Model-Driven Systems Engineering for Netcentric System of Systems With DEVS Unified Process

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Outline

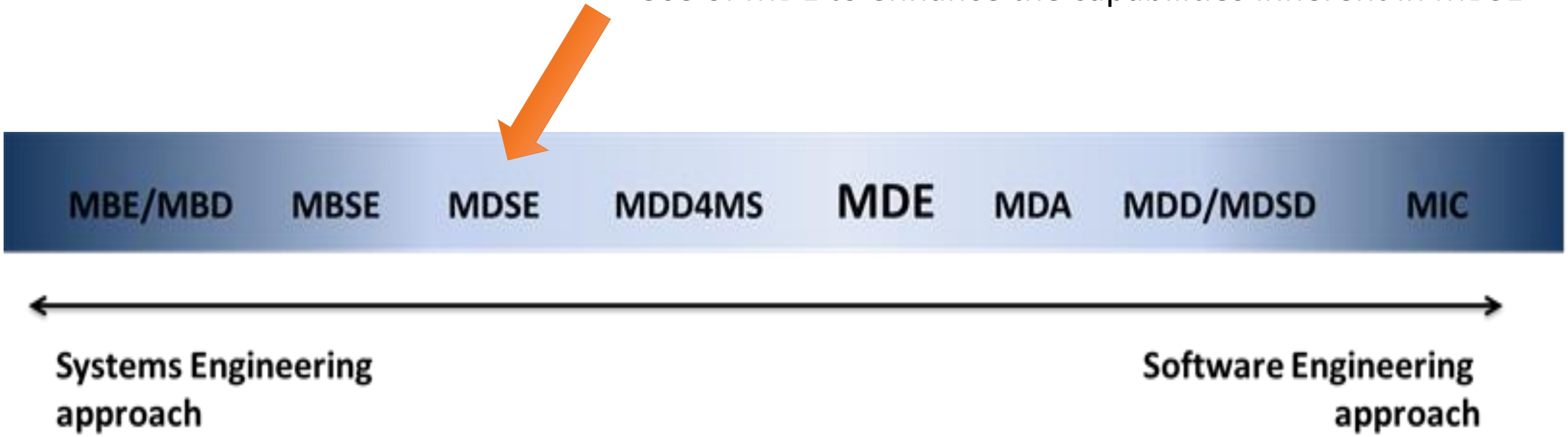
- Model-based and Model-driven: Flavors
- Metamodeling and Domain-Specific Languages
- Theory of M&S and Levels of Systems specifications
- DEVS Unified Process and DEVSML Stack
- Netcentric SoS: EDA and DEVS together

Model-Based and Model-Driven Flavors

- MBE/MBD: Model-Based Engineering/Design
  - 1980s: Wymore and Zeigler
  - Design, development, integration, validation, verification, testing, documentation, maintenance
- MBSE: Model-Based Systems Engineering
  - Analysis and Design phases, systems complexity, team communication
- MDE: Model-Driven Engineering
  - 2000s
  - Focus on Transformations and metamodels: Usage of models in various phases
- MDA: Model-Driven Architecture
  - 2000s, OMG
  - MOF: Guidelines for specifying and structuring models: context independence
- MDD/MDSD: Model-Driven Software Development
  - 1990s: OMG, Eclipse, Microsoft and others
- MIC: Model Integrated Computing
  - 1990s: ISIS
  - Open integration framework to support formal analysis tools, verification techniques and model transformations

Models in Systems/Software Engineering

MDSE: Model-Driven Systems Engineering
Use of MDE to enhance the capabilities inherent in MBSE

