SYSML AS A COMMON INTEGRATION PLATFORM FOR CO-SIMULATIONS – EXAMPLE OF A CYBER PHYSICAL SYSTEM DESIGN METHODOLOGY IN GREEN HEATING VENTILATION AND AIR CONDITIONING SYSTEMS

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Faites de votre projet un succès

United Technologies Research Center

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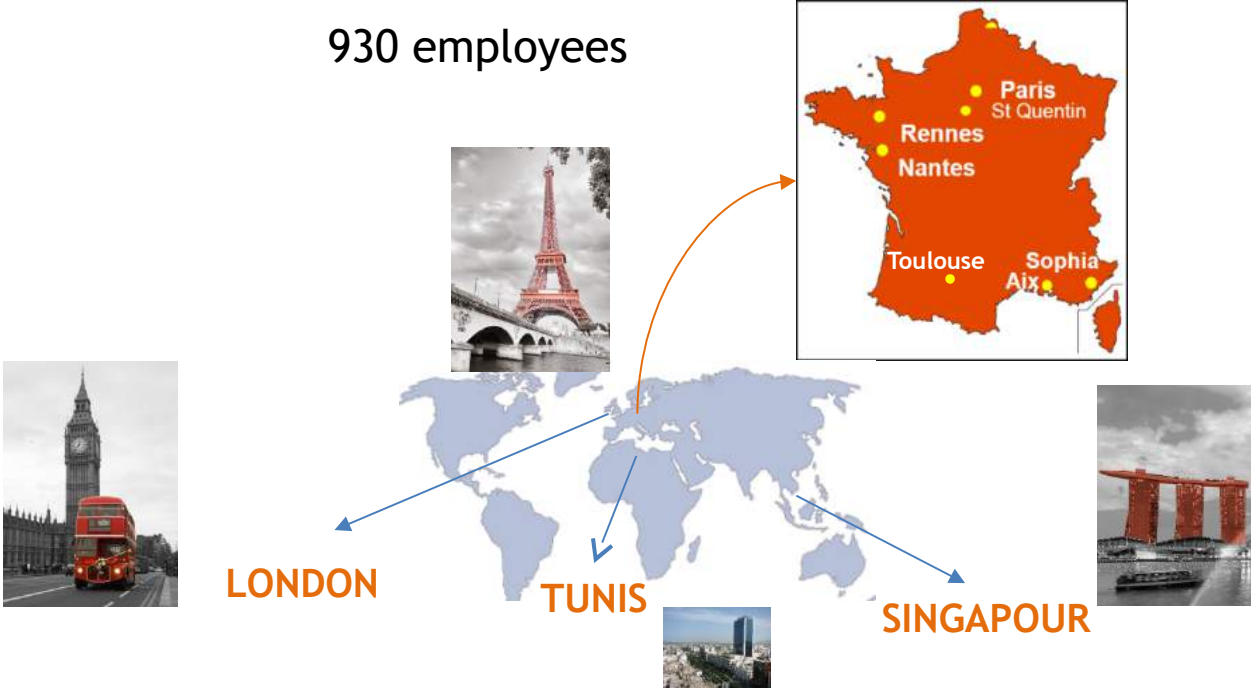United Technologies Research Center Ireland

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2016 CEE-SEC(R)

WHY TO CO-SIMULATE CYBER-PHYSICAL SYSTEMS AND HOW?

Capital   20 M€

Sales   82 M€

Staff   930 employees

LONDON

TUNIS

SINGAPOUR

Paris
St Quentin
Rennes
Nantes
Toulouse
Sophia
Aix

Senior engineers
650

Architects
250

.Net, JEE, C++, web, BI
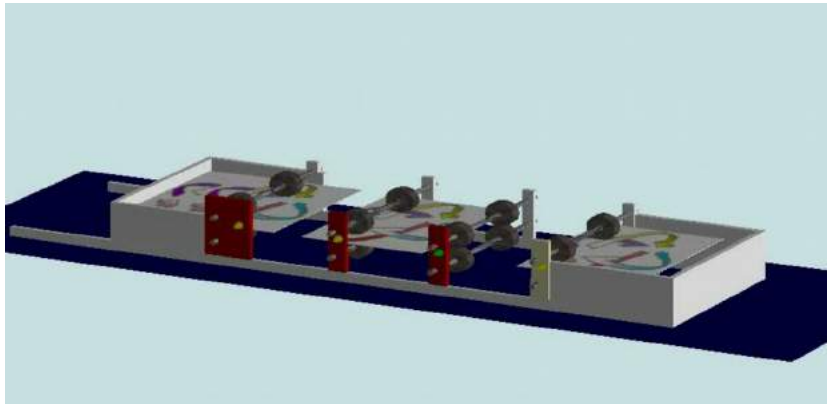Architects, urbanists, experts, project managers, project directors

