

# Architectures de Contrôle Commande Hétérogènes Distribuées

*Appliquées aux systèmes industriels et à la  
domotique pour l'aide au handicap*

**Florent de Lamotte**

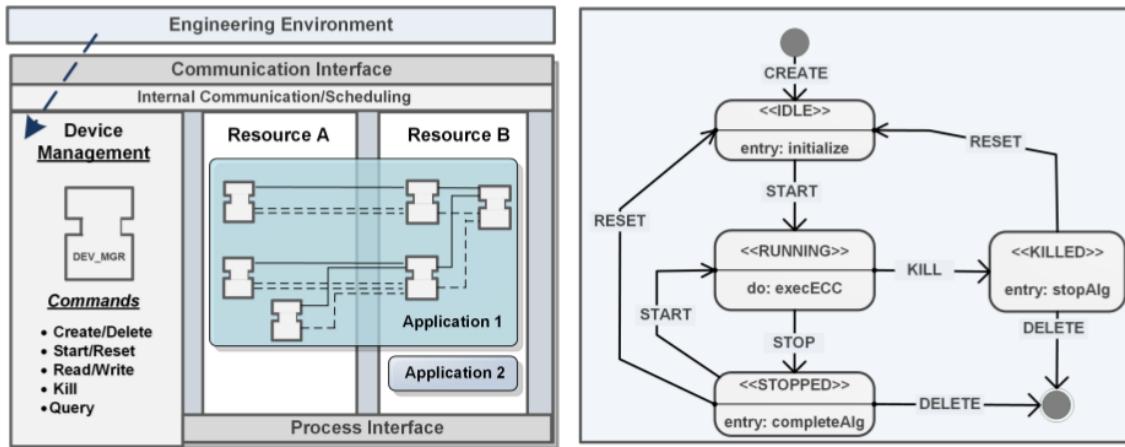
**Lab-STICC**

**<florent.lamotte@univ-ubs.fr>**

# Aperçu

## Application

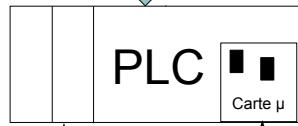
- UML
- SysML
- AADL
- IEC61131-3
- IEC61499



SCADA/Supervision/MES

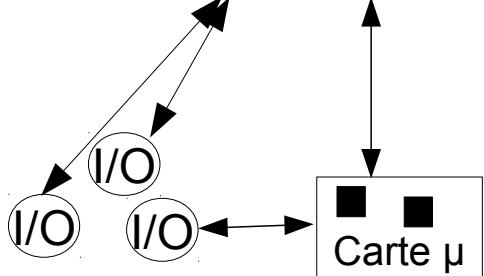
Déployée sur :

Réseau local



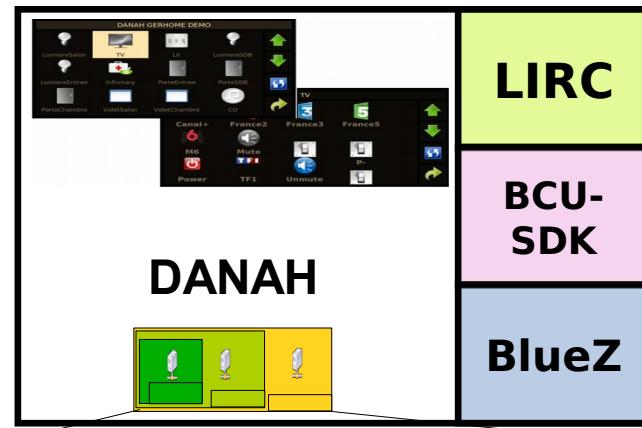
Contrôle/Commande

Réseau de Terrain



I/O

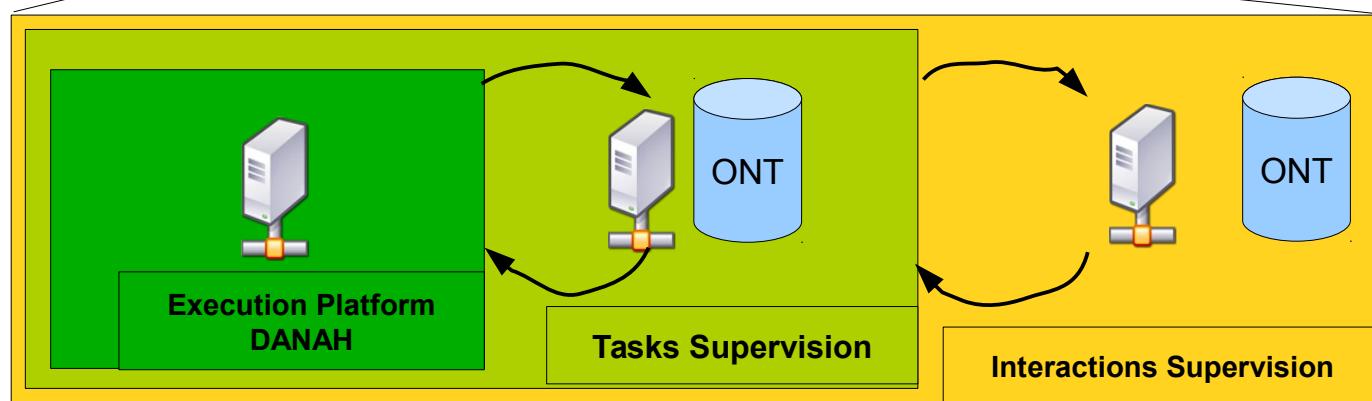
# Architecture Domotique plate-forme DANAH



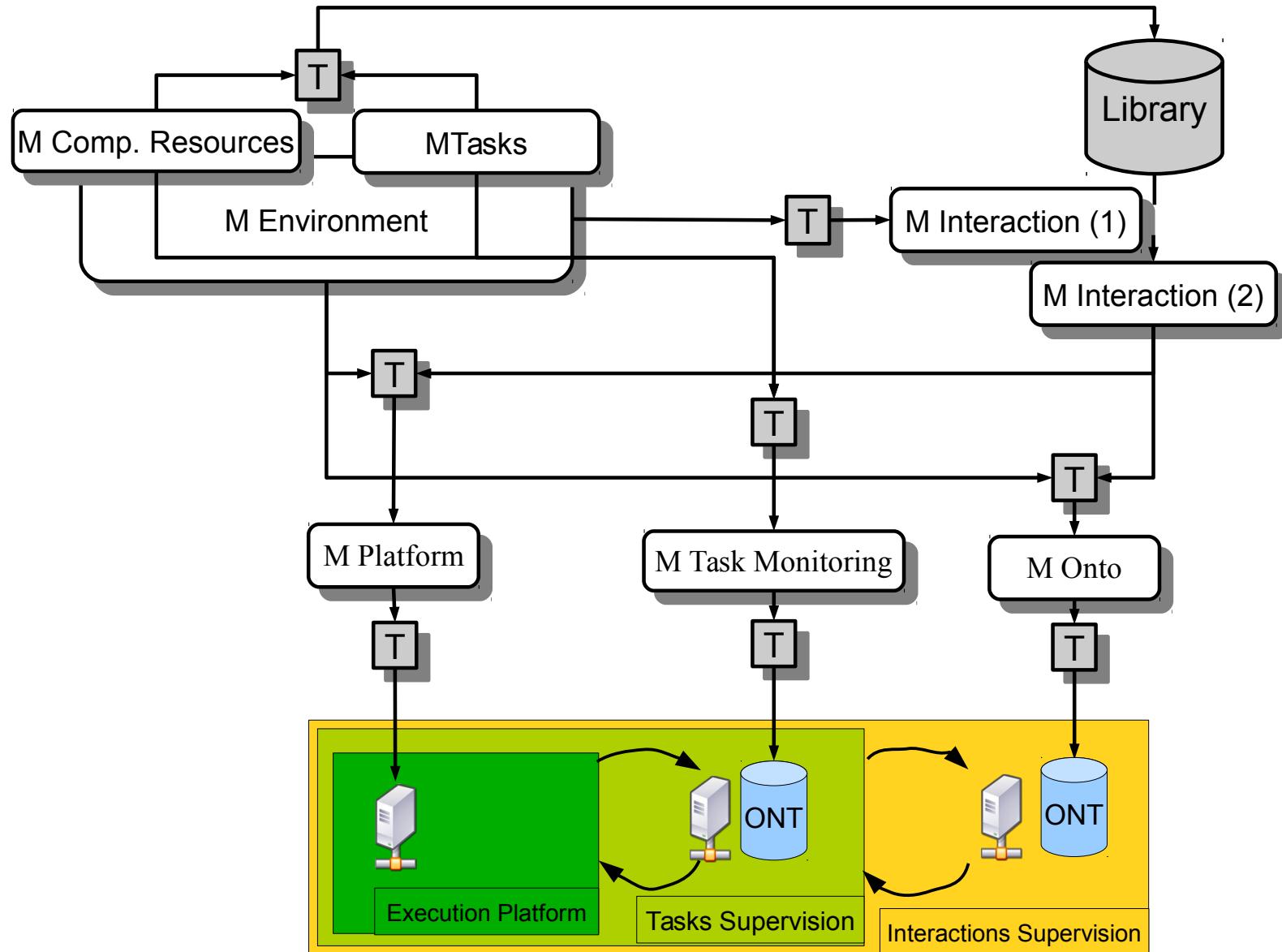
IguanaIR

KNX/EIB

Bluetooth Dongle

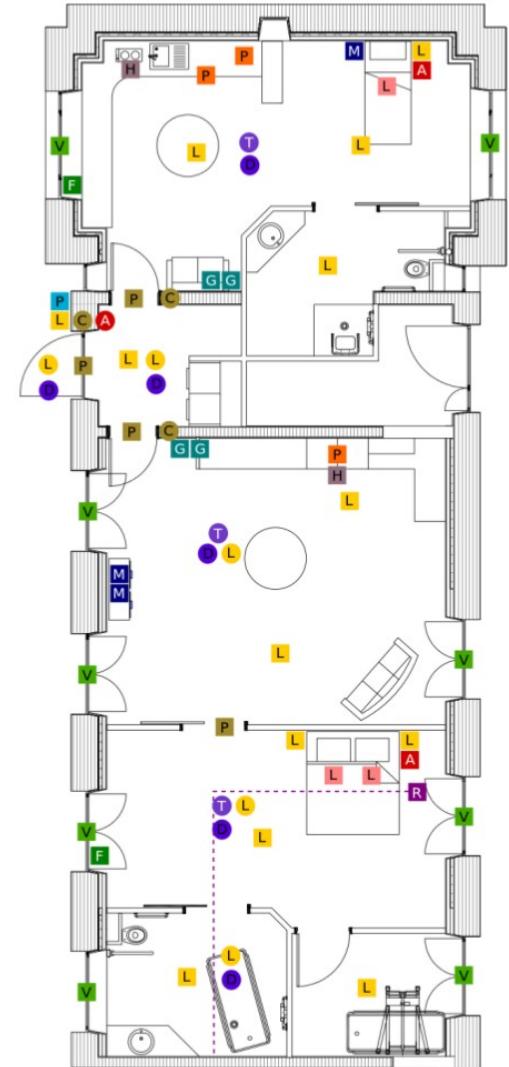


# Flot de conception de l'environnement



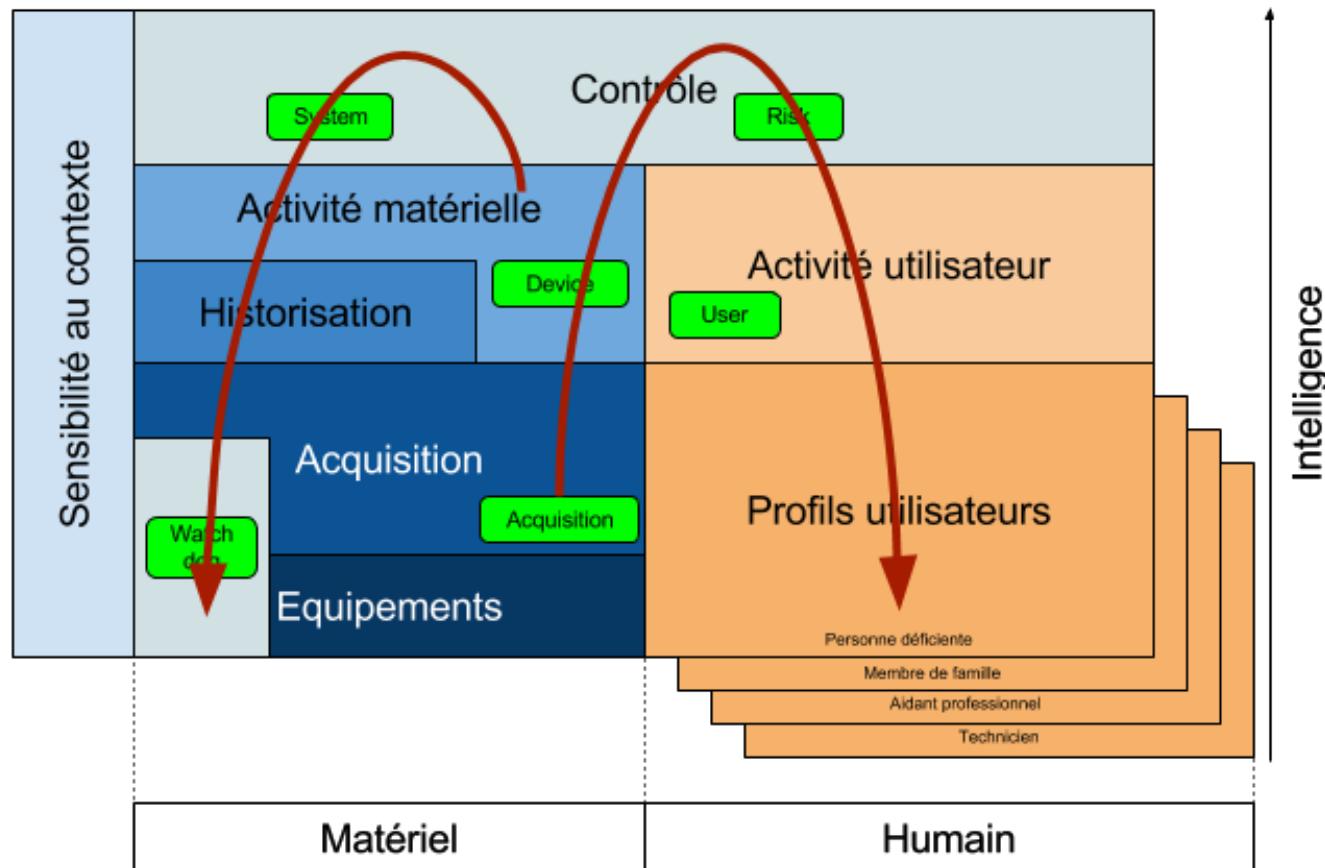
# Plate-formes

- Appartements Tremplins Kerpape
- Appartements ENSIBS
- Experiment'AAL
- DOMUS / Sherbrooke



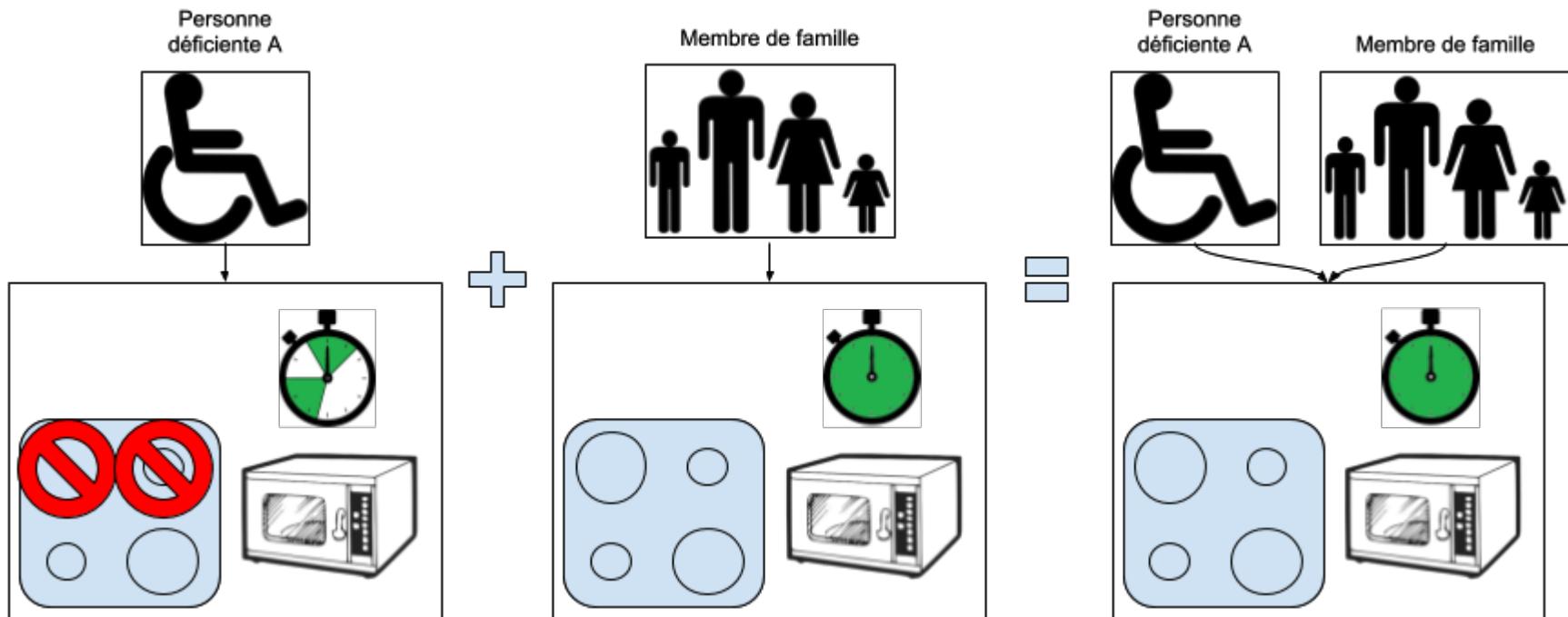
# Architecture StoveMAS (N. Kuijpers)

SMA basé sur JADE



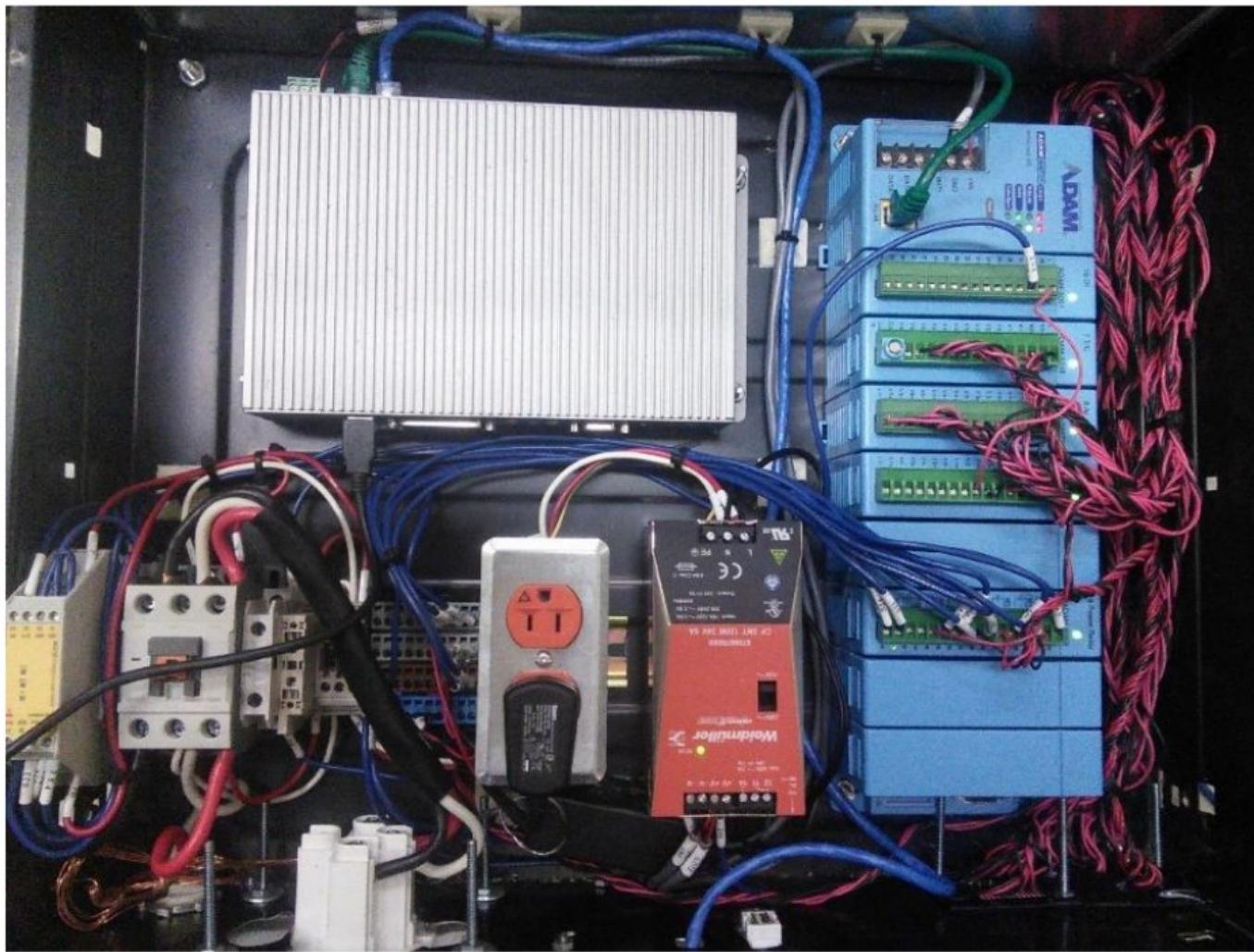
# Domicile multi-usagers

- Profils utilisateurs

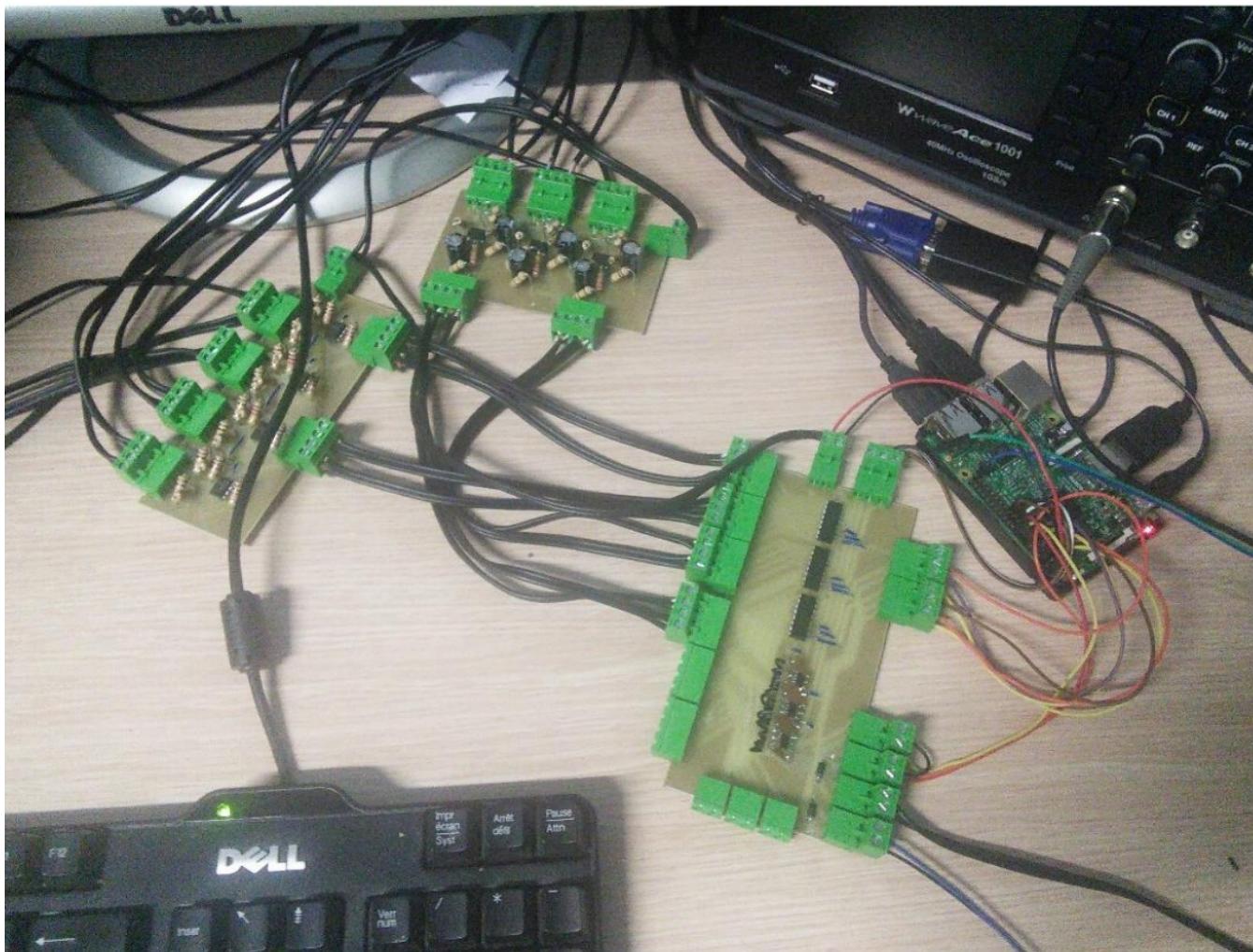


# Déploiements

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# Déploiements



A installer dans les appartements de l'ENSIBS

# Design and integration of custom electronics for the control of the head of an industrial robot

Florent de Lamotte

Lab-STICC

[\*\*<florent.lamotte@univ-ubs.fr>\*\*](mailto:<florent.lamotte@univ-ubs.fr>)

