

Formalization of Systems Engineering processes:

A method to adapt generic processes to different application contexts

Samuel ROCHET

26 novembre 2007

Plan

1 Context & problematic

- Context
- Problematic

2 Propositions

- Choice of process of reference
- SE processes formalization
- Processes adaptation to businesses and projects
- Validation et Verification of models of processes

3 Conclusion

- Conclusion

1 Context & problematic

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2 Propositions

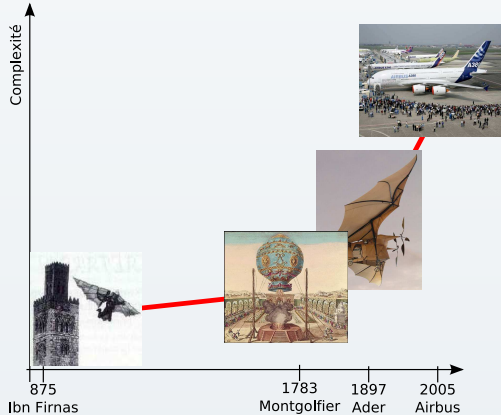
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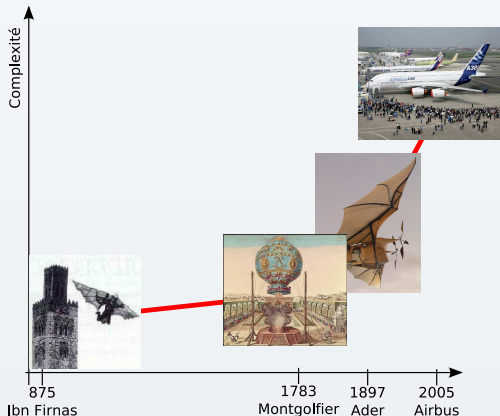
Increasing systems complexity

Example, the aviation



Increasing systems complexity

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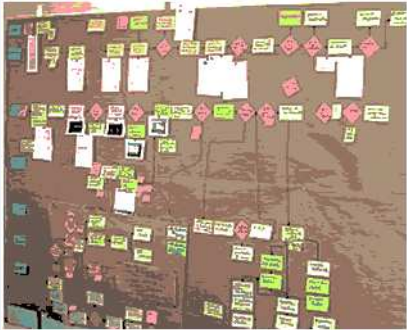


2 axes of complexity :

- 1 technical complexity
- 2 organizational complexity

Manage complexity

Systems Engineering (SE) (1970)

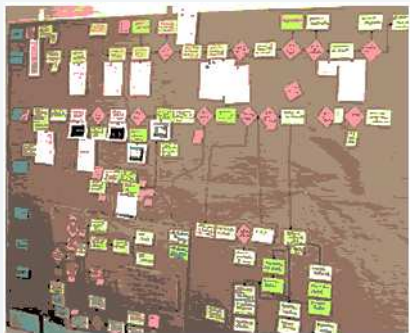


Systems Engineering (SE) :

An approach and interdisciplinary means allowing systems realization and deployment.

Manage complexity

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Can be considered as

- 1 application of engineering techniques to engineering of systems,

Manage complexity

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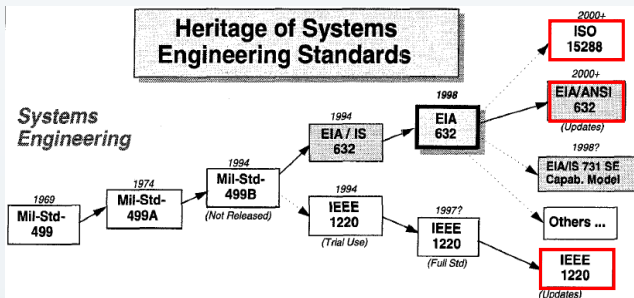
Systems Engineering (SE) :

An approach and interdisciplinary means allowing systems realization and deployment.

Can be considered as

- 1 application of engineering techniques to engineering of systems,
- 2 and application of a systematic approach to engineering efforts.

Systems Engineering Standards



[Martin98]

The use of a systematic approach is done via standards.

- built through several years by consortiums like INCOSE or AFIS
- based on companies experimental skills
- bring to evolve

Systems Engineering processes

SE standards defined **benchmark processes**.

A process is [EIA632] :

a set of interrelated **tasks** that, together, transform **inputs** into **outputs**.

Those elements are material, information or both.

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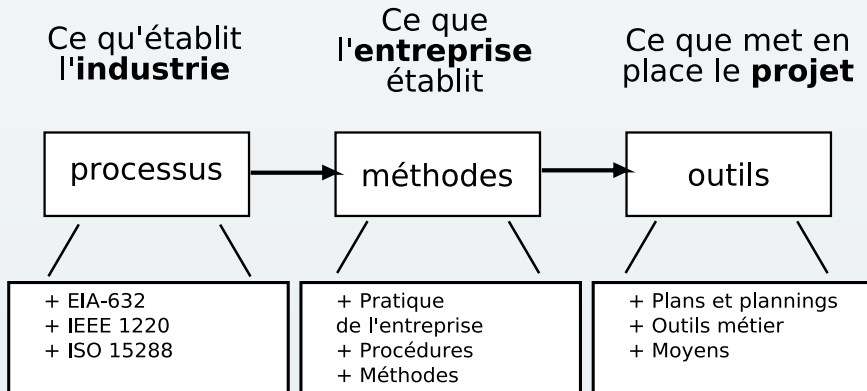
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Application of SE recommendations

[AFIS]



For practical purposes



Problematic



How to apply described processes ?

- Where to start, which processes to retain ?



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- Where to start, which processes to retain ?
- How to integrate and to share textual recommendations ?



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- Where to start, which processes to retain ?
- How to integrate and to share textual recommendations ?
- How to integrate business aspects ?
- How to integrate project aspects ?
- How to ensure respect of recommendations ?
- Standards are they compatible ?
- Which part of reuse ?

Problematic

General problematic

How to define and to apply all activities required for development of a complex product ?

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Means

To use acquired experience \Rightarrow **SE standards.**

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Means

To use acquired experience \Rightarrow **SE standards.**

particular problematic

How, in practice, apply **generic recommendations** to **projects** by nature, **specifics** ?

Propositions

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- 1 To start from a scenario given by SE standards (EIA-632).

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- 1 To start from a scenario given by SE standards (EIA-632).
- 2 To elicit a global generic model of multi-processes interactions.
- 3 To improve it with specificities of business and project.
- 4 To ensure approach coherence by a mechanism of validation.

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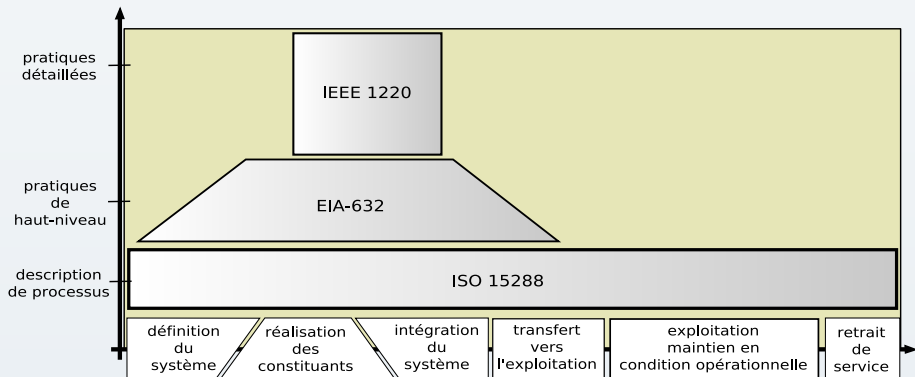
Systems engineering standards

Three main standards in SE :

IEEE 1220,

EIA-632,

ISO 15288



Choice of a standard

Approach validation on one standard.

selection of EIA-632 :

- Compromise between life cycle coverage and detailed practices.

Choice of a standard

Approach validation on one standard.

selection of EIA-632 :

- Compromise between life cycle coverage and detailed practices.
- Strong utilization by local industrials (Airbus, TOPCASED).

Precision

The choice of EIA-632 is not restrictive :

Presented techniques and methods can be applied on others SE standards.

Standard can be :

- One standard (IEEE 1220, EIA-632 or ISO 15288);
- A combination of standards.