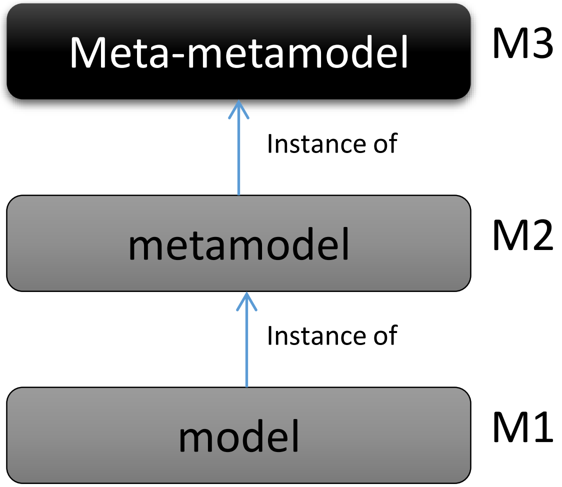


MDE
Key Enabler promoting automated transformations

- Metamodeling

  M1, M2, and M3 Levels

- Domain Specific Languages
  - Defined at M2 Level
  - Oriented to a problem domain/context
  - Metamodeling process is called Domain Specific Modeling (DSM)



Theory of Systems M&S: Concepts (1/2)

- System Specification Formalisms: Continuous or Discrete
  - DESS, DTSS, Quantized
- Hierarchy of Systems Specifications
  - Closed under composition

<table>
<tr><th>Level</th><th>Name</th><th>System Specification at this level</th><th>Elements from the Framework for M&S</th><th>Verification and Validation</th></tr>
<tr><td>4</td><td>Coupled Systems</td><td>Systems built from component systems with a coupling recipe</td><td>Model, Simulator, Experimental Frame</td><td rowspan="2">Structural Validity, simulator correctness</td></tr>
<tr><td>3</td><td>I/O System Structure</td><td>System with state and transitions to generate the behavior</td><td>Model, Simulator, Experimental Frame</td></tr>
<tr><td>2</td><td>I/O function</td><td>Collection of input/output pairs partitioned according to initial state</td><td>Model, Source System</td><td>Predictive Validity</td></tr>
<tr><td>1</td><td>I/O behavior</td><td>Collection of input/output pairs from external black-box view</td><td>Model, Source System</td><td>Replicative Validity</td></tr>
<tr><td>0</td><td>I/O frame</td><td>Input and output variables and ports together with values over a time base</td><td>Source System</td><td></td></tr>
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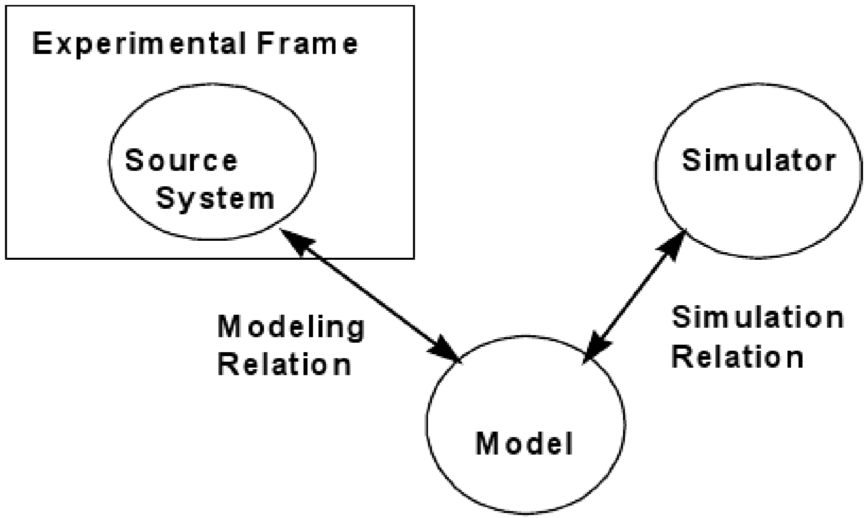
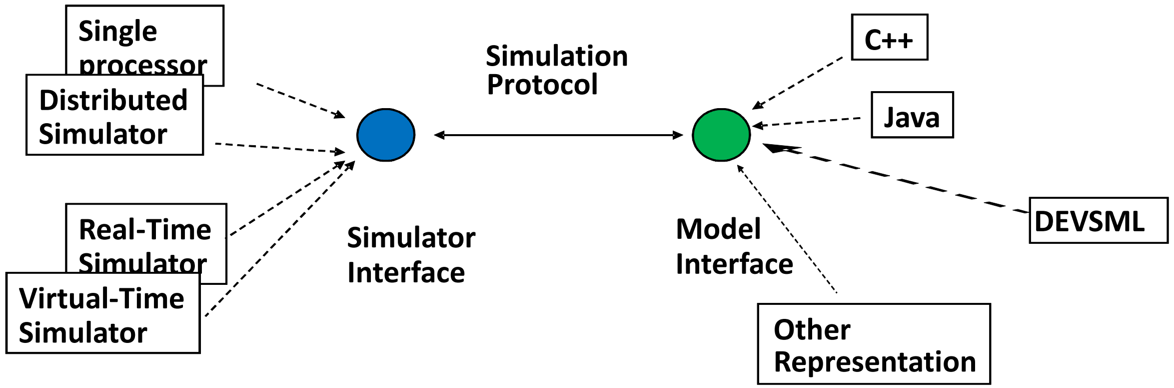
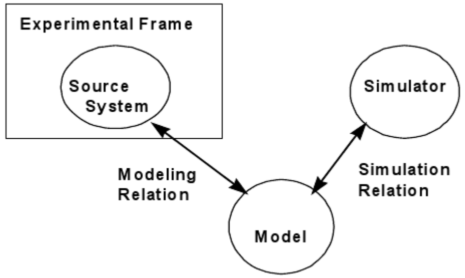
Theory of Systems M&S: Concepts (2/2)

