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From UAF to SysML: Transitioning from System of Systems to Systems Architecture

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Speakers (1)

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- ▷PhD, MS, and BS in Software Systems Engineering
- ▷17 years in Software and Systems Engineering
- ▷UAF co-chairman in OMG, member of INCOSE and NATO ACaT
- ▷Originator of the MagicGrid Framework
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- ▷Lives in Kaunas, Lithuania

Speakers (2)

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- ▷Mater’s degree in Information Systems Engineering
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- ▷>16 years in Software and Systems Engineering
- ▷Member of INCOSE
- ▷Member of MagicGrid development team
- ▷Co-author of MagicGrid BoK
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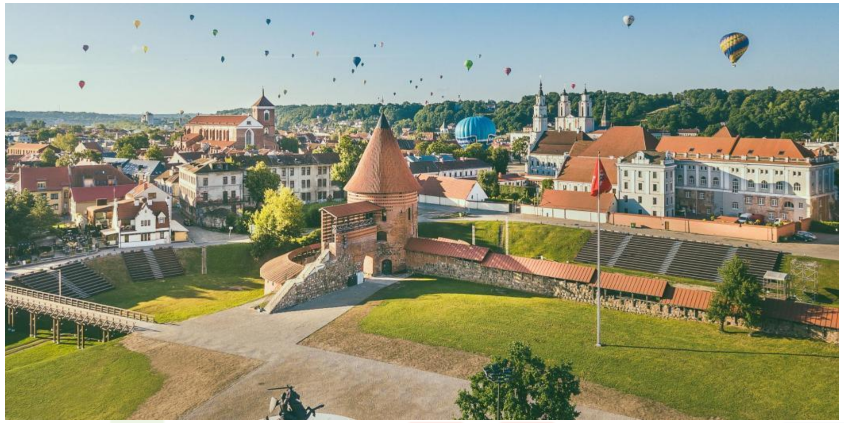


Outline

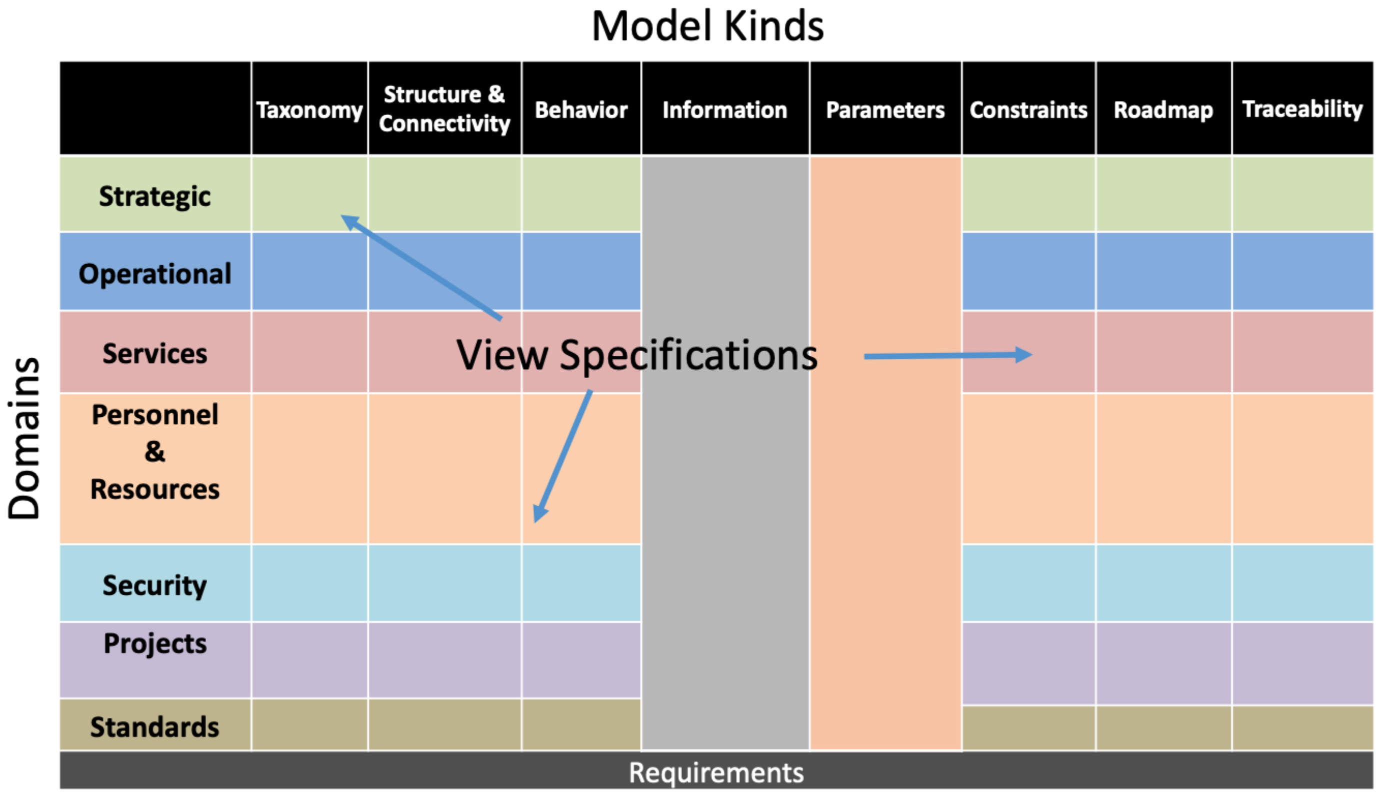
1. Motivation
2. Suggested approach
3. Case Study
4. Conclusions