Modelio

Interacting computing, physical, human elements
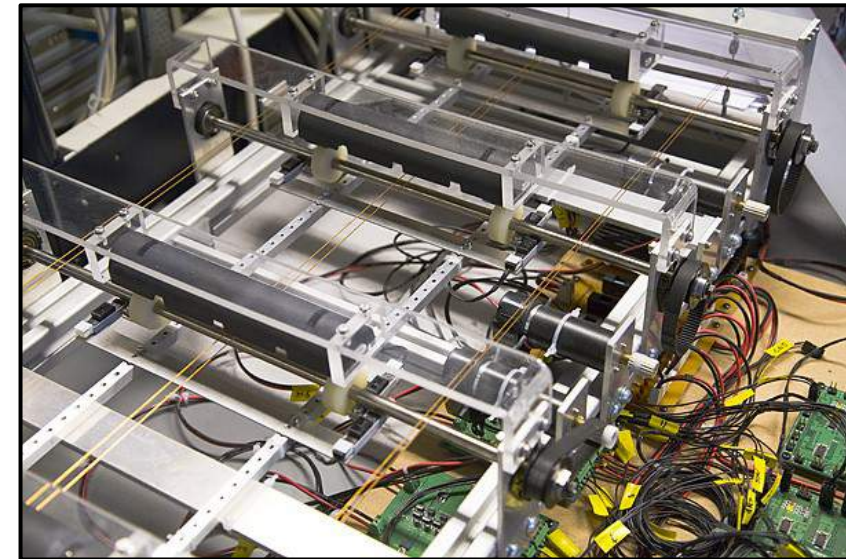
Increasingly complex logic ~80% of control software
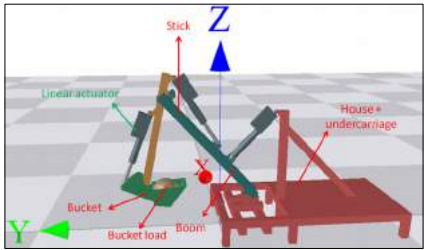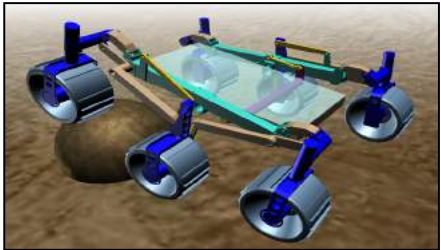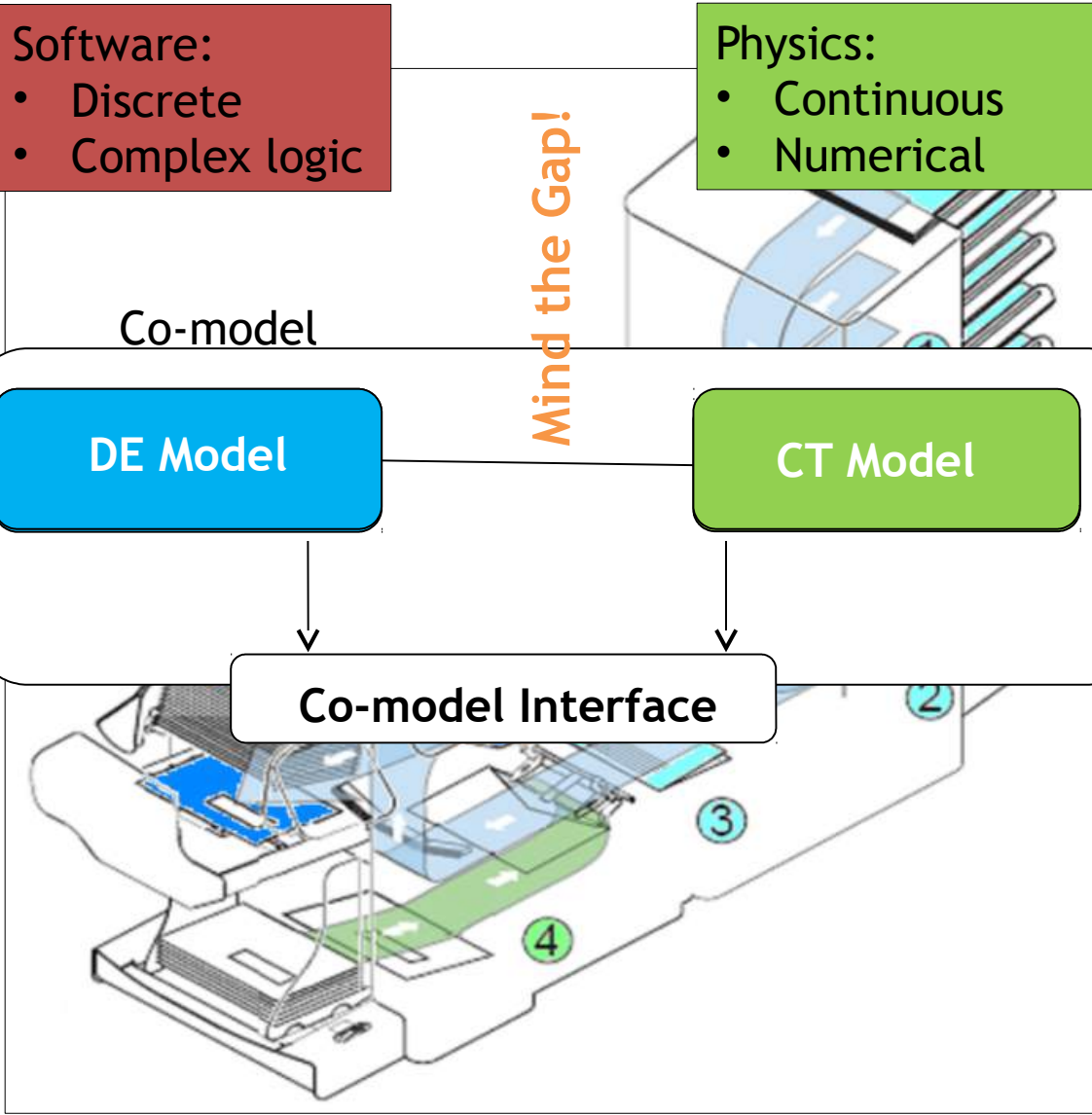
Error detection and recovery