- Source-System, Model, Simulator, Experimental-Frame

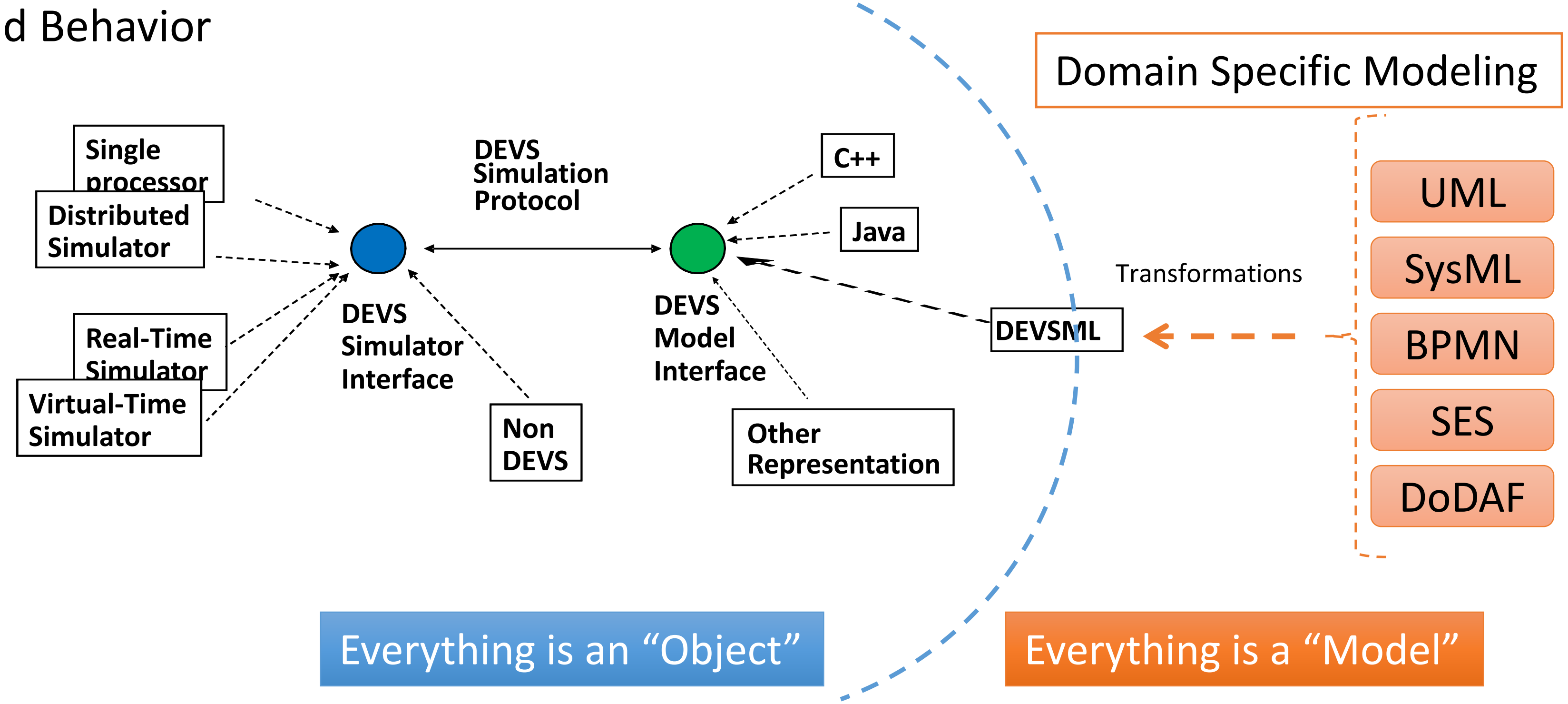