Standard co-developed by :

- Electronic Industries Alliances (EIA)
- International Council on System Engineering (INCOSE)

Content :

- 13 processes (5 groups)
- 33 requirements on these processes

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Content :

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≠ product requirements.

Standard co-developed by :

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Content :

- **13 processes** (5 groups)
- **33 requirements** on these processes
equivalent to processes and described by **tasks**.

- **Technical management**

- ▶ Planning Process
- ▶ Assessment Process
- ▶ Control Process

- **Supply and acquisition**

- ▶ Supply Process
- ▶ Acquisition Process

- **System Design**

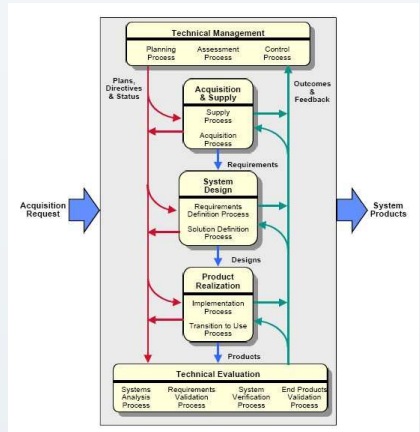
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- **Product realization**

- ▶ Implementation Process
- ▶ Transition To Use Process

- **Technical evaluation**

- ▶ Systems Analysis Process
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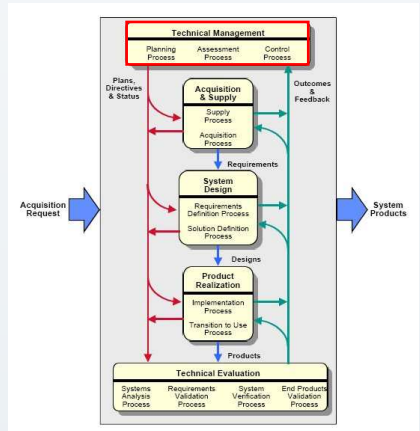
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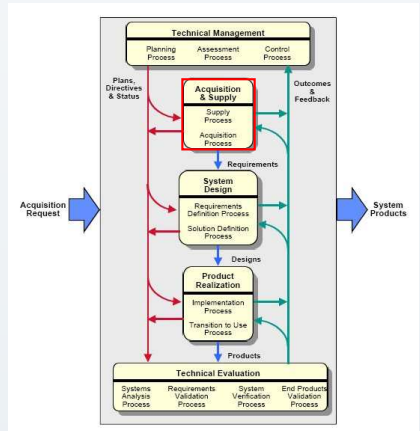
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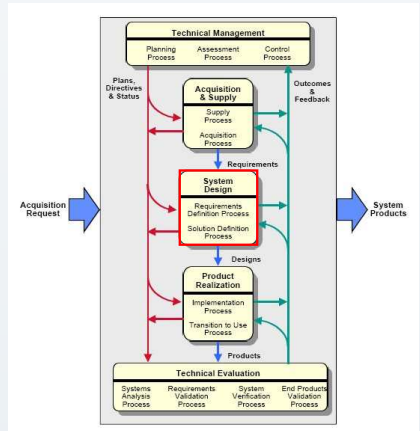
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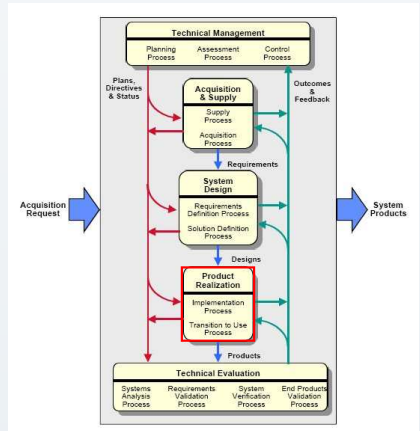
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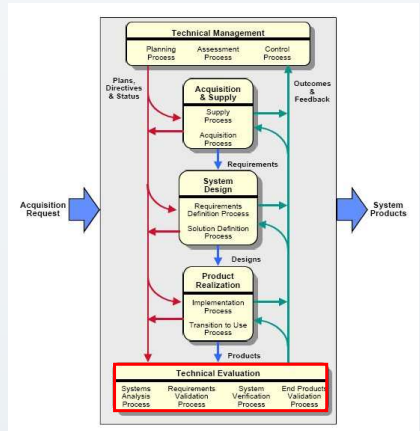
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EIA-632 model

Concepts to integrate :

- processes
- system and building blocks
- life cycle

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| | OSSAD | BPMN | UML | SPEM |
|-----------------------|-------|------|-----|----------------|
| Semantic of processes | ✓ | ✓ | ✗ | ✓ |
| Metamodel | ✗ | ✗ | ✓ | ✓ |
| Life Cycle concept | ✗ | ✗ | ✗ | ✓ |
| Support by tools | ✓ | ✓ | ✓ | as UML profile |

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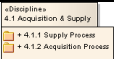



Choice of **Software Process Engineering Metamodel** (UML and profile SPEM).

EIA-632 model processes

EIA-632 processes

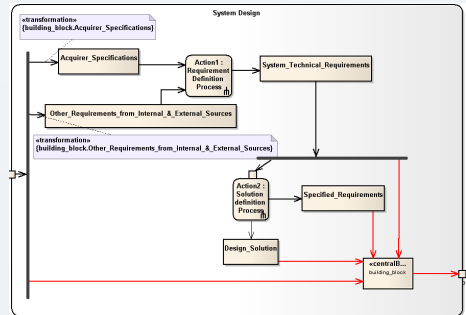
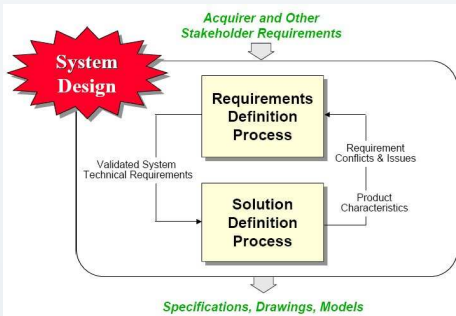
Correspondences EIA-632 / SPEM-UML

Processes modeled in **activity diagrams**.

| EIA-632 | Type UML | Stereotype SPEM | Icon |
|-------------|----------|-----------------|---|
| Group | Activity | Discipline |  |
| Process | Activity | Process |  |
| Requirement | Activity | Activity |  |
| Task | Action | Step |  |

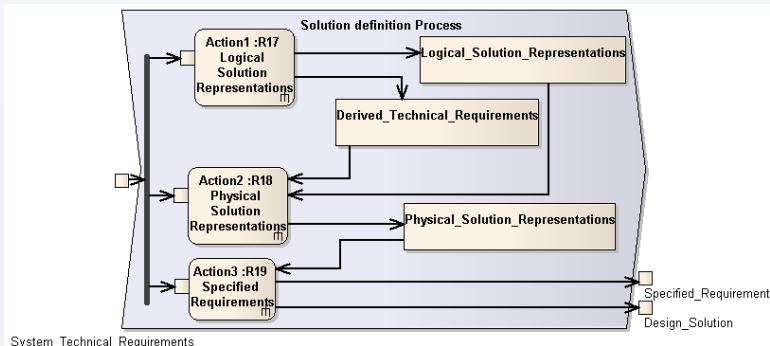
Example of business model construction

Example, “end product validation”



EIA-632 processes

Process : Solution Definition Process



Solution definition process requirements :

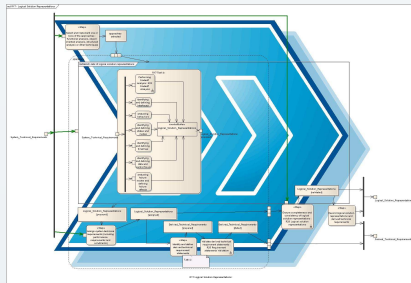
- logical solution representations
- physical solution representations
- Specified Requirements

EIA-632 processes

Requirement 17 – Logical Solution Representations

Requirement 17 tasks :

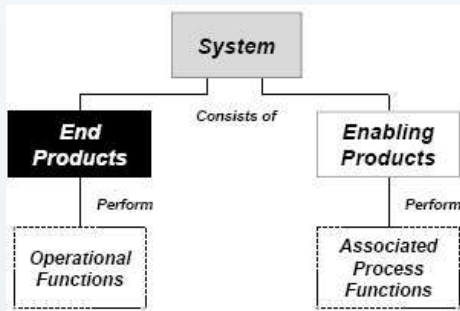
- a Select and implement one or more appropriate approaches to providing an abstract definition of the solution to the system technical requirements. For the approaches selected, complete the appropriate tasks from (b) through (d) below that aid in defining logical solution representations.
- b Establish sets of logical solution representations by (1) doing tradeoff analyses (see Requirement 23), (2) identifying and defining interfaces, states and modes, timelines, and data and control flows, (3) analyzing behaviors, and (4) analyzing failure modes and defining failure effects.
- c Assign system technical requirements (especially performance requirements and constraints from the system technical requirements) to elements of the logical solution representations, e.g., subfunctions, groups of subfunctions, objects, and data structures.
- d ...



