

***4th OpenModelica Workshop,
February 6, 2012
Linköping***

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Virtual Commissioning in DCE A Roadmap

Bosch Rexroth. The Drive & Control Company

Bosch – Three Business Sectors

Bosch Group overall



- €47.3B in sales
- 283,500 associates
34,500 of those associates in research and development

Automotive Technology



- 59% share of sales
- World and technological leader as an automotive technology supplier

Industrial Technology



- 14% share of sales ¹ Bosch Rexroth AG (100 % Bosch)
- Drive & Control Technology ¹, Packaging Technology, Solar Energy

Consumer Goods and Building Technology



- 27% share of sales² ² including other segments
- World's largest power tool manufacturer, leading in household appliances, thermotechnology, and safety engineering

2010 - Figures



Bosch Rexroth. The Drive & Control Company

Drive and Control Company



Complete: Technologies and Services



Linear Motion Technology Industrial Hydraulic Controls Assembly Technology
Electric Drives and Controls Industrial Hydraulic Cylinders

Product Groups

Transmission Units Power Units, Manifolds, and Hydraulic Accessories
Pneumatics

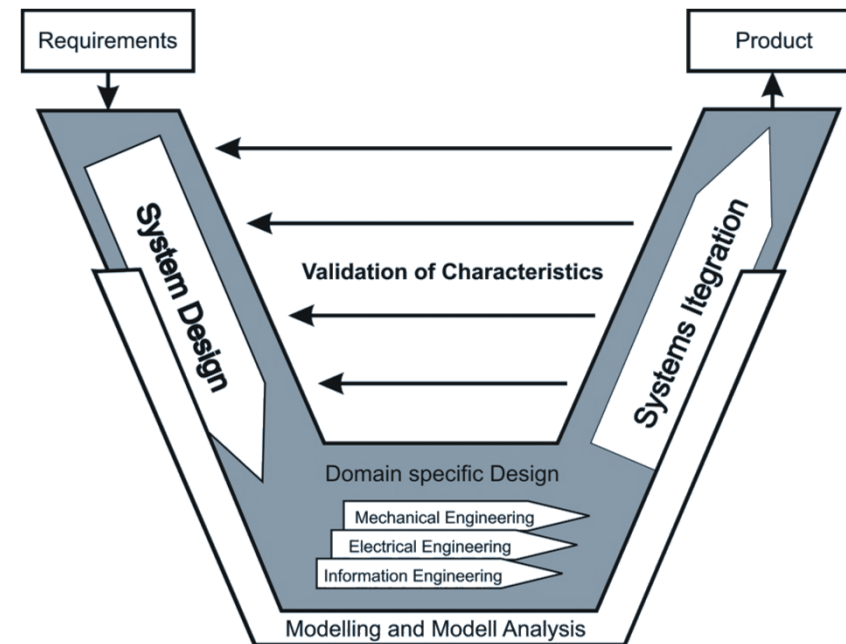
Mobile Controls Compact Hydraulics
Mobile Electronics Pumps and Motors

