



Automatic Traceability between Models and Requirements

Trigger for SE Interoperability



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



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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....

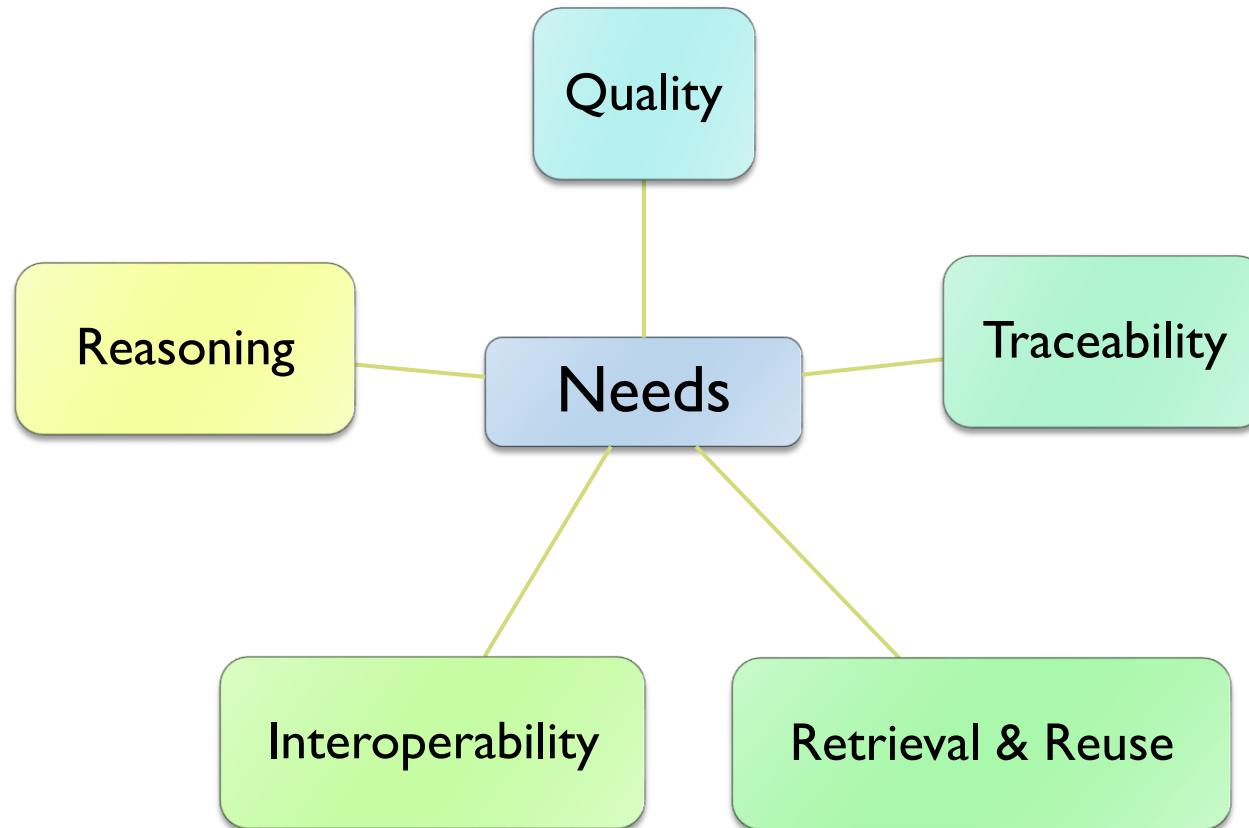
Model Based Systems Engineering (MBSE)

- *“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 SE Vision 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)

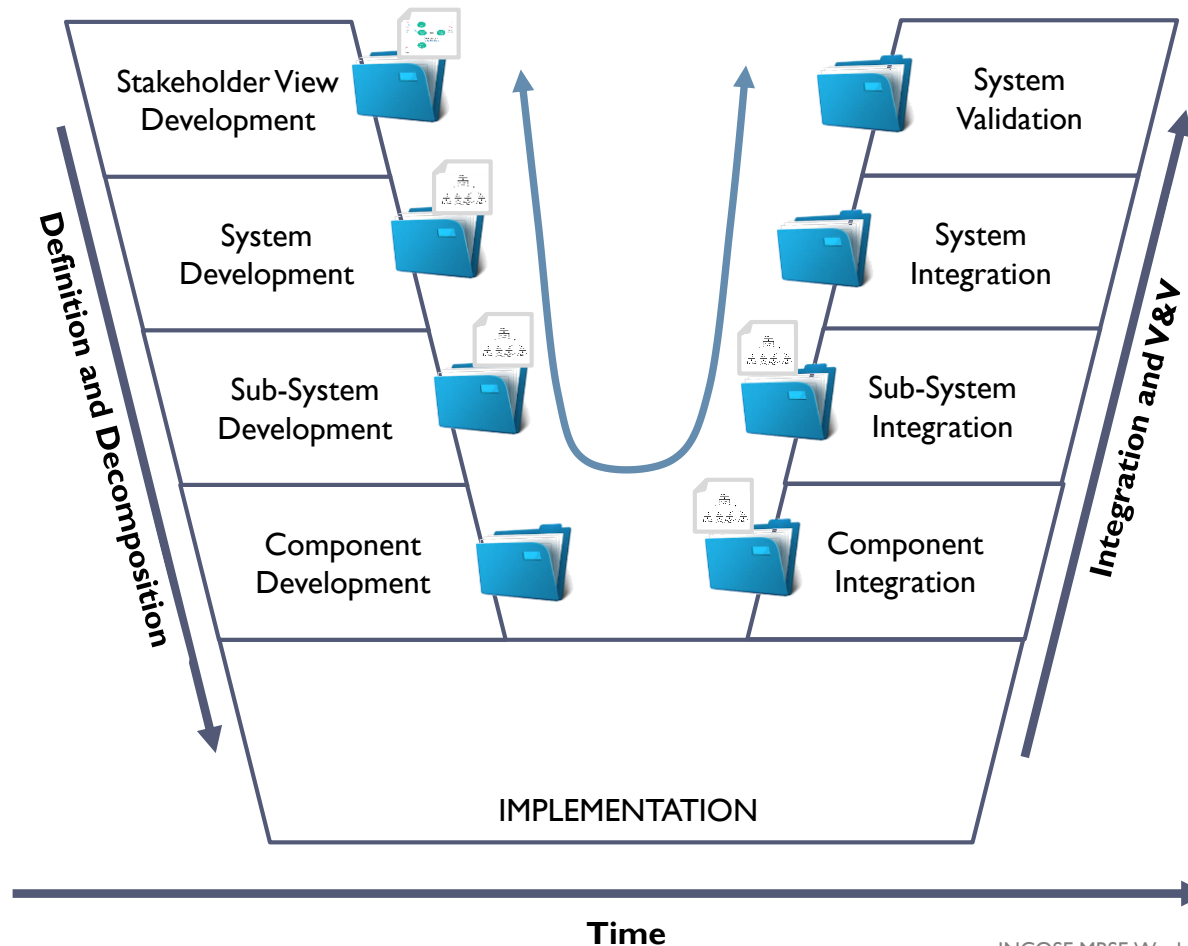
Current needs in SE



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

Systems Engineering – From Document Centric (DBSE)

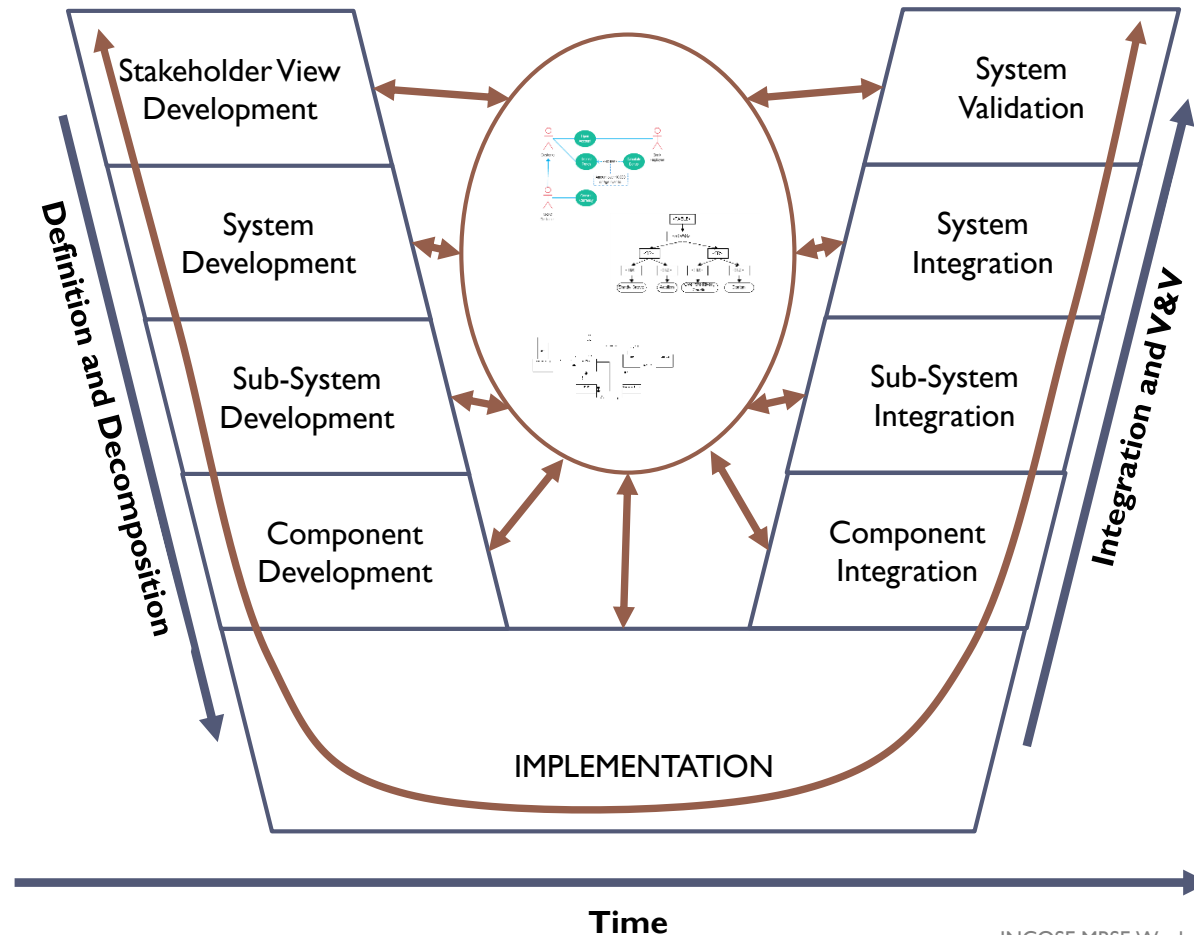
Stand-alone models related through documents. Documents are part of configuration management systems.



