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Towards V&V suitable Domain Specific Modeling Languages for MBSE: a toolled approach

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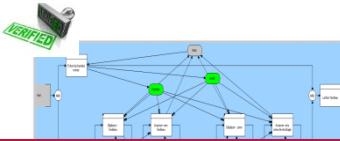
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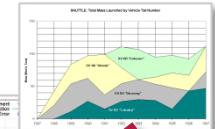
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MBSE context: research problematic



Functional /
Behavioural



1) To create Domain Specific Modeling Language (DSML) suitable for modelling a system (multi disciplinary, multi views / aspects, ...) i.e. building models

Each Model is...

- A partial and incomplete, may be false but crucial representation of the Sol
- An input for reasoning during

2) Model V&V: as
(Verification), just

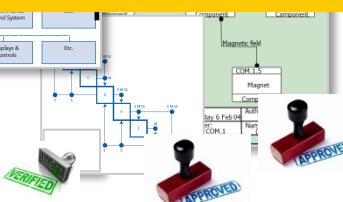
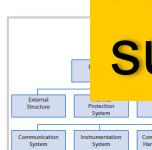


and conformity
as (Validation)



Contribution:

A tool-equipped approach for the design and use of V&V
suitable Domain Specific Modeling Languages for MBSE



Physical /
Organic
Systems Engineering

→ (Safety, Costs,
Mechanical...)



Agenda

Illustrated background

Contributions

Case study

Conclusion and Perspectives



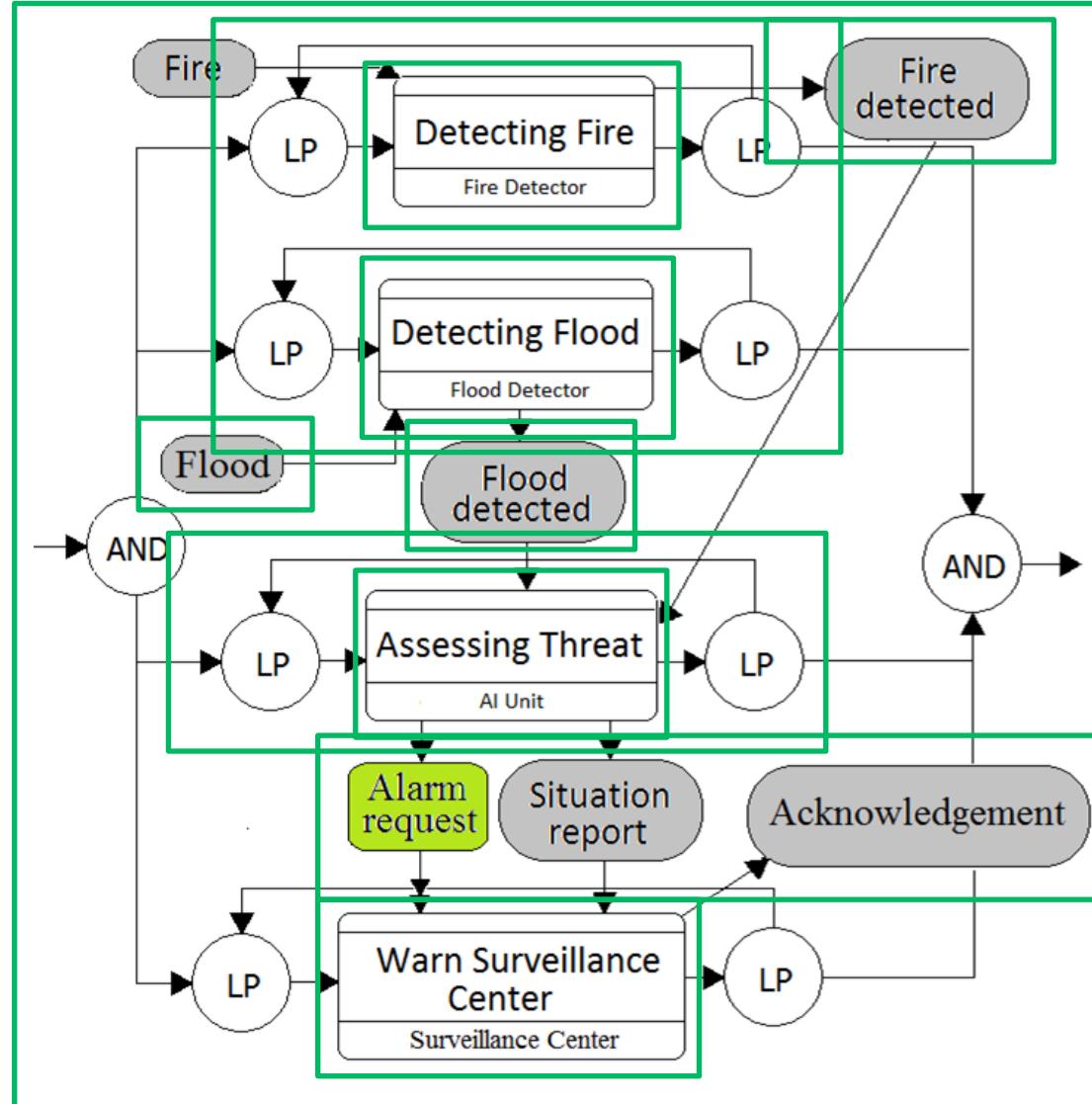
Illustrated background

Illustration: enhanced Functional Flows Block Diagram (eFFBD)