Large Hydraulic Drives Wind Turbine Gearboxes

Motivation

Simulation as a Development-Tool

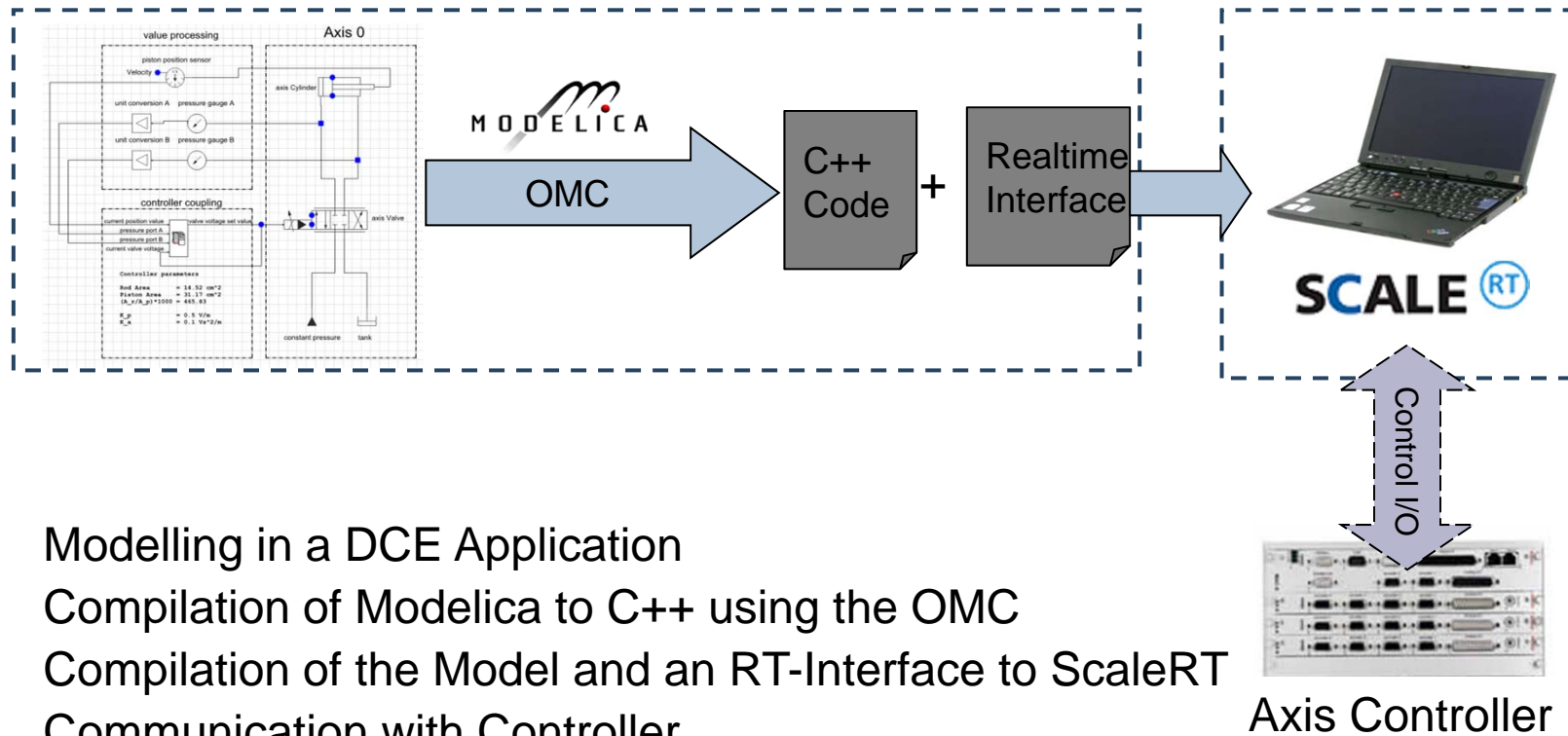
- Verification
- Optimization
- Commissioning



Outline

- Motivation
- **Vision**
- Starting Point
- Future Work

Automated Toolchain for Virtual Commissioning



- Modelling in a DCE Application
- Compilation of Modelica to C++ using the OMC
- Compilation of the Model and an RT-Interface to ScaleRT
- Communication with Controller

Application Example

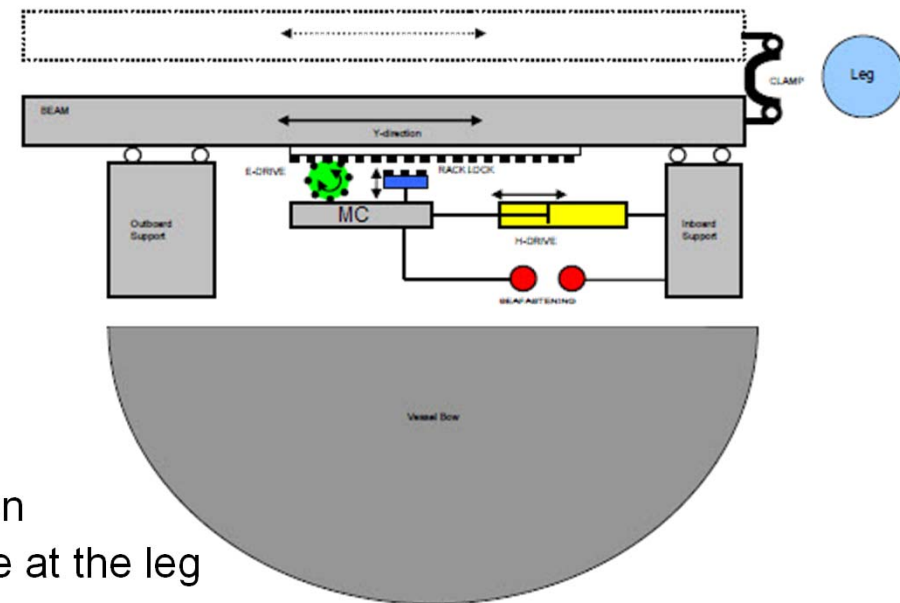
- Pieter Schelte
 - Installation and removal oil platforms
 - 382 m length, 117 m width
 - Installation power 95 MW
 - Topside: weight >10.000 t
 - Ready for operation end 2014

