A Domain Model-Centric Approach for the Development of Large-Scale Office Lighting Systems

Richard Doornbos, Bas Huijbrechts, Jack Sleuters, Jacques Verriet, Kristina Ševo, Mark Verberkt

Signify ESI

ESI: hosted by TNO[*] in partnership with high-tech industry and universities

Mission: To advance industrial innovation and academic excellence in embedded systems engineering
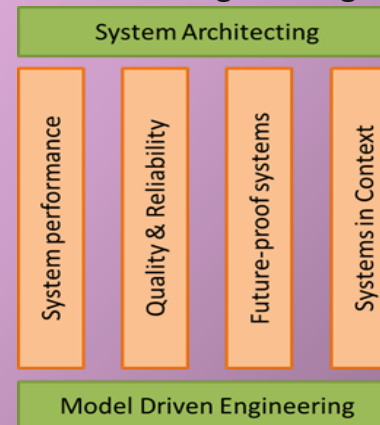
Synopsis

- ❑ ~55 staff members, many with extensive industrial experience
- ❑ 5 Part-time Professors
- ❑ Working at industry locations
- ❑ Program turnover 2017: ~10Mio €

Technology Profile

- ❑ ESI → Cyber Physical Systems
- ❑ Multi-disciplinary system overview
- ❑ System analysis and system synthesis
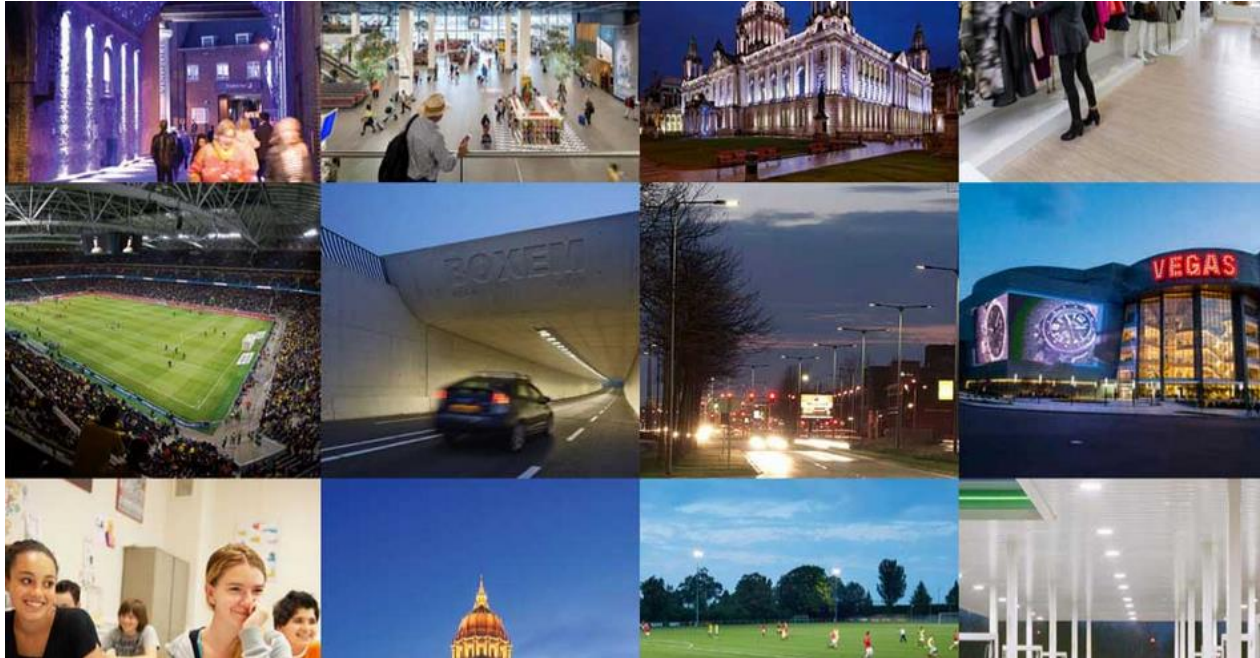- ❑ Model driven engineering

System Architecting			
System performance	Quality & Reliability	Future-proof systems	Systems in Context
Model Driven Engineering			

Partners

Signify

ASML PHILIPS

THALES océ

ThermoFisher SCIENTIFIC A CANON COMPANY

TU/e technische universiteit eindhoven TUDelft Delft University of Technology

NXP Radboud University

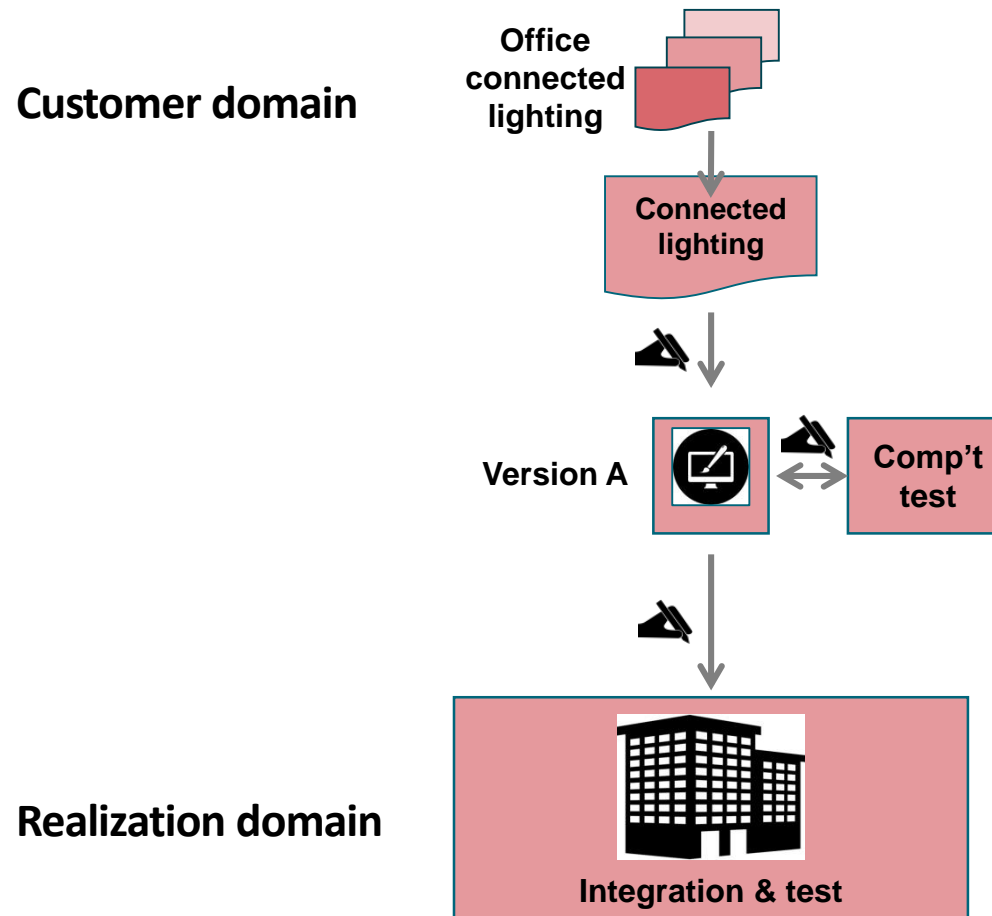TNO UNIVERSITY OF TWENTE.