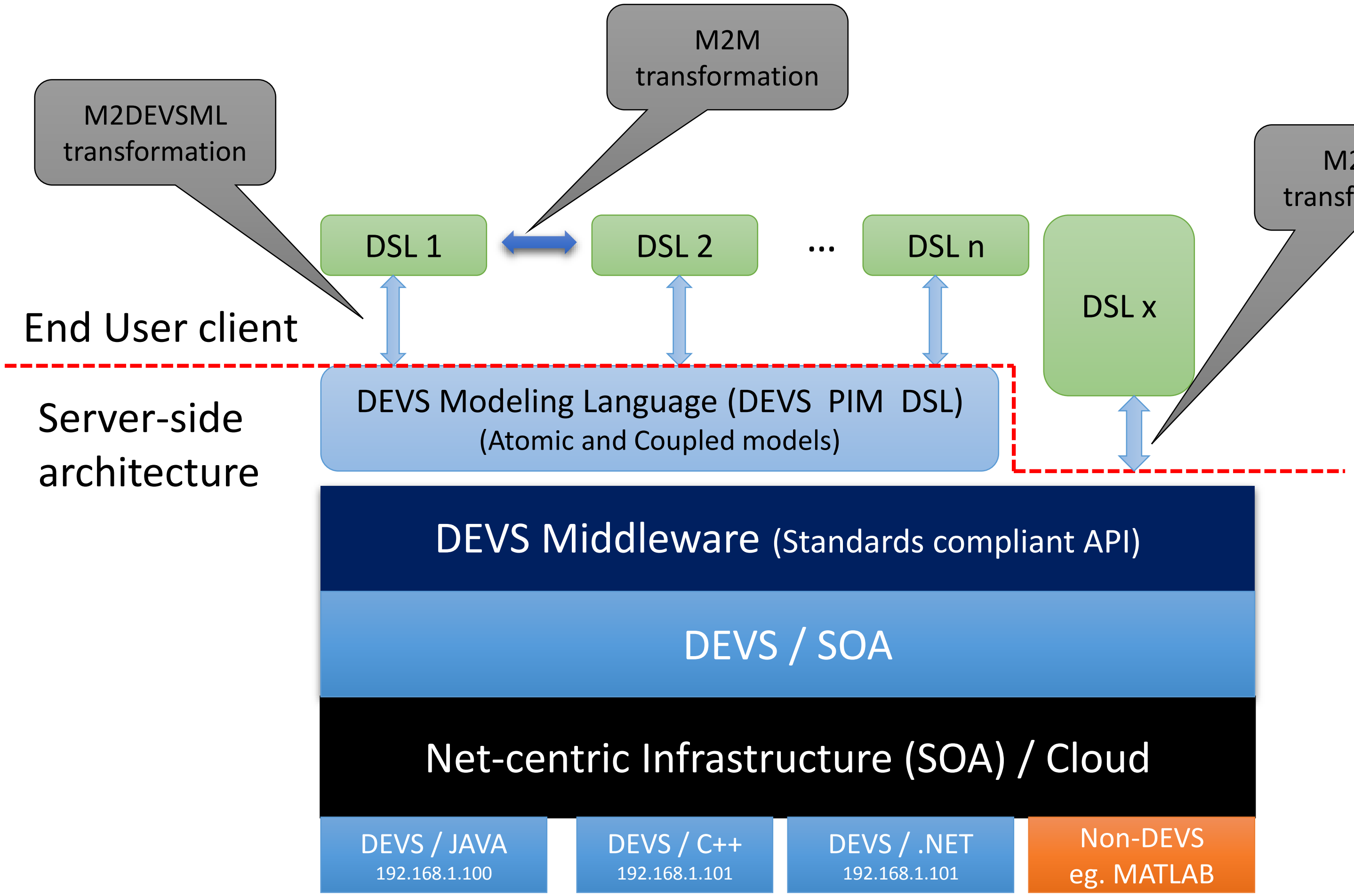
Object or Model?



