32nd Annual INCOSE international symposium
hybrid event
Detroit, MI, USA
June 25 - 30, 2022

Think Globally, Act Locally: Adapting MBSE for the Enterprise Context

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Overview

- Introduce concepts of DE, MBSE and ESE, and show how they relate
- Define Levels of Enterprise MBSE Maturity
- Identify Heuristics for Enterprise-Ready Modeling
- Bottom Line: Local modeling efforts should adopt principles and practices that enhance the value of those models that contribute to enterprise understanding

Think Globally (to enable enterprise objectives)
when Acting Locally (to achieve local program objectives)

What is Digital Engineering?

An integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal.

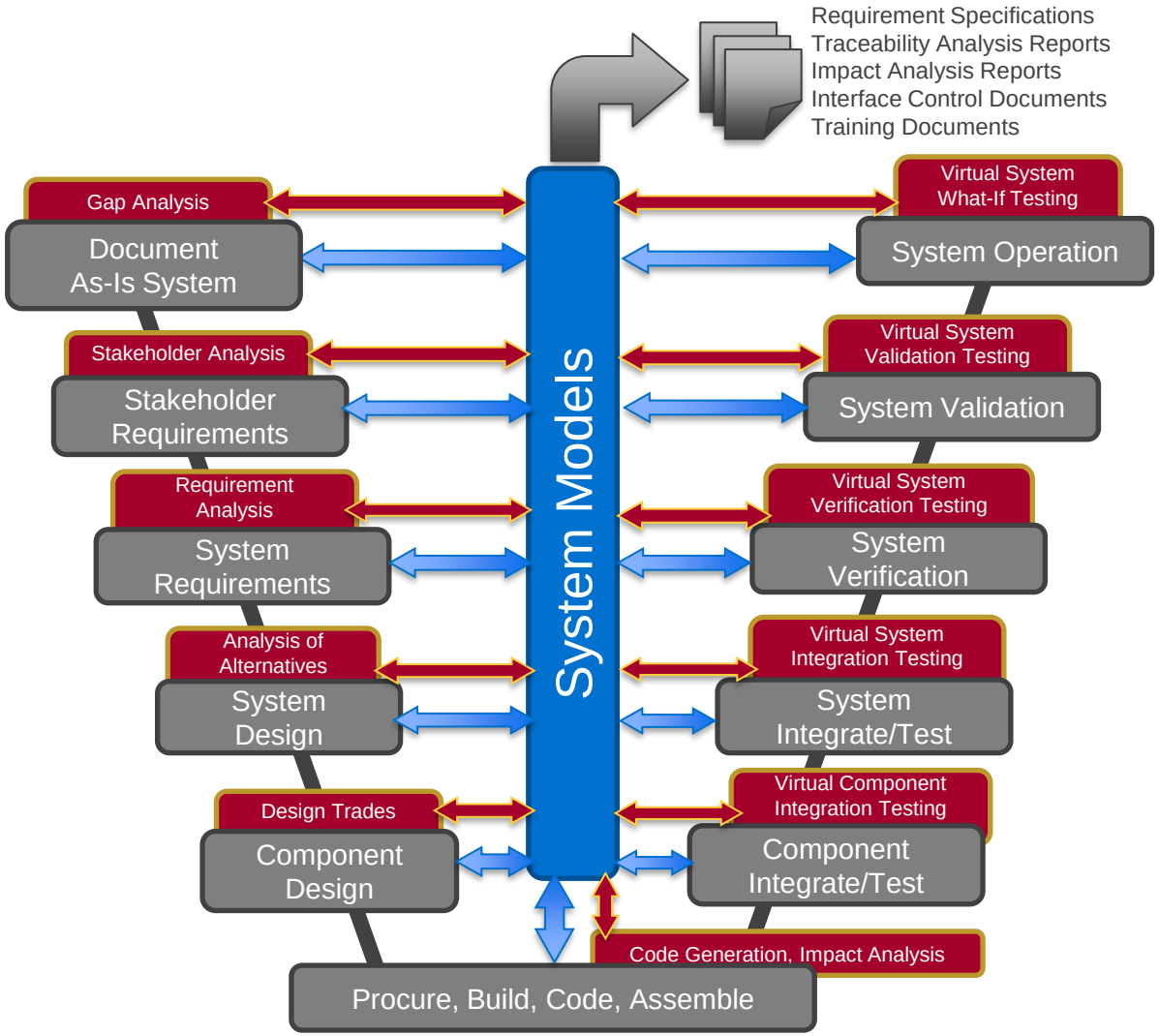
DoD Digital Engineering Strategy, 2018

- Digital engineering (DE) is a transformation of engineering policies and practices across an enterprise to capitalize on the increasingly digital nature of engineering work, data, knowledge, and skills
- DE harnesses the ubiquitous computing and networking capabilities to link authoritative information sources and analysis processes with each other across an enterprise
- An integrated DE environment improves the efficiency and effectiveness of communication among disciplines to enable faster and better decision-making