[*] **TNO = the Netherlands Organisation for applied scientific research**
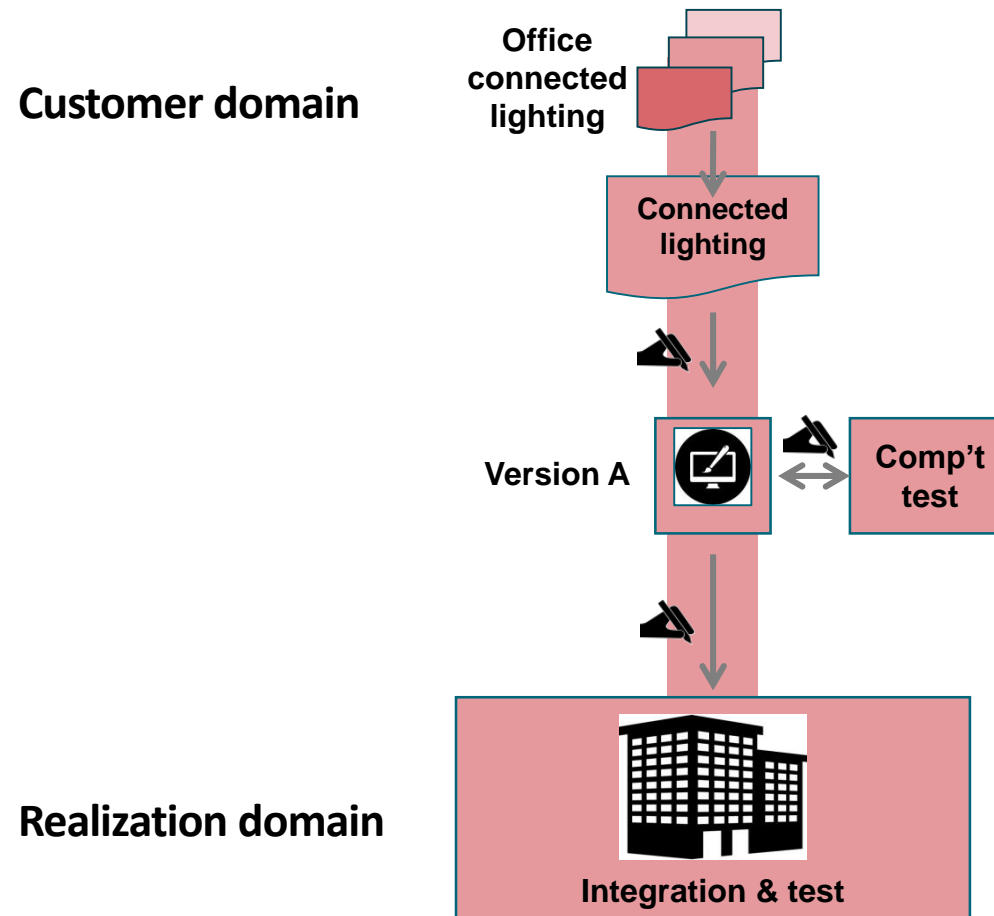
Signify (Philips Lighting)