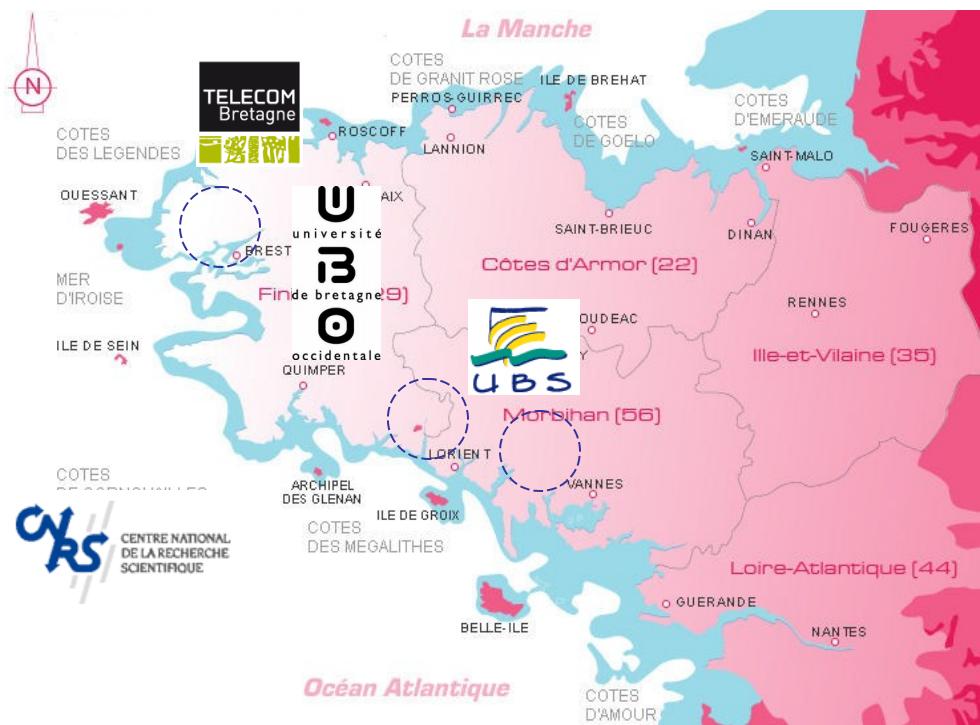
# **Outline**

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- **Contexte**
- **Historique**
- **Environnement domotique**
- **Travaux menés dans l'équipe**
  - Navigation de fauteuils roulants
  - Projet Quatra
  - Conception de système domotique
  - Analyse des usages
  - Conception du système de services
  - Implantation des services sur une architecture distribuée

# The Lab-STICC

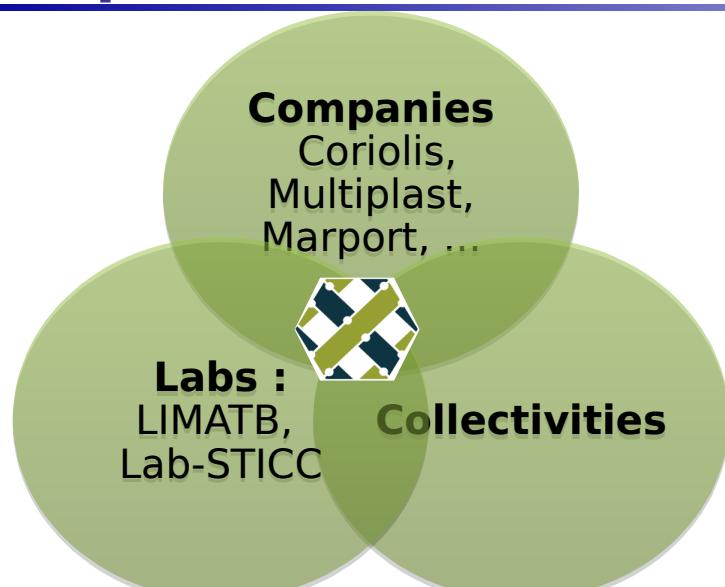
- “*Laboratoire des Sciences et Techniques de l’Information, de la Communication et de la Connaissance*”
  - From sensors to knowledge
- **4 research centers**
  - Brest (2)
  - Lorient (1)
  - Vannes (1)
- **Lab-STICC is**
  - 350 personnels
    - 175 researchers
    - 175 PhD students
  - 2.5M€ in contracts in 2007
  - Scientific production over 4 years
    - 25 book chapters
    - 200 journal papers
    - 500 conference papers
    - 23 patents
    - 80 PhD



# ComposiTIC Technical Platform



plateau technique  
compositIC



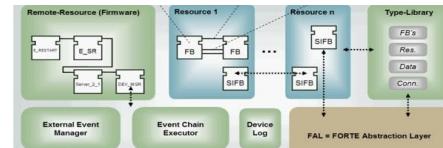
Formulation and production  
of semi-finished products  
(tape, 3D-printing inks)



Robotic shaping  
process



Tests of  
products



Realtime Control-  
Command

Design and generation  
of control code

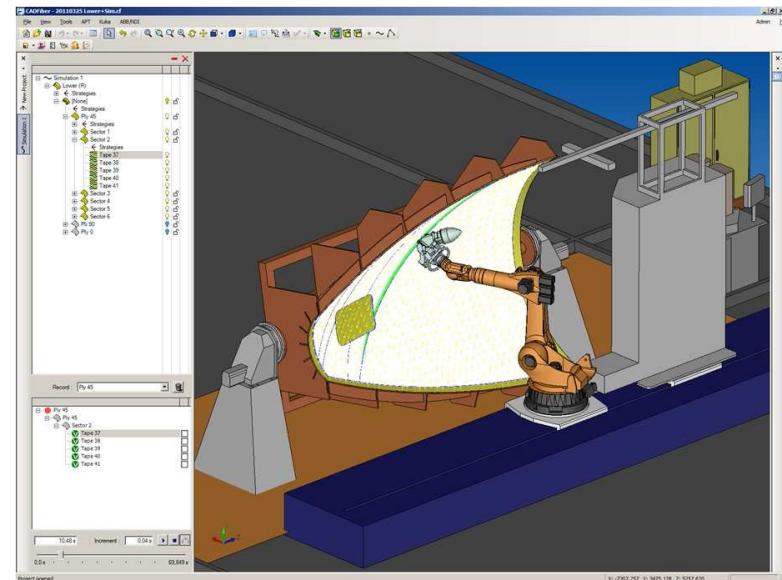
Control-command  
architecture

# Coriolis Composites Fiber Placement Robot

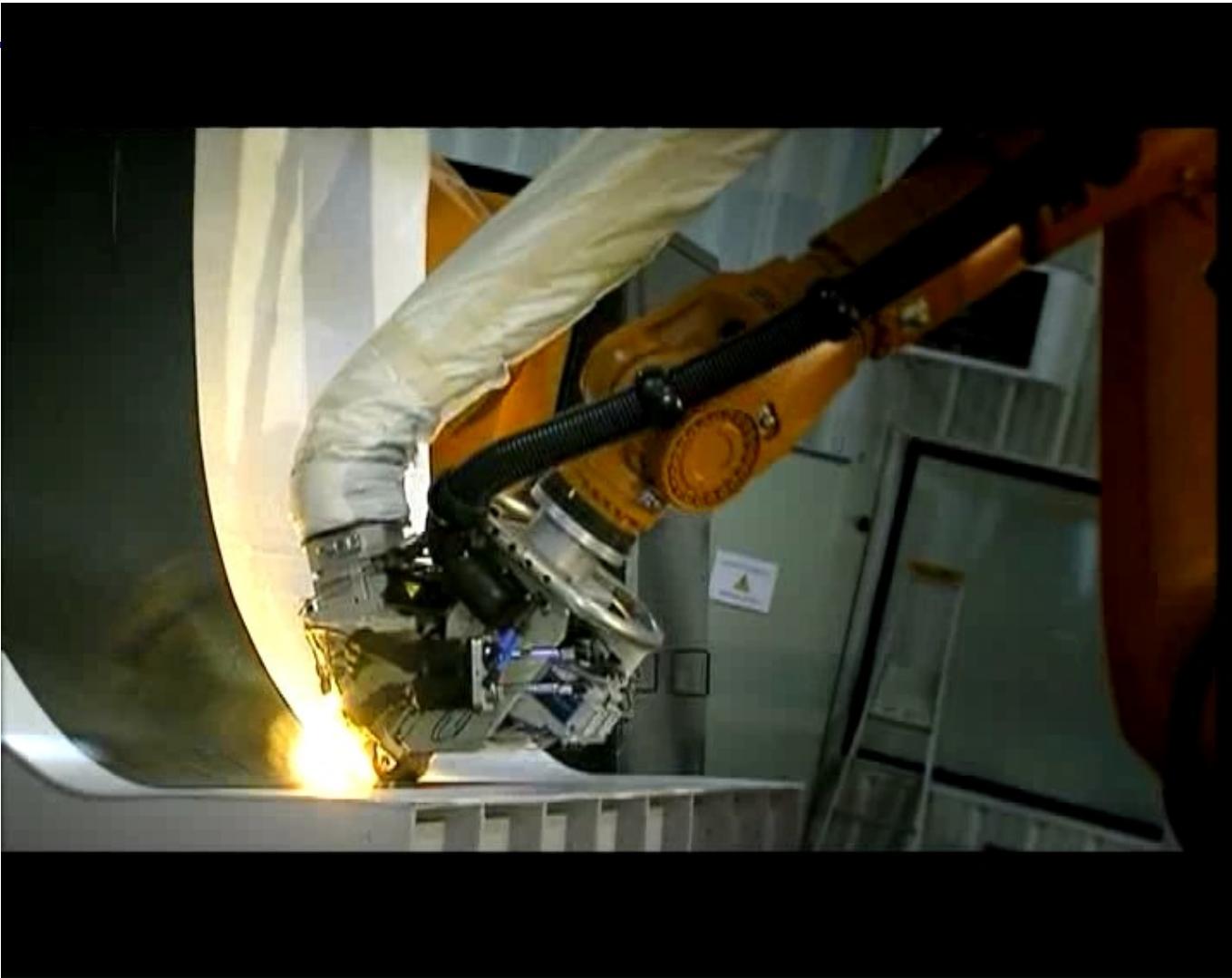


A robot

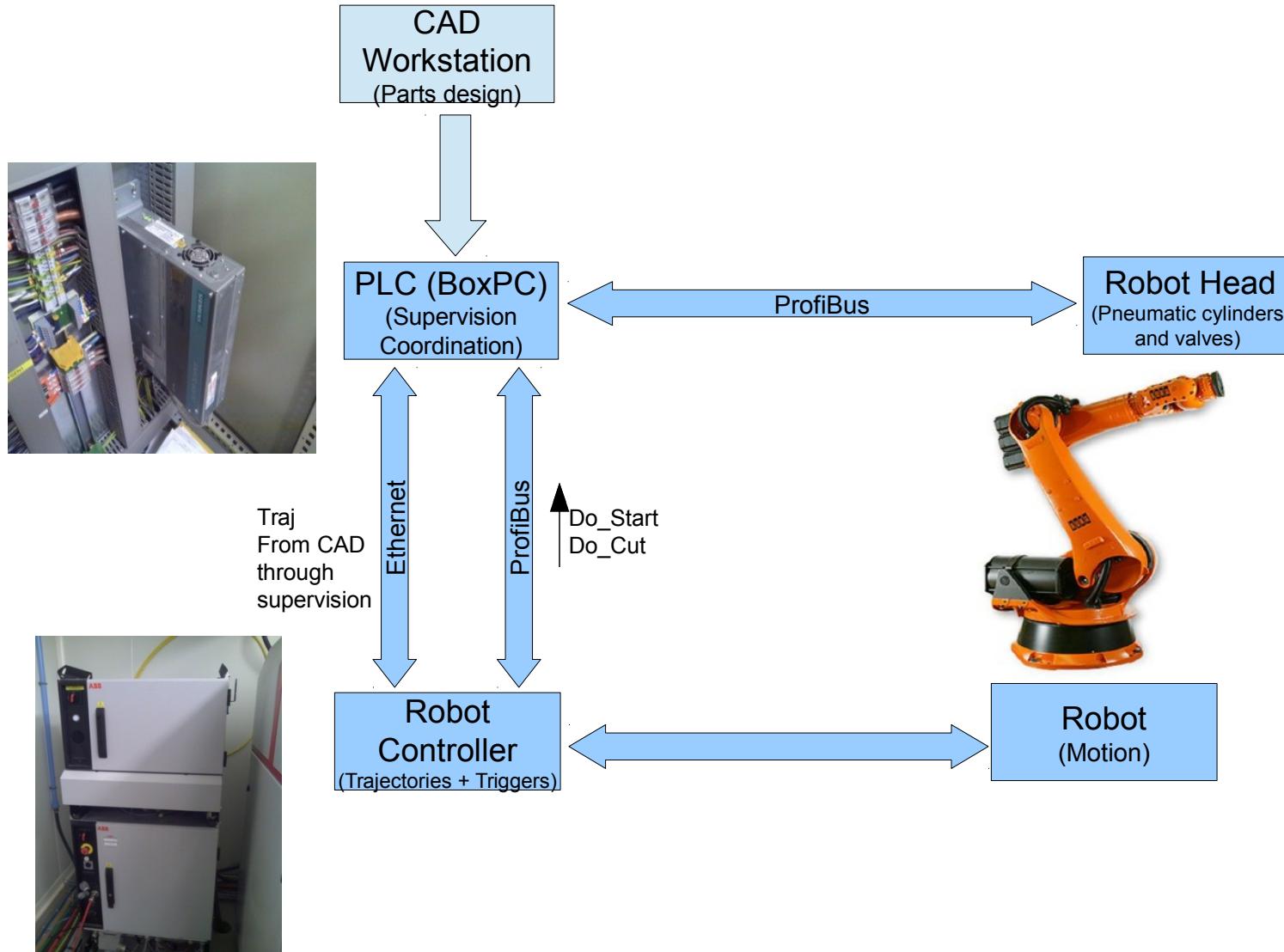
- Unique technology for placing carbon fibers
  - A robot
  - A software tool (CADFiber) to design the parts
- Figures
  - 3500 m<sup>2</sup> near Lorient (subsidiaries in Germany, Canada and UK)
  - 90 people
  - Big clients such as
    - *Airbus*
    - *EADS*
    - *Rolls-Royce*



CAD Fiber Tool



# Current Control-Command Architecture



# The robot head

- **Responsible**
  - bringing and cutting the tapes
  - heating
- **3 actuator per tape**
- **Up to 32 tapes (8 / 16 / 24 / 32)**
  - 96 actuators



# Trigger mechanism

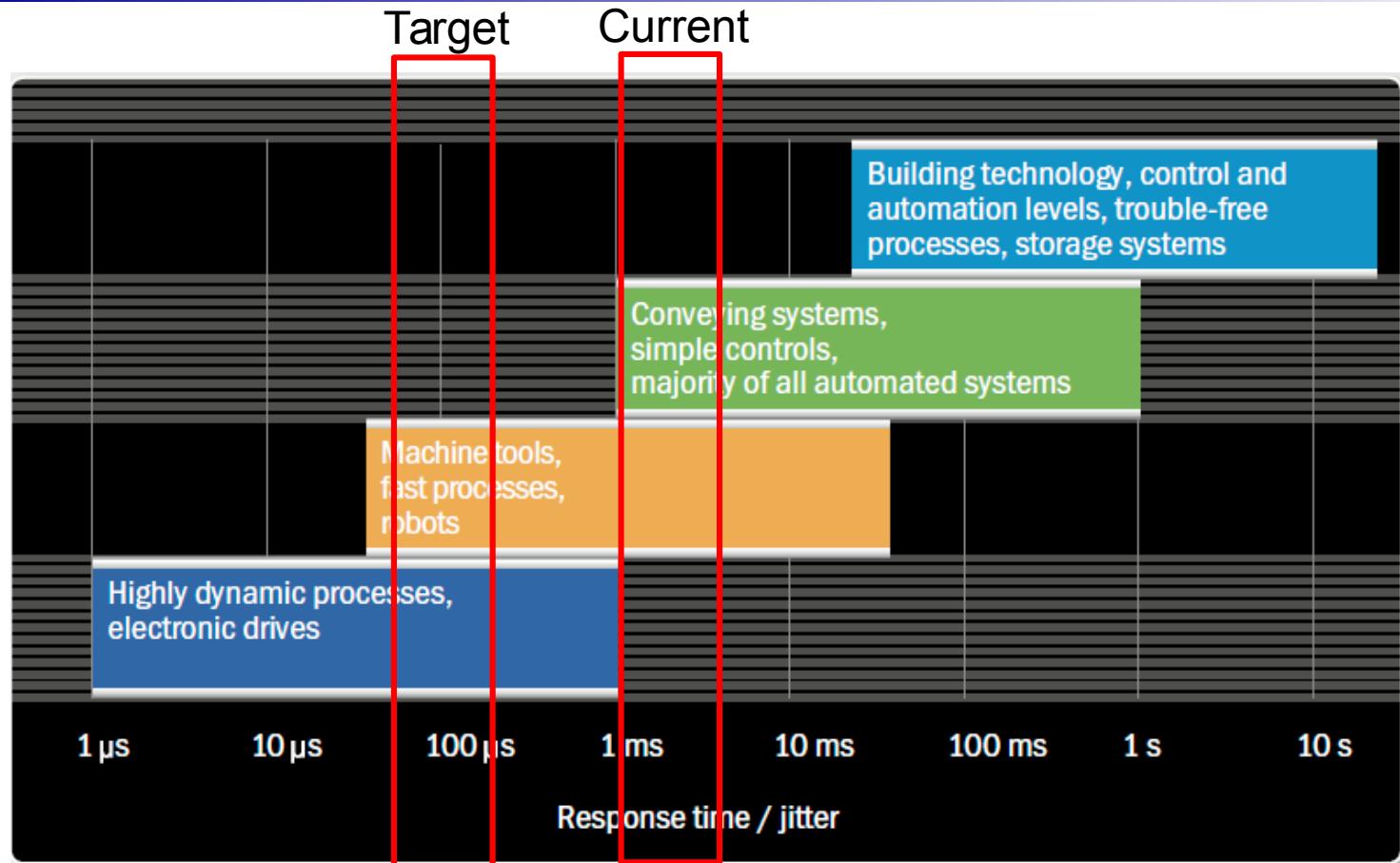
- **Trajectory and cuttings are generated by CADFiber and stored in the controller**
  - Cuttings = triggers
  - Sent by anticipation (network latency + cutting latency)  
hardwritten in the robot code
- **Path of a trigger in the system**
  - Generated by the controller
  - Sent to the PLC through ProfiBUS
  - PLC filters orders according to supervision
  - Sent to the head through ProfiBUS
  - ProfiBUS valves control the air to the cylinders

# Limitations

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- **Some defects in the cutting**
- **New constraints**
  - Current
    - *Cutting speed : 40 cm/s*
    - *Precision : 1mm (=> 2.5ms cycle)*
  - Target
    - *Cutting speed : 1 m/s*
    - *Precision : 1/10 mm (=> 0.1ms cycle)*
- **Current solution :**
  - Siemens motion controller
  - Simotion SCOUT TM17 module
    - *Controls I/Os directly from the motion controller*

# Class of systems



Realtime class and application areas (IAONA classification)

# Objectives

- **Collaboration to develop a new solution**
  - Coriolis : overcome current limitations
  - Lab-STICC : set up a test platform to design methodologies targeting *industrial embedded electronics*
- ***Develop a testbench***
  - *For Lab-STICC use*
- ***Tests on the robot***

