

Design Ontology Supporting Model-based Systems Engineering Formalisms

Jinzhi Lu
ICT for Sustainable Manufacturing

jinzhi.lu@epfl.ch

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Jinzhi Lu and Dimitris Kiritsis

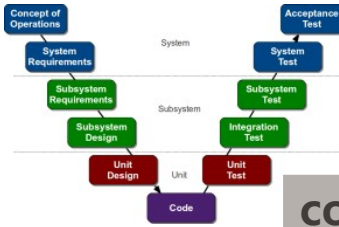
EPFL, École Polytechnique Fédérale de Lausanne

Chair of IOF Systems Engineering WG

EPFL Background



Standards



Process



Business model

control



Electronics engineers



Software



Project managers



Mechanical Engineers



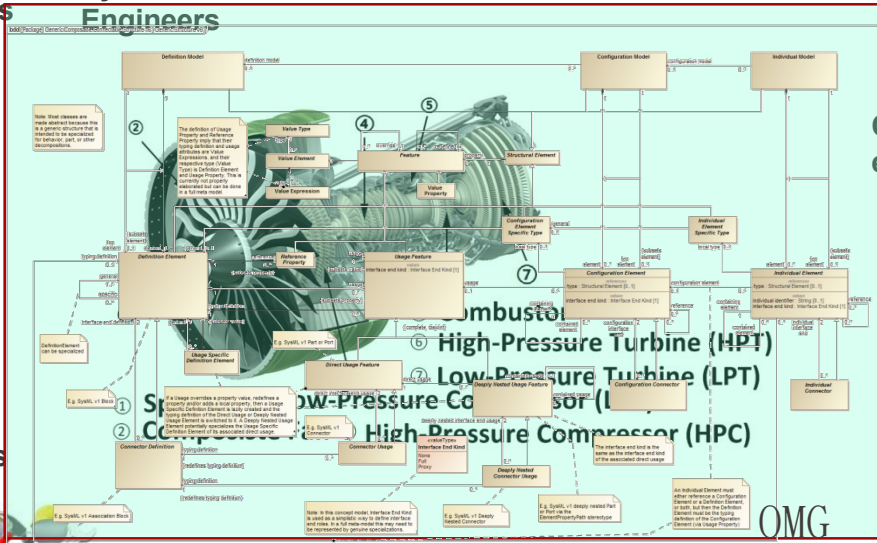
System Engineers



Testers



Training managers



Domain engineers...



IT managers



Information



Quality engineers

enable



Safety engineers



Stakeholders



Tools



Data...



Knowledge

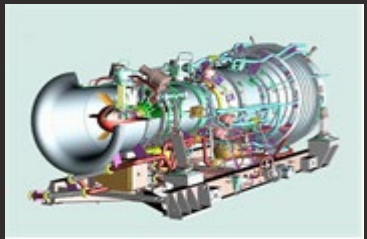


Model...


Efficiency




EPFL Model integration



CAD



FEM models



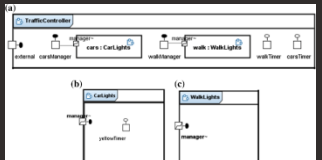
Model checking models
Testing models



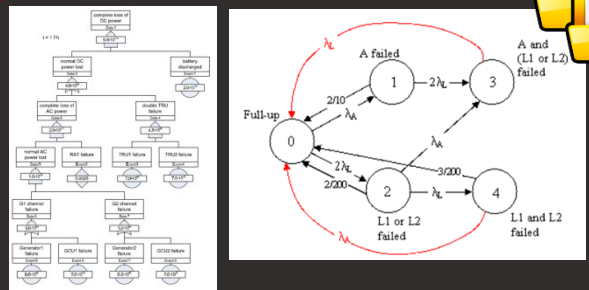
interface



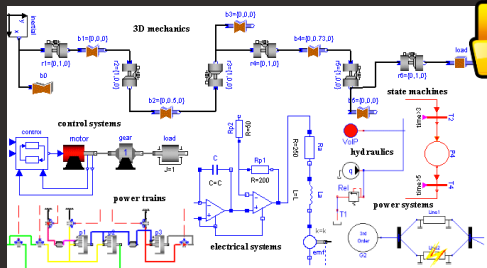
CFD models

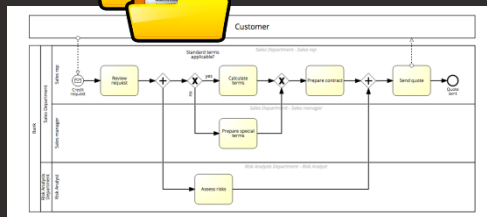
Property models



Analysis Models



Performance models

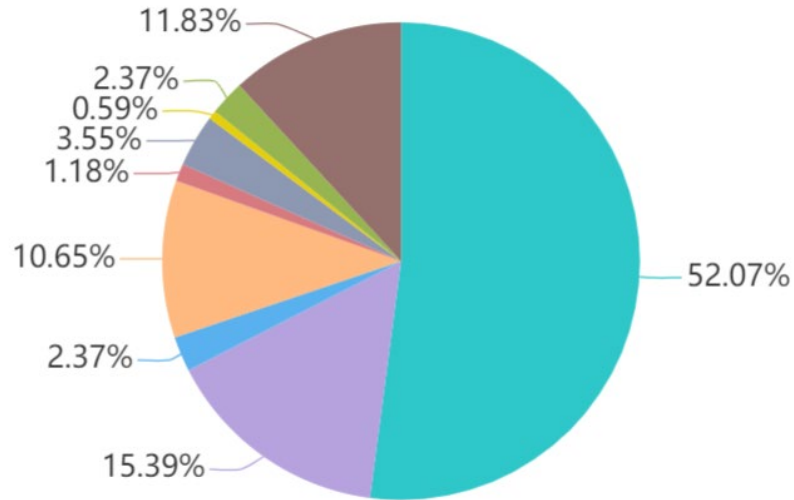


Process models...

EPFL Model-based Systems Engineering review

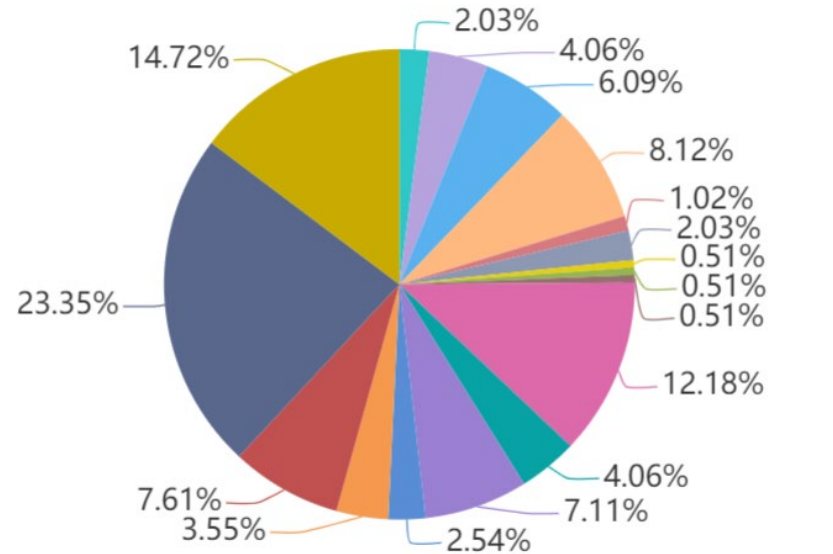
Our Journal article: **A Systematic Literature Review of MBSE Tool-chains** (IEEE SJ under review)

Modeling language



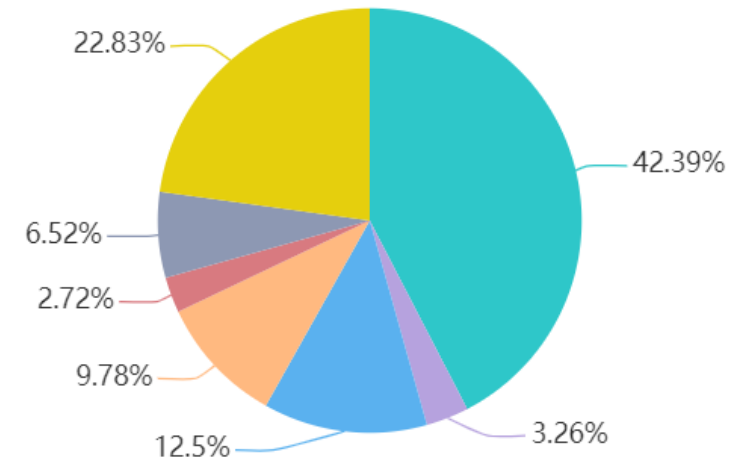
- SysML
- UML
- AADL
- DSML
- BPMN
- Modelica
- Python
- C
- Others

