good Digital Transformation metrics have some traits
  - —Measure people **adoption**, and enterprise process **adoption**
  - —Analyze breadth of **usability**, and issues with **usability**
  - —Measure **productivity** indicators
  - —Generate **new value** to the enterprise (revenue, operational efficiency, etc.)

Agile/DevOps and Digital Business



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RT-182 Results

DE Success Measures from RT-182

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:
- Defects/Design Escapes
- AoA coverage
- Design space explored
- SE rigor
- CM

Knowledge Transfer:
- Data/Model reuse
- Link to Mission Eng
- Depth of review
- Expanded Visualization
- Innovation

Velocity/Agility:
- Data/model reuse
- Decision times
- Cycle time/Agility
- Data search time
- Standards

User Experience:
- Collaboration
- Automation
- Interoperability

Adoption:
- Pace of adoption
- Infrastructure investment
- Enterprise process & tool integration
- Tool/model interoperability
- Role/Skill transition

Outcome driven metrics from RT-217

- Reduce defects & design escapes
- More robust, SoS-based AoAs
- Increase design space exploration
- Improved SE rigor & maturity
- SE has more time for quality control
- Comprehensive, effective CM
- Increase speed of finding & using data
- Improve agility
- More rapid program decision cycles
- Data & model reuse
- Incorporation of standards
- Improved collaboration across disciplines & locations
- Improved reasoning/inference – leads to better automation
- Improve modularity and interoperability
- Manage Complexity – knowledge sharing & transfer
- Repeatable link to mission level simulation, capabilities
- Expanded visualizations for pattern analysis & decision making
- Amount of system reviewed in SETR process
- Enable innovation
- Pace of DE/MBSE adoption
- Infrastructure investment
- Enterprise process & tool integration
- Tool/model interoperability successes
- Replace tech writers with modelers

Initial Literature Review Results

- Searched 20 journals and conference proceedings for any paper that mentions Model-Based Systems Engineering. Identified papers that mention a benefit of MBSE and what the source of that benefit was: measured gains, observed gains, perceived gains (no source for benefit), reference
  - Total Papers that mention MBSE: 852
    - Papers that mention benefits: 361
      - Measured gains: 3
      - Observed gains: 27
      - Perceived gains: 236
      - Reference: 114
      - Misc.: 2

*Kaitlin Henderson (VT) PhD studies

MBSE Benchmarking Survey

Objective	• Assess **value and effectiveness** of MBSE adoption for improving business outcomes (gov't, industry) – benefits vs. traditional methods. Develop a profile of MBSE use and meeting expectations across the life cycle. • Where are we as organizations, and as an industry? Building models, or **using** models? Applying what we learn. • Enable adopters to conduct a qualitative or quantitative assessment of their progress against MBSE best practices and guidance on developing an improvement roadmap
Method	• Conduct an industry survey of MBSE capability. Align with **INCOSE draft DE Capabilities Definition matrix.** • **Characterizing MBSE practices, capability, value, benefits**. • Probe alignment and integration with other adopter initiatives (e.g., PLM, DevOps, cross-discipline) • Collect and share best practices and assets on MBSE benefits/value from community
Organizational Involvement	• Participation call through industry associations: INCOSE (lead), NDIA, … • Government sponsorship and support: DoD (OUSD R&E), FFRDCs (SERC) • Survey administration by DoD SERC (Stevens Institute) - "honest broker" to protect proprietary data.
Schedule	• Survey: define (Sep-Oct); instrument (Oct-Nov); distribute (Dec-Jan); analyze (Feb-Mar)
Core Team	• INCOSE: Garry Roedler; Troy Peterson • NDIA: M&S Committee (Chris Schreiber); SE Division (Joe Elm, Geoff Draper; Garry Roedler) • SERC: Tom McDermott, Nicole Hutchinson

MBSE Survey Overview

Topics	Summary of Survey Questions
1. MBSE Usage	1. MBSE strategy documented at enterprise level 2. MBSE processes & tools integrated, inform enterprise staff *3. Q: Primary value of cross-functional MBSE integration?*
2. Model Manage-ment	4. Taxonomy for modeling across organization 5. Well-defined processes/tools for model management. 6. Standard org guidance for model management/tools *7. Q: Business value from consistent model management?*
3. Technical Manage-ment	8. Modeling basis for enterprise org processes 9. MBSE process support for technical reviews *10. Q: Value of MBSE (or digital engrg) in technical reviews?*
4. Metrics	11. Modeling provides measurable improvement across projects 12. Consistent metrics across programs/enterprise? *13. Q: Most useful metrics?*
5. Model Quality	14. Defined processes/tools for V&V of models 15. Defined processes/tools for data/model quality assurance
6. Data Manage-ment	16. Org approach for data interface between tools 17. Data managed independent of tools for portability *18. Q: Data management roles/processes?*