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



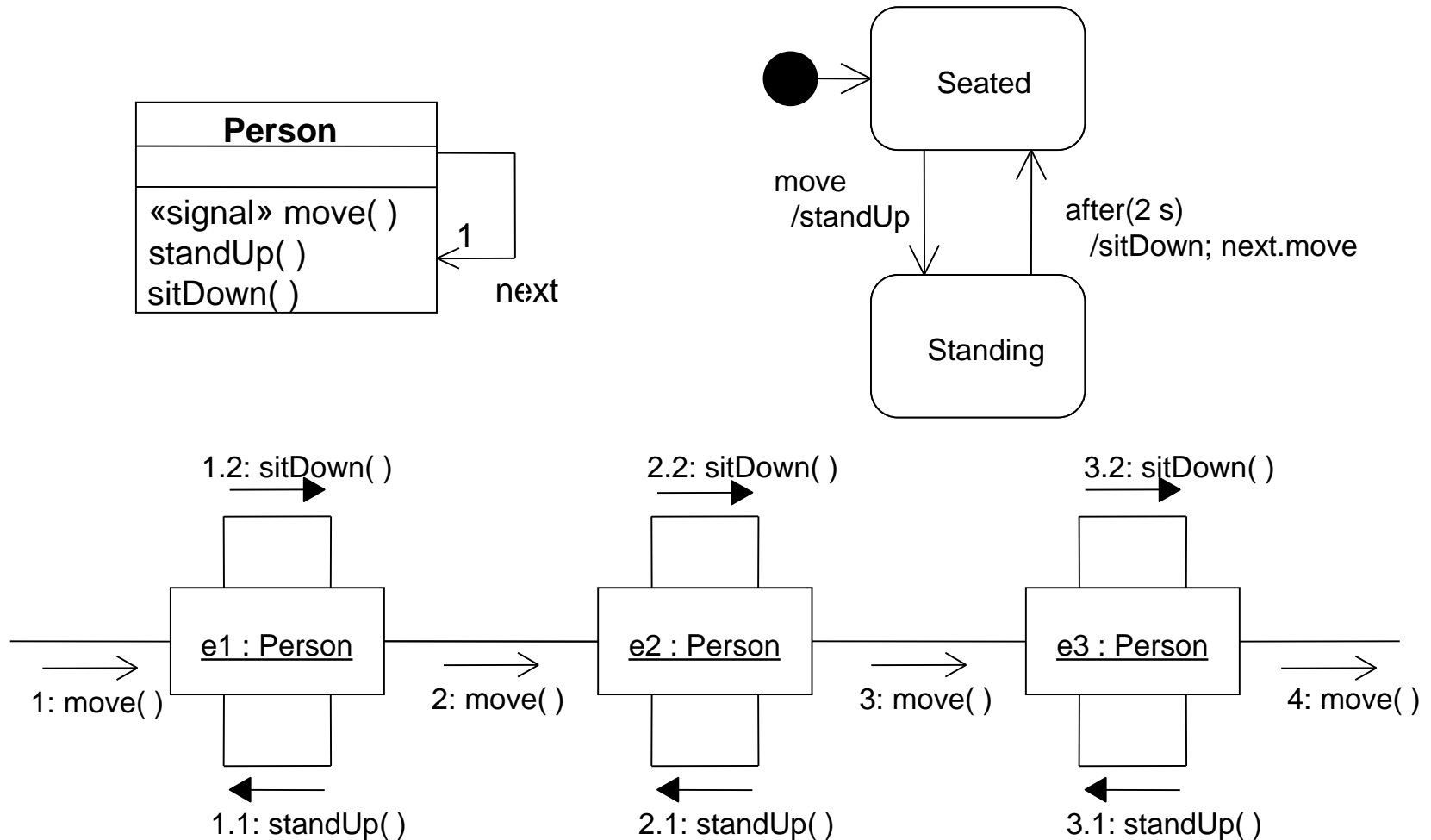
INCOSE MBSE Workshop, Jan 2014

Model Based Systems Engineering (MBSE)

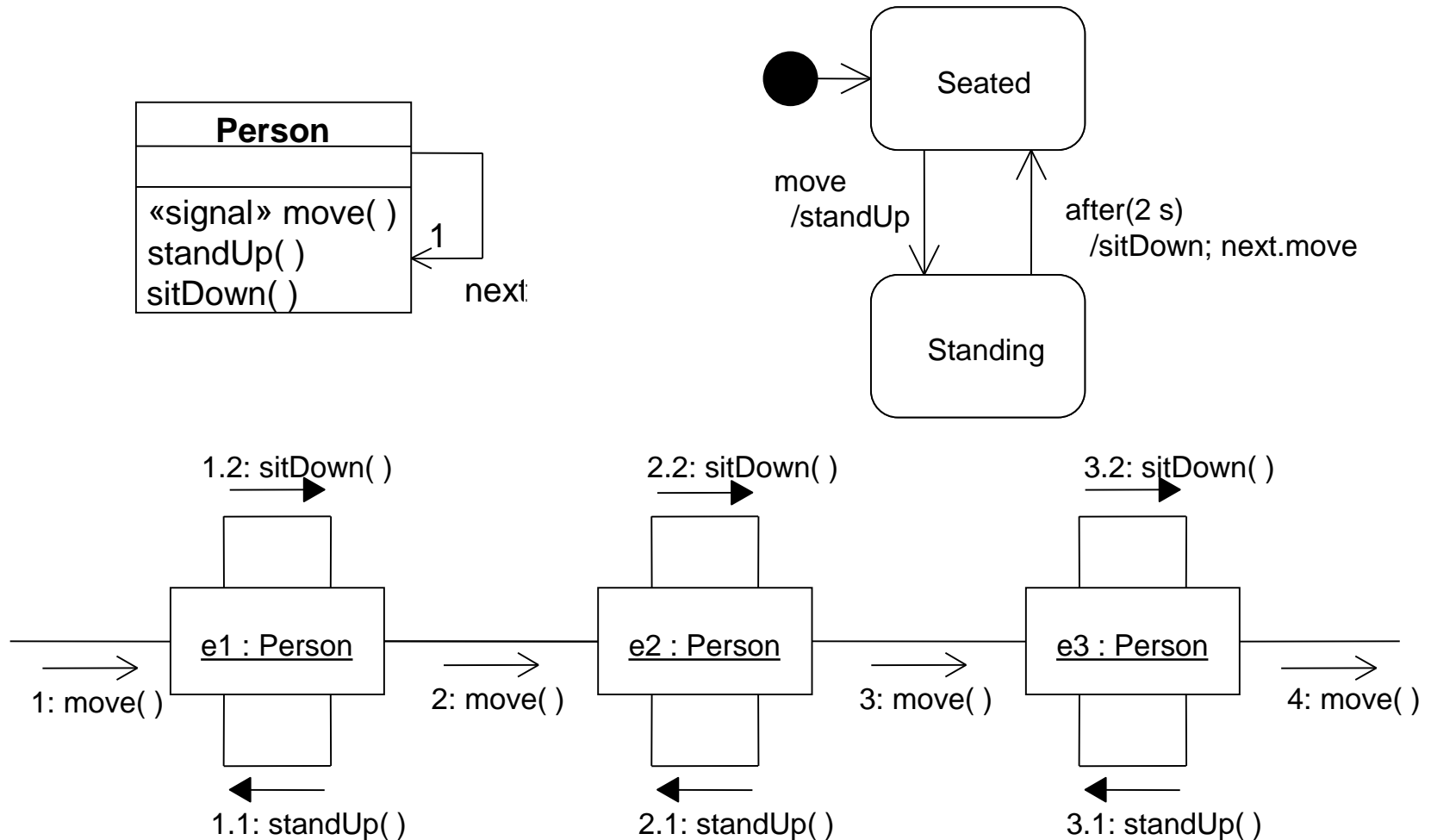
But...

- 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?



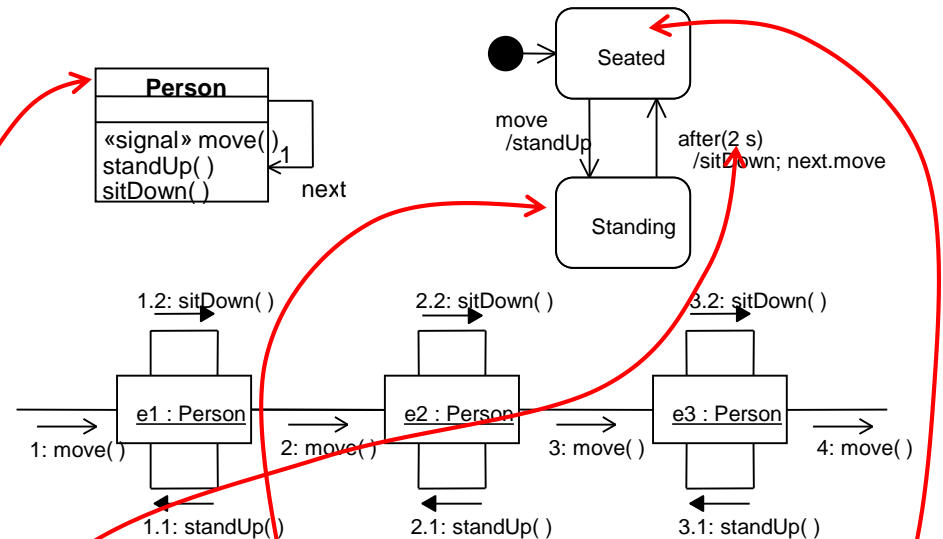
It is clear what I want to model, right?



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?