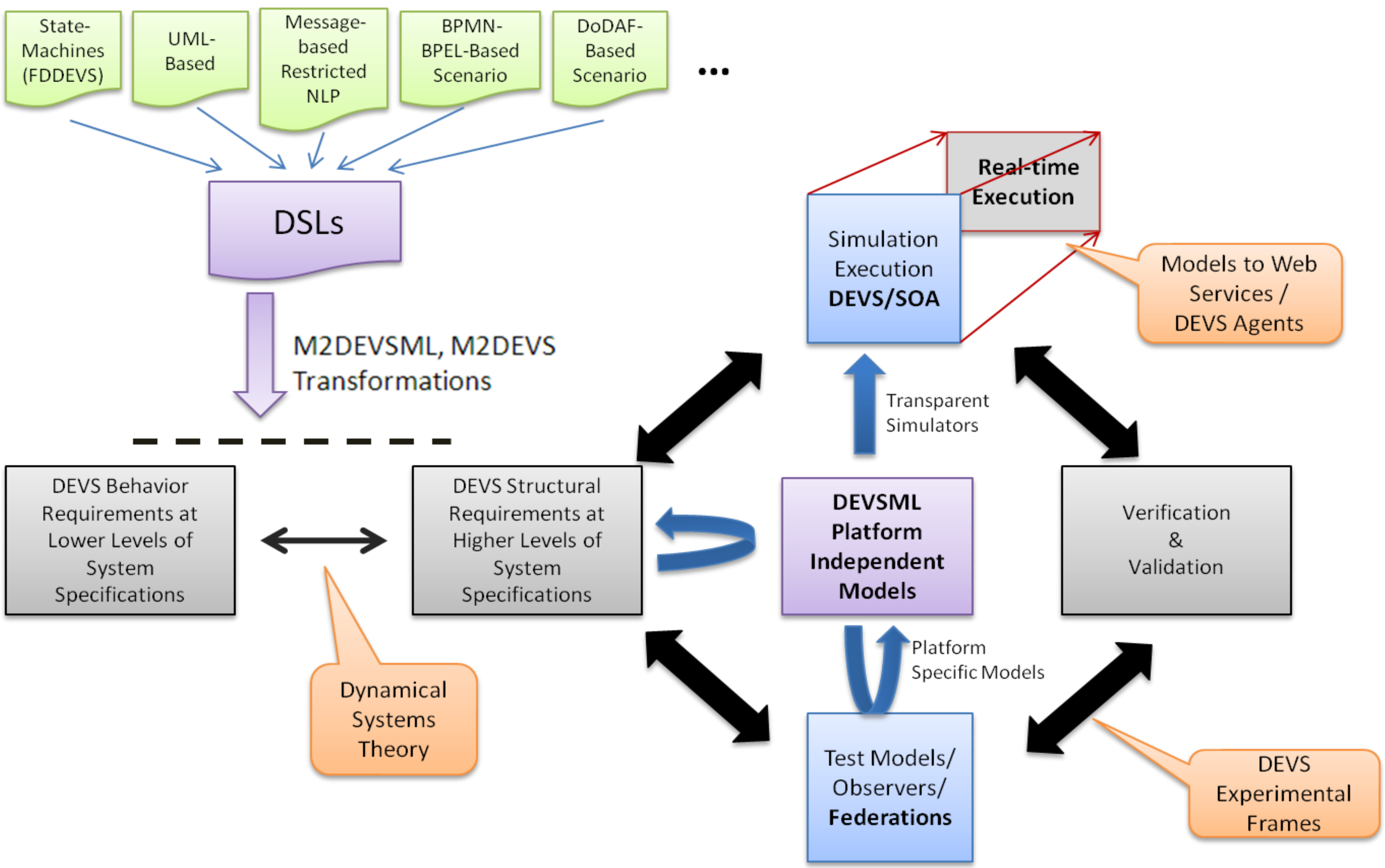
- Separation of Model and Simulator: a critical requirement
- Model develops abstractions and simulator executes a model
- The Abstraction chain, layered, hierarchy
- Model transformations
- Semantic anchoring
- Structure and Behavior