Motivation – Purpose

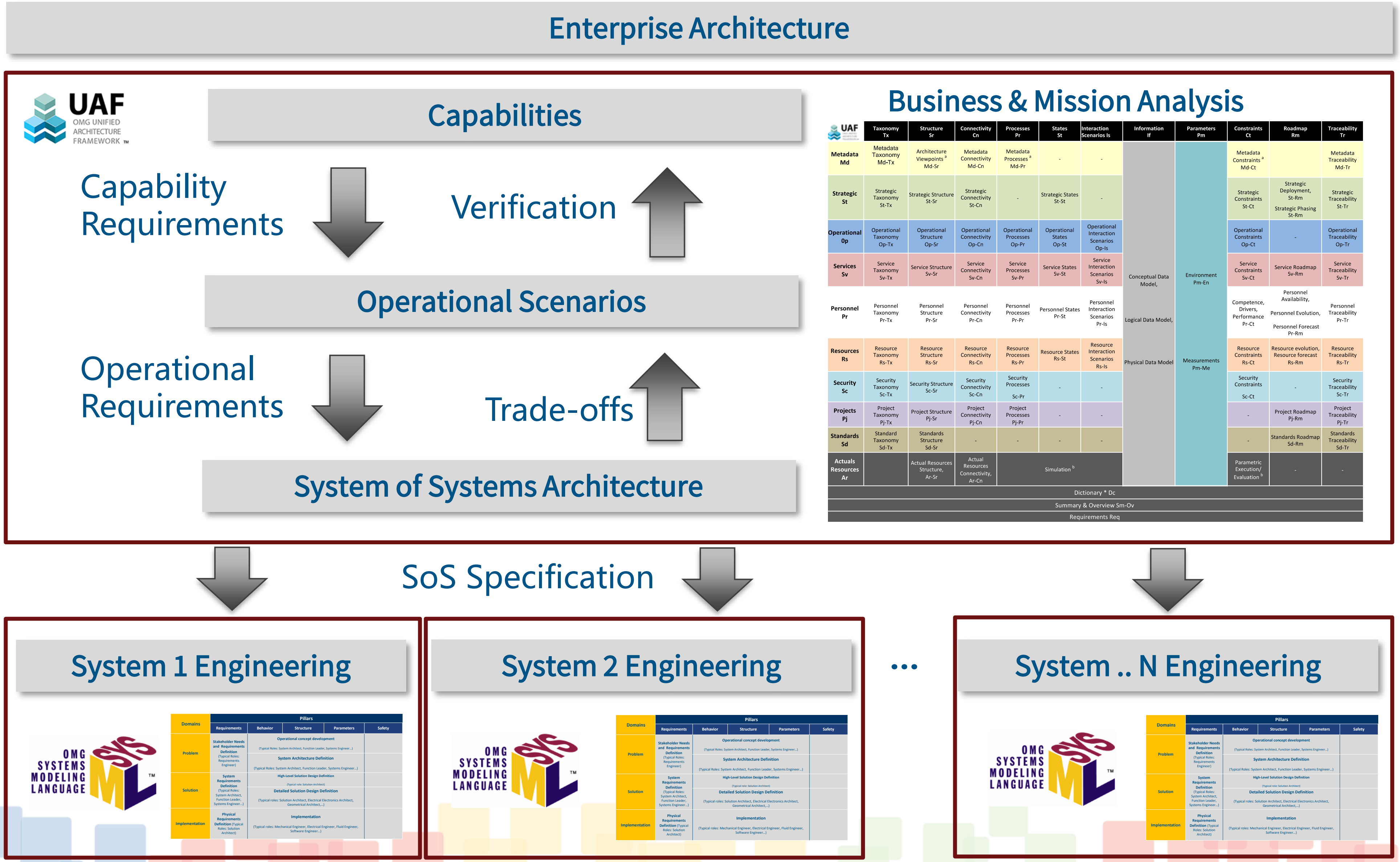
- In the scope of SoS, it is important to establish a digital environment for multiple organizations to interact, especially when transitioning from system of systems (SoS) architecture to architectures of different SOIs
- There are different Standards and Techniques for both and connection between the two is currently the Gap that is not well defined.
- The purpose of this presentation is to introduce a detailed approach for ensuring this digital continuity in the model-based environment utilizing standard-based modeling frameworks and languages.

UAF for System of Systems Engineering

- Knowledge of an SoS can be captured using the Unified Architecture Framework (UAF)
- UAF layout (also known as a UAF Grid) is organized into rows and columns, where:
  - Rows are **domains**
  - Columns are **model kinds**
  - Intersection of a row and column is called a **view specification**



SoSE Meets SE



System of Systems Architecture

UAF OMG Unified Architecture Framework	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Interaction Scenarios Is	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability Tr
Metadata Md	Metadata Taxonomy Md-Tx	Architecture Viewpoints [a] Md-Sr	Metadata Connectivity Md-Cn	Metadata Processes [a] Md-Pr	-	-			Metadata Constraints [a] Md-Ct		Metadata Traceability Md-Tr
Strategic St	Strategic Taxonomy St-Tx	Strategic Structure St-Sr	Strategic Connectivity St-Cn	-	Strategic States St-St	-			Strategic Constraints St-Ct	Strategic Deployment, St-Rm Strategic Phasing St-Rm	Strategic Traceability St-Tr
Operational Op	Operational Taxonomy Op-Tx	Operational Structure Op-Sr	Operational Connectivity Op-Cn	Operational Processes Op-Pr	Operational States Op-St	Operational Interaction Scenarios Op-Is			Operational Constraints Op-Ct	-	Operational Traceability Op-Tr
Services Sv	Service Taxonomy Sv-Tx	Service Structure Sv-Sr	Service Connectivity Sv-Cn	Service Processes Sv-Pr	Service States Sv-St	Service Interaction Scenarios Sv-Is	Conceptual Data Model,	Environment Pm-En	Service Constraints Sv-Ct	Service Roadmap Sv-Rm	Service Traceability Sv-Tr
Personnel Pr	Personnel Taxonomy Pr-Tx	Personnel Structure Pr-Sr	Personnel Connectivity Pr-Cn	Personnel Processes Pr-Pr	Personnel States Pr-St	Personnel Interaction Scenarios Pr-Is	Logical Data Model,		Competence, Drivers, Performance Pr-Ct	Personnel Availability, Personnel Evolution, Personnel Forecast Pr-Rm	Personnel Traceability Pr-Tr
Resources Rs	Resource Taxonomy Rs-Tx	Resource Structure Rs-Sr	Resource Connectivity Rs-Cn	Resource Processes Rs-Pr	Resource States Rs-St	Resource Interaction Scenarios Rs-Is	Physical Data Model	Measurements Pm-Me	Resource Constraints Rs-Ct	Resource evolution, Resource forecast Rs-Rm	Resource Traceability Rs-Tr
Security Sc	Security Taxonomy Sc-Tx	Security Structure Sc-Sr	Security Connectivity Sc-Cn	Security Processes Sc-Pr	-	-			Security Constraints Sc-Ct	-	Security Traceability Sc-Tr
Projects Pj	Project Taxonomy Pj-Tx	Project Structure Pj-Sr	Project Connectivity Pj-Cn	Project Processes Pj-Pr	-	-			-	Project Roadmap Pj-Rm	Project Traceability Pj-Tr
Standards Sd	Standard Taxonomy Sd-Tx	Standards Structure Sd-Sr	-	-	-	-			-	Standards Roadmap Sd-Rm	Standards Traceability Sd-Tr
Actuals Resources Ar		Actual Resources Structure, Ar-Sr	Actual Resources Connectivity, Ar-Cn	Simulation [b]					Parametric Execution/ Evaluation [b]	-	-