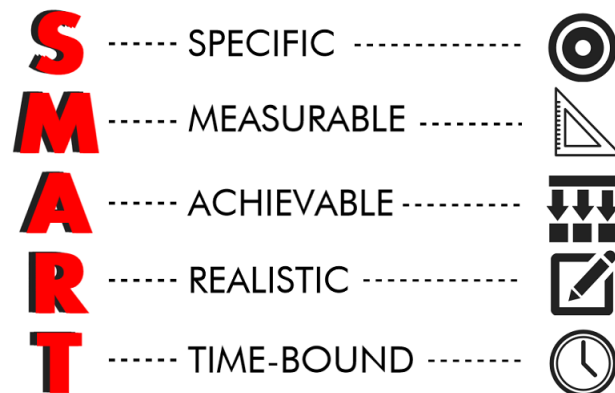
- Not really!!
- Natural Language can be really ambiguous

**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

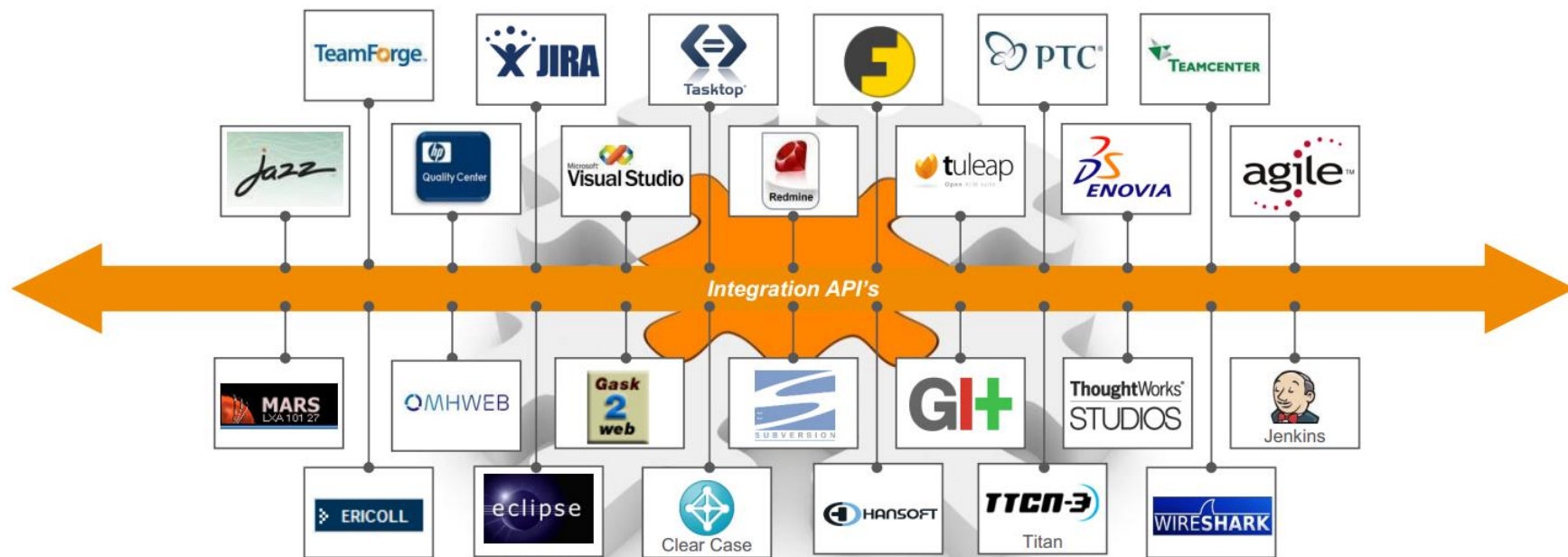
- We need the best of both worlds
- ... and we need to connect both worlds
- Both, for humans and also for computers
- What must be the **glue** in the middle of both worlds?



Knowledge Centric Systems Engineering

Interoperability needs

“A real engineering environment...”



Mats Berglund (Ericsson) <http://www.ices.kth.se/upload/events/I3/84404189f85d41a6a7d1cafd0db4ee80.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

File Edit View Insert Link Analysis Table Tools Discussions Authoring user Rectify RG 8.2 Change Management Help

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 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 Higend FFDS Camera

ID

ID	Text
2	1 Introduction
4	1.1 Scope
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	1.2 Architecture
13	1.2.1 Drone subsystem
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	1.2.2 Camera
14	The camera should be a standard FFDS Camera
15	The camera should be a Higend FFDS Camera

Username: jmfuentes Exclusive edit mode

Requirements Authoring Tool

File Authoring

Drone subsystem

Module selector

View: Simple view, Quality view, Full view

Requirements: New, Edit, Remove

Import: Paste requirements, Extract requirements

Knowledge base: Suggestions

Requirements:

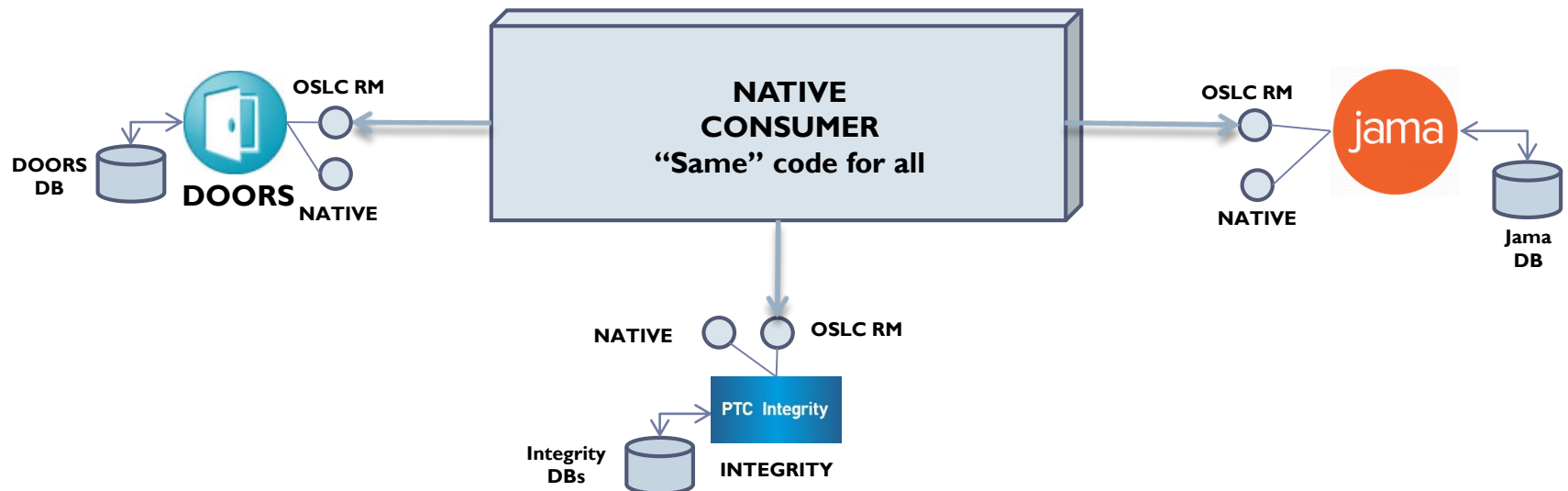
ID	Label	Text	Correctness	Score	Co...	Consistency	Issues
2	Introduction		★ ★ ★	N/A	0	★ ★ ★	N/A
4	Scope		★ ★ ★	N/A	0	★ ★ ★	N/A
5	N/A	A drone subsystem shall be designed to prov...	★ ★ ★	N/A	0	★ ★ ★	N/A
3	Architecture		★ ★ ★	N/A	0	★ ★ ★	N/A
13	Drone subsystem		★ ★ ★	N/A	0	★ ★ ★	N/A
7	N/A	The drone system 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 Higend FFDS Camera	★ ★ ★	N/A	0	★ ★ ★	N/A

Total requirements: 13

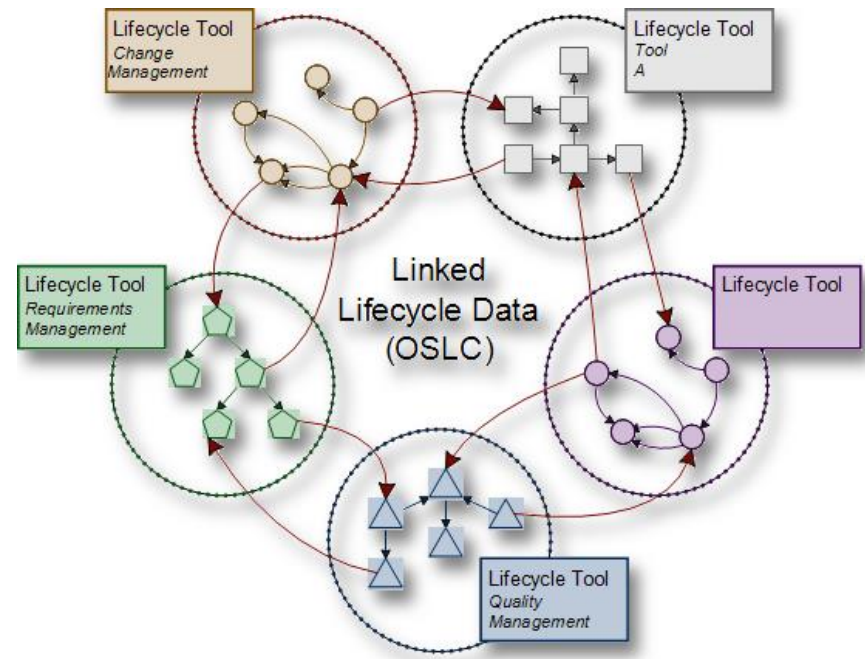
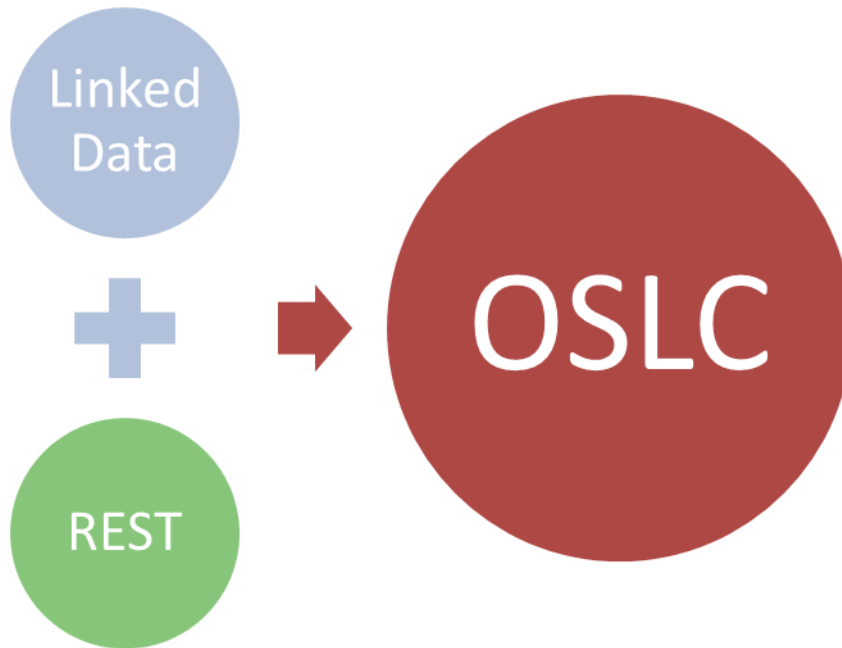
RMS Repository: 36677@localhost; Project: Slides examples; User: jmfuentes

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

OSLC Building blocks (keywords)

REST Architect.