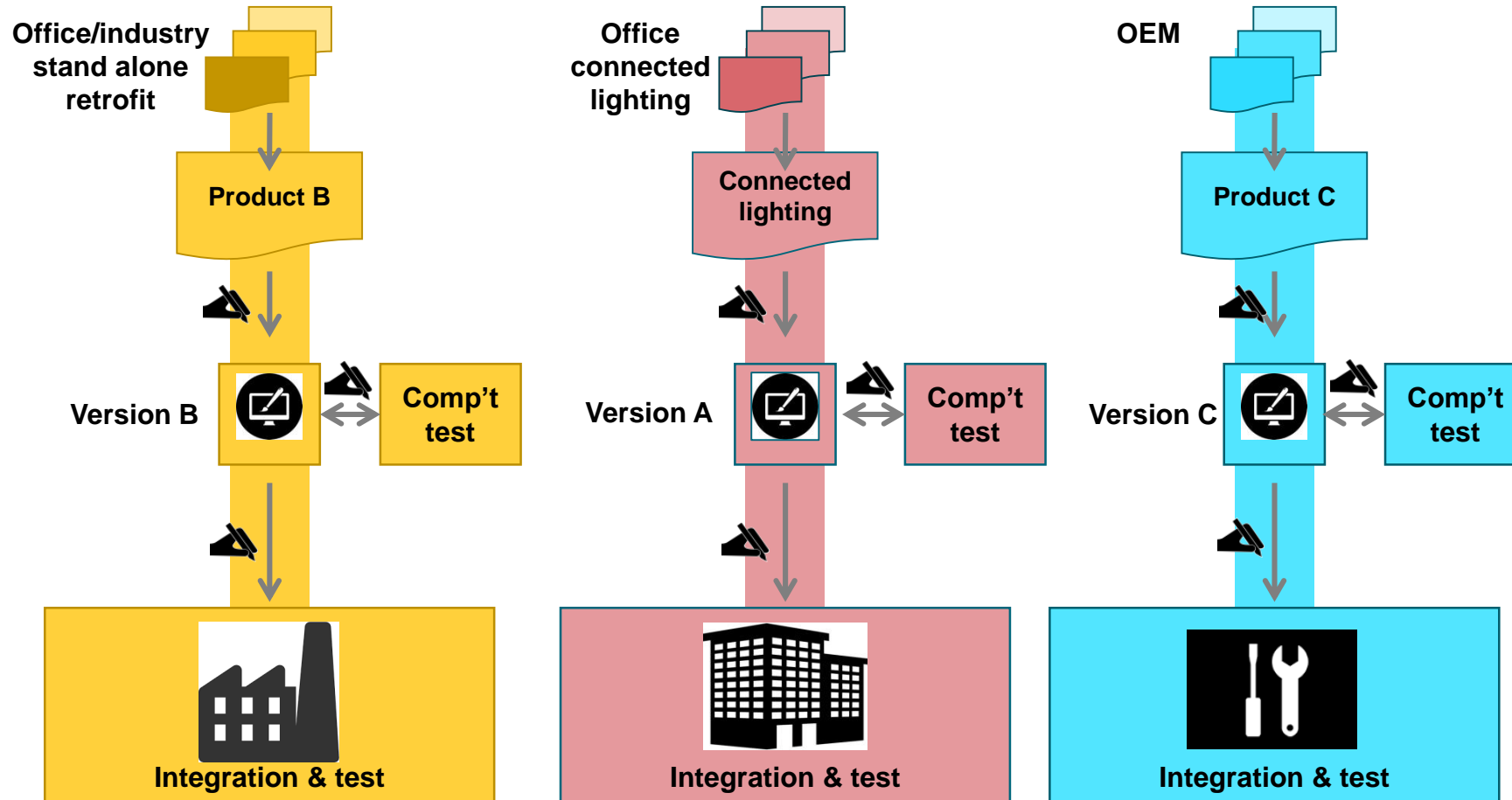**Number one in conventional lighting, LED and connected lighting**
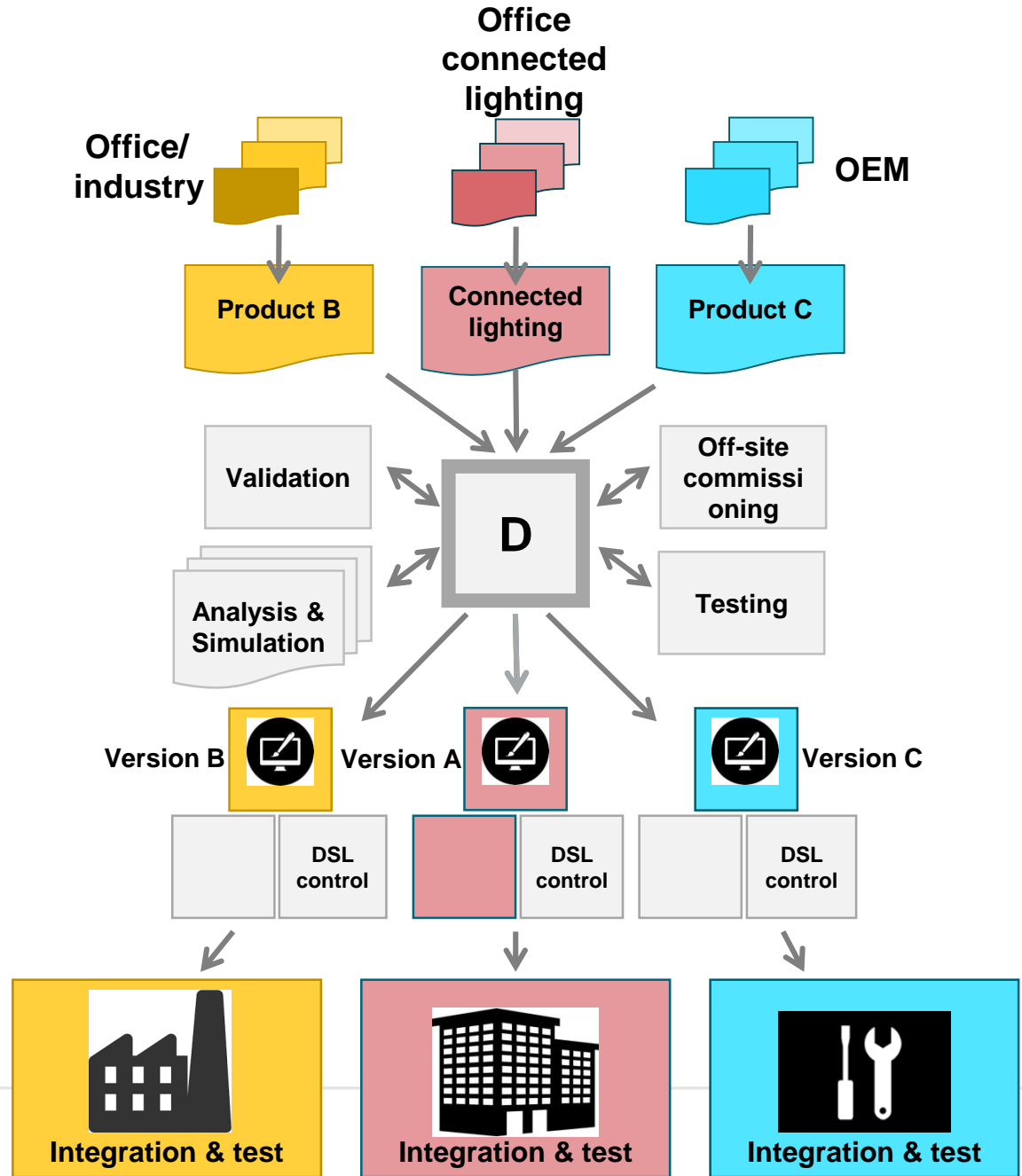
Product creation process