Dictionary * Dc

Summary & Overview Sm-Ov

Requirements Req

SysML/MagicGrid for Systems Engineering

- Architecture of a single SOI can be captured using Systems Modeling Language (SysML) and MBSE Grid (MagicGrid) Framework
- MagicGrid defines the modeling workflow that aligns with technical processes determined by ISO/IEC/IEEE 15288:2015
- MagicGrid layout is organized into rows and columns, where:
  - Rows represent the **domains**
  - Columns represent the **four pillars of SysML**
  - Intersection of a row and a column represents a view specification, which can be visualized in the form of a relevant SysML diagram

		PILLAR			
DOMAIN		REQUIREMENTS	STRUCTURE	BEHAVIOR	PARAMETERS
	PROBLEM (BLACK BOX)	Stakeholder Needs	System Context	Use Cases	Measures of Effectiveness
	PROBLEM (WHITE BOX)		Conceptual Subsystems	Functional Analysis	MoEs for Subsystems
	SOLUTION	System Requirements	System Structure	System Behavior	System Parameters
		Subsystem Requirements	Subsystem Structure	Subsystem Behavior	Subsystem Parameters
		Component Requirements	Component Structure	Component Behavior	Component Parameters
	IMPLEMENTATION	Implementation Requirements			

Systems Engineering Processes

UAF OMG UNIFIED ARCHITECTURE FRAMEWORK

Business or Mission Analysis

Systems Engineering

Domains	Pillars			
	Requirements	Behavior	Structure	Parameters
Problem	Stakeholder Needs Definition	Operational concept development		
		Transform of stakeholder needs into stakeholder requirements		
Solution	System Requirements Definition	Architecture Definition		
		High-Level Design Definition		
		Detailed Design Definition		
Implementation	Physical Requirements Definition	Implementation		

Specialty Engineering
(e.g. Safety, Security, Human Factors)

ISO15288

OMG SYSTEMS MODELING LANGUAGE SysML™

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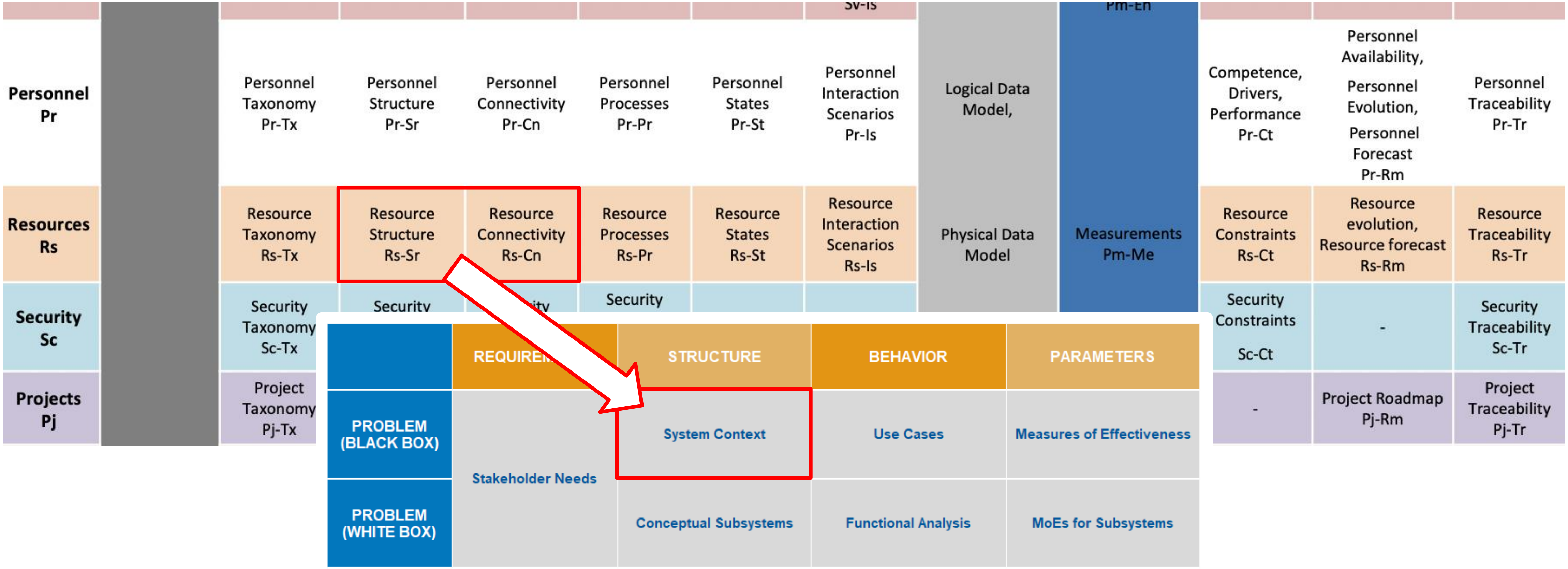
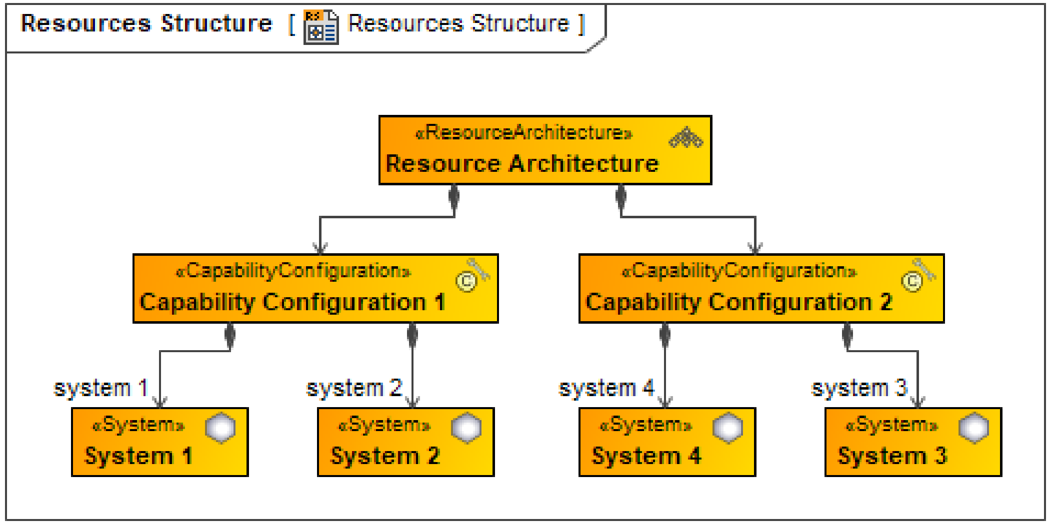
From Resource Structure & Connectivity Views (UAF) to System Context (SysML/MagicGrid)