EIA-632 model

processes + system and building blocks

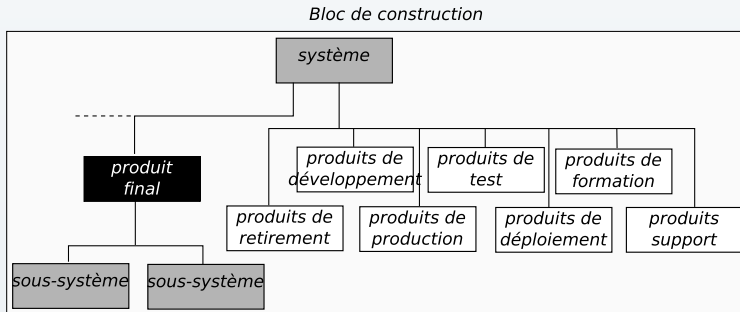
EIA-632 system structure



System and building block

- A system is composed of **end products** and **enabling products**

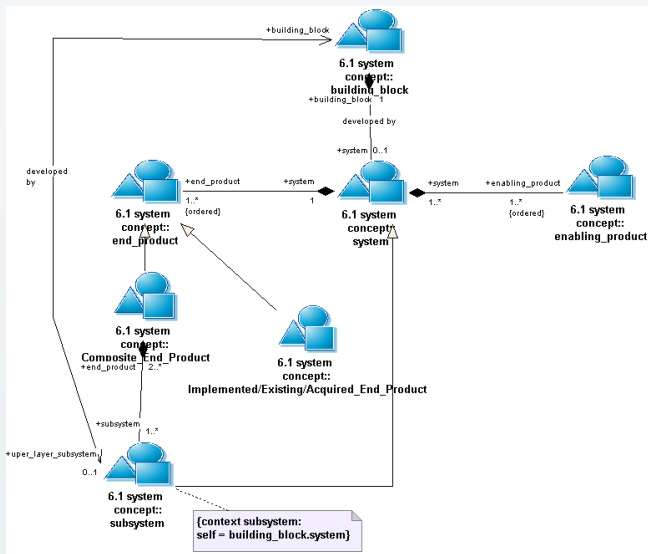
EIA-632 system structure



System and building block

- A system is composed of **end products** and **enabling products**
- A **building block** contains a system, its end products and its enabling products.

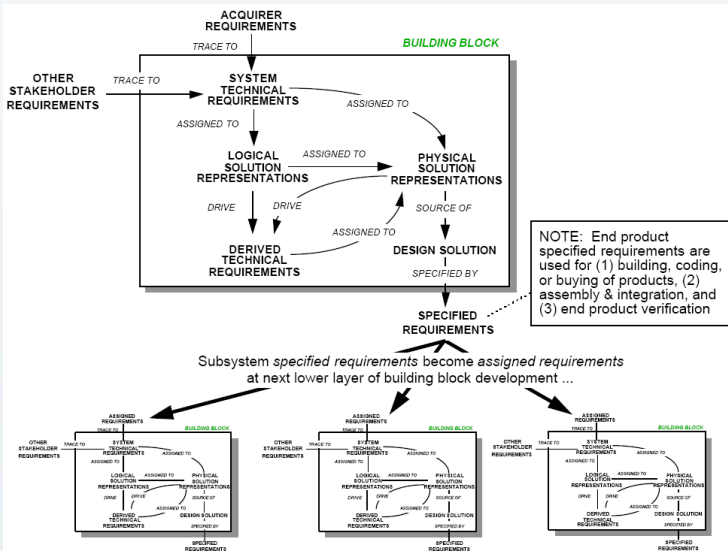
Model of system structure concept



EIA-632 model

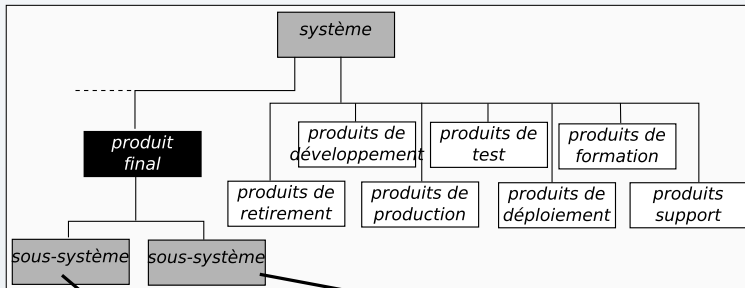
processes + system and building blocks + life cycle

Requirements and building blocks

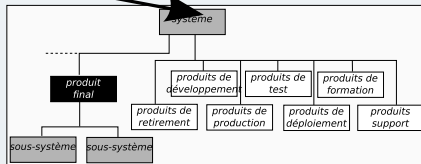
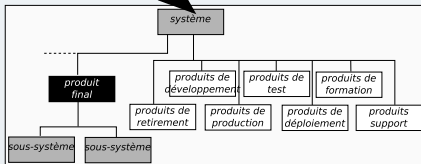


Requirements and building blocks

Bloc de construction de couche N

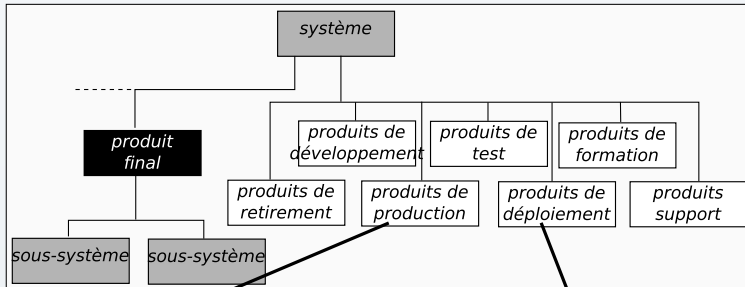


Blocs de construction de couche N+1

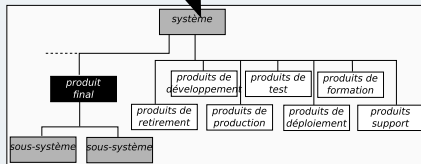
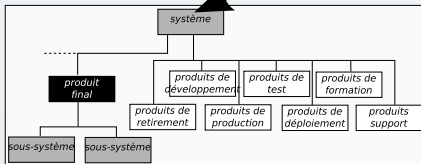


