Unified Architecture Framework (UAF) for System of Systems Modeling

Matthew Hause
PTC Engineering Fellow
mhause@ptc.com

April 2016
• What is the UAF?
• System of Systems Modeling
• Coverage requirements for SoS
• Conclusion
• Questions?
Why Model Based Systems Engineering (MBSE)?

• Pictures paint a thousand words
  – Visio is good at this
  – Language is not controlled

• Modeling languages add semantics and constraints
  – Control what is being said and how it is said

• MBSE is enabled by SysML*, which is a common language of expression that captures:
  – Structure
  – Behavior
  – Requirements
    • Functional
    • Non Functional

• Models can be quantifiable and executable

* Systems Modeling Language (OMG SysML™)
What is UPDM?

• UPDM is the *Unified Profile for DoDAF and MODAF* (+ NAF + DNDAF)
• UPDM is NOT a new Architectural Framework
• UPDM is NOT a methodology or a process
• UPDM is a graphical enterprise modeling language
• UPDM was developed by members of the OMG with help from industry and government domain experts

<table>
<thead>
<tr>
<th>DOD (US)</th>
<th>MITRE</th>
<th>PTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOD (UK)</td>
<td>Raytheon</td>
<td>IBM</td>
</tr>
<tr>
<td>SWAF (Swedish Armed Forces)</td>
<td>Lockheed Martin</td>
<td>No Magic</td>
</tr>
<tr>
<td>DND (Canada)</td>
<td>General Dynamics</td>
<td>Sparx</td>
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<td></td>
<td>L3</td>
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<tr>
<td></td>
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<td>Mega</td>
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</table>
Why is UPDM so popular with practitioners of MBSE?

– No standardized frameworks for MBSE exist
– Integration with existing OMG standards, e.g. SysML, UML
– Tool vendors support: Implemented in most popular modeling tools:
  IBM Rhapsody, No Magic MagicDraw, PTC Integrity Modeler
– Defense and Industry driven

Common repository (Integrated Architecture Repository)

– Application of engineering analysis methods
  • Impact Analysis
  • Coverage Analysis
  • Trade-off Analysis
  • Behavioral execution
  • Requirements compliance analysis
  • Model-based testing
– Interoperability
Why a Unified Architecture Framework (UAF)?

• Proliferation of frameworks that UPDM was being asked to support

• Need to support industry and federal usage as well as military
  – Commercialization, whilst still supporting architect needs

• Ability to support other frameworks
  – By Extension
  – By Mapping
Why a Unified Architecture Framework Profile (UAFP)*?

• An MBSE approach to a layered “model of models” (MOM)

• IDEAS* based format for a Domain MetaModel (DMM) that allows implementation by non-SysML based tools
  – Same format as DoDAF, MODAF and NAF

• UAF enables the development of integrated model layers (e.g., outcomes model layer and a component layer)

*UAFP is the planned OMG update to the UPDM standard
UPDM version 3/UAFP

- UAF is the DMM Basis of the UAFP For all tool vendors
- UAFP is the SysML based profile

- Use of IDEAS brings a high degree of formality to the DMM
  - Most of it working from the same basis

IDEAS based

UML profile based

MODAF v1.2.004

MODEM

NAF v4.0

DoDAF 2.02 change 1

DNDAAF

Other influences...

DMM PROFILE
• UPDM RFP requirement: ”The UPDM V3.0 domain metamodel shall be derived from MODEM and DM2, both of which are based upon the International Defence Enterprise Architecture Specification Foundation [IDEAS].”