- Resource-oriented

RDF (graph data model)

Linked Data

Serialization

- RDF/XML & JSON

Service Provider

Resource Shape

Query Capability

Configuration Management

Delegated User Interface

Authentication

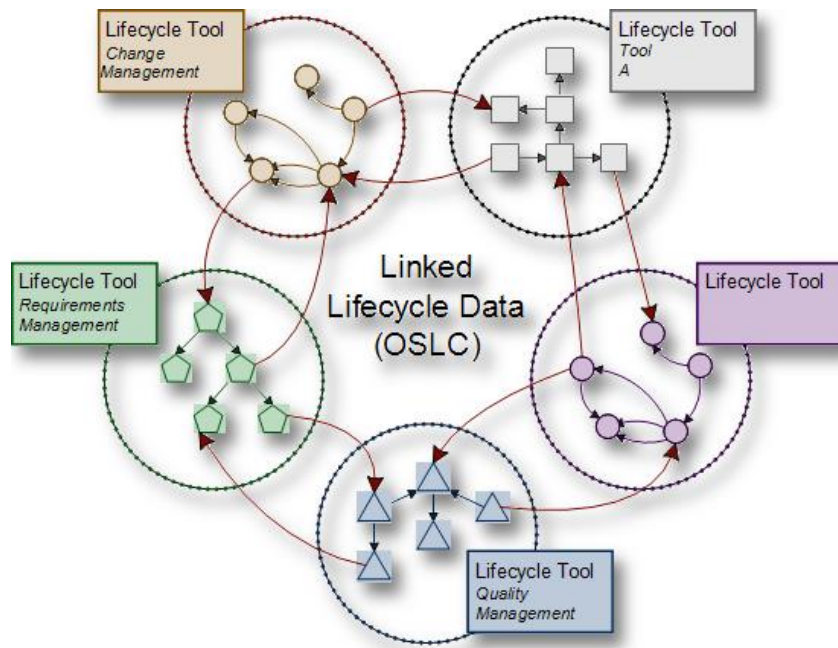
- OAUTH 2.0

Resource

- Collection

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
OSLC Core: Common Properties						
dcterms:title	exactly-one	unspecified	XMLLiteral	n/a	n/a	Title (reference: Dublin Core) of the resource represented as rich text in XHTML content. SHOULD include only content that is valid inside an XHTML 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. SHOULD 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. SHOULD include only content that is valid inside an XHTML 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

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);

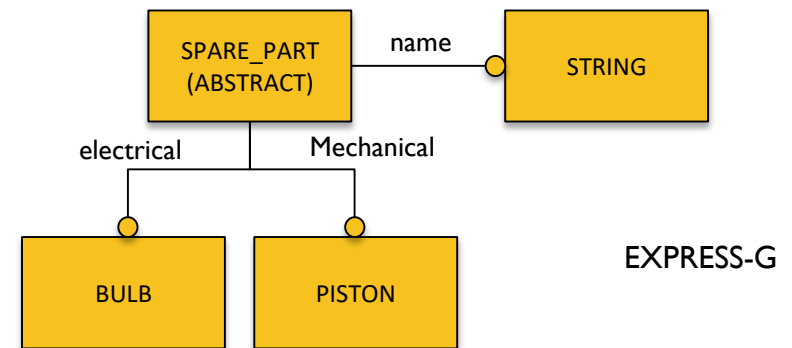
END_ENTITY;

ENTITY Piston

SUBTYPE OF (Spare_Part);

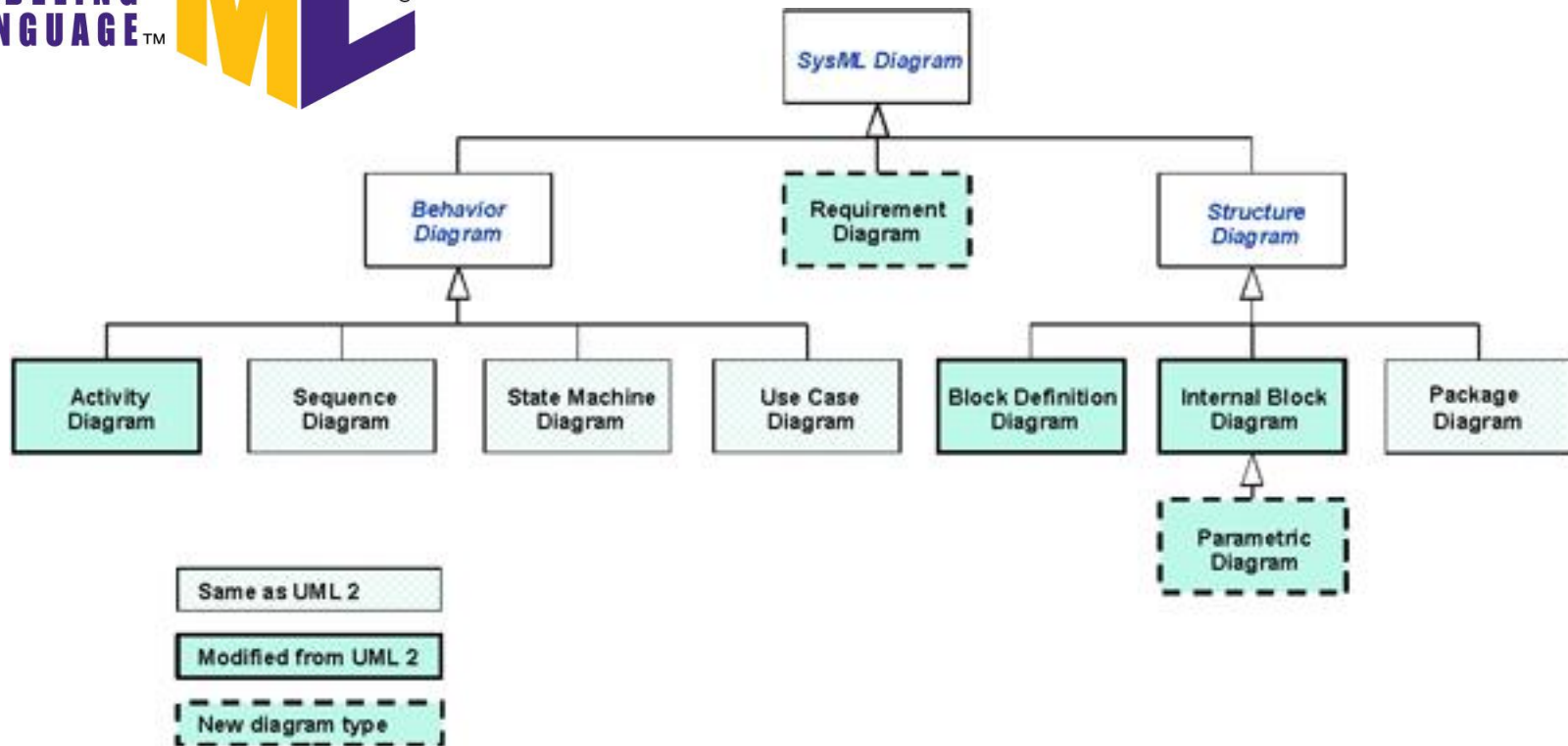
END_ENTITY;

END_SCHEMA;