Customer domain

Office connected lighting

Connected lighting

Version A

Comp't test

Realization domain

Integration & test

Product creation process

Customer domain

Office connected lighting

Connected lighting

Version A

Comp't test

Realization domain
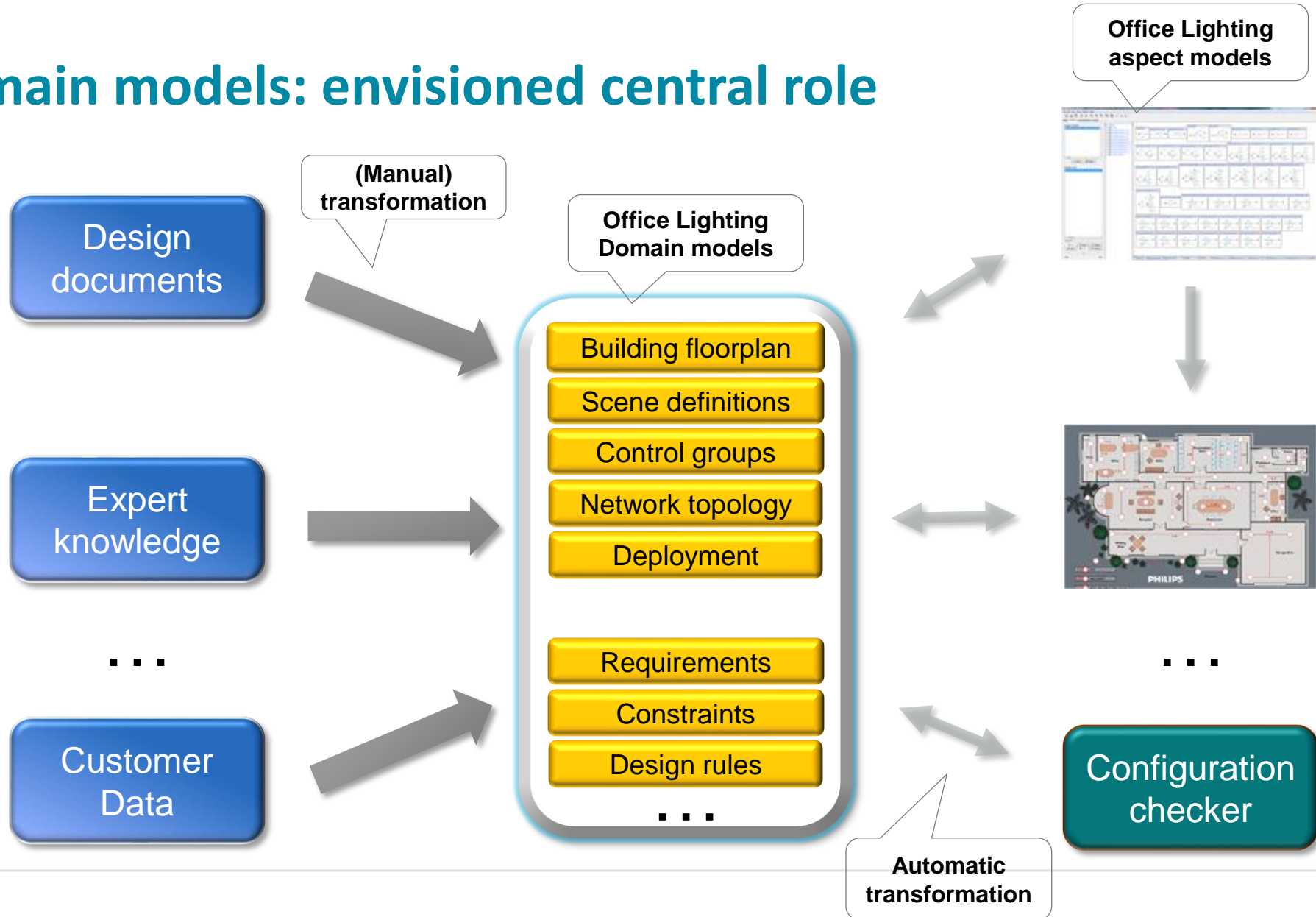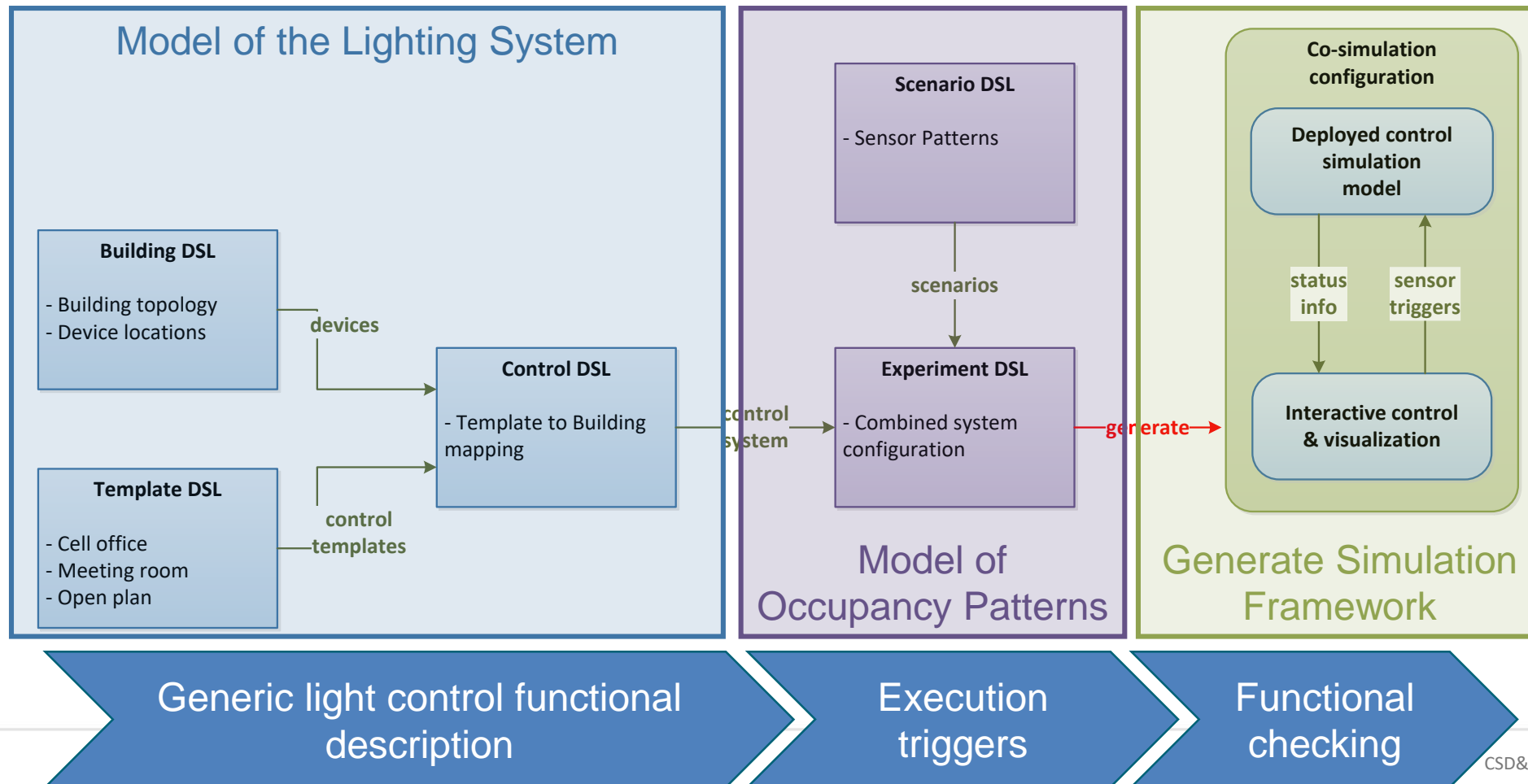
Integration & test

Product creation process

DSL Solution

Domain models: envisioned central role

Design documents

(Manual) transformation

Office Lighting Domain models

Office Lighting aspect models

Office Lighting Domain models

- Building floorplan
- Scene definitions
- Control groups
- Network topology
- Deployment