Requirements and building blocks

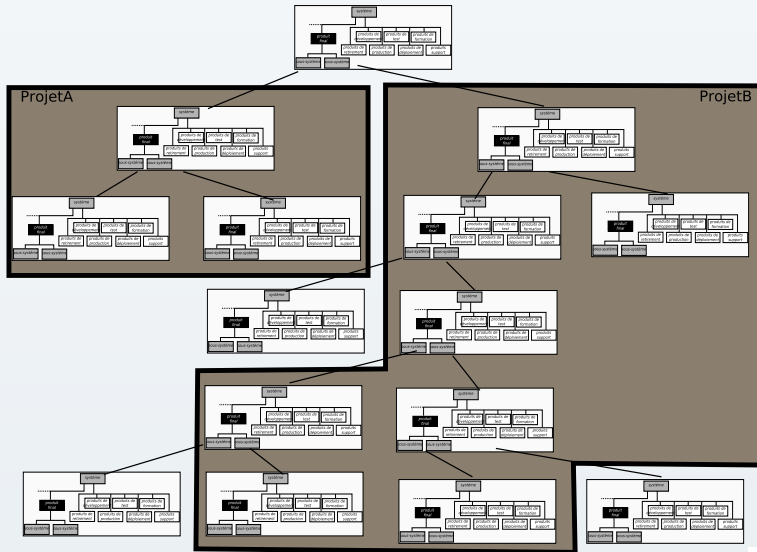
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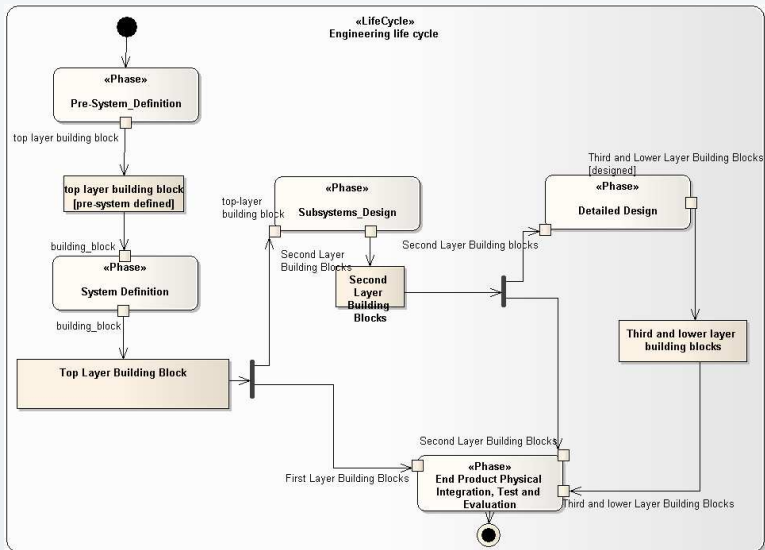
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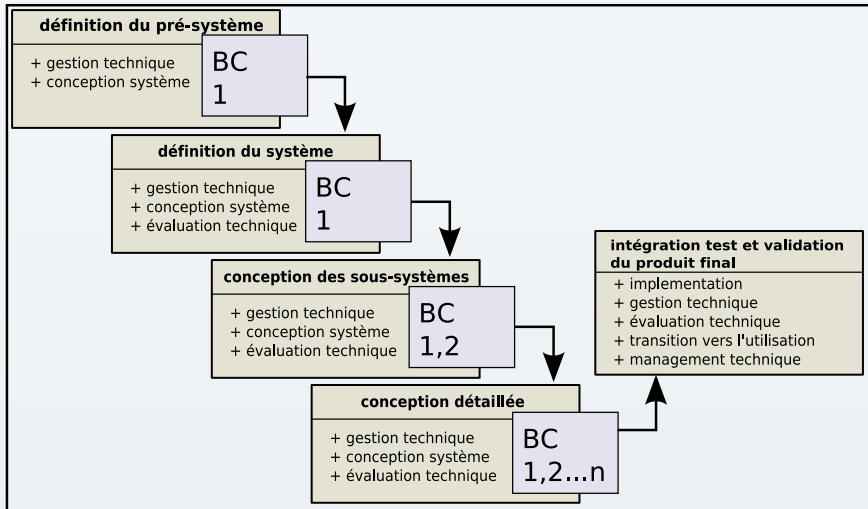
layered design



Life cycle model



Life cycle



- Processes define system components
- engineering of each of them is done via processes

EIA-632 model analysis

Few numbers :

from 140 pages to 69 packages, 79 diagrams, 1534 elements, 1502 connections...

<http://www.lesia.insa-toulouse.fr/~rochet/>

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Model has shown :

- compartment descendant then ascendant (life cycle),
- different roles for elements at the same level (groups et processes),
- workflow coherency (recursive processes).

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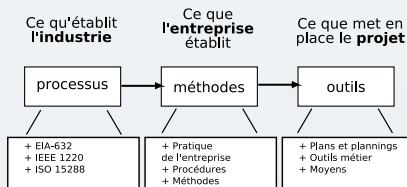
- Conclusion

How to integrate business aspects ? How to integrate project aspects ?

Described processes are generic and need to be adapted at a context.

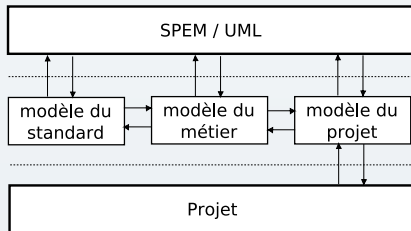
We need to integrate specificities linked to :

- company business ;
- a specific project ;



Proposed approach

From standards to businesses and from businesses to projects

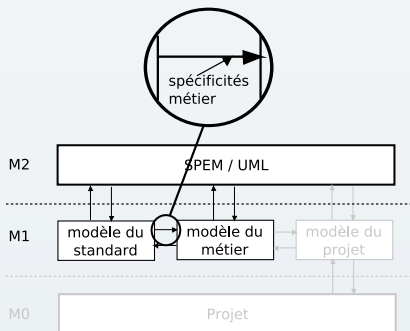


Processes modeling in 3 steps :

- 1 model of standard ;
- 2 model of business ;
- 3 model of project.

Project is an instance of model of project.

From model of standard to model of business

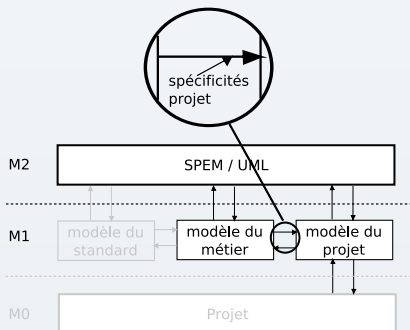


Business specificities are identified from **norms and standards** of the domain

For example :

- 1 aeronautic,
- 2 railway,
- 3 medical,
- 4 defense...

From model of business to model of project



Project specificities are identified from company **procedures and practices.**

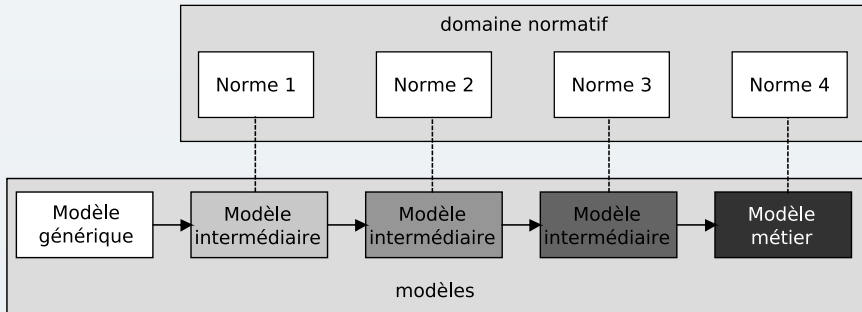
For example :

- 1 methods,
- 2 internal procedures,
- 3 company structure and organization...

Incremental construction of models

Methodology of construction

- 1 Identify specificities in norms, standards, recommendations or practices of the company.
- 2 Integrate them manually in the model.



Construction operators

Model construction is done by :

- **creation** (new tasks)

Construction operators

Model construction is done by :

- **creation** (new tasks)
- **specialization** (work products types)

Construction operators

Model construction is done by :

- **creation** (new tasks)
- **specialization** (work products types)
- **refining** (task described by a process)

Example of construction

Case of design of personal protective equipment

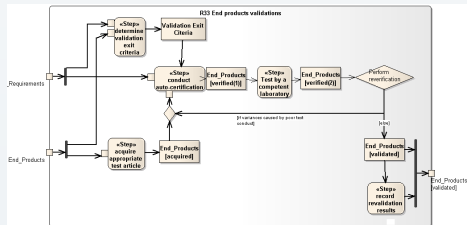
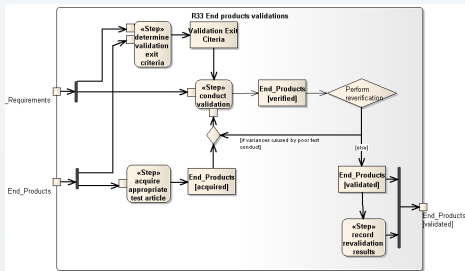


Example of personal protective equipment (89-656-CEE) :

- specific marking ;
- imposed notice ;
- periodical verifications ;
- test by an independent laboratory.
- ...