Modeling tool



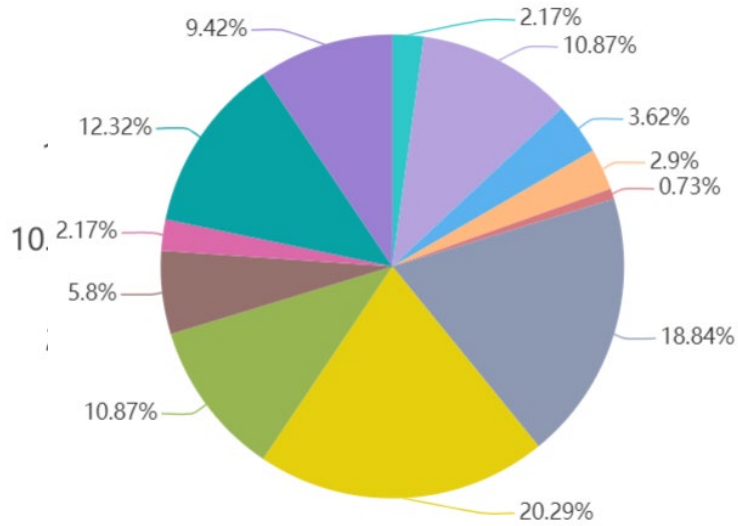
- Rational Requisite Pro
- IBM Rational DOORS
- IBM Rhapsody
- Magic Draw
- Visual Paradigm
- Enterprise Architect
- MWorks
- SimulationX
- MetaEdit+
- Matlab&Simulink
- Visio
- Eclipse
- Scade
- Home model tools
- OpenModelica
- None
- others

Tool-integration



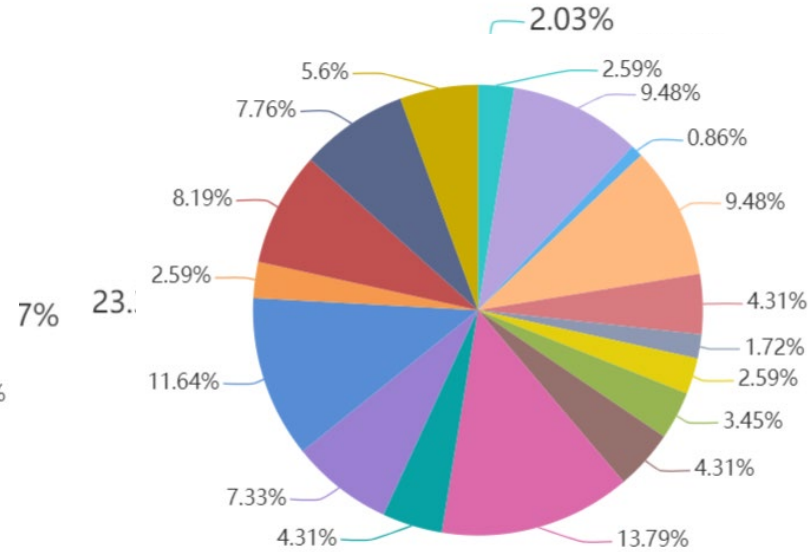
- Data integration
- Control integration
- Platform integration
- Process integration
- Presentation integration
- others
- none

Modeling language



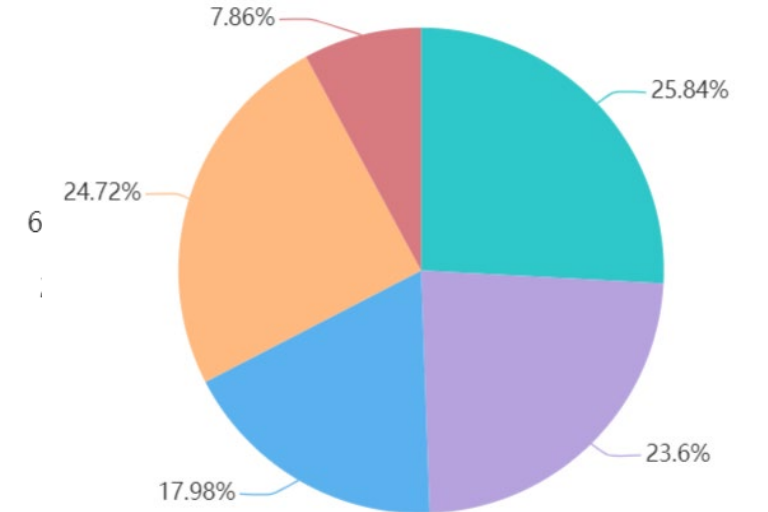
- AADL
- UML
- BPMN
- DSL proposed by tools
- self-dedigned DSL
- SysML
- Matlab Language
- Modelica
- Python
- Fortran
- C
- C++

Modeling tool



- Eclipse
- Home made tools
- others
- Dymola
- Matlab&Simulink
- Saber
- AMESim
- Visio
- Flowmaster
- Rational Requisite Pro
- IBM Rational DOORS
- Visual Paradigm
- MWorks
- SimulationX
- Borland CaliberRM
- IBM Rhapsody
- Magic Draw

Tool-integration



- Data integration
- Control integration
- Platform integration
- Process integration
- Presentation integration