- Topside Lifting System (TLS)
 - TLS divides into:
 - Y-Drive
 - Z-Drive
 - Simulation phases:
 - Active Motion Compensation (AMC)
 - Constant Pushing (CP)



Topside Lifting System

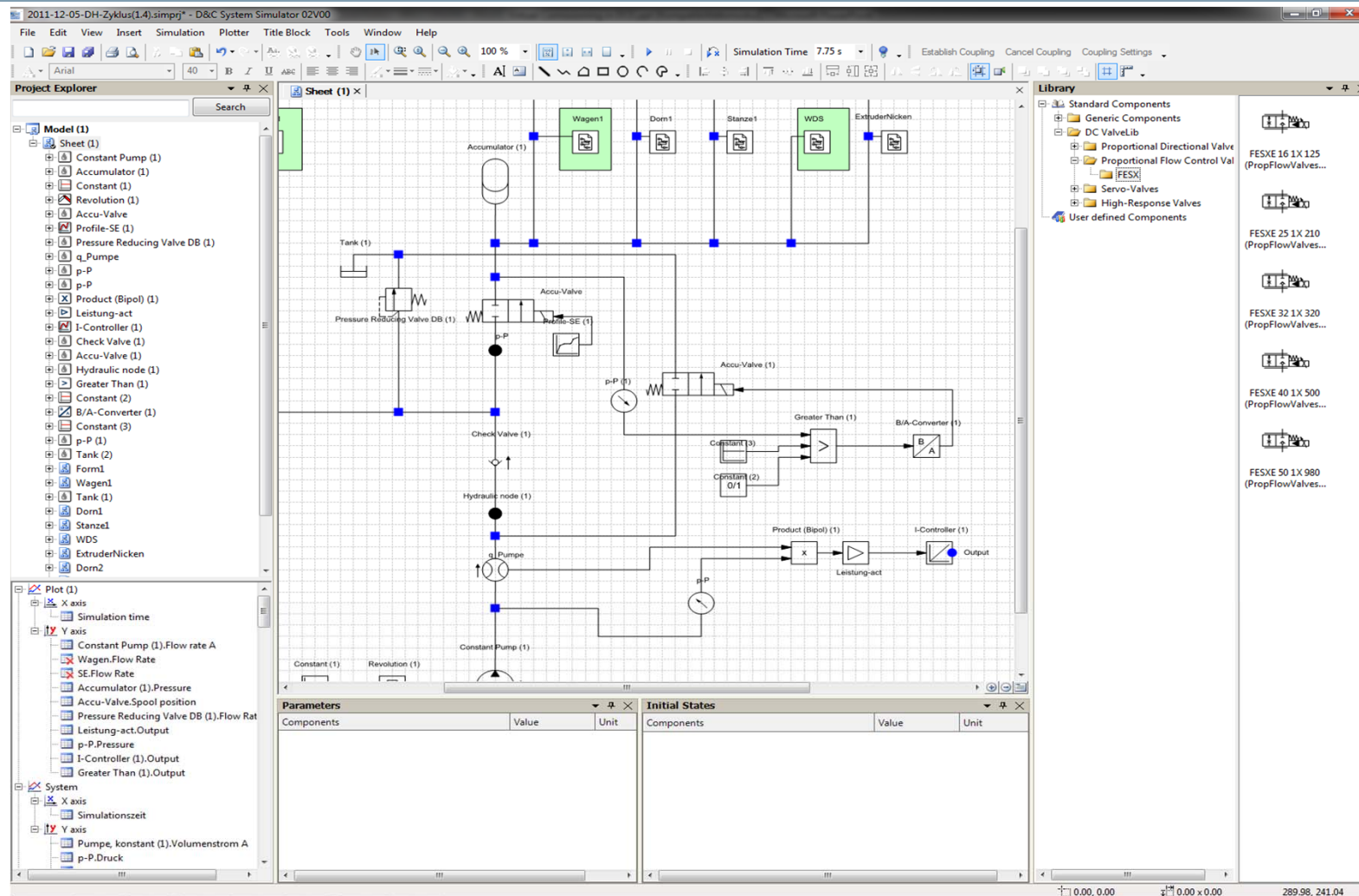
- Components
 - Hydraulic unit
 - 3-Chamber active heave compensation cylinder
 - 3-Way valve
 - Tank and pressure source
 - Accumulator
 - Electrical drive
 - Rack-pinion and ideal gears
 - Beam and motor carriage mass
 - Force controller
- Functions
 - AMC for sea and parasitic motion
 - Applying a constant pushing force at the leg