Function

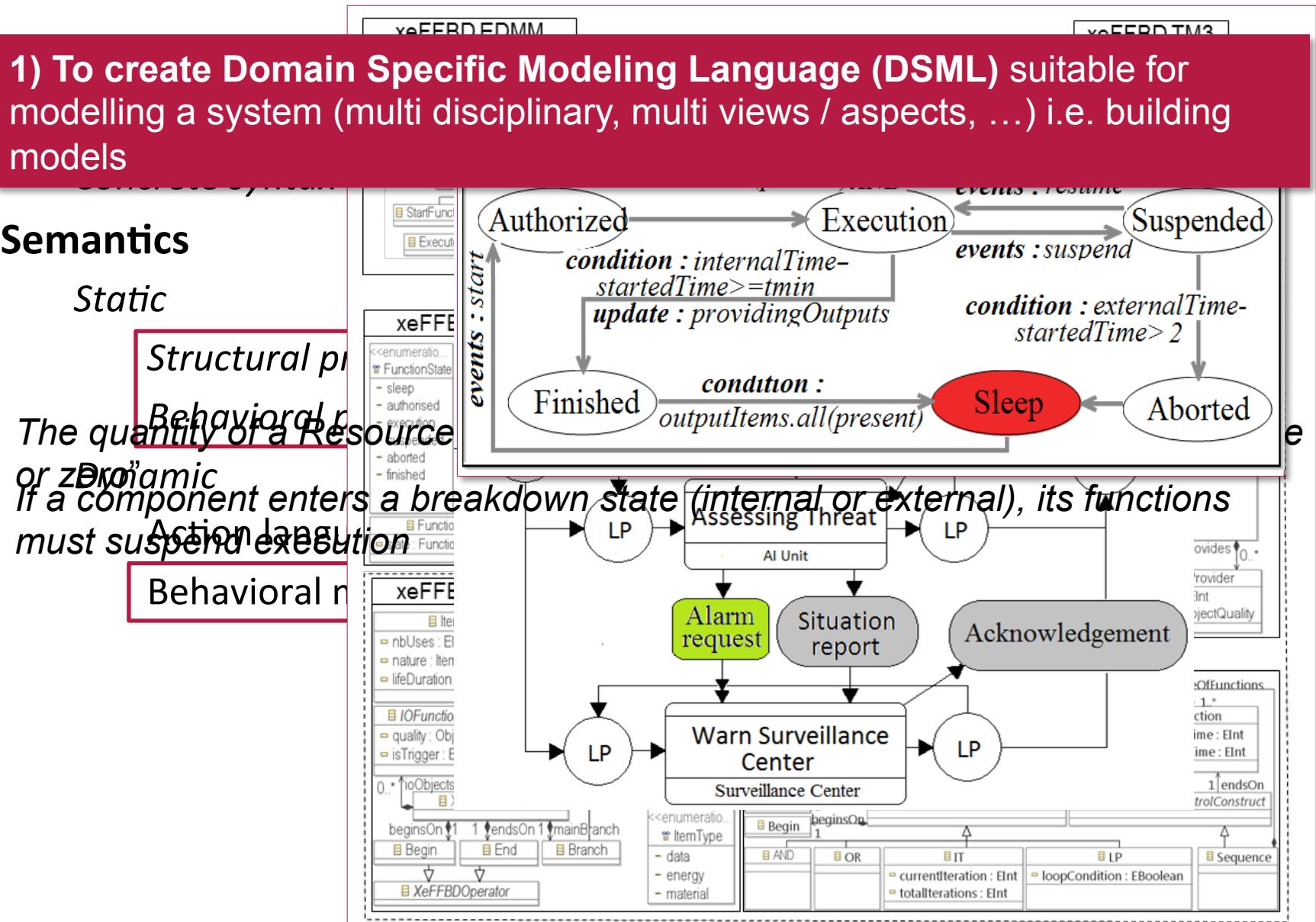
Flow
(I/O, Trigger)

Construct
(parallelism, choice, loop, ...)



Functional / Behavioural model (dynamics of a system)

1) To create DSML: things to consider



2) Model V&V

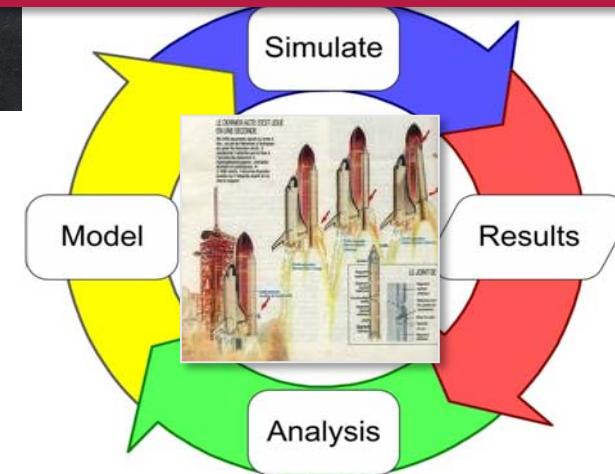
Excellent

2) Model V&V: assure model's well-formedness, coherence and conformity (**Verification**), justifiability and relevance for expert's objectives (**Validation**)

Expert's model evaluation

Model simulation

Formal properties proof



Based on 3rd party formal approaches (M2M transformation)

(+) *Reuse of existing approaches*

(-) *Information loss, relevance between the source and the target*

Detailed contribution

A *tool-equipped approach for the design of DSMLs*
allowing Verification and Validation of models by
using simultaneously simulation and formal
properties proof

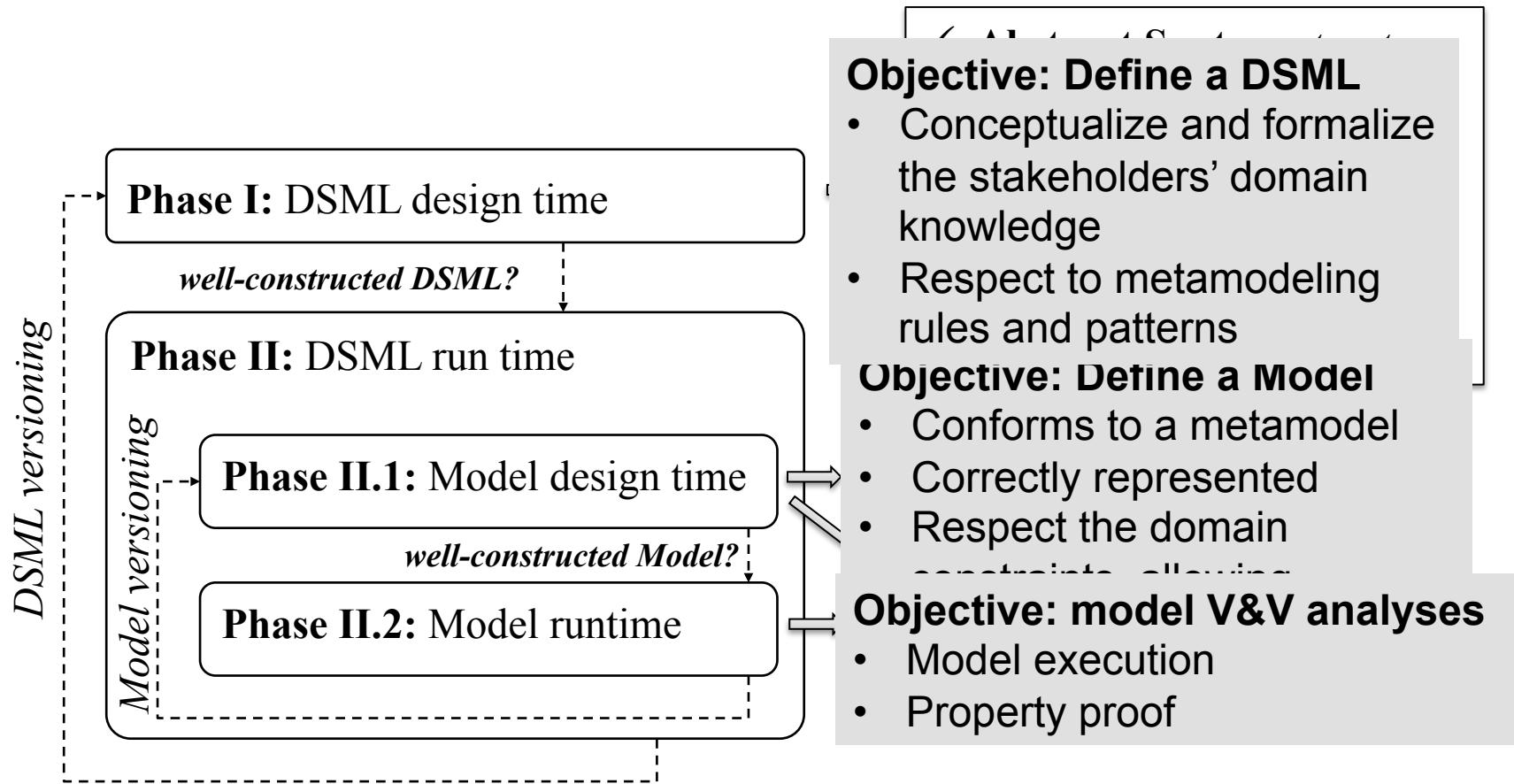
**xviCore: eXecutable, Verifiable
and Interoperable Core**