Collaborative development

Diverse disciplines cultures, abstractions, formalisms typically tackled separately

Need for design space exploration

Software:
- Discrete
- Complex logic

Physics:
- Continuous
- Numerical

Mind the Gap!

Co-model

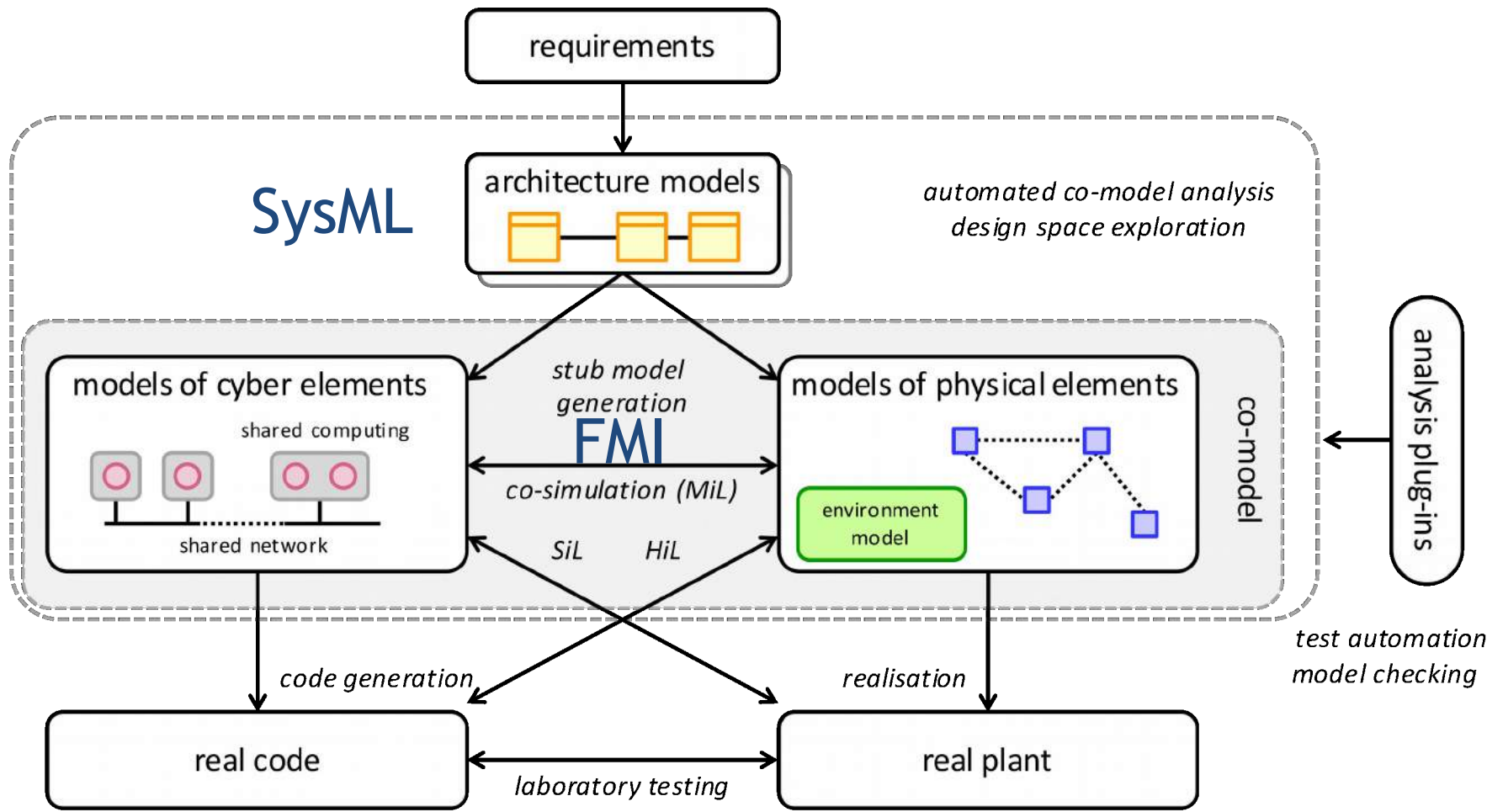**DE Model**

CT Model

Co-model Interface
