# Part 4: Industrial Applications and Cyber-physical Systems

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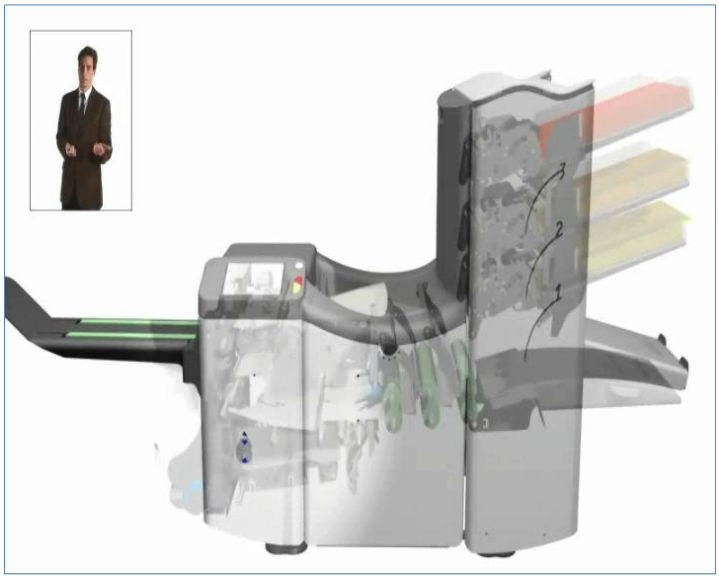
## Industrial Case Studies

- Three substantial case studies, done by the companies

| Application | Document Handling | Dredging Excavator | Self-balancing Scooter |
|---|---|---|---|
| Company | Neopost | Verhaert | Chess WISE & Chess iX |
| Challenge | Concurrent design | Product robustness | Manage complexity |
| Fault Source | Error handling | Operator error | Design faults |
| Improvement | Model-in-loop sim | Design exploration | Reliability analysis |
| Approach | DE-first | CT-first | DE-first, CT-first & contract-first |
| Prior | 20-sim | - | VDM & 20-sim |

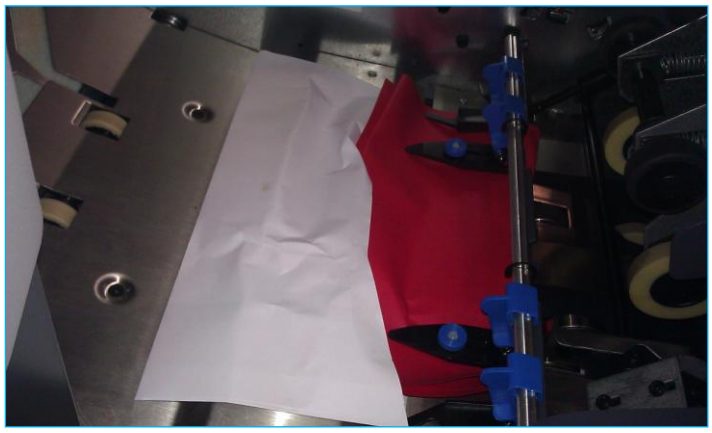
- Smaller challenges, mainly done by the project team
  - Flare Dispensing System (Terma)
  - Tilt Tray Conveyor System (Crisplant)
  - Planetary Rover (ESA ESTEC)