Different modeling languages

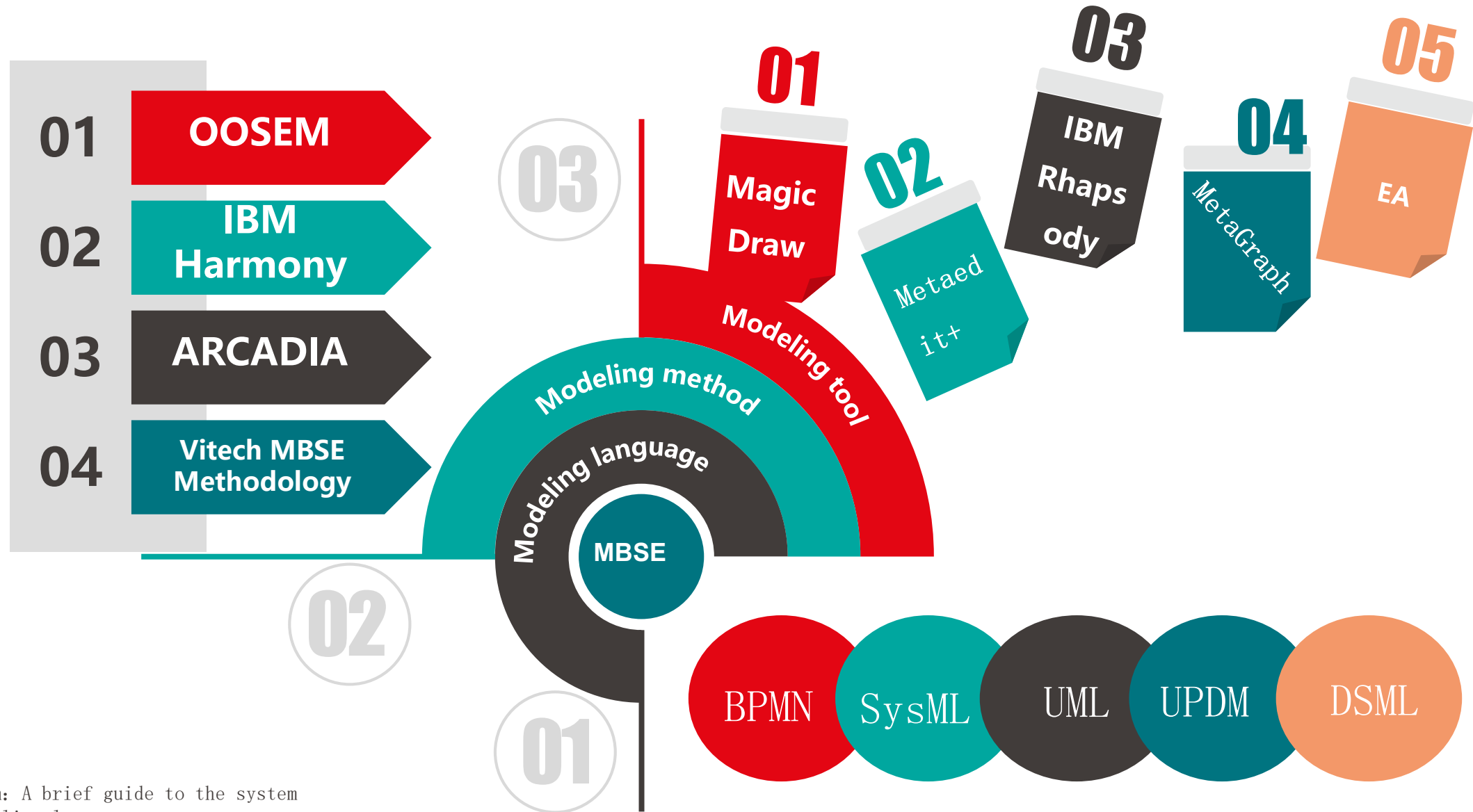


Different modeling tools



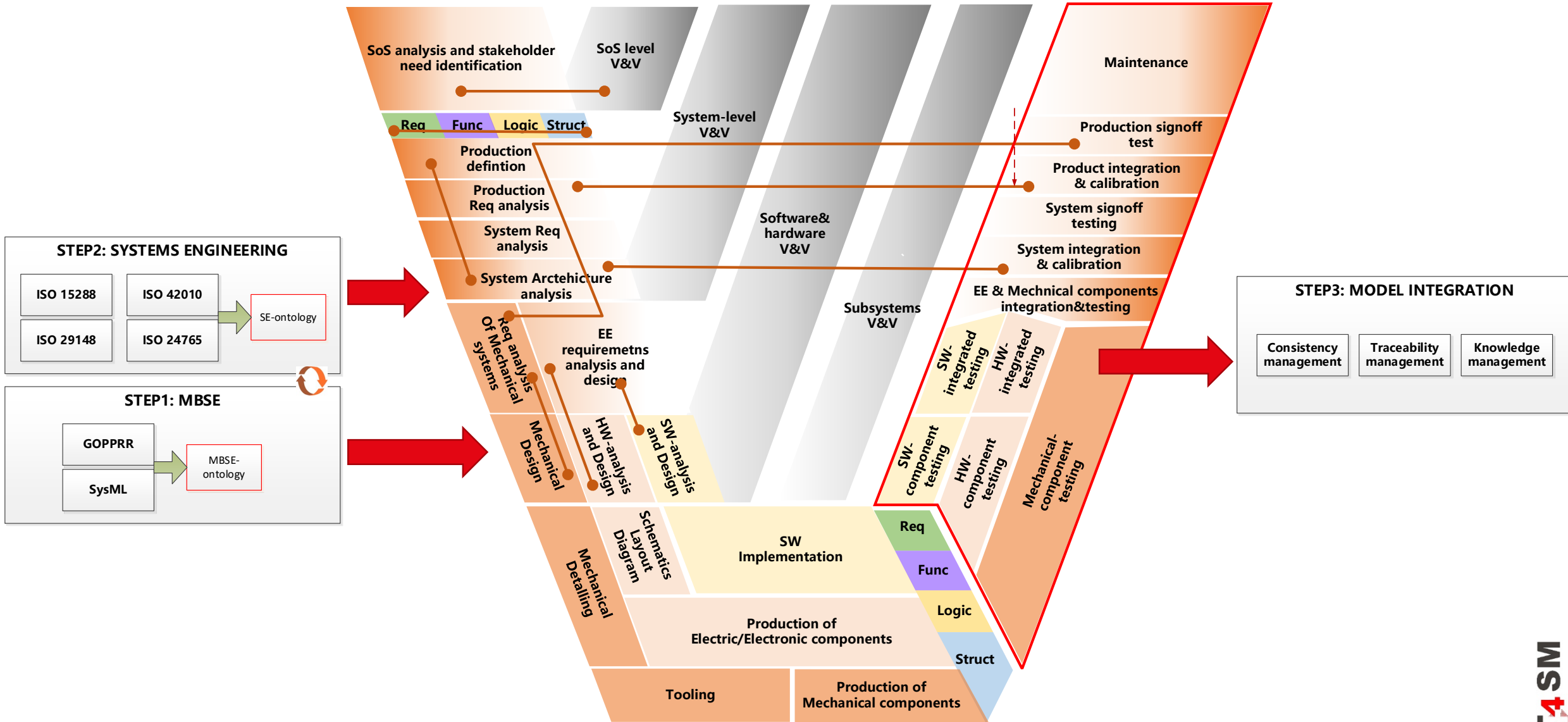
Integration is the future

EPFL Model-based Systems Engineering review



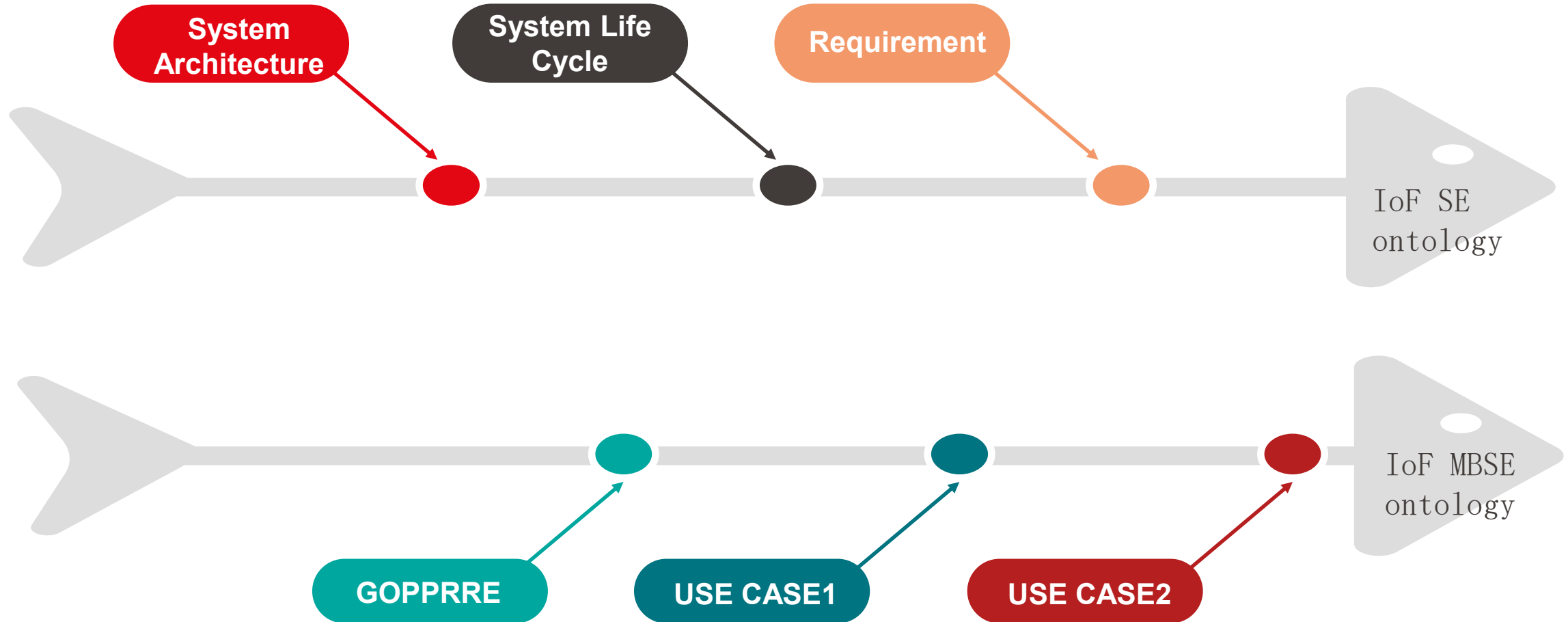
From: A brief guide to the system modeling language