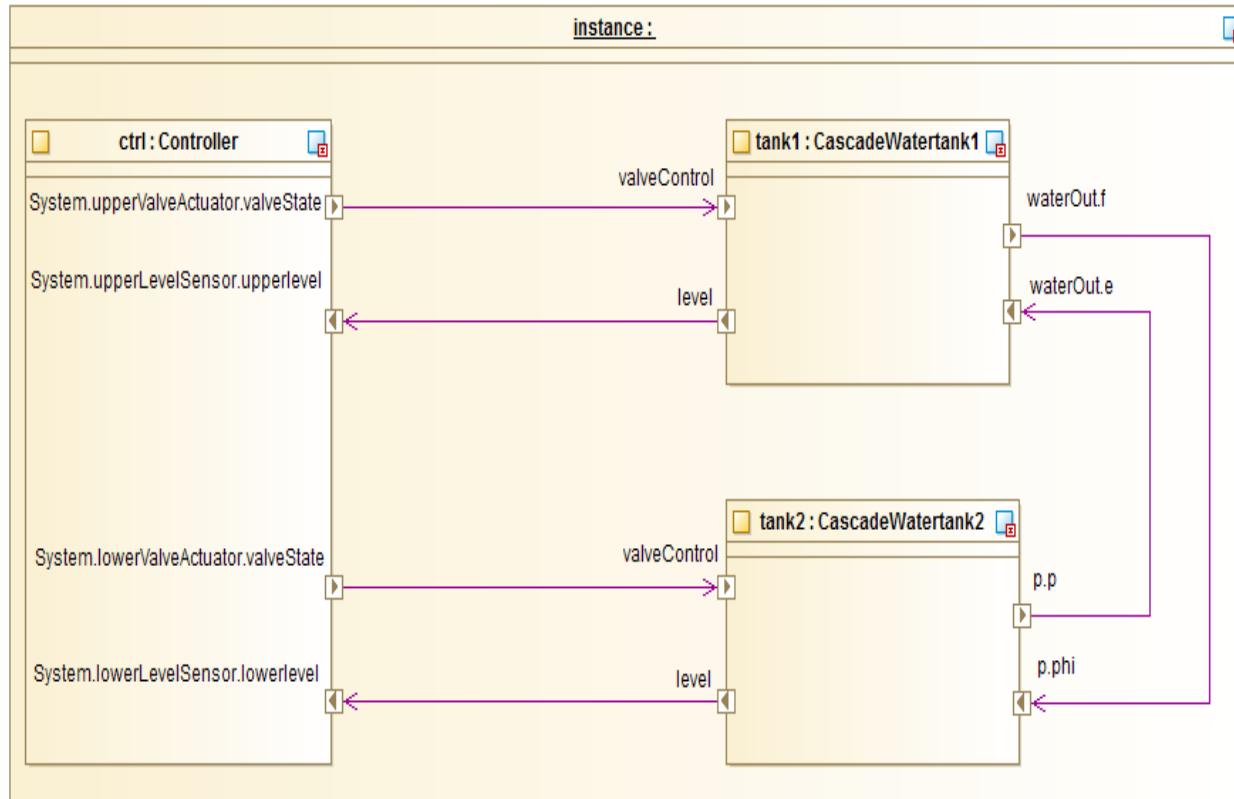
Functional Mock-up Interface

| define interfaces and packaging of simulators

We propose SysML as a language to define orchestrations of co-simulations on the system level

FMI and co-simulation configuration are generated

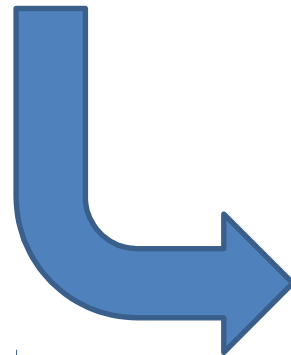Co-simulation orchestration engine executes test scenarios.