Digital engineering is about bridging information stovepipes, aggregating local pockets of knowledge into an integrated global body of knowledge

Model Based Systems Engineering Context

- System models are **central** to execution of SE processes
- MBSE improves **knowledge capture** and **information sharing**…
  - … among technical disciplines
  - … between organizations
  - … spanning life cycle phases
- MBSE improves **efficiency and effectiveness of SE execution**
- MBSE facilitates continuous application of **concurrent engineering** across disciplines and life cycle phases

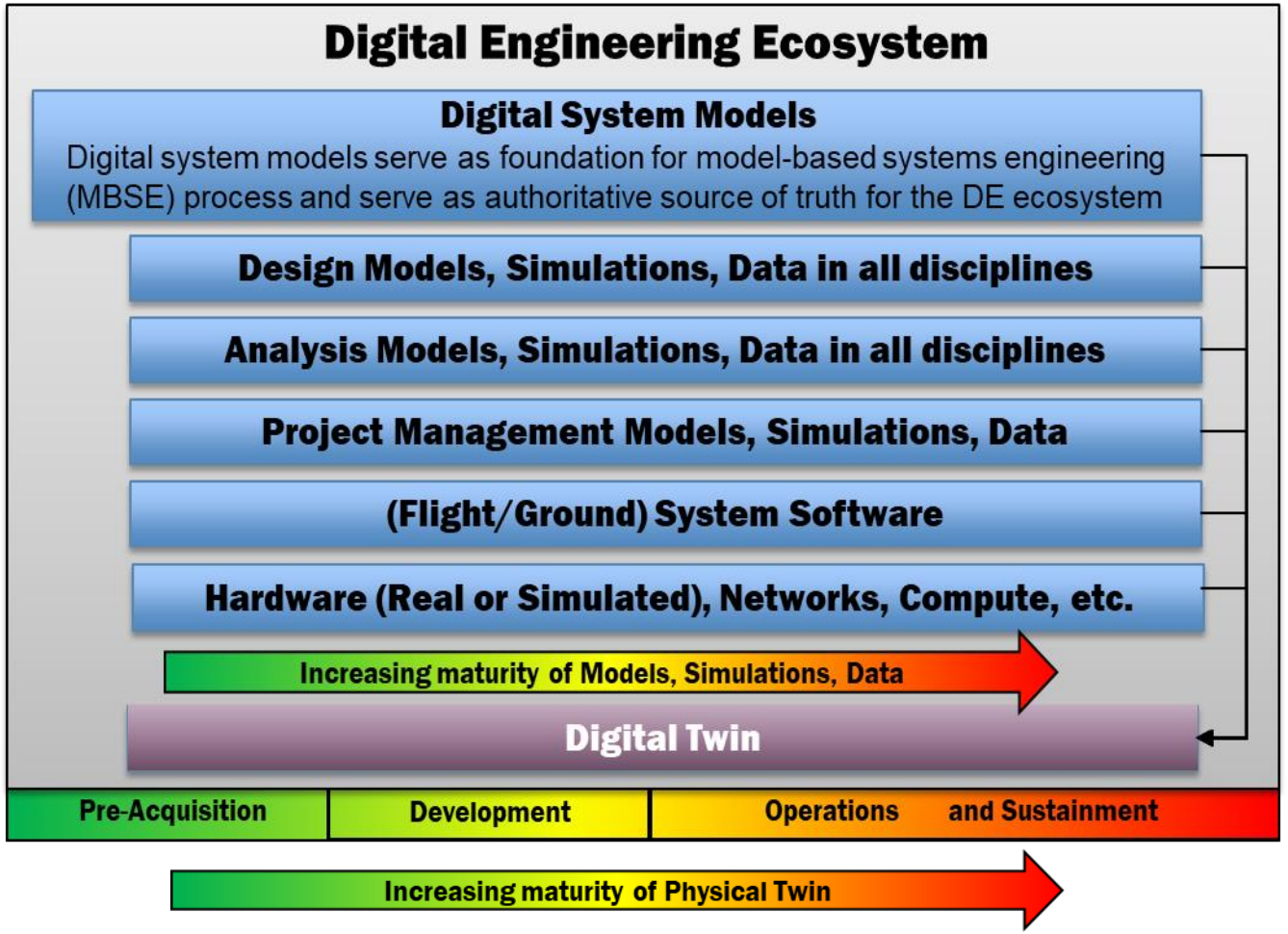


Benefits and Challenges of Modeling

Benefits of Modeling	Challenges of Modeling
Reduces ambiguity of representation	Reduces flexibility of representation
Reduces inconsistency of content	Exposes inconsistency in knowledge—what is ground truth?
Reduces inconsistency of nomenclature	Requires consensus on a standard nomenclature
Enables more dynamic interrogation of underlying knowledge to answer other questions	Requires more advanced knowledge of mechanisms for querying models and visualizing the results
Enables analysis of multi-level relationships	Requires discipline in applying consistent modeling methods
Improves maintenance of the body of knowledge over time	Requires investment in tools and training in their use