Topics	Summary of Survey Questions
7. Model Sharing and Reuse	19. Teams establish, share, reuse org model libraries 20. Org interface around models for stakeholder use 21. Shared models used to consistently manage programs across lifecycle *22. Q: org implementation for data/model discovery, reuse?*
8. Modeling Environments	23. Modeling environment security 24. Modeling environment protects IP 25. Cross-discipline processes for tools, data interoperability *26. Q: value from collaborating on models across disciplines*
9. Organizational Implementation	*27. Q: most challenging org obstacles for MBSE?* *28. Q: Best organizational enablers for MBSE?* *29. Q: Biggest changes our org needs forMBSE?*
10. Workforce	30. Organization defined critical roles to support MBSE *31. Q: Top MBSE roles in your organization?* 32. Org staffing adequate to fill MBSE-related roles?
11. MBSE Skills	33. Defined critical skills for MBSE *34. Q: The most critical skills for MBSE?*
12. Demographics	Organizational size, domain, MBSE experience

Survey content is derived from the draft INCOSE Digital Engineering Capabilities Definition

Draft INCOSE DE Capabilities Definition Matrix

- Basis from The Aerospace Corporation MBSE Community Roadmap and the NASA MSFC MBSE Maturity Matrix
- Developed through a series of workshops with INCOSE and NDIA to form a proposed comprehensive Model-Based Enterprise Capability Matrix
- Will complete and release as an INCOSE DE Capabilities Document, Jan 2020

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 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

Organizational Maturity Capabilities

- DE incorporated into organization policy & work instructions
- Appropriate tools, environments, methods, resources available
- Organizational lexicon & taxonomies integrated into data repositories
- Model management activities in place
- DE basis incorporated into SE process descriptions for each phase
- Model CM applied
- Digital Threads and Digital Twin artifact baselines maintained in process
- Requirements traceable across programs at the enterprise level
- Model development practices in place
- DE basis incorporated into SETR criteria, processes, and artifacts
- Have a quality and improvement program that incorporates modeling
- Have a DE-based SE metrics program including model metrics
- Model reuse standards, processes, and activities
- Model development standards, processes, and activities
- Model assurance standards, processes, and activities
- Fully federated data & IT infrastructure
- Data interchange across tools
- Data change notification and traceability
- Data and model libraries established and shared
- Data interrogation standards, processes, and activities
- Simulation standards, processes, and activities
- Data & information supports discoverable knowledge (data-driven decision processes)
- Enterprise planning & decisions from digital artifacts (threads and twins)
- Tool research & improvement forums in place
- Model exchange standards, processes, and activities with acquirers and subcontractors
- Training programs
- Model development standards
- Roles, competencies, and skills in place

WRT 1008 Model Curation – INCOSE SE Leading Indicators Guide

- Requirements – growth, volatility, discovery
- System Definition Change Backlog – rate, resolution time, closure rate
- Interface Trends - discovery
- Requirements Validation - completed
- Requirements Verification - completed
- Work Product Approval - in-work, rework
- Review Action Item Closure - burndown
- Risk Exposure – number, burndown
- Risk Treatment - #actions
- Technology Maturity – TRLs and change
- Technical Measurement - TPMs
- SE Staffing & Skills – plan/actual
- Process Compliance - discrepancies
- Facility & Equipment Availability
- Defects/Errors – discovery, closure, phase containment
- System Affordability – cost & confidence
- Architecture – base measures, maturity by review cycle
- Schedule & Cost Pressure – budget, schedule, risks