Contributions

Conceptual contributions: life cycle

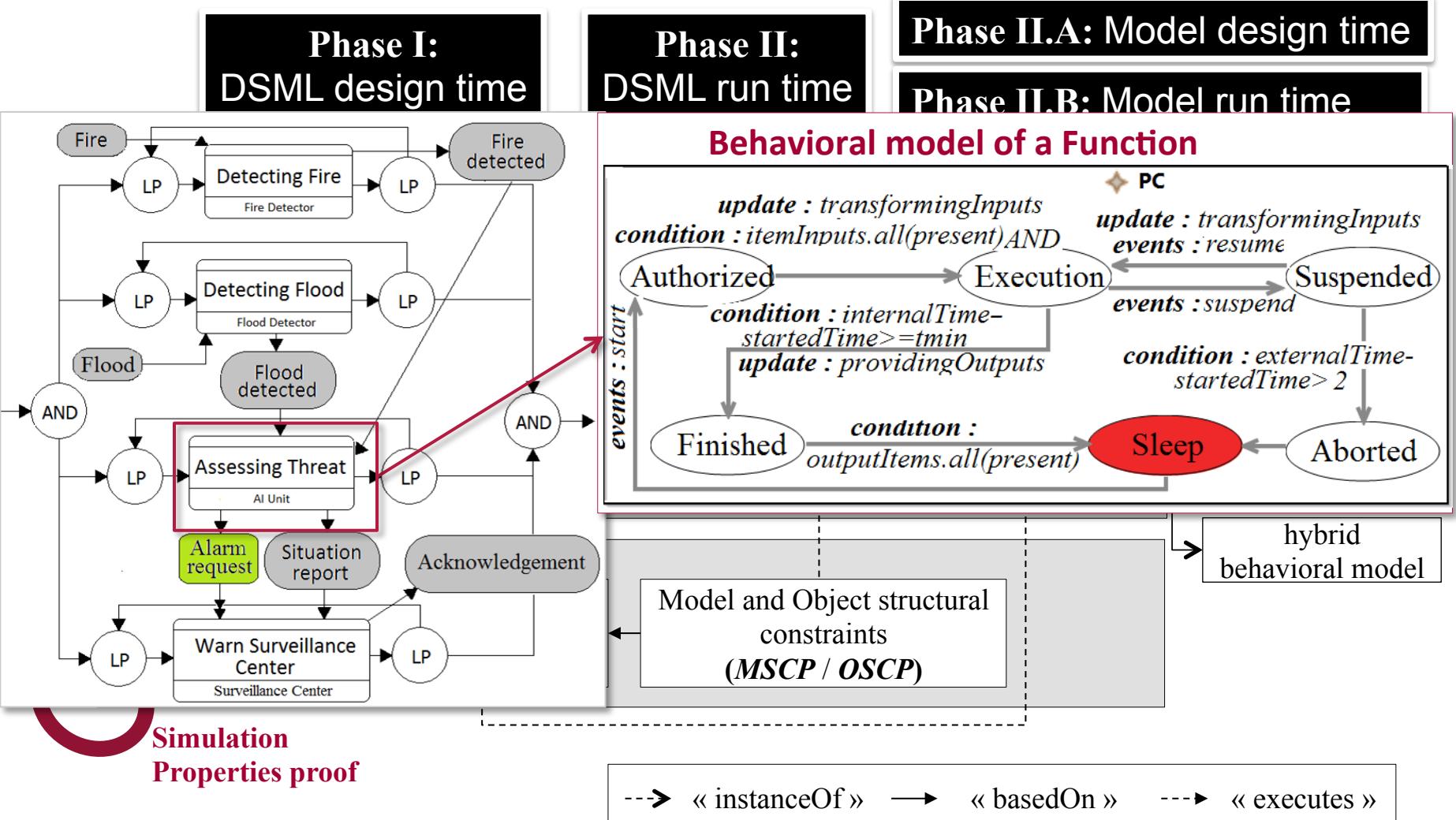
Contribution goal: to provide stakeholders with a life cycle including the design of V&V suitable DSMLs and models



Conceptual contributions: meta languages

xviCore follows previously proposed lifecycle

xviCore promotes 3 meta-languages



Conceptual contributions: simulation mechanisms

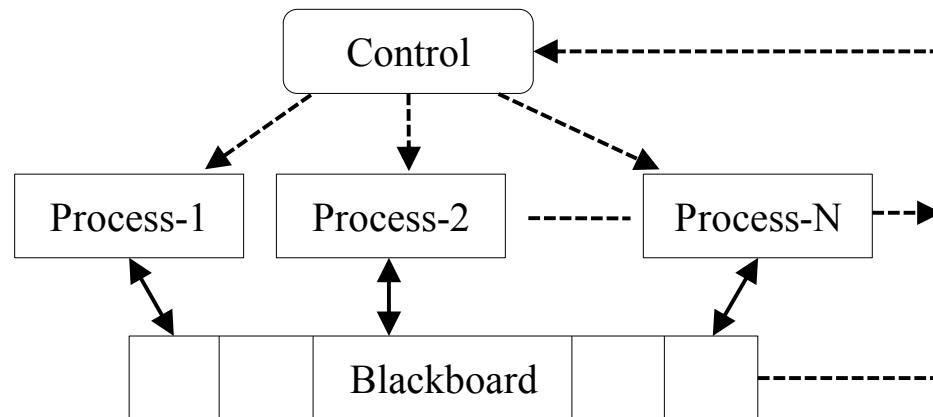
Observation

The operational semantics is defined as a set of **behavioral models** that are associated to chosen domain concepts of a DSML

Problem

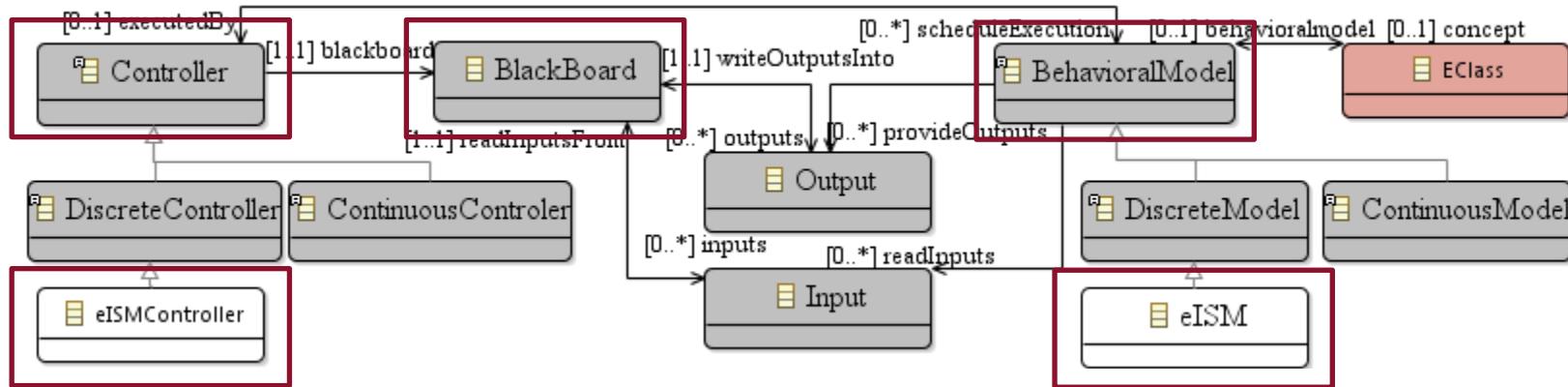
How to coordinate all behavioral models from one or several DSMLs during simulation?