– Mandatory requirements (excerpt):
  – Provide Domain Metamodel derived from MODEM and DM2
  – An Architecture Framework Profile Using SysML
  – Supports BPMN 2.0
  – Use of SysML Requirements Elements and Diagrams
  – Use of SysML Parametrics Elements and Diagrams Mapped to Measurements
  – Traceability Matrix to Supported Frameworks

– Non mandatory features (excerpt):
  – UML Profile for NIEM
  – Information Exchange Packaging Policy Vocabulary (IEPPV)
  – Viewpoints in Support of SoS Life Cycle Processes and Analyses
  – Support for Additional Viewpoints beyond those defined in DoDAF, MODAF/ MODEM, NAF, and the Security Viewpoint from DNDAF
  – Human Systems Integration (HSI)
Grid Approach for NATO Architecture Framework (NAF 4)

Enterprise
- Capability Taxonomy (NCA-2, NCA-3, NCA-2, AV-2, SV-2)
- Enterprise Vision (NCO-1, SV-1)
- Capability Dependencies (NCO-4, SV-4)
- Standard Processes (NCO-6, SV-6)
- Effects

Service
- Service Taxonomy (NCA-3, NCA-1, AV-2, SV-1)
- Service Interfaces (NSOV-2, SV-2)
- Service Functions (NSOV-3, SV-3)
- Service States (NSOV-4, SV-4)
- Service Interactions (NSOV-4b, SV-4b)
- Service I/F Parameters (NSOV-4c, SV-4c)
- Service Policy (NSOV-4d, SV-4d)
- Service Delivery

Logical
- Node Types (NCA-2, AV-2)
- Logical Scenario (NCO-4, SV-4)
- Node Interactions (NCO-3, NCO-3, SV-3)
- Logical Activities (NCO-4b, SV-4b)
- Logical States (NCO-6, SV-6)
- Logical Sequence (NCO-6c, SV-6c)
- Logical Data Model (NCO-12a, SV-12a)
- Logical Constraints (NCO-12b, SV-12b)
- Lines of Development (NCA-4, AV-2)

Resources
- Resource Types (NCA-2, AV-2, NCA-3, AV-2, SK-8)
- Resource Structure (NCO-4, NCO-1, SV-1)
- Resource Connectivity (NCO-3, NCO-6, SK-2, SK-8)
- Resource Functions (NCO-4b, SV-4b)
- Resource States (NCO-12b, SV-12b)
- Resource Sequence (NCO-12b, SV-12b)
- Physical Data Model (NCO-12b, SV-12b)
- Resource Constraints (NCO-12b, SV-12b)
- Configuration Management (NCA-8, SK-8)

Deployed
- Master Data (NCA-2, AV-2)
- Deployed Resources (NCO-4, NCO-4, SV-4, SV-4)

Architecture
- Meta-Data Definitions (NCA-1, AV-1/2)
- Architecture Products
- Architecture Correspondence ISO42010
- Methodology Used (NCA-4, AV-3)
- Architecture Status (NCA-1, AV-1)
- Architecture Versions (NCA-1, AV-1)
- Architecture Meta-Data (NCA-1, AV-1)
- Standards (NCA-1, AV-1)
- Architecture Plan
Why the Grid?

- Very hard to manage the views with so many contributing frameworks
  - Leads to very complex mapping tables
  - Unwieldy descriptions
- Provides an abstraction layer so it is possible to map many other frameworks onto the DMM
  - HSI views and SoS Lifecycle views
- Commercializes the UAF while supporting architect needs
  - Still the same underlying architectural data structures and view constructs that support base frameworks
  - Same data model, different presentation layer
<table>
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<tr>
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<th>Connectivity</th>
<th>Processes</th>
<th>States</th>
<th>Interaction Scenarios</th>
<th>Information If</th>
<th>Parameters</th>
<th>Constraints</th>
<th>Roadmap</th>
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**Dictionary**: Dc Summary & Overview Sm-Ov

**Requirements Req**:
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<th>States St</th>
<th>Interaction Scenarios Is</th>
<th>Information If</th>
<th>Parameters Pm</th>
<th>Constraints Ct</th>
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<th>Traceability Tr</th>
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<td>PV-1</td>
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<td>Parametric Execution/Evaluation</td>
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</table>

Dictionary * Dc (AV-2)

Summary & Overview SmOv (AV-1, OV-1 graphic)

Requirements Rq
SoS Modeling Requirements

• An analysis of information needed to develop a useful SoS model using UAF showed that most SoS model elements are already covered by the UAF DMM.