Digital Engineering Context

An Ecosystem of Models, Simulations, and Data



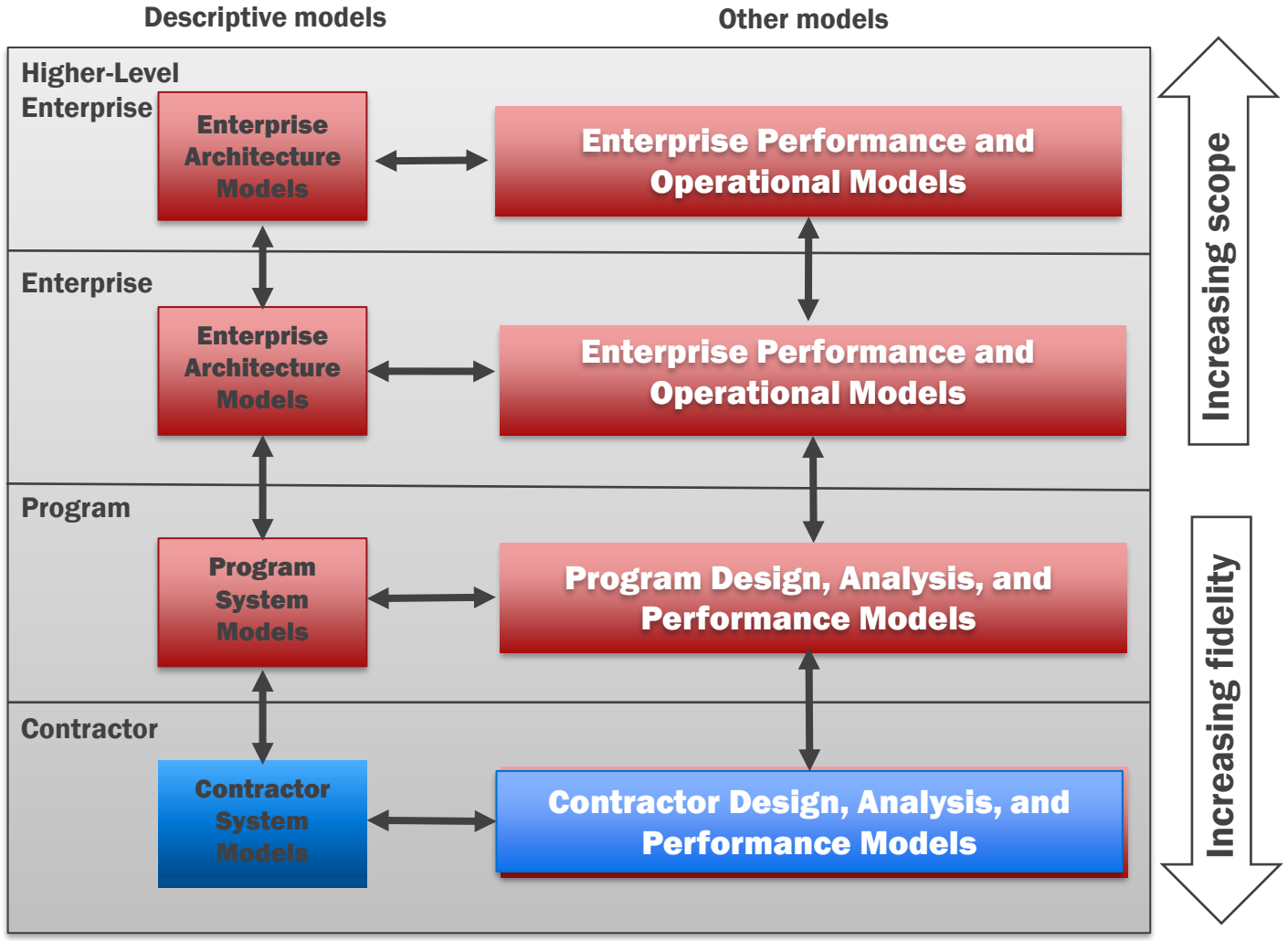
- Digital Engineering (DE) ecosystem includes models, simulations, and data across many disciplines
- Digital system models (DSM) are central to MBSE implementation
- Digital Twin integrates models, simulations, and data across all disciplines and incorporates unit-specific characteristics
- Digital Twin evolves to keep pace with the Physical Twin