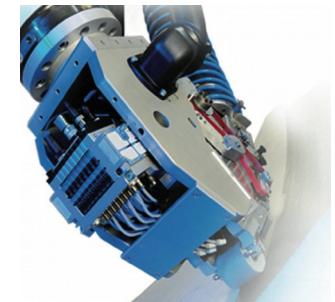
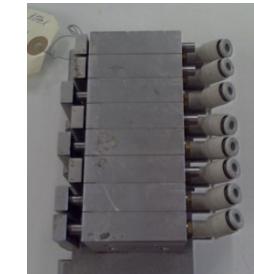
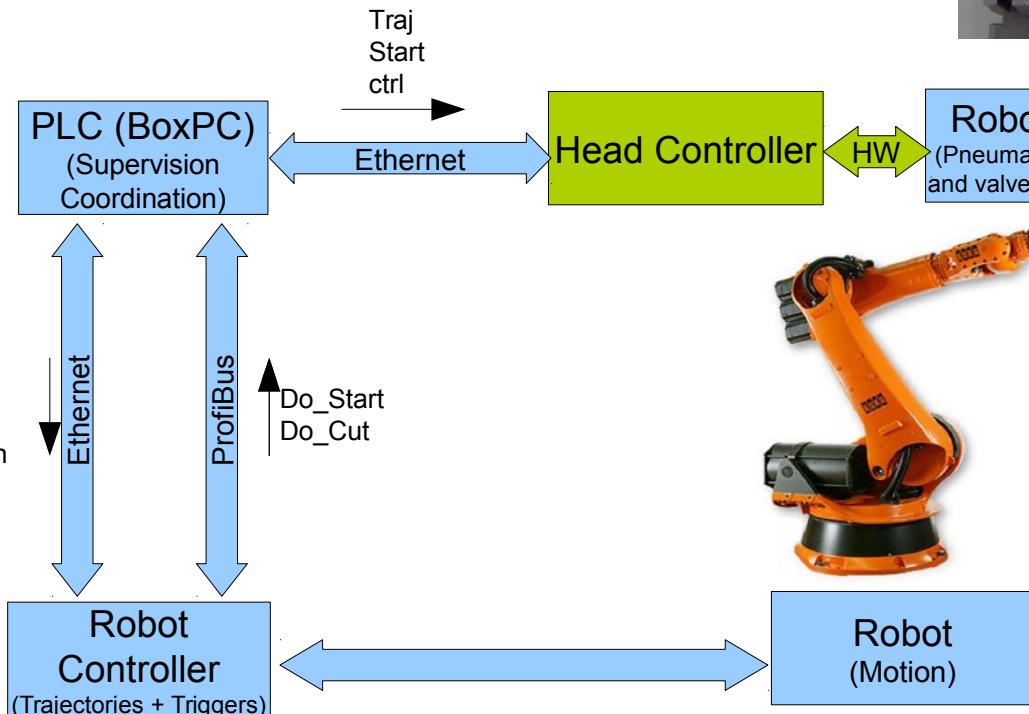
# Principle

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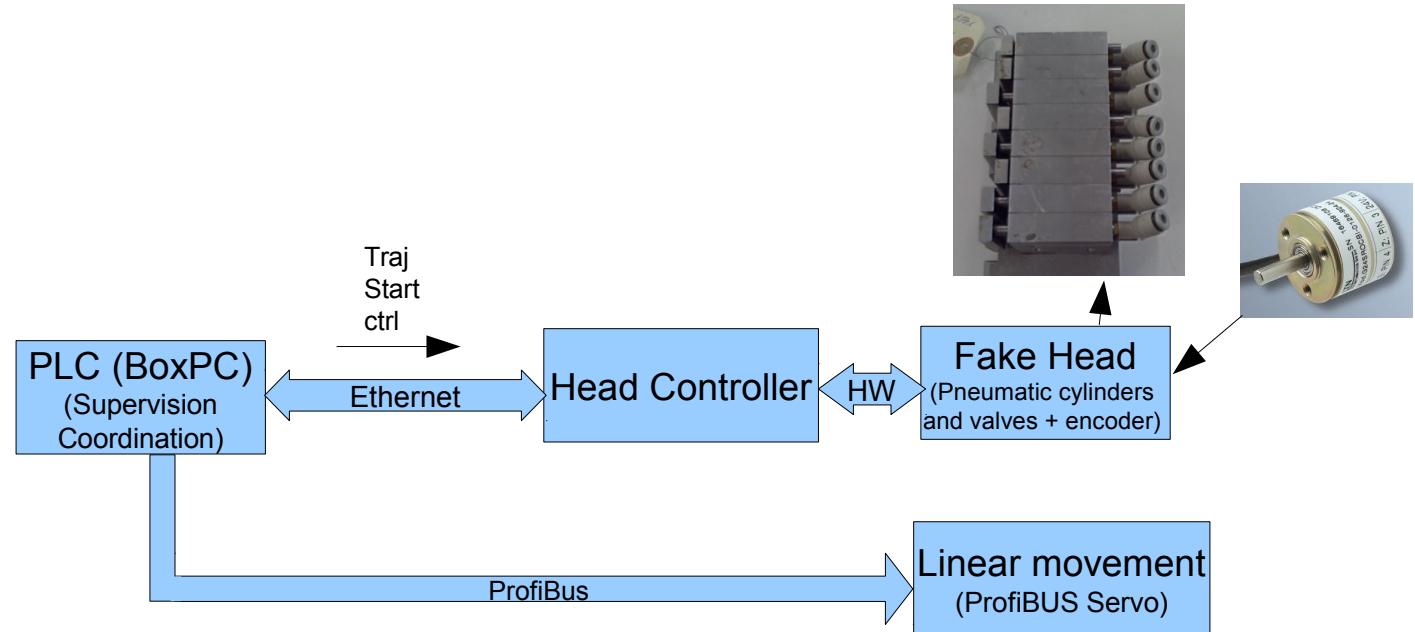
- Design a dedicated controller for the head
- Use an encoder available
- Perform a local control
  - Read the encoder position
  - Directly control cylinders



# Proposed architecture

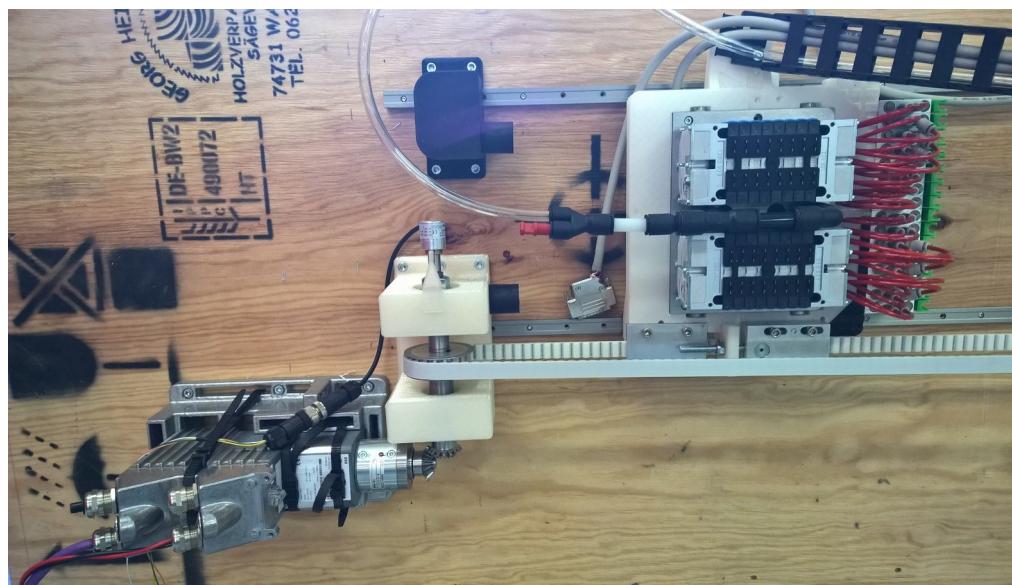
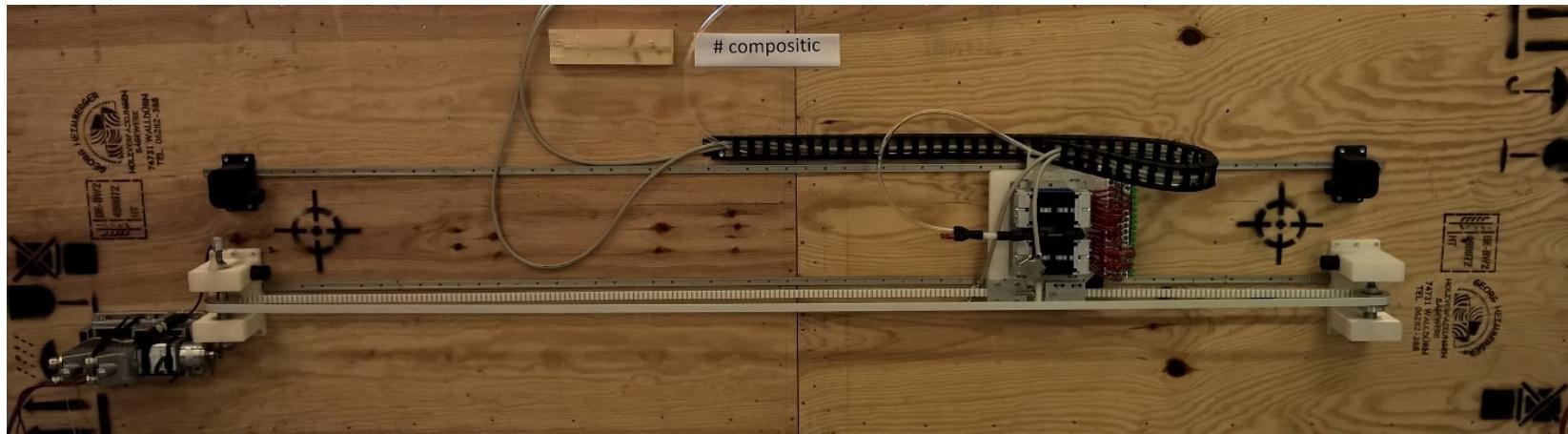


# The TestBench



- **Functional tests of the head controller without access to the robot**
  - The robot is used for other tasks

# The TestBench



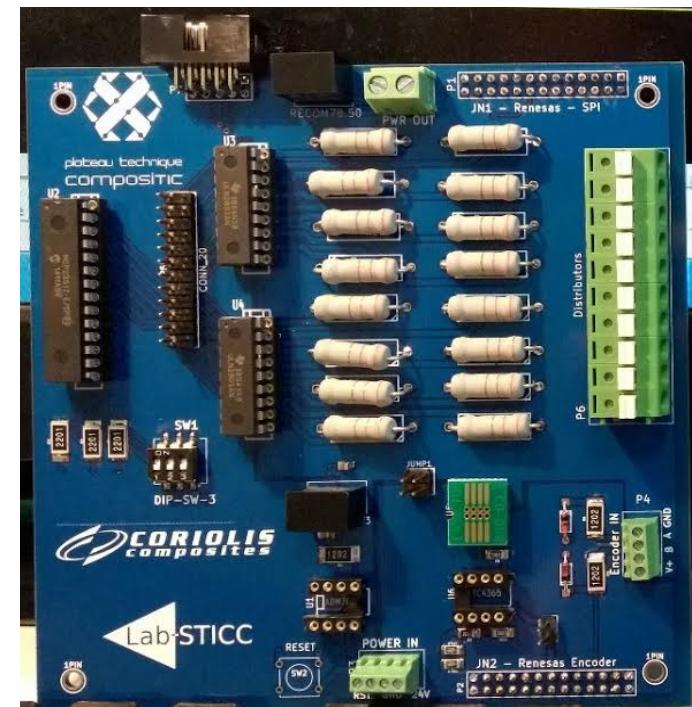
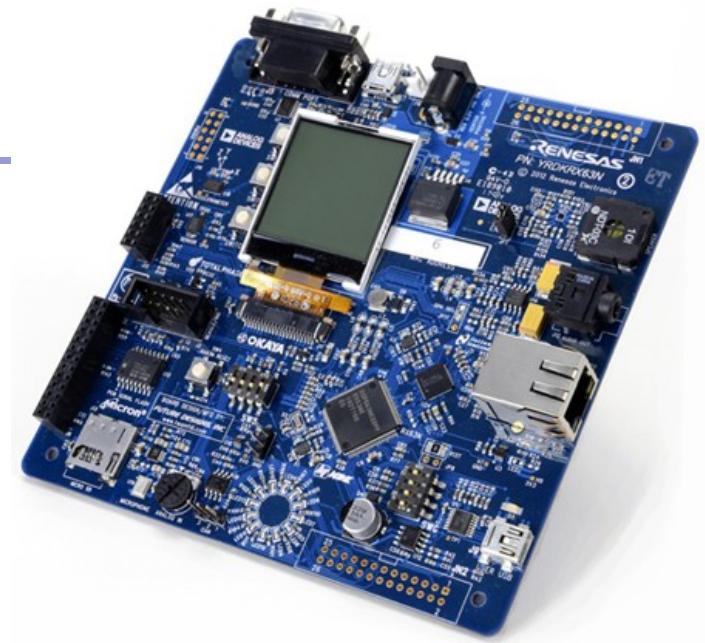
# The head controller prototype

- **Needs**

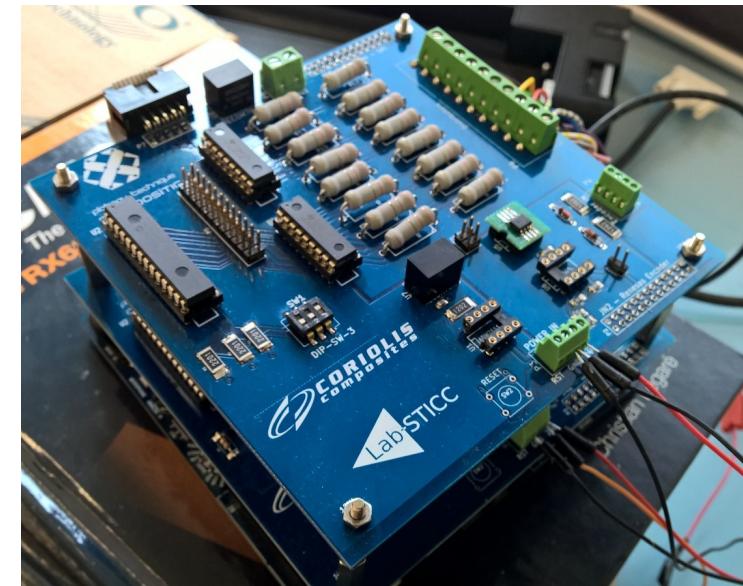
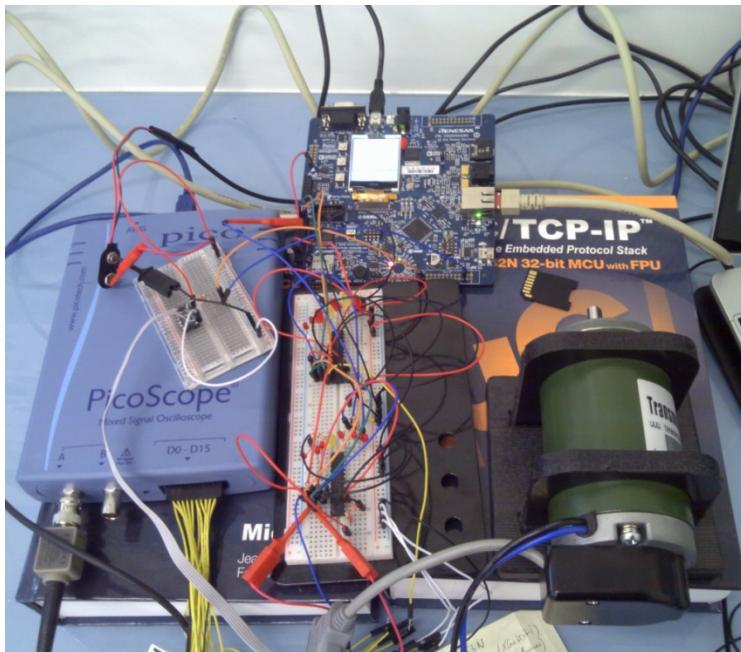
- 100 $\mu$ s cycle time
- Communication with supervision
  - *To load trajectories*
  - *To apply filters (inhibit a tape)*
  - *To change/start trajectories*
- Store trajectories
- Control of the valves
- Decoder

# Hardware

- **Available RX63 board**
  - 100MHz MCU / 128ko RAM / 1MO flash / SD-Card port
  - Integrated debugger
  - FreeRTOS / GCC (no licence)
  - Ethernet communication (uIP)
  - Already used as a teaching platform
- **Daughter board**
  - SPI I/O Expander : MCP23S17
    - 16bits
    - 10MHz (works at 24MHz)
    - 16 IOs in  $6.9\mu s$  at 9MHz
  - Level Shifter : ULN2803A
    - $3.3 \rightarrow 24V$



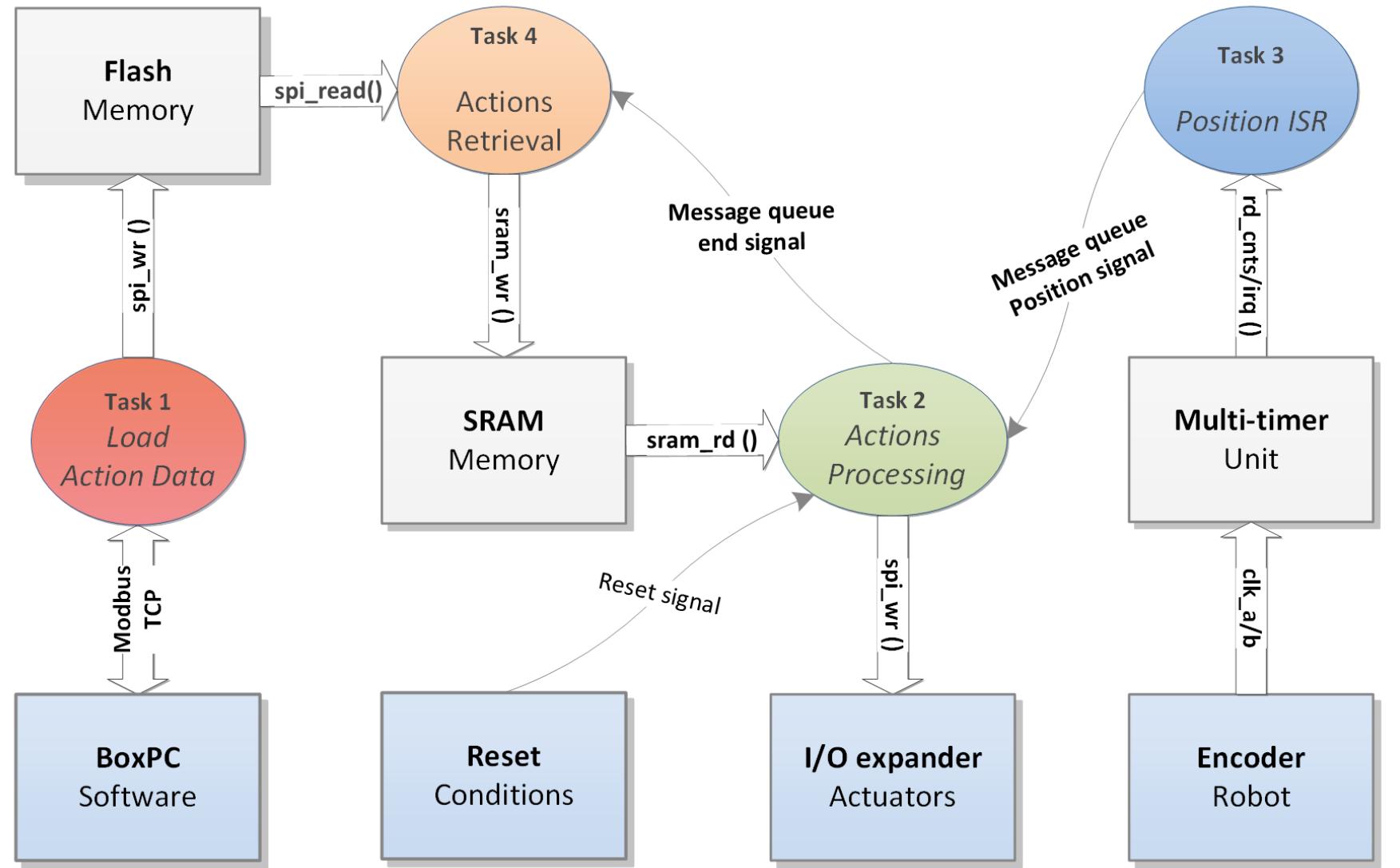
# Some iterations



# Software Considerations

- **MCU**
  - Use of hardware timer for decoding position
- **FreeRTOS**
  - Tick lowered to 100 $\mu$ s
  - Task 2 has highest priority and a period of 1 tick
- **Communication**
  - Use of a ModbusTCP task over uIP
- **Memory**
  - Not enough space on RAM for all the trajectories
    - *1 traj in RAM*
  - Trajectories are stored in the SD-Card

# Software tasks



# Tests

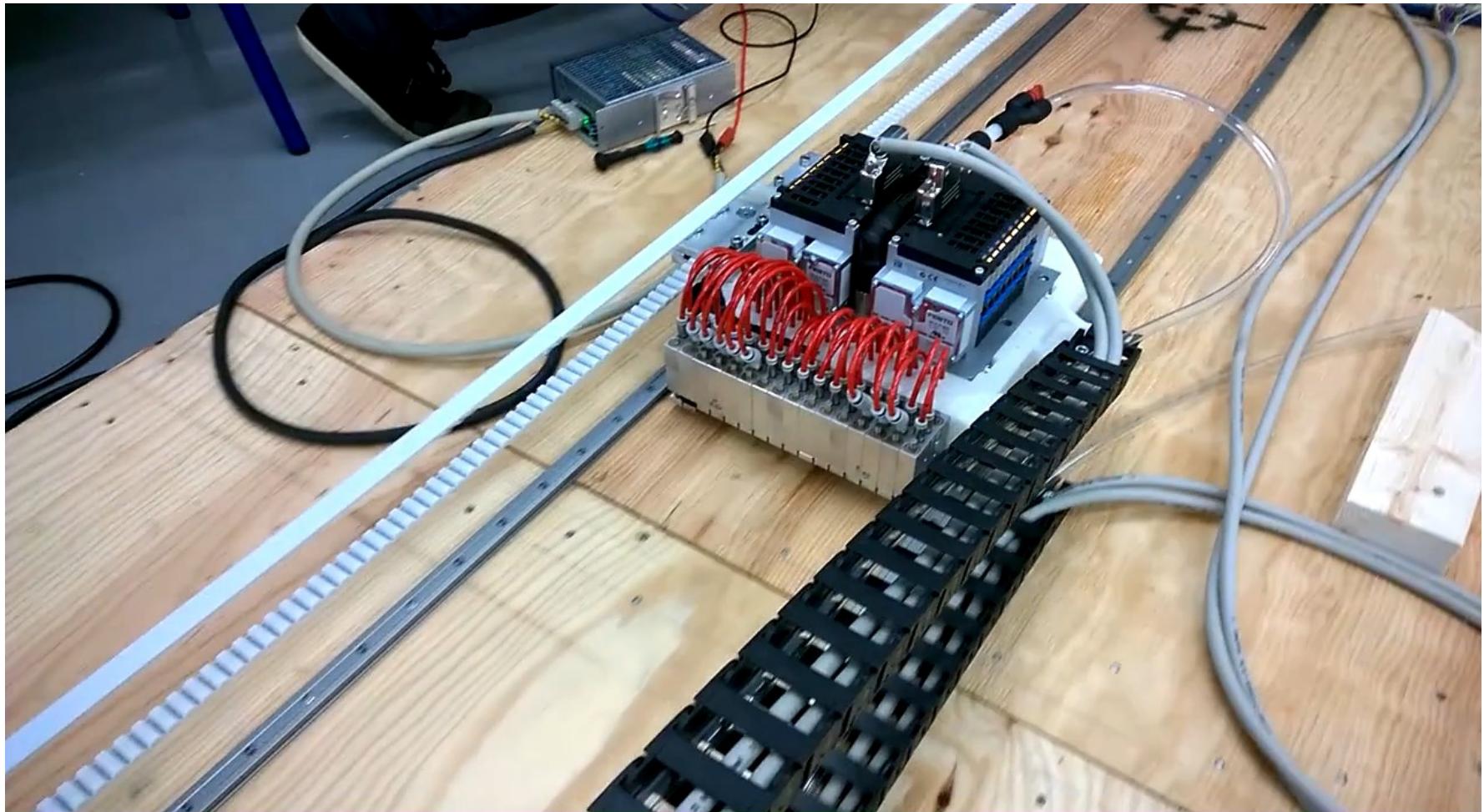
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plateau technique  
**compositIC**