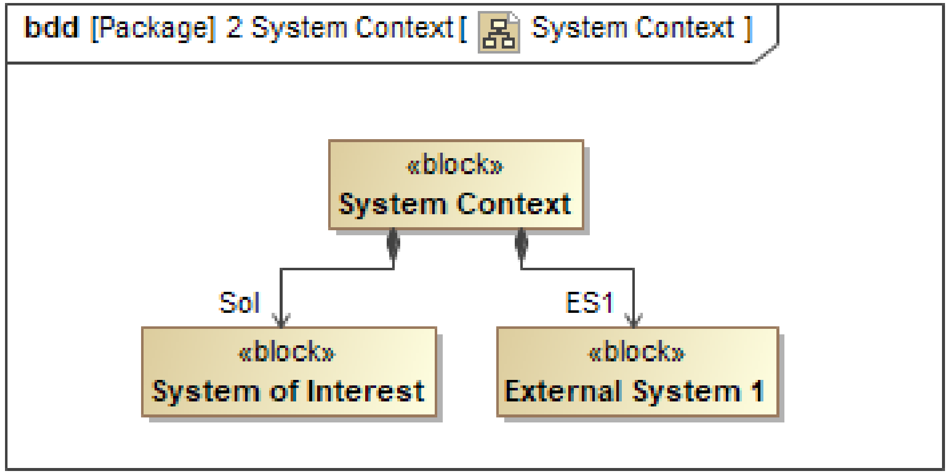
Capability Configuration (UAF)

- The UAF **Resources domain** captures how **different resources** (including humans and systems) interact to implement operational needs and **achieve capabilities** of the SoS
- In the Resource Structure view, resources are grouped into logical containers – **capability configurations**. Each capability configuration relates to (exhibits) the capability it has to achieve
- **Multiple** capability configurations can be specified to achieve the **same** capability at the same or different periods of time



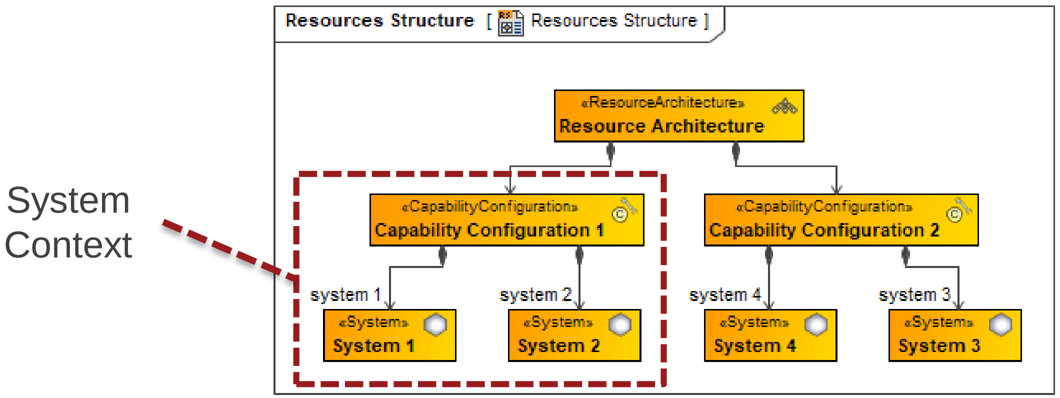
System Context (SysML/MagicGrid)

- **System context** determines the **external view** of the SOI
- It **includes SOI** itself as well as **external systems** and **users** that interact with the SOI to exchange data, matter, and energy
- They are all captured in the SysML model as blocks

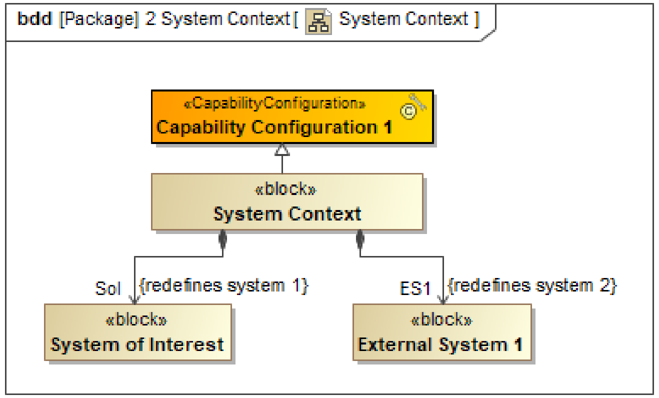


Specifying System Context

- The **System Context** view in the SysML model can be considered a **subset of the Resources Structure** view of the UAF model
- It is important to identify which **capability configuration** to choose as **an input to analyze the system context of the particular SOI**, by applying MagicGrid