- Requirements
- Constraints
- Design rules

. . .
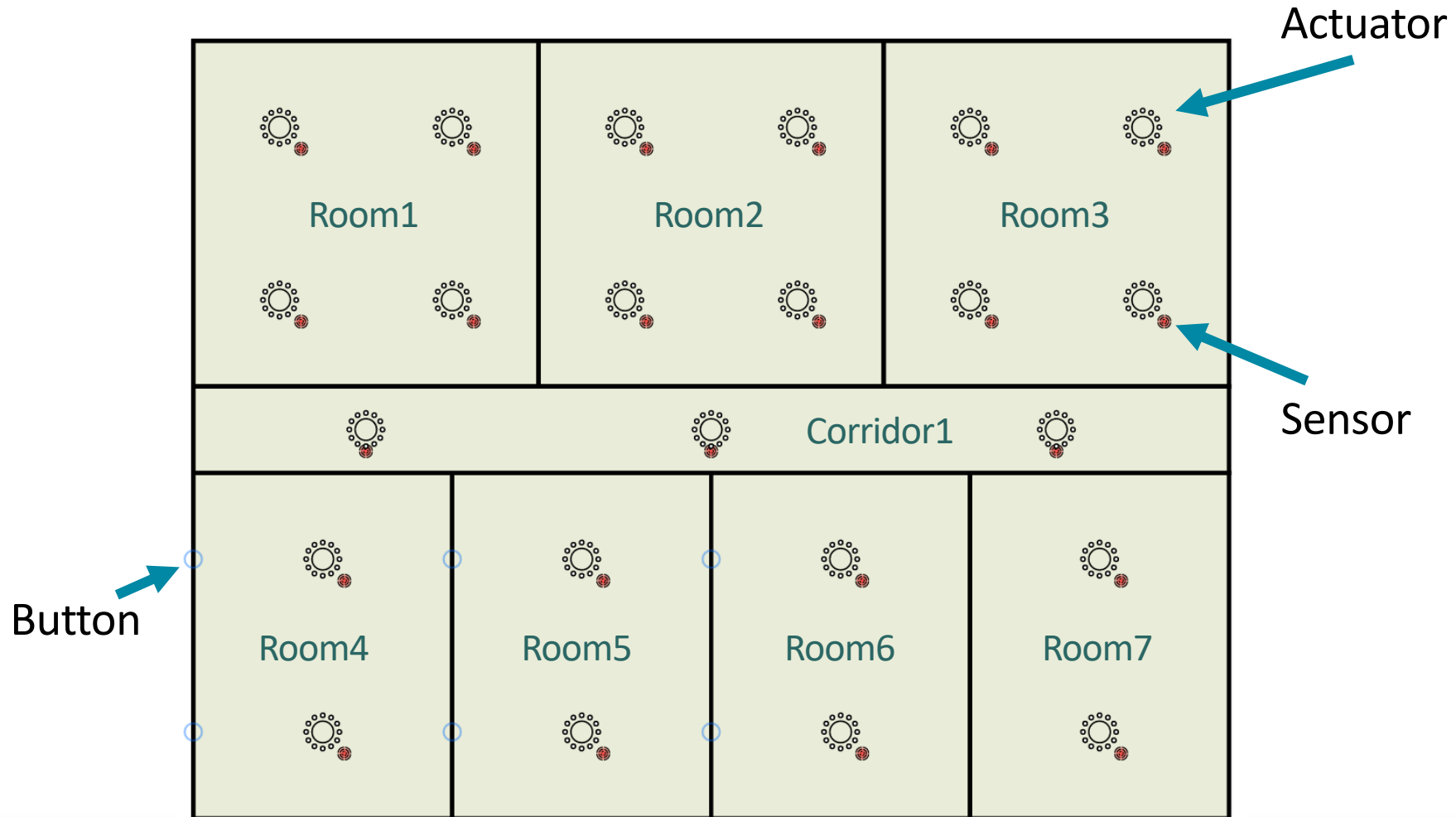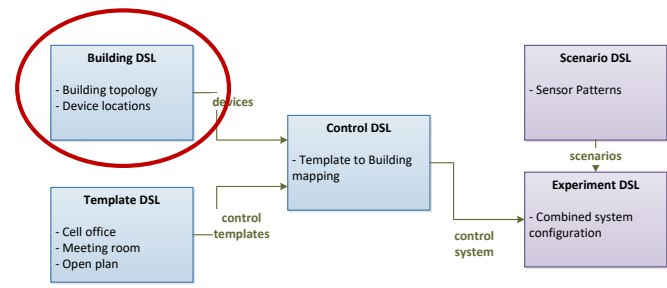
Expert knowledge

. . .