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# Tests on the testbench



# Test on the robot

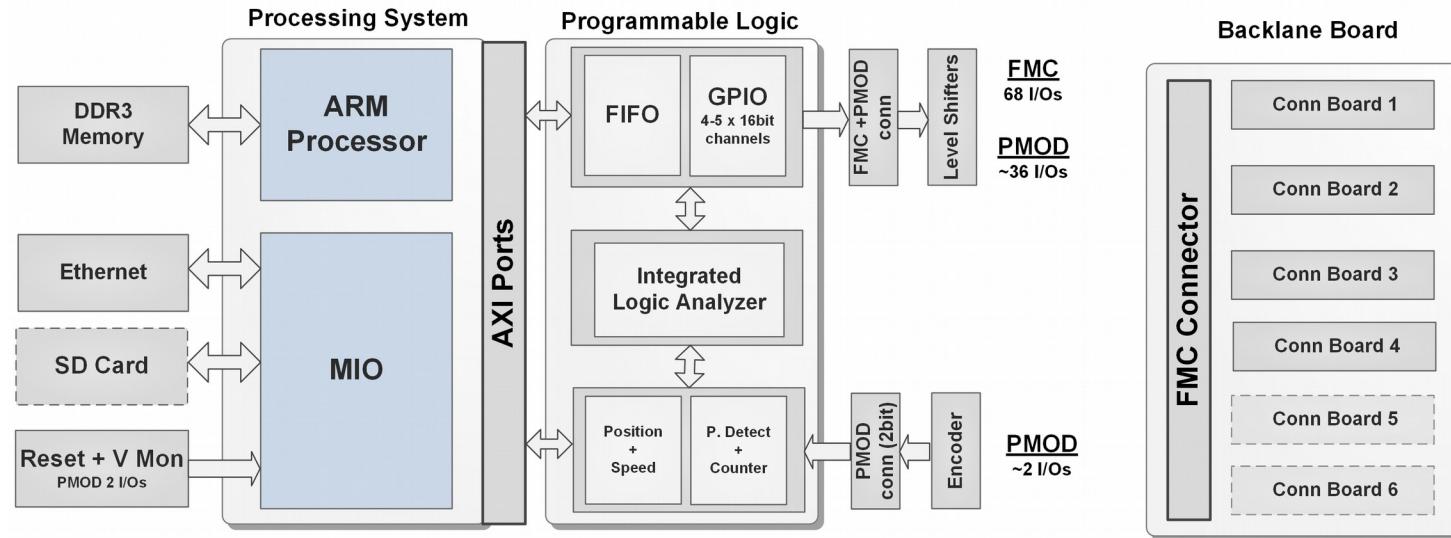


# Summary

- **Functional tests were good after some tweaking**
  - Set up origins and scales
  - Transitions between tapes
- **Possibility to do some patterns that the robot was unable of**
- **Solution is kept by Coriolis for future developments**
  - Needs hardening

# Research perspectives

- Currently setting up an **FPGA version**
  - Using Xilinx's Zync platform
    - *Port of the software version*



- Design of custom hardware in the *FPGA Logic*
- **FPGA will open door to other types of control**
  - Vision for heating control

# Computer Aided Design

- **Use MDE Techniques for**
  - designing global application
  - Map it onto the platform
    - *PLC's*
    - *Custom design*
    - *Industrial/Sensor Network*
  - Generate code
    - *IEC code*
    - C
    - VHDL

# Design, co-simulation and reconfiguration of industrial conveying systems

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Lab-STICC

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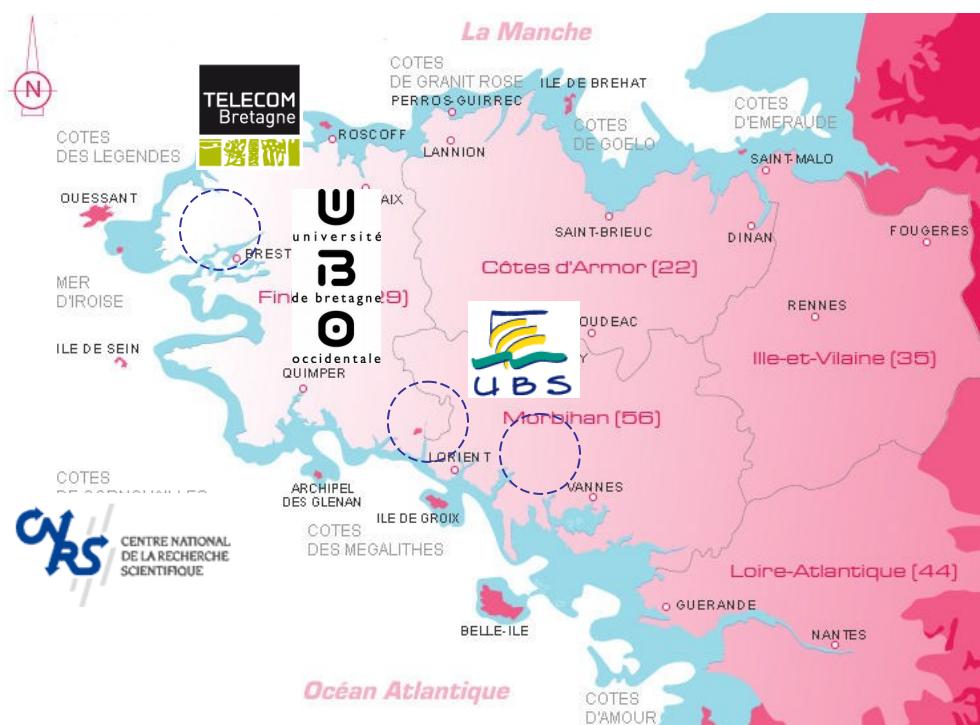
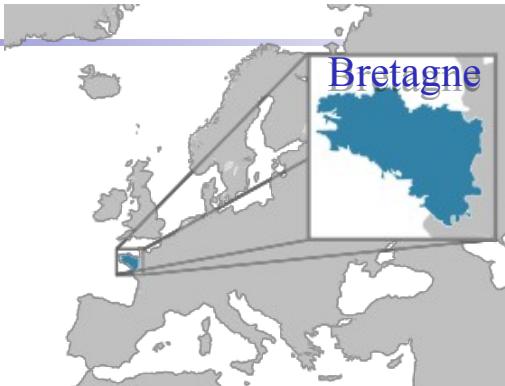
# Outline

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- **Context**
  - The Lab
  - Syleps
- **Academic Results**
  - Design methodology for transitic systems
  - Code generation
  - Co-Simulation of transitic systems
  - Re-configuration
- **Conclusions**

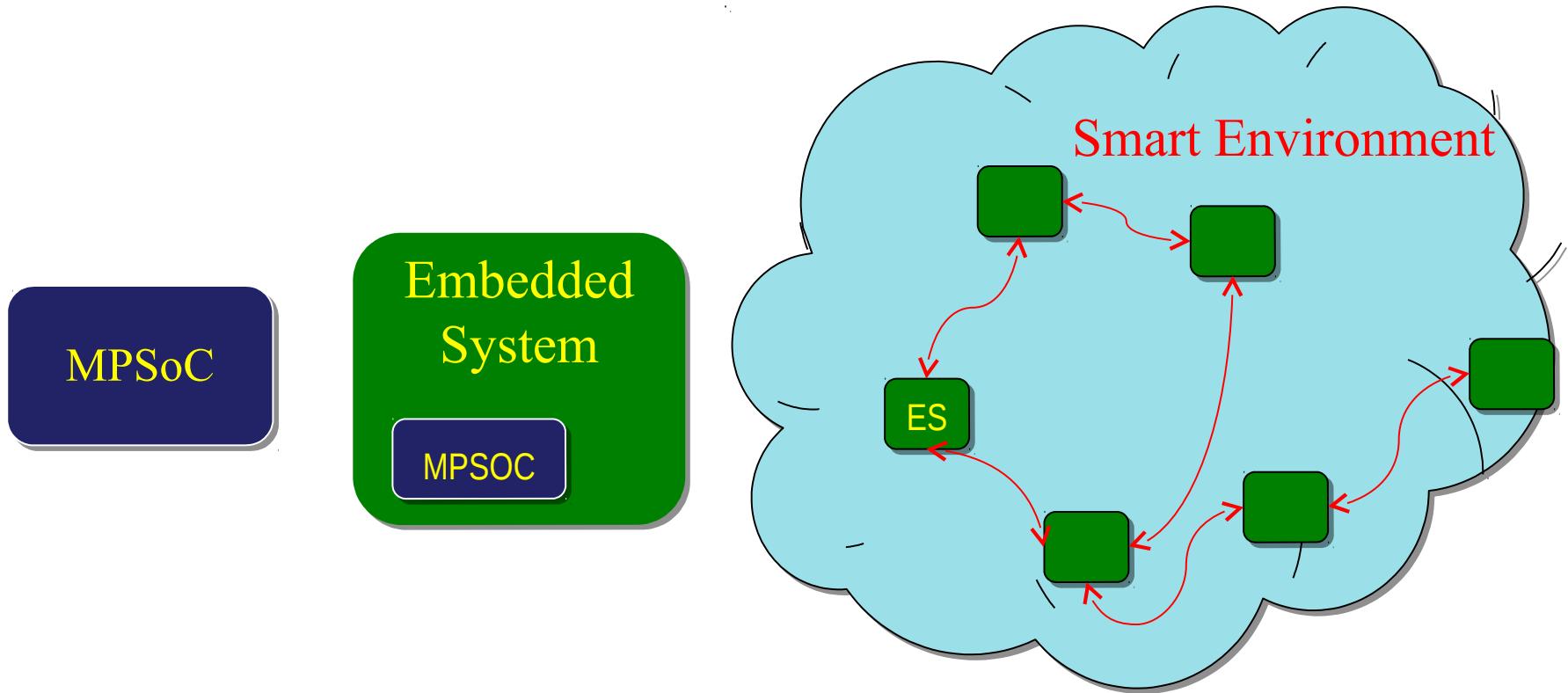
# The Lab-STICC

- “*Laboratoire des Sciences et Techniques de l’Information, de la Communication et de la Connaissance*”
  - From sensors to knowledge
- **4 research centers**
  - Brest (2)
  - Lorient (1)
  - Vannes (1)
- **Lab-STICC is**
  - 450 people
    - 230 *researchers*
    - 220 *PhD students*
  - 2.5M€ in contracts in 2007
  - Scientific production over 4 years
    - 25 *book chapters*
    - 200 *journal papers*
    - 500 *conference papers*
    - 23 *patents*
    - 80 *PhD*

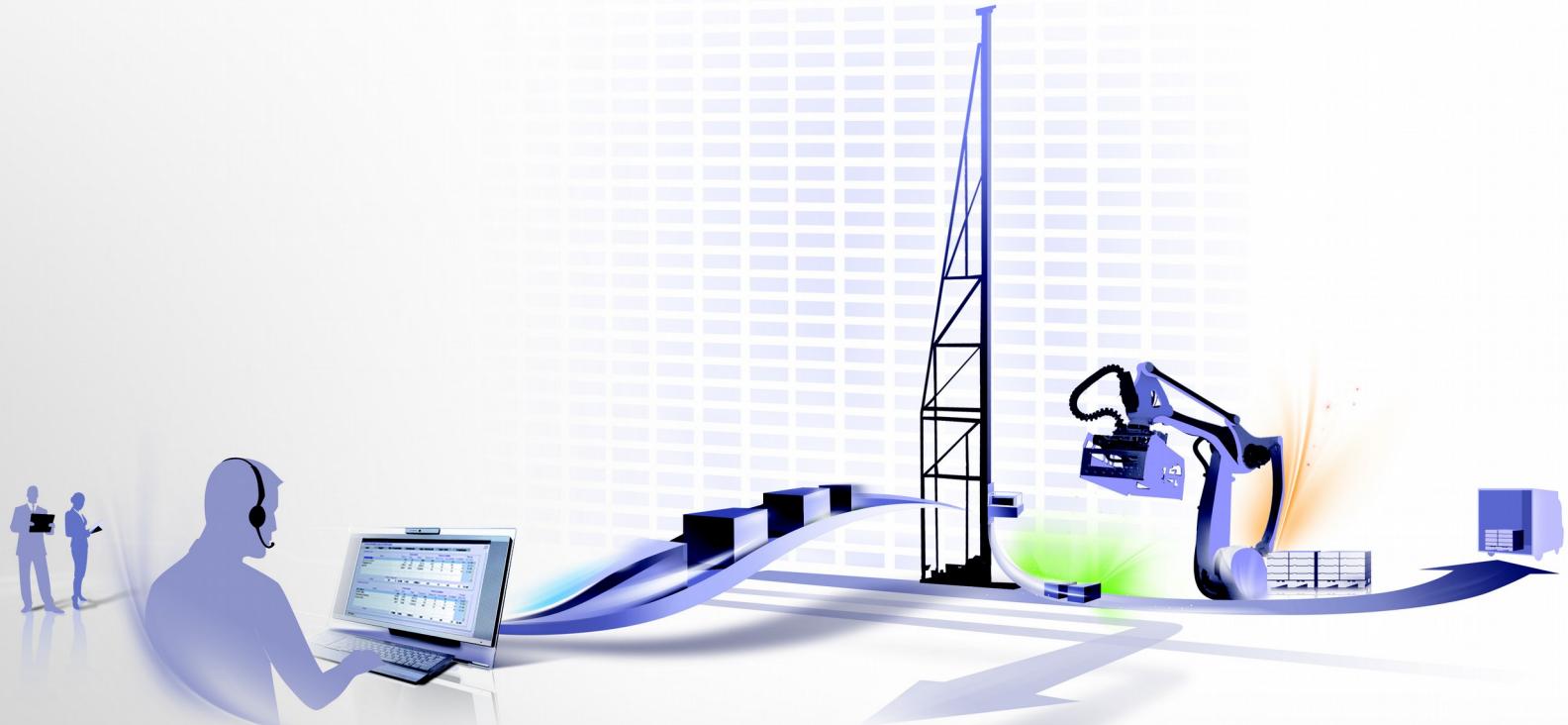


# The MOCS team

MOCS: 38 Staff, 40 PhD, 3 research axis with interactions



# Syleps



- **Specialized in intra-logistics**
  - Software solutions
  - Integration
    - *Automatisms / Storage / Robotics*

# Figures

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Creation	1975 : Sydel 2013 : Syleps
Capital	6 000 000 €
Turnover	20 M €
People	175
Area	12 000 m <sup>2</sup>
R & D	6 % of turnover

# Markets



## Agribusiness

- » Fresh products
- » Frozen products
- » Fruits and vegetables
- » Dry products



## Manufacturing

- » Industrial furnitures
- » Spare parts
- » Cosmetics, pharmacy
- » Textile...



## Distribution and Logistics

- » Logistic centers (supermarkets)
- » Distributors
- » Logistic providers
- » E-commerce, Drives

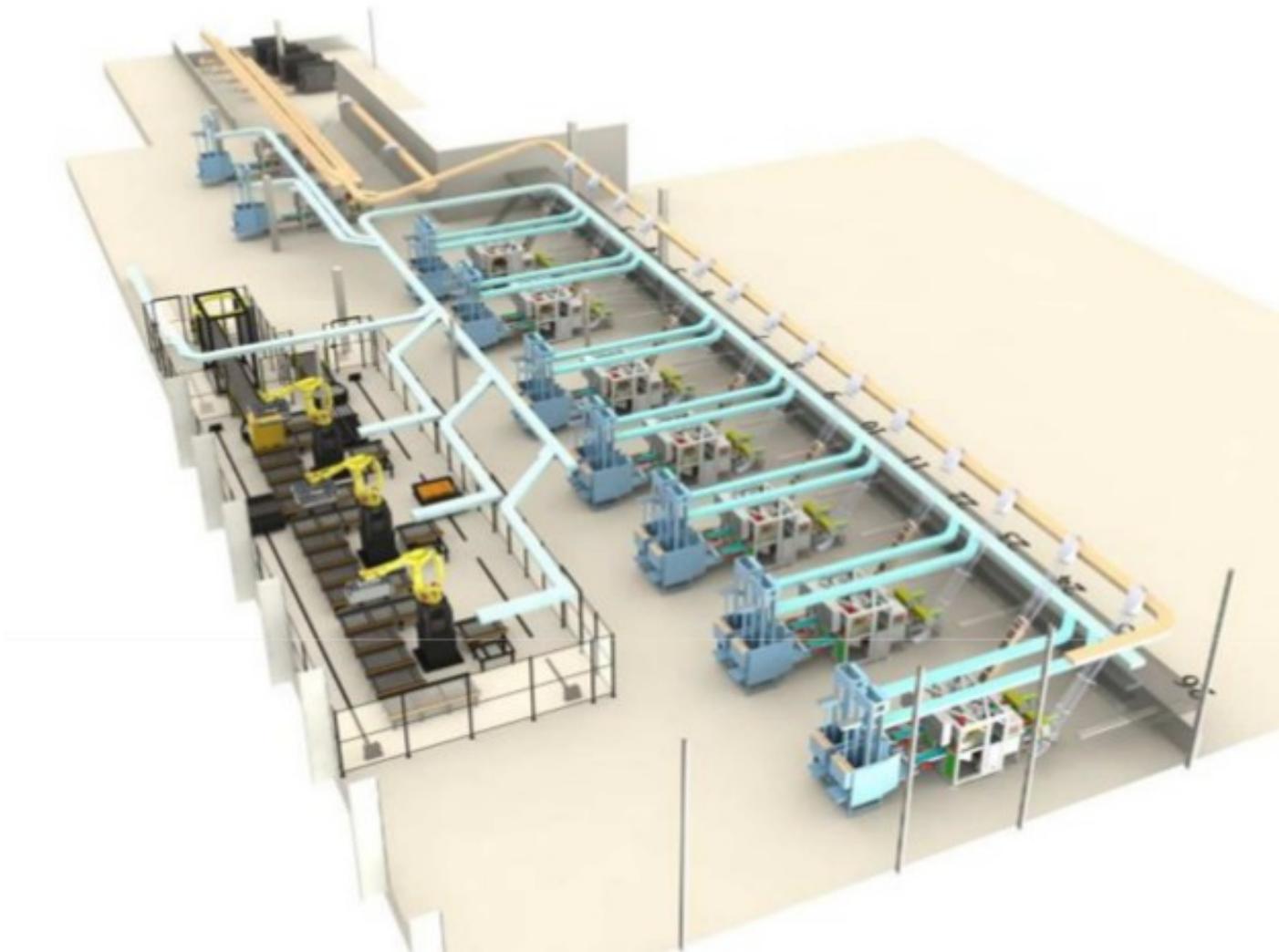
# Products

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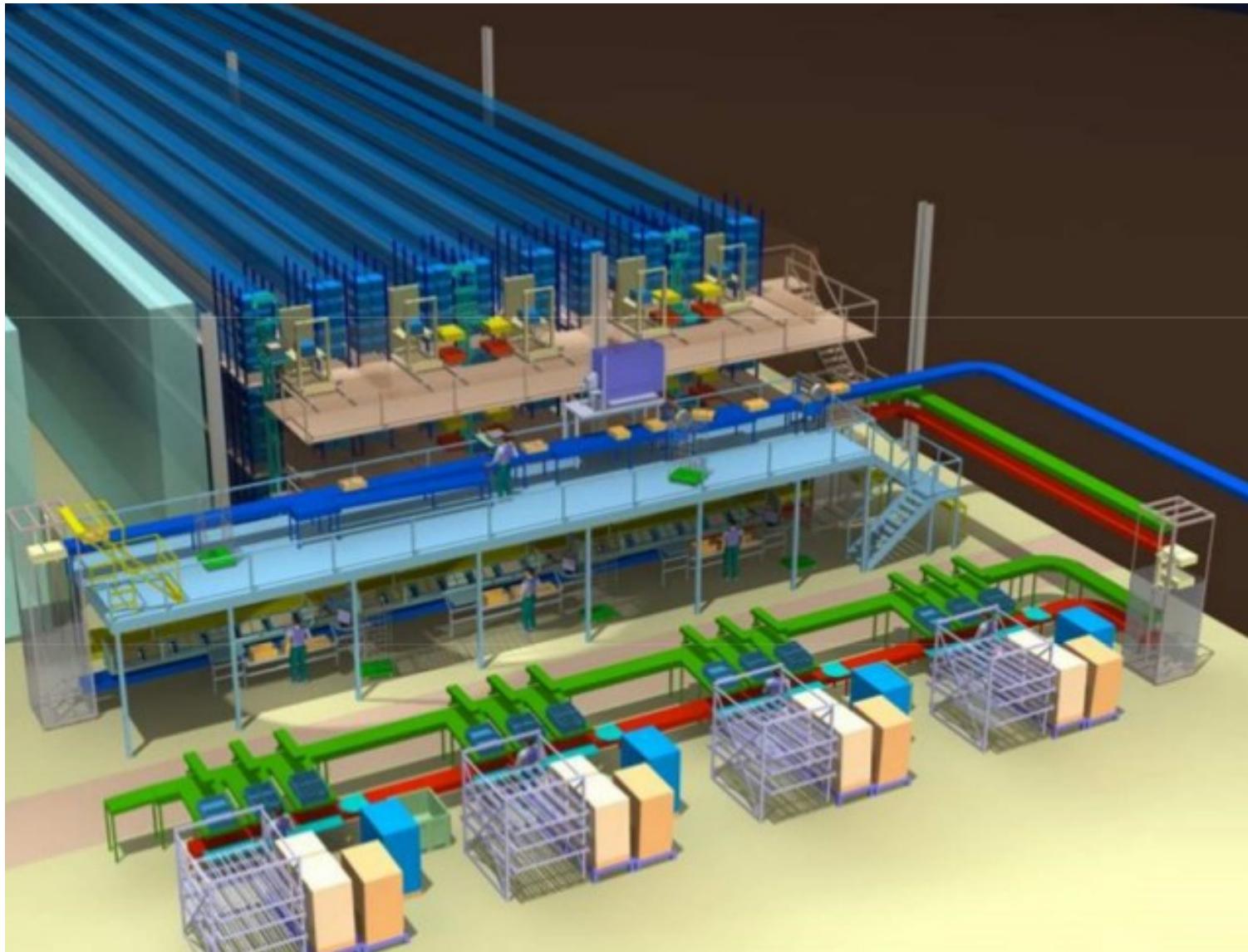
- **Software (CAPM, MES)**
  - Sydel Univers
- **Hardware**
  - Transitics (Conveying systems)
  - Storage
  - Paletizing



