



## Table of contents

- Introduction
- MBSE – Fundamentals
  - MBSE vs DBSE
- Interoperability
  - OSLC / STEP / SysML / FMI
- OSLC KM and SRL
- Case Study – Automatic Traceability Between Seq. Diag. and Requirements

## Presenter's profile

- José Fuentes
  - Chief Operating Officer at The REUSE Company
  - Board member of AEIS (INCOSE Spanish Chapter)
  - Main contributor to the INCOSE Guide for Writing Requirements
  - Member of the following INCOSE Working Groups:
    - Requirements WG
    - Ontology WG



José Fuentes

Jose.fuentes@reusecompany.com  
jose.fuentes@aeis-incose.org

## Brief description of The Reuse Company



**T** (he) **R** (euse) **Q** (ompany)y

**Trace + Retrieval + Quality**

**Towards systematic Reuse**

By means of: **Repositories** containing **Ontologies and Assets**

# Model Based Systems Engineering

The present trend....

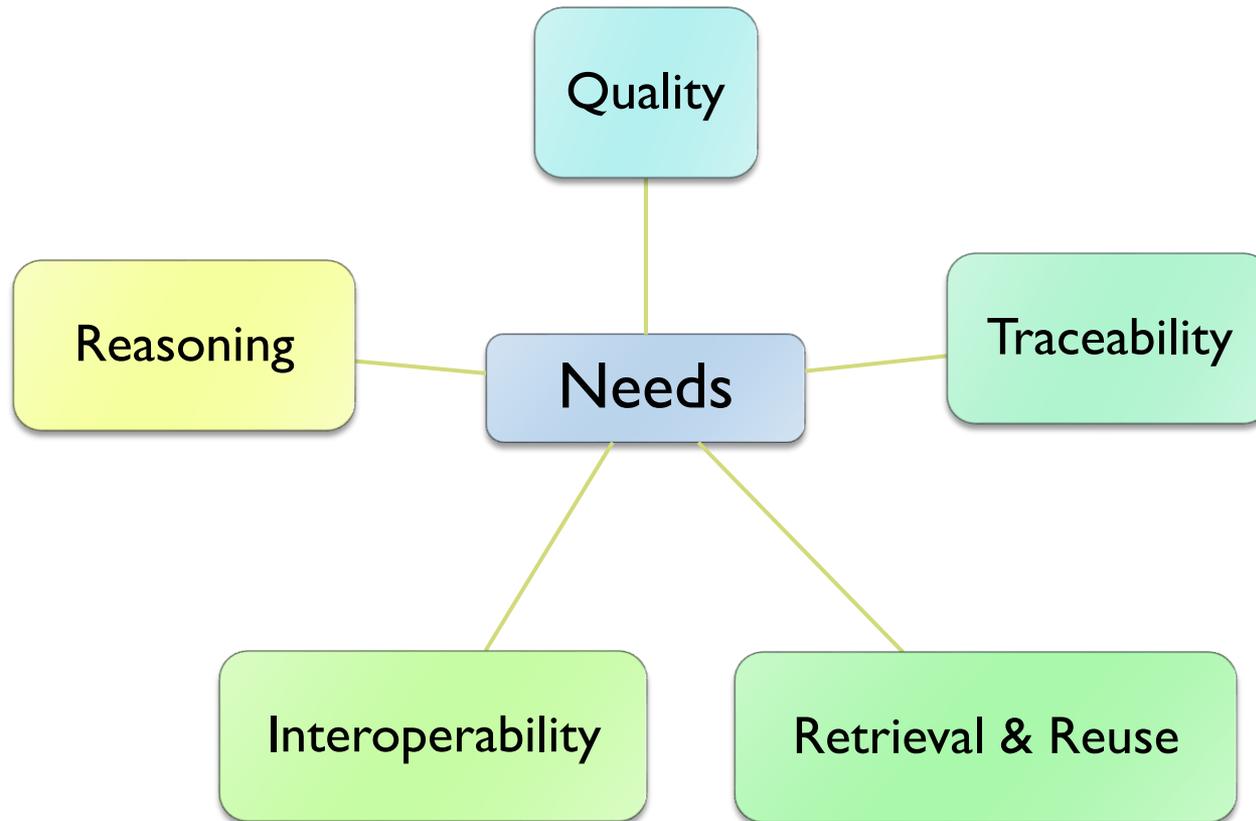
## Model Based Systems Engineering (MBSE)

- *“The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.”*

INCOSE SEVision 2020 ( INCOSE-TP-2004-004-02 September, 2007)

- Models as part of the flow information among activities and processes
- Eases traceability possibilities
- Enable computers to operate (transformations, simulations, V&V aids)

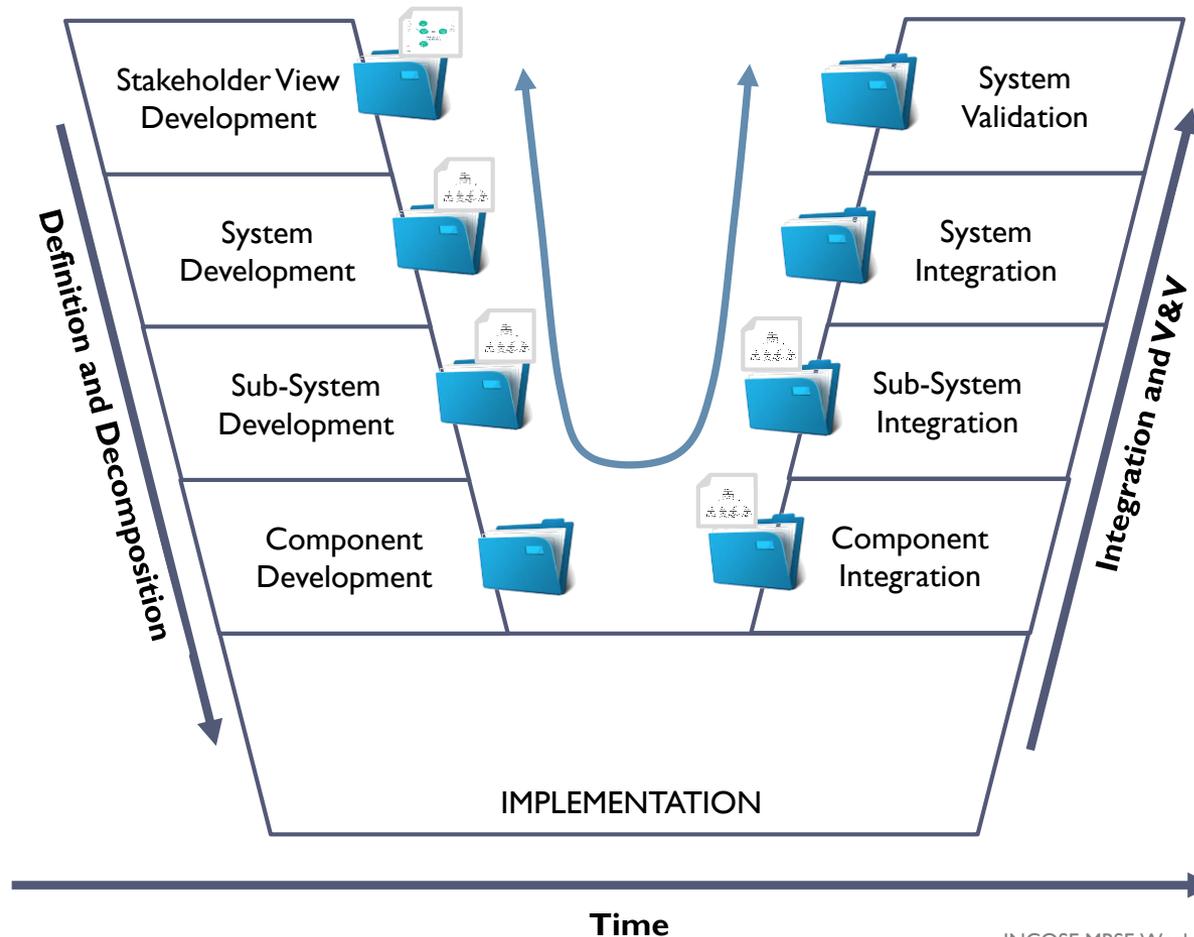
## Current needs in SE



- Are these needs covered/solved/managed by MBSE?

Systems Engineering – From Document Centric (DBSE)

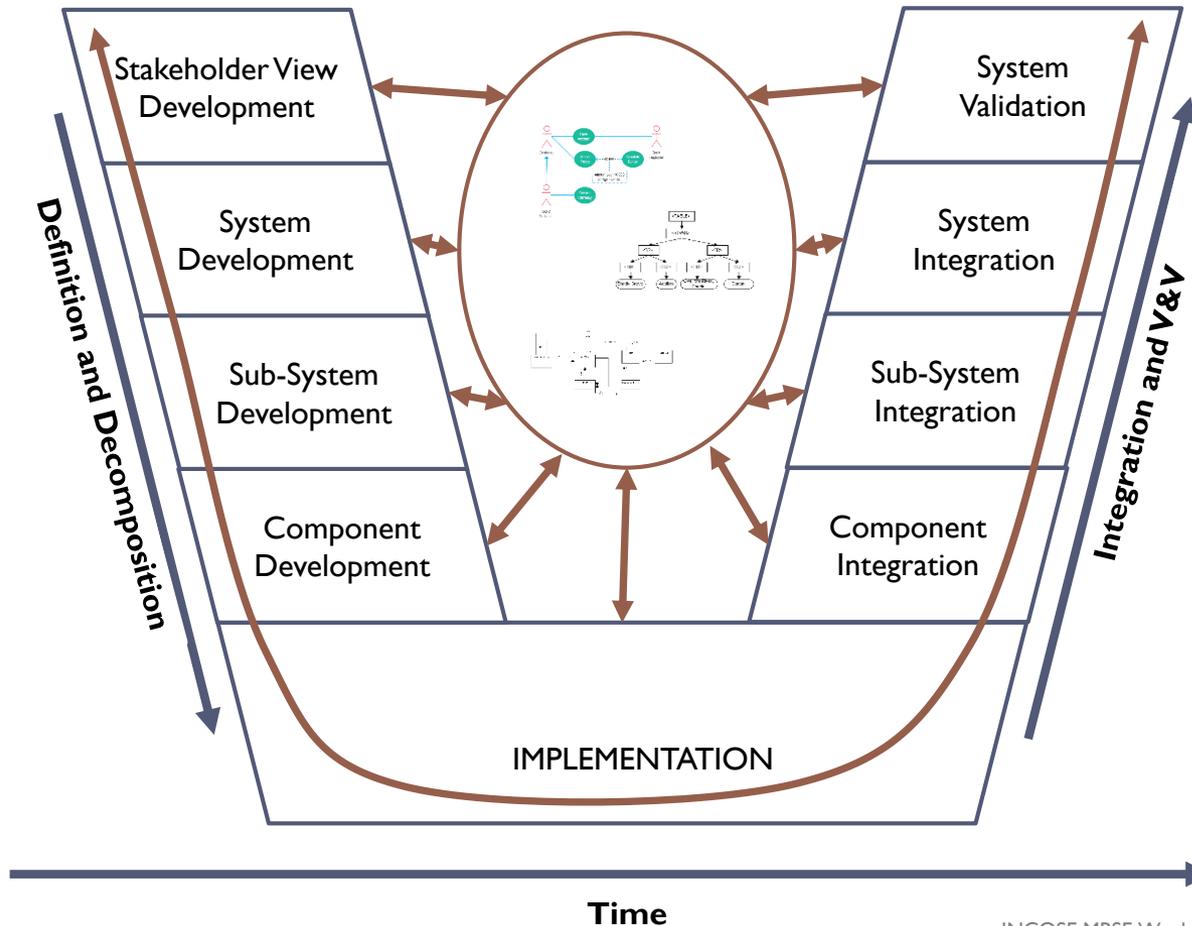
Stand-alone models related through documents. Documents are part of configuration management systems.