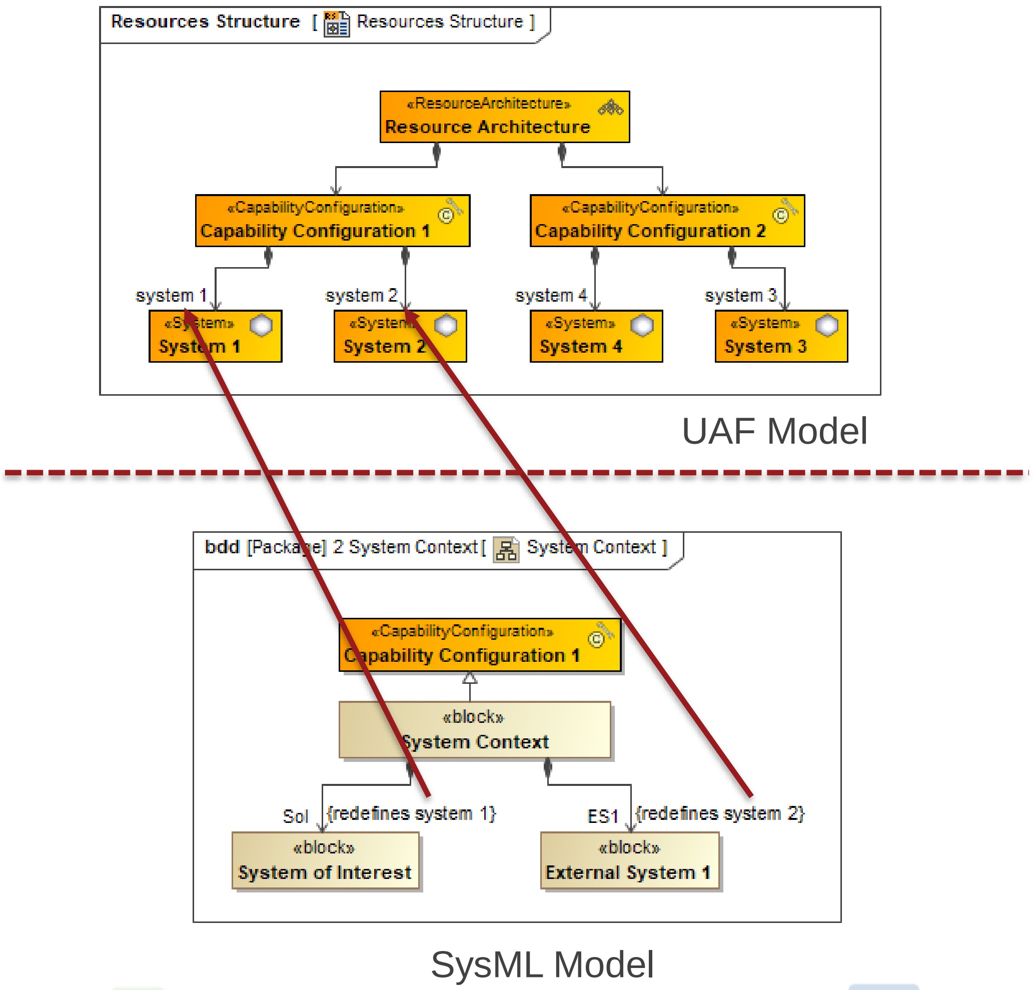
UAF Model



SysML Model

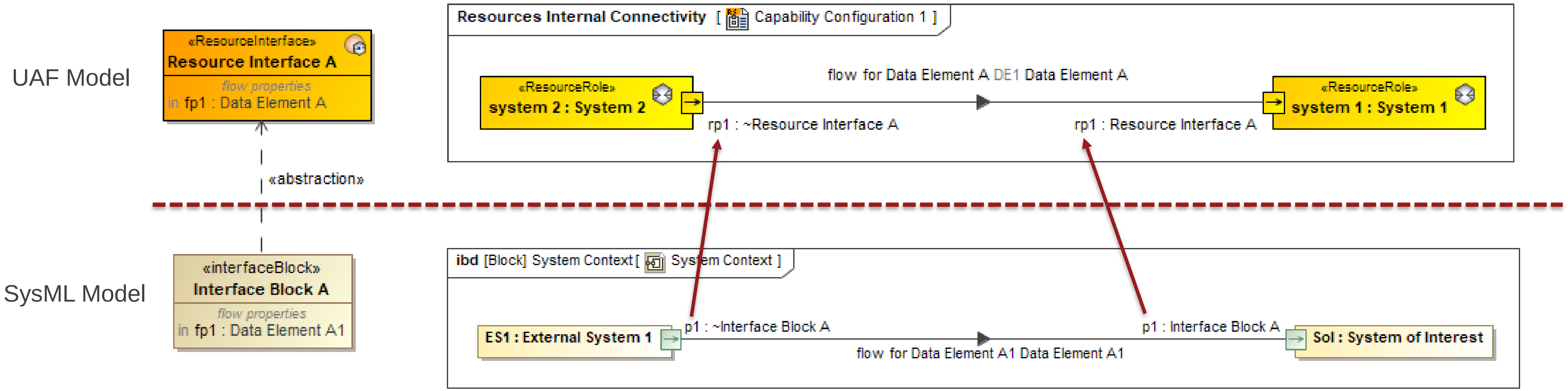
Specifying Participants of System Context

- Block that captures the **system context** becomes a **subtype of the capability configuration** and inherits all its parts
- These **parts are redefined to type them with blocks that capture copies** of the SOI, users, or external systems **in the SysML model**
- This enables to elaborate the system context information in the SysML model (without modifying the UAF model)



Specifying Interactions of System Context (1)