• Some aspects of SoS management processes are out of scope of UAF modeling and need to be covered with other modeling tools and techniques:
  – SoS Program Management (tools such as MS Project)
  – SoS Cost analysis and budgeting (financial analysis tools)
  – SoS Risk analysis and mitigation plans (analysis tools)

• However, for all processes listed above, UAF defines elements, constraints or relationships that are needed to link UAF model elements as inputs to external tools:
  – The linking will be supported by tool vendors through an industry exchange standards such as OSLC.

• Following table provides a subset of identified model elements/concepts from the review (see paper) and their mapping to elements in UAF:
  – Full table to be published in UAF specification for OMG at Sept. 2015 technical meeting.
## UPDM coverage for SOS M&S

| Element                                                                 | Definition                                                                                                                                                                                                                                                                                                                                 | Mapping to UAF                                                                                                                                                                                                                     |
|-------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Asset/ Resource: System info (constituent system and service architecture models) | Resource/System — A functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements; that group of elements forming a unified whole. [24]                                                                                                                                                              | Resource: Abstract element placeholder to indicate that resources can be exchanged in Operational and Systems views.                                                                                                               |
| Capability Objectives (Vision, goal, objective)                        | The ability to perform a function, task, or action [25]                                                                                                                                                                                                                                                                                      | Enterprise Goal: A specific, required objective of the enterprise that the architecture represents.                                                                                                                               |
## UPDM coverage for SOS M&S

<table>
<thead>
<tr>
<th>Element</th>
<th>Definition</th>
<th>Mapping to UAF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONOPS</strong></td>
<td>Concept of operations — A verbal or graphic statement that clearly and concisely expresses what the joint force commander intends to accomplish and how it will be done using available resources. Also called CONOPS. [26]</td>
<td>CONOPS: A high level operational concept related to one or more missions. The Diagram describes a mission, class of mission, or scenario; and highlights the main operational elements and interesting or unique aspects of operations.</td>
</tr>
<tr>
<td><strong>Integrated Master Schedule (IMS)</strong></td>
<td>Set of SoS SE activities and milestones plus key single system activities and milestones that are driving SoS critical path. Focus is on key synchronization points among SoS constituents and pointers to development schedules of constituent systems for the current SoS increment. [21]</td>
<td>Project: A time-limited endeavor to create a specific set of products or services. UAF elements: Project and Project Milestone</td>
</tr>
<tr>
<td><strong>Technical Plan(s)</strong></td>
<td>Focus is on planning the implementation and test of changes to constituent systems to execute a SoS increment. [21]</td>
<td>A technical plan in UAF may be modeled as a specialization of SysML Test case, associated with a model layer (structure, behavior, and parametrics)</td>
</tr>
<tr>
<td>Outcomes: Desired Result</td>
<td>Definition</td>
<td>Mapping to UAF</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Effect — 1. The physical or behavioral state of a system that results from an action, a set of actions, or another effect. 2. The result, outcome, or consequence of an action. 3. A change to a condition, behavior, or degree of freedom. [24]</td>
<td>DesiredEffect: A desired state of a Resource.</td>
</tr>
</tbody>
</table>

| Performance Measures (metrics) Performance data | Measures of performance are defined in an enterprise’s Business Motivation Model as objectives. They may be based on risks and potential rewards identified in assessments. Key Performance Indicators (KPI) / Critical Success Factors (CSF) are not especially distinguished in the model; enterprises can make the distinction if they choose to. [22] | Measurement: MeasurableProperty: A property of something in the physical world, expressed in amounts of a unit of measure. The property may have a required value - either specified by the defaultValue |
# UPDM coverage for SOS M&S

<table>
<thead>
<tr>
<th>Element</th>
<th>Definition</th>
<th>Mapping to UAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td>A statement that identifies a system, product or process’ characteristic or constraint, which is unambiguous, clear, unique, consistent, stand-alone (not grouped), and verifiable, and is deemed necessary for stakeholder acceptability. [27]</td>
<td>SysML: A requirement specifies a capability or condition that must (or should) be satisfied. A requirement may specify a function that a system must perform or a performance condition that a system must satisfy. Requirements are used to establish a contract between the customer (or other stakeholder) and those responsible for designing and implementing the system.</td>
</tr>
<tr>
<td>Systems Information</td>
<td>Focus is on system-level information that affects SoS level capability objectives. Extends beyond technical issues to include operational, fiscal, organizational, and planning issues. [21]</td>
<td>Systems (solutions) model layer elements and relationships, fiscal info can be modeled as attributes (or measurement element) of model elements.</td>
</tr>
</tbody>
</table>
Example SoS: Marvelous Parcel Service (MPS)