# Some realizations



## Some realizations



# R&D service

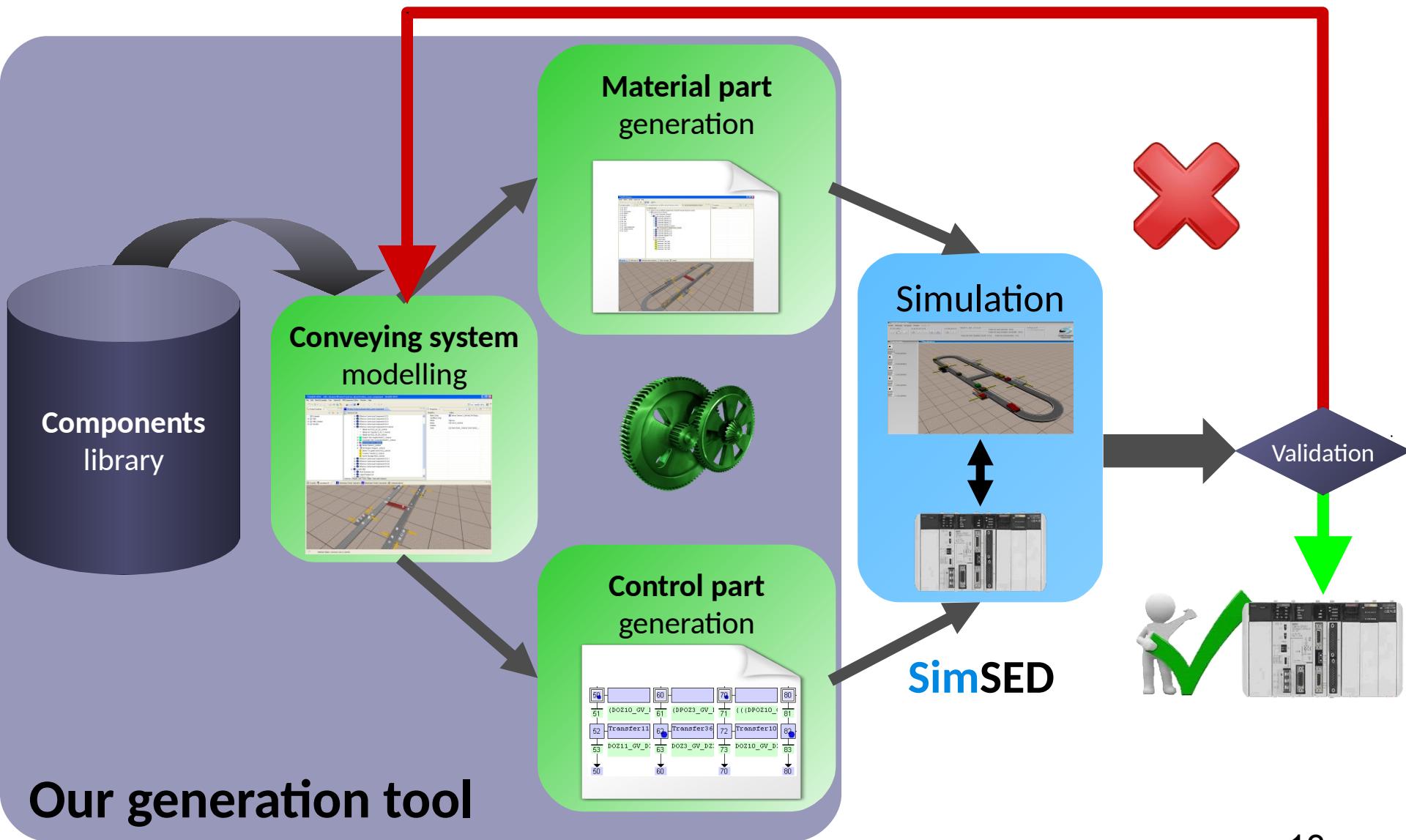
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- **Created in 1983**
- **Recognized as Research Center in 1984**
  - 4 PhD
  - 2 regional research projects
  - More than 100 job placements (5-10 / year)
- **Links with Lab-STICC since its creation in 1998**
  - SimSED project ( 3 PhDs )

# Collaboration History

- **1999 – 2002 : PRIR Project ACSYR**
  - Design Tool for Distributed System
- **2001 – 2002 : PUCE Plan**
  - Design of a Nano-PLC
- **2001 : Start of the SimSed Project**
  - 2000 : PhD 1 Design approach for transitic systems
    - *J.-S. Mouchard*
  - 2004 : PhD 2 Design of a dependable approach
    - *J.-L. Lallican*
  - 2010 : PhD 3 Component approach for a multi-version command of reconfigurable transitic systems
    - *R. Bevan*

# Low level control design flow



# Component Based Approach

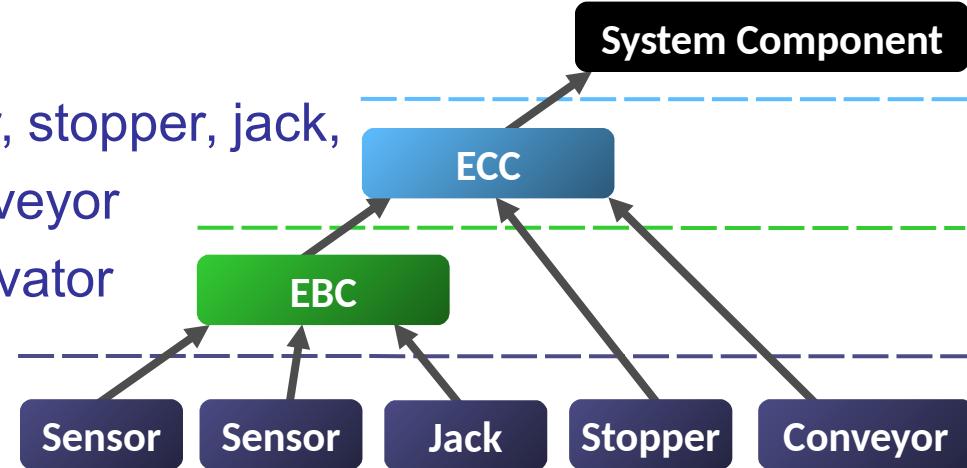
**A system is seen as an assembling of components**

- **Component**
  - Reusable element
  - Models a part of the system
  - Includes several Viewpoints and Operations
- **View : a component is composed of 4 views**
  - Operative part
  - Control part
  - Constraints
  - Topological

# Typology of components

- **Simple components**

- **Basic component:** sensor, stopper, jack,
- **Support component:** conveyor
- **Handling component:** elevator



- **Aggregated components**

- **Enriched Base Component (EBC):** association of basic components
- **Effective Contextual Component (ECC):** association of a support component with basic components & EBCs
- **System Component:** association of ECCs

# Global design flow

## Component-based approach

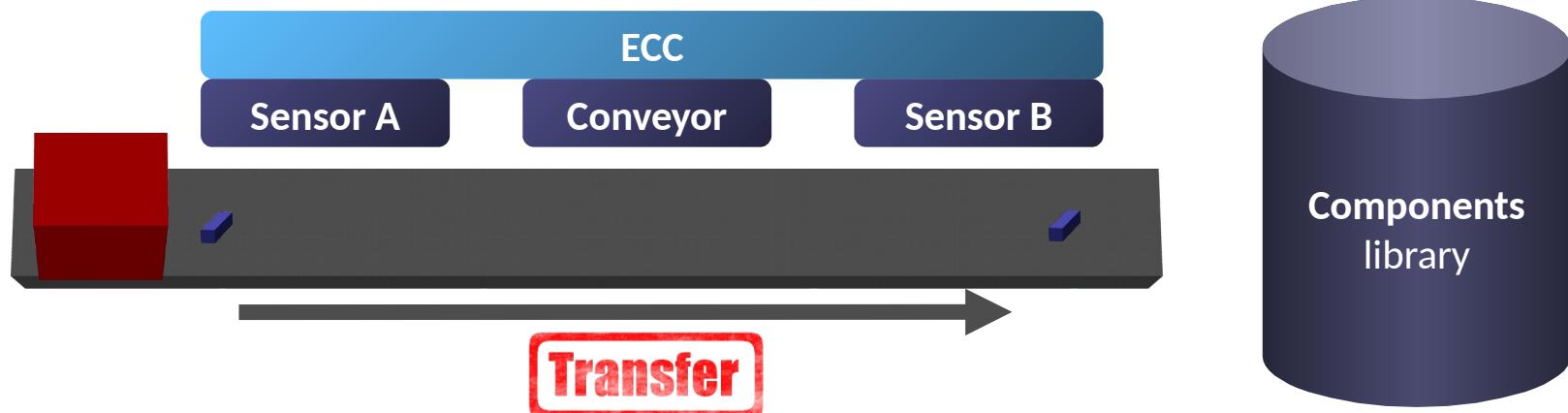
- **Typology of operations**

- **Basic operation**



- **Contextual operation**

- **Effective contextual operation**

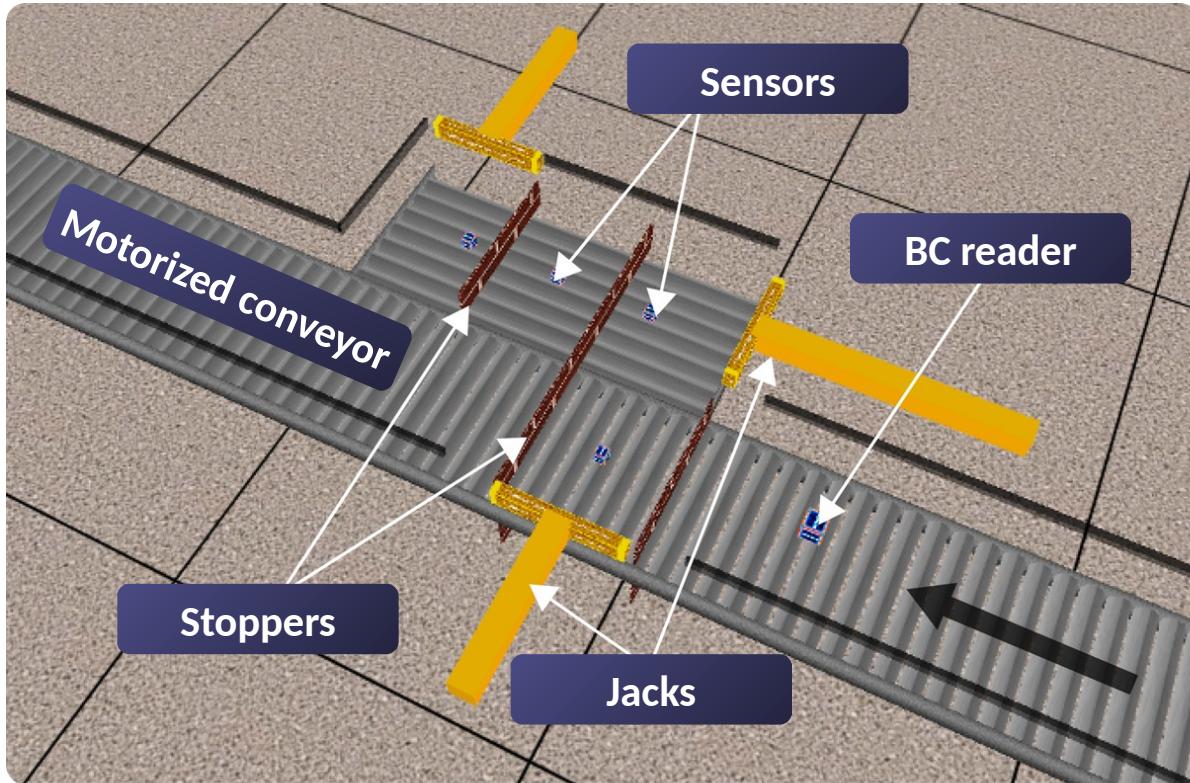


# Global design flow

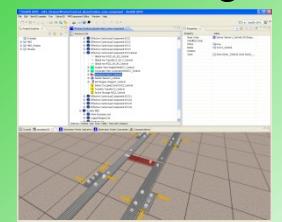
## Case study

- Domain-Specific Language (DSL)
  - Example of a working area

Operative part view  
Topological view  
Operations  
Constraints view  
Control view



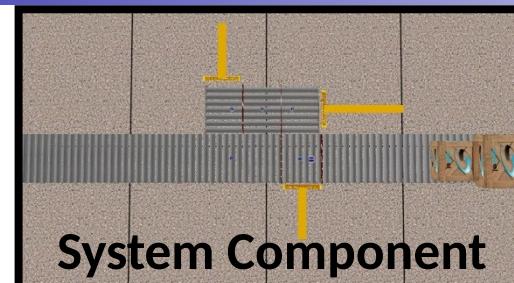
Conveying system  
modelling



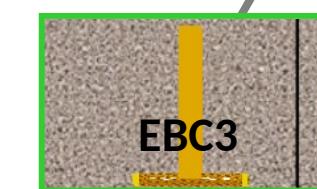
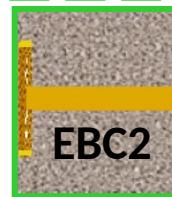
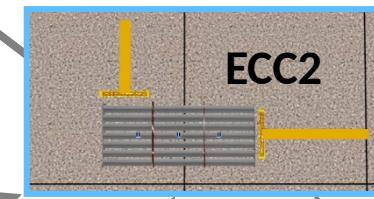
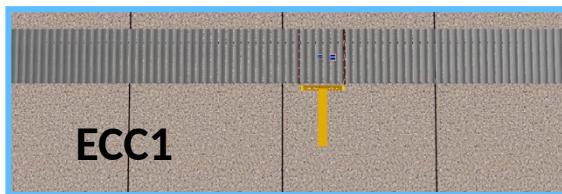
# Global design flow

## Case study

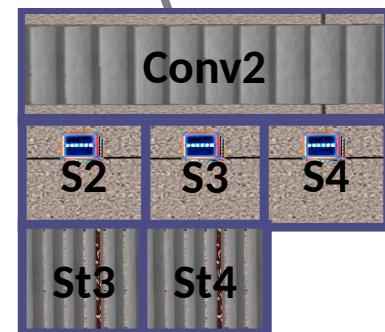
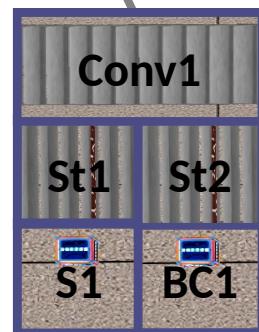
**Bottom-up approach**



→ Operative part view  
Topological view  
Operations  
Constraints view  
Control view



Position,  
length...

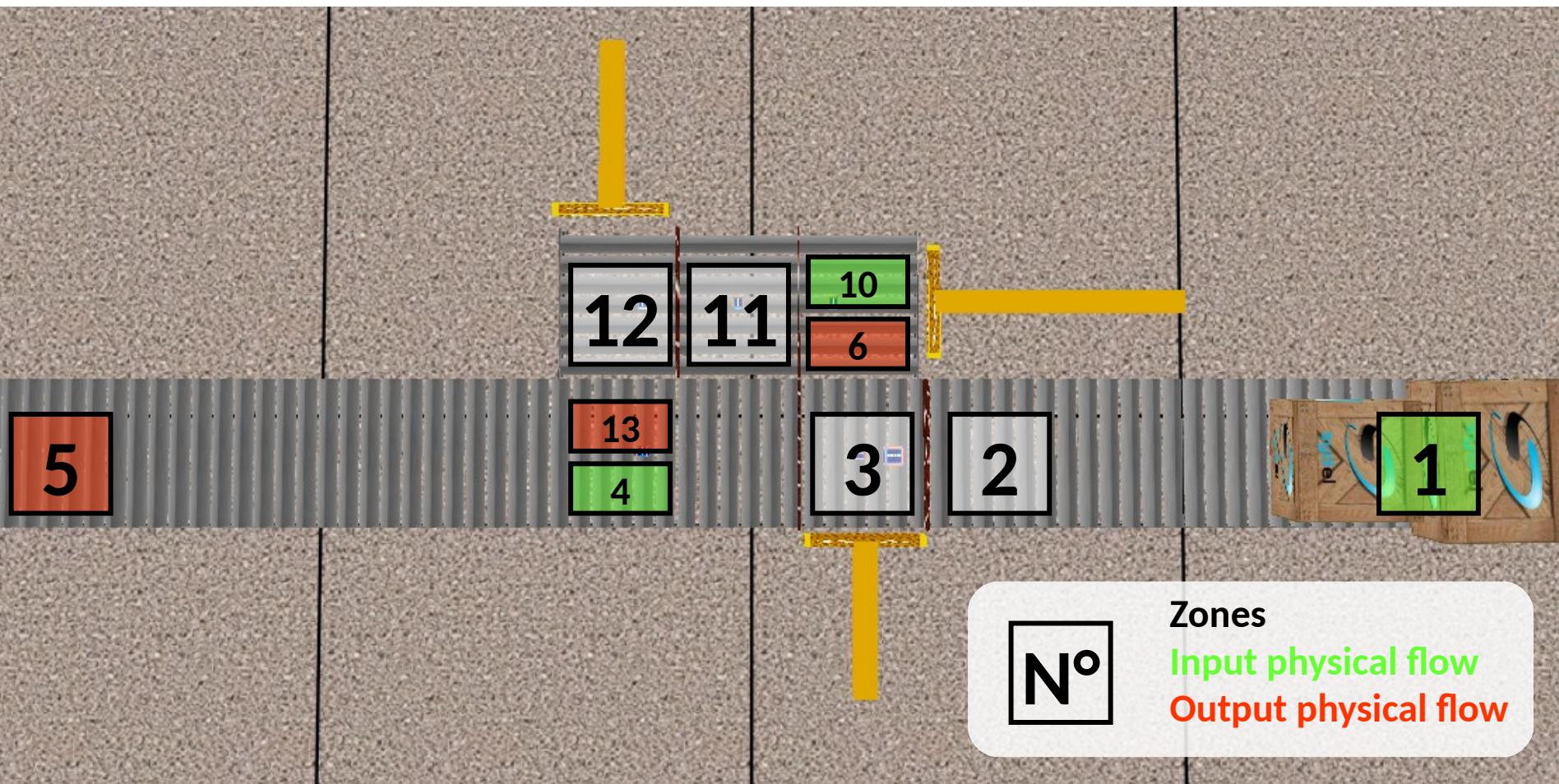


# Global design flow

## Case study

- Characteristic areas

Operative part view  
→ Topological view  
Operations  
Constraints view  
Control view

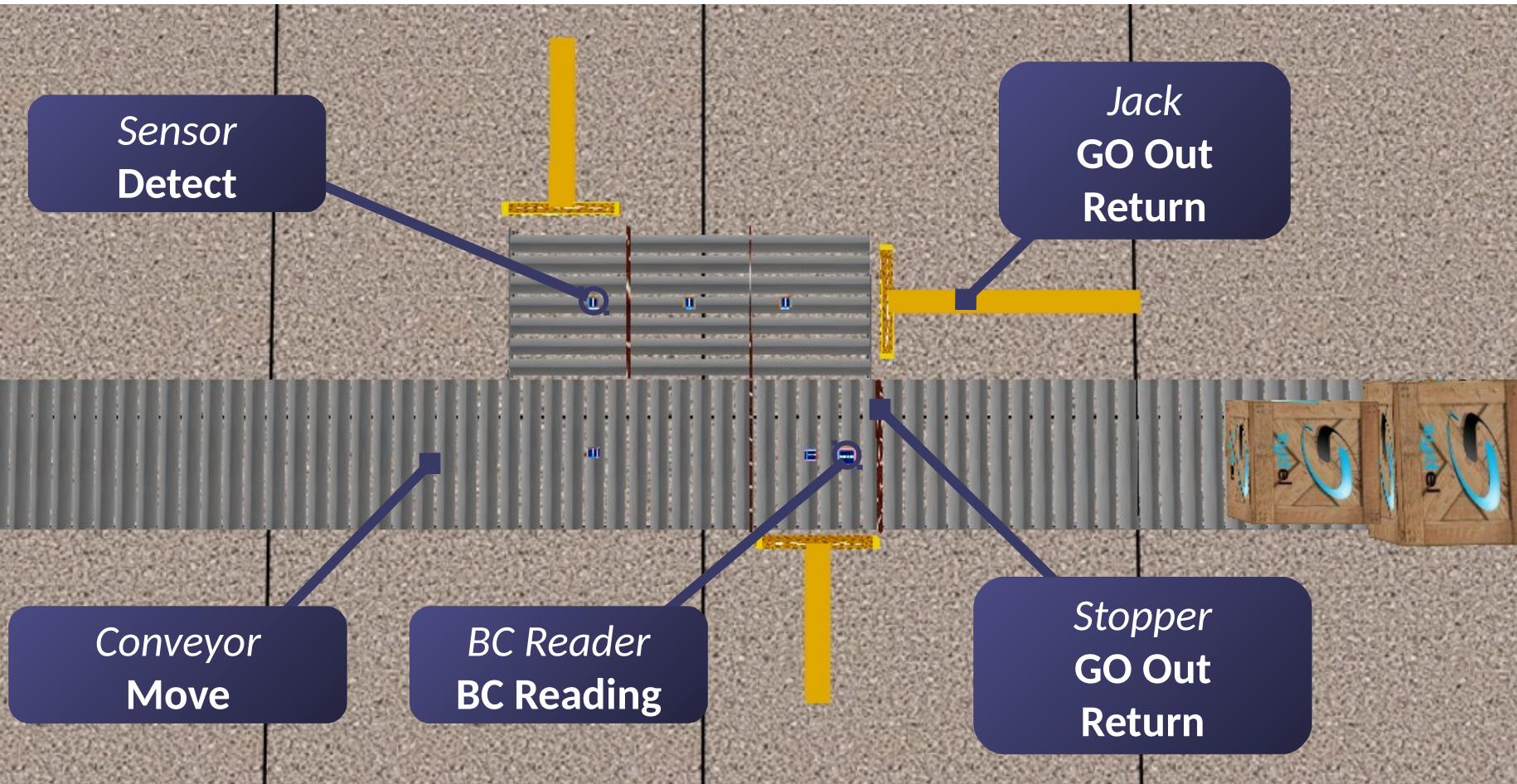


# Global design flow

## Case study

- Basic operations

Operative part view  
Topological view  
→ Operations  
Constraints view  
Control view