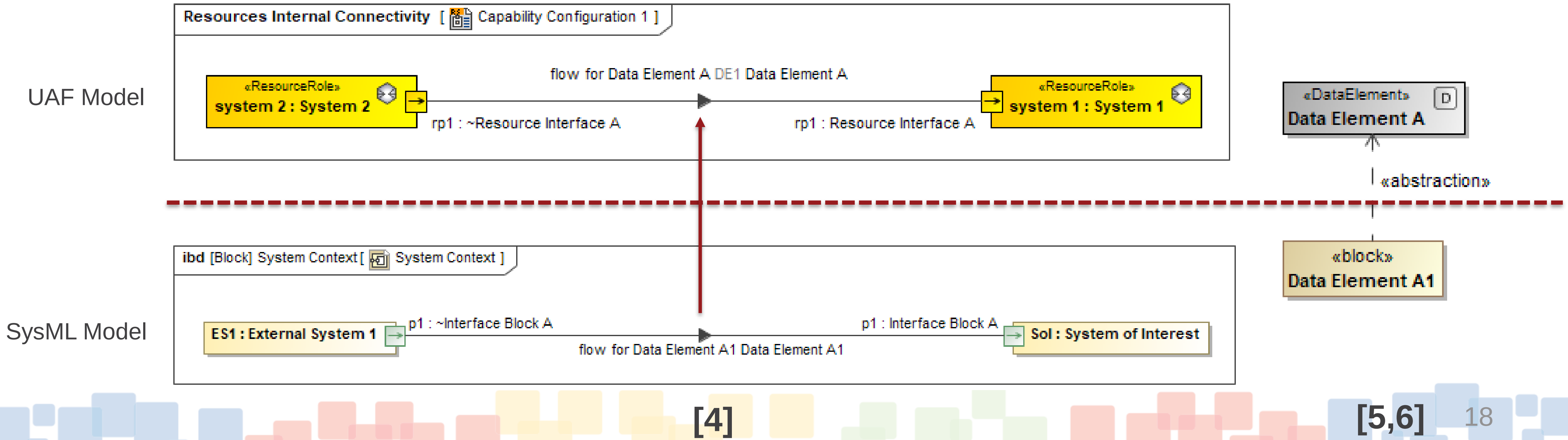
1. Create relevant SysML interface blocks
2. Create abstractions from the SysML interface blocks to UAF resource interfaces
3. Create proxy ports in SysML model and redefine UAF resource ports with them



[1,2] [3]

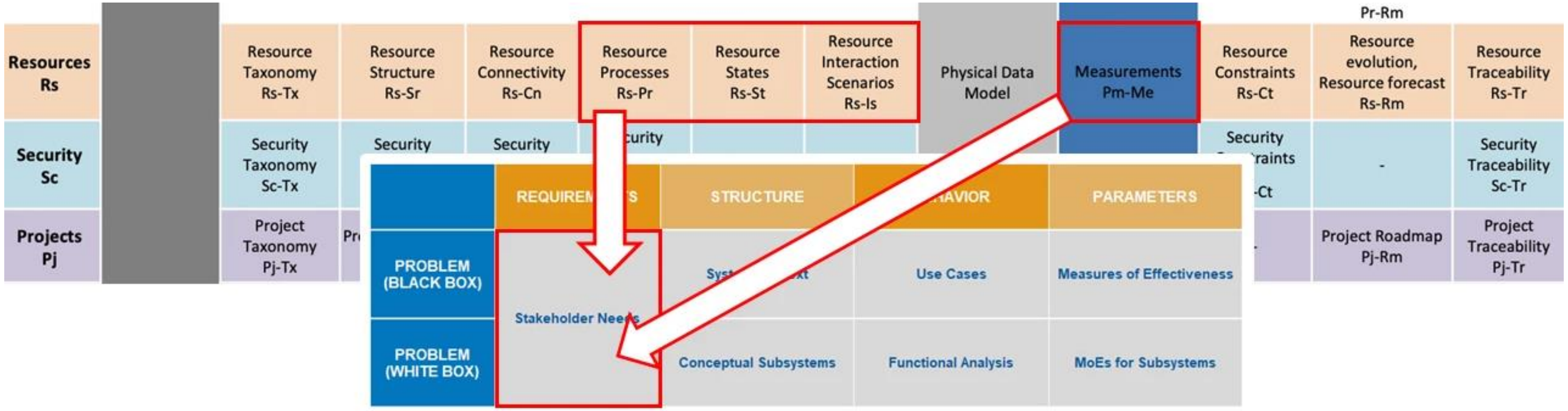
Specifying Interactions of System Context (2)

4. Create connectors in SysML and redefine UAF resource connectors with them
5. [optional] Create SysML element to capture the item that flows
6. [optional] Create abstraction from that SysML element to the relevant UAF element



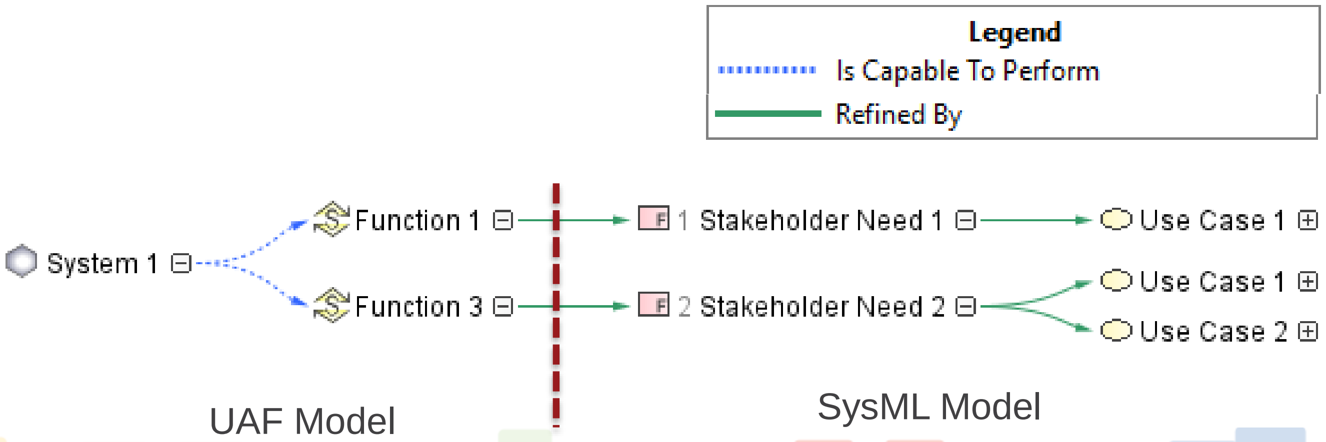
From Resources Domain Views (UAF) to Stakeholder Needs (SysML/MagicGrid)

- According to MagicGrid, stakeholder needs for the single SOI can be captured by interviewing stakeholders, giving them questionnaires, discussing needs in focus groups, or studying documents written in diverse formats.
- In addition to these information sources, the **UAF model of the SoS can serve as input to the stakeholder needs as well**:
  - The **Resource Processes**, **Resource States**, and **Resource Interaction Scenarios** Viewpoints can be used for identifying functional stakeholder needs
  - The **Resources Measurements** Viewpoint can be used for non-functional SNs