requirements

SysML

architecture models

automated co-model analysis
design space exploration

stub model generation

FMI

co-simulation (MiL)

models of cyber elements

shared computing

shared network

SiL   HiL

models of physical elements

environment model

co-model

analysis plug-ins

code generation

realisation

test automation model checking

real code

laboratory testing

real plant

1. Direct link with requirements models
2. Overview of all sub systems
3. Actionable systems models
4. Testing on the system level

generation

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Buildings are responsible for 40% of energy consumption and 36% of EU CO_2 emissions
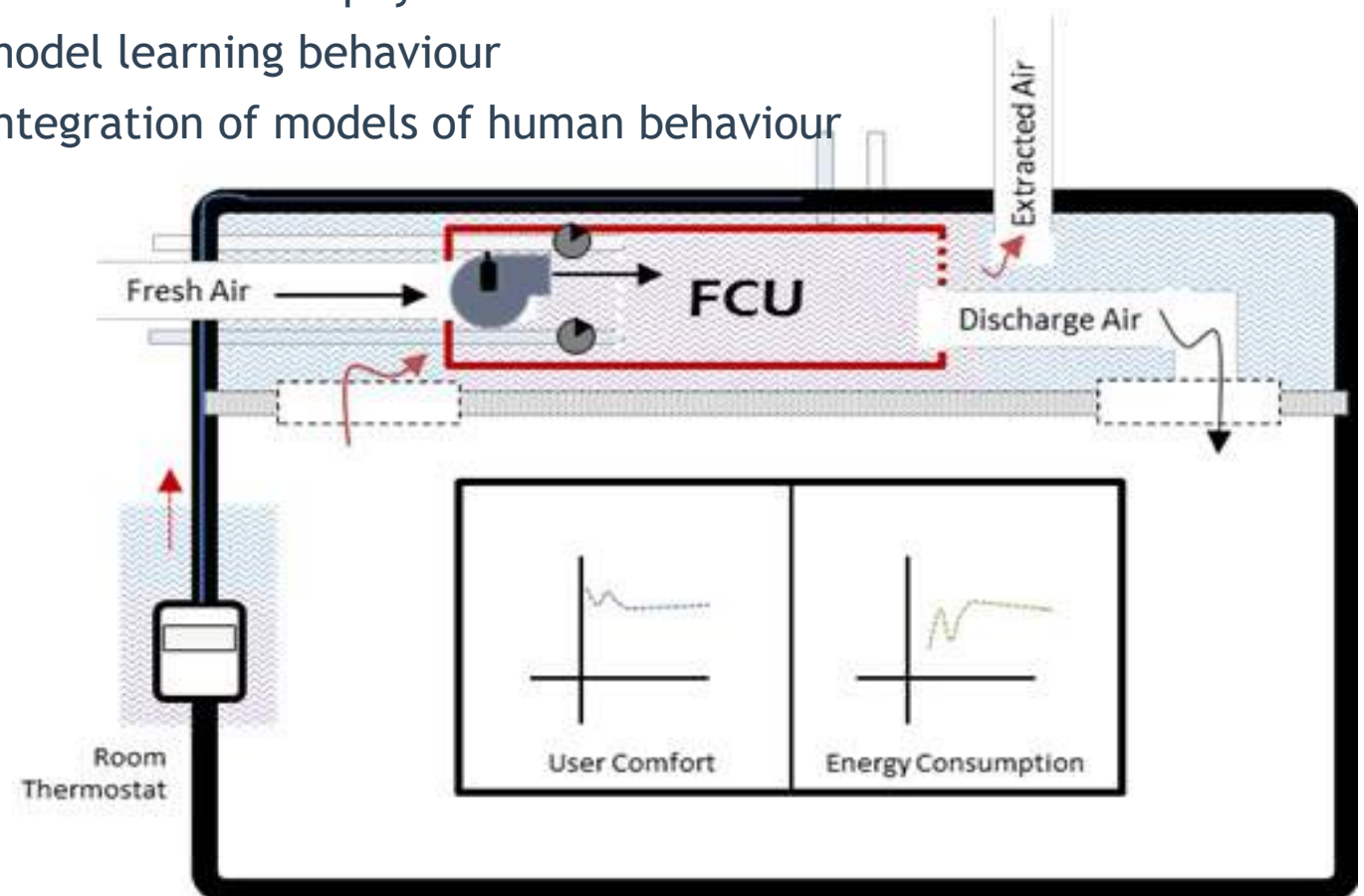
1. Models of large-scale, open, diverse data integration
2. .... coupled with models of physics
3. Need to model learning behaviour
4. Possible integration of models of human behaviour