Customer Data

Configuration checker
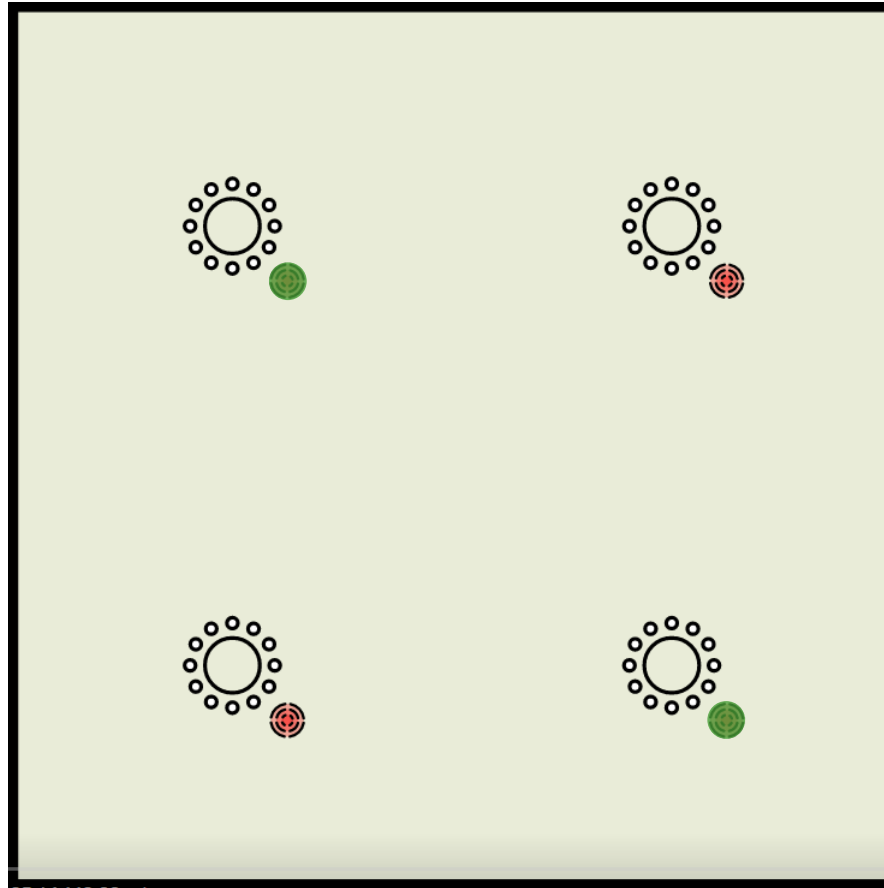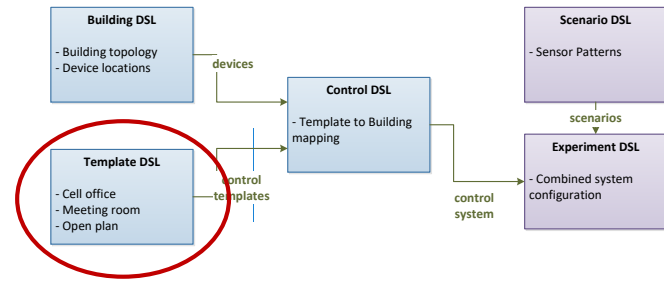
Automatic transformation
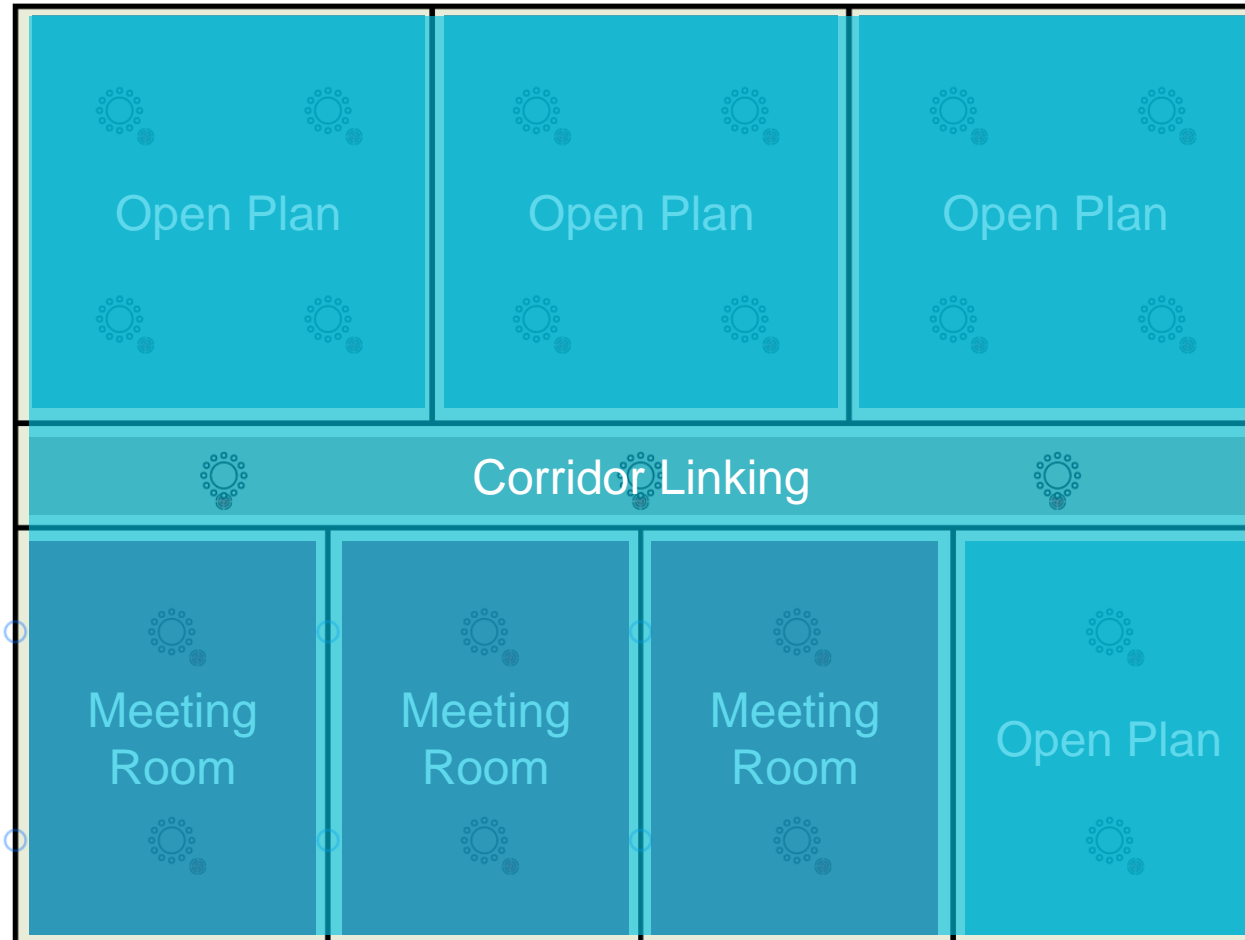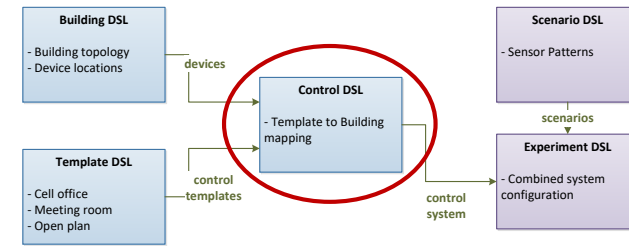
PHILIPS

. . .