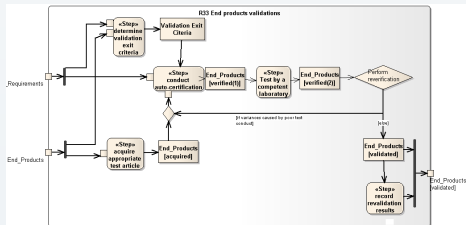
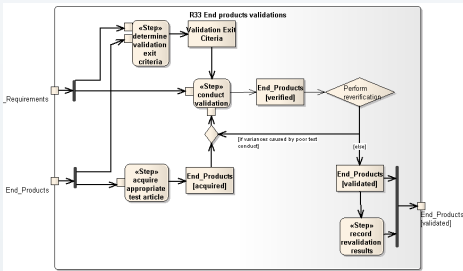
Example of model of business

Example of “end product validation”



Example of model of business

Example of “end product validation”

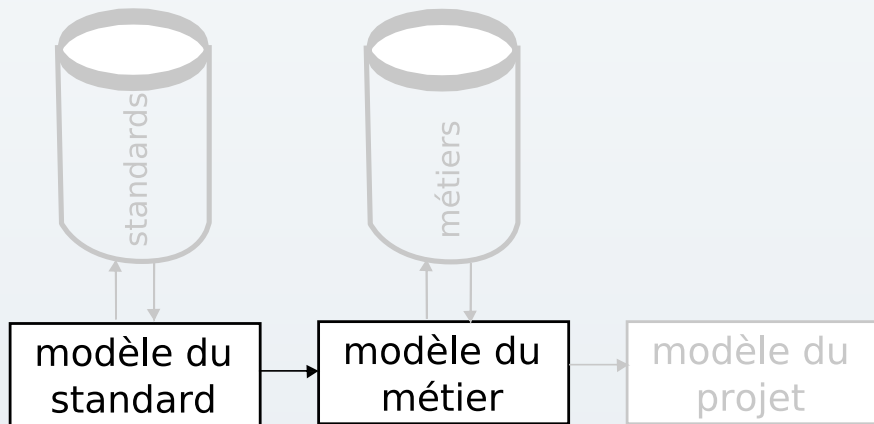


modifications :

- new activity of “validation by an independent laboratory”
- “conduct validation” renamed in “conduct of auto-certification”
- workproducts up to date.

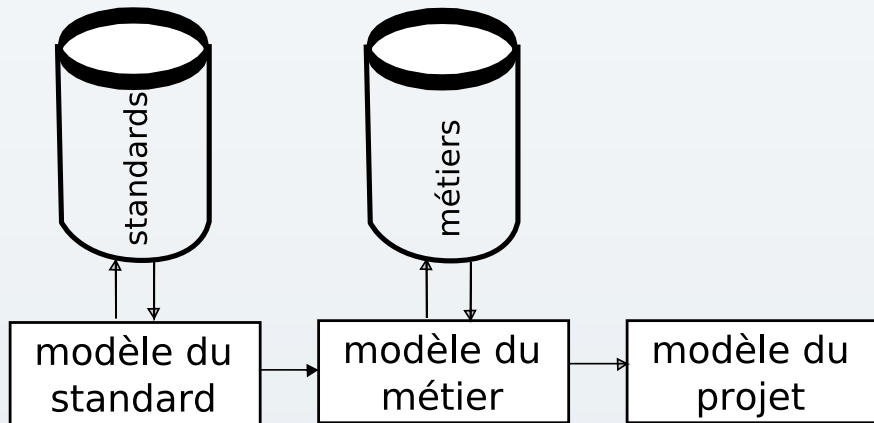
Construction of models

Construction of all models or reuse

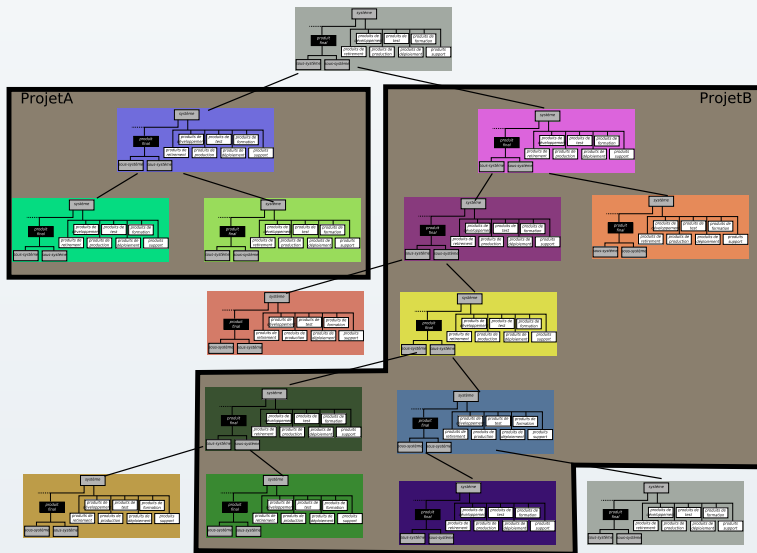


Construction of models

Construction of all models or reuse



Implications on life cycle



Implications of the approach

Processes associated to each product depend of business model.

- Each product follows a **design specific to its business.**

Implications of the approach

Processes associated to each product depend of business model.

- Each product follows a **design specific to its business**.
- The use of a common referential ensure **global coherency** of the project.

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- Conclusion

The need of validation

Hypothesis :

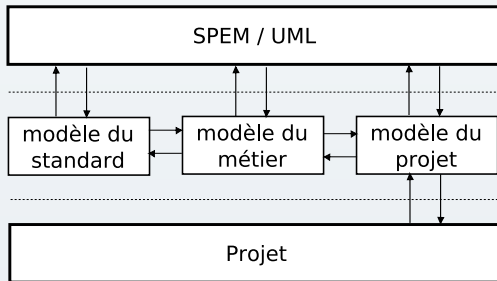
Transmission of properties through models.

Problems :

Which properties ? How to ensure there presence in models ?

Kinds of properties

We consider two kinds of properties :

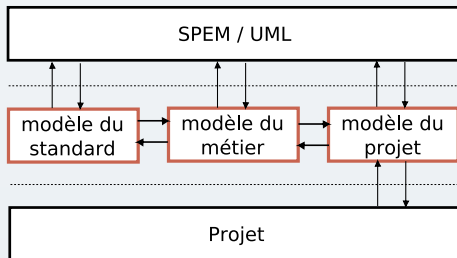


Kinds of properties

We consider two kinds of properties :

- intra-model properties

propriétés intra-modèle



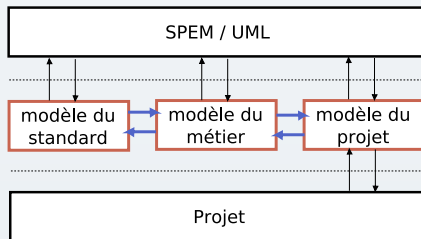
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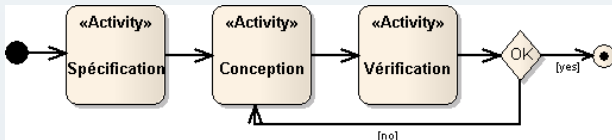
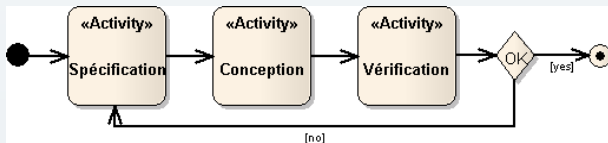


Example of properties

Intra-model properties

Intra-model properties

"it must be allowed to go back over each step of the process"

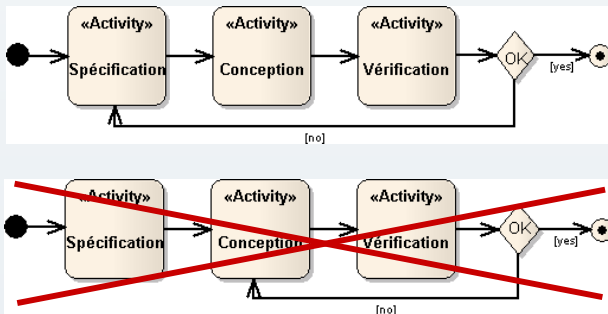


Example of properties

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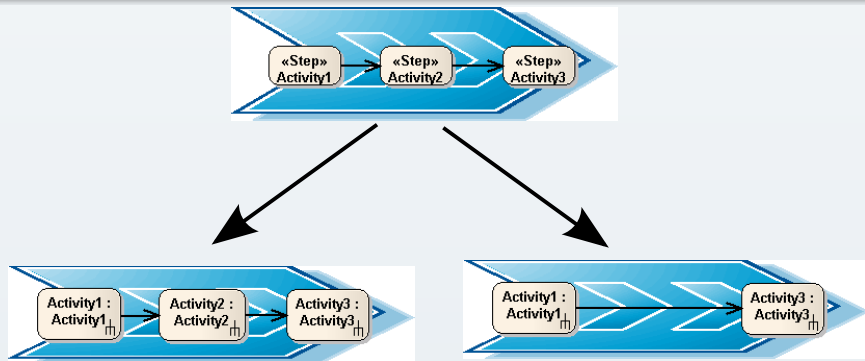