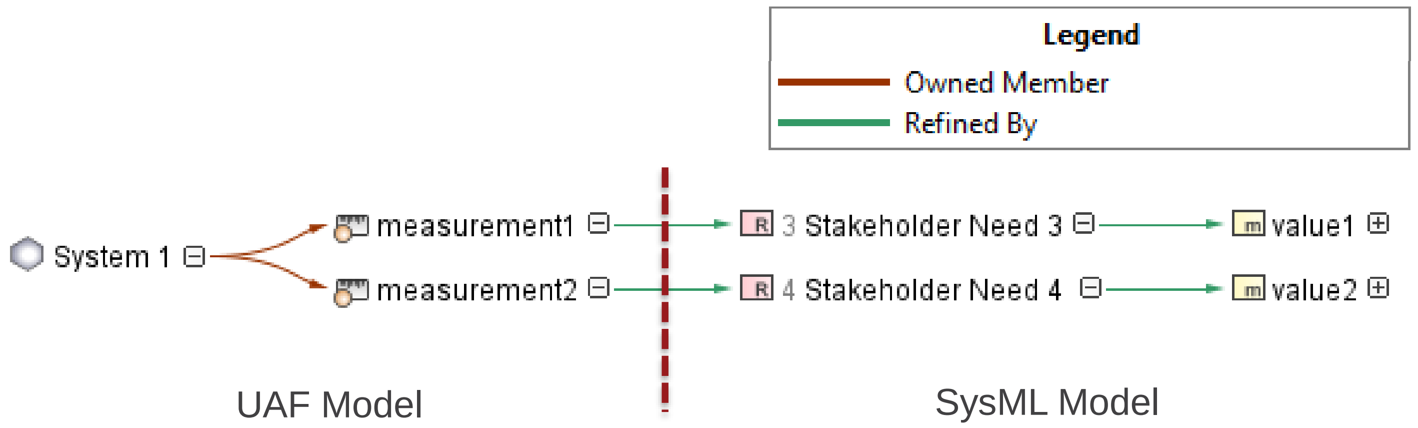
Functional Stakeholder Needs

- The subset of functions defined in the **Resource Processes View**, that are allocated (using the Is Capable To Perform relationship) to the system which becomes the SOI in the SysML model, motivate the creation of one or more **functional stakeholder needs** for that SOI
- This also applies to the case of states and interactions allocated to the relevant system in the UAF model
- When stakeholder needs are captured, SysML refine relationships can be established from them to the relevant functions, states, or interactions in the UAF model
- When use cases of the SOI are captured in the SysML model, SysML refine relationships can help to convey which stakeholder needs these use cases refine

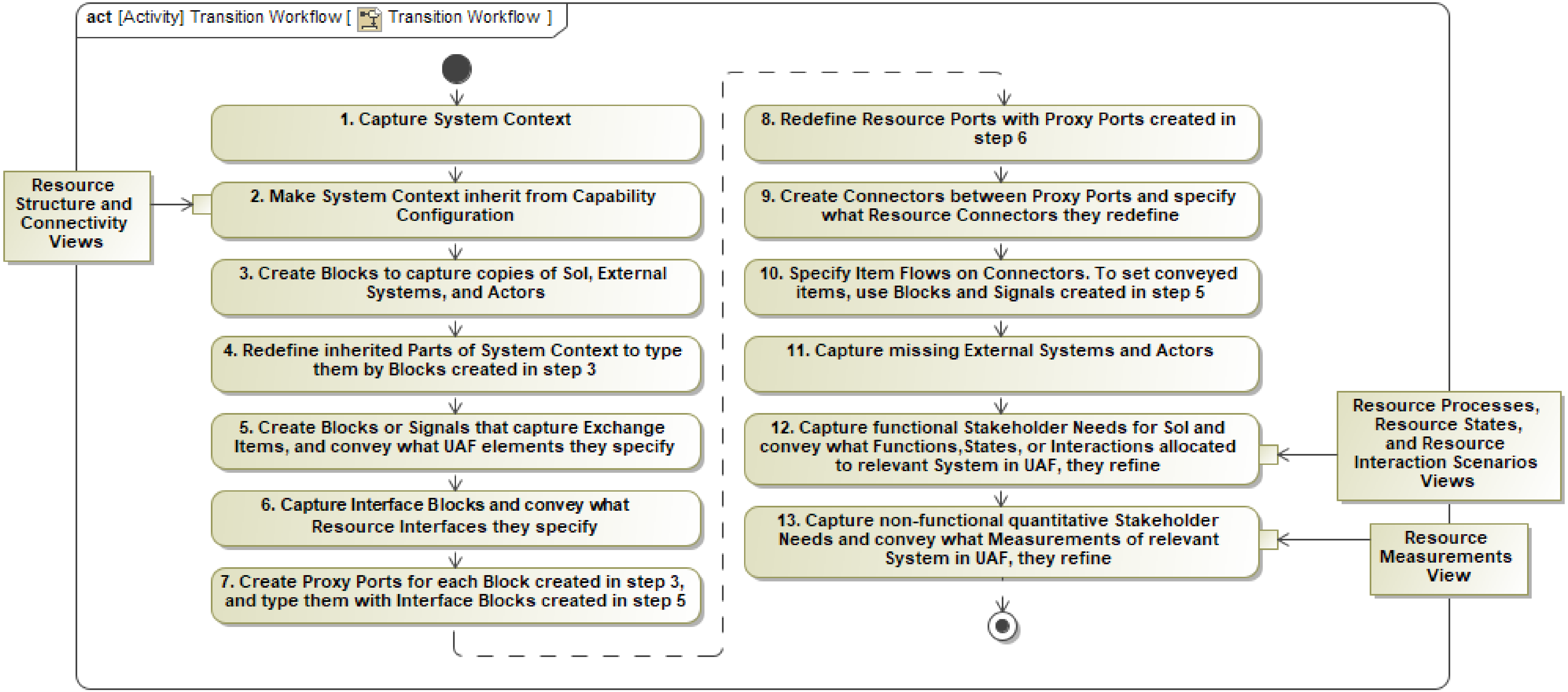


Non-Functional Stakeholder Needs

- **Measures** that are owned by the system which becomes the SOI in the SysML model motivate the creation of one or more **non-functional quantifiable stakeholder needs** for that SOI
- When stakeholder needs are captured, SysML refine relationships can be established from them to the relevant measures in the UAF model
- When MoEs of the SOI are captured in the SysML model, SysML refine relationships can help to convey which stakeholder needs these MoEs refine