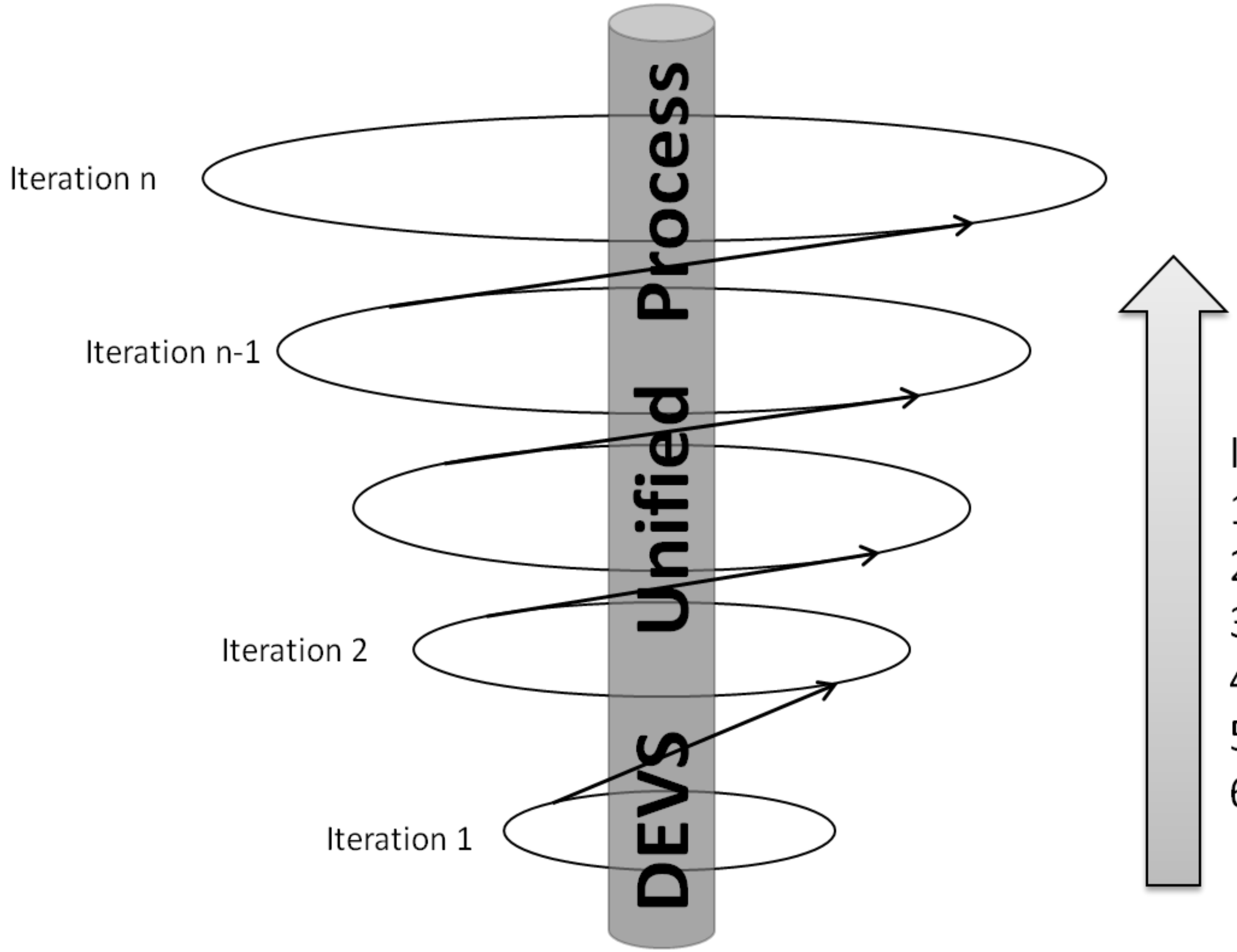
DEVSML Stack: Netcentric DEVS Virtual Machine



