FRENEMIES: OPM AND SYSML TOGETHER IN AN MBSE MODEL

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Engineering Fellow, MBSE Specialist

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• Introduction
• MBSE
• SysML
• OPM
• An OPM Profile in a SysML tool
• Conclusions
• Questions and Answers?
Industrial Innovation Platform

- $100M Revenue
- > 50% Bookings Growth FY16
- 1,200 End Customers
- 250 OEMs/Resellers
- Ecosystem of SI's, partners

**PHYSICAL WORLD**

**PHYSICAL PRODUCTS & SYSTEMS & SPACES**

**DIGITAL TWIN**

**DIGITAL WORLD**

PLM Solutions

- $1B Revenue
- 10% Bookings Growth FY16
- 28,000 End Customers
- 70% Direct Sales
- 30% VARs (~400)
- Ecosystem of SI's, partners

**CAD** creo®

**PLM** windchill®

**ALM** integrity®

**SLM** servigistics®
• OPM and SysML are different means of achieving MBSE, each with their own benefits, issues, supporters and detractors.

• But first, let’s look at some definitions.
MODEL-BASED SYSTEMS ENGINEERING (MBSE)

- The NDIA defines Model-Based Systems Engineering (MBSE) as “an approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition life cycle.”
  - There are a variety of methods in use
  - Some are standards based and others are proprietary
  - Different tools can be used at different points in the lifecycle and for different purposes.
    - Like mechanical tools, no single MBSE tool is best for all purposes
    - A mix of tools may be necessary for a single task
THE SYSTEMS MODELING LANGUAGE (SYSML)

• Diagrams for system requirements, behavior, structure and parametric relationships.
  – Used to define high-level abstract systems down to detailed physical systems.

• Developed by the Object Management Group (OMG) and INCOSE.
  – Organizations from industry, academia, government, standards organizations, etc.
  – Many books on its basic notation and how to use SysML in large complex systems.
  – More than 10 commercial implementations of SysML tools are available, as well as freeware and shareware.

• Integrations between SysML tools and other SE tools such as Matlab, requirements engineering tools, PLM tools, process tools, etc.
  – Open System Lifecycle Collaboration (OSLC) has provided a standardized means of connecting tools that do not require point to point integrations.
  – Mandated for the development of many different military systems.

• SysML V2 is under development now.
OBJECT PROCESS METHODOLOGY (OPM)

• “Conceptual modeling language and methodology for capturing knowledge and designing systems.
  – Based on a minimal universal ontology of stateful objects and processes that transform them
  – OPM can be used to formally specify the function, structure, and behavior of artificial and natural systems in a large variety of domains.
  – A software package called OPCAT, for generating OPD and OPL, is freely available.
  – OPCAT is the only OPM tool, and integration with other SE tools is limited.
    • (Note: I am happy to be corrected on this point.)
MOTIVATION FOR THE PAPER

• OPM is used in systems engineering graduate courses at both the California Institute of Technology (CalTech) and the Massachusetts Institute of Technology (MIT).
  – Students graduating from these institutions are struggling to integrate the differing styles, philosophies, concepts and processes of SysML and OPM.

• A literature search reveals some papers that contrast SysML and OPM, but none that describe how the two can work together.

• This presentation discusses a synergy rather than promoting one language over another.

Ref: Systems Modeling Languages: OPM Versus SysML
Yariv Grobshtein, Valeriya Perelman, Eliyahu Safra, Dov Dori
• OPM model represents the system under design or study in graphics and text for improved representation, understanding, communication, and learning.
  – In OPM, an object is a thing that exists, or might exist, physically or informatically.
  – A process is a thing that transforms an object by creating or consuming it, or by changing its state.

• The main author of OPM is Dov Dori

• OPM is bimodal; it is expressed both visually/graphically in Object-Process Diagrams (OPD) and verbally/textually in Object-Process Language (OPL), a set of automatically-generated sentences in a subset of English.