Digital Engineering integrates information across all disciplines and life cycle phases built on a foundation of MBSE

Digital Engineering Context

The Network of Interconnected Models

- Decisions at all levels are informed by a comprehensive knowledge of impacts and dependencies
- Models at each layer of the organization are loosely coupled with models in adjacent layers
- Sharing of models reduces duplicative work and reduces the risk of inconsistencies
- Synchronization of models enforces concept of authoritative source of truth (ASOT)
- System models provide authoritative sources of data to feed other disciplines and domains



Model integration enables integration of knowledge from isolated islands to holistic knowledge at all levels

What is Enterprise Systems Engineering?

Enterprise SE is the application of SE principles, concepts, and methods to the planning, design, improvement, and operation of an enterprise. Enterprise SE is an emerging discipline that focuses on frameworks, tools, and problem-solving approaches for dealing with the inherent complexities of the enterprise. Furthermore, enterprise SE addresses more than just solving problems; it also deals with the exploitation of opportunities for better ways to achieve the enterprise goals.

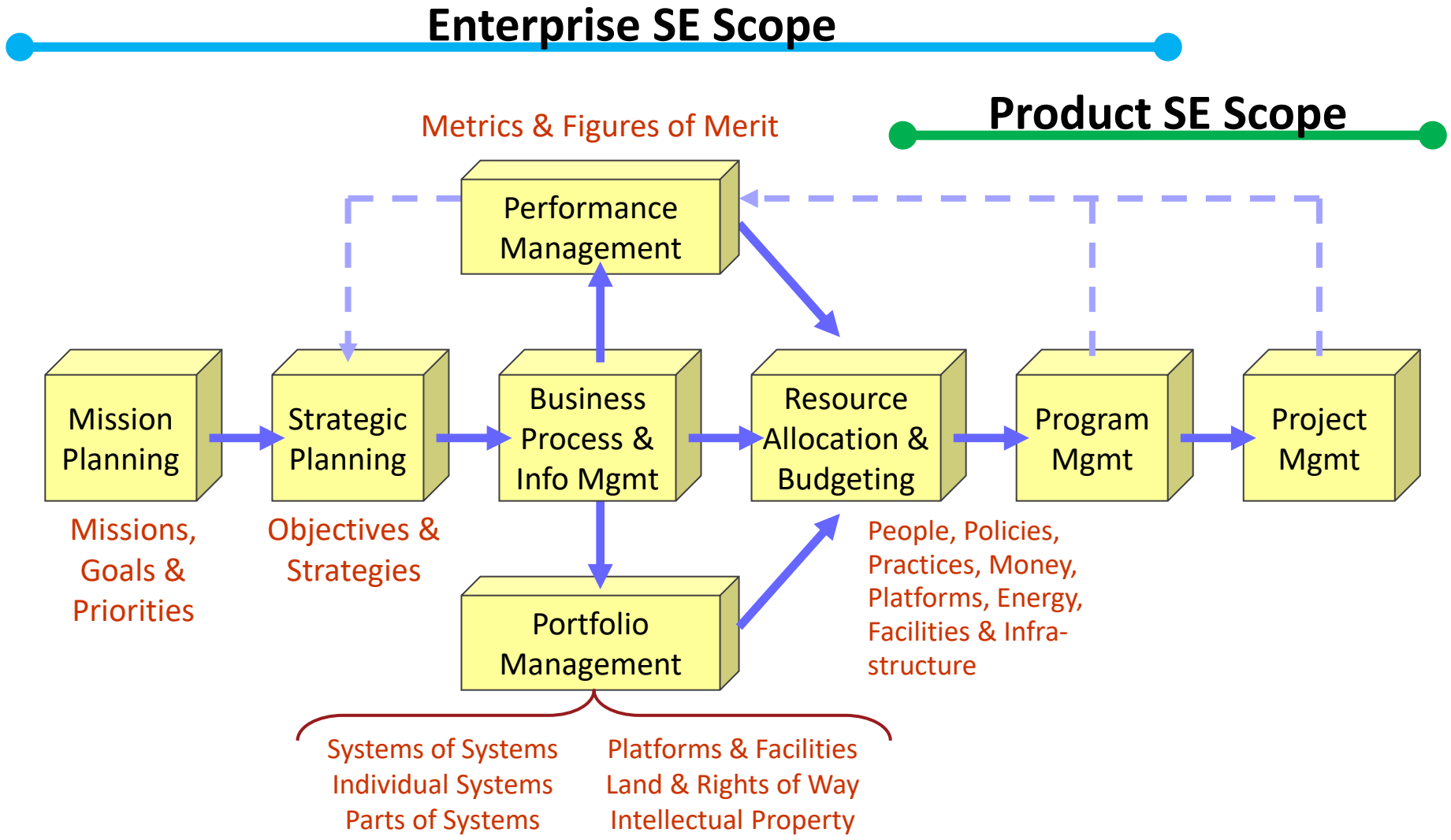
INCOSE Systems Engineering Handbook, 2015