# Document Handling: context

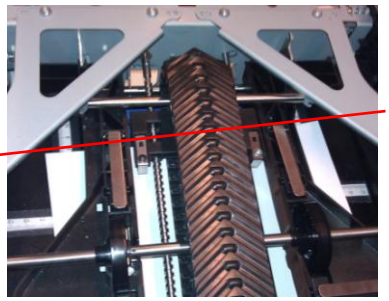


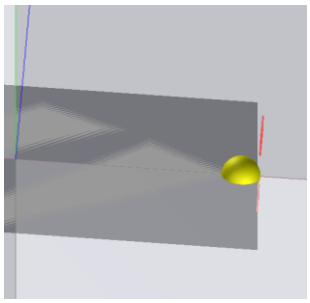


# Document Handling: failure



# Document handling: error discovery

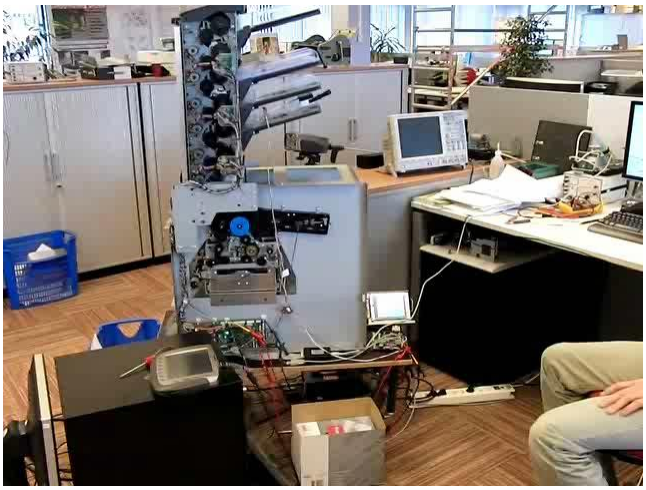




- Mechanical design error was spotted before first prototype
- A competent sheet alignment co-model was developed
- Simulation model was (re)used to validate control software



# Document Handling: it works!



# Dredging Excavator



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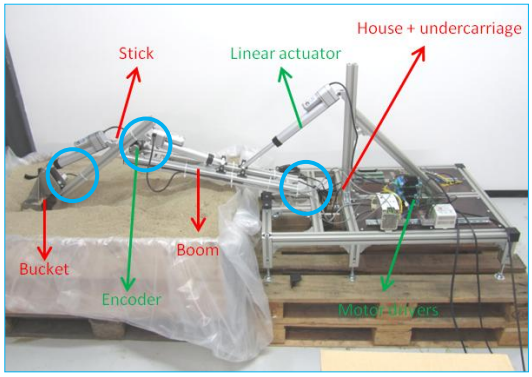
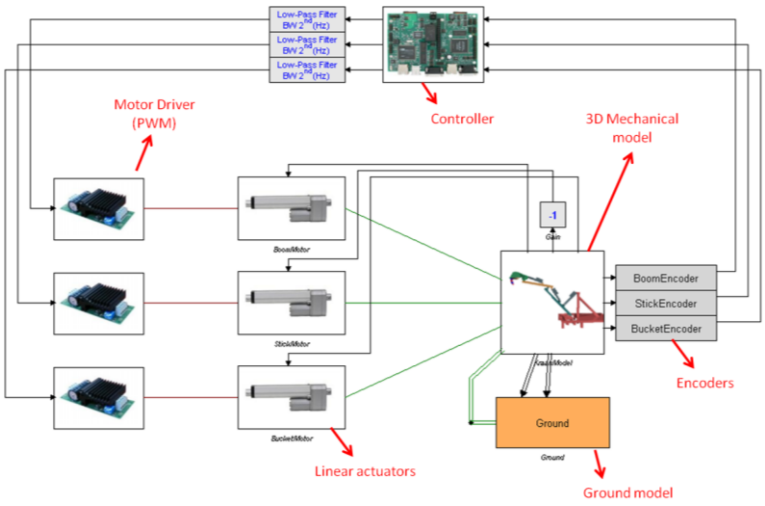
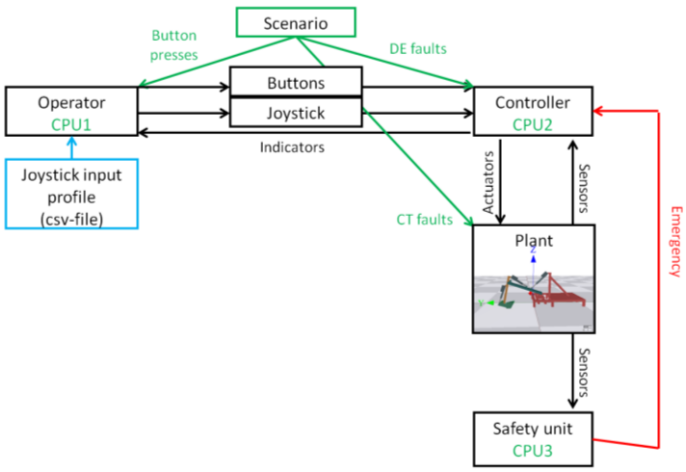