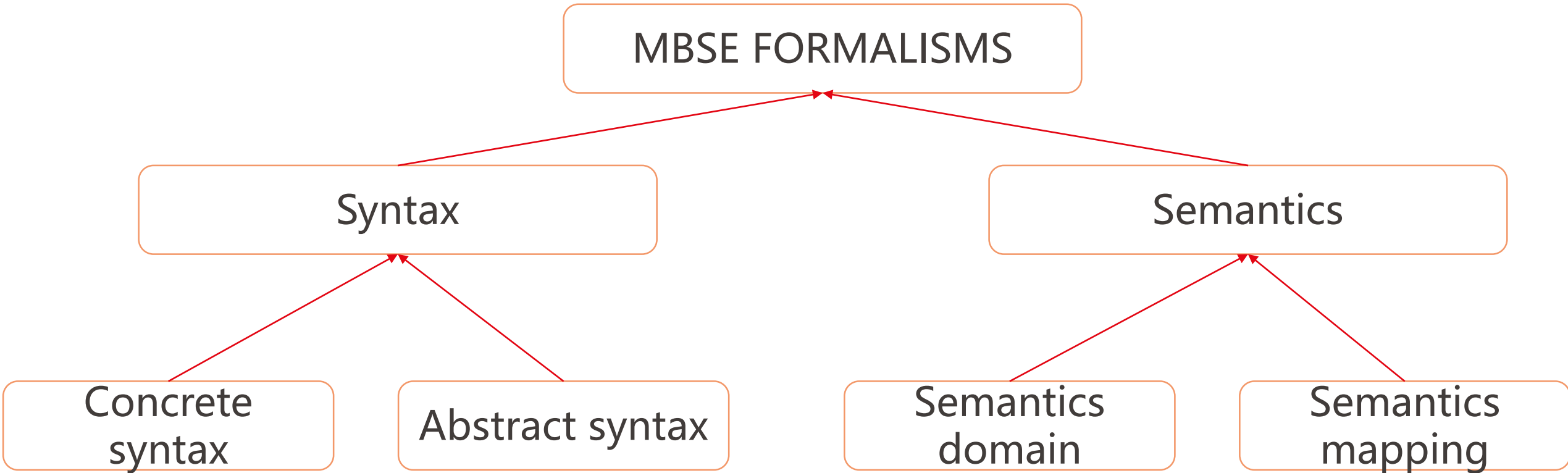
EPFL Model integration

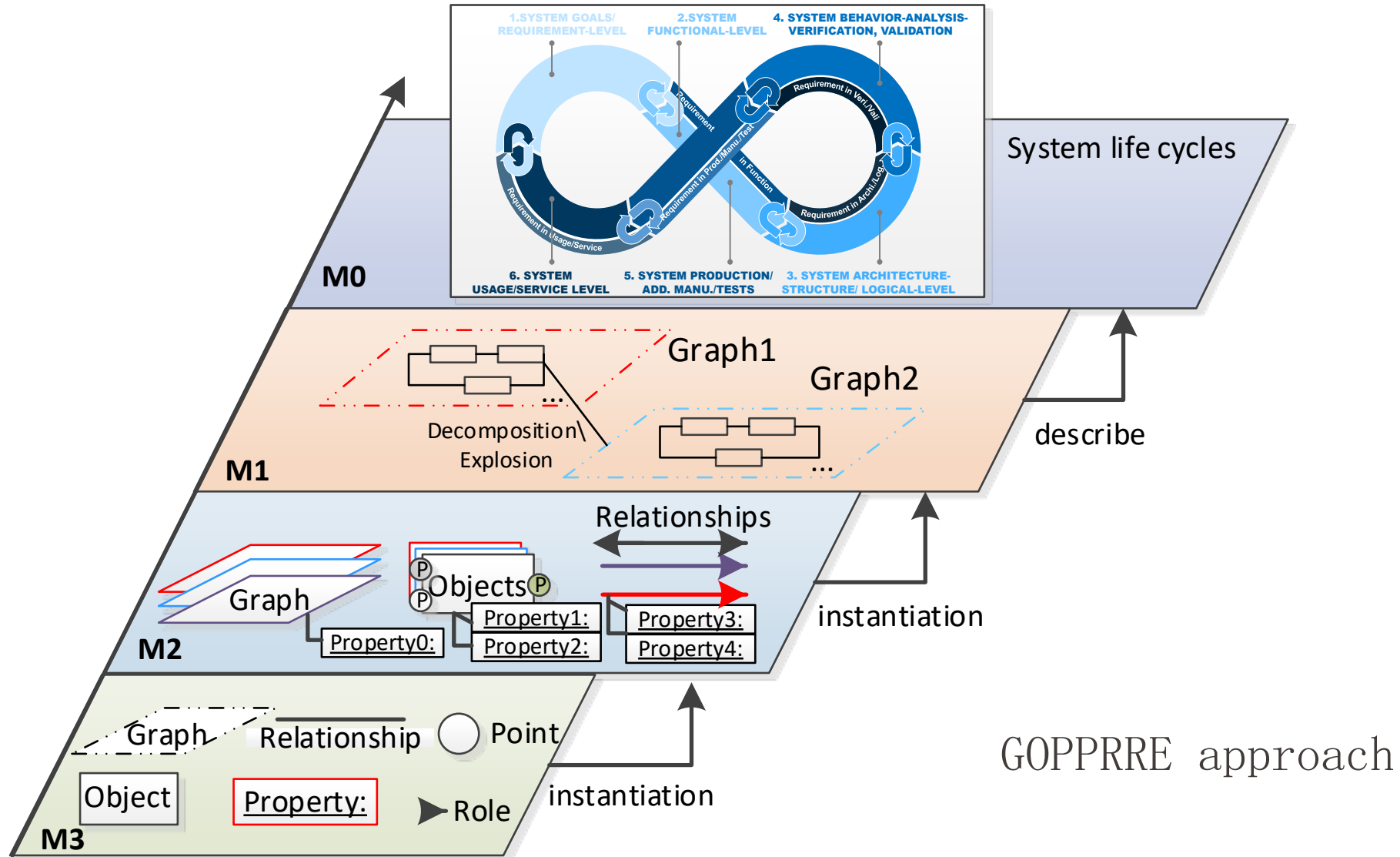


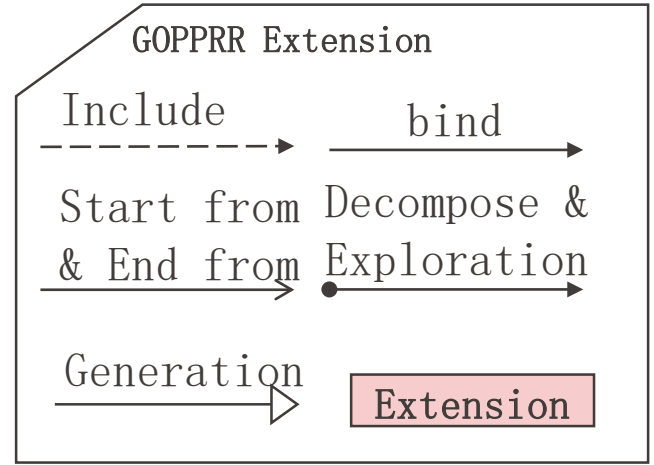
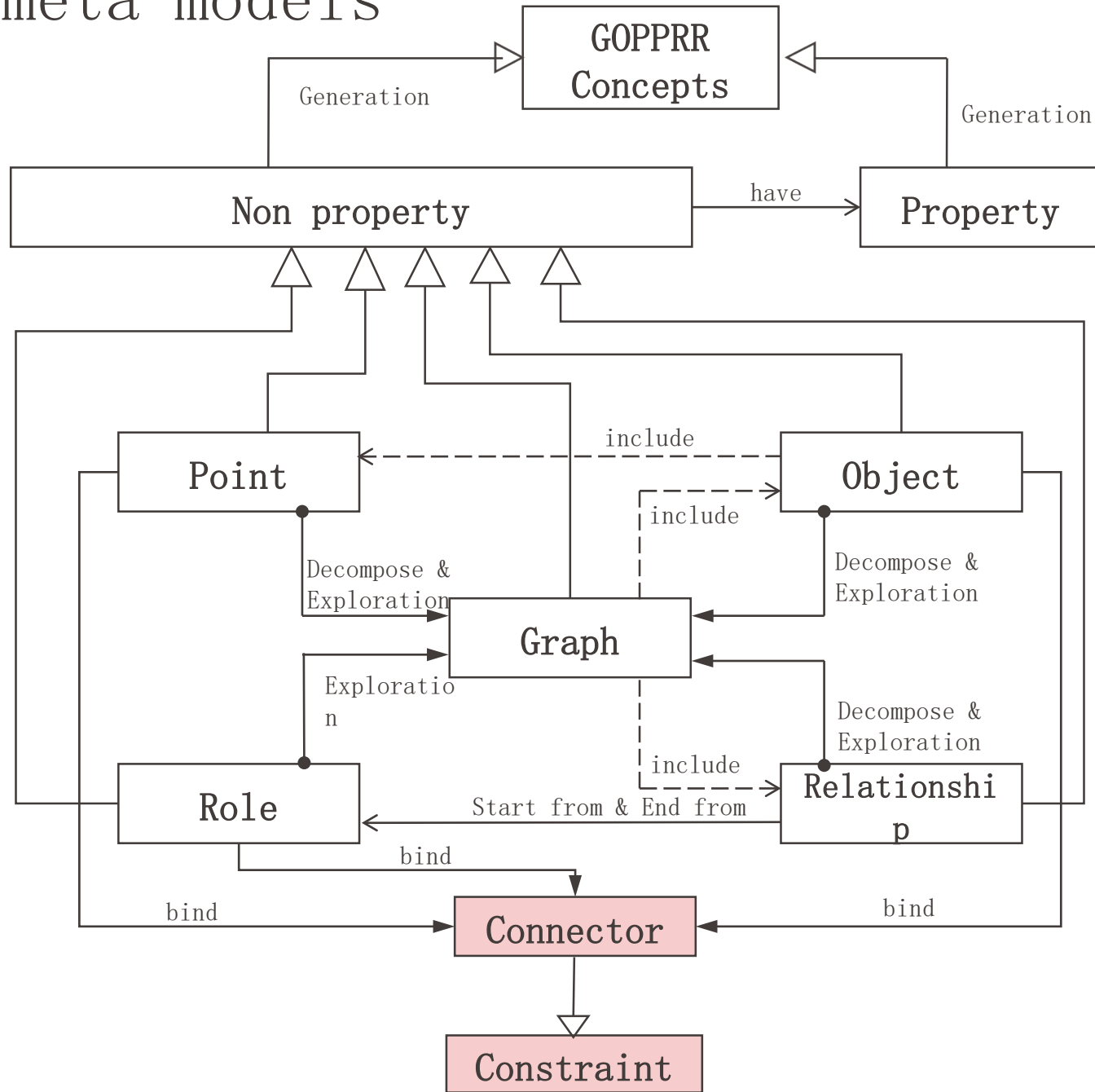
- System lifecycle of complex system