- Enterprise systems engineering (ESE) is the application of systems engineering (SE) methods, processes, and tools to better inform decision making within and about the enterprise
- An enterprise has many characteristics of a very complex socio-technical system
- But an enterprise is not simply a large system; it also comprises business processes and organizations
- A disciplined SE approach can be adapted to improve enterprise management and evolution
- ESE requires additional methods, processes, and skill sets to address these unique aspects

Enterprise systems engineering is about improving speed and quality of enterprise decisions

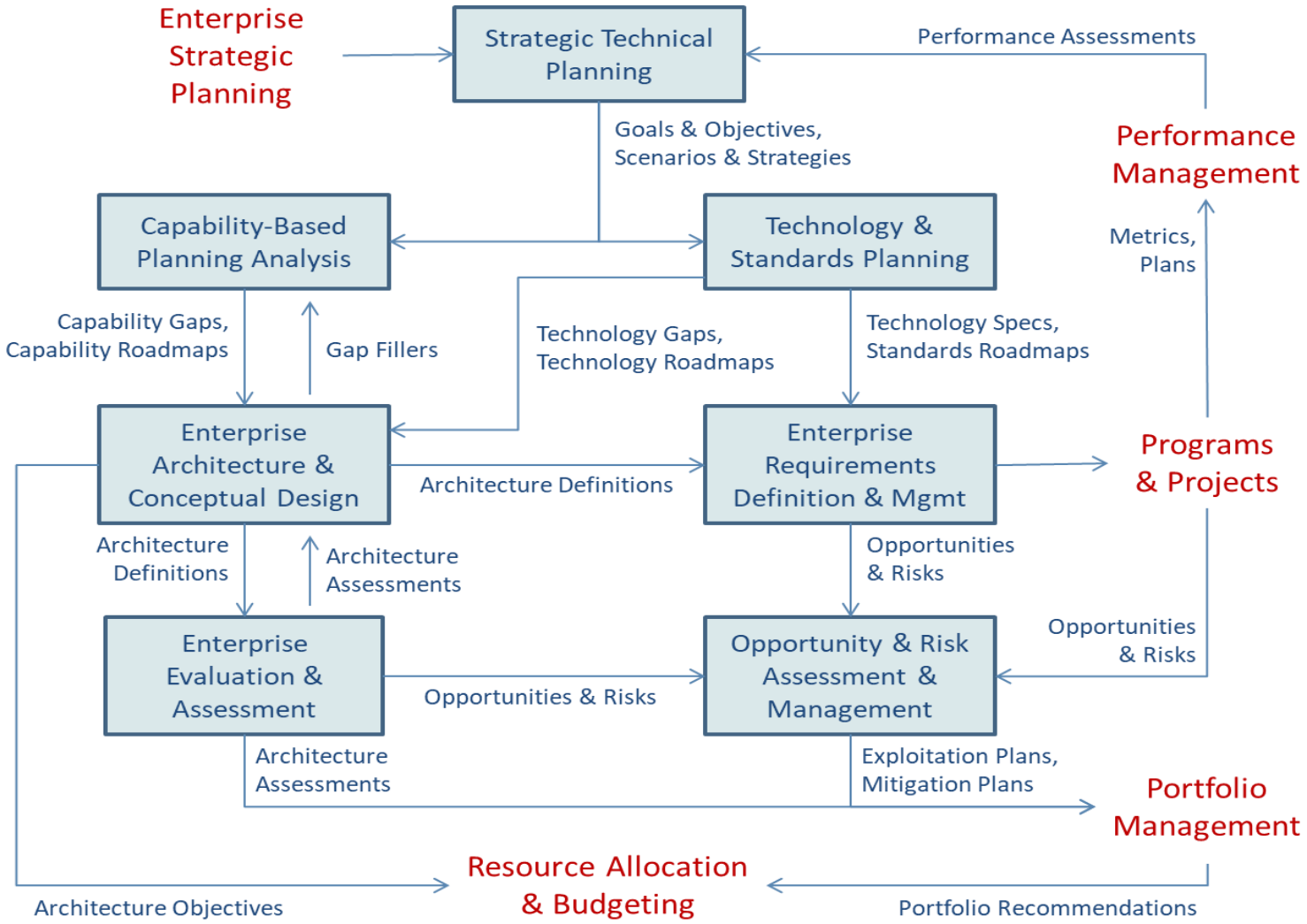
Enterprise Systems Engineering Context

Scope of ESE



Enterprise Systems Engineering Context

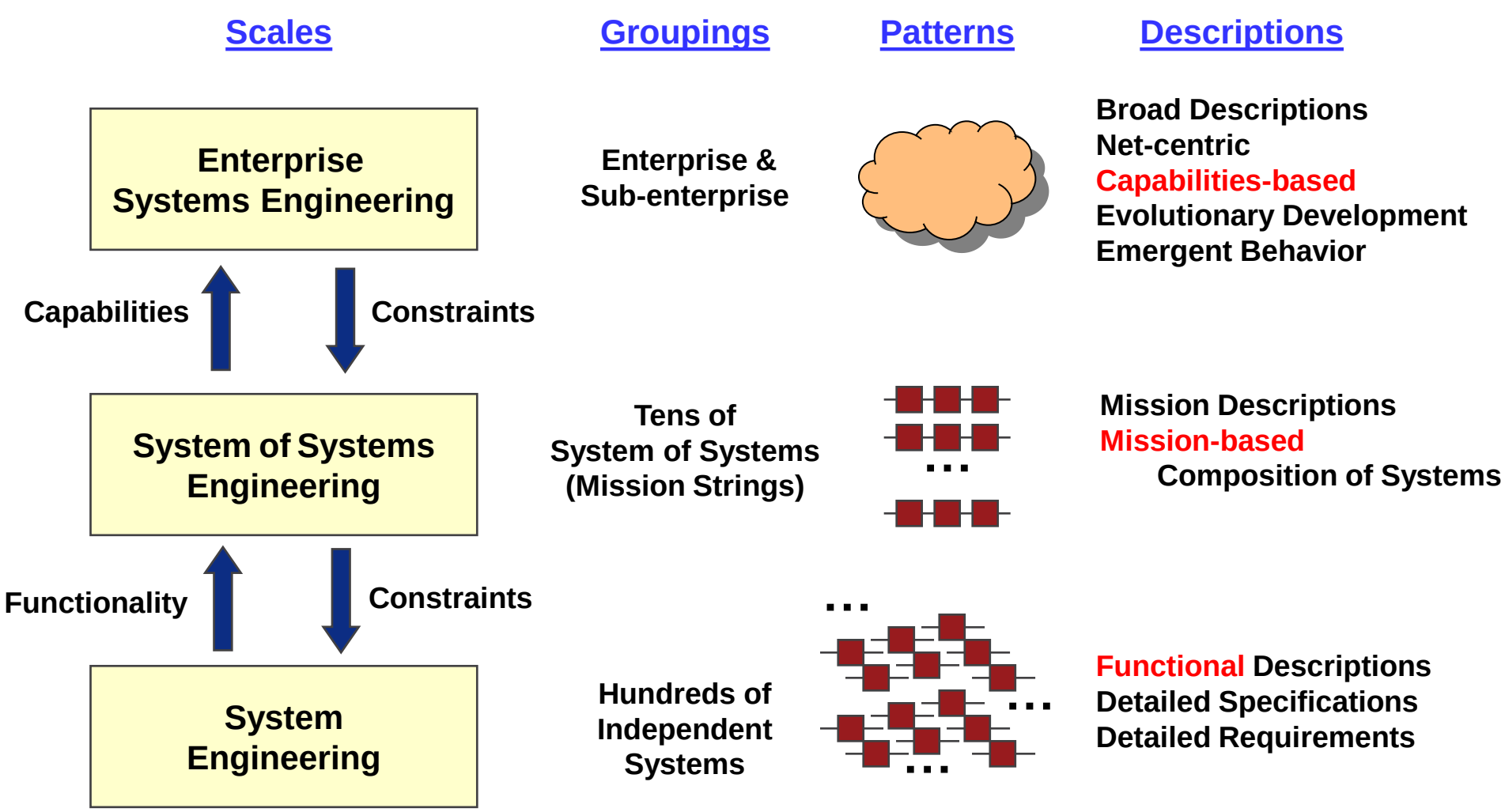
ESE Processes



ESE Processes bring SE discipline to more directly address enterprise objectives

Enterprise Systems Engineering Context

Relation of ESE with SOSE and SE



Different groupings and patterns are revealed at different scales

How does DE add value to ESE?