# Dredging Excavator (CT model)






# Dredging Excavator (DE model)

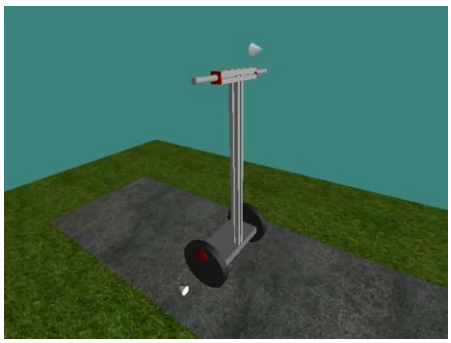


# Dredging Excavator (Assisted Mode)

- DSE to optimise end-stop protection parameters
- Emergency Switch controller behaviour validated
- Assisted Mode-specification validated on scale model

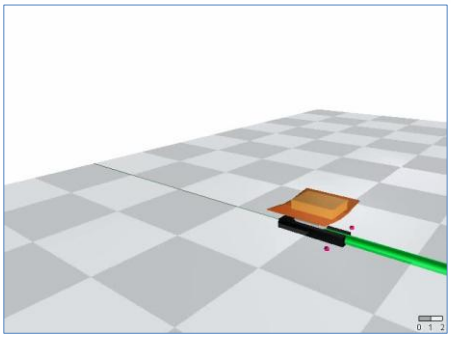


# Self-balancing Scooter



- Several design conflicts discovered and resolved
- Behaviour with integrated fault handling validated
- Test and integration phase was very short
  - almost “first time right”

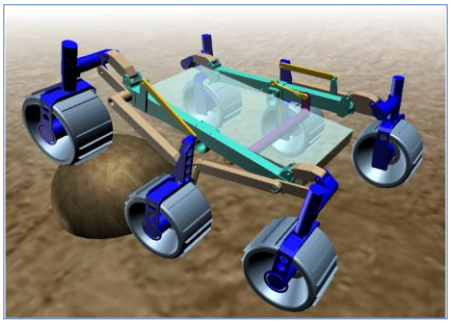
# Tilt Tray Conveyor System

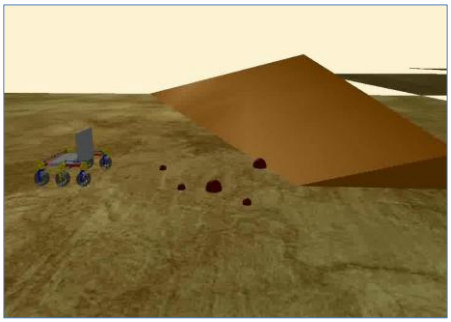


- Co-simulation model of the banking function
- Described behaviour of parcels on a moving 3-D banking device
- A good contact model between parcel / tray is essential



# Planetary Rover





- Existing CT model extended with DE model of locomotion
- Contact models helped investigate behaviour on obstacles
- Simple safety controller added

# Deployment Experience

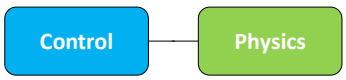
*"Simulation will become increasingly important for Neopost. Test setups and physical prototypes will become more costly and have less availability. … The most critical current drawback of the Crescendo technology is the incompatibility with the tools we use for generating the code for the embedded platform."*

*"We see great potential in the Crescendo technology during the development of complex systems …that are difficult to test due to high risk, cost, timing constraints. … Adding a GUI could broaden the use of the tool to non-software engineers. Graphical tools for visual validation of discrete behaviour … would be beneficial as well... Finally, an increase in simulation speed would of course be a welcome improvement."*

*"The complexity of embedded systems is ever increasing with the focus on: error handling, safety, and added functionality. This cannot be overseen by a single lead engineer or engineering team. To avoid making expensive mistakes, modern systems cannot be developed anymore without utilising modelling ... When following this sort of concurrent and holistic model-based development principles, a technology like Crescendo is a critical enabler."*