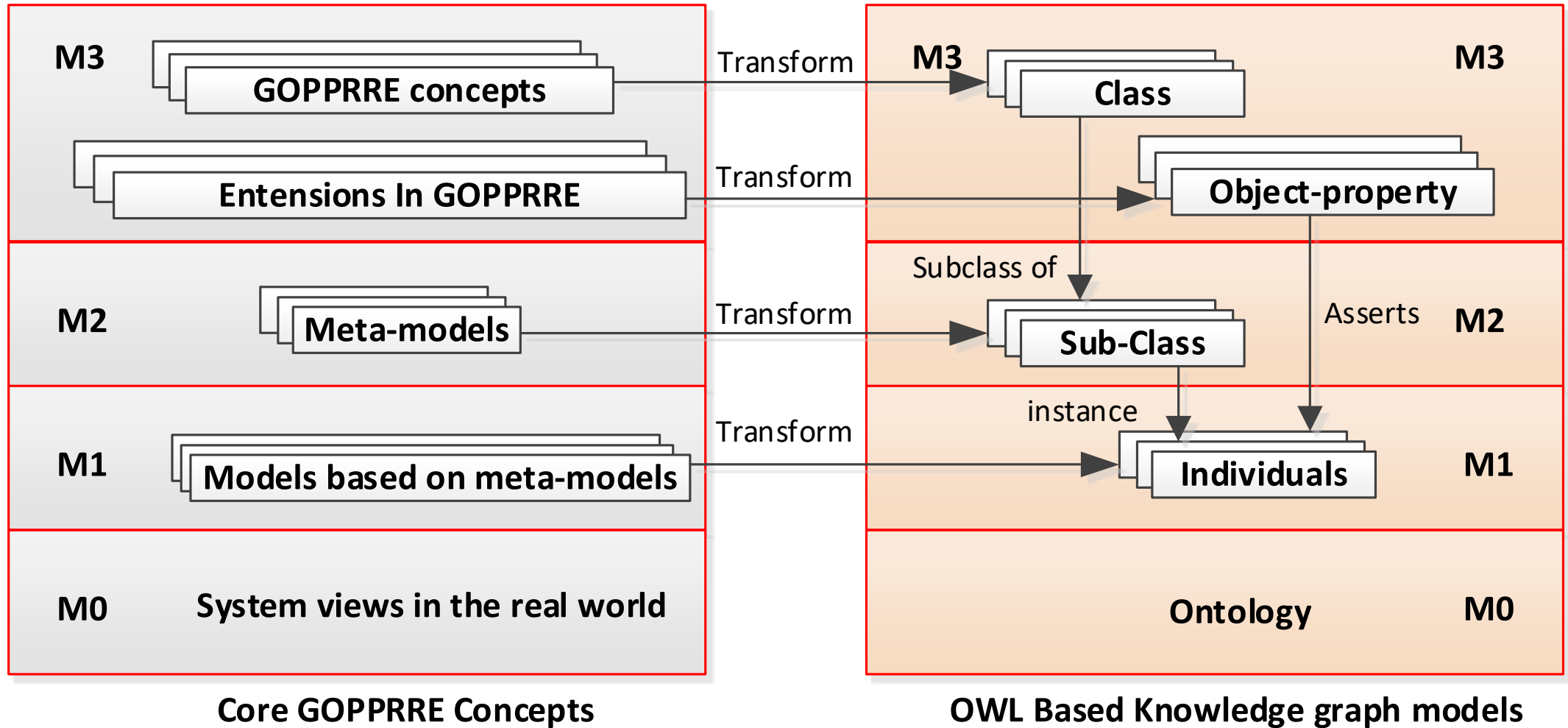
EPFL IoF SEWG Ontology Roadmap







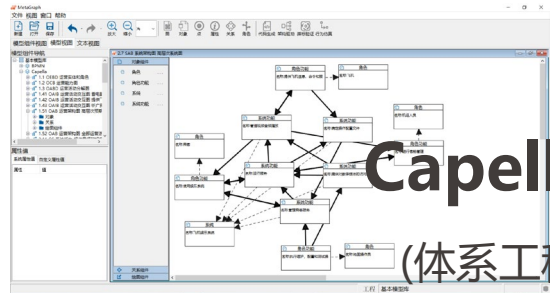
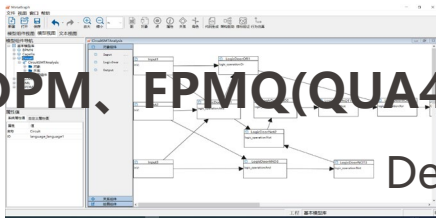




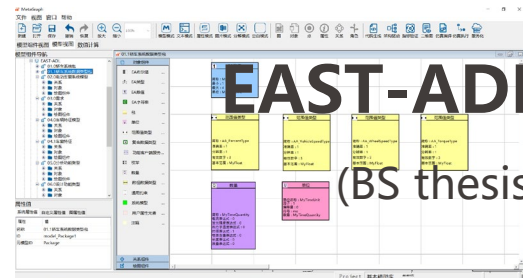
EPFL MBSE Formalisms

UAF, OPM, FPMQ(QUA4LITY)...

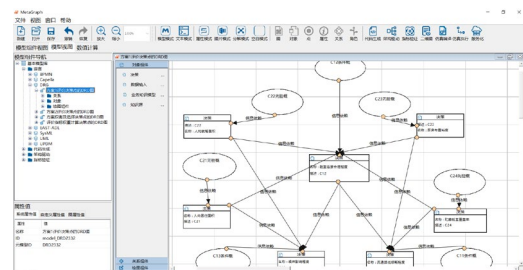
Developing



Capella
(体系工程)



EAST-ADL
(BS thesis)



DMN

IoF SE Ontology supporting MBSE formalisms.