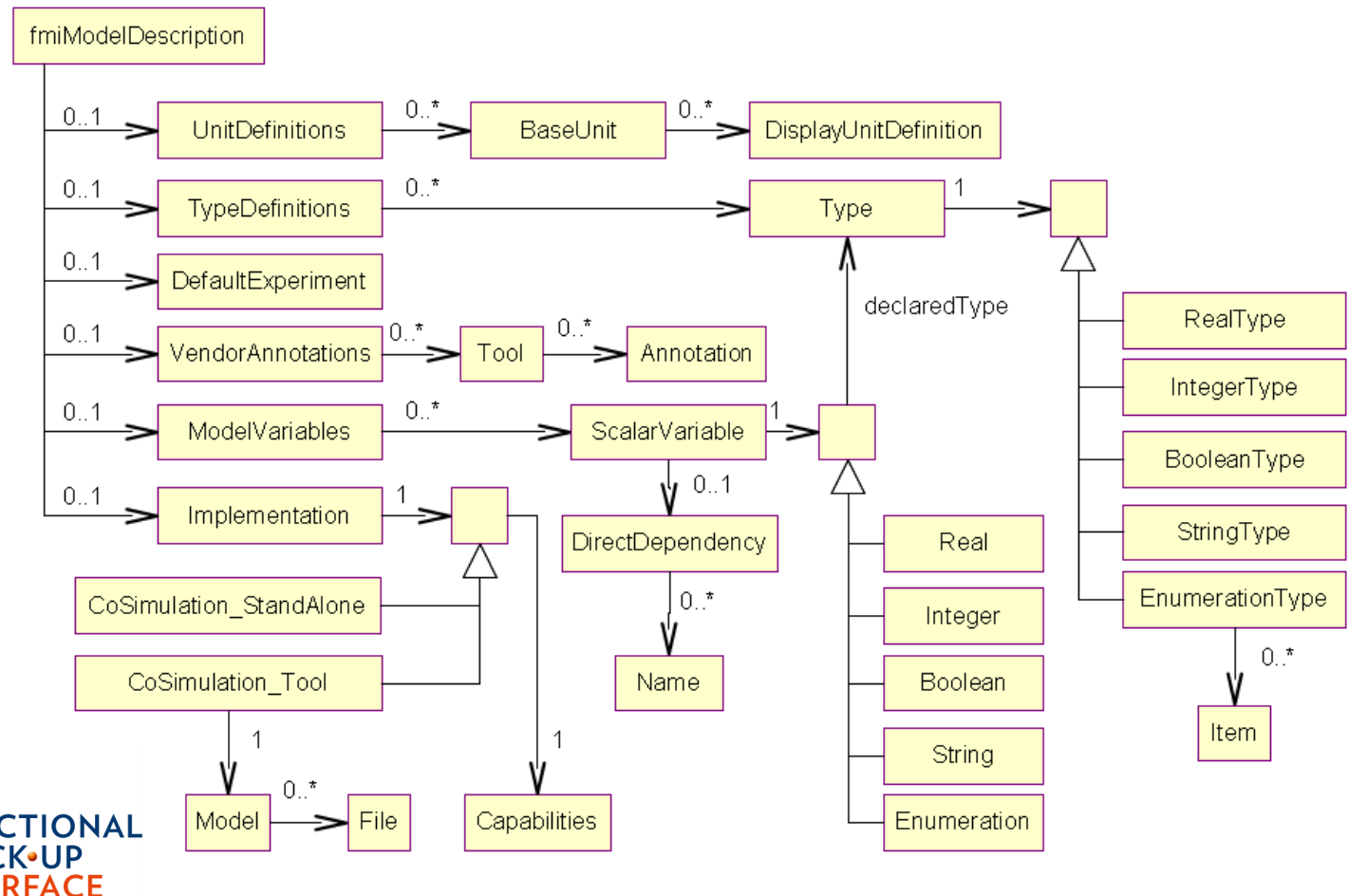


-- EXPRESS --

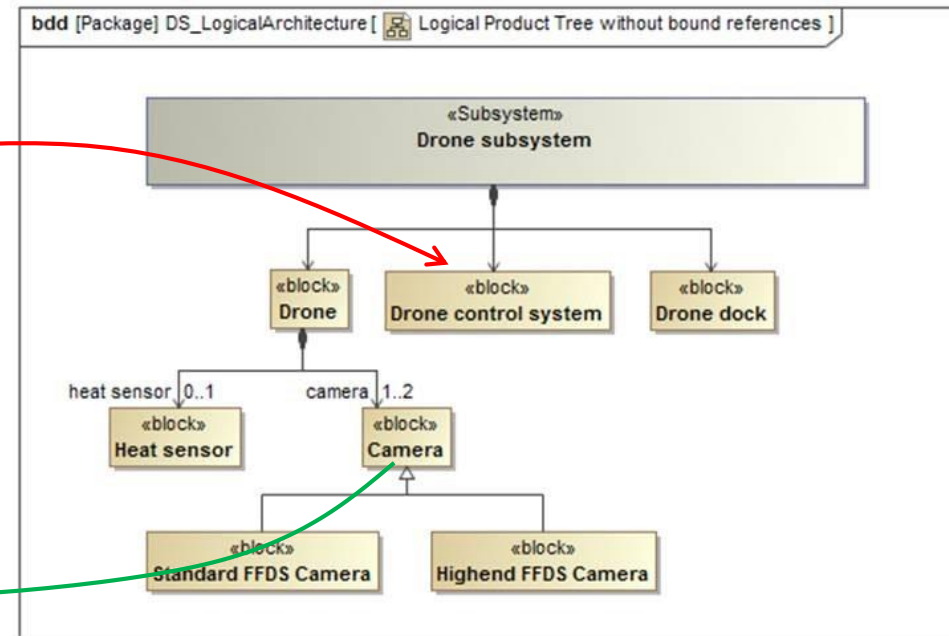
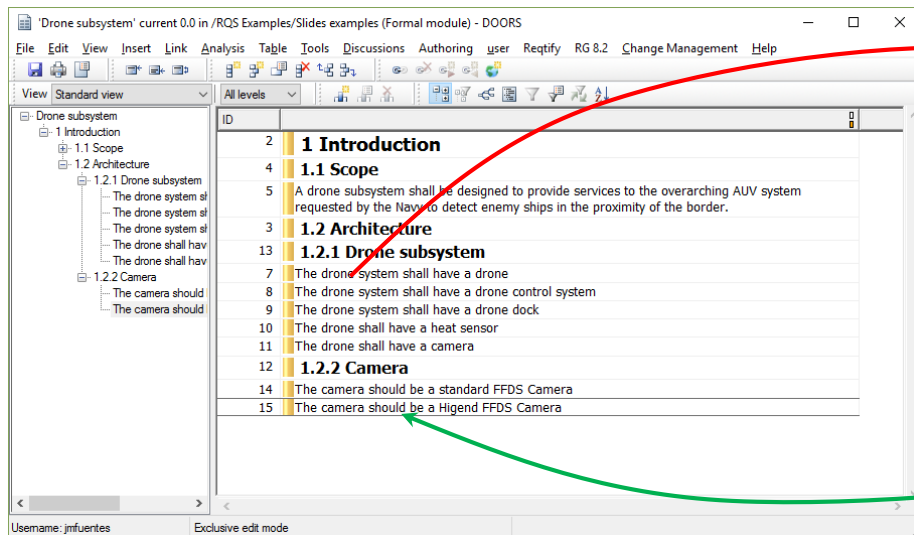
SysML – Interoperability at Logical (Architectural) Level



FMI/FMU – Interoperability at Physical (Mathematical) Level



So, if our problem is...

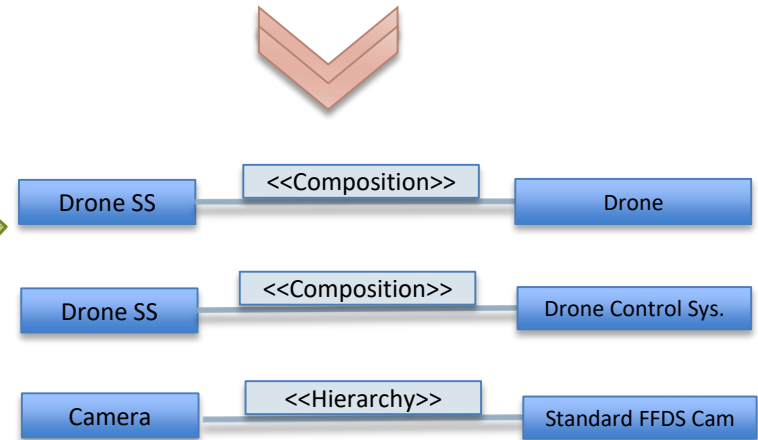
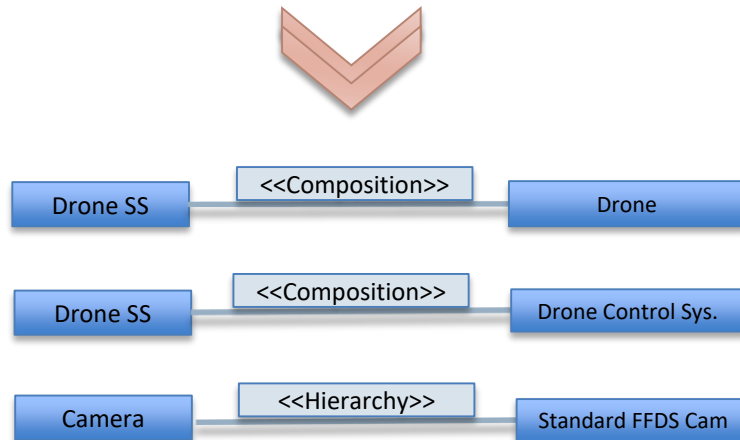
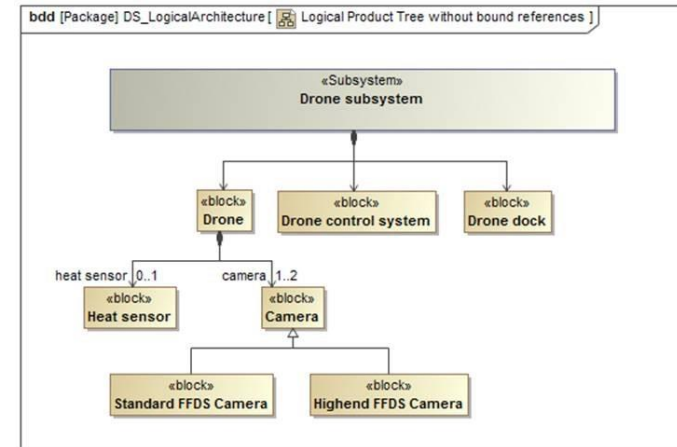
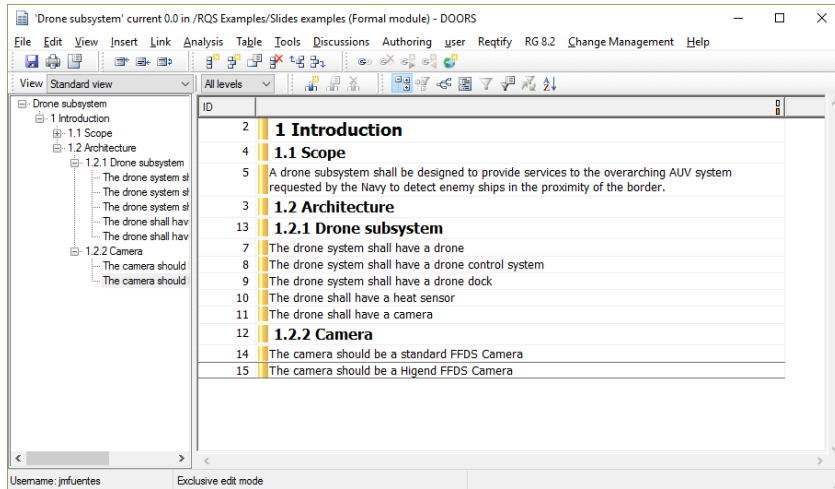


- Need for real **interoperability** implies a common way to represent inter domain knowledge