• OPM is an ISO standard OPM ISO 19450

• OPM is being further developed
Canonical Architecture Representation with OPD

- Architecture is made up of operands + processes (functions) plus instrument objects (form)
- Examples:
  - Image is captured by digital camera
  - Homeowner is sheltered by a house
  - Traveler is safeguarded by evacuation instructions
  - Vehicle is supported (in transit) by bridge
(Basic) OPM Cheat Sheet

Object

State 1  State 2

Process

Structural Links
Object-Object
(don’t forget to label)

Transforming (Procedural) Link
Object-Process
(no need to label)

Agent (who/what is doing it)
Instrument (what is required)

Enabling Links
(Object-Process)

Decomposition/Aggregation
Exhibition/Characterization

Specialization/Generalization
(Seen in concepts)
Classification/Instantiation

Remember to always indicate the system boundary

There is more to it! Additional Resources (for those interested):
- ISO 19450 (New!)
- Dov Dori’s book (available at libraries.mit.edu)
## Two Common languages for modeling: SysML v/s OPM (notations)

<table>
<thead>
<tr>
<th>Element</th>
<th>OPM</th>
<th>SysML</th>
<th>OPM</th>
<th>SysML</th>
<th>OPM</th>
<th>SysML</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Object</td>
<td>«block» ::Block</td>
<td>Processing</td>
<td>«activity» Activity</td>
<td>Use Case</td>
<td>Object</td>
</tr>
<tr>
<td>Behavior</td>
<td>Use Case</td>
<td>State 1</td>
<td>State 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relationships</th>
<th>OPM</th>
<th>SysML</th>
<th>OPM</th>
<th>SysML</th>
<th>OPM</th>
<th>SysML</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregation</td>
<td>Assembly</td>
<td>«block» ::Assembly</td>
<td>part</td>
<td>«block» ::Part</td>
<td>Structural link</td>
<td>part</td>
</tr>
<tr>
<td>Object/Behavior Link</td>
<td>Object</td>
<td>object</td>
<td>processing</td>
<td>instrument</td>
<td>instrument</td>
<td>processing</td>
</tr>
</tbody>
</table>
### Two Common languages for modeling SysML v/s OPM (notations)

<table>
<thead>
<tr>
<th>OPM</th>
<th>SysML</th>
<th>OPM</th>
<th>SysML</th>
<th>OPM</th>
<th>SysML</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part</strong></td>
<td>Use Case1</td>
<td>«activity» Activity3</td>
<td><strong>Type</strong></td>
<td>«block» Block1</td>
<td><strong>Processing</strong></td>
</tr>
<tr>
<td>Processing</td>
<td>«activity» Activity1</td>
<td>«dependency»</td>
<td>Generalization/ Specialization</td>
<td>Generalization/ Specialization</td>
<td>Use Case</td>
</tr>
<tr>
<td><strong>Process – Part Flow</strong></td>
<td>A link between the behavior and structure could only be done via the dependency</td>
<td><strong>Structural Link</strong></td>
<td><strong>Interface/Flow</strong></td>
<td><strong>Behavior Aggregation</strong></td>
<td><strong>Include</strong></td>
</tr>
</tbody>
</table>

**Use Case**

**Attribute**

**Type**

**Attribute**

**Use Case**

**Processing**

**Use Case**

**Processing**

**Use Case**

**Processing**

**Use Case**
COMBINING THE TWO
• Simple Profile
  – Extends SysML
  – Defines elements as extensions of Blocks
  – Processes modeled as blocks as well
  – Relationships are extensions of Trace
  – “Open Dot” is requires, “Closed Dot” is provides

• Elements can be used as part of SysML model

• Basic diagram is the BDD
  – Uses SysML notation

• Some limitations
### TEMPLATE FOR DIAGRAMS

<table>
<thead>
<tr>
<th>bdd [Package] OPM Template [Example]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Operands</strong></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
• Defines components of Wine Bottle system
• Defines processes of different varieties for opening wine bottles
  – Opening, removing, breaching, destroying, vaporizing, etc.
  – Defined using inheritance.
• Defines the Fluid operand and methods of energizing it