01

02

07

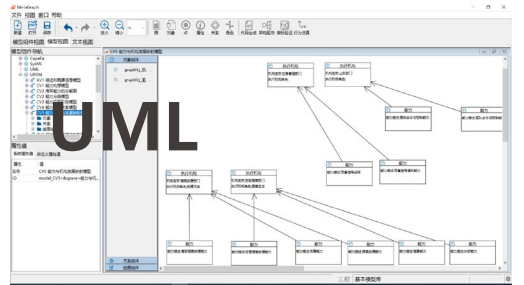
03

**IoF MBSE
Ontology**

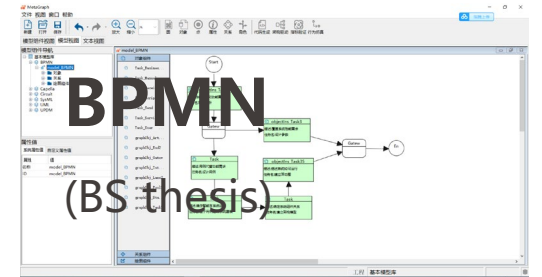
06

04

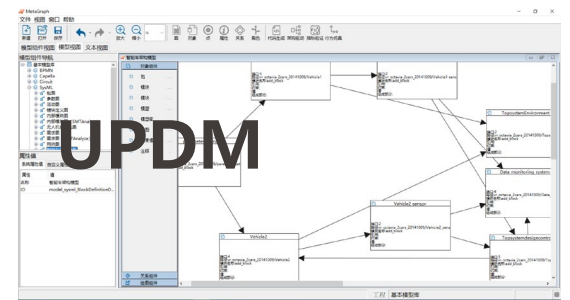
05



UML

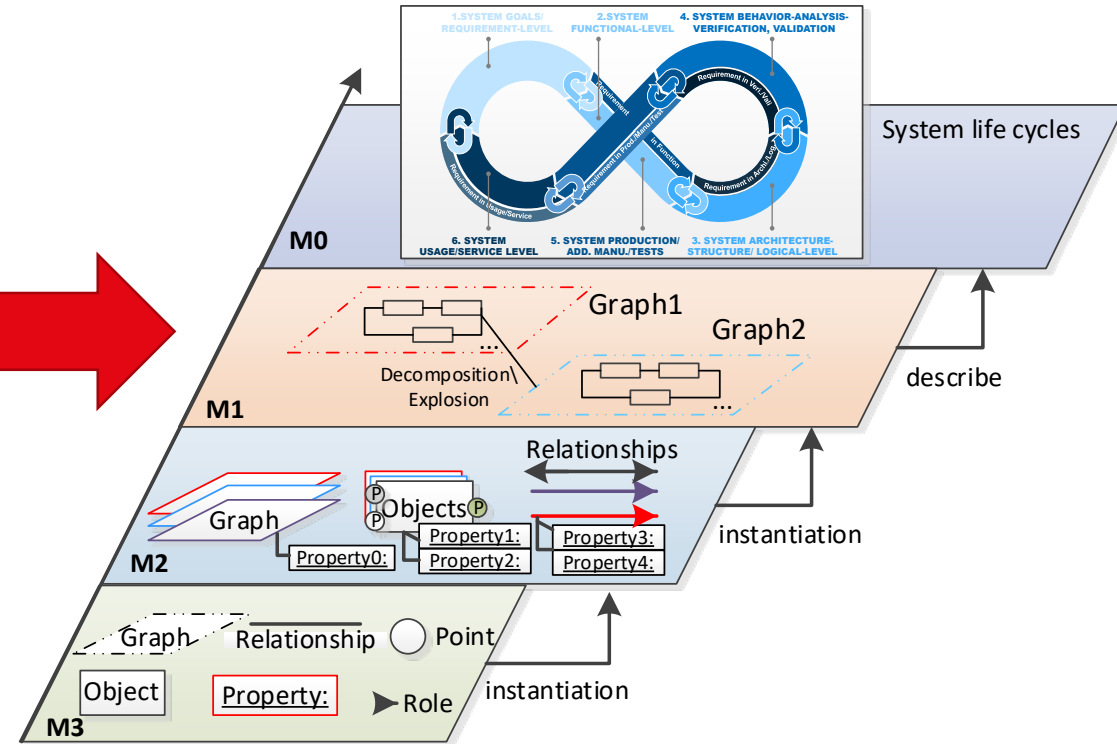
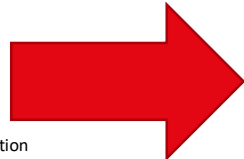
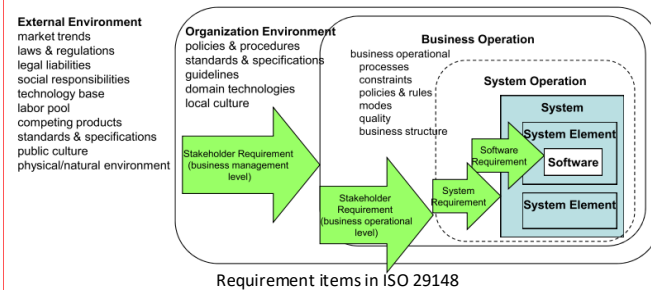
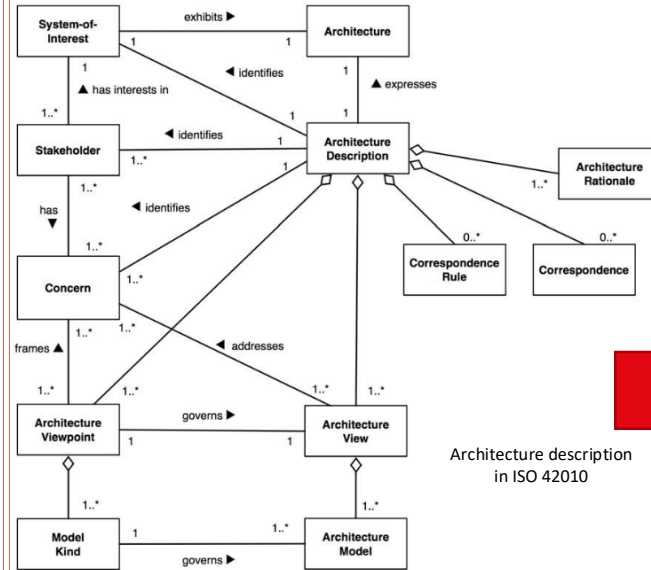
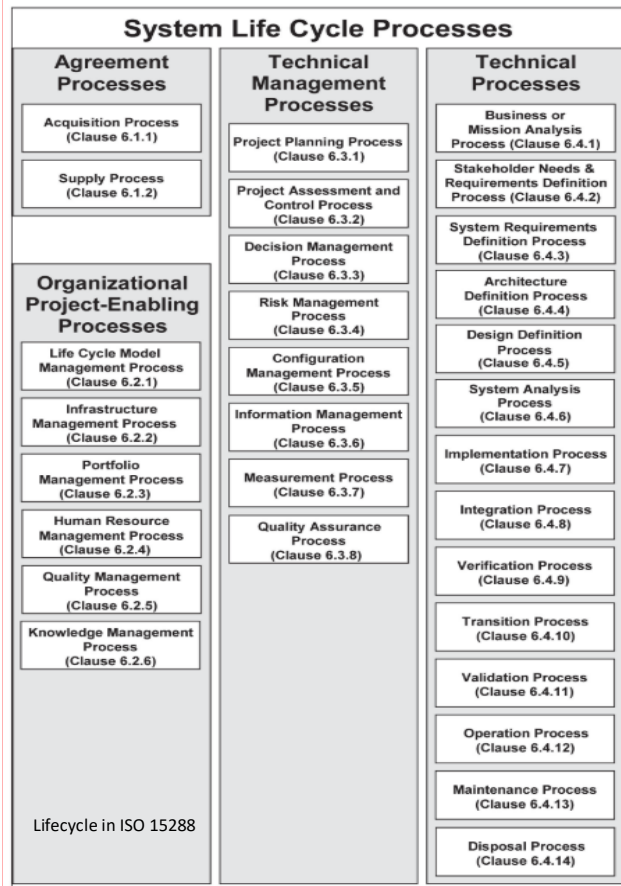


BPMN
(BS thesis)

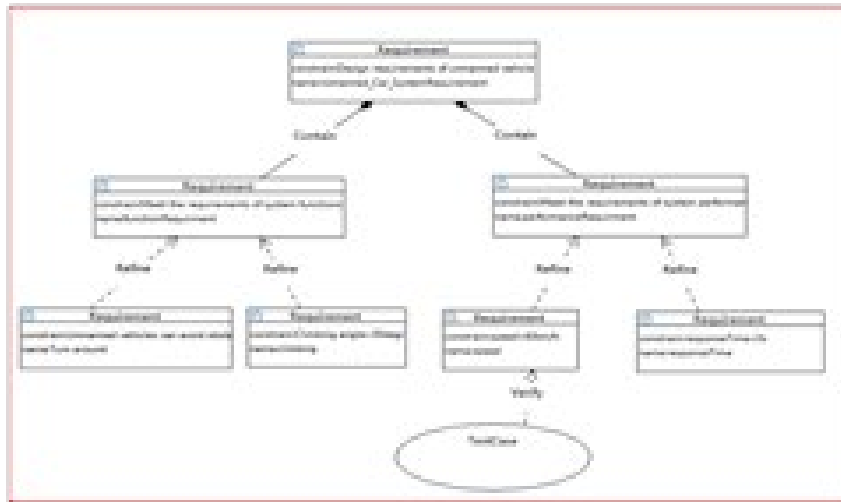


UPDM

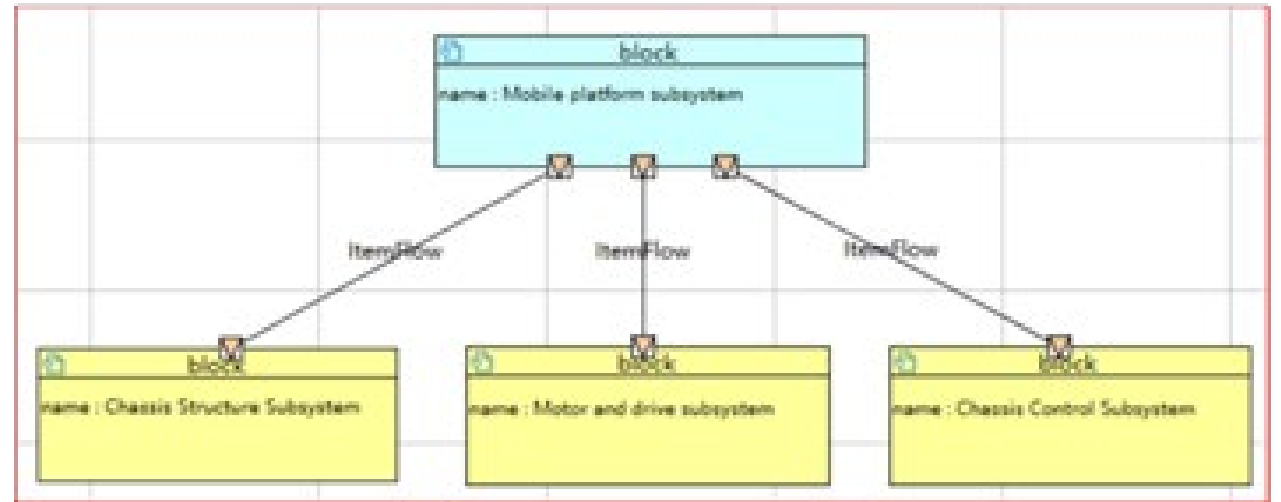
Language	Graph	Object	Point	Property	Relationship	Role	Reference
SysML	9 (9)	73 (64)	11 (11)	10 (10)	31 (31)	62 (0)	Magic Draw
BPMN	1 (1)	81 (77)	0 (0)	53 (46)	5 (3)	10 (0)	Camunda Modeler
UPDM	52 (52)	100 (123)	7 (6)	84 (96)	57 (50)	54 (0)	Magic Draw
EAST-ADL	10 (9)	67 (62)	17 (17)	93 (93)	23 (21)	68 (64)	MetaEdit+
OPM	1 (1)	3 (3)	0 (0)	9 (8)	15 (15)	12 (4)	Opcat
UML	14 (15)	83 (78)	5 (5)	98 (96)	43 (47)	71 (0)	Magic Draw
DMN	1 (1)	4 (5)	1 (0)	5 (2)	3 (3)	6 (0)	Camunda Modeler
Capella	29 (29)	48 (40)	5 (3)	4 (1)	29 (28)	42 (0)	Capella