State of the art: Blackboard Design Pattern (Engelmore and Morgan, 1988)



Methodological contribution: simulation mechanisms

Objective: applying the Blackboard Design Pattern in the MBSE context



- Allows data exchange between behavioral models

Proof of concept (Vandermeulen, 1996) (SIVI)

- Based on a simple execution algorithm
 - Read inputs from blackboard
 - Calculate future state
 - Write outputs into blackboard
- and other original rules

Underlying structure based on the LTL (Linear Temporal Logic)

Methodological contribution: verification mechanisms

Formal properties proof mechanisms of xviCore approach

Formal specification

- syntaxes i.e. structure of the model
- dynamic semantics i.e. behavioral models)

Formal properties (structural and behavioral properties)

- using property modelling language: UPSL-SL(Chapurlat, 2013)

A model-checker tool (bridging specification and properties)

Reuse of existing tools :

OCL interpreter for structural properties

LTL model checker for behavioral properties

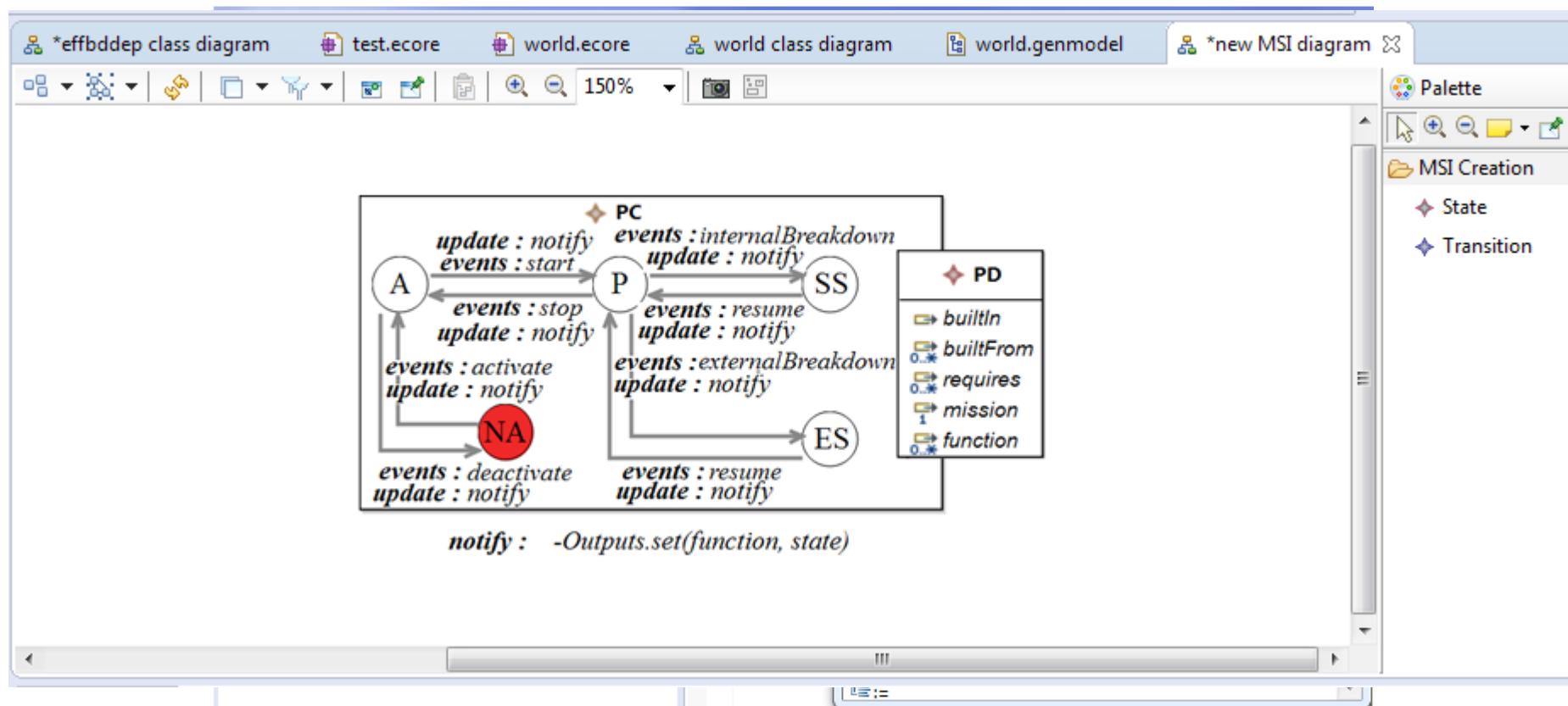
Technical contribution: current editors

DSML design

Editor for the DSML structure

Editor for the DSML behavior

Editor for the DSML constraint



Technical contribution: extending EMF

We have extended the code generation library of EMF

Generation of a simulation library

Simulation

Sirius - toto/src/toto/impl/TotoPackageImpl.java - Obeo Designer Community

Sirius - toto/src/toto/impl/TotoPackageImpl.java - Obeo Designer Community

File Edit Source Refactor Navigate Search Project Run Window Help

File Edit Source Refactor Navigate Search Project Run Window Help

Properties < Interpreter Problems Console Call Hierarchy Search Debug

New_configuration [Eclipse Application] C:\Program Files (x86)\Java\jre1.8.0_31\bin\javaw.exe [3 juil. 2015 18:09:59]
org.eclipse.emf.ecore.impl.1BlackTableRowImpl@1b7678a (timeOfAdding: 5, varName: debit, varType: EDouble, varValue: 2.5, receivers: [toto.impl.ReservoirImpl@b6561b (niveauEau: 7.3, niveauEauMax: 10.0, niveauEauMin: 1.0), toto.impl.ReservoirImpl@b6561b (niveauEau: 9.8, niveauEauMax: 10.0, niveauEauMin: 1.0)], sender: toto.impl.ReservoirImpl@b6561b (niveauEau: 7.3, niveauEauMax: 10.0, niveauEauMin: 1.0))

Global logic time : 6

Runing MSI : VanneMSI pour l'object : toto.impl.VanneImpl@194a966 (debit: 0.0, debitMax: 2.0, croissanceDebit: 0.2, decroissanceDebit: 0.2)

VanneMSI incrementation de temps externe (6 UT)

VanneMSI IE : lecture des entrees

VanneMSI IE : calcule des vars propositionnels

VanneMSI initialisation T interne

VanneMSI PC : etat currant (avant CEF-ARS) : Sclosed

VanneMSI incrementer T interne

VanneMSI PC : CEF State before CEF : closed

VanneMSI State after CEF : closed

VanneMSI IS : execution des fonction de mis a jour

VanneMSI MSI : Stability Reached...