- MPS CONOPS consists of Corporate Headquarters carrying out standard business functions, Regional Distribution Centers responsible for warehousing, fleet management, tracking and transfer, Delivery Vehicle Fleet composed of the vehicles that make deliveries for a particular distribution center, Storefronts and Drop Boxes, and Customers - business and residential.
Concept of Operations
• SoS model for MPS. It identifies system nodes (e.g., platforms, units, facilities, locations) and key interfaces, details about connections and data traffic. The major systems of Headquarters, Delivery Vehicles, Distribution Center, Operations and business and residential customers are shown. Implemented protocols and communications networks are identified.
Capabilities

NCV-4 [Capability] Parcel Services [NCV-4]

GV : Governance
SC : Secure Communications
PD : Parcel Delivery
PTrns : Parcel Transport
OC : Online Communications
OP : Online Payment
FM : Fleet Management
LG : Logistics
PP : Parcel Pickup
PTrk : Parcel Tracking
AM : Account Management
SEC : Security
OC : Online Communications
PP : Parcel Pickup
PTrn : Parcel Transport
LG : Logistics
FM : Fleet Management
OP : Online Payment
SC : Secure Communications
 GV : Governance

PTC
Integrated Development Schedule
Performance Measures

AV-3 [Architectural Description] Typical [AV-3]

- Measure Type: On Time Delivery
  - Measurement: Percent On Time: Percent

- Measure Type: Average Express Transit
  - Measurement: Time: s

- Measure Type: Package Delivery
  - Measurement: Delivery Receipt: s

NAV-3 [Architectural Description] Actual [NAV-3]

- Actual Property Set: Current Transit: Average Express Transit
  - Intention: Estimate
  - Time: s = 20:00

- Actual Property Set: Current OTD: On Time Delivery
  - Intention: Estimate
  - Percent On Time: Percent = 80%

- Actual Property Set: Required Transit: Average Express Transit
  - Intention: Estimate
  - Time: s = 18:00

- Actual Property Set: Required OTD: On Time Delivery
  - Intention: Percent On Time: Percent = 85%

- Actual Property Set: Required Delivery: Package Delivery
  - Intention: Estimate
  - Delivery Receipt: s = 30

[Architectural Description] Structure [NSV-7]

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<th>System Resource</th>
<th>Name</th>
<th>Intention</th>
<th>Property</th>
<th>Minimum Value</th>
<th>Actual Value</th>
<th>Maximum Value</th>
<th>Unit</th>
<th>Quantity Kind</th>
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<td>Intention</td>
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<td>Current Transit</td>
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<td>25.00</td>
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<td>Time</td>
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<tr>
<td>Required Transit</td>
<td>Estimate: Time</td>
<td>15.00</td>
<td>18.00</td>
<td>25.00</td>
<td>Second</td>
<td>Time</td>
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<tr>
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<td>5.00</td>
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<td>Second</td>
<td>Time</td>
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<td>0.30</td>
<td>20.00</td>
<td>20.00</td>
<td>Second</td>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat Screen Plasma Monitor</td>
<td>Required Update: Status Change Update</td>
<td>0.30</td>
<td>20.00</td>
<td>20.00</td>
<td>Second</td>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handheld</td>
<td>Current Update: Status Change Update</td>
<td>0.30</td>
<td>20.00</td>
<td>20.00</td>
<td>Second</td>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Required Update: Status Change Update</td>
<td>0.30</td>
<td>20.00</td>
<td>20.00</td>
<td>Second</td>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Web Presence</td>
<td>Current Update: Status Change Update</td>
<td>0.30</td>
<td>20.00</td>
<td>20.00</td>
<td>Second</td>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Required Update: Status Change Update</td>
<td>0.30</td>
<td>20.00</td>
<td>20.00</td>
<td>Second</td>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Access</td>
<td>Distribution Center</td>
<td></td>
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</tr>
</tbody>
</table>
Desired Outcome (System States and Metrics)