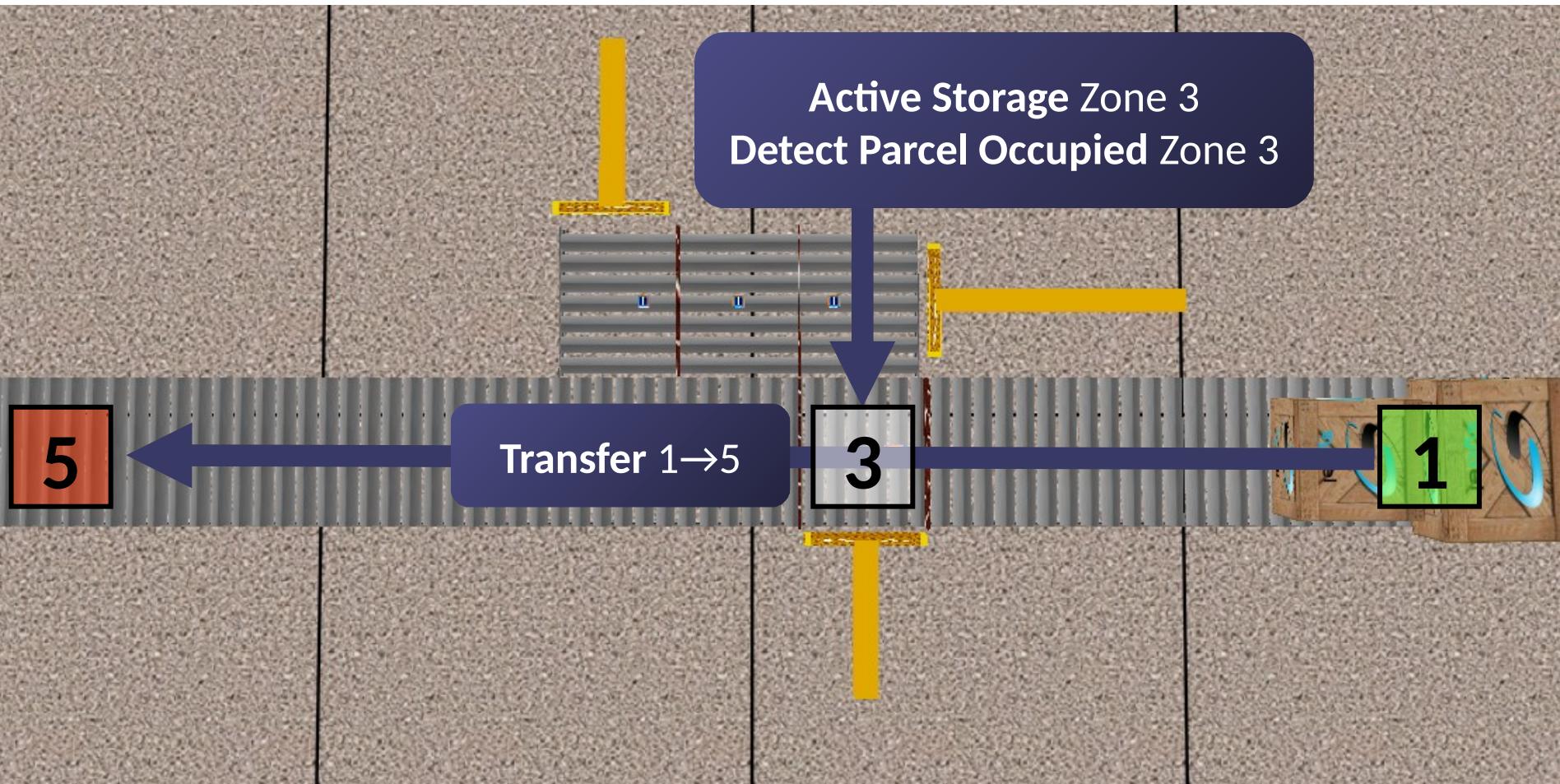


# Global design flow

## Case study

- Effective contextual operations

Operative part view  
Topological view  
→ Operations  
Constraints view  
Control view

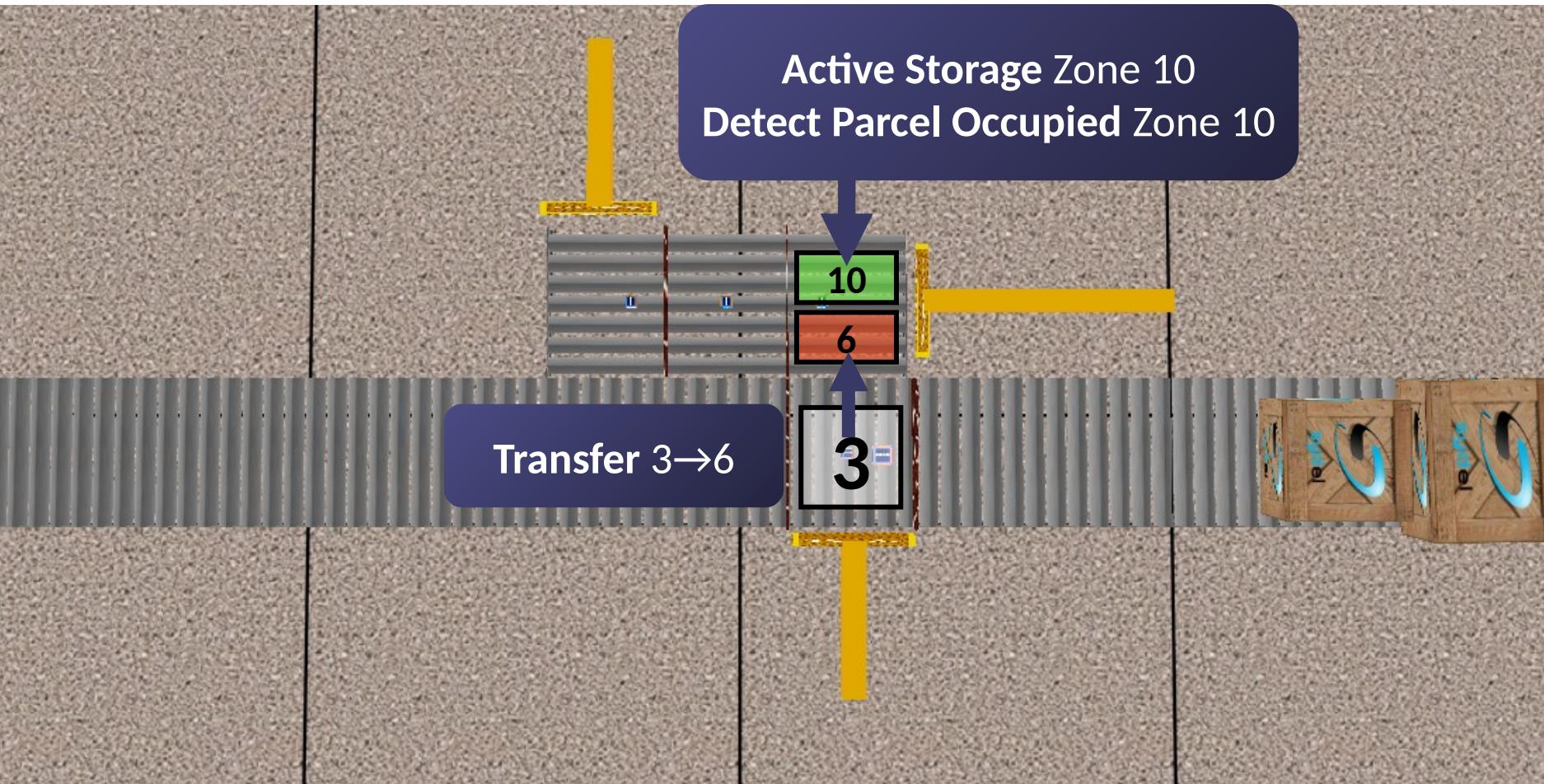


# Global design flow

## Case study

- Effective contextual operations

Operative part view  
Topological view  
→ Operations  
Constraints view  
Control view

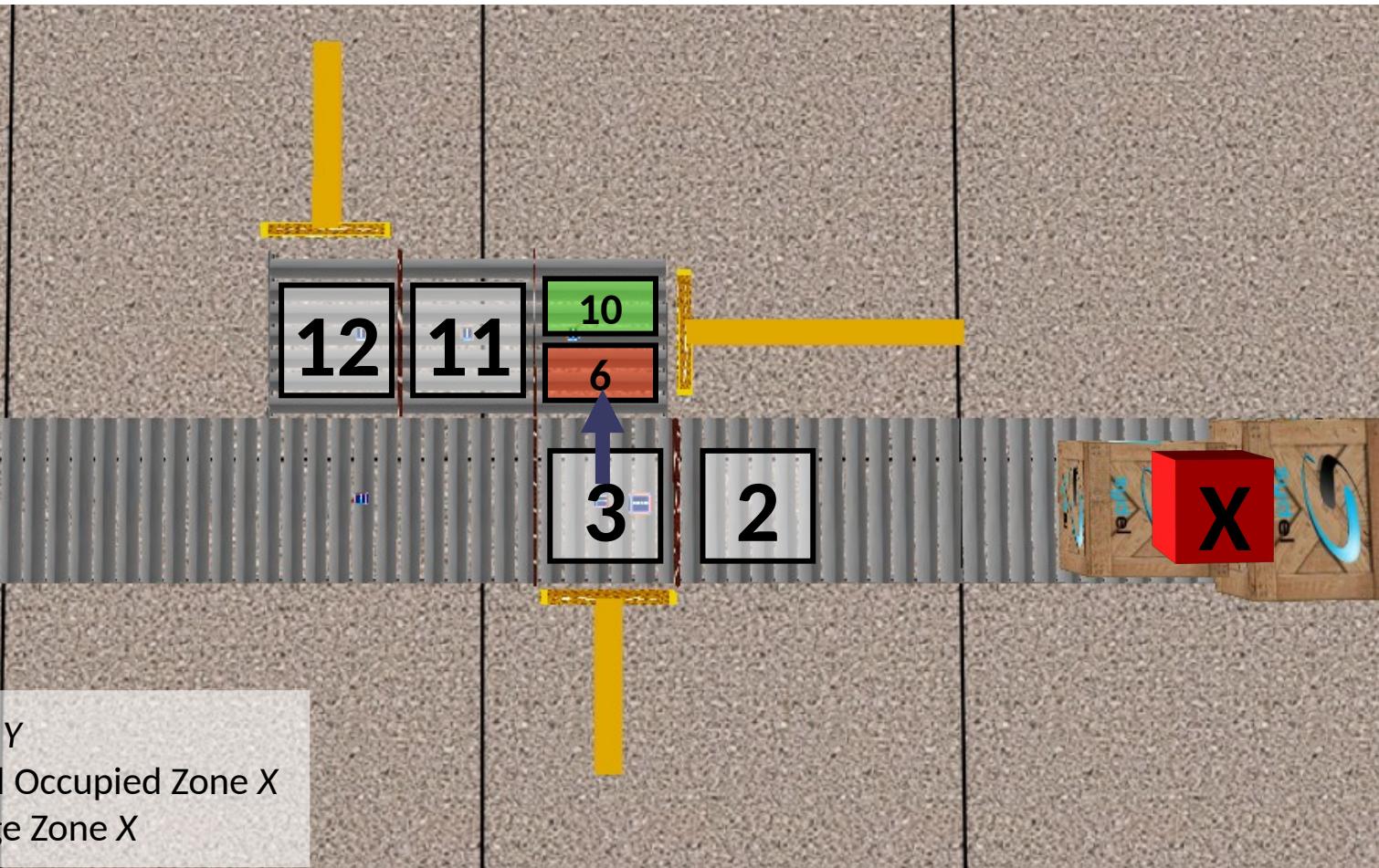


# Global design flow

## Case study

- Activation/deactivation conditions

Operative part view  
Topological view  
Operations  
→ Constraints view  
Control view



# Global design flow

## Case study

- Activation/deactivation conditions

Operative part view  
Topological view  
Operations  
→ Constraints view  
Control view

$$\begin{aligned} T3 \rightarrow 6 &= DPOZ3 \cdot \overline{DPOZ10} \cdot \overline{T10 \rightarrow 11} \cdot \overline{T11 \rightarrow 12} \\ \overline{T3 \rightarrow 6} &= DPOZ3 \end{aligned}$$

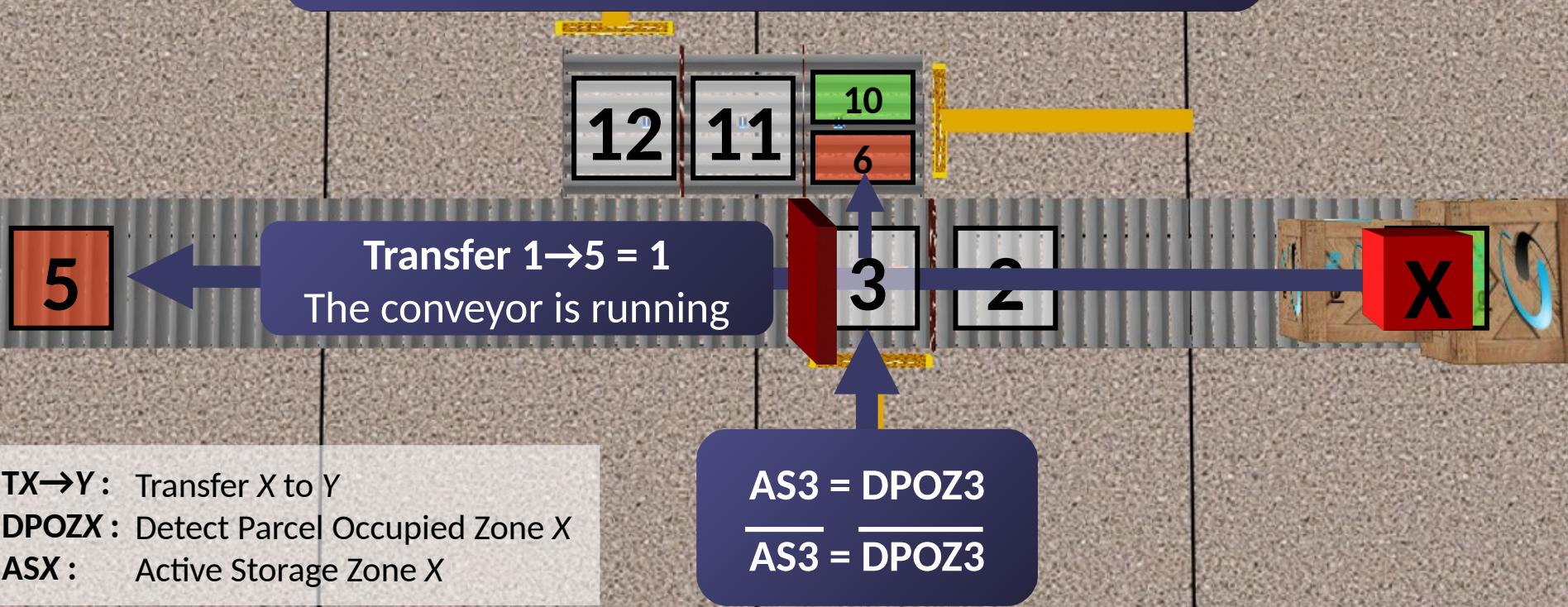
Transfer  $1 \rightarrow 5 = 1$   
The conveyor is running

$$\begin{aligned} AS3 &= DPOZ3 \\ \overline{AS3} &= \overline{DPOZ3} \end{aligned}$$

$TX \rightarrow Y$ : Transfer X to Y

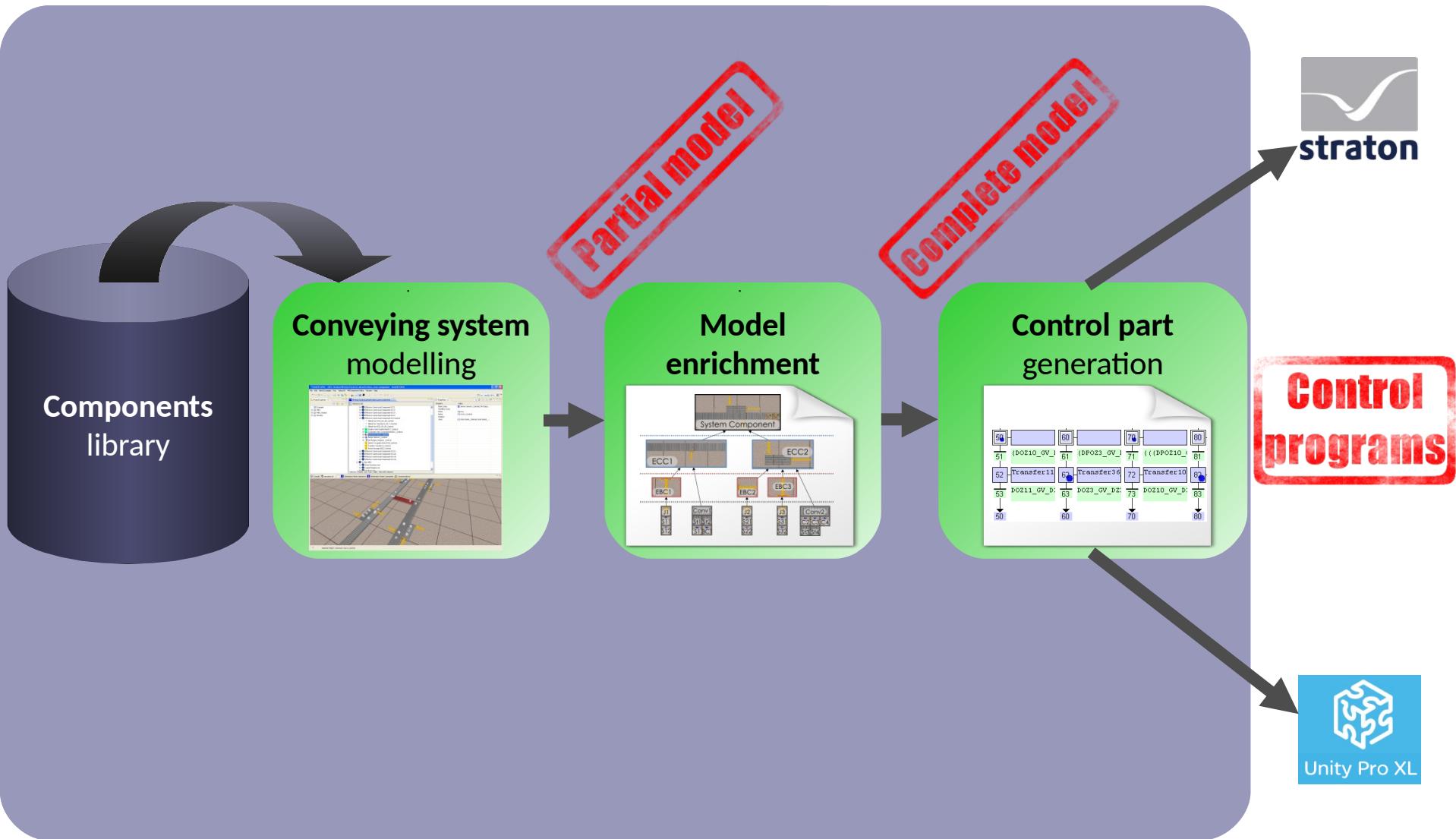
$DPOZX$ : Detect Parcel Occupied Zone X

$ASX$ : Active Storage Zone X



# Low Level control code generation

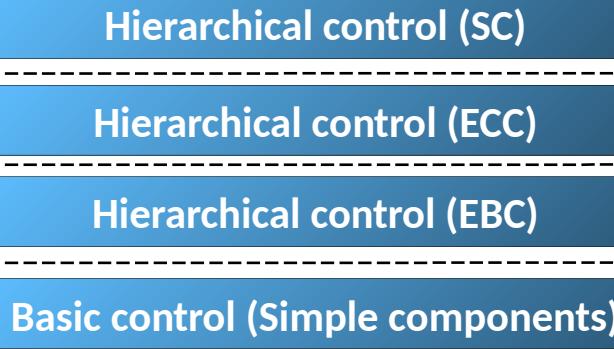
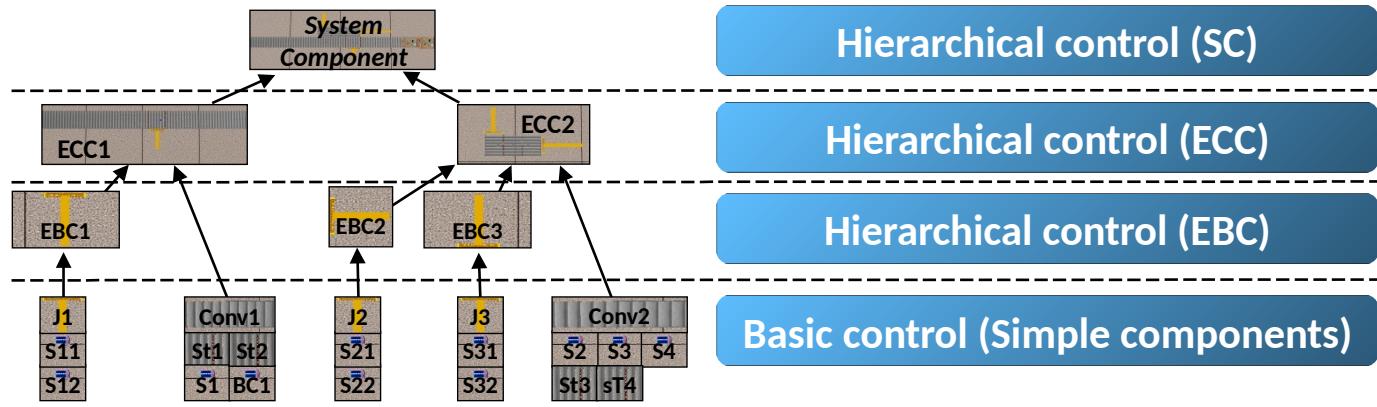
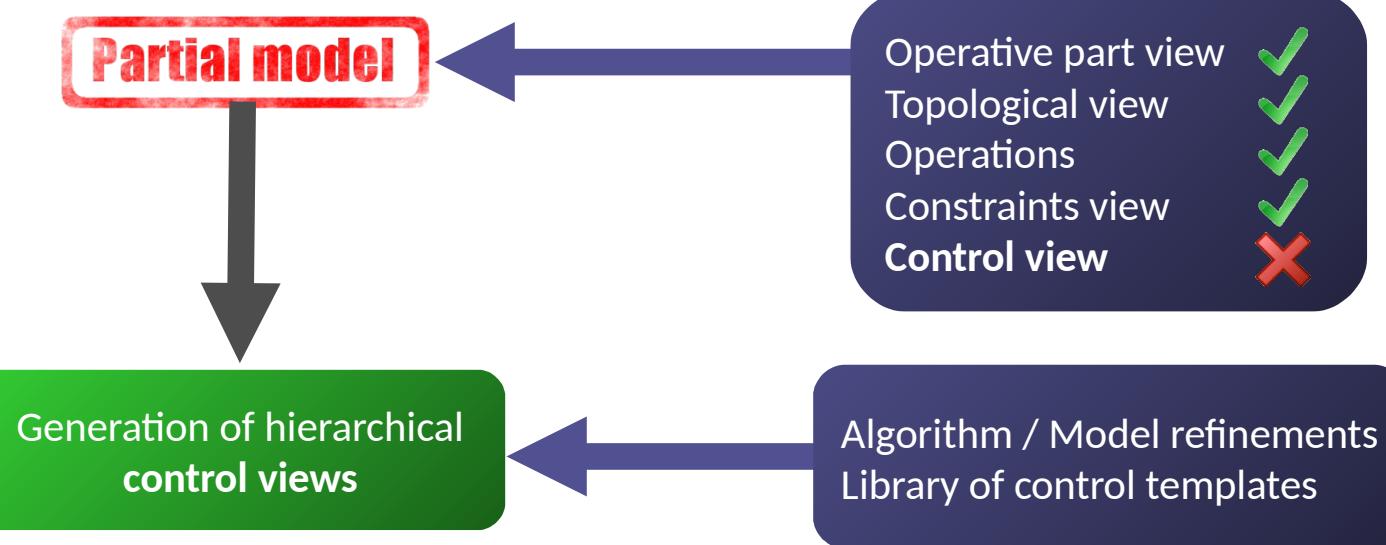
## Overview