Runing MSI : ControllerNewMSI pour l'object : toto.impl.ControllerImpl@bdd996

ControllerNewMSI incrementation de temps externe (6 UT)

ControllerNewMSI IE : lecture des entrees

ControllerNewMSI IE : calcule des vars propositionnels

ControllerNewMSI initialisation T interne

ControllerNewMSI PC : etat currant (avant CEF-ARS) : SOF

ControllerNewMSI incrementer T interne

ControllerNewMSI PC : CEF State before CEF : OF

ControllerNewMSI State after CEF : OF

ControllerNewMSI IS : execution des fonction de mis a jour

ControllerNewMSI MSI : Stability Reached...

Runing MSI : ReservoirMSI pour l'object : toto.impl.ReservoirImpl@b6561b (niveauEau: 7.3, niveauEauMax: 10.0, niveauEauMin: 1.0)

ReservoirMSI incrementation de temps externe (6 UT)

ReservoirMSI IE : lecture des entrees

ReservoirMSI IE : calcule des vars propositionnels

ReservoirMSI initialisation T interne

ReservoirMSI PC : etat currant (avant CEF-ARS) : Ss1

ReservoirMSI incrementer T interne

ReservoirMSI PC : CEF State before CEF : s1

ReservoirMSI State after CEF : s1

ReservoirMSI IS : execution des fonction de mis a jour

ReservoirMSI MSI : Stability Reached...

Runing MSI : VanneMSI pour l'object : toto.impl.VanneImpl@105dcab (debit: 2.5, debitMax: 3.0, croissanceDebit: 0.5, decroissanceDebit: 0.5)

VanneMSI incrementation de temps externe (6 UT)

VanneMSI IE : lecture des entrees

VanneMSI IE : calcule des vars propositionnels

VanneMSI initialisation T interne

VanneMSI PC : etat currant (avant CEF-ARS) : Sopening

VanneMSI incrementer T interne

VanneMSI PC : CEF State before CEF : opening

VanneMSI State after CEF : opening

VanneMSI IS : execution des fonction de mis a jour

VanneMSI MSI : Stability Reached...

Printing TN

Printing the content of the Black Table

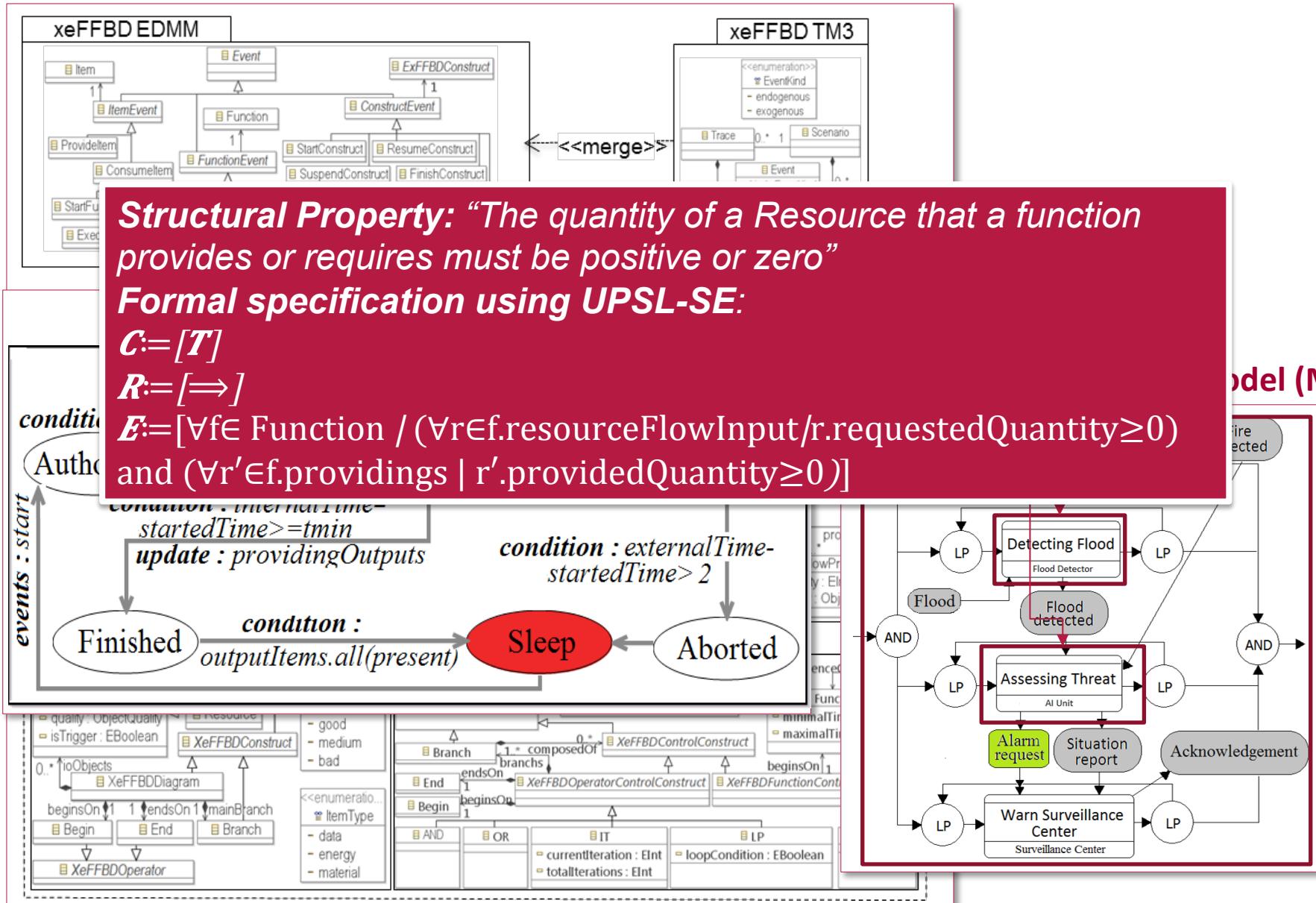
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org.eclipse.emf.ecore.impl.1BlackTableRowImpl@1bd0006 (timeOfAdding: 5, varName: open, varType: Event, varValue: true, receivers: [toto.impl.VanneImpl@105dcab (debit: 3.0, debitMax: 3.0, croissanceDebit: 0.5, decroissanceDebit: 0.5), toto.impl.VanneImpl@194a966 (debit: 0.0, debitMax: 2.0, croissanceDebit: 0.2, decroissanceDebit: 0.2)], sender: toto.impl.VanneImpl@194a966 (debit: 0.0, debitMax: 2.0, croissanceDebit: 0.2, decroissanceDebit: 0.2))