DEVS Unified Process



Spiral nature of DUNIP



Increasing:
1. Complexity
2. Integration
3. Requirements
4. Components
5. Tests
6. Validity

MBSE/DUNIP with other MB/MD Flavors

Features	System/Software Engineering approaches							
	MBE	MBSE	MDSE / DUNIP	MDD4MS	MDE	MDD / MDSD	MDA	MIC
Use of DSLs	Y	Y	Y	Y	Y	Y	Y	Y
Alignment with Systems theory	Y	Y	Y	-	-	-	-	-
DSL representation with metamodeling	-	-	Y	Y	Y	Y	Y	Y
Guidance for model transformations	-	-	Y	Y	Y	Y	Y	Y
Support for component reusability	Y	Y	Y	Y	-	-	-	Y
Code generation/execution	Y	Y	Y	Y	-	Y	Y	Y
Code deployment mechanisms	Y	Y	Y	-	-	Y	-	Y
Tool support for overall process	-	-	Y	Y	Y	Y	-	Y
Applicable to all domains	Y	Sys. Engg.	Sys. Engg.	Y	Y	Soft. Engg.	Soft. Engg.	Soft. Engg.

Netcentric Event Driven Architectures

- SOA:
  - The Key Enabler as events are structured rather than just messages in discrete event systems
- Granular at Event level: Have semantics associated
- Functional components
  - Producer
  - Consumer
  - Processor
  - Reaction (automate/human)
  - Processing Backbone (ESB/Cloud)