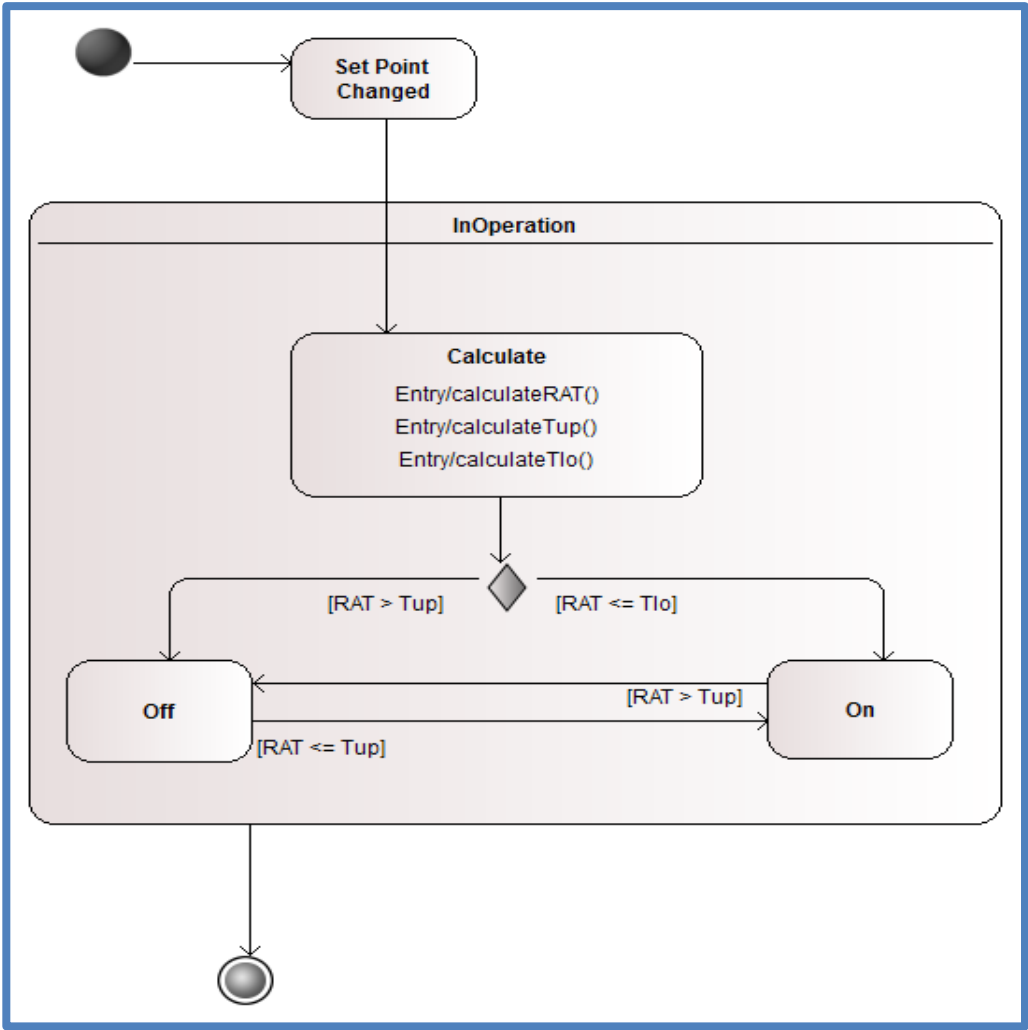# Experiment –step towards "green" buildings