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

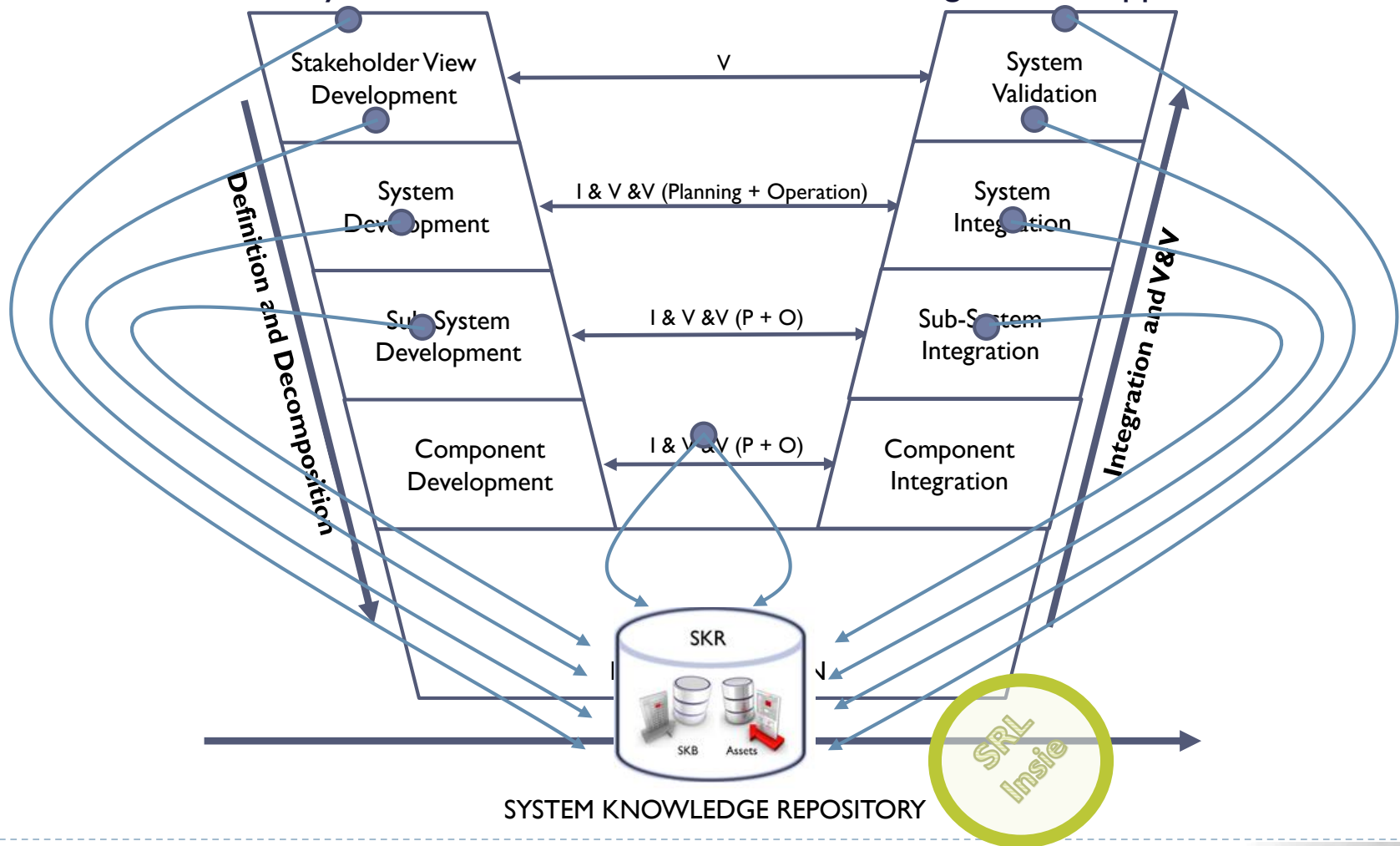


SRL

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

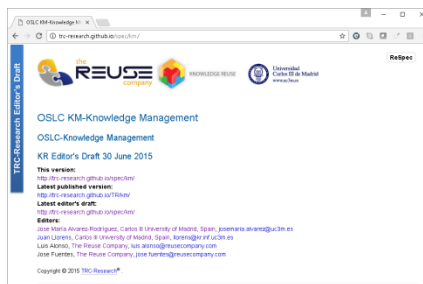


SRL

System Representation Language

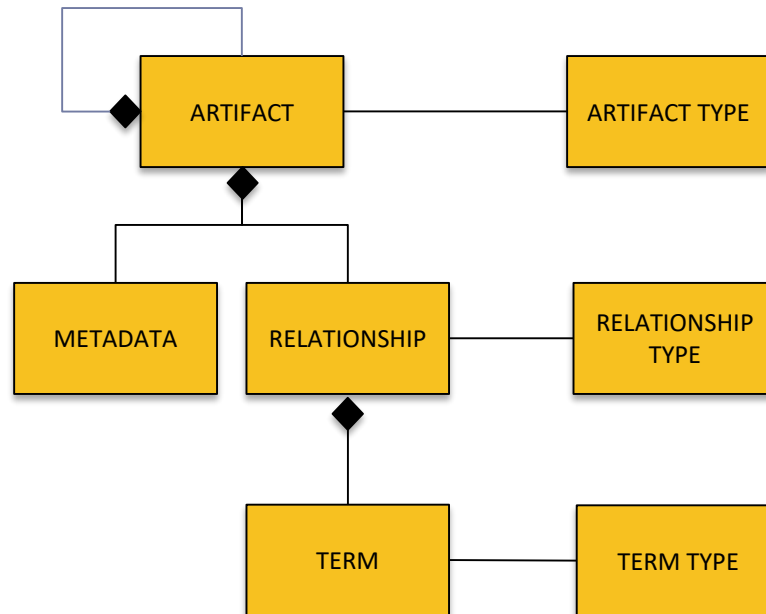
New **Domain**

New **Resource Shape**

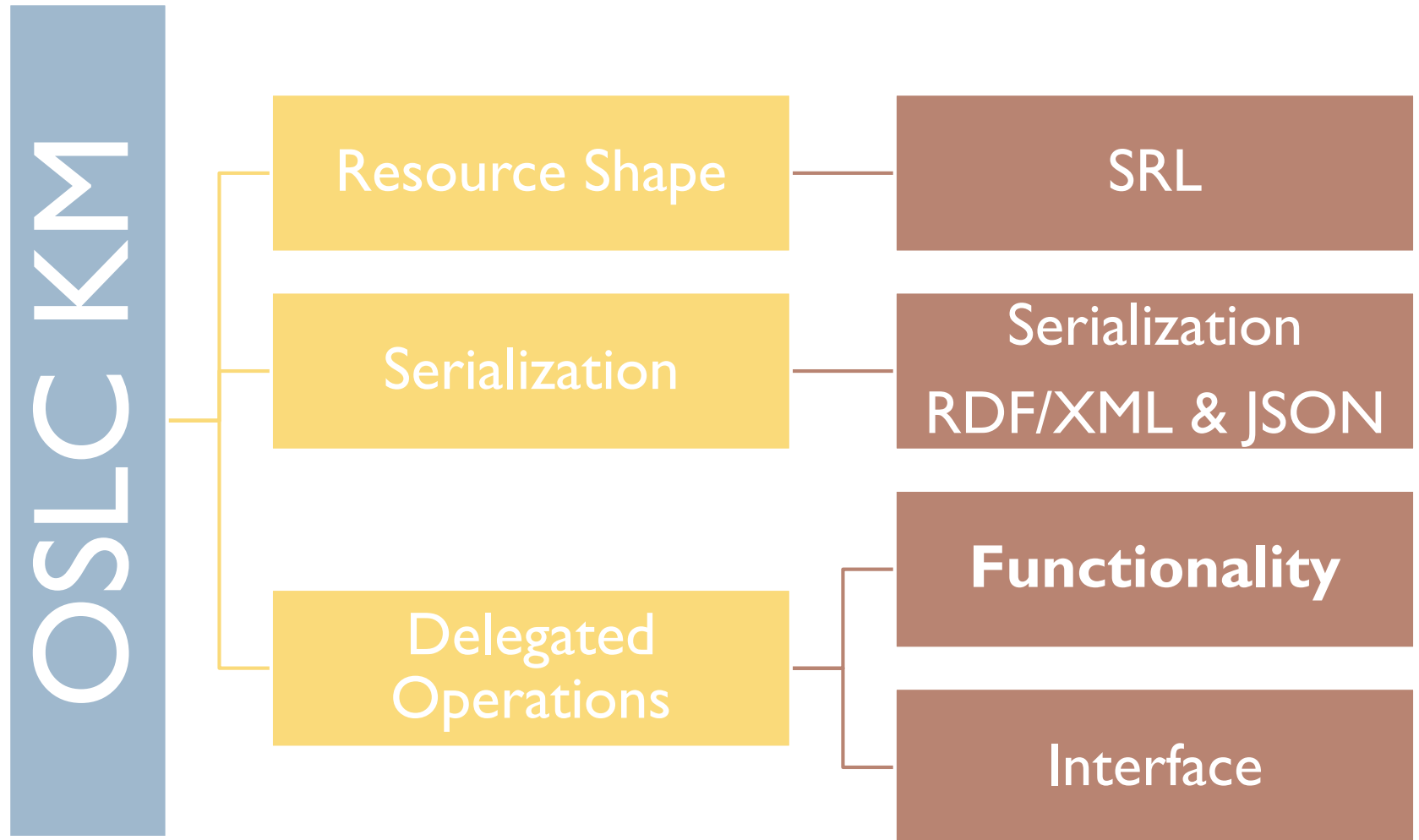


<http://trc-research.github.io/spec/km/>

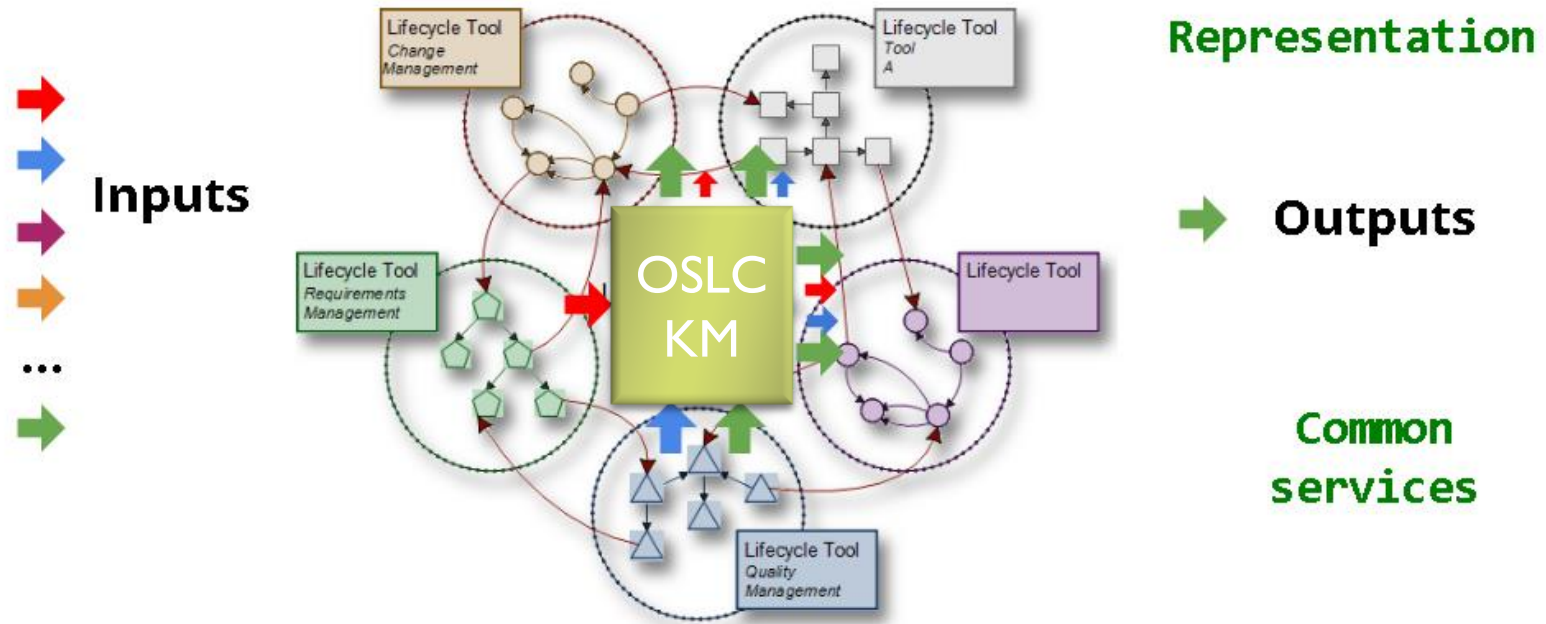
System Representation Language (SRL) – Ground Metamodel



The approach...