Outline

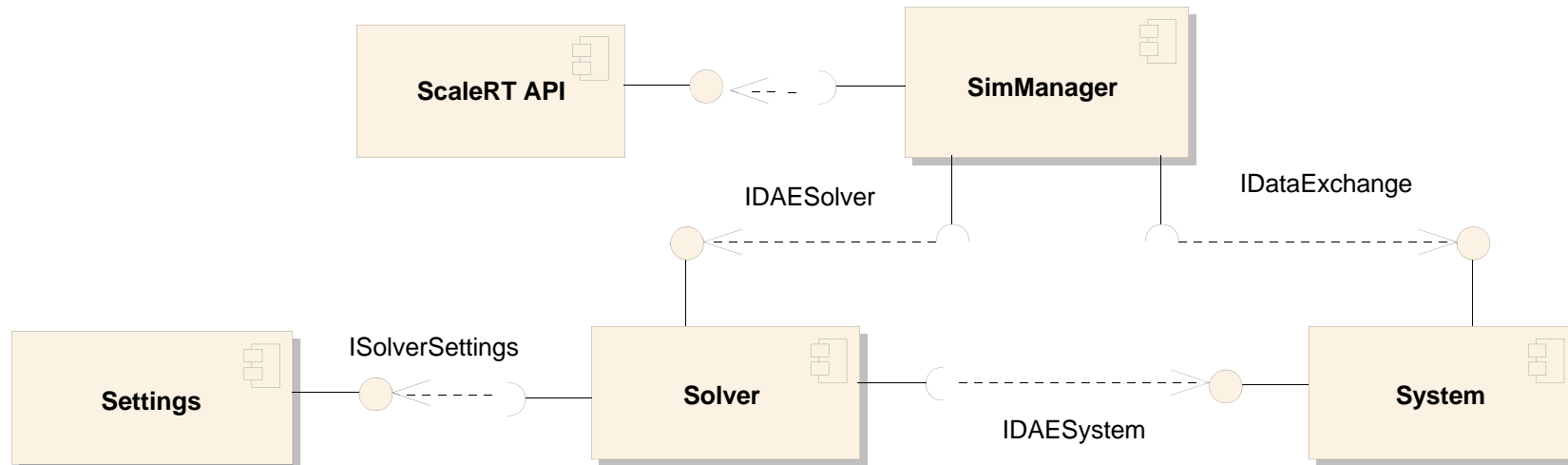
- Motivation
- Vision
- **Starting Point**
- Future Work

Modelica-Based Modelling Application



Running a Modelica-Model on ScaleRT

C++ Runtime



SimManager

- Controls the simulation (Main Loop)