**NSV-10b [Resource] Parcel [NSV-10b]**

- **«ResourceAtomicState» Requesting Pickup**
  - do: Request Pickup
  - [Complete] /

- **«ResourceAtomicState» Delivering**
  - do: Provide Waybill and Parcel
  - do: Send Parcel Status
  - do: Send Vehicle Status
  - [Package Accepted] /

- **«ResourceAtomicState» In Transit to Delivery**
  - do: Drive to Destination
  - [Vehicle Loaded] /
  - Send Parcel Status

- **«ResourceAtomicState» At Distribution Center**
  - do: Unload Vehicle
  - do: Scan Waybill
  - do: Load Vehicle
d  - do: Calculate Route
  - do: Send Parcel Status

- **«ResourceAtomicState» Awaiting Pickup**
  - [Pickup Approved] /

- **«ResourceAtomicState» Processing Request**
  - do: Accept Waybill and Parcel
  - do: Accept Payment
  - do: Scan Waybill
  - do: Authorize Credit Account

- **«ResourceFinalState»**
  - [Payment Accepted] /
  - Send Parcel Status

- **Destination Reached**

---

**rationale**

This state assumes a local delivery. For air transport between distribution centers more detail would need to be added.
System Requirements (Showing Traceability)

**Requirement**
UNCLOS 1982

The United Nations Convention on the Law of the Sea (UNCLOS), Article 98:
Every State shall require the master of a ship flying its flag, in so far as he can do so without serious danger to the ship, the crew or the passengers to render assistance to any person found at sea in danger of being lost to proceed with all possible speed to the rescue of persons in distress, if informed of their need of assistance, in so far as such action may reasonably be expected of him after a collision, to render assistance to the other ship, its crew and its passengers and, where possible, to inform the other ship of the name of its own ship, its port of registry and the nearest port at which it will call.

**Requirement**
US NSP

The primary framework for the U.S. SAR system is provided in the NSP. This key document, which is produced by the National Search and Rescue Committee (NSARC) and signed by high-level officials within the Federal government, should be familiar to all SAR personnel, and is included as Appendix A to this Supplement. The NSP describes the U.S. SAR organization, key authorities and their responsibilities, and primary principles and policies upon which our SAR system is based. The NSP was developed taking into account the provisions of the IAMSAR Manual, Volume 1, Chapter 5 and its Appendix I.

**Capability**
Recovery

**Capability**
Assistance

**Requirement**
Render Assistance

The ship master shall render assistance to any person found at sea in danger of being lost.

**Requirement**
Proceed to Rescue

The ship master shall proceed with all possible speed to the rescue of persons in distress, if informed of their need of assistance, in so far as such action may reasonably be expected of him.

**Requirement**
Post Collision

The ship master shall render assistance to the other ship, its crew and its passengers and, where possible, to inform the other ship of the name of its own ship, its port of registry and the nearest port at which it will call.

**Standard Activity (Operational)**
Assist Victim

**Standard Activity (Operational)**
Find Victim

**Capability**
Search

**Standard Activity (Operational)**
Track Victim

**Capability**
Assistance

**Capability**
Inform

**Maritime Rescue Architecture v1**

[High Level Operational Concept] Maritime Rescue
Conclusions

- The UAF is a Model-Based Systems Engineering (MBSE) approach to a layered “model of models” (MOM)
- UAFP can be used with integrated SysML modeling and simulation tools to assemble complex SoS models
  - Provide built-in analysis techniques
- New technologies can and will be applied to extend the use of UAF architectures to enable
  - Architecture Federation
  - Tool Federation
  - Improved interoperability
- Improves the discovery and reuse of architectural artifacts
- Supports Systems of Systems
Questions and Answers

Thanks for your attention!

Speaker

Matthew Hause
PTC Engineering Fellow
mhause@ptc.com