Domain Specific languages

Building model

Light behavior model: Open Plan

Control model: mapping Behavior templates onto Devices

Example

```
Template LinkedCorridor
    Parameters
        IntegerParameter LevelOff MinValue 0 MaxValue 100 DefaultValue 0
        IntegerParameter LevelOn MinValue 0 MaxValue 100 DefaultValue 100
        IntegerParameter LevelBackground MinValue 0 MaxValue 100 DefaultValue 50
        IntegerParameter HoldTime MinValue 0 MaxValue 1500 DefaultValue 1000
        IntegerParameter OtherHoldTime MinValue 0 MaxValue 1500 DefaultValue 10
    SensorGroups
        SensorGroup CorridorGroup Features Occupancy
        SensorGroup LinkedGroup Features Occupancy
    ActuatorGroups
        ActuatorGroup CorridorLuminaires Features Dimmable

    ControllerGroups

    States
        State Off
            Level CorridorOff1 Value LevelOff ActuatorGroups CorridorLuminaires
        State On
            Level CorridorOn1 Value LevelOn ActuatorGroups CorridorLuminaires
        State Background
            Level CorridorBackground1 Value LevelBackground ActuatorGroups CorridorLuminaires
    InitialState Off

    Transitions
        Transition
            Source Off Background
            Trigger Occupancy CorridorGroup
            Destination On
        Transition
            Source Off
            Trigger Occupancy LinkedGroup
            Destination Background
        Transition
            Source On
            Condition TimeSinceLastOccupancyDetection CorridorGroup >= HoldTime AND TimeSinceLastOccupancyDetection LinkedGroup <= OtherHoldTime
            Destination Background
        Transition
            Source On
            Condition TimeSinceLastOccupancyDetection CorridorGroup >= HoldTime AND TimeSinceLastOccupancyDetection LinkedGroup >= OtherHoldTime
            Destination Off
        Transition
            Source Background
            Condition TimeSinceLastOccupancyDetection LinkedGroup >= OtherHoldTime
            Destination Off
```
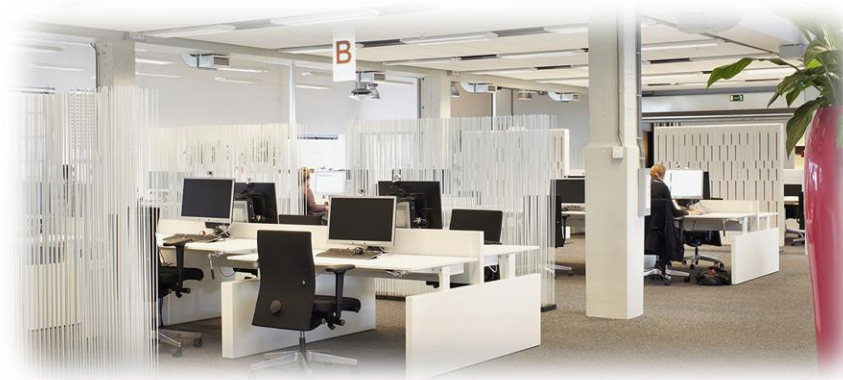
Linked Corridor template
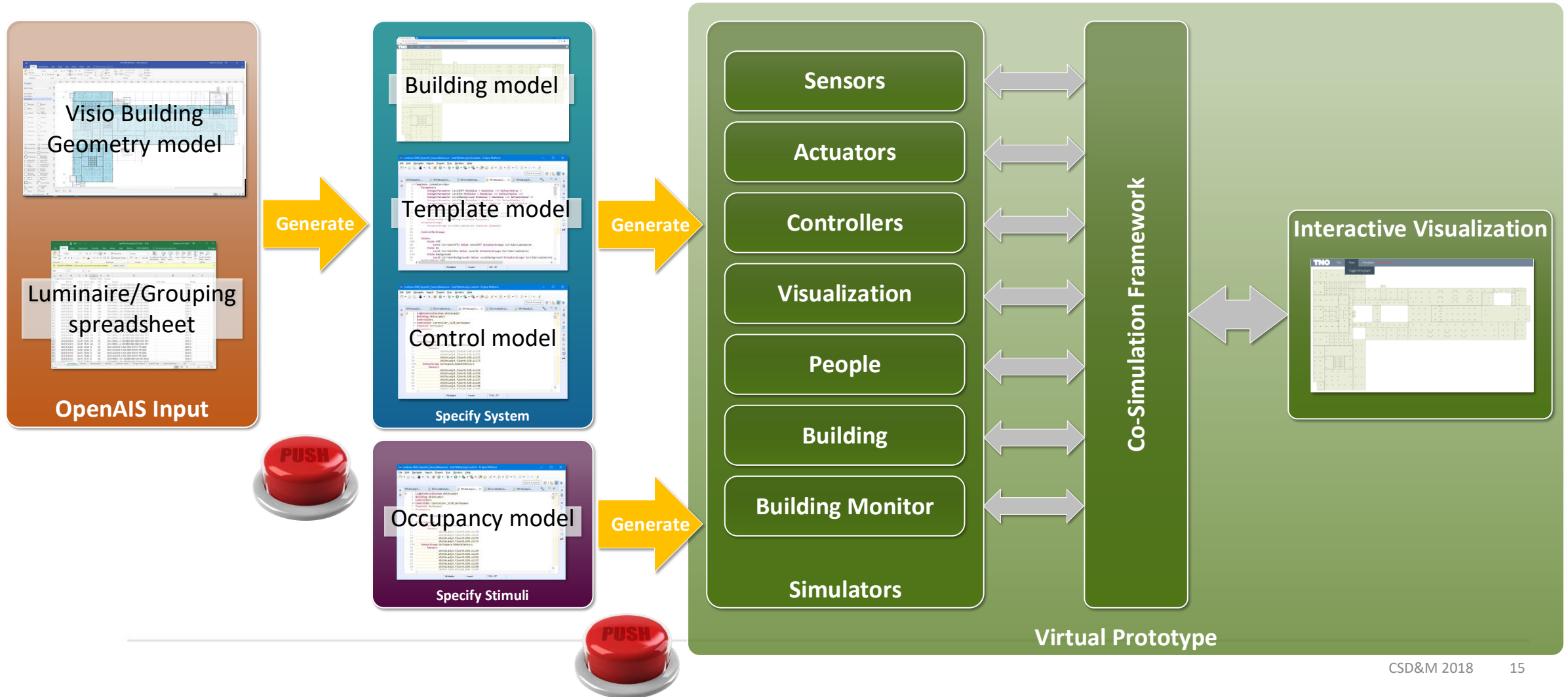Two sensor groups: linked rooms, corridor