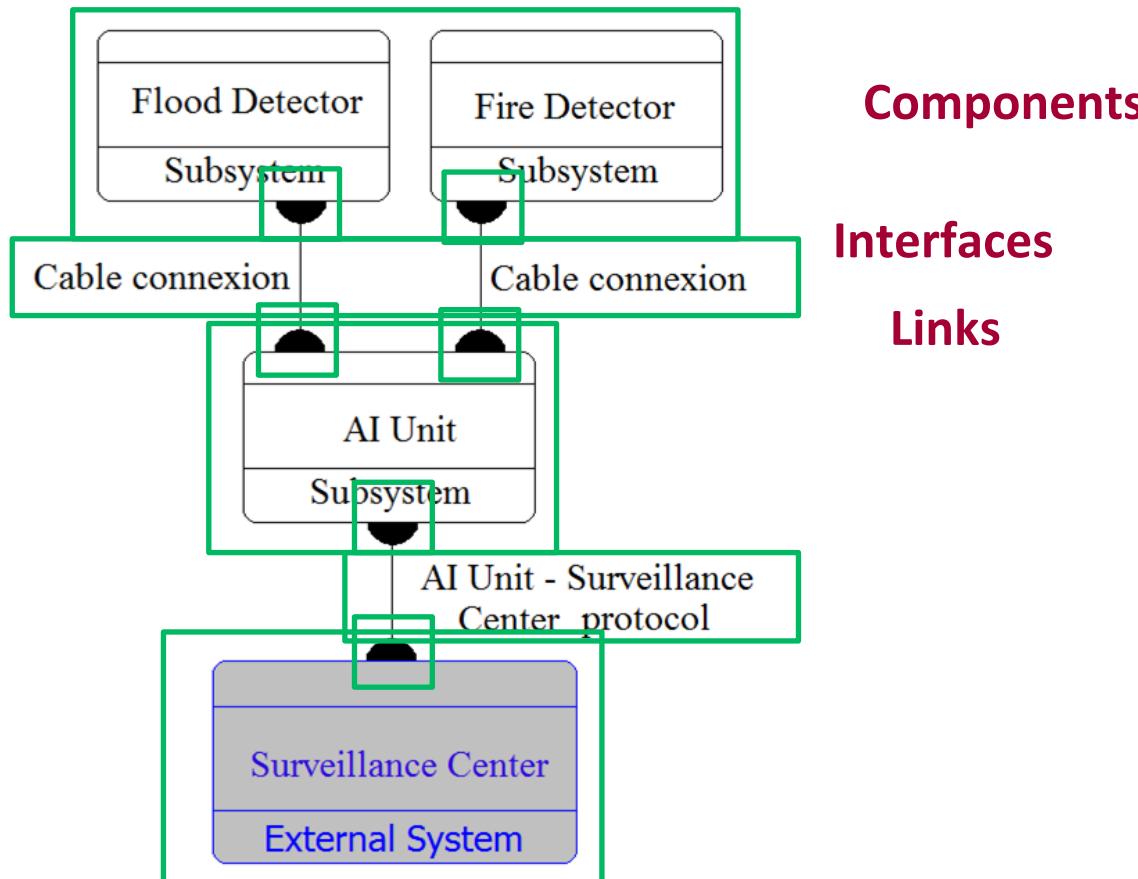
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Application case: EFFBD and PBD

Reminder: enhanced Functional Flows Block Diagram (eFFBD)



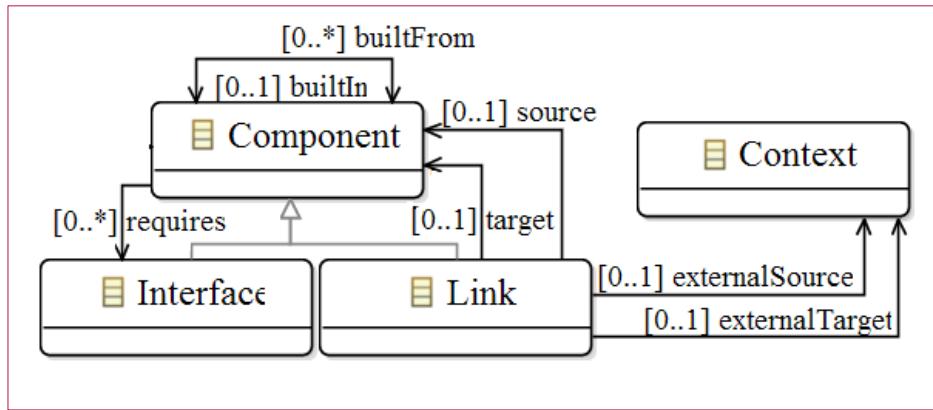
Sum up and application to Physical Block Diagram (PBD)



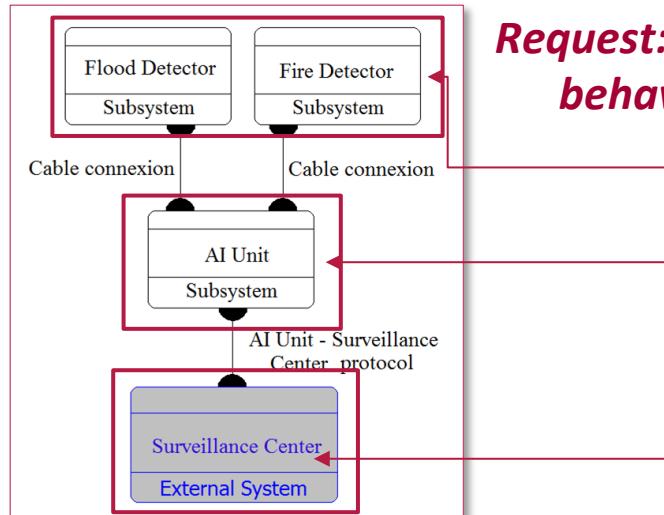
Model of architectural composition (the physical components of a system)

Example: Physical Block Diagram (PBD)

PBD abstract syntax (SP)

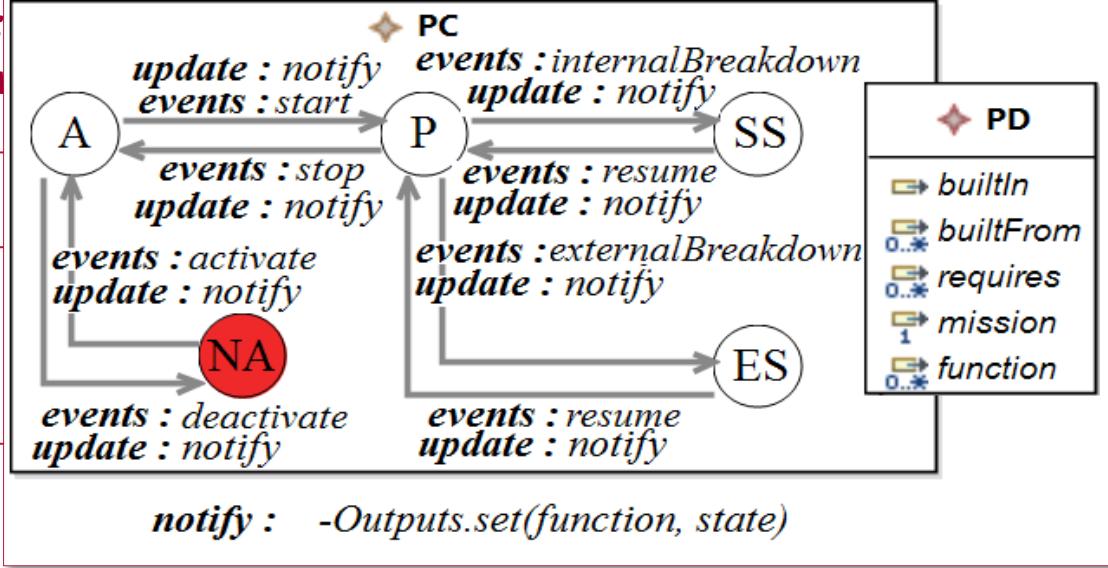


PBD model (MSP)