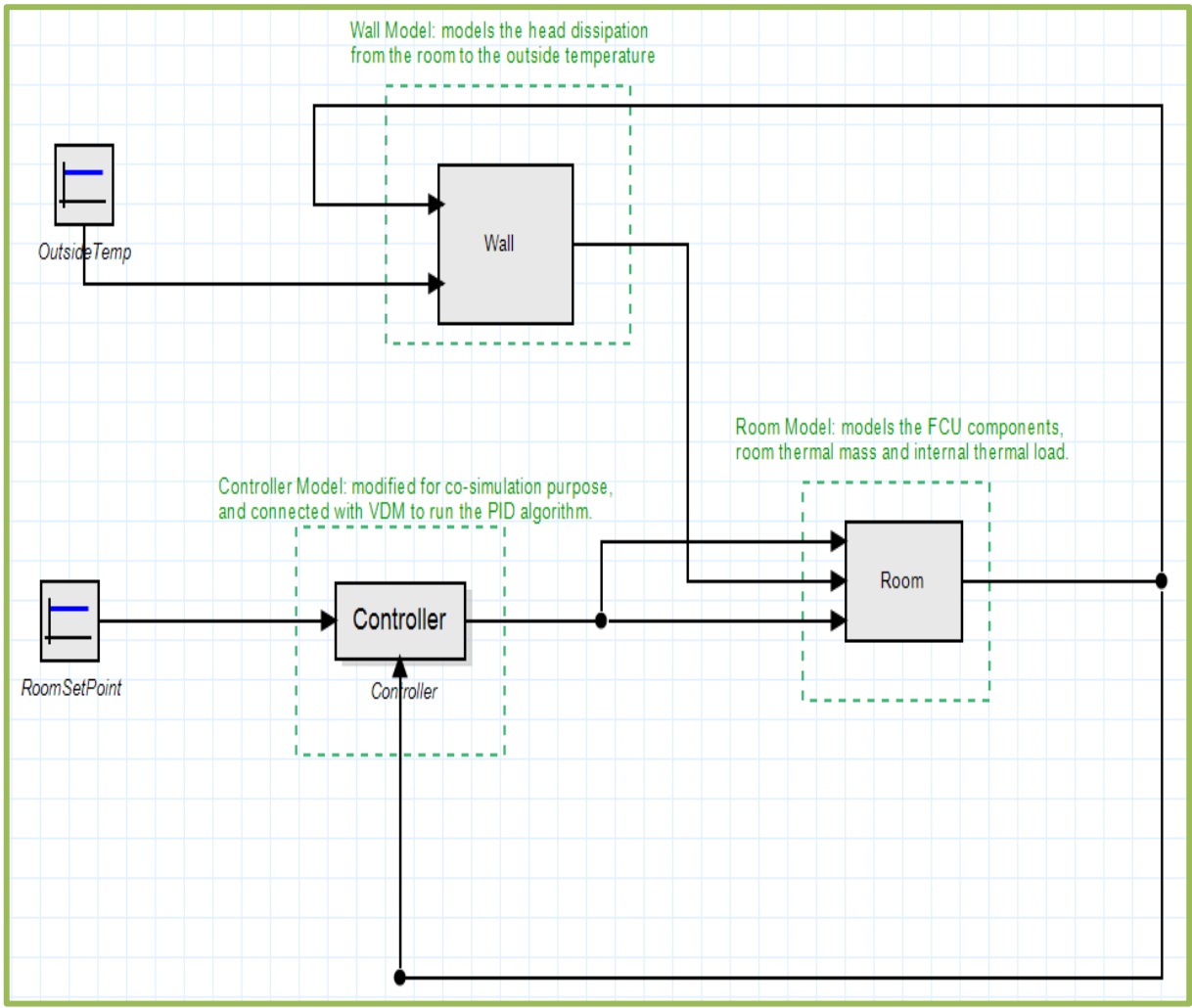
- Optimise
  - User comfort
  - Energy consumption