Interoperability with OSLC KM



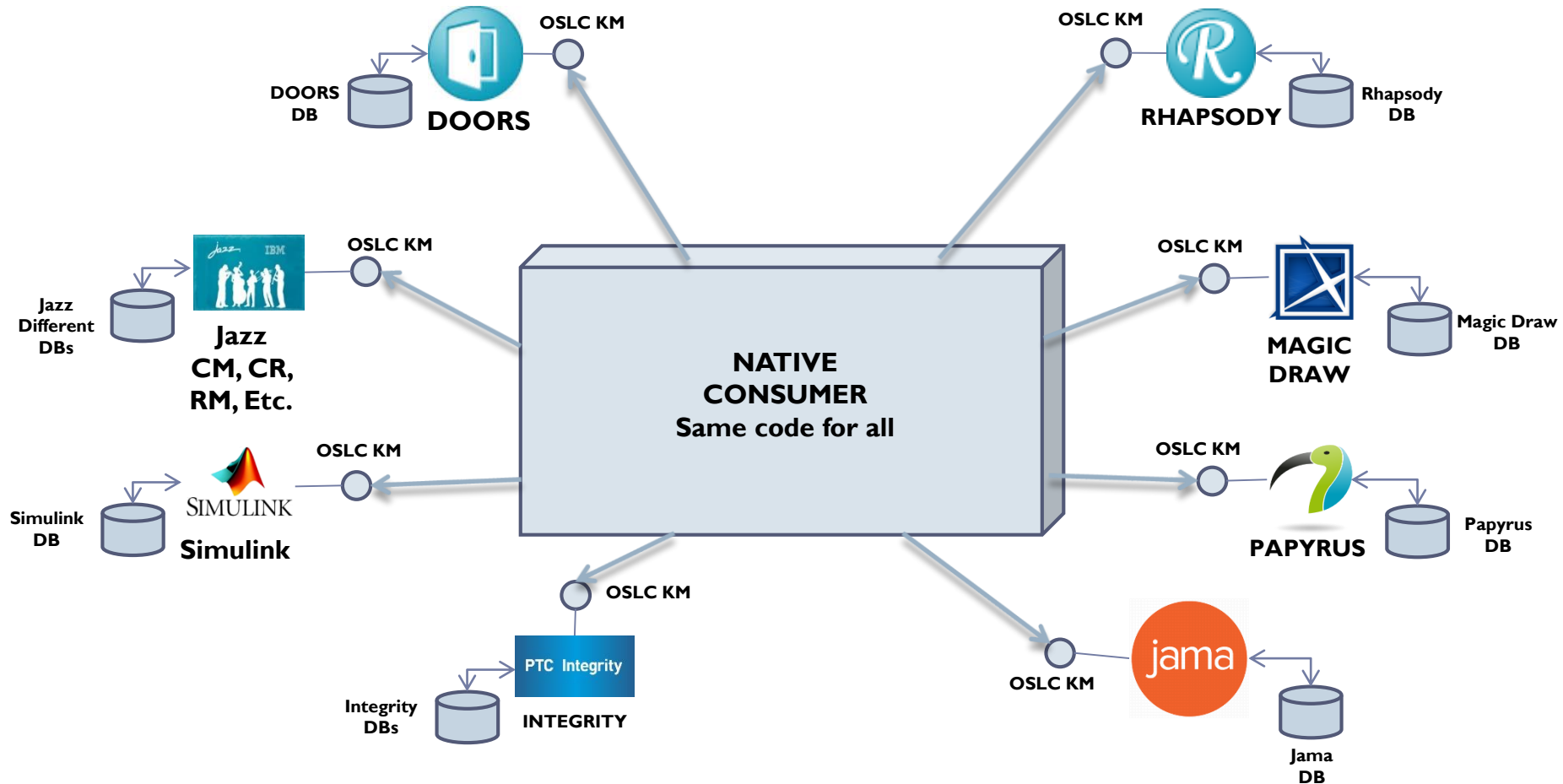
Benefits of a common language within all the SE processes and activities

- 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)

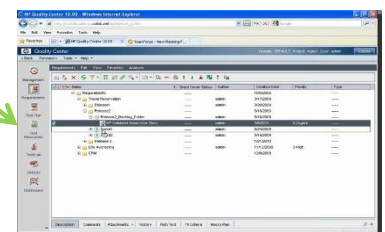
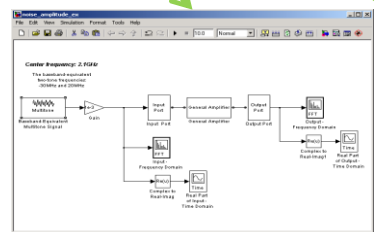
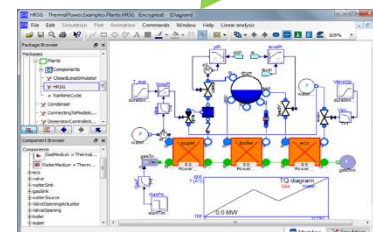
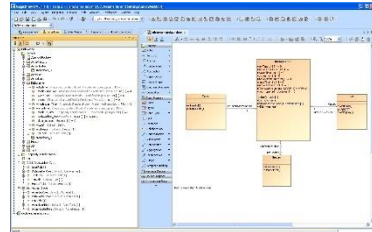
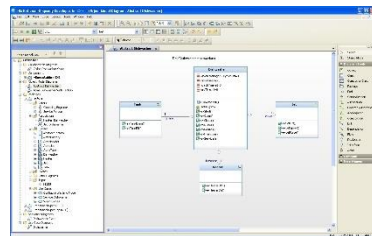
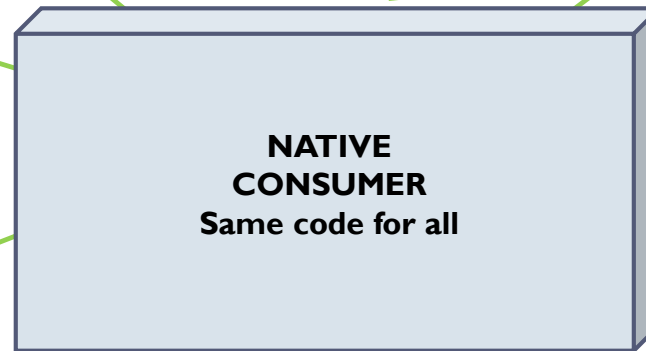
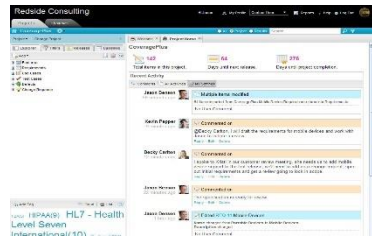
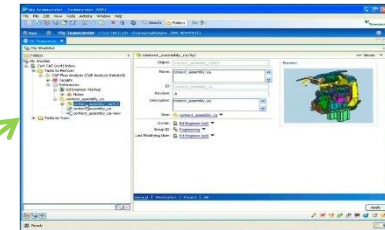
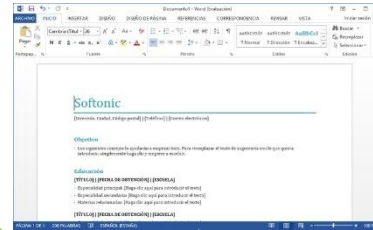


“One *language* to understand them all; one language to interoperate them all”

Example : Access to all-kinds work-products content



		Equipment	Priority
HA_Fnc_1	1 Calling the elevator	Failover	
HA_Fnc_2	The potential passenger can be in any of the rooms and can call an elevator by pressing either the floor button or call the elevator.	True	High
HA_Fnc_3	The potential passenger waits for the doors to open before entering into the elevator. The potential passenger can become a passenger	True	
HA_Fnc_4	2 In the elevator		
HA_Fnc_5	Once in the elevator, a passenger can select the floor or a number of floors where he wants to go to itself	Failover	Medium
HA_Fnc_6	Each elevator has a limit of 16 persons to visit. Once the elevator has been selected a potential passenger or a passenger has selected a destination, then the elevator will move to the respective floor	Failover	
HA_Fnc_7	3 Elevator at selected floor	Failover	
HA_Fnc_8	When the elevator has arrived at a floor and the doors have opened, then the passenger can get in the elevator, once	True	High



Case Study

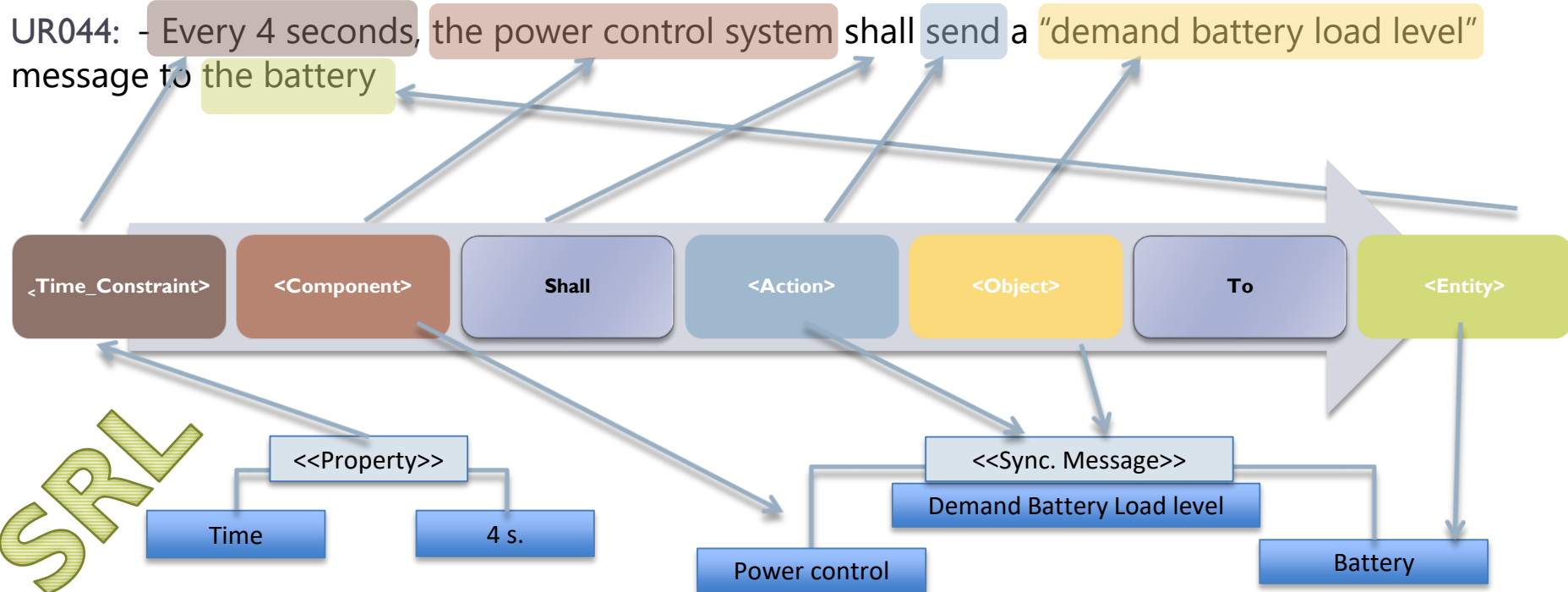
Automatic Traceability between Requirements and Models

Requirements Side:

Representing Requirements (Natural Language) in SRL

Basics: Formalization of Requirements Statements

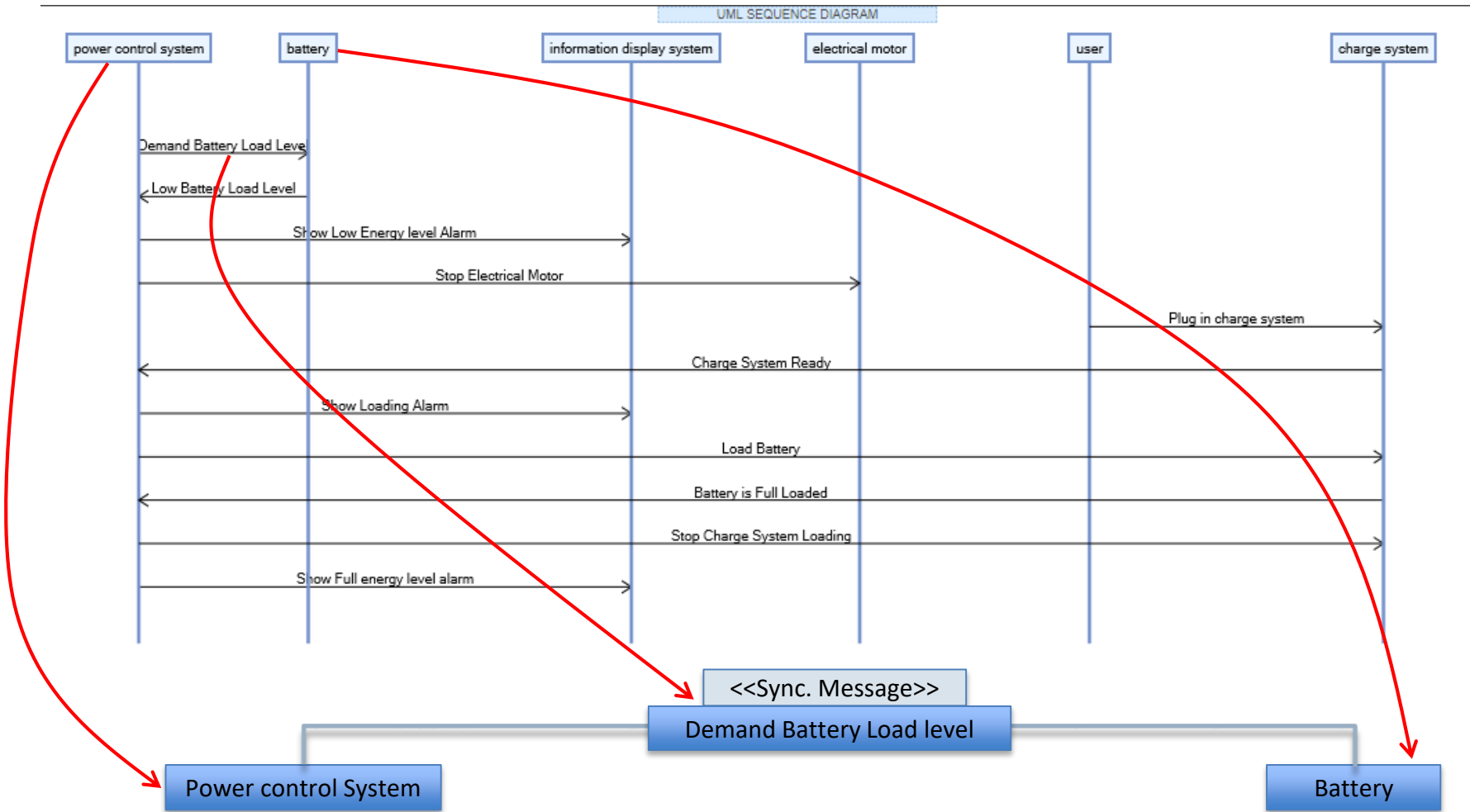
- Necessary IT solutions that attempt to represent and formalize Requirements as Conceptual Graphs
- Using Ontologies and Requirements Patterns



Models Side:

Representing Sequence Diagrams in SRL

Structured Information -> SRL: a Straightforward transformation



Knowledge Centric Systems Engineering

Traceability

Requirements Quality Analyzer

File Quality Control Workbook configuration Quality Assurance

3-Electrical Power System Reqs

Worksheet selector Requirements Correctness Completeness Consistency Knowledge base

Simple view Quality view Metrics Users Charts Metrics Metrics Suggestions

Requirements:

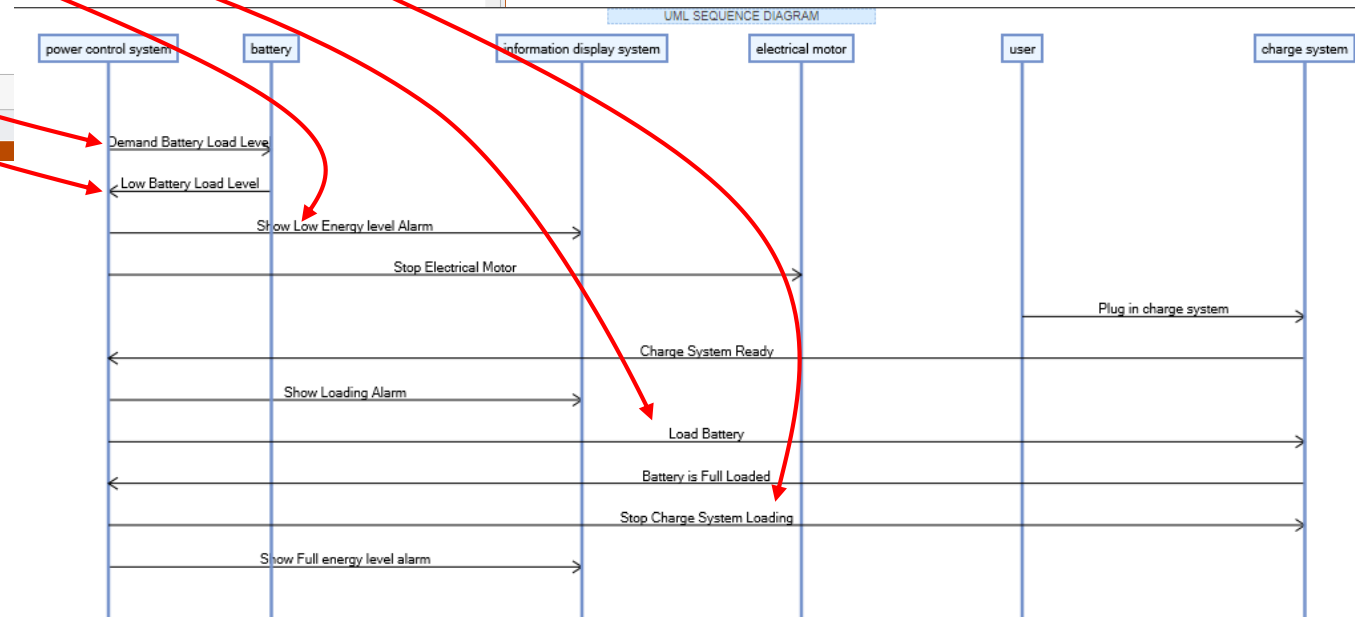
ID	Text	Correctness	Score	Mandatory me...	Correctness qu...	Consistency	Issues
1	every 1 seconds, the power control system shall send a demand battery load level message to the ba...	★ ★ ★	1.73	0	04/03/2016 13...	★ ★ ★ ★	0
2	when the voltage level is below 11.5V, the battery shall send a "low battery 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

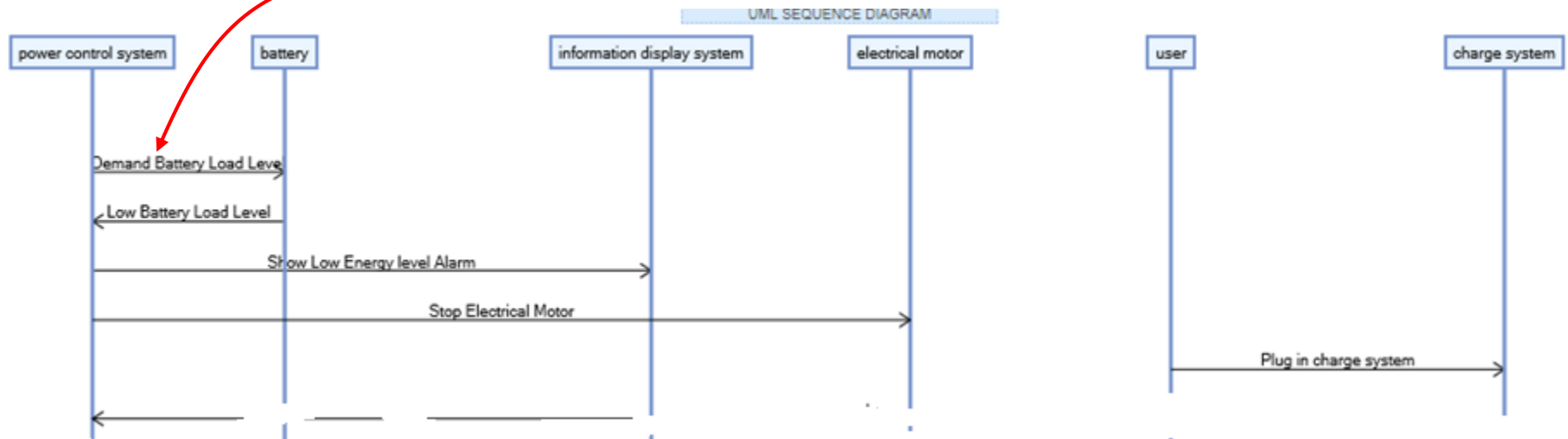
4-Models-Content Coverage Example: Requirements Spec

- 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

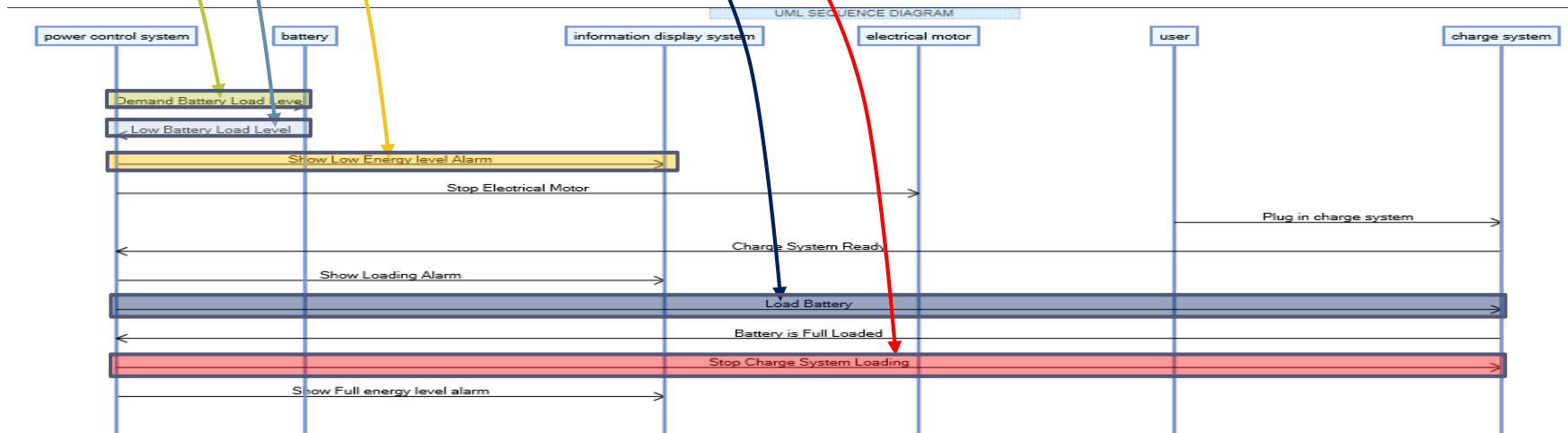
4-Models-Content Coverage Example: Matching process

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 (II)
 - 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





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