Transition Workflow



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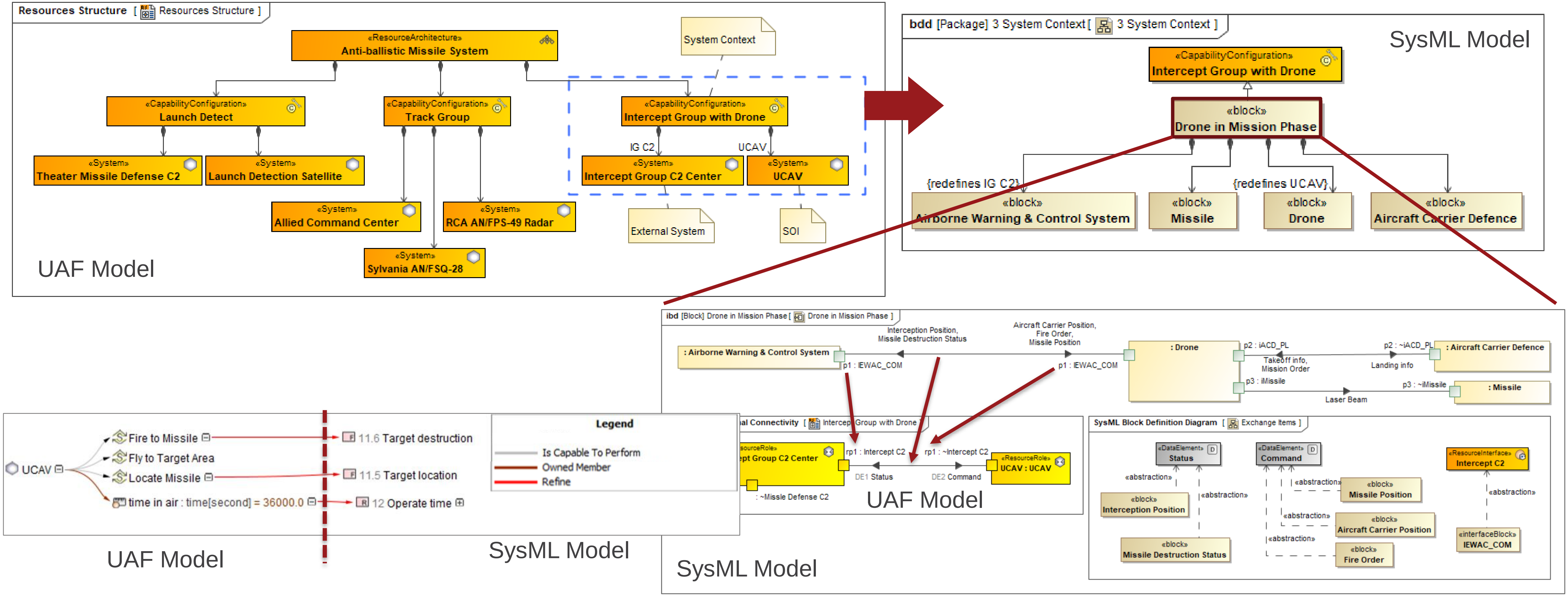
Case Study



Resources Structure [Resources Structure]
«ResourceArchitecture» Anti-ballistic Missile System
System Context
«CapabilityConfiguration» Launch Detect
«CapabilityConfiguration» Track Group
«CapabilityConfiguration» Intercept Group with Drone
IG C2
UCAV
«System» Theater Missile Defense C2
«System» Launch Detection Satellite
«System» Intercept Group C2 Center
«System» UCAV
«System» Allied Command Center
«System» RCA AN/FPS-49 Radar
External System
SOI
«System» Sylvania AN/FSQ-28
UAF Model
bdd [Package] 3 System Context [3 System Context]
SysML Model
«CapabilityConfiguration» Intercept Group with Drone
«block» Drone in Mission Phase
{redefines IG C2}
{redefines UCAV}
«block» Airborne Warning & Control System
«block» Missile
«block» Drone
«block» Aircraft Carrier Defence
ibd [Block] Drone in Mission Phase [Drone in Mission Phase]
Interception Position, Missile Destruction Status
Aircraft Carrier Position, Fire Order, Missile Position
: Airborne Warning & Control System
p1 : IEWAC_COM
: Drone
p2 : iACD_PL
p2 : ~iACD_PL
: Aircraft Carrier Defence
Takeoff info, Mission Order
Landing info
p3 : iMissile
p3 : ~iMissile
: Missile
Laser Beam
UCAV
Fire to Missile
Fly to Target Area
Locate Missile
time in air : time[second] = 36000.0
11.6 Target destruction
11.5 Target location
12 Operate time
Legend
Is Capable To Perform
Owned Member
Refine
UAF Model
SysML Model
al Connectivity [Intercept Group with Drone]
rp1 : Intercept C2
rp1 : ~Intercept C2
«ResourceRole» UCAV : UCAV
DE1 Status
DE2 Command
: ~Missle Defense C2
UAF Model
SysML Block Definition Diagram [Exchange Items]
«DataElement» Status
«DataElement» Command
«ResourceInterface» Intercept C2
«abstraction»
«block» Missile Position
«block» Interception Position
«block» Aircraft Carrier Position
«interfaceBlock» IEWAC_COM
«block» Missile Destruction Status
«block» Fire Order
SysML Model

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Conclutions

- There is a growing demand in industry to digitally connect SoS engineering with systems engineering disciplines.
- At the moment there are no existing techniques clearly defining this transition.
- It is clear that to maintain digital continuity between the two, the MBSE approach is a necessity.
- We have chosen UAF as the tool to capture knowledge on SoS and MagicGrid with SysML to capture knowledge on Systems.
- We described a smooth standards-based approach of transitioning from SoS to SysML and proved it by applying it to a real-world example model.
- The work done is communicated to the OMG UAF working group and MagicGrid community with the goal of including the proposed methodology in the guidance documents for both frameworks.
- Automated support from the tool vendors could speed up the transition dramatically. We were working closely with one of the tool vendors, Dassault Systemes, to provide such functionality in their model-based engineering suite.

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