- DE improves the management and exchange of exponentially growing sources of data, information, and knowledge spanning an enterprise
  - That improvement can be applied to the execution of individual acquisition or operational projects, but it can also be applied to the enterprise itself

- DE enables the seamless exchange of information from many disparate sources spanning the enterprise—and external entities that interact with the enterprise—to improve the speed and quality of communication

- DE across an enterprise enables the aggregation of information from many sources into a broader and deeper understanding of the composition, behavior, and dependencies of the enterprise and its constituents

- Without DE use in the enterprise, ESE is significantly hindered by inefficient communication and limited access to the diverse and expanding body of knowledge
  - How can you make good enterprise decisions if you don't have a comprehensive understanding of the enterprise, the situation, and the broader implications of choices?
  - How can you make good decisions having global implications if your only information is local in nature?

DE is a fundamental enabler for ESE; ESE without DE is like designing systems without the benefit of computers

Degrees of Enterprise-Level MBSE Implementation

- MBSE is applied at different levels of maturity in the Enterprise
  - **Level 0:** Deploy MBSE in an ad hoc manner on multiple programs
  - **Level 1:** Efficiently and consistently deploy MBSE on multiple programs managed by an enterprise
  - **Level 2:** Federate program-level system models to enable MBSE to be performed on the enterprise's technical systems
  - **Level 3**: Perform systems engineering using models on some combination of the enterprise's technical and business architectures in an integrated manner
- The ideal implementation of system modeling may differ in each of these cases
  - Local application of modeling practices can have significant implications for integration of those models to achieve enterprise objectives
  - Need to balance the needs of individual programs with the needs of the enterprise

Think Globally (to enable enterprise objectives) when Acting Locally (to achieve local program objectives)

Level 0 – Individually Optimized MBSE Implementations

- At Level 0, programs within an enterprise adopt their own MBSE approaches at their own pace
  - Unique modeling methodologies
  - Unique modeling processes
  - Unique modeling toolsets and repositories
  - Unique modeling templates
  - Unique modeling profiles--usually SysML-based (and possibly other languages)
  - Little reuse of models and datasets

- These programs may have one or more prime contractors, who may or may not be doing MBSE
  - Unique modeling methodologies
  - Unique modeling processes
  - …
- Each program may optimize their approach to meet their own needs, at best

- Enterprise doesn’t have an effective model ecosystem to support ESE activities

Level 1 – Standardized MBSE Implementations

- At Level 1, programs within an enterprise achieve efficiencies by minimizing unnecessary divergence in their MBSE implementation
  - Common modeling methodologies
  - Common modeling processes
  - Common modeling toolsets and repositories
  - Standardized modeling templates
  - Standardized modeling profiles—often SysML
  - Decent reuse of models between programs
- Each program may still optimize their approach, tailoring the common and standardized elements as needed to address their unique needs
- Enterprise is closer to having an effective modeling ecosystem to support ESE activities
- However, the standards may not be sufficient to enable seamless interoperability

Level 2 – Standardized Enterprise-Ready MBSE Implementations

- At Level 2, enterprise-level systems MBSE is used to manage the integrated set of technical systems comprising the enterprise

- Programs within an enterprise achieve even greater opportunities for enterprise integration by minimizing divergence in their MBSE implementation and by adopting key Enterprise-Ready modeling practices
  - Clear Partitioning of ASOT
  - Modeling for Federation
  - Modeling for Reuse
  - Exploiting Abstraction Layers

- Enterprise primed to achieve an effective modeling ecosystem to support ESE activities

- Starting to use enterprise level modeling approaches, such as the Unified Architecture Framework (UAF) Profile from OMG

Level 3 – Apply MBSE on the Enterprise Itself

- At Level 3, MBSE is applied to engineer the enterprise itself
  - The enterprise is treated as a complex system of interest for the application of systems engineering
  - This system includes not only technical system components, but also humans and organizations
  - Technical architecture and business architecture are modeled in an integrated fashion
  - Enables greater understanding and more effective architecting spanning both materiel and non-materiel solutions

- Enterprise level issues and solutions are given prominence
  - Modeling strategic drivers and challenges (and the mission and business capabilities that address them)
  - More focus on capability-driven system development (rather than just function and requirements driven)
  - Modeling aggregations of projects (and their dependencies) rather than just individual projects

- Level 2 needs for MBSE are also needed at Level 3
  - Also needed may be other modeling languages or approaches suited for modeling enterprise-level concerns and challenges
    - Such as the UAF Profile and Business Process Modeling Notation (BPMN) modeling languages

Heuristics and Patterns for Enterprise-Ready Modeling

Authoritative Sources of Truth (ASOT)