Example of properties

Inter-models properties

Inter-models properties

"All activities in an original model must be present in the modified model"

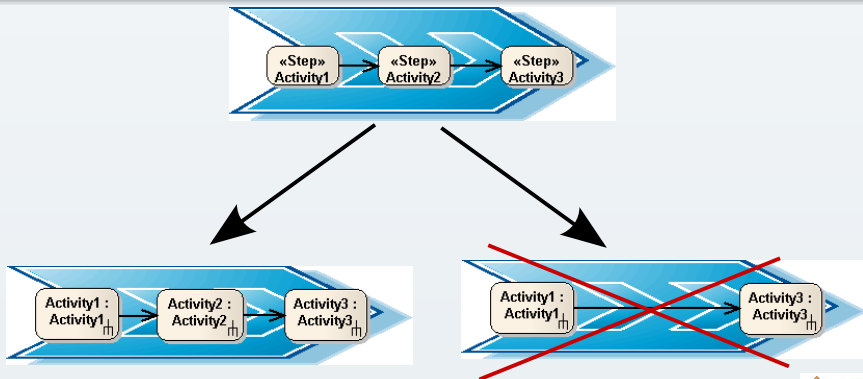


Example of properties

Inter-models properties

Inter-models properties

"All activities in an original model must be present in the modified model"



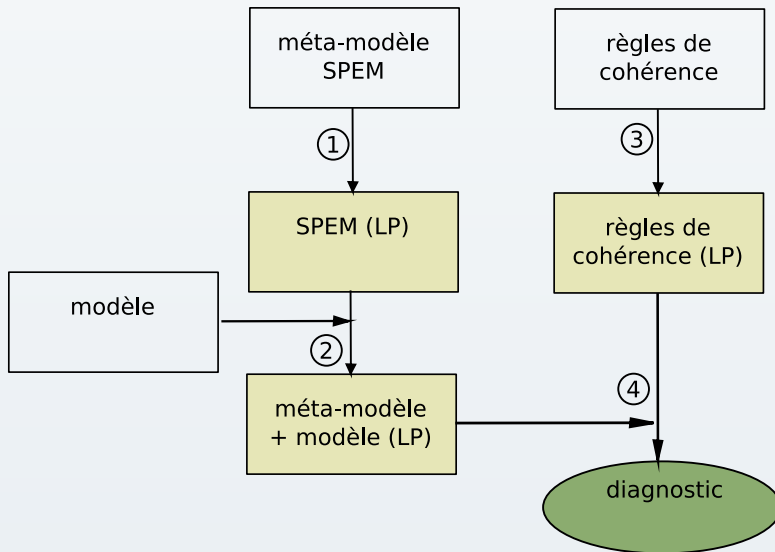
Principe of verification

Verification based on logic programming.

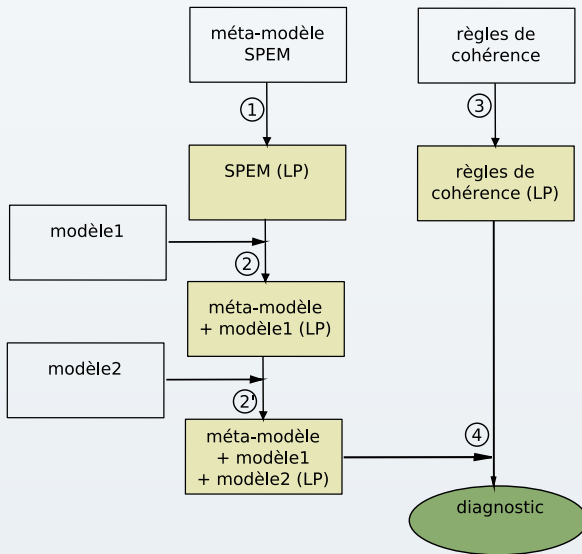
Adaptation of [Malgouyres2006].

| Logic programming | Model |
|---|--------------------------------------|
| Knowledge base (facts) | Model (See like information) |
| Deduction base (rules) | expression of incoherencies |
| Interrogation of base knowledge base and deduction base (goals) | automatic detection of incoherencies |

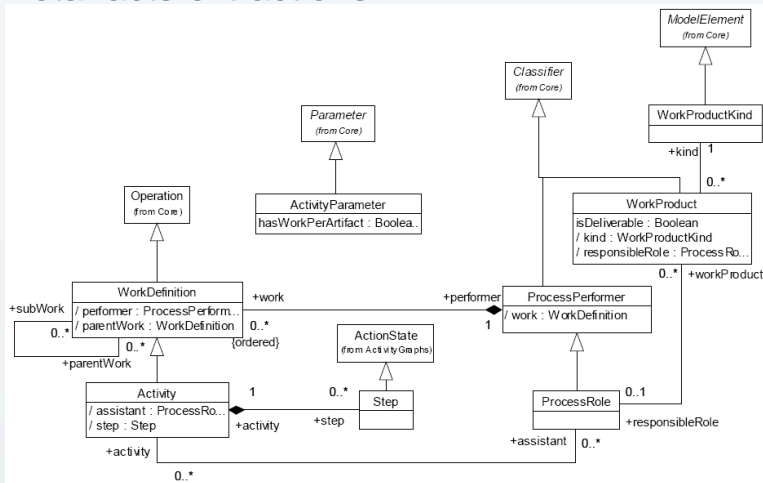
Coherency rules verification on one model



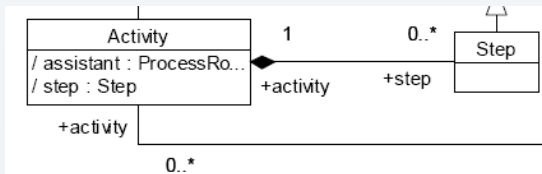
Coherency rules verification between models



Meta-facts extractions

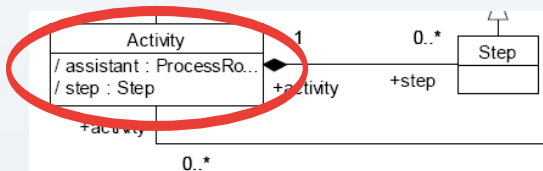


Meta-facts extractions



Addition to knowledge base :

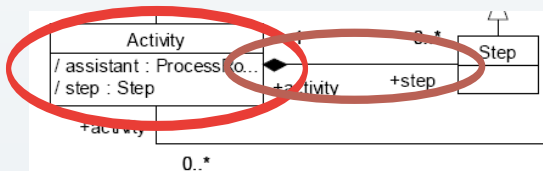
Meta-facts extractions



Addition to knowledge base :

- of metamodel elements

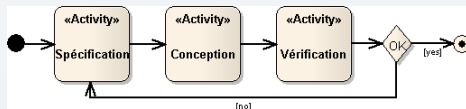
Meta-facts extractions



Addition to knowledge base :

- of metamodel elements
- and there relations

Facts extraction

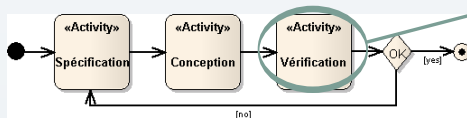


```
...  
callBehaviorAction(id5,...).  
callBehaviorAction(id4,...).  
callBehaviorAction(id3,...).  
controlFlow(id13,...).  
...
```

```
...  
literalInteger(id15,...).  
package(id0,...).  
sPEMActivity(id5,...).  
...
```

Addition to knowledge base :