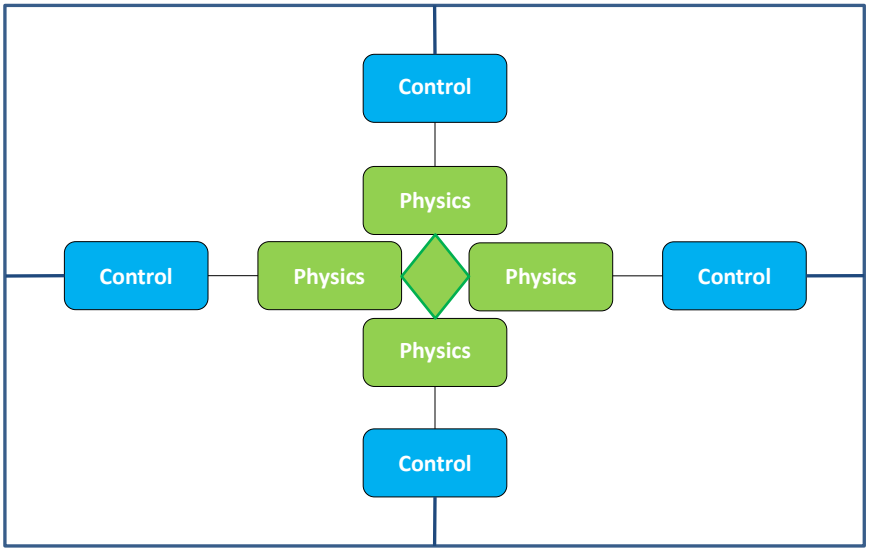


# Towards Cyber-Physical Systems




- We have looked at individual embedded systems
- CPSs are networked groupings of digital devices
- … which may require more elaborate co-models!

# Towards Cyber-Physical Systems






# CPS Examples

**Agricultural Logistics**

- Smart devices (harvesters, trucks, storage systems)
- Data to planning subsystems
- Integrating dynamic data (weather, soil condition, moisture, storage capacity, prices, … )
- Dynamic re-planning to harvesting logistics

# CPS Examples

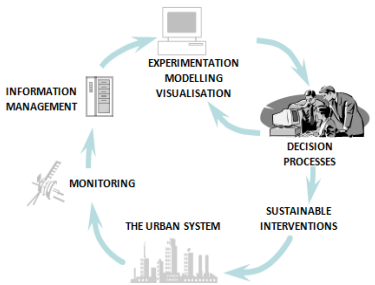
1970s


2010




Newcastle 'greenest' British city

2050?

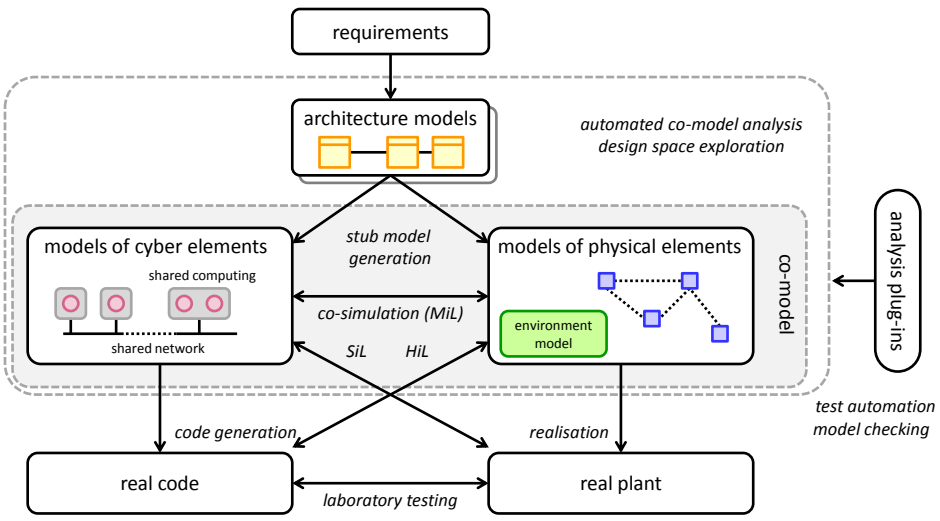



reactive

intelligence



# CPS co-modelling



# The Challenges

- Foundations, methodology, practice and experience
  - Deployment to date has been encouraging
  - Semantic basis is still restricted to specific formalisms
  - Model interchange will encourage methodologies to develop
  - Pragmatics, including performance!
- Encouraging "Cyber-Physical Thinking"
  - Moving easily across engineering domains, trading off between them



# Your Thoughts, Please!

- Thanks for your time today.
- Have we met your expectations?
- Do you think this work addresses real challenges?
- What do you see as the barriers to deploying more collaborative modelling and design techniques?

# Collaborative Modelling and Co-simulation

Tools and Techniques for Designing Embedded Systems

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