- Establish clear lines of responsibility for individual pieces of information
  - Each piece of information should have a single authoritative digital source, a source that all other consumers can get access to and rely upon
- Federate authoritative sources across the enterprise
  - To improve awareness of dependencies and synergies across the enterprise
- Don’t only focus on approved baselines
  - Much of the work involves deciding what the baseline should be in the first place
- Remove impediments to discovery, access, and exploitation of data
  - While some of these are technical, many are non-technical (cultural)
- Establish the value proposition for ensuring those models remain useful throughout the life cycle
  - Make them useful enough to warrant keeping them continually updated
  - Make them easy to update

The Authoritative Source of Truth concept is critical for enterprise MBSE

Heuristics and Patterns for Enterprise-Ready Modeling

Partition authoritative sources of truth

- Establish clear lines of ownership
  - Who owns the element?
  - Who owns the relationship?

- Define ASOTs to make it clear who is responsible for managing that information
  - Clarify participants in governance processes
  - Identify dependencies between ASOTs

- Partition models to maximize cohesion, minimize coupling, eliminate redundancy
  - Exploit tools that enable connecting ASOTs residing in their native repositories
  - Use “reference models” that pre-define standard partitioning constructs

- Avoid large monolithic model files
  - Is your model the authoritative source for all of that content?
  - Are you willing to open up the entire model to anyone who needs just a part of it?

Heuristics and Patterns for Enterprise-Ready Modeling

Model to facilitate federation

- Architect and implement models to facilitate their federation
  - Syntactic interoperability – Can the models talk to each other?
  - Semantic interoperability – Can the models understand each other?

- Start building on the right foundation for federation
  - Define standards for modeling methods
  - Exploit standard profiles where possible
  - Create standards where they don’t currently exist
  - Define standard definitions of terms, ontologies of concepts
  - Extend standard profiles where needed—and it will be needed—but try to achieve consensus and add those extensions to the local enterprise standard
    - Unified Architecture Framework (UAF) Profile can be a good foundation for both enterprise- and system-level modeling, building on the SysML foundation

Heuristics and Patterns for Enterprise-Ready Modeling

Model to facilitate reuse (slide 1 of 2)

- Architect and implement models to facilitate reuse of model components
  - Establish modeling patterns to encourage such reuse
  - Use pre-populated modeling templates to save time and effort

- Be careful when defining elements and relationships
  - Make sure the definition is enduring and intrinsic, independent of context
    - Example: Stakeholder
    - Example: System of interest

- Be careful of making assumptions based on model organization
  - Unique types or stereotypes may be needed to distinguish important distinctions that may not survive the reuse process, e.g., package containment

- Use standard approaches for modeling at the enterprise level
  - Frameworks like the Unified Architecture Framework (UAF) already capture the ontology of enterprise level concepts, such as capabilities and roadmaps, projects and milestones, etc
  - The UAF Profile marries these enterprise concepts with the SysML language in a standard way

Heuristics and Patterns for Enterprise-Ready Modeling

Model to facilitate reuse (slide 2 of 2)

- Beware of composition misuse
  - If the whole is created/destroyed, the part is also created/destroyed
  - The part represents a unique entity that is typed by the block, and exists only in the context of its owning block
  - These semantics are often inappropriate for reuse and federation

- Beware of direct relationships based on intuition of indirect relationships
  - Can often lead to multiple redundant paths through the model from point A to point B
  - Frequently based on anecdotal information
    - May be situational and difficult to validate

- Beware of untyped relationships or generic relationships with loose semantics
  - Dependency, Abstraction, satisfy, verify, etc.
  - Loose semantics limit understanding and reuse opportunities

Heuristics and Patterns for Enterprise-Ready Modeling

Exploit abstraction layers

- Integration of models might take place at different levels of abstraction

- Define layers of abstraction to hide unnecessary details from potential users

- Define abstraction layers to serve as a stable interface for model federation
  - Consider using “tiers” of architectures (e.g.,, enterprise, mission area, mission, system)
    - Facilitates separation of concerns in modeling
    - Creates different levels of federation for models
  - Take advantage of different domains for clear model separation
    - Such as strategic, operational, services, resources, etc. as depicted in the UAF Grid

Summary

- Digital Engineering is a critical enabler for Enterprise Systems Engineering
  - Improves the management and exchange of exponentially growing sources of data, information, and knowledge spanning an enterprise
  - Enhances the utility of architecture and engineering models for all domains involved
- DE enables seamless exchange of information from disparate sources spanning the enterprise
  - Manage authoritative sources of truth to avoid redundancy, inconsistency, and chaos
  - Stitch local pockets of information into an integrated global body of knowledge
- Programs within an enterprise achieve even greater opportunities for enterprise integration by
  - Minimizing divergence in their MBSE implementation
  - Adopting key Enterprise-Ready modeling practices

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