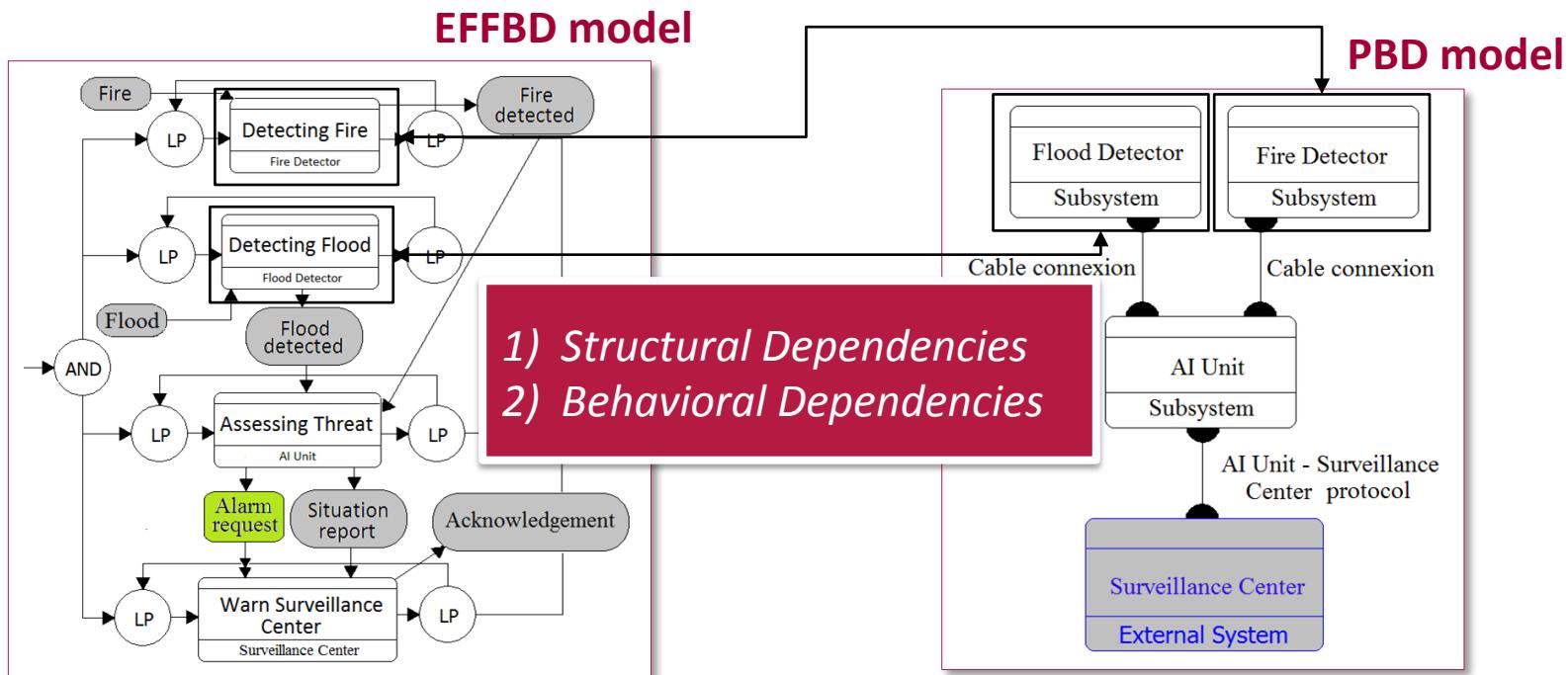
*Request:
behavior*

PBD BP (for Component)



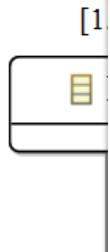
Dependencies between eFFBD and PBD

*“Physical components of a system **perform** one or more functions and functions are **allocated** to a component”*



Dependencies between eFFBD and PBD

EFFBD DSN



Constraint:

“If a component enters a breakdown state (internal or external), its functions must suspend execution”

Formal specification using UML-SE:

$$C := [\forall c \in \text{Component} \mid c.\text{State} = \text{SS} \text{ OR } c.\text{State} = \text{ES}]$$

$$R := [\Rightarrow]$$

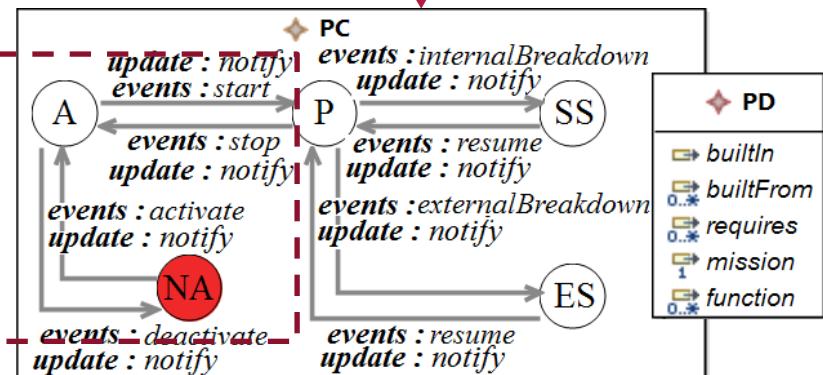
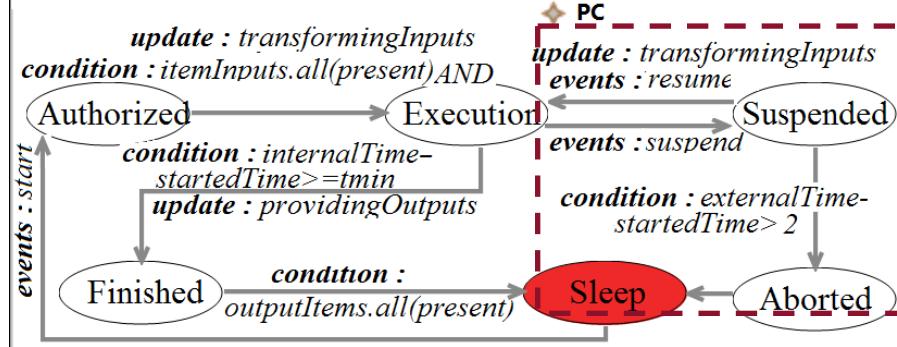
$$E := [o(\forall f \in c.\text{performs} \mid f.\text{State} \neq \text{Execution})]$$