INCOSE MBSE Workshop, Jan 2014

## ...Towards Model Based (MBSE)

- MBSE: Shared system model with multiple views and connected to discipline models. Reusable model-based engineering with virtual product development and simulation capability



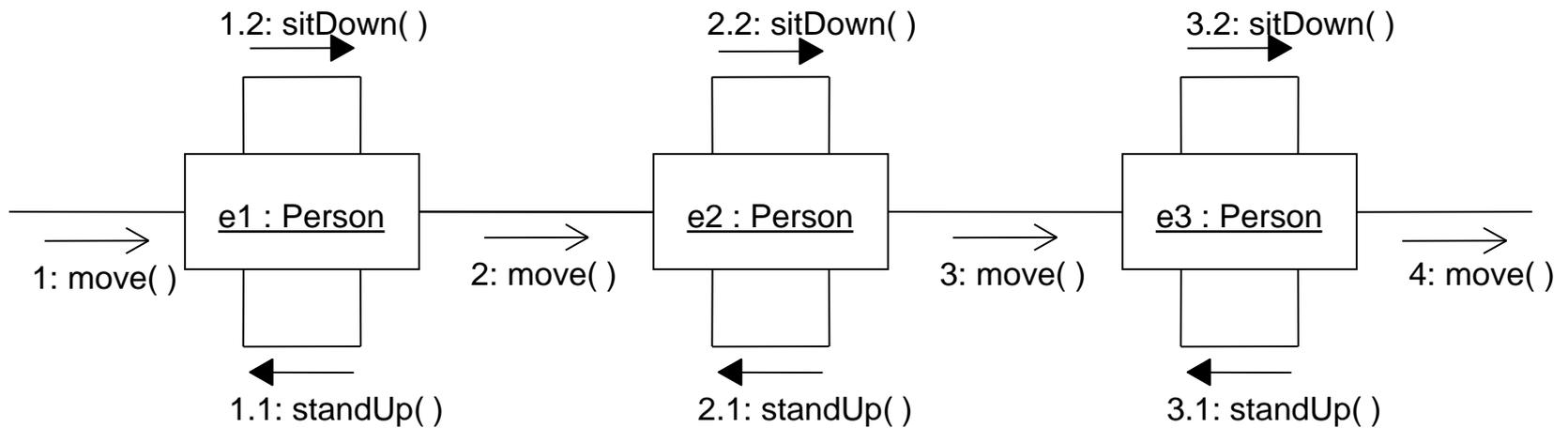
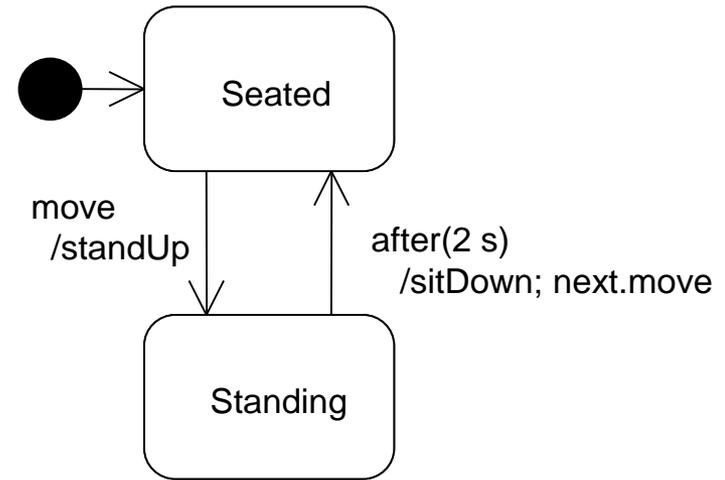
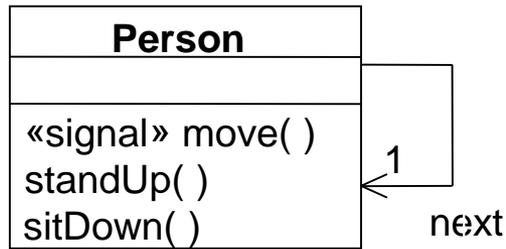
INCOSE MBSE Workshop, Jan 2014

## Model Based Systems Engineering (MBSE)

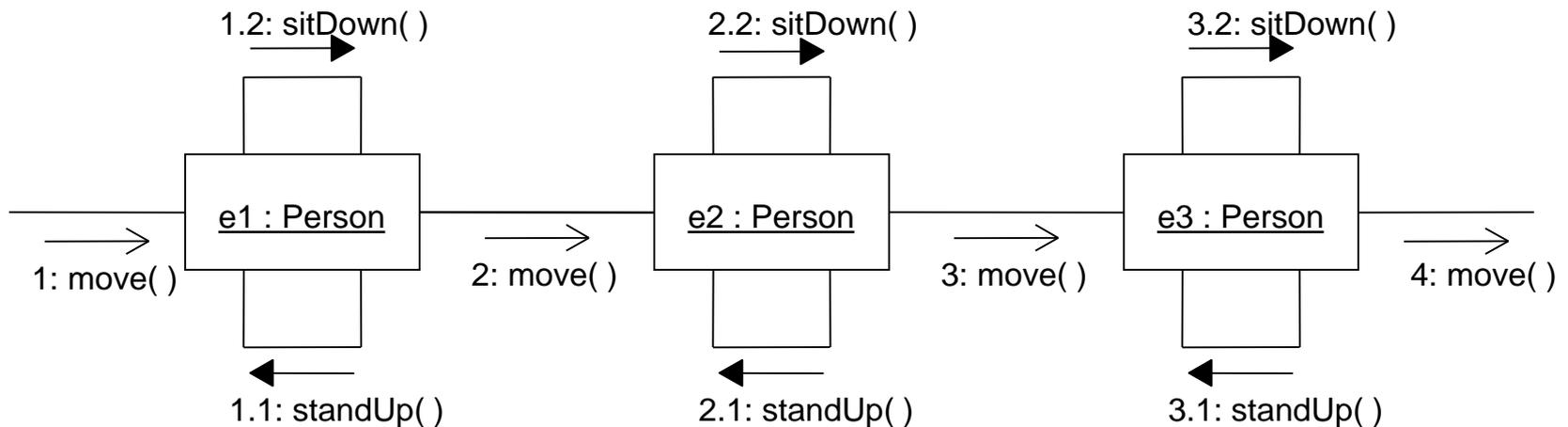
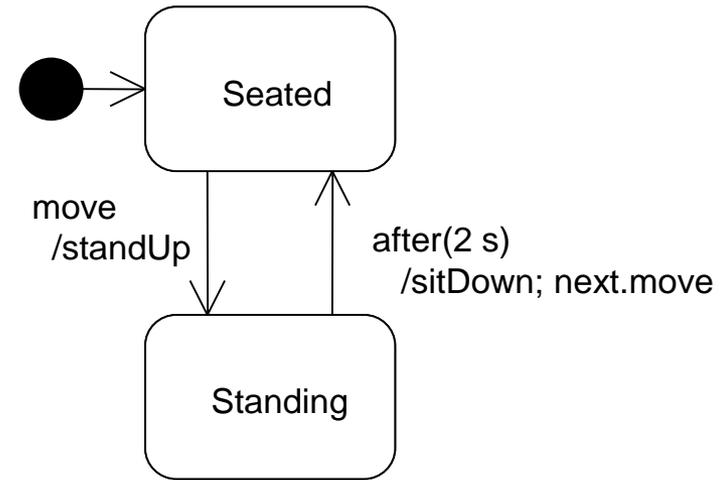
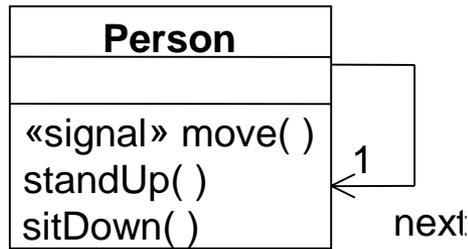
But...

- Requirements Specs and Mgmt.?,
  - Stakeholders needs?,
  - Operational Documentation?,
  - Maintenance Documentation?
- 
- Are models really useful to communicate between humans?
  - Every single human?

It is clear what I want to model, right?



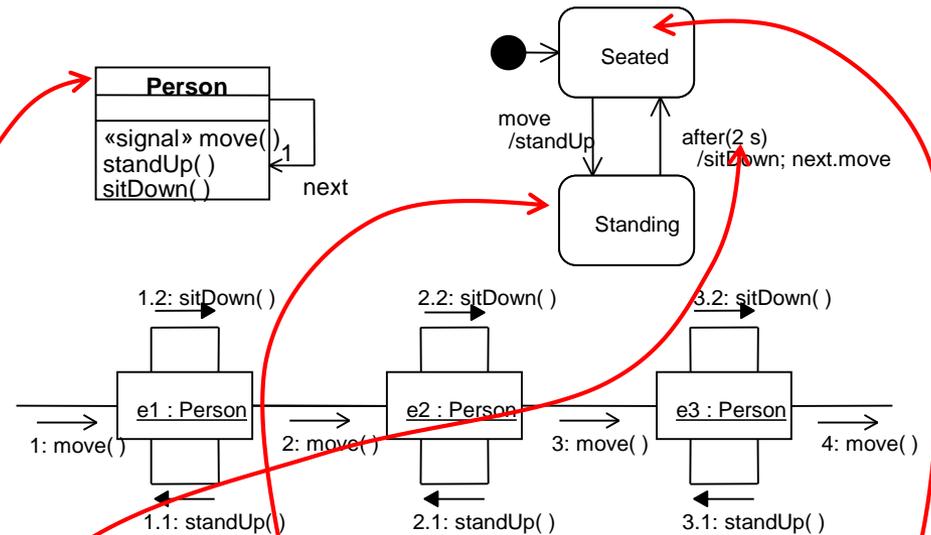
It is clear what I want to model, right?



It is clear what I want to model, right?



It is clear what I want to model, right?



➤ The “WAVE” in a Stadium

- I need a **logical model** for a computer to simulate what humans call “**the wave**” in a stadium.
- Consider the possibility to do the wave by **standing up** from a **sitting** position.
- I want the wave to be **slow**, so the **person** must wait a long time before (s)he sits down.

## Are NL and NL Requirements the solution?

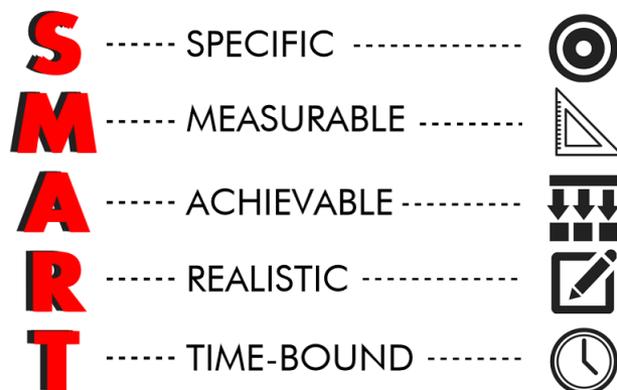
- Not really!!
- Natural Language can be really ambiguous

**MY WIFE TOLD ME TO  
PUT THE PIE IN THE  
OVEN AT 120 DEGREES**



# Are NL and NL Requirements the solution?

- High quality requirements are a **MUST** in Systems Engineering



Every single requirement is correct



The set of requirements represents a complete definition of the product (ISO 24766)



Not a single requirement conflicts with another one in the set

## Natural Language (DBSE) vs. MBSE

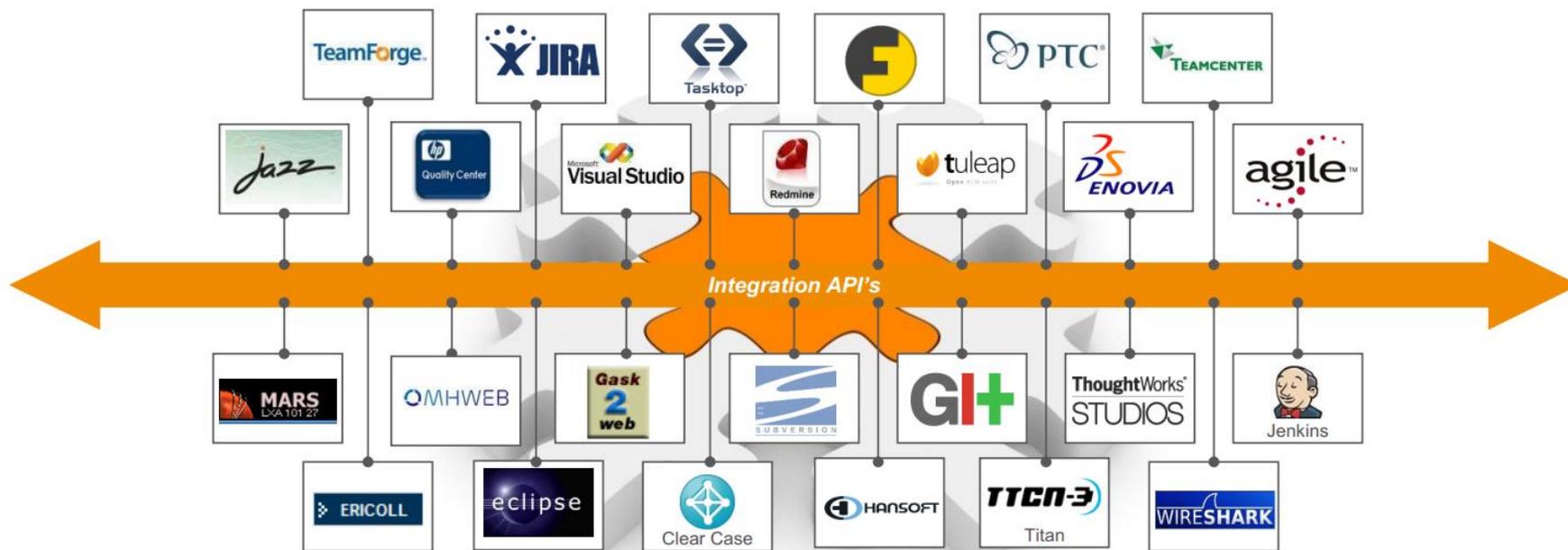
- We need the best of both worlds
- ... and we need to connect both worlds
- Both, for humans and also for computers
- What must be the **glue** in the middle of both worlds?



# Knowledge Centric Systems Engineering

## Interoperability needs

“A real engineering environment...”