Facts extraction

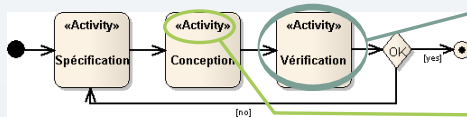


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```

Addition to knowledge base :

- of model elements
- of stereotypes

Coherency rules formalization

| Rule in natural language | Coded rule |
|--|---|
| <i>“An activity A is not verifiable if it can reach an activity B then this one can not reach activity A.”</i> | <pre>noVerifiable(IdAct1) :- isActivity(IdAct1 ,_), isActivity(IdAct2 ,_), IdAct1 \= IdAct2 , reach(IdAct1 , IdAct2), not(reach(IdAct2 , IdAct1)).</pre> |
| <i>“An activity is missing if it is present in the original model and not in the derived model.”</i> | <pre>missing(IdAct) :- isActivity(IdAct ,_), getName(IdMdOriginal , modeloriginal), getName(IdMdDerive , modelderive), inModel(IdAct , IdMdOriginal), not(inModel(IdAct , IdMdDerive)).</pre> |

Validation tool

The screenshot shows the UML2LP validation tool interface. It includes a menu bar (Menu, Options, Help) and a toolbar (Transform, Compare, Analyze). The main window is divided into several sections:

- Rules file:** A table listing rules with columns for Rule name/Arity and Evaluation. Red arrows point to the 'Rules file' and 'Add Rules' buttons (1 and 2).
- Rules Table:** A table with 3 columns: #, Rule name/Arity, and Evaluation. It lists 102 rules. Red arrows point to the 'Select all', 'Deselect all', and 'Check' buttons (4, 5, and 6). The 'Check' button is highlighted with a red arrow (6).
- Request:** A text input field for entering a request. A red arrow points to it (7).
- Results:** A text area displaying the results of the validation. A red arrow points to it (8).
- Buttons:** 'Clear' and 'Save' buttons are located at the bottom right. Red arrows point to them (9 and 10).

Red arrows numbered 1 through 10 point to various UI elements: 1 points to 'Rules file', 2 points to 'Add Rules', 3 points to the 'Evaluation' column, 4 points to 'Select all', 5 points to 'Deselect all', 6 points to 'Check', 7 points to the 'Request' input field, 8 points to the 'Results' text area, 9 points to the 'Save' button, and 10 points to the 'Clear' button.

Use of coherency rules

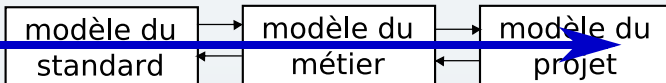
Rules can be employed like :

Use of coherency rules

Rules can be employed like :

- construction rules

Règles de
construction

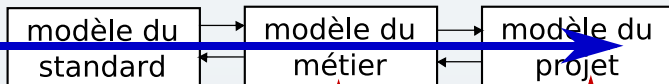


Use of coherency rules

Rules can be employed like :

- construction rules
- business rules

Règles de
construction



Règles métier

1 Context & problematic

- Context
- Problematic

2 Propositions

- Choice of process of reference
- SE processes formalization
- Processes adaptation to businesses and projects
- Validation et Verification of models of processes

3 Conclusion

- Conclusion

Abstract

Work done :

- 1 **Study** of recommended scenarios for engineering of a complex system (standards of SE, EIA-632)

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- 1 **Study** of recommended scenarios for engineering of a complex system (standards of SE, EIA-632)
- 2 **formalization** of a standard in generic model
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- 4 proposition of a mean to **validate** models in order to ensure coherency of the approach

Contributions

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- practical **method of application** of SE recommendations,

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Answer to complexity management

- Standards gives general answers without links with concrete problematics of projects.
- Approach developed here allows to link them.

Perspectives

EIA-632 analysis and feedback :

- analysis of the standard
- point up of ambiguities and **feedback to INCOSE**

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Perspectives

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Application :

- application in an **industrial context**

For present-time

Diffusion of the approach :

- **ATLAS** ANR project

For present-time

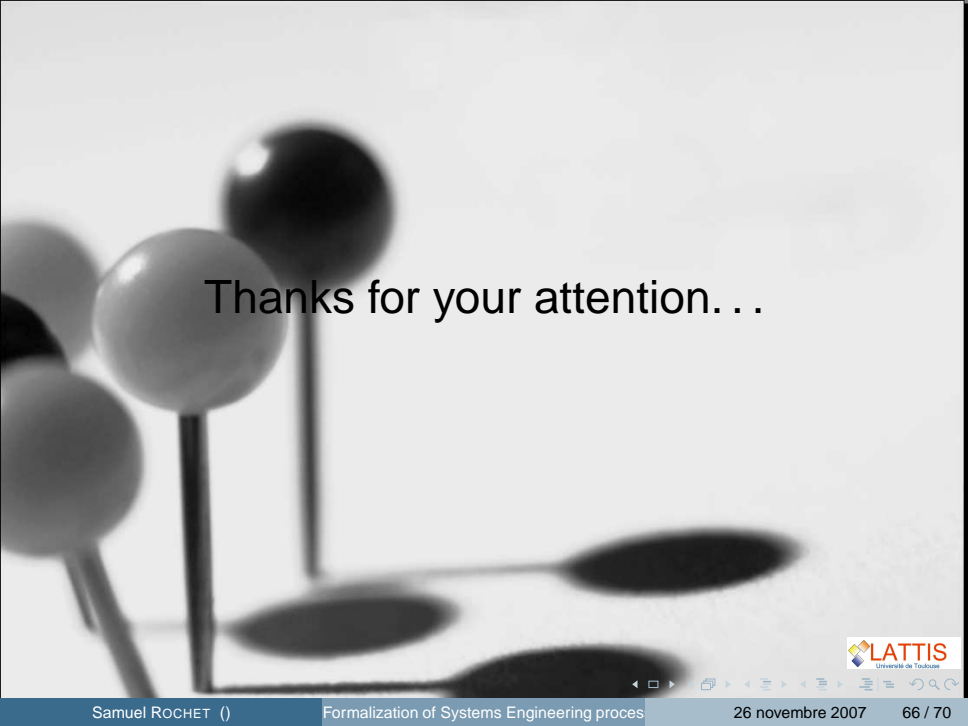
Diffusion of the approach :

- **ATLAS** ANR project
- scientific collaboration with the **LAAS-CNRS**

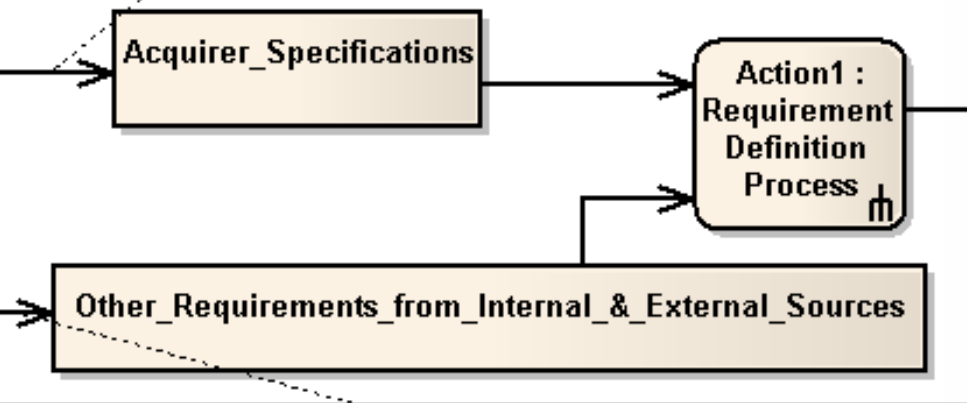
For present-time

Diffusion of the approach :