Event Processing in EDA

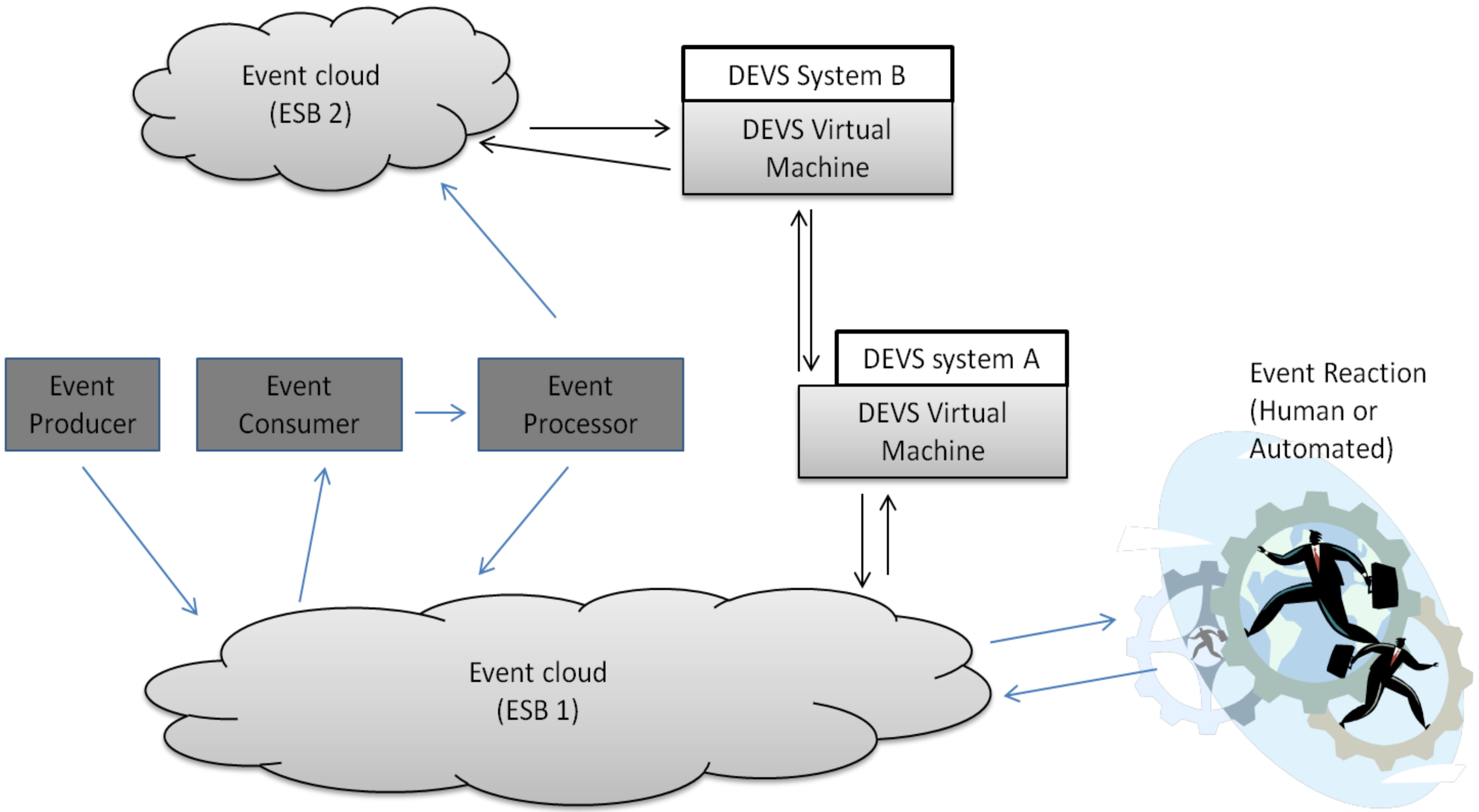
- SEP: Simple Event Processing
  - Exclusively processed and may not have event reactions
- ESP: Event-Stream Processing
  - Events have Temporal nature and multiple correlated events may elicit a reaction
- CEP: Complex Event Processing
  - Multiple ESP on different time scales with meaningful logical reactions
  - Pattern matching on information sets

Contrasting EDA and DEVS Systems Hierarchy

- EDA is a software paradigm and results in real-time event-driven “system” as a whole
- No framework to manage abstract time i.e. there is no simulator
- EDA is stateless: State travels with event

Level	Name	EDA
4	Coupled systems	Does not exist. There is no containment to specify system hierarchy.
3	I/O System	Does not exist
2	I/O Function	Complex event processing
1	I/O Behavior	Event stream processing
0	I/O Frame	Simple Event processing

EDA and DEVS Together



Conclusions (1/2)

- MBE and MBSE has been in use since 80s
- Object-oriented software engineering led to the emergence of MDE and various other paradigms such as MDD, MDSD and MIC
- DEVS Formalism pioneered MBE/MBSE and largely used for complex dynamical systems engineering
- DUNIP: technological advancement of DEVS incorporates MDE with DEVS resulting in MDSE
- Advanced tooling led to DEVSML stack incorporating MDE concepts

Conclusions (2/2)

- DSLs such as UML, SySML, DoDAF, BPMN through the DEVSML stack become executable through M2M, M2DEVS and M2DEVSML transformations
- DEVSML resulted in a netcentric DEVS Virtual Machine for fast deployment and transparent simulation framework
- Standards in netcentric environment led to paradigms such as SOA and EDA.
- EDA and DUNIP together brings M&S to complex netcentric enviroments
- Acknowledges the role of end-user as a DSL designer to its role as a event reactionary thereby transforming a netcentric SoS to a Complex Adaptive System (CAS)

Questions/Comments