OpenAIS White Lady Pilot

- **Landmark historical building**

- **Installed and commissioned November 2017**
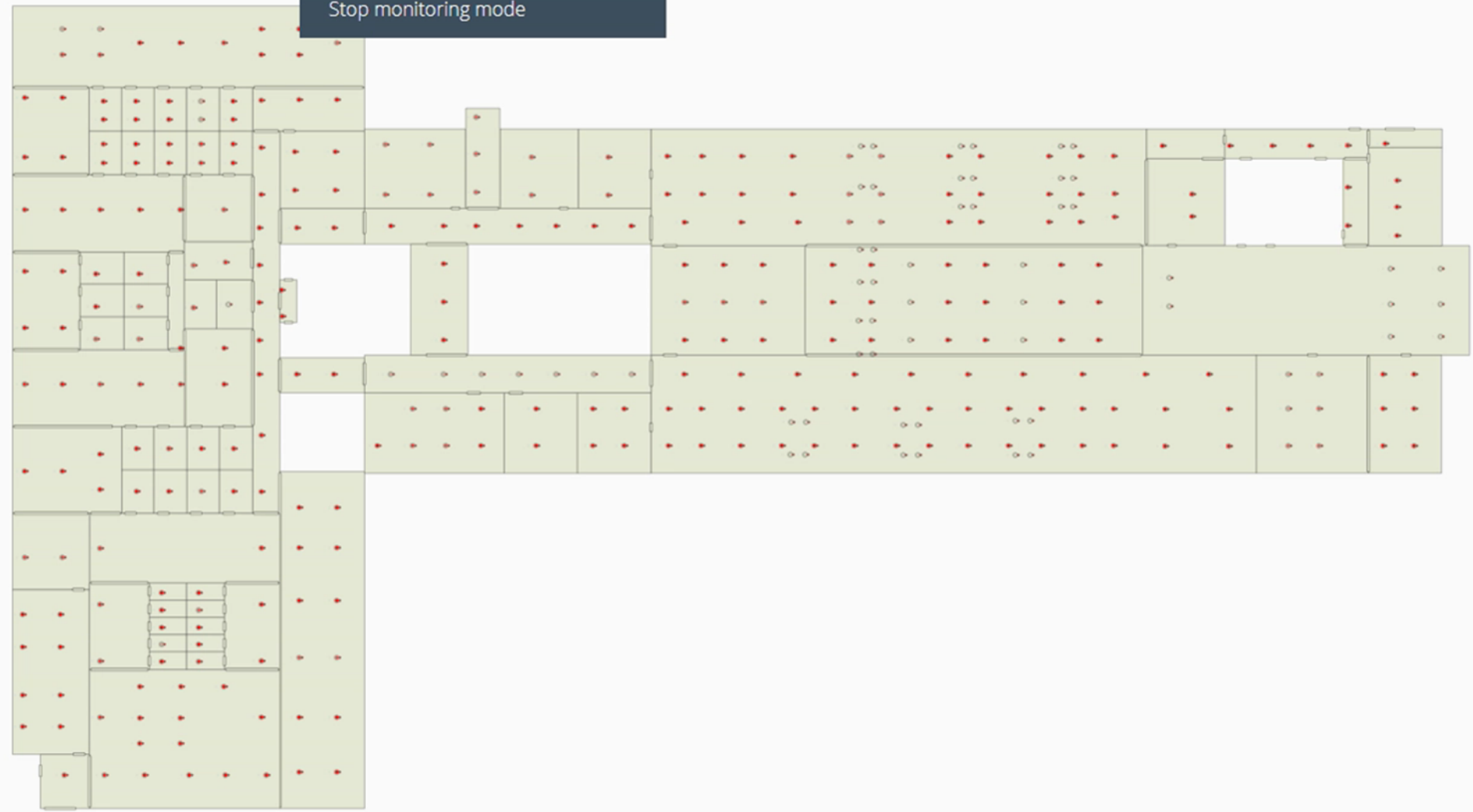
- **The entire 5th floor, 367 luminaires**

What we will demo
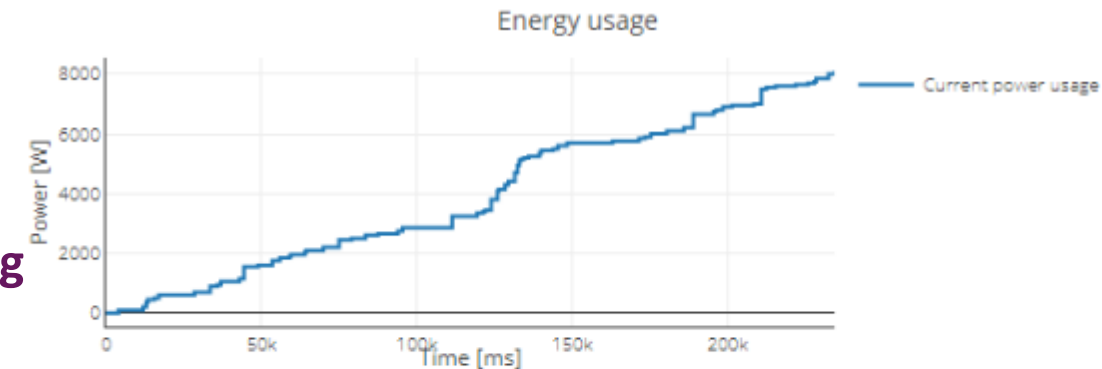
Disconnect

Stop monitoring mode

Design space exploration
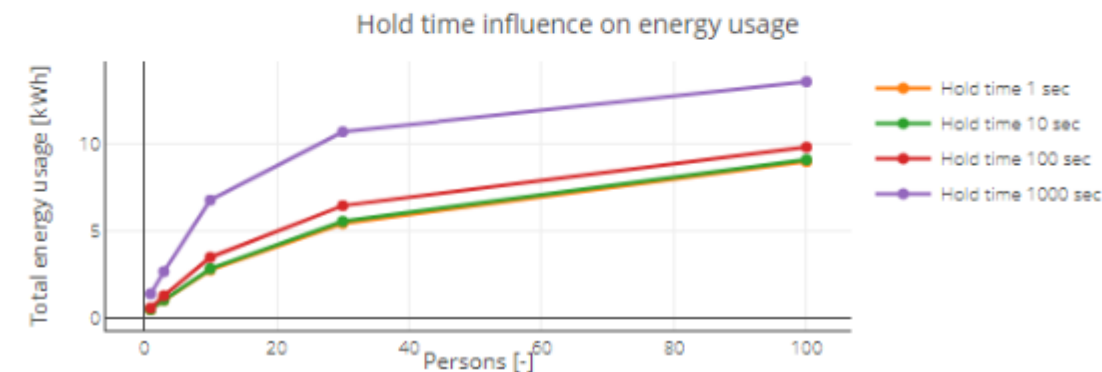
Add energy monitor to virtual prototype

Run scenario with many people working in the building

Monitor energy usage of the scenario by changing configurations

- Vary behavior template model parameters like
  - Hold time
  - Task level
  - Background level
- Vary behavior mapping on devices in control model

Total energy usage: 0.253 [kWh]

Adoption

Code generation

Via research department

Adaptation of languages
- Practicalities (range, units, etc.), more compact, defaults
- Extra validations

Embedding into business unit
- Extensive preparations to reduce risks
- Step-wise introduction aligned with the product roadmap

Conclusions

Code generation

Virtual prototyping

Adoption by industrial partner

Generic approach, now extended for IOT domain
- to be presented at ModelsWard 2019

Thank you!