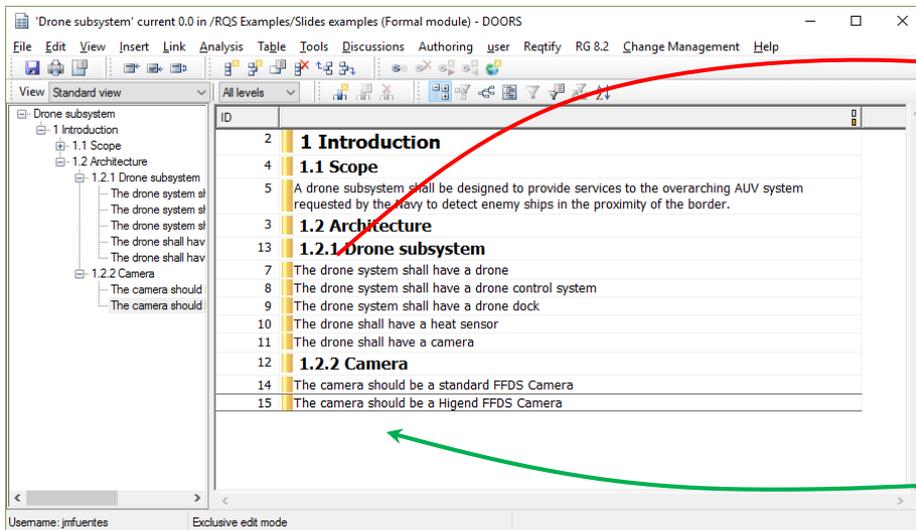
Mats Berglund (Ericsson) <http://www.ices.kth.se/upload/events/13/84404189f85d41a6a7d1cafd0db4ee80.pdf>

- Multiple **domains**
  - Different **types of artifacts**
- Need of **intra-operability**
  - Intra-domain
- Need of **interoperability**
  - Inter-domain

## Interoperability

Open Services for Life-cycle Collaboration (OSLC)  
Standard for the Exchange of Product model data (STEP) - ISO 10303  
Other

## Interoperability (or intra-operability)



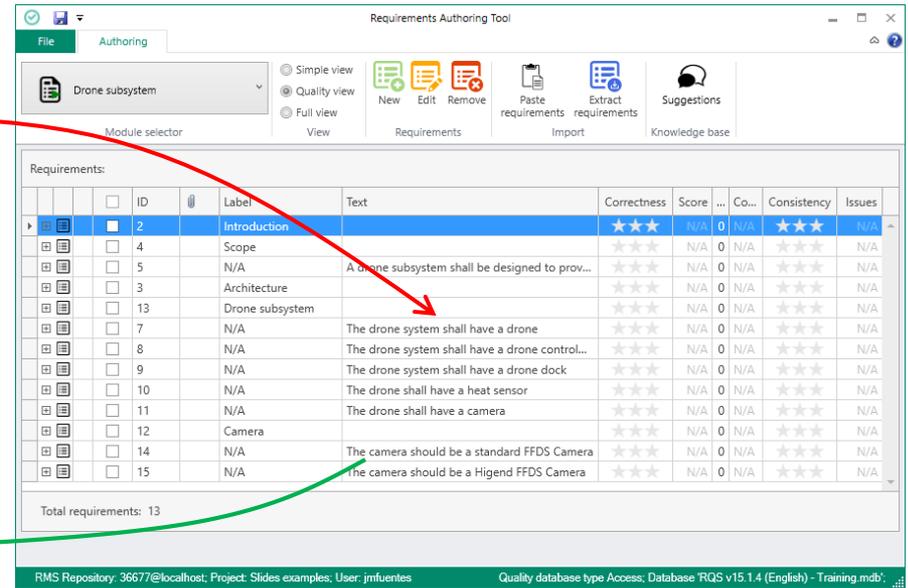
Drone subsystem' current 0.0 in /RQS Examples/Slides examples (Formal module) - DOORS

View: Standard view | All levels

- Drone subsystem
  - 1 Introduction
    - 1.1 Scope
      - 1.2 Architecture
        - 1.2.1 Drone subsystem
          - The drone system shall have a drone
          - The drone system shall have a drone control system
          - The drone system shall have a drone dock
          - The drone shall have a heat sensor
          - The drone shall have a camera
        - 1.2.2 Camera
          - The camera should be a standard FFDS Camera
          - The camera should be a Higid FFDS Camera

ID	Text
2	<b>1 Introduction</b>
4	<b>1.1 Scope</b>
5	A drone subsystem shall be designed to provide services to the overarching AUV system requested by the navy to detect enemy ships in the proximity of the border.
3	<b>1.2 Architecture</b>
13	<b>1.2.1 Drone subsystem</b>
7	The drone system shall have a drone
8	The drone system shall have a drone control system
9	The drone system shall have a drone dock
10	The drone shall have a heat sensor
11	The drone shall have a camera
12	<b>1.2.2 Camera</b>
14	The camera should be a standard FFDS Camera
15	The camera should be a Higid FFDS Camera

Username: jmfuentes | Exclusive edit mode



Requirements Authoring Tool

Module selector: Drone subsystem

View: Simple view | Quality view | Full view

Requirements: New | Edit | Remove

Import: Paste requirements | Extract requirements

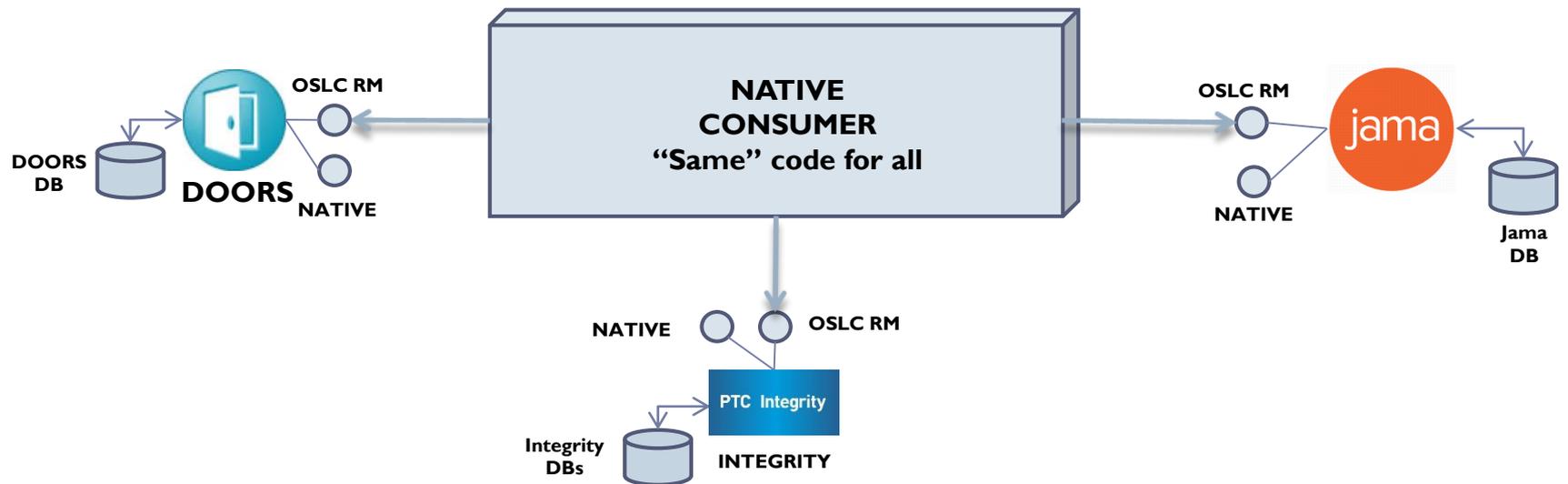
Knowledge base: Suggestions

ID	Label	Text	Correctness	Score	Co...	Consistency	Issues
2	Introduction		☆☆☆	N/A	0	☆☆☆	N/A
4	Scope		☆☆☆	N/A	0	☆☆☆	N/A
5	N/A	A drone subsystem shall be designed to prov...	☆☆☆	N/A	0	☆☆☆	N/A
3	Architecture		☆☆☆	N/A	0	☆☆☆	N/A
13	Drone subsystem		☆☆☆	N/A	0	☆☆☆	N/A
7	N/A	The drone system shall have a drone	☆☆☆	N/A	0	☆☆☆	N/A
8	N/A	The drone system shall have a drone control...	☆☆☆	N/A	0	☆☆☆	N/A
9	N/A	The drone system shall have a drone dock	☆☆☆	N/A	0	☆☆☆	N/A
10	N/A	The drone shall have a heat sensor	☆☆☆	N/A	0	☆☆☆	N/A
11	N/A	The drone shall have a camera	☆☆☆	N/A	0	☆☆☆	N/A
12	Camera		☆☆☆	N/A	0	☆☆☆	N/A
14	N/A	The camera should be a standard FFDS Camera	☆☆☆	N/A	0	☆☆☆	N/A
15	N/A	The camera should be a Higid FFDS Camera	☆☆☆	N/A	0	☆☆☆	N/A

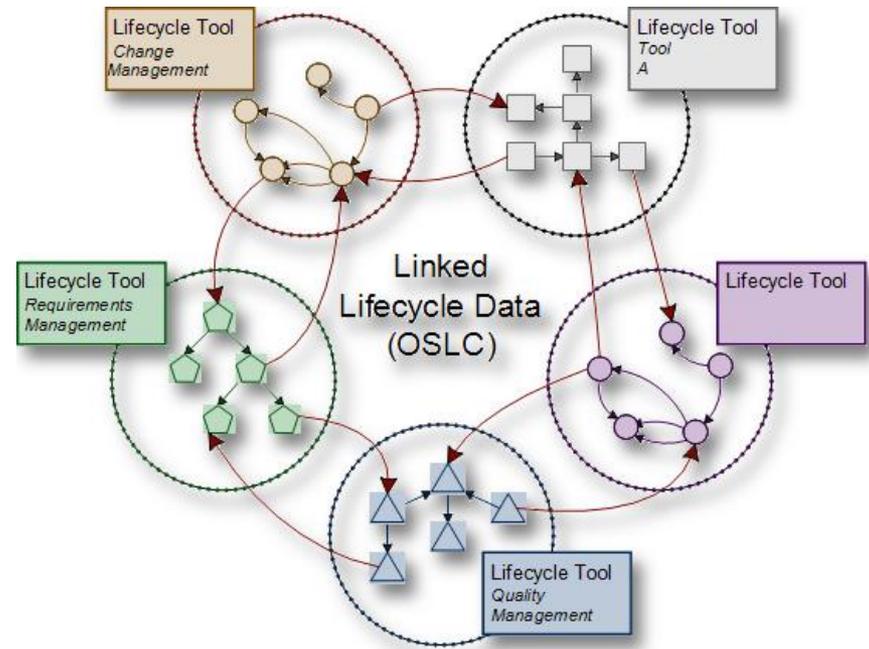
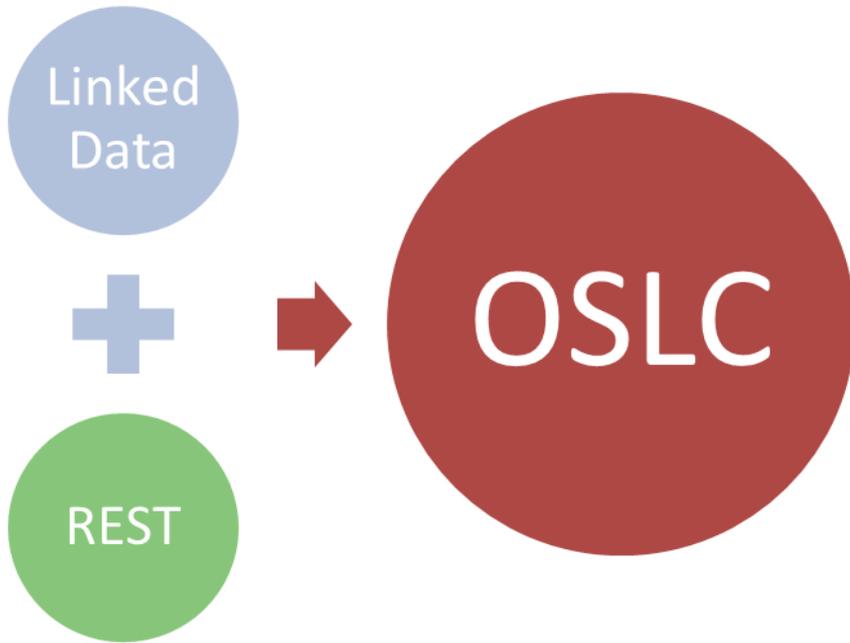
Total requirements: 13

RMS Repository: 36677@localhoet, Project: Slides examples, User: jmfuentes | Quality database type Access, Database 'RQS v15.1.4 (English) - Training.mdb'