Fresh Air

FCU

Extracted Air

Discharge Air

Room Thermostat

User Comfort   Energy Consumption

Software:
- Discrete
- Complex logic

Physics:
- Continuous
- Numerical

InOperation

Set Point Changed

Calculate
Entry/calculateRAT()
Entry/calculateTup()
Entry/calculateTlo()

[RAT > Tup]   [RAT <= Tlo]

Off   [RAT > Tup]   **On**

[RAT <= Tup]

Wall Model: models the head dissipation from the room to the outside temperature

OutsideTemp   Wall

Controller Model: modified for co-simulation purpose, and connected with VDM to run the PID algorithm.

Room Model: models the FCU components, room thermal mass and internal thermal load.

RoomSetPoint   Controller   Room
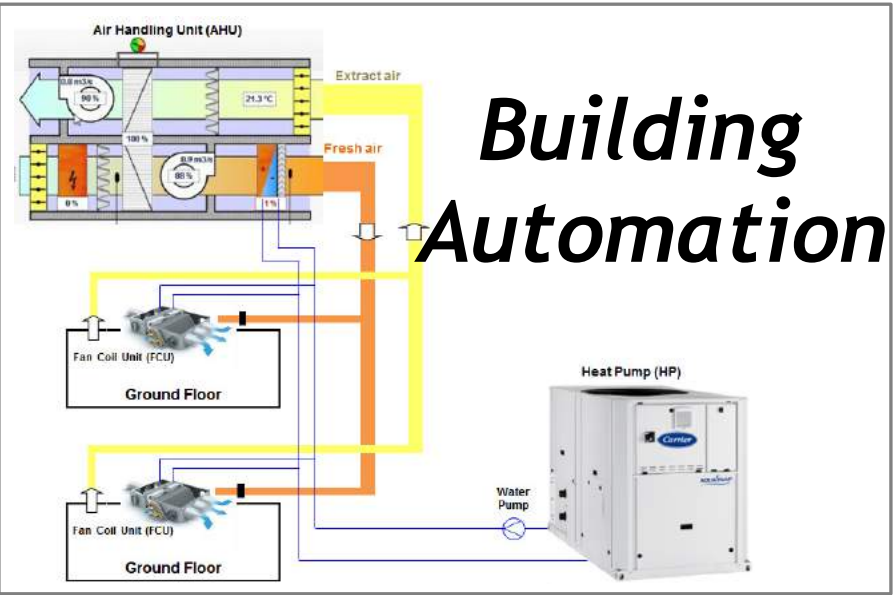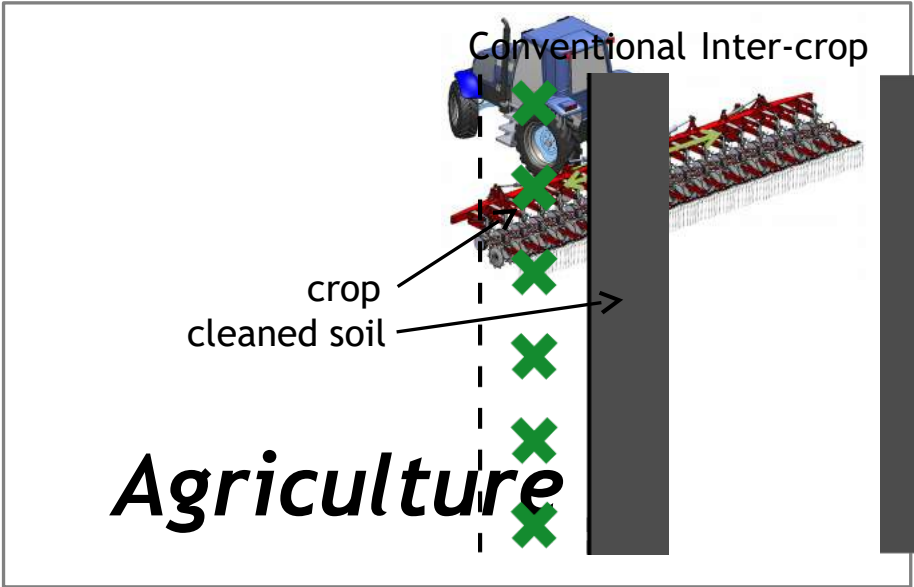
Controller

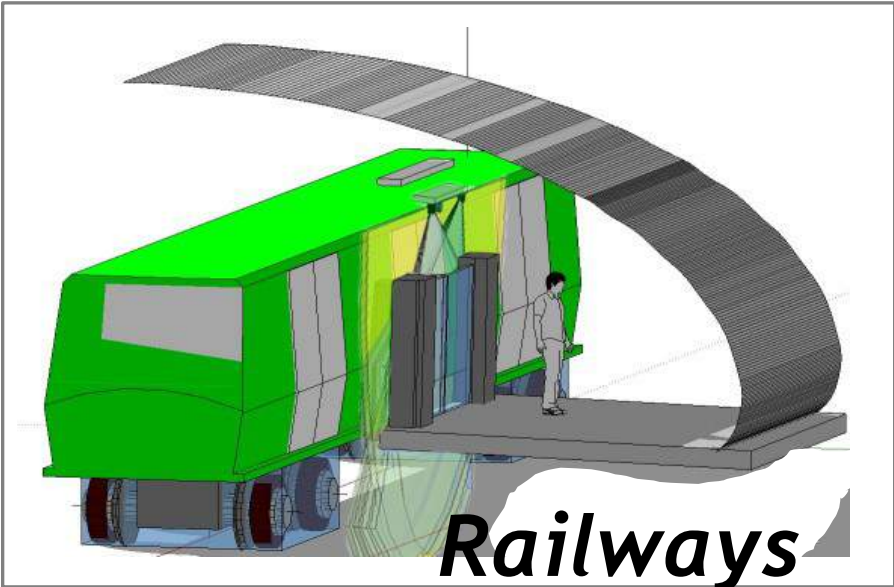**1.** More accurate way to calculate building performance i.e. comfort and energy consumption.

| Energy consumption for fan movement
| Energy consumption for the CPU of the FCU micro-controller
| Water flow through the coil

2. Step forward in accurate design of green buildings

Supply Air Temperature

Entering Water Temperature

Room Air Temperature

Time [Min]

Railways

Conventional Inter-crop

crop
cleaned soil

Agriculture

Building Automation

Automotive

HTTP://INTO-CPS.AU.DK/

AARHUS UNIVERSITET

UNITED TECHNOLOGIES

TWT GmbH Science & Innovation

LINKÖPINGS UNIVERSITET
Linköping University

Newcastle University

controllab

THE UNIVERSITY of York

Verified

KONGSKILDE

CLEARSY SYSTEM ENGINEERING

2016 CEE-SEC(R)

European Commission

Andrey Sadovykh

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