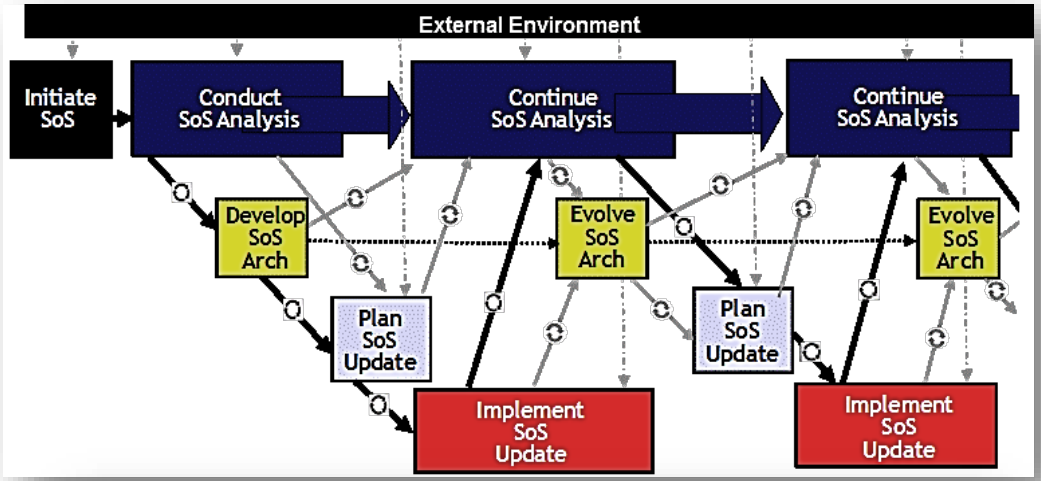
* Effected by DE

Which of These Digital Innovations will Transform the Engineering Disciplines?

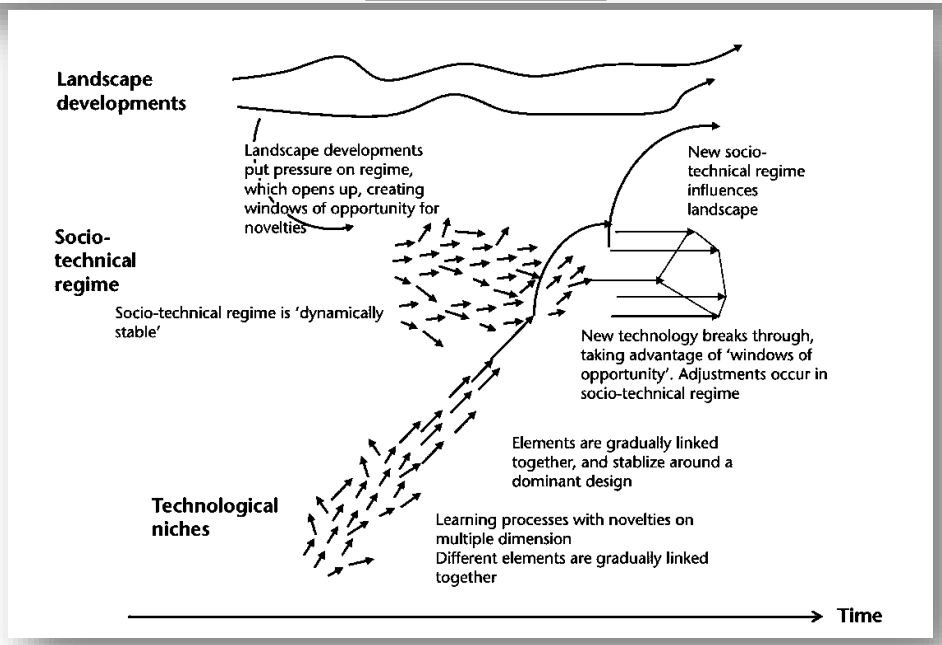
- **5G mobility** – enhanced bandwidth and connectivity mobile services
- **Collaborative telepresence** – Highly realistic, haptics enabled video conferences
- **AI and ML** – Artificial Intelligence and Machine Learning
- **Immersive Realities** – Human, Augmented, and/or Virtual Reality technology integration
- **Blockchain** – Blockchain derived technologies to manage workflows
- **Cloud Evolution** – Evolving cloud computing architectures
- **NL/Chatbots/social robots** – true human realistic natural language interfaces
- **IoT** – Internet of Things sensors and architectures
- **Low-code SW** – Domain specific design languages/visual composition design methods
- **DevSecOps** – Secure Continuous development and deployment environments
- **Quantum computing** – Evolving non-binary computing architectures
- **Advanced Manufacturing** – Rapid programming/realization of hardware design
- **DNA-based Data Storage** – High speed, ultra-high capacity storage devices
- **Digital Identities** – Computer (not human) determines identity verification

* SERC Project WRT-1001 presented to the Digital Engineering Working Group 08/2019

Competing Views of Innovation System Evolution



The wave model (Dahmann, etal.)



Multilevel View of technology transitions (Geels)

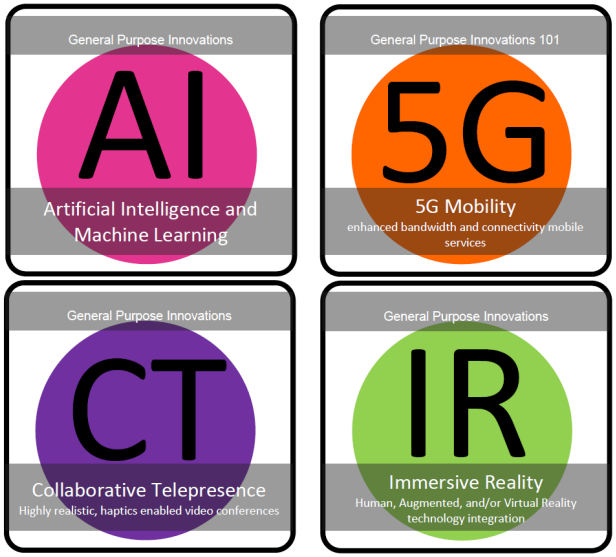
GPI Application Generator

Start with a pressing challenge, then generate ideas

challenge:

How might we improve tool and model interoperability?