# Example: Access to all-kinds work-products content

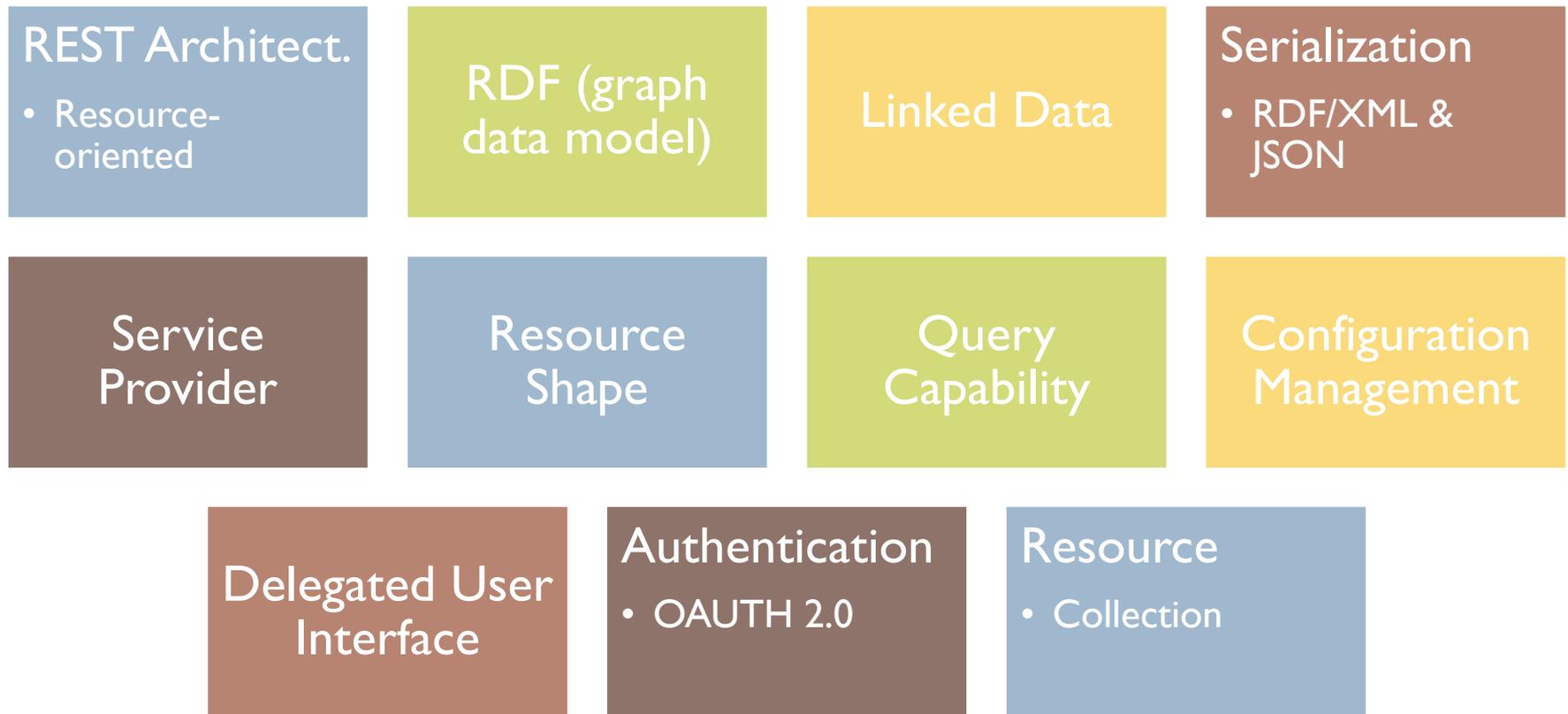


# Open Services for Lifecycle Collaboration (OSLC)



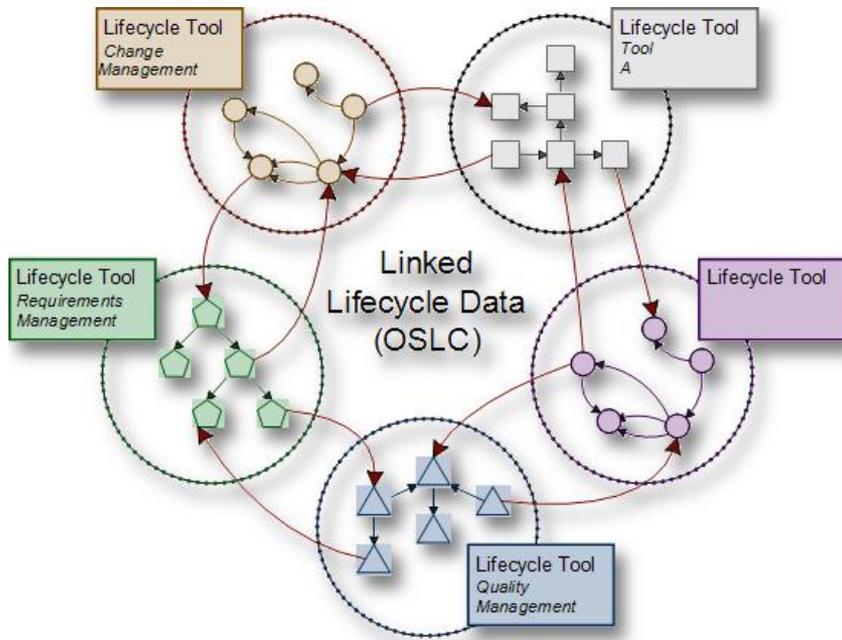
Source: [http://upload.wikimedia.org/wikipedia/en/7/7e/OSLC\\_diagram.png](http://upload.wikimedia.org/wikipedia/en/7/7e/OSLC_diagram.png)

## OSLC Building blocks (keywords)



# Intra-operability-OSLC

## Open Services for Life-cycle Collaboration



**OSLC resource to OSLC resource**  
**Individual** problem solving

<http://www.oasis-osl.org/>

## Eg: OSLC – Requirements Management – Resource Shape

Prefixed Name	Occurs	Read-only	Value-type	Representation	Range	Description
<b>OSLC Core: Common Properties</b>						
dcterms:title	exactly-one	unspecified	XMLLiteral	n/a	n/a	Title (reference: Dublin Core) of the resource represented as rich text in XHTML content. <b>SHOULD</b> include only content that is valid inside an XHTML <span> element.
dcterms:description	zero-or-one	unspecified	XMLLiteral	n/a	n/a	Descriptive text (reference: Dublin Core) about resource represented as rich text in XHTML content. <b>SHOULD</b> include only content that is valid and suitable inside an XHTML <div> element.
dcterms:identifier	zero-or-one	True	String	n/a	n/a	An identifier for a resource. This identifier may be unique with a scope that is defined by the RM provider. Assigned by the service provider when a resource is created. Not intended for end-user display.
oslc:shortTitle	zero-or-one	unspecified	XMLLiteral	n/a	n/a	Short name identifying a resource, often used as an abbreviated identifier for presentation to end-users. <b>SHOULD</b> include only content that is valid inside an XHTML <span> element.
dcterms:subject	zero-or-many	False	String	n/a	n/a	Tag or keyword for a resource. Each occurrence of a dcterms:subject property denotes an additional tag for the resource.

[http://open-services.net/bin/view/Main/RmSpecificationV2#Resource\\_Requirement](http://open-services.net/bin/view/Main/RmSpecificationV2#Resource_Requirement)

## STEP – ISO 10303

- STEP Schema:
  - Information model written in EXPRESS
- EXPRESS:
  - STEP's data definition language
- EXPRESS-G:
  - Graphical form of EXPRESS
- STEP File:
  - Populated STEP Schema
- Application Protocol (AP):
  - Implementable portion of STEP.S Schema for particular application.

## STEP – ISO 10303

### SCHEMA PBS

ENTITY Spare\_Part

ABSTRACT SUPERTYPE OF (ONEOF (Gear\_Shift, Piston));

Name: STRING;

electrical OPTIONAL Bulb

Mechanical OPTIONAL Piston

END\_ENTITY;

ENTITY Bulb

SUBTYPE OF (Spare\_Part);

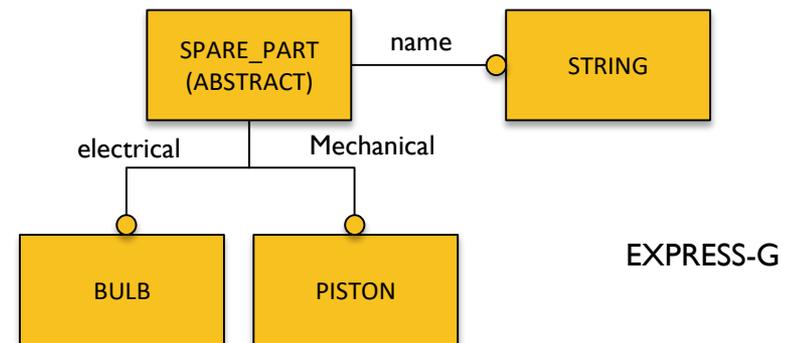
END\_ENTITY;

ENTITY Piston

SUBTYPE OF (Spare\_Part);

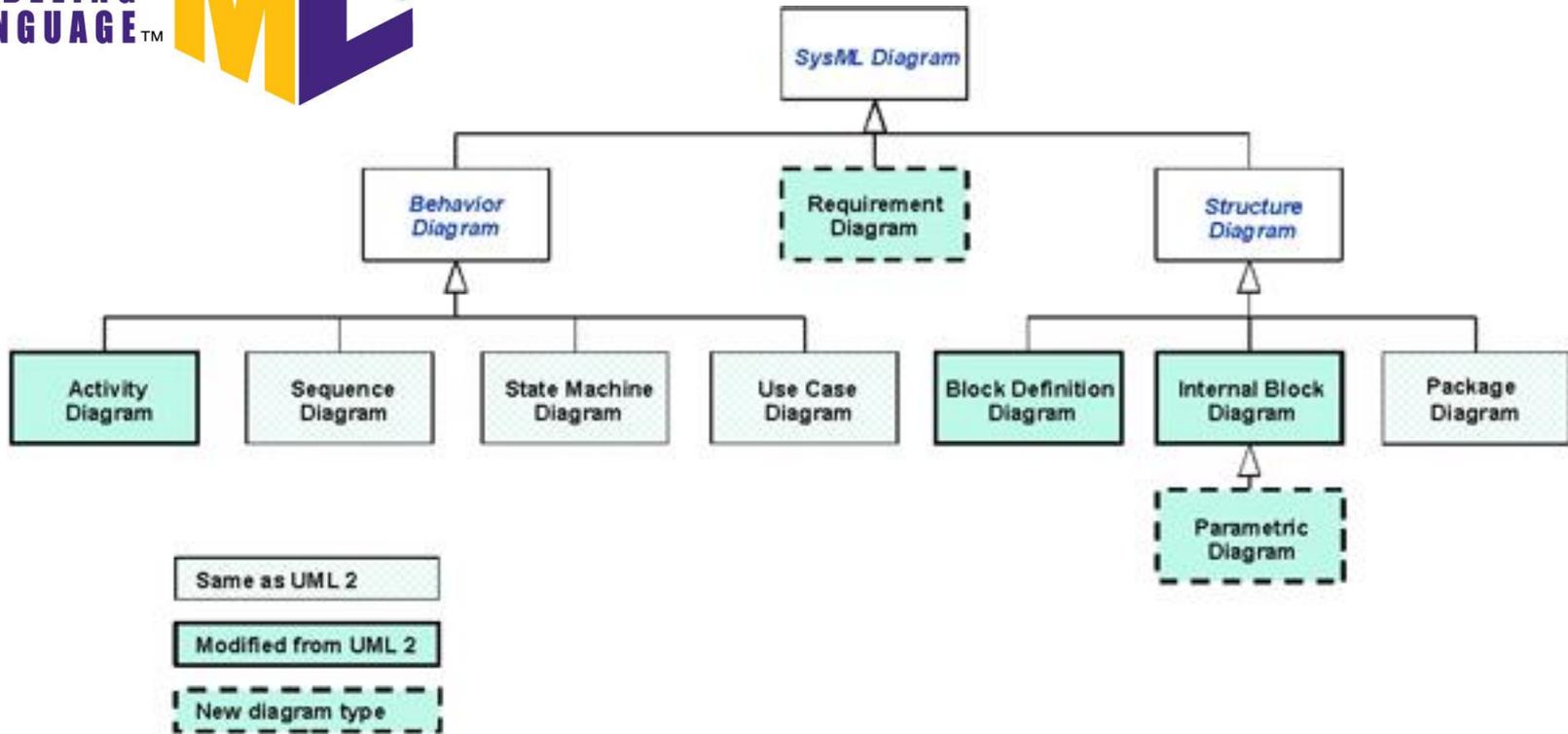
END\_ENTITY;

END\_SCHEMA;