ISO 24765

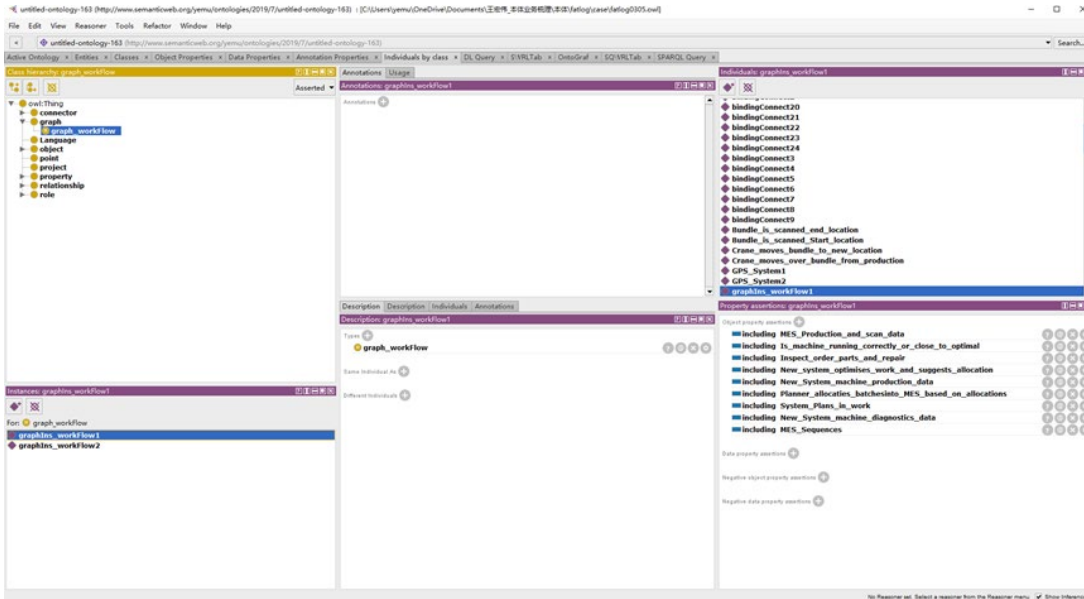


Requirement Diagram

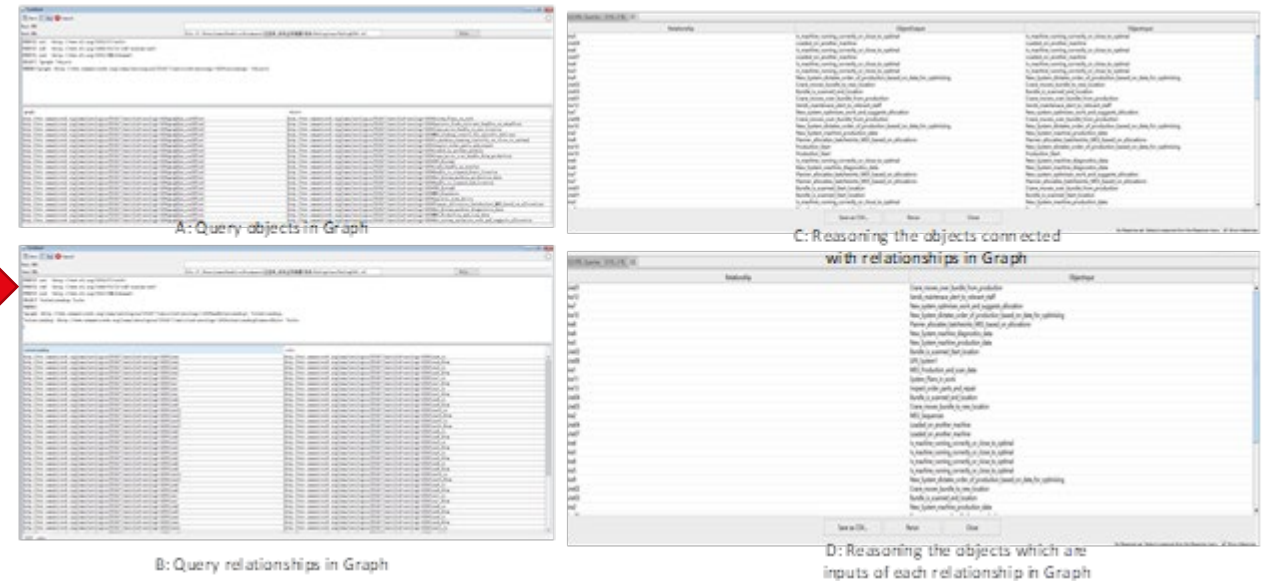


Internal block Diagram

EPFL SysML Case

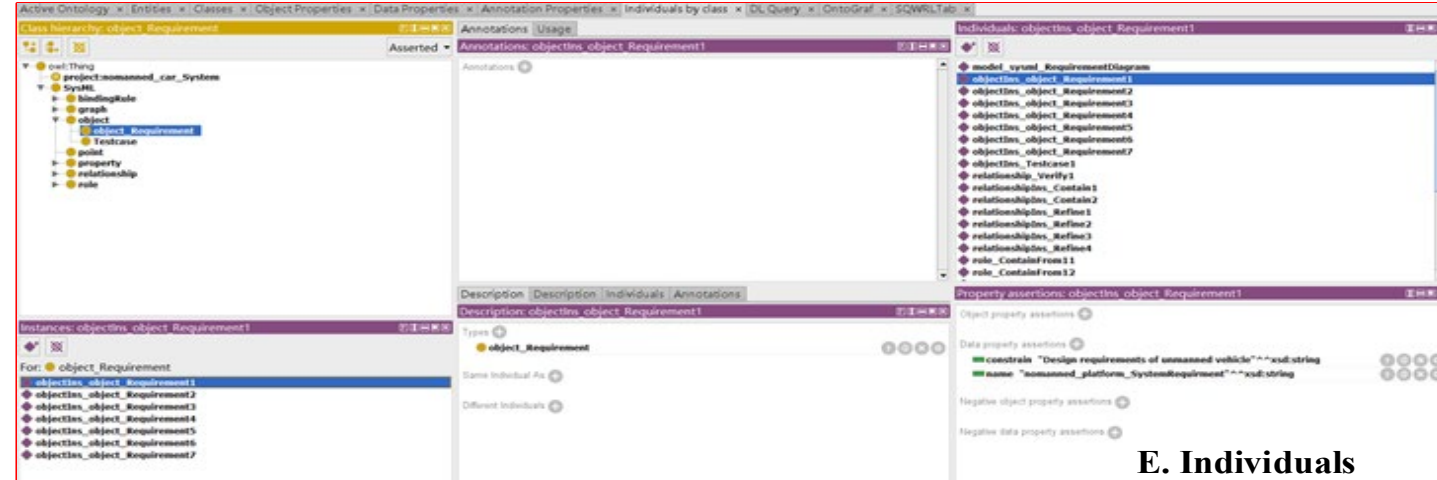
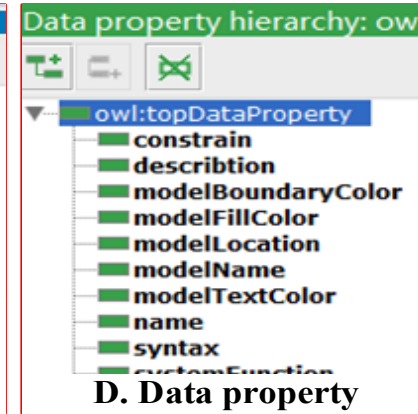
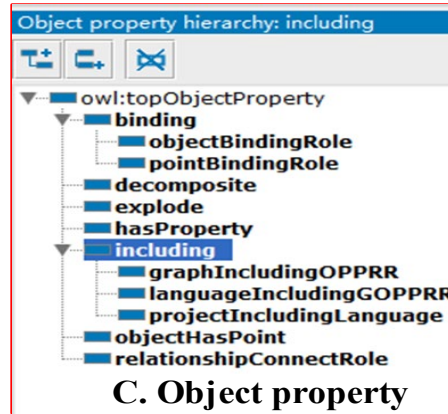
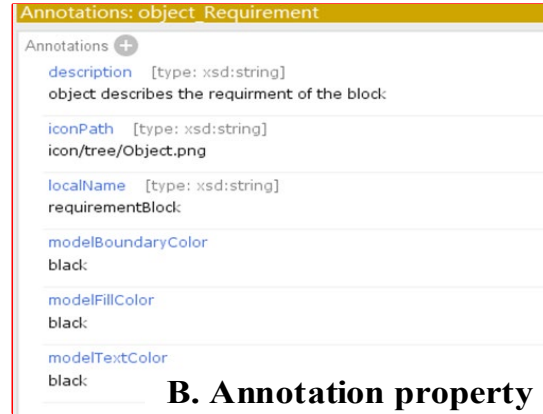
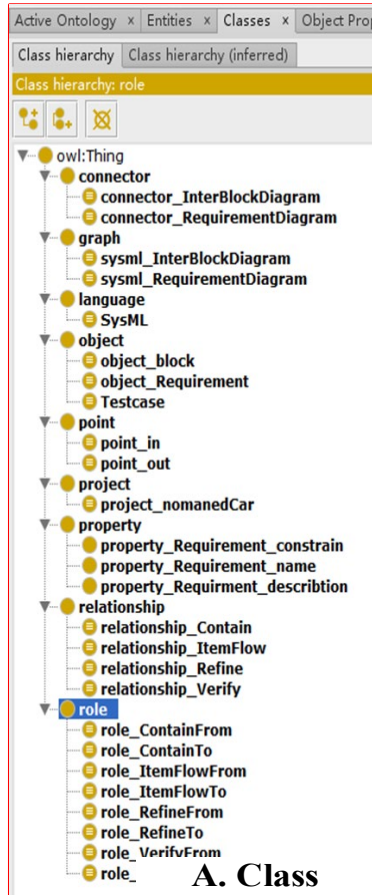