DSML

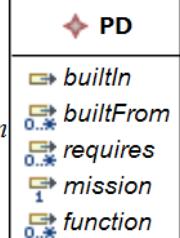
Structural
Dependencies



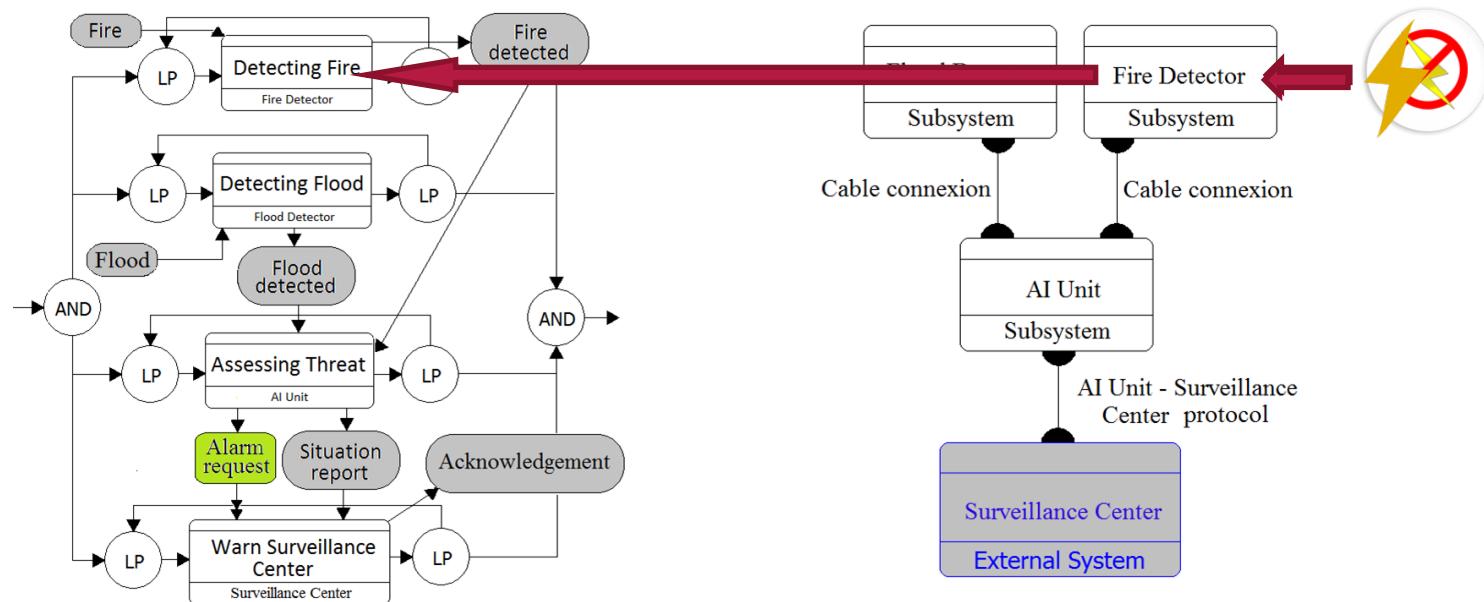
Behavioral dependencies



notify : -Outputs.set(function, state)



Simulation of eFFBD and PBD



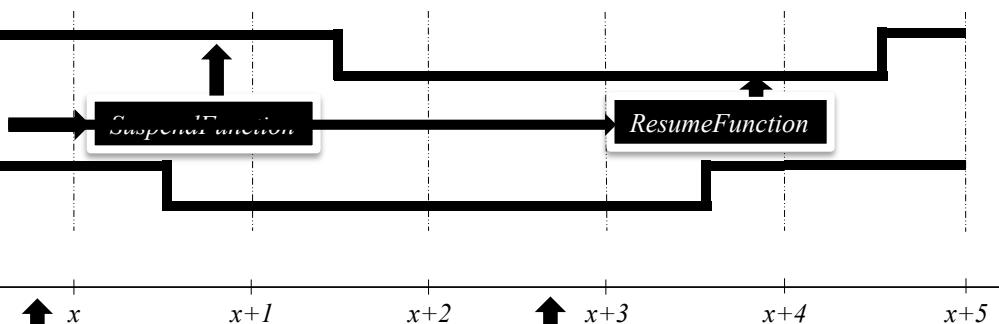
Detecting Fire

*Execution
Suspended*

Fire Detector

*Producing
External Stop*

Global time scale



Conclusion and Perspectives

Research focus

Modelling Complex Systems

Contributions

A lifecycle process for modeling, verification and validation

An approach for the design of DSMILs and models

Simulation and Formal verification of properties

Tool support

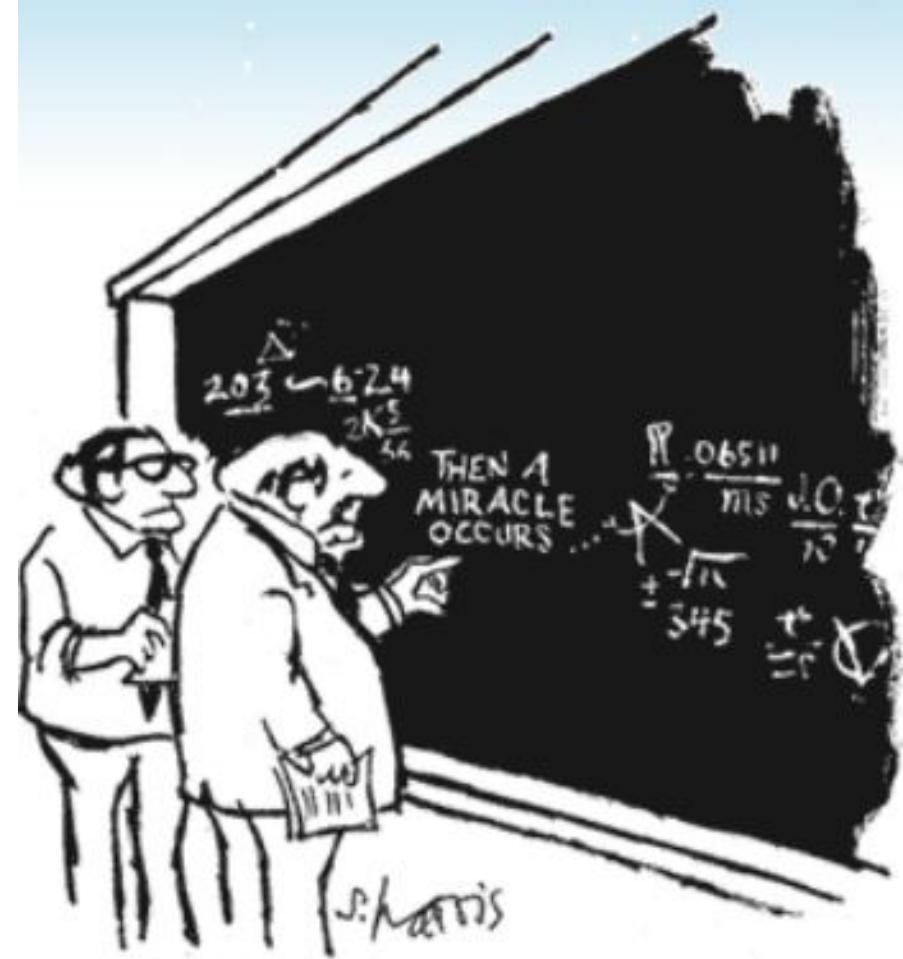
Application case: eFFBD and PBD

Future works

Continuous and Hybrid behavioral models

Thank you
for your attention

Questions?



"I THINK YOU SHOULD BE MORE
EXPLICIT HERE IN STEP TWO."