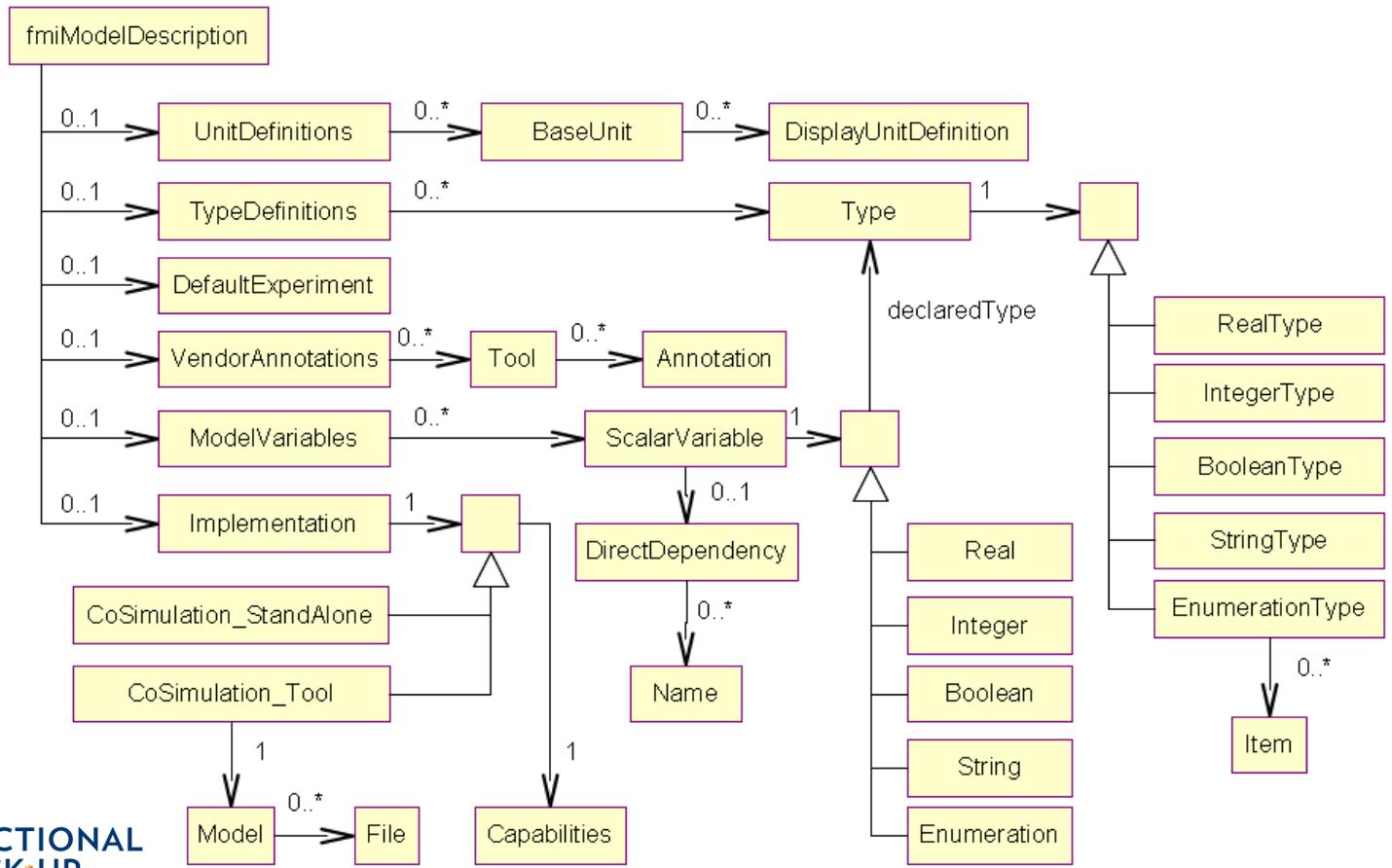


-- EXPRESS --

# SysML – Interoperability at Logical (Architectural) Level

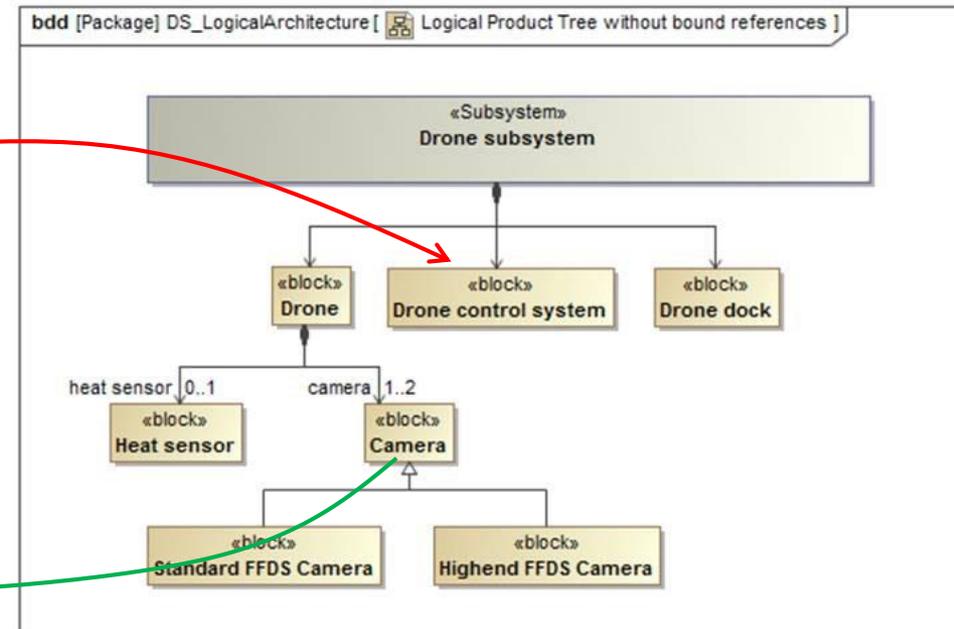
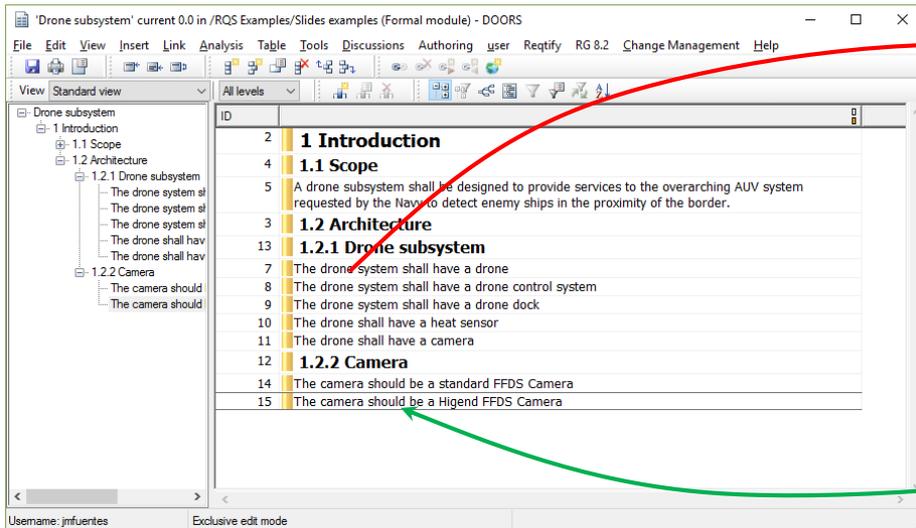


# FMI/ FMU – Interoperability at Physical (Mathematical) Level



[https://resources.qtronic.de/fmusdk/FmuSdk\\_reference.html](https://resources.qtronic.de/fmusdk/FmuSdk_reference.html)

So, if our problem is...

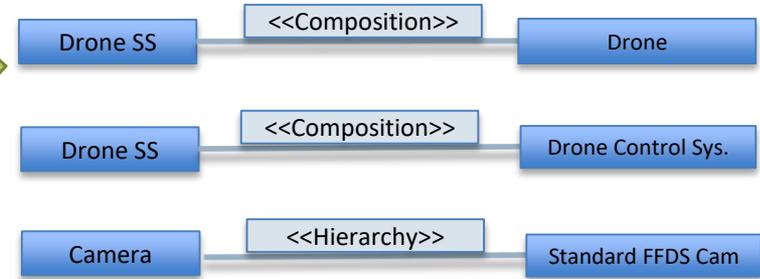
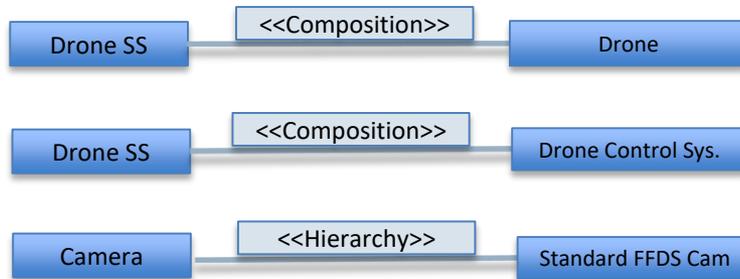
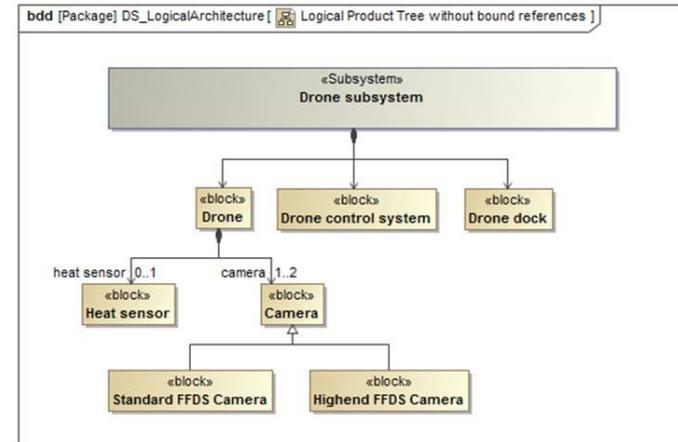
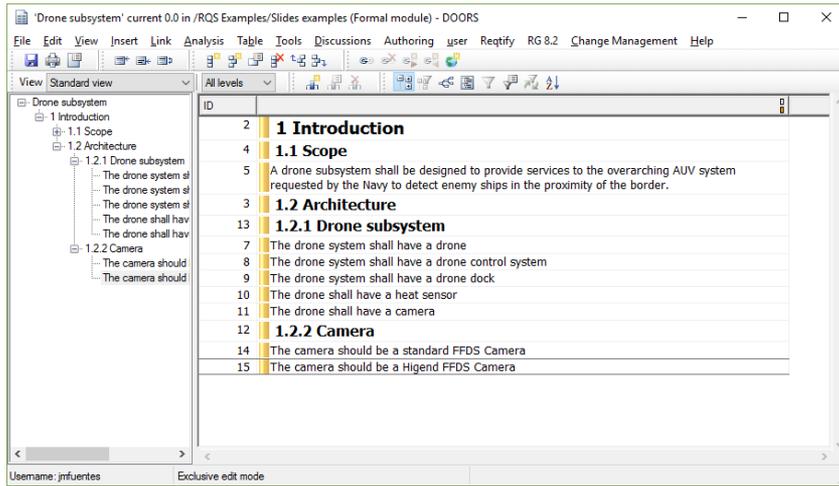


- Need for real **interoperability** implies a common way to represent inter domain knowledge

# Knowledge Centric Systems Engineering (KCSE)

The need of a common language  
- System Representation Language (SRL) -

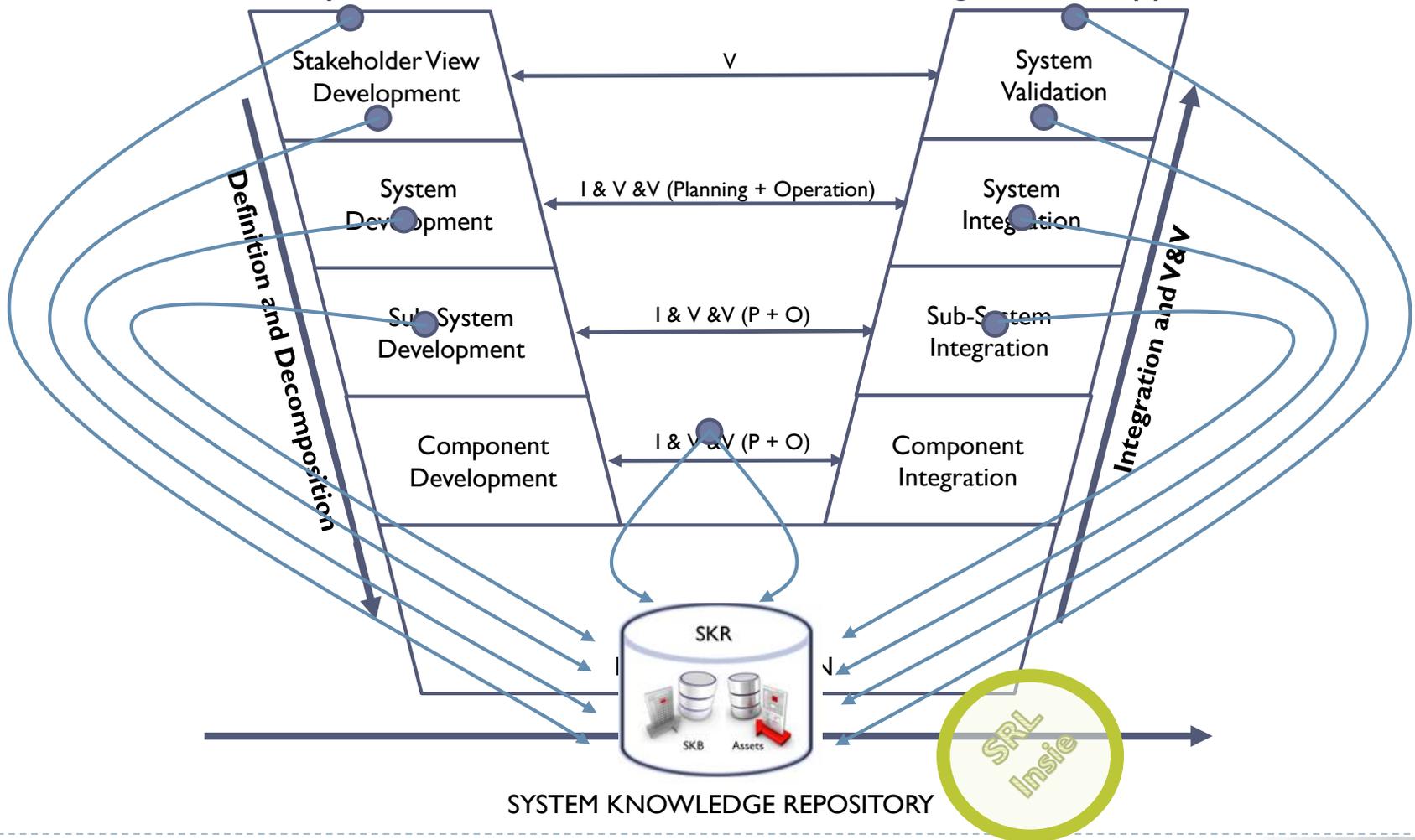
## Means to solution: Need for Inter (and not Intra) Operability