Ontology model



Evaluated by SQWRL and Sparql

See the demo



Algorithm 1 Query the owl models using SPARQL

```

PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
//Query the objects in the graphs.
SELECT ?graph ?object
WHERE {?graph
<http://www.semanticweb.org/yemu/ontologies/2019/7/untitled-ontology-163#including> ?object}
// Query the relationships in the graphs.
SELECT ?relationship ?role
WHERE {
?graph
<http://www.semanticweb.org/yemu/ontologies/2019/7/untitled-ontology-163#including> ?relationship
?relationship
<http://www.semanticweb.org/yemu/ontologies/2019/7/untitled-ontology-163#relationshipConnectRole> ?role.
}

```

Algorithm 2 Reasoning the owl models using SQWRL

```

// Reasoning the objects connected with relationships
connector(?Graph) ^ relationship_Refine(?Relationship) ^
role_RefineFrom(?FromRole) ^ role_RefineTo(?ToRole) ^
hasRelationship(?Graph, ?Relationship) ^
relationshipConnectRole(?Relationship, ?FromRole) ^
relationshipConnectRole(?Relationship, ?ToRole) ^
binding(?FromRole, ?ObjectOutput) ^ binding(?ToRole,
?ObjectInput) -> sqwrl:select(?Relationship,
?ObjectOutput, ?ObjectInput)
// Reasoning the objects which are inputs of the
relationships
connector(?Graph) ^ relationship_Refine(?Relationship) ^
role_RefineFrom(?FromRole) ^ role_RefineTo(?ToRole) ^
hasRelationship(?Graph, ?Relationship) ^
relationshipConnectRole(?Relationship, ?FromRole) ^
relationshipConnectRole(?Relationship, ?ToRole) ^
binding(?FromRole, ?ObjectOutput) ^ binding(?ToRole,
?ObjectInput) -> sqwrl:select(?Relationship, ?ObjectInput)

```

```

SELECT ?object
WHERE {
  graph http://www.semanticweb.org/yves/ontologies/2019/7/untitled-ontology-163#including ?object
}

```

A: Query objects in Graph

```

SELECT ?relationship ?role
WHERE {
  graph http://www.semanticweb.org/yves/ontologies/2019/7/untitled-ontology-163#relationship ?relationship.
  ?relationship http://www.semanticweb.org/yves/ontologies/2019/7/untitled-ontology-163#relationshipConnectRole ?role.
}

```

B: Query relationships in Graph

Relationship	ObjectOutput	ObjectInput
Line5	Is_machine_running_correctly_or_close_to_optimal	Is_machine_running_correctly_or_close_to_optimal
Line4	Loaded_on_another_machine	Loaded_on_another_machine
Line7	Is_machine_running_correctly_or_close_to_optimal	Is_machine_running_correctly_or_close_to_optimal
Line4	Loaded_on_another_machine	Loaded_on_another_machine
Line3	Is_machine_running_correctly_or_close_to_optimal	Is_machine_running_correctly_or_close_to_optimal
Line2	Is_machine_running_correctly_or_close_to_optimal	Is_machine_running_correctly_or_close_to_optimal
Line9	New_System dictates_order_of_production_based_on_data_for_optimising	New_System dictates_order_of_production_based_on_data_for_optimising
Line10	Crane_moves_bundle_to_new_location	Crane_moves_bundle_to_new_location
Line3	Crane_moves_over_bundle_from_production	Crane_moves_over_bundle_from_production
Line12	Sends_maintenance_alert_to_relevant_staff	Sends_maintenance_alert_to_relevant_staff
Line7	New_system_optimises_work_and_suggests_allocation	New_system_optimises_work_and_suggests_allocation
Line6	Crane_moves_over_bundle_from_production	Crane_moves_over_bundle_from_production
Line10	New_System dictates_order_of_production_based_on_data_for_optimising	New_System dictates_order_of_production_based_on_data_for_optimising
Line2	New_System_machine_production_data	New_System_machine_production_data
Line8	Planner_allocates_batchesinto_MES_based_on_allocations	Planner_allocates_batchesinto_MES_based_on_allocations
Line10	Production_Start	New_System dictates_order_of_production_based_on_data_for_optimising
Line10	Production_Start	Production_Start
Line4	Is_machine_running_correctly_or_close_to_optimal	New_System_machine_diagnostics_data
Line4	New_System_machine_diagnostics_data	New_System_machine_diagnostics_data
Line7	Planner_allocates_batchesinto_MES_based_on_allocations	New_System_optimises_work_and_suggests_allocation
Line7	Planner_allocates_batchesinto_MES_based_on_allocations	Planner_allocates_batchesinto_MES_based_on_allocations
Line3	Bundle_is_scanned_Start_location	Crane_moves_over_bundle_from_production
Line3	Is_machine_running_correctly_or_close_to_optimal	Bundle_is_scanned_Start_location
Line10	New_System_machine_production_data	New_System_machine_production_data

C: Reasoning the objects connected with relationships in Graph

Relationship	ObjectInput
Line12	Crane_moves_over_bundle_from_production
Line12	Sends_maintenance_alert_to_relevant_staff
Line7	New_system_optimises_work_and_suggests_allocation
Line10	New_System dictates_order_of_production_based_on_data_for_optimising
Line4	Planner_allocates_batchesinto_MES_based_on_allocations
Line4	New_System_machine_diagnostics_data
Line3	New_System_machine_production_data
Line2	Bundle_is_scanned_Start_location
Line6	GPS_System1
Line1	MES_Production_and_scan_data
Line11	System_Plans_in_work
Line13	Inspect_order_parts_and_repair
Line4	Bundle_is_scanned_and_location
Line3	Crane_moves_bundle_to_new_location
Line3	Crane_moves_over_bundle_from_production
Line4	Loaded_on_another_machine
Line4	Loaded_on_another_machine
Line4	Is_machine_running_correctly_or_close_to_optimal
Line3	Is_machine_running_correctly_or_close_to_optimal
Line6	Is_machine_running_correctly_or_close_to_optimal
Line5	Is_machine_running_correctly_or_close_to_optimal
Line9	New_System dictates_order_of_production_based_on_data_for_optimising
Line2	Crane_moves_bundle_to_new_location
Line3	Bundle_is_scanned_and_location
Line2	New_System_machine_production_data

D: Reasoning the objects which are inputs of each relationship in Graph

See the demo

THANK YOU!