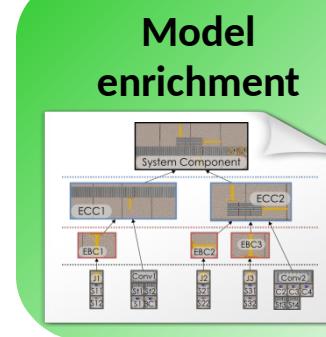
# Global design flow

## Generation

### • Generation of the control views



Operative part view  
Topological view  
Operations  
Constraints view  
→ Control view



# Global design flow

## Generation

- **Generation of the control views**

**Partial model**



Generation of hierarchical control views

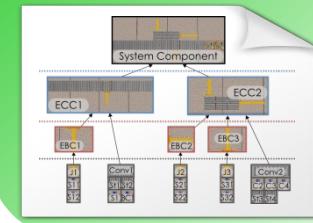


**Complete model**

- Operative part view ✓
- Topological view ✓
- Operations ✓
- Constraints view ✓
- Control view ✓

Operative part view  
Topological view  
Operations  
Constraints view  
→ Control view

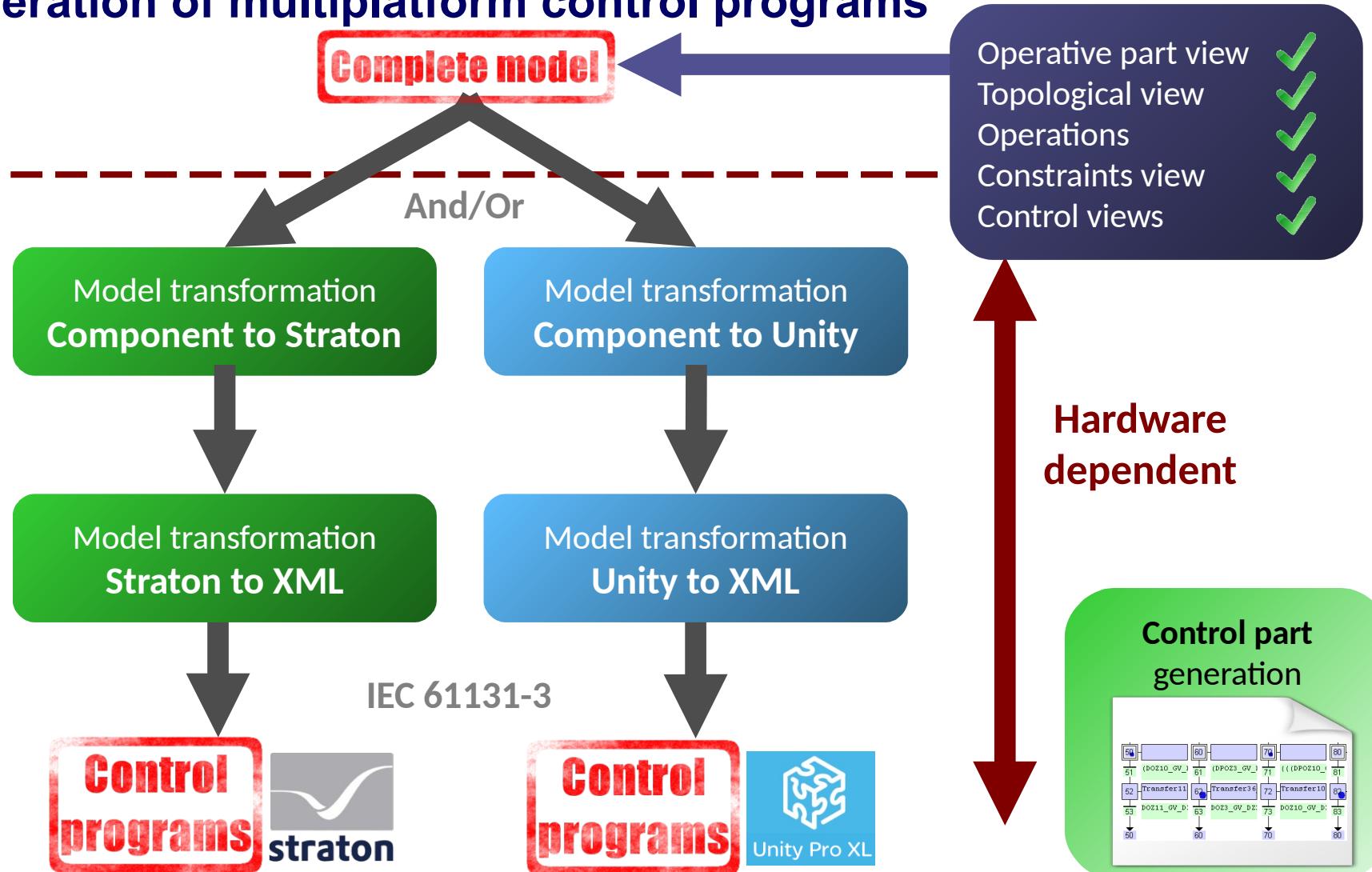
**Model enrichment**



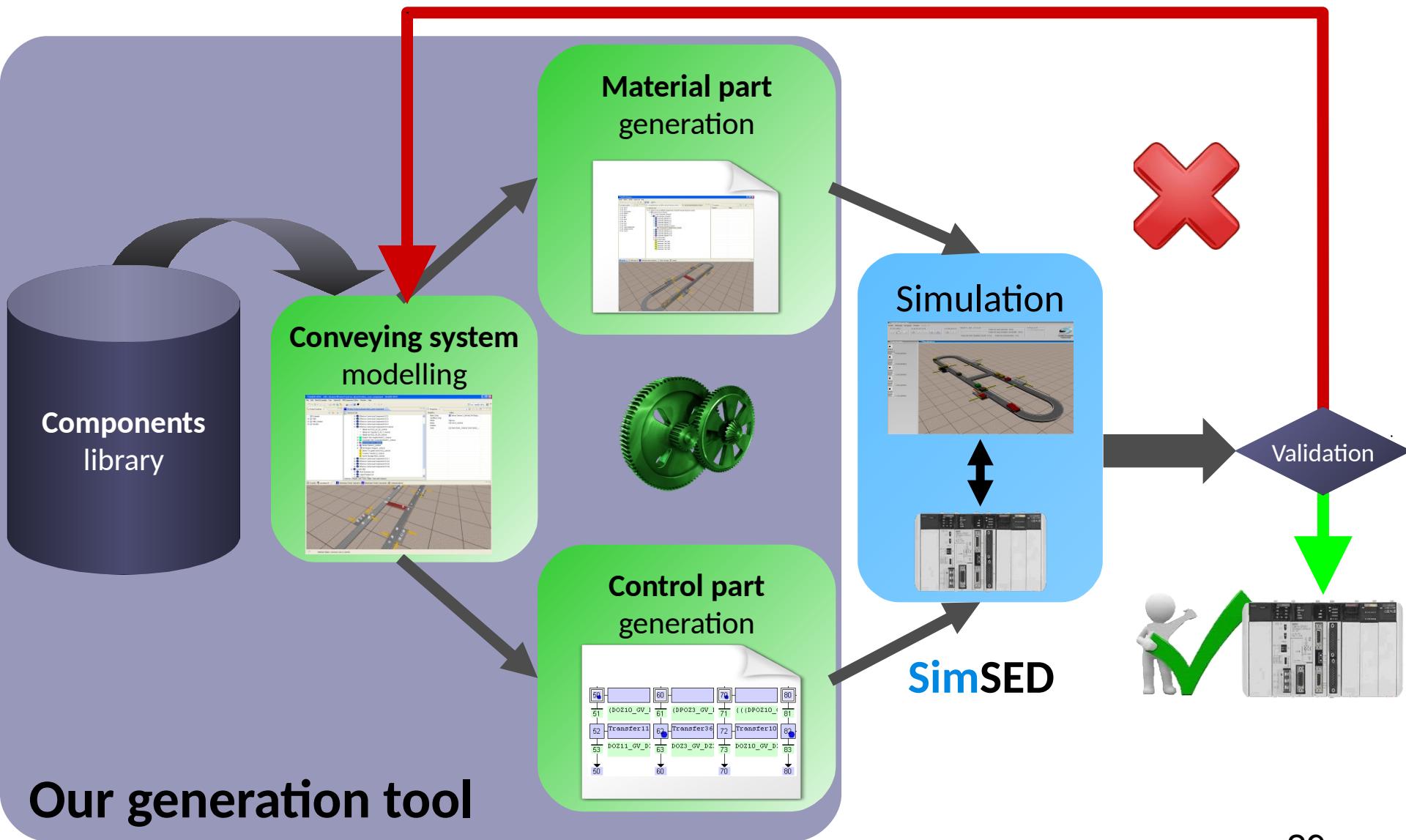
# Global design flow

## Generation

- Generation of multiplatform control programs



# Low level control design flow

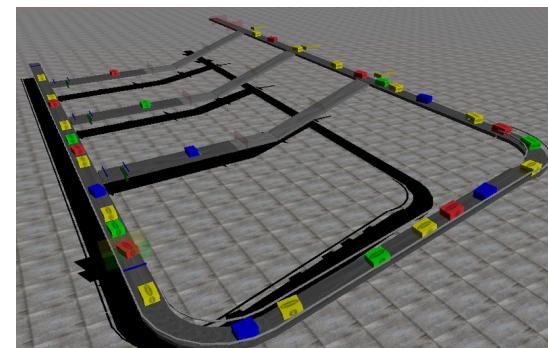
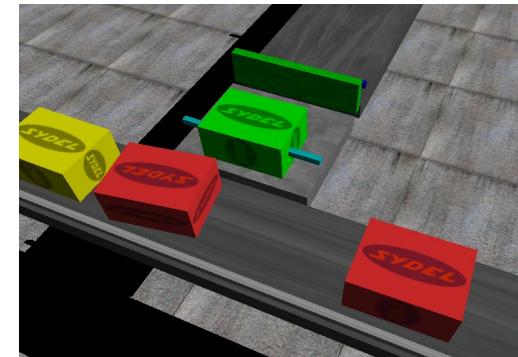
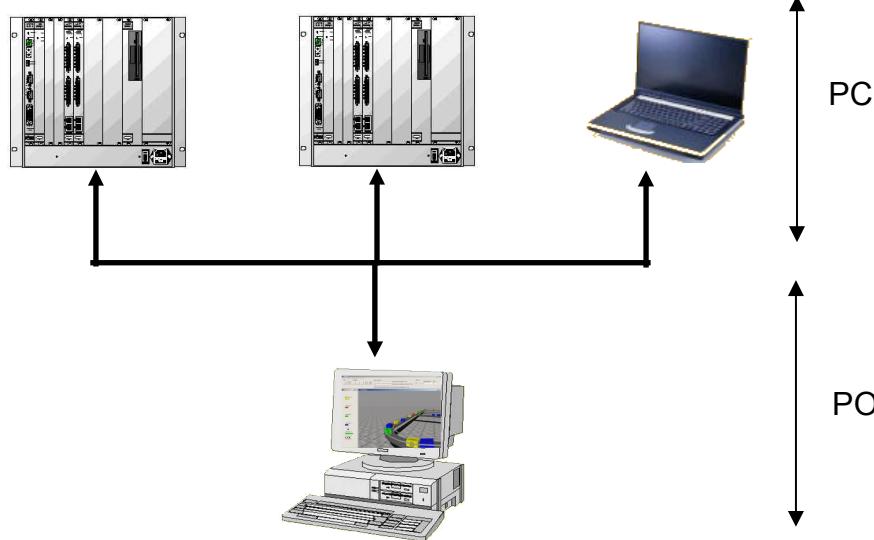


# Simulation of the system

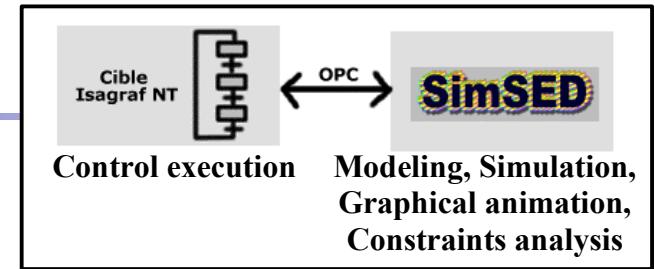
- **Discrete event simulation / stream simulation**
  - High level
  - Good for stream optimization
- **Physical simulation**
  - Validation of the low level control
- **Hardware in the loop**
  - You can put the real PLC to control the “virtual plant”

# SimSED Simulation

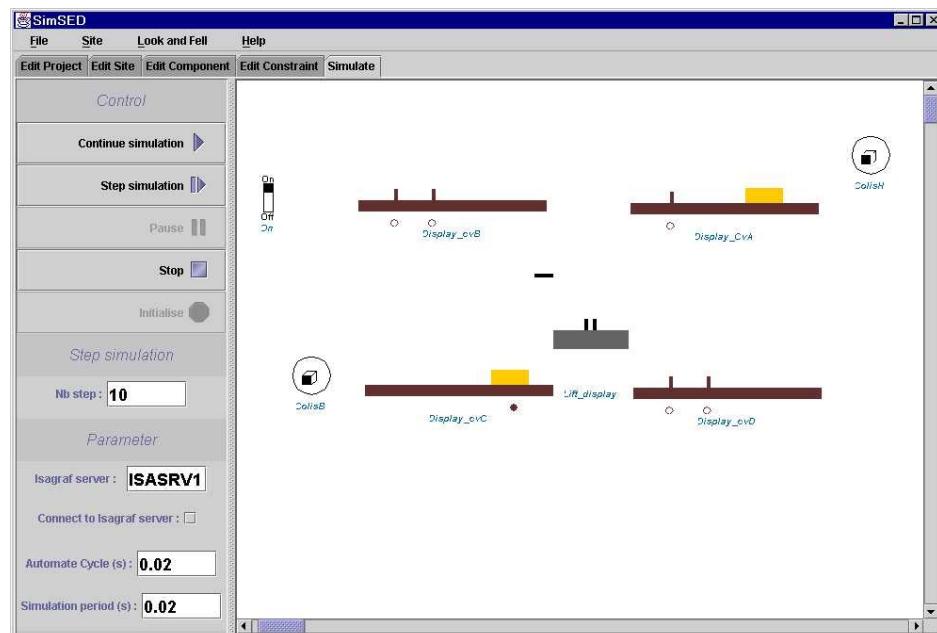
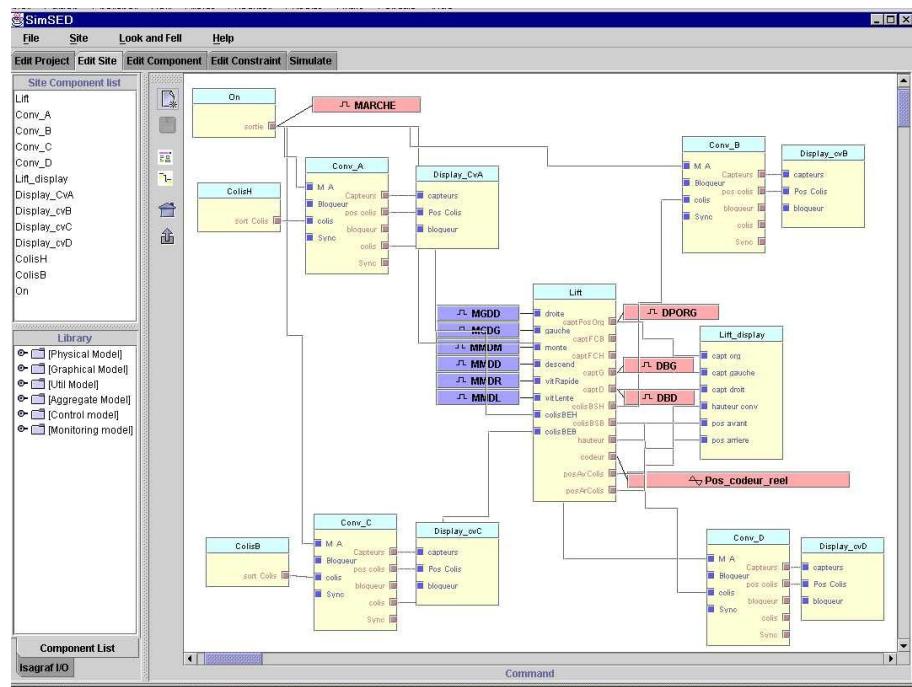
- **Simulation model generated from components**
- **Operational part simulation**
- **Virtual reality**
- **Physical engine (ODE)**
- **Multi-PLC**
- **Respects PLC cycles**



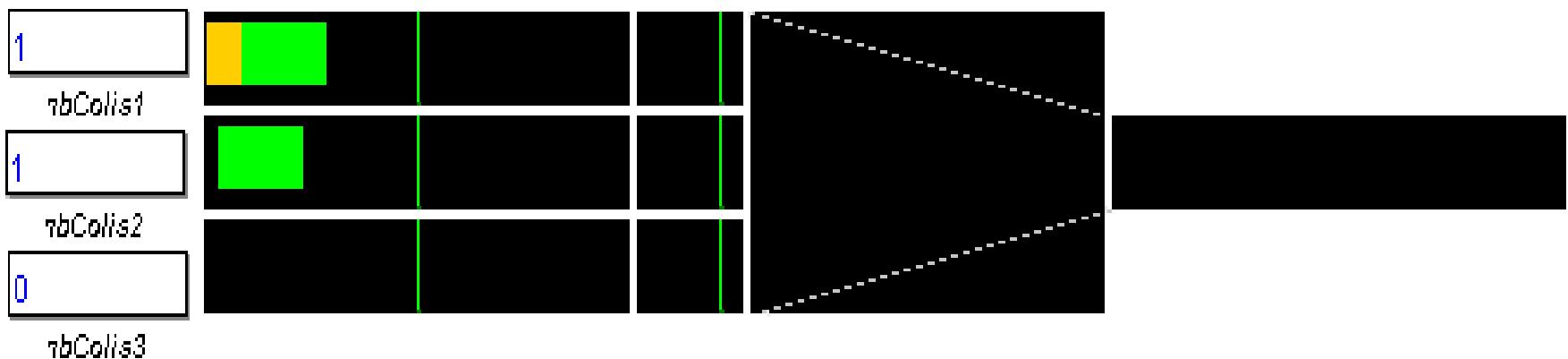
# Development of SimSED



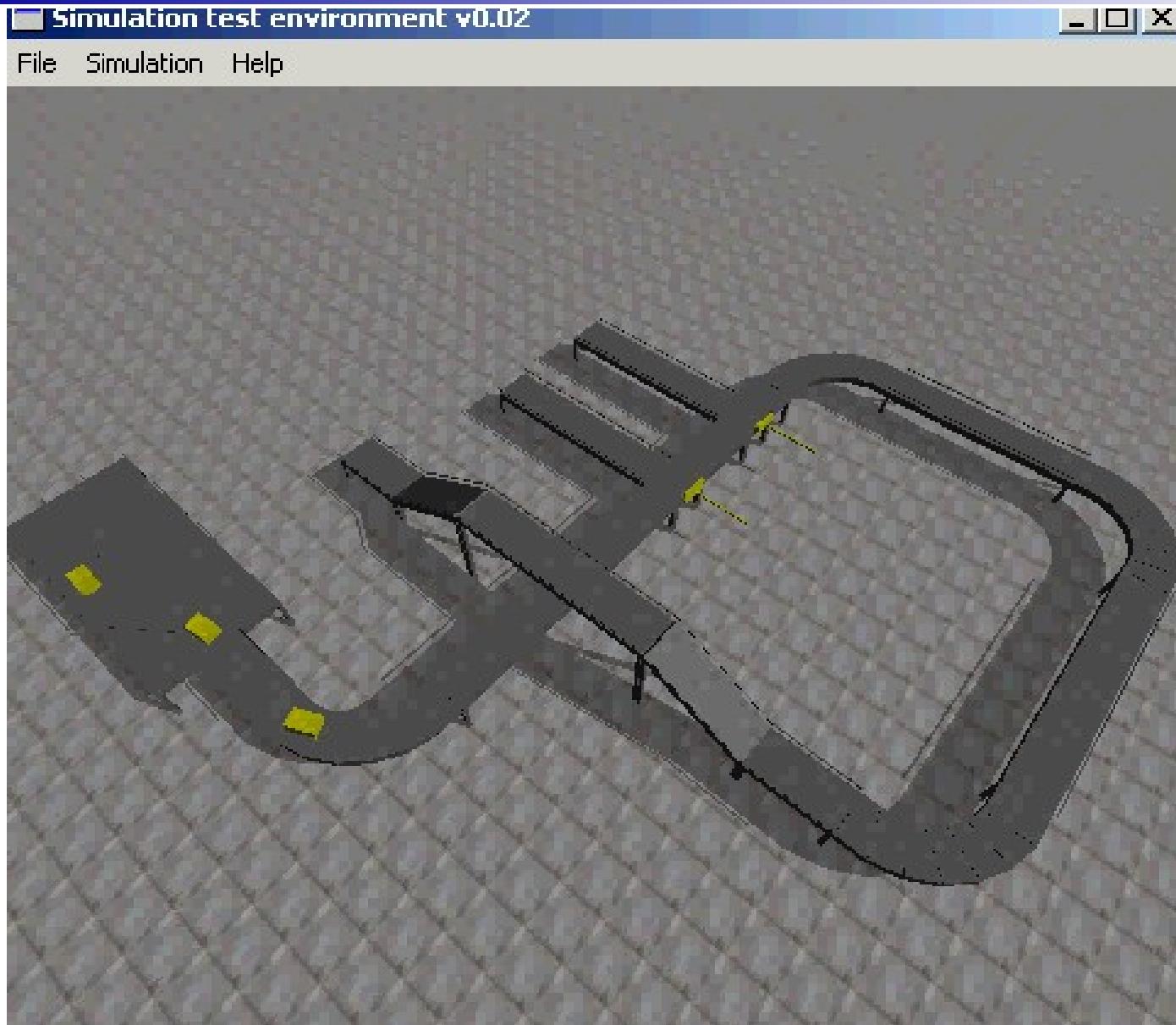
- Object of the first project ACCSYR
  - One contribution of first PhD
  - Lots of job placements !!! (supervised by PhDs in Syleps)