➤ Define a common language to represent Requirements and Models

# The GOAL

MBSE must smoothly integrate formal and structured information with fuzzy, flexible and necessary unstructured information in a knowledge centric approach

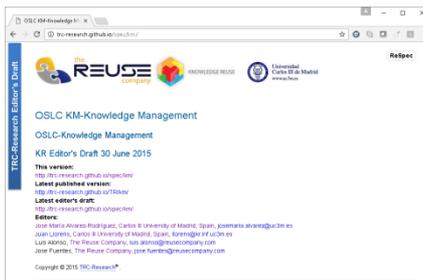


# SRL

System Representation Language

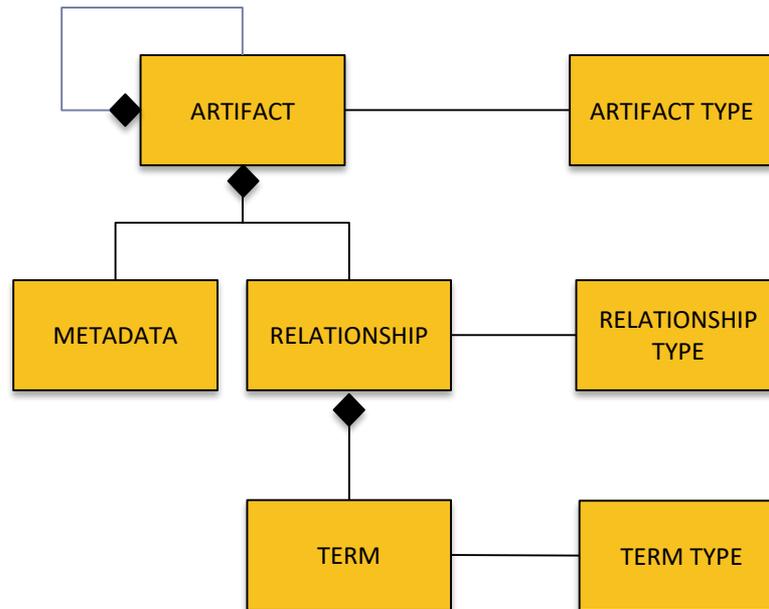
New **Domain**

New **Resource Shape**

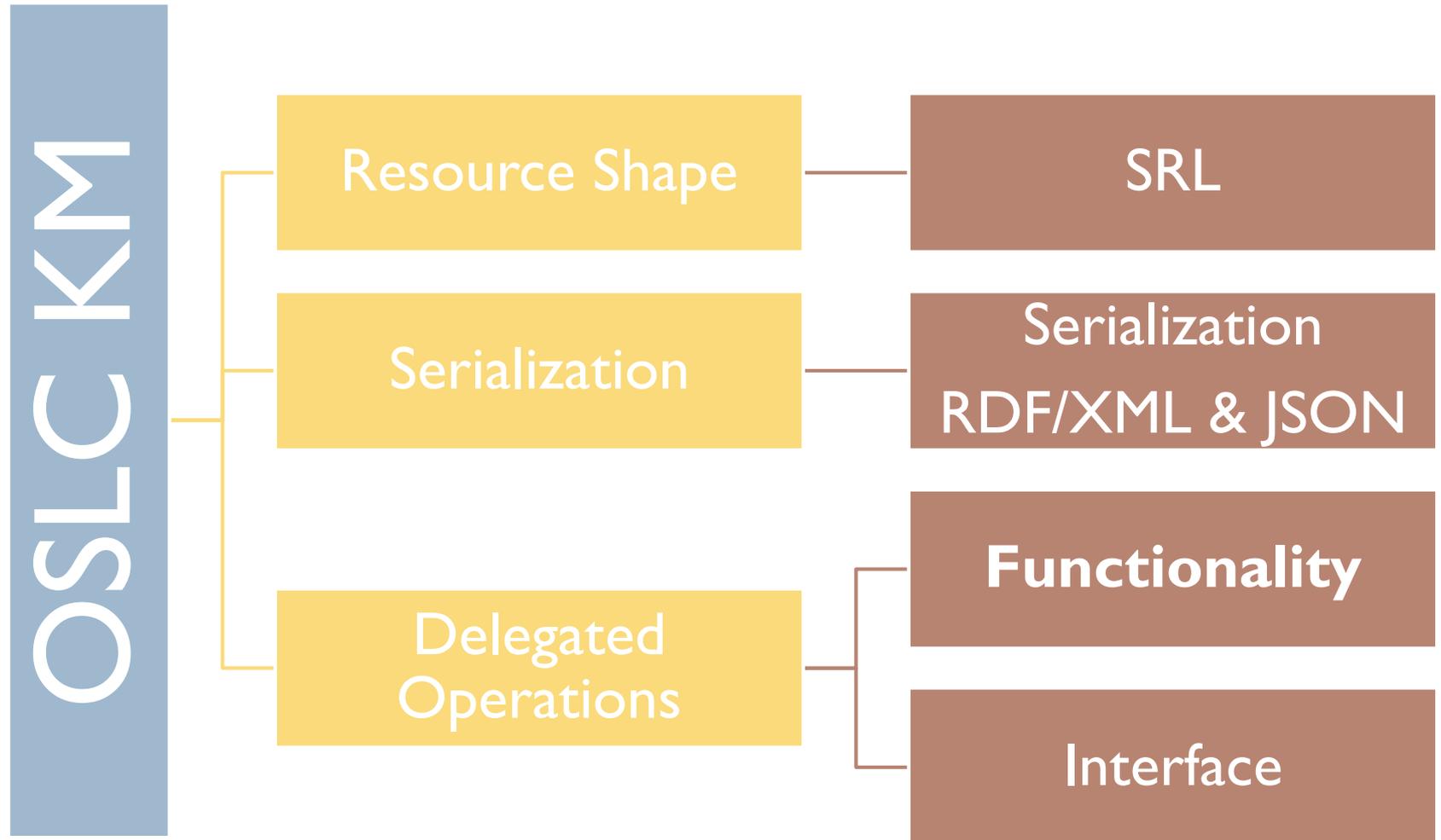


<http://trc-research.github.io/spec/km/>

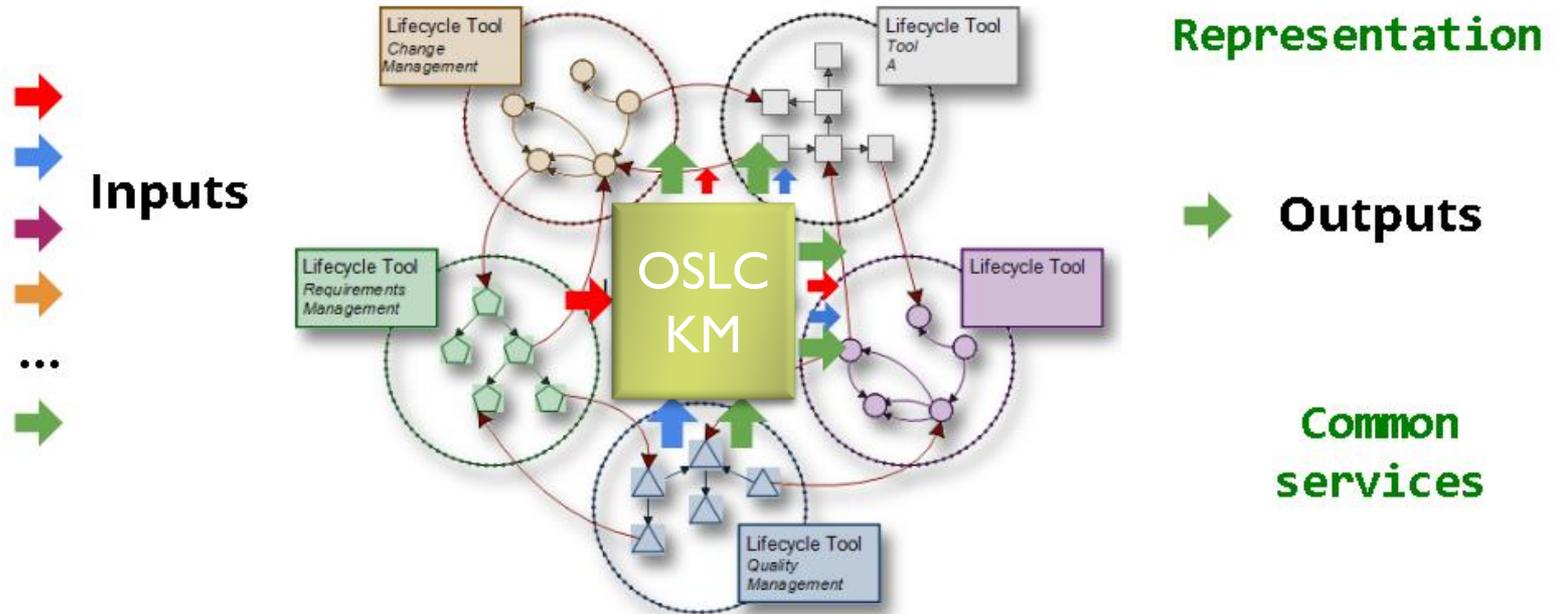
# System Representation Language (SRL) – Ground Metamodel



## The approach...



# Interoperability with OSLC KM



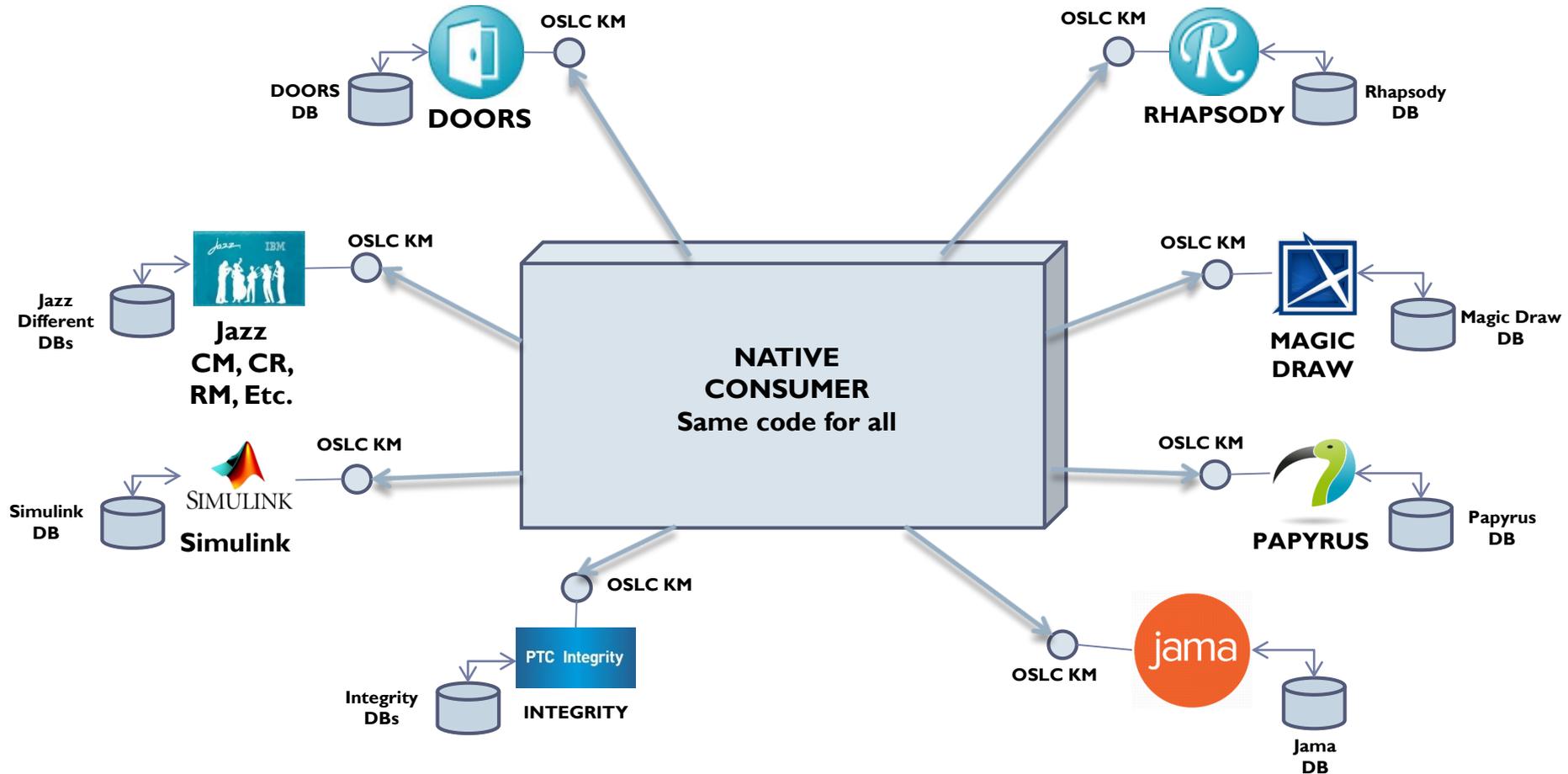
## Benefits of a common language within all the SE processes and activities