• Defines Value Instruments for achieving processes
• Pump System and its components.
• A combination of Value and Supporting Instruments and Blocks
PUMP SYSTEM STRUCTURAL BREAKDOWN W/GRAPHICS
- Elements taken from the OPM example
- Torque and Force added as Value Types
- Interfaces added to define how systems interact

```
<table>
<thead>
<tr>
<th>bdd [Package] SysML Pump System [Flows and Interfaces]</th>
</tr>
</thead>
<tbody>
<tr>
<td>«Operand» Internal High P Flow</td>
</tr>
<tr>
<td>«Operand» Internal High V Flow</td>
</tr>
<tr>
<td>«Operand» Internal Low p Flow</td>
</tr>
<tr>
<td>«Operand» Water Leakage</td>
</tr>
<tr>
<td>«valueType (dataType)» Torque</td>
</tr>
<tr>
<td>«valueType (dataType)» Force</td>
</tr>
<tr>
<td>«block» Pressure Measurement</td>
</tr>
<tr>
<td>«interfaceBlock» Fastener</td>
</tr>
<tr>
<td>«interfaceBlock» Power IF</td>
</tr>
<tr>
<td>«interfaceBlock» HP Water IF</td>
</tr>
<tr>
<td>«interfaceBlock» LP Water IF</td>
</tr>
<tr>
<td>«interfaceBlock» Torque IF</td>
</tr>
<tr>
<td>«interfaceBlock» Measurement IF</td>
</tr>
</tbody>
</table>
```
• Activities created from the original OPM elements
• Guide and Contain, and Support were not used.
• Defined as a continuous, parallel sequence.
• Similar to the SysML V1 Distiller example
- Defines the system interactions in a defined order and links behavior.
WHY IS THIS USEFUL?

• Demonstrates that the different languages can be used together in a single tool
  – Alternative would be to create the OPM model in OPCAT use printout as a basis for traceability
  – The integrated approach means that true impact analysis and traceability can be done.

• An OPM Model can created as a starting point with SysML used to refine the concepts
  – The elements were then used to create the SysML diagrams
  – Some additions and changes were needed
  – Alternative would be to create separate OPM and SysML models and create trace links between them

• Other concepts can be added such as parametrics, executable state machines, traceability to requirements, analysis and PLM tools, etc.
CONCLUSIONS

• Many of the concepts in OPM can be duplicated in a SysML tool
  – There is some cognitive dissonance
  – Provide an alternative means of looking at a system
  – Provide a starting point for people familiar with OPM
  – Both are useful

• The models demonstrate that the languages can be used together
  – OPM as a starting point can be used to develop a detailed SysML model

• More work and research are needed
  – ALL OPM concepts were not added as this was more of a proof of concept than a solution.
  – The text portion of OPM (OPL) was not implemented.
  – “Finally, defining a hybrid methodology exploiting the advantages of the two languages seems to be a challenging issue.” Systems Modeling Languages: OPM Versus SysML
ACKNOWLEDGEMENT AND THANKS

• Examples were taken from the Edward Crawley et al Book System Architecture: Strategy and Product Development for Complex Systems

• MIT SDM course slides

• Rob Day and John Deere for their help in creating the model and gaining an understanding of OPM

• Tutorials and papers by Dov Dori
WORKING TOGETHER TO ACHIEVE COMMON GOALS

THE GOLDEN SPIKE

THE CHANNEL TUNNEL
FAMOUS FRENEMIES

• Nicole Richie and Paris Hilton

• Jennifer Aniston and Courteney Cox

• Lauren Conrad and Heidi Montag

• Paris Hilton and Lindsay Lohan

• Selena Gomez and Miley Cyrus

• Whitney Port and Olivia Palermo

• Winona Ryder and Gwyneth Paltrow

• Selena Gomez and Demi Lovato

http://www.zimbio.com/Famous+Frenemies/articles
Thank You!

ptc