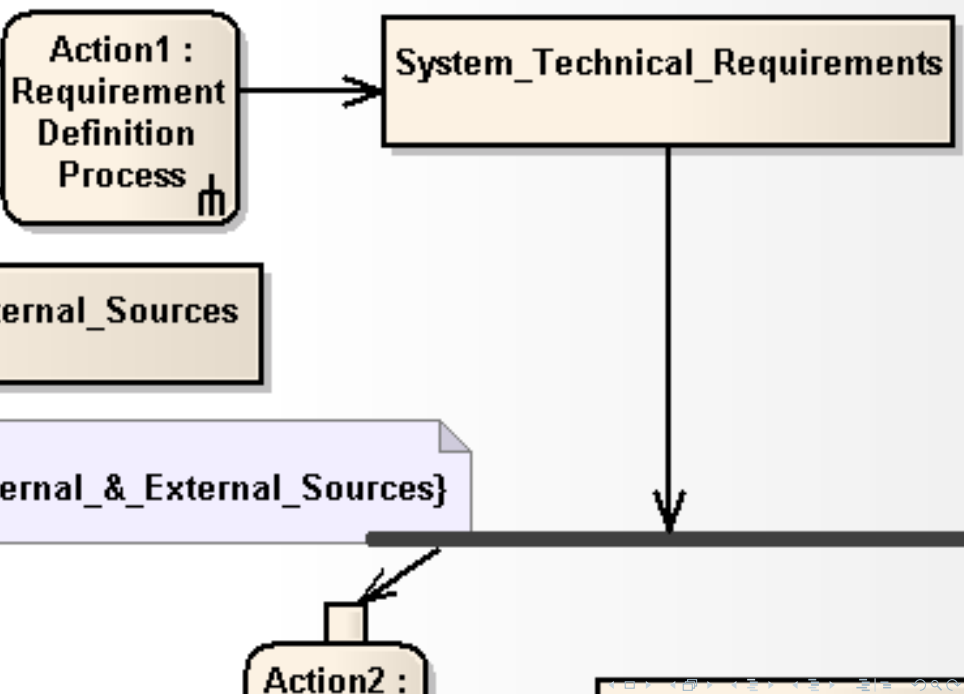
- **ATLAS** ANR project
- scientific collaboration with the **LAAS-CNRS**
- **TOPCASED** project



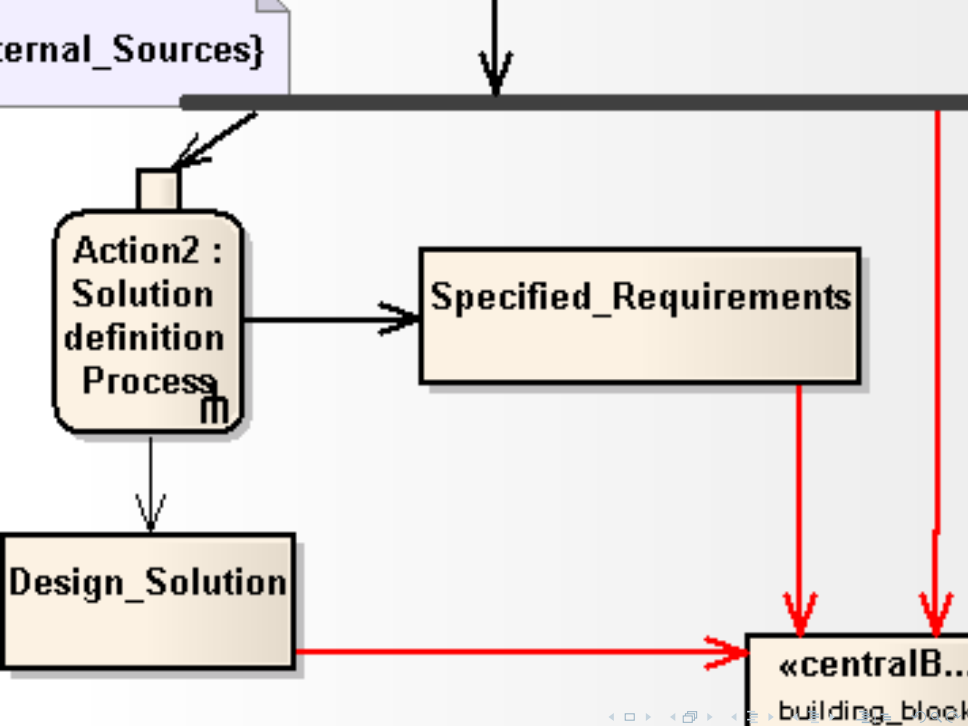
Thanks for your attention...

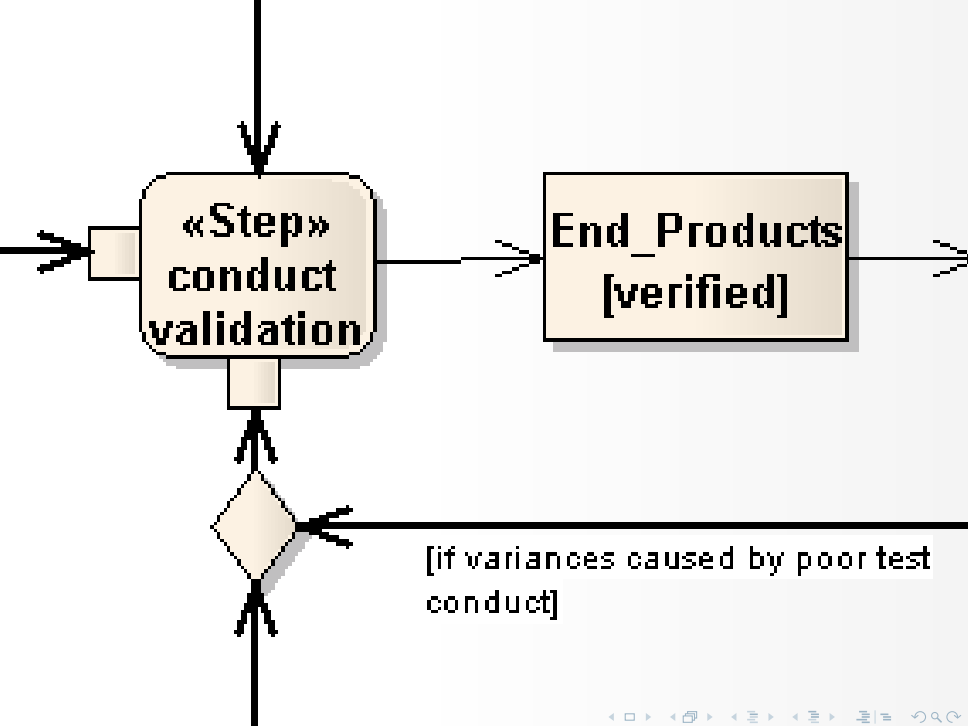


«transformation»
{building_block.Other_Requirements_from_Internal_&_External_Sources}

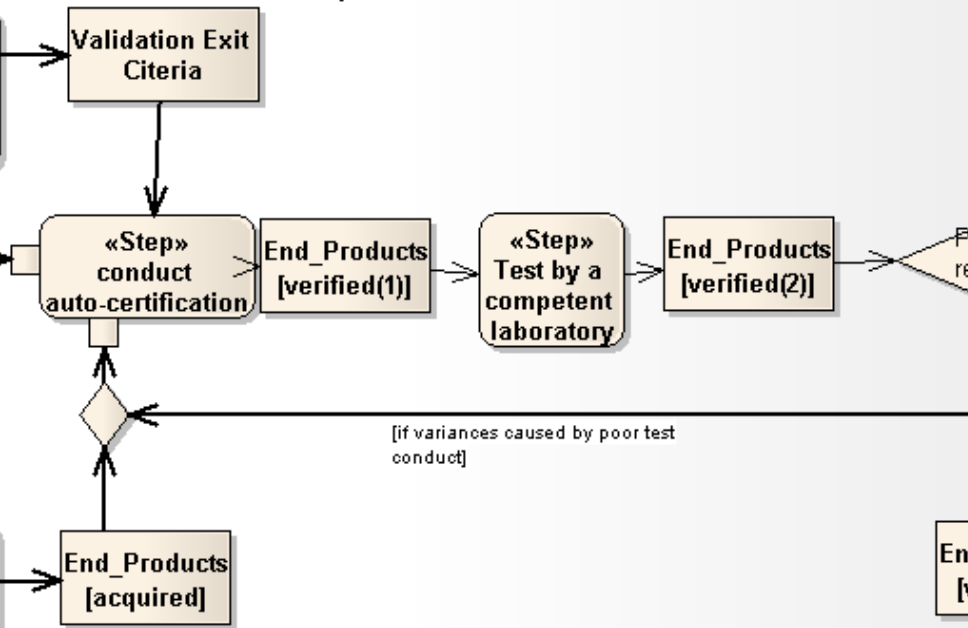


Internal_Sources}





R33 End products validations



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15 Septembre 2004.



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