- The common language for communication purposes
  - Not specifically needed for humans to communicate (we use and will use Natural language)
  - Specifically needed for computers to communicate
  - The computers only have to “understand” one ADDITIONAL language besides the native representation language used in every different artifact (as we humans want to do)



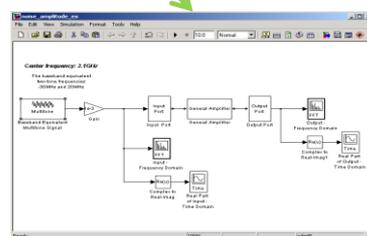
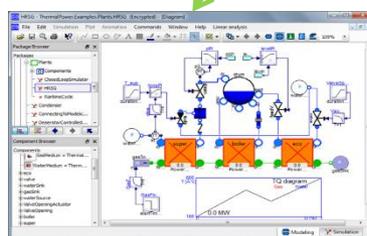
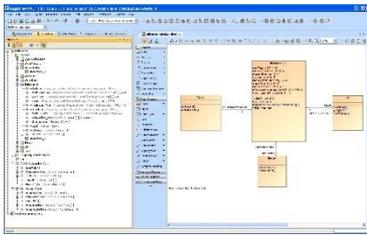
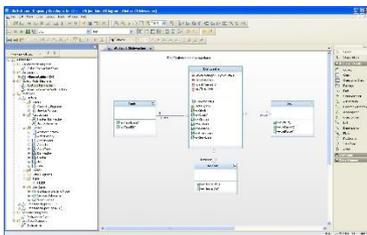
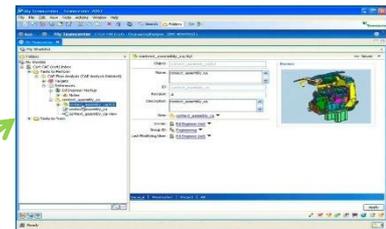
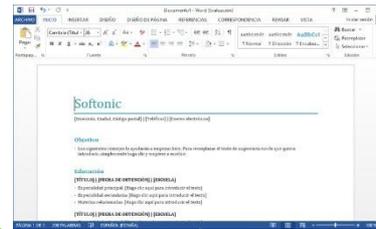
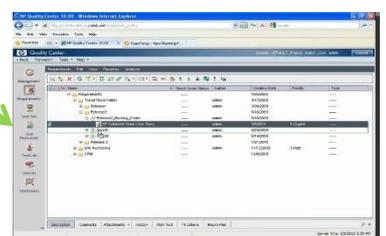
“One *language* to understand them all; one language to interoperate them all”

## Example : Access to all-kinds work-products content



## Ideal tool interoperability using OSLC KM

ID	Requirement	Priority
H4_Req_1	1 Calling the elevator	High
H4_Req_2	A potential passenger can be on any of the floors and can call an elevator by pressing either the up or button to call the elevator.	High
H4_Req_3	The potential passenger waits for the doors to open before entering into the elevator. The potential passenger now becomes a passenger	Medium
H4_Req_4	2 In the elevator	Medium
H4_Req_5	Once in an elevator, a passenger can select the floor or a number of floors where he wants to go to. floor	Medium
H4_Req_6	Each elevator will have a lot of floors to visit. Once the elevator has been called by a potential passenger or a passenger has selected a destination, then the elevator will move to the appropriate floor.	Medium
H4_Req_7	3 Elevator at selected floor	High
H4_Req_10	When the elevator has arrived at a floor and the doors have opened, then the passenger can get the elevator. room	High

Test Case	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail
TC1	Pass	Pass	Pass	Pass
TC2	Pass	Pass	Pass	Pass
TC3	Pass	Pass	Pass	Pass
TC4	Pass	Pass	Pass	Pass
TC5	Pass	Pass	Pass	Pass
TC6	Pass	Pass	Pass	Pass
TC7	Pass	Pass	Pass	Pass
TC8	Pass	Pass	Pass	Pass
TC9	Pass	Pass	Pass	Pass
TC10	Pass	Pass	Pass	Pass

## Case Study

# Automatic Traceability between Requirements and Models

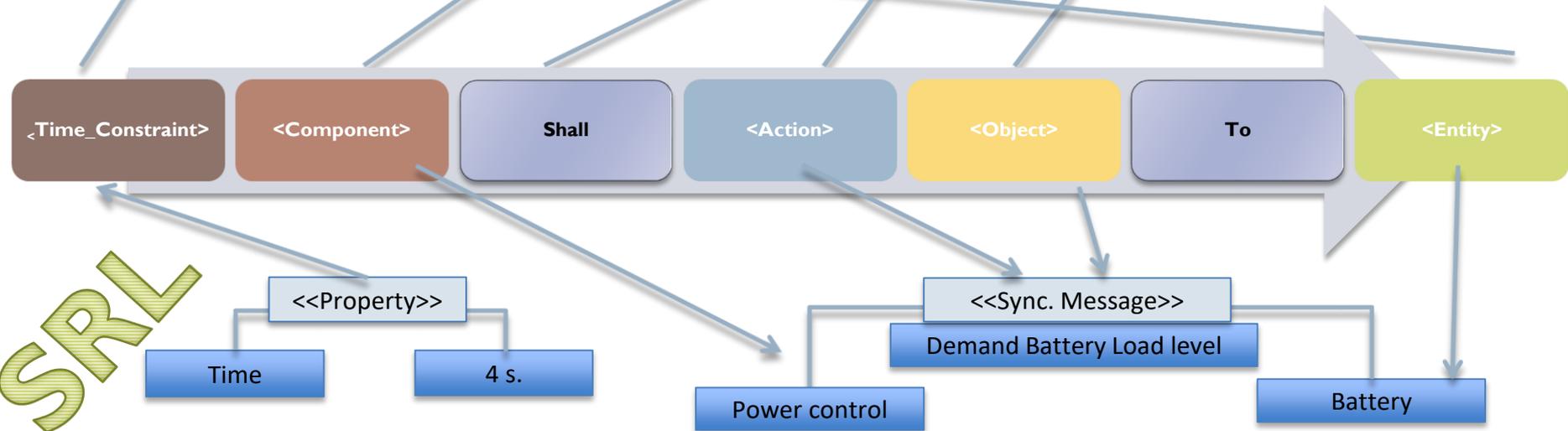
## Requirements Side:

### Representing Requirements (Natural Language) in SRL

# Basics: Formalization of Requirements Statements

- Necessary IT solutions that attempt to represent and formalize Requirements as Conceptual Graphs
- Using Ontologies and Requirements Patterns

UR044: - Every 4 seconds, the power control system shall send a "demand battery load level" message to the battery



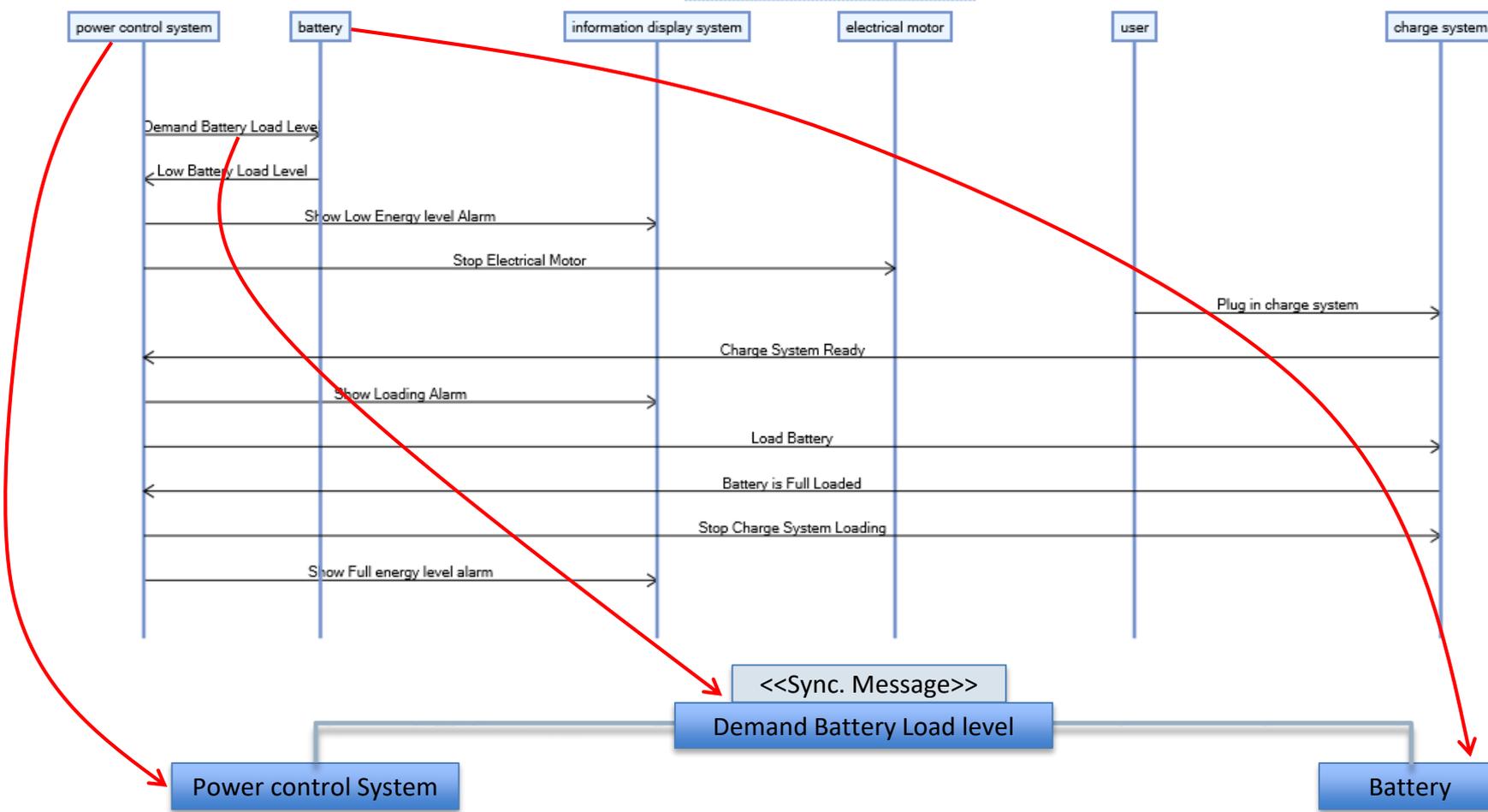
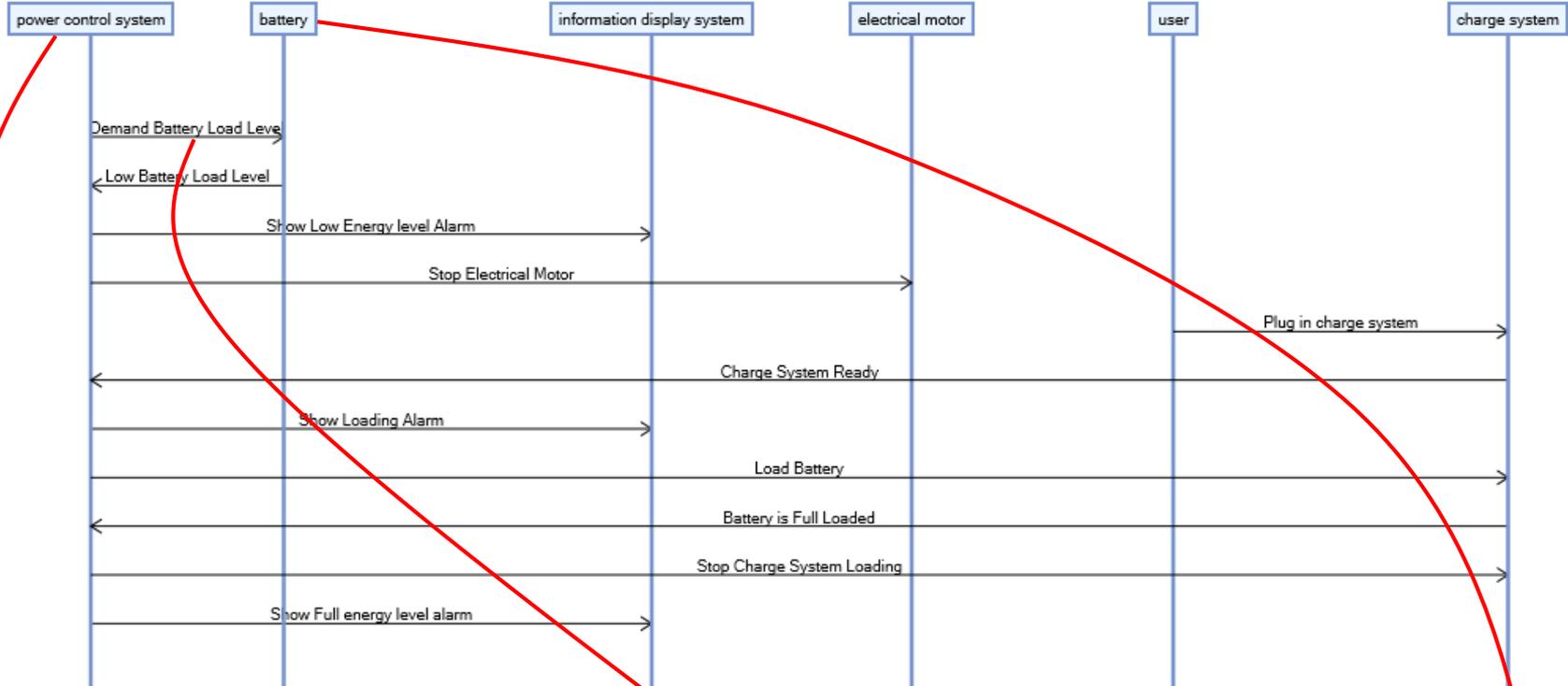
SRL