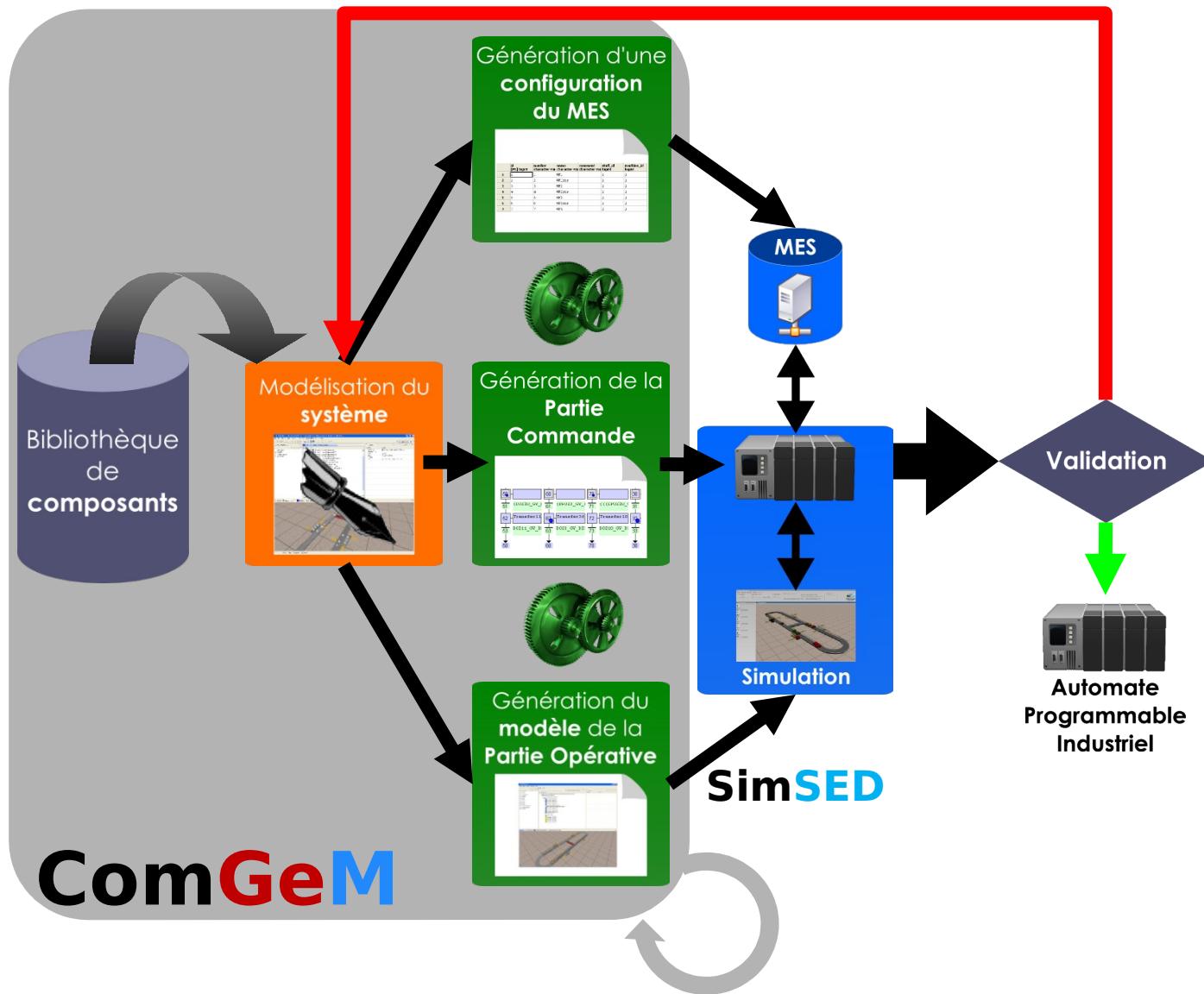
# Old video (~2002)



# Not so recent video (~2007)

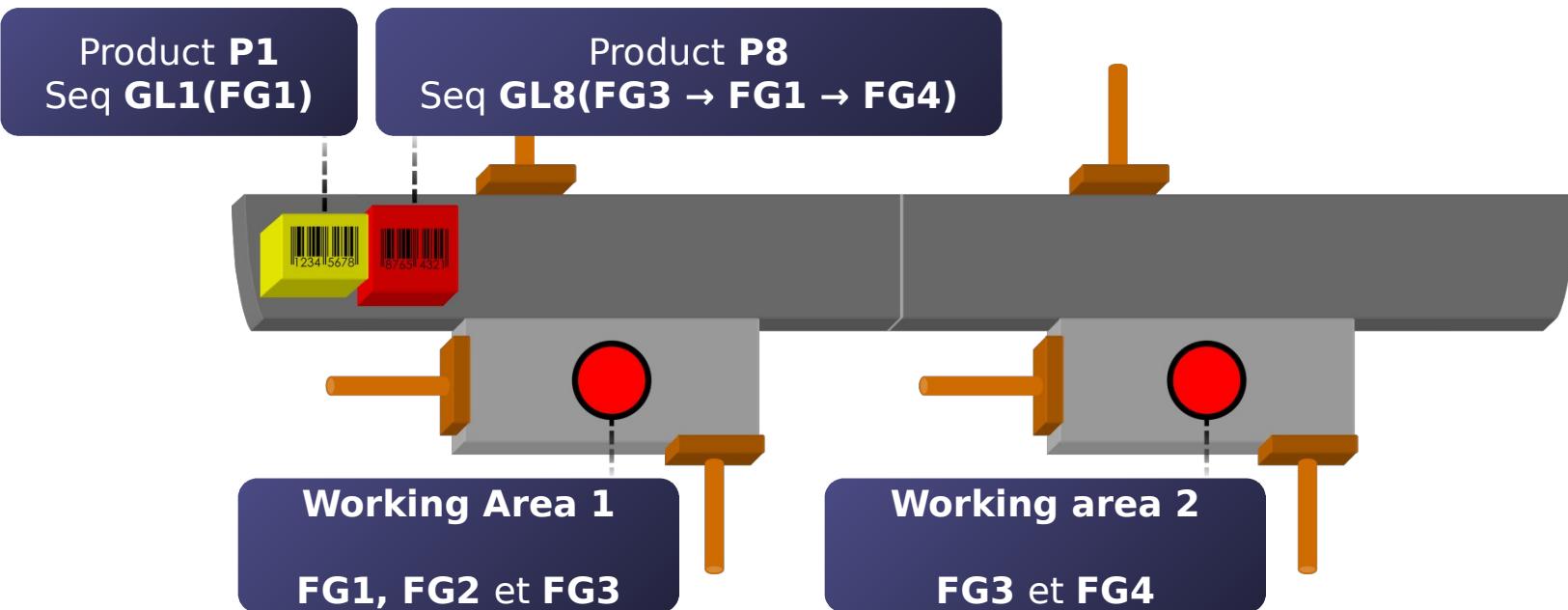


# High level control generation and reconfiguration



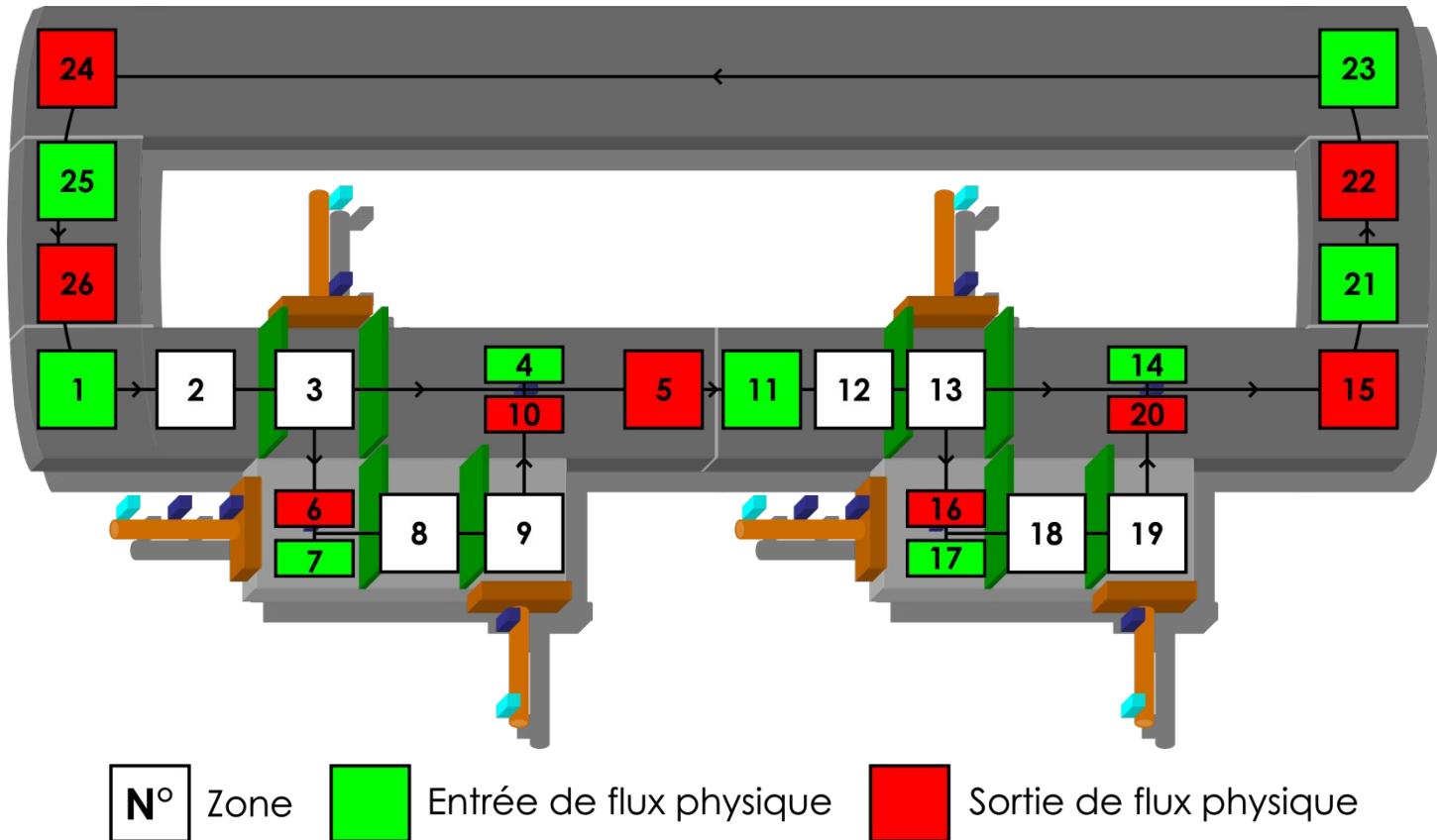
# Product description

- Stored in MES

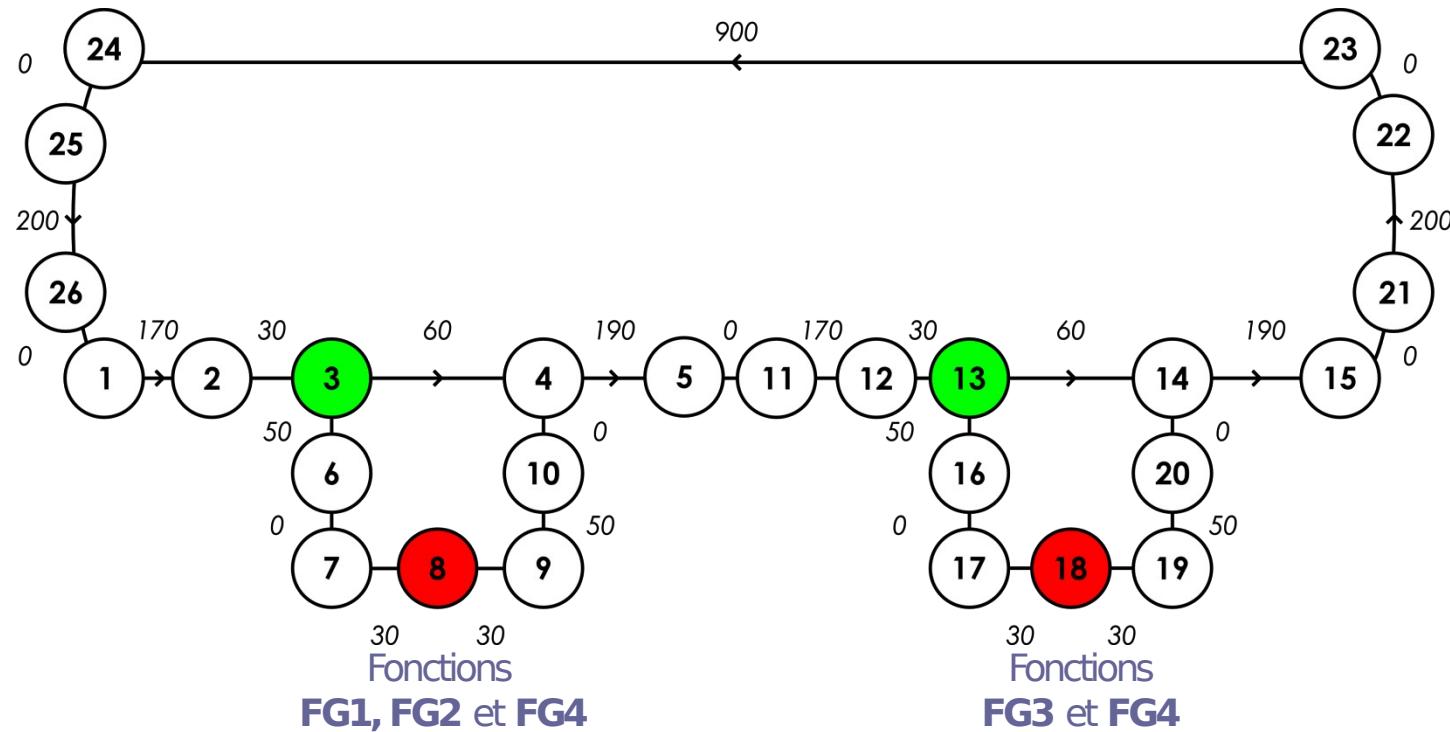


# Topological view of the system

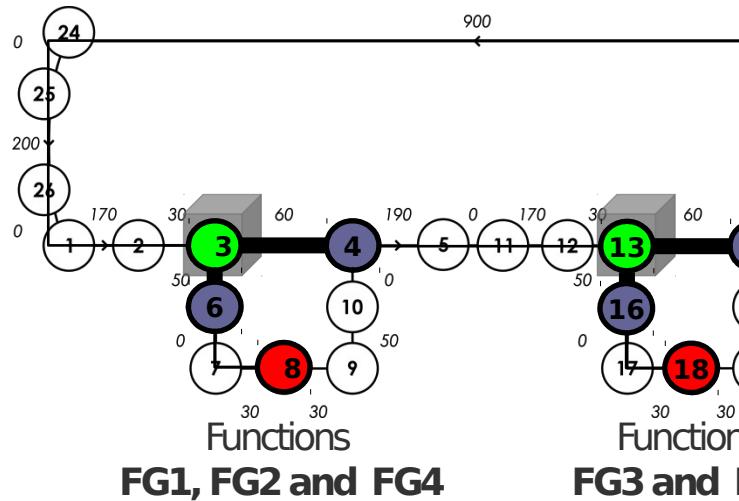
From components aggregation



# Obtention of an oriented graph



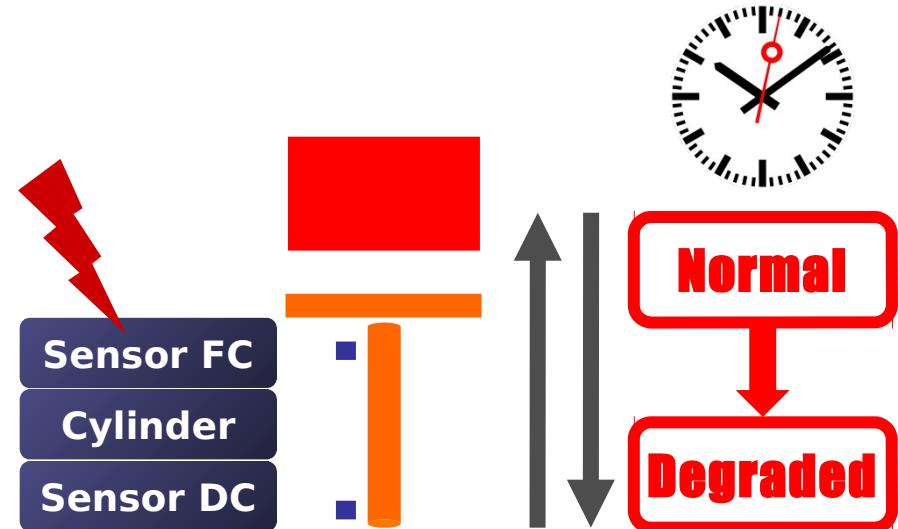
# Obtention of routing tables



Source routing zone	Functions	Dest routing zone
Zone 3	FG1	Zone 6
Zone 3	FG2	Zone 6
Zone 3	FG3	Zone 4
Zone 3	FG4	Zone 6
Zone 3	FG4	Zone 4
Zone 3		Zone 14
Zone 13	FG1	Zone 14
Zone 13	FG2	Zone 14
Zone 13	FG3	Zone 16
Zone 13	FG4	Zone 16
Zone 13	FG4	Zone 14

# Reconfiguration PLC Level

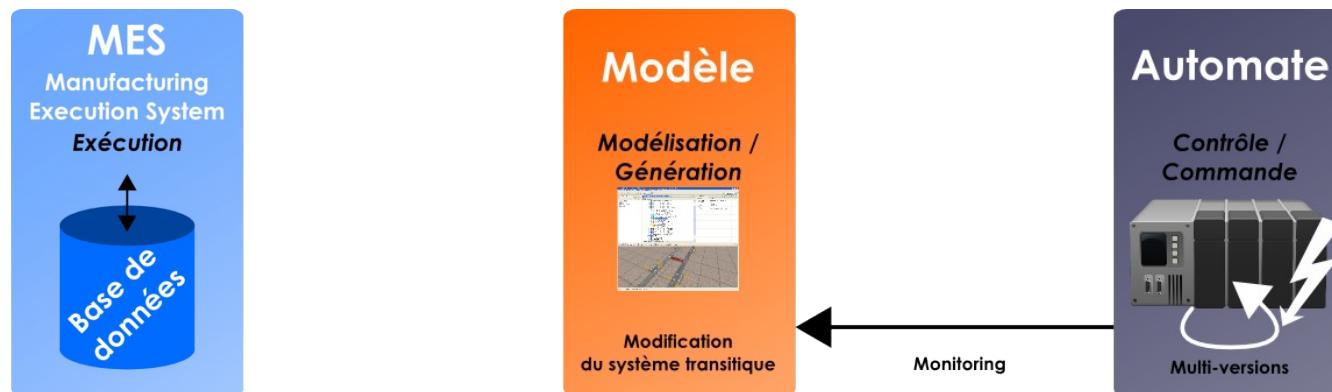
## » Failure of a component



## » Multi-versions control

- » nominal
- » degraded

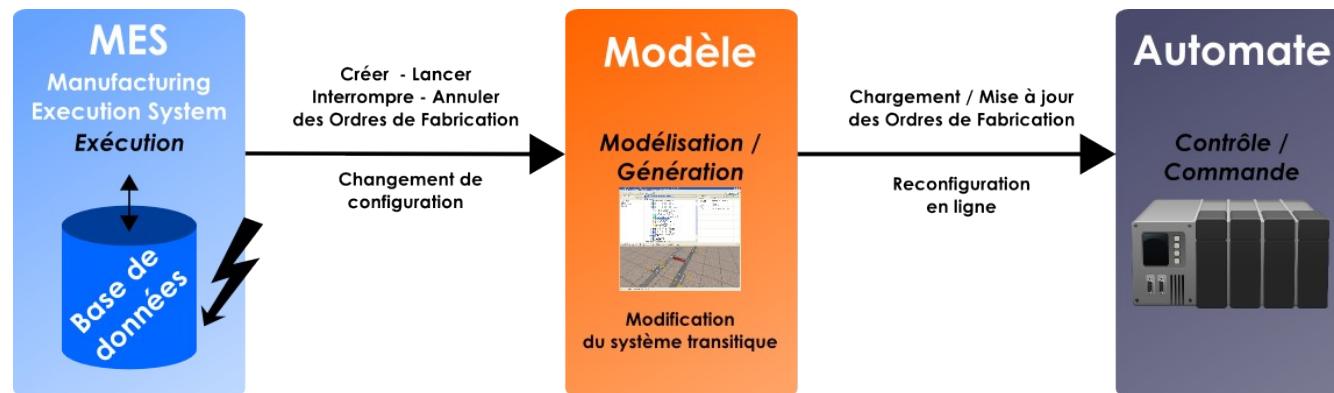
## » On line



# Reconfiguration

## « MES » Level

- » Rapid changes in demand
- » Management of products, fabrication orders
- » On line



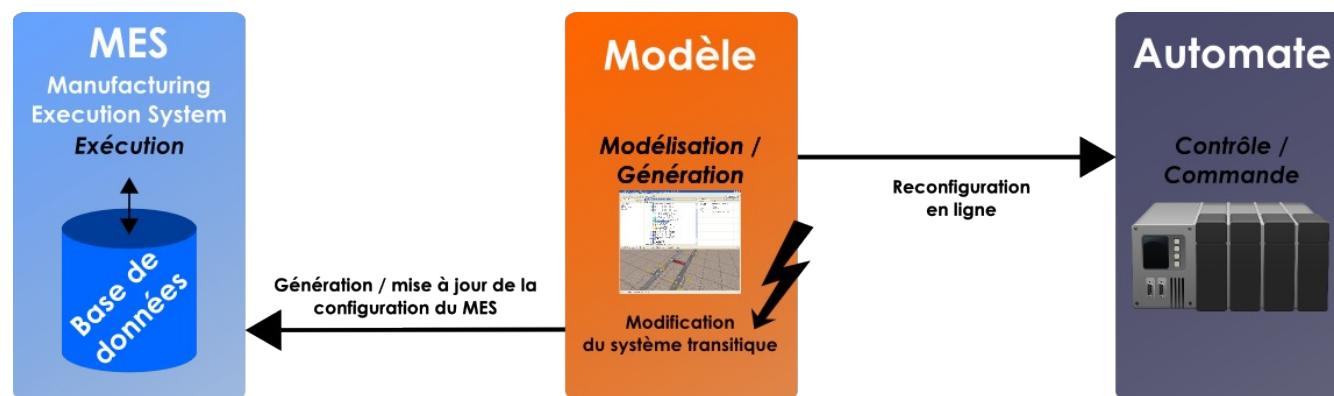
# Reconfiguration Generator level

## » Changes at the model level

- » Function modifications
- » Working areas modification
- » Removing of a routing zone

## » Dynamic update of routing

## » On line



# Summary

Soutenance de thèse

9 décembre 2013



**Approche composant pour la commande multi-  
versions des systèmes transitiques  
reconfigurables**

Romain BÉVAN  
[romain.bevan@univ-ubs.fr](mailto:romain.bevan@univ-ubs.fr)



Université  
de Bretagne Sud



# Benefits for Syleps

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- **They use SimSED internally for the simulation part**
  - Some cases around 2004-2006 (after more than 5 years)
  - More cases after 2007
    - *Cyclic use because of the need of modelling*
    - *They've recruited some PhD's*
- **SimSED helped to tackle control code bugs**
  - Before implementing the plant (speeds set-up time)
  - Remote debug
    - *Bug reproduction and correction*

# Future Collaborations

- Heterogenous palletizing
- Securing field network and ITS