GPI Cards



General Purpose Innovation Matrix

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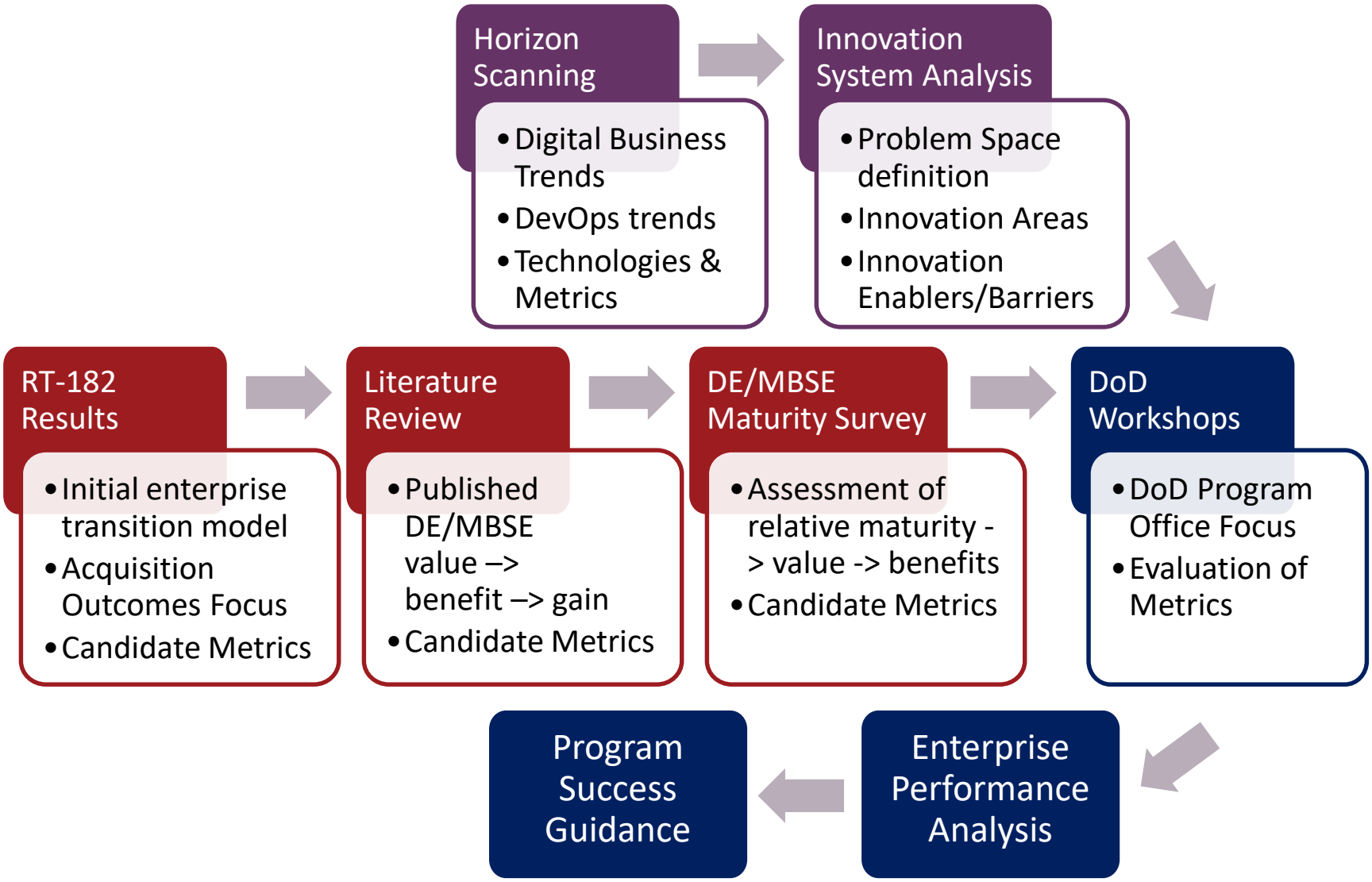
That may have an impact on... / Specific innovation application area...	GPI Card:
Your Problem Aspect:	Innovation Idea 1:
	Innovation Idea 2:
	Innovation Idea 3:

Summary and Completion



Questions?

Thank you!