## Models Side:

# Representing Sequence Diagrams in SRL

# Structured Information -> SRL: a Straightforward transformation

UML SEQUENCE DIAGRAM



# Knowledge Centric Systems Engineering

## Traceability

Requirements Quality Analyzer

3-Electrical Power System Reqs

Requirements

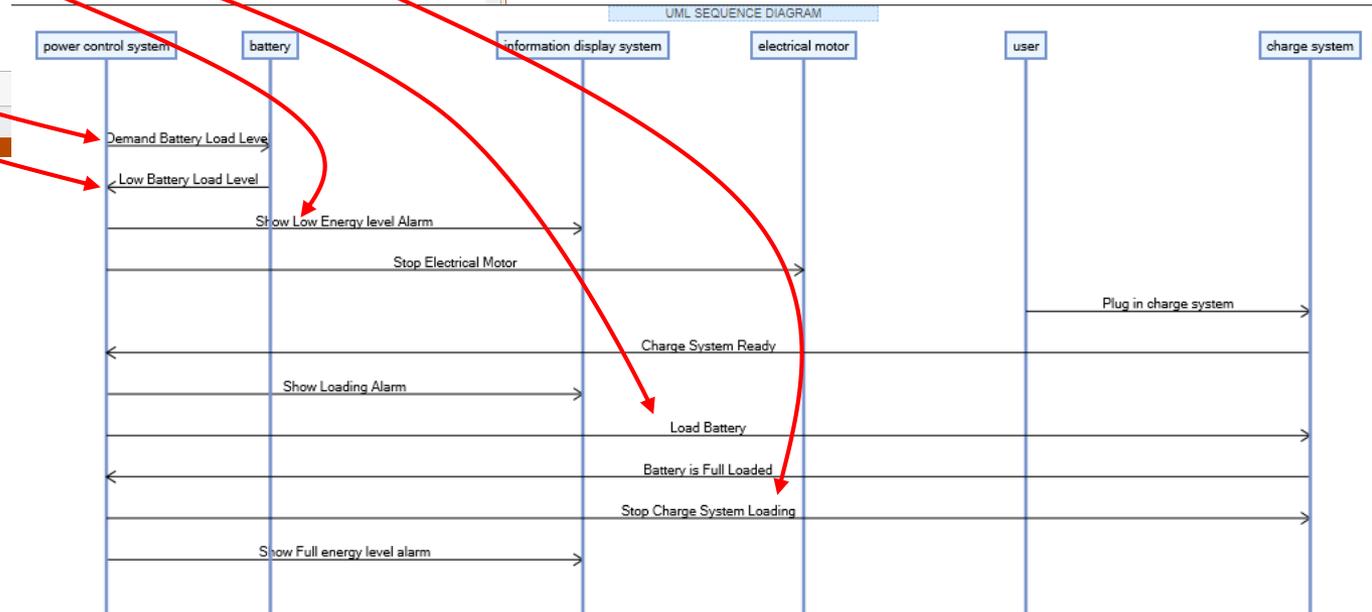
ID	Text	Correctness	Score	Mandatory me...	Correctness qu...	Consistency	Issues
1	every 1 seconds, the power control system shall send a demand battery load level message to the ba...	☆☆☆	1.73	0	04/03/2016 13...	☆☆☆☆	0
2	when the voltage level is below 11.5V, the battery shall send a "low battery load level" message to the...	☆☆☆	20.00	1	04/03/2016 13...	☆☆☆☆	0
3	if the battery is low, the power control system shall send a "show low energy level alarm" signal to the...	☆☆☆	1.82	0	04/03/2016 13...	☆☆☆☆	0
4	The user must plug in the cable to the electrical power	☆☆☆	1.53	0	04/03/2016 13...	☆☆☆☆	0
5	When the bicycle is charging, the power control system shall send a "Charge battery" signal to the ch...	☆☆☆	2.40	0	04/03/2016 13...	☆☆☆☆	0
6	When the battery is loading, the charge system shall send a "charge system loading" message to the...	☆☆☆	1.92	0	26/03/2016 18...	☆☆☆☆	0

Total requirements: 6

RMS Repository: Requirements; Project: Bicycle Requirements.xls RMS User: Llorens-tablet@lorens

Matches requirements with relationships between elements of whatever model

Checks if the requirements specification covers all the relationships in the model, or the contrary.



Resolved at SRL Level

## 4-Traceability KPI (KPP)

- (In)-Completeness of Requirements specs against models
  - This metric compares the number of Relationship that are extracted from the requirements specification (through requirements patterns formalizations) with the Relationships that are extracted from a set of models accessed by OSLC KM
  - Returns a % value (from 0 to 1) representing the coverage ratio:

$$Ratio = \frac{\text{Relationships found in the selected Model(s)} \\ \text{that are **not** found in the Requirements Specification}}{\text{All relationships found in the selected Model(s)}}$$

0 = 0% = nothing in the model(s) is missing in the Spec

1 = 100% = everything represented in the model(s) is missing in the Spec

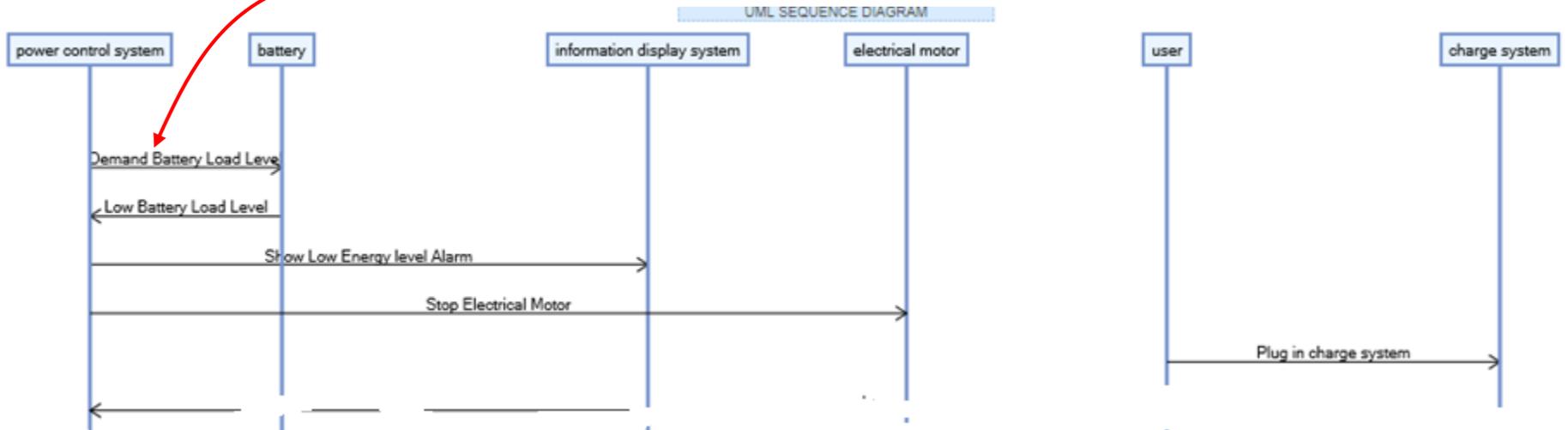
## 4-Models-Content Coverage Example: Requirements Spec

- Every 4 seconds, the power control system shall send a "demand battery load level" message to the battery
- When the voltage level is below 11,5V, the battery shall send a "low battery load level" message to the power control system.
- If the battery is low, the power control system shall send a "show low energy level alarm" signal to the information display system
- The user must plug in the bicycle to the electrical power
- When the bicycle is charging, the power control system shall send a "Load battery" signal to the charge system.
- When the battery is loaded, the charge system shall send a "stop charge system Loading" message to the Power control system

➤ Total number of Requirements in Specification = 6

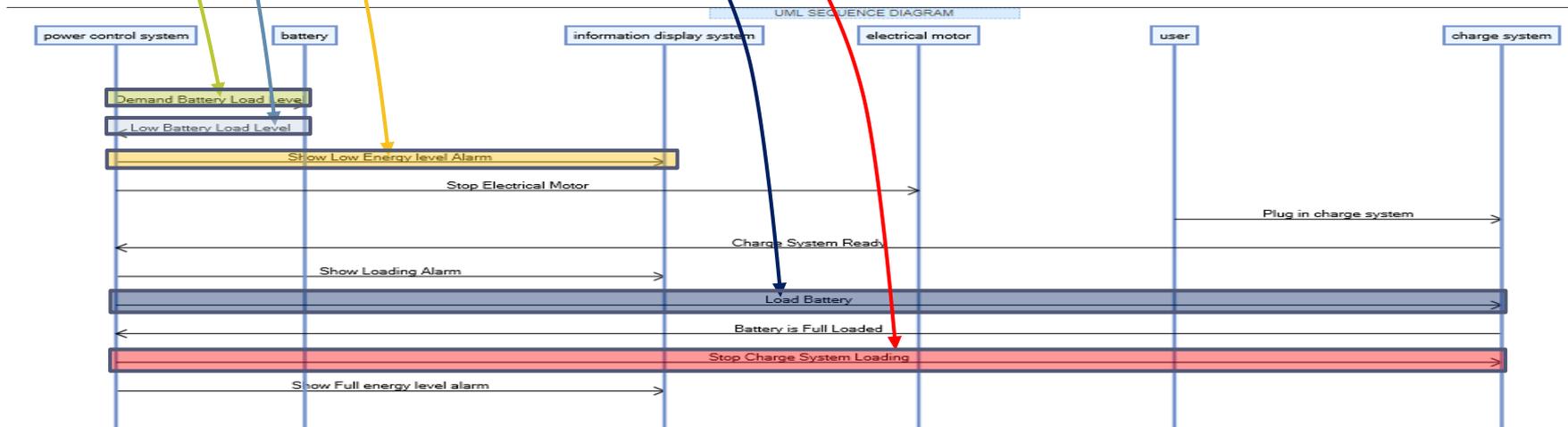
# 4-Models-Content Coverage Example: Matching process

every 4 seconds, the **power control system** shall **send** a "demand battery load level" message to the **battery**



## 4-Models-Content Coverage: Calculations

- Every 4 seconds, the power control system shall send a "demand battery load level" message to the battery
- When the voltage level is below 11,5V, the battery shall send a "low battery load level" message to the power control system.
- If the battery is low, the power control system shall send a "show low energy level alarm" signal to the information display system
- The user must plug in the bicycle to the electrical power
- When the bicycle is charging, the power control system shall send a "Load battery" signal to the charge system.
- When the battery is loaded, the charge system shall send a "stop charge system Loading" message to the Power control system



- Total number of Matches = 5
- Number of Requirements with no match in the model = 1
- Number of transitions in the model with no match in requirements = 6

## 4-Models-Content Coverage: Calculations

- ▶ Incompleteness Coverage =  $6/11 = 54.55\%$  → returned value = 0.55
  - ▶ The specification is 55% incomplete!
  
- ▶ It controls all the relationships (11)
  - ▶ Even if they are duplicated between the same 2 elements

## Other scenarios based on a knowledge centric approach

- Consistency checking among different disciplines
- Traceability discovery
- Work product reuse: based on semantic retrieval
- Automatic creation of work products along the left part of the “V”
- Quality Analysis scoreboard
- Requirements translation

## Contact information



José M. Fuentes



jose.fuentes@reusecompany.com



+34 912 17 25 96



@ReuseCompany



<https://www.linkedin.com/in/josemiguel Fuentes/>