System

- Holds the DAE equations

Solver

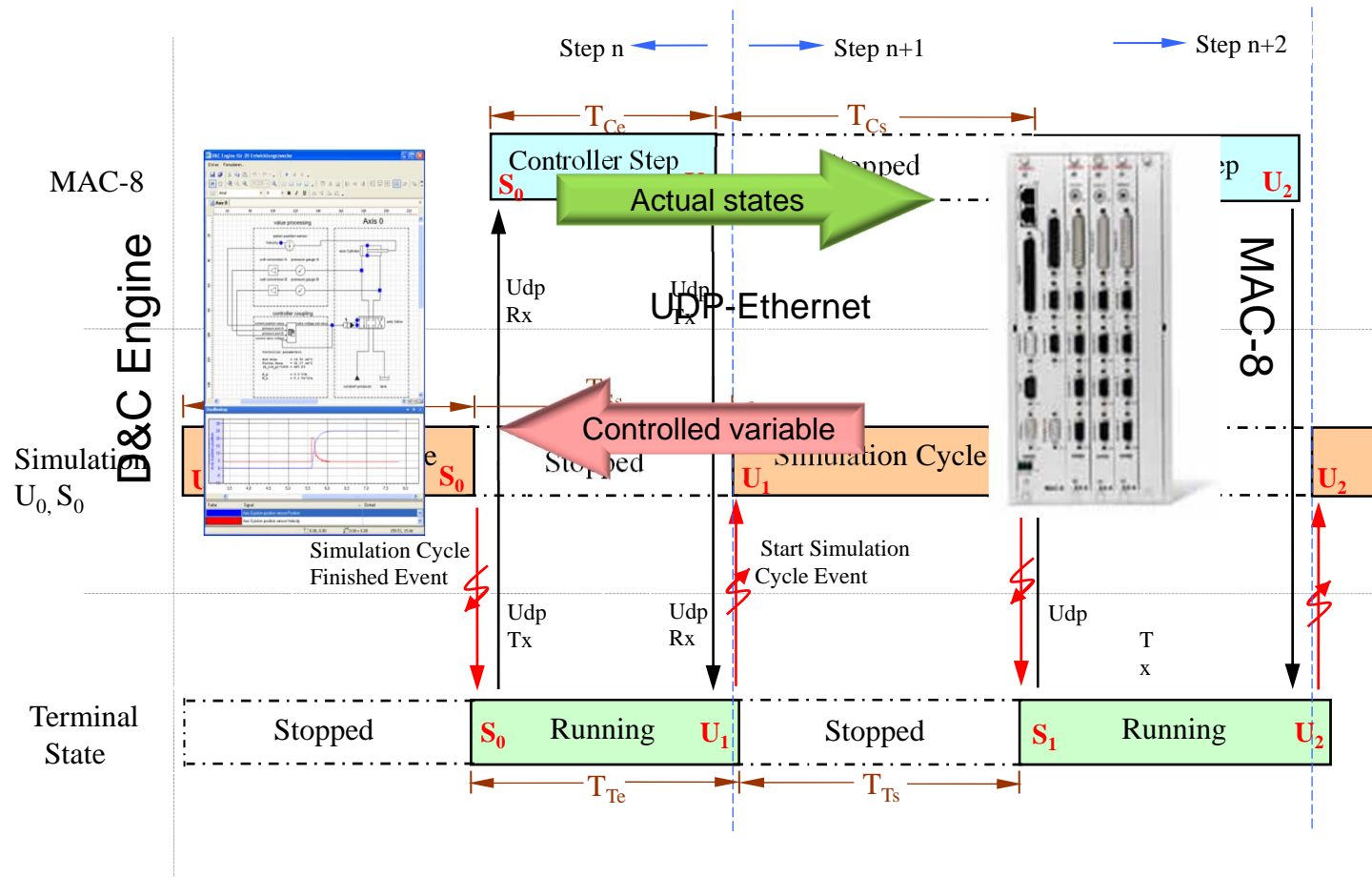
- Encapsulates the numerical time integration method

Settings

- Configuration of the solver

Communication with a PLC

Communication via Handshake



Outline

- Motivation
- Vision
- Starting Point
- **Future Work**

Modelica-Based Modelling Application

The screenshot displays the Modelica-based modelling application interface. The main window shows a hydraulic system diagram with components like Tank (1), Accumulator (1), Wagen1, Dorn1, Stanzel1, WDS, ExtruderNicken, and a pump system. The diagram includes various valves, pumps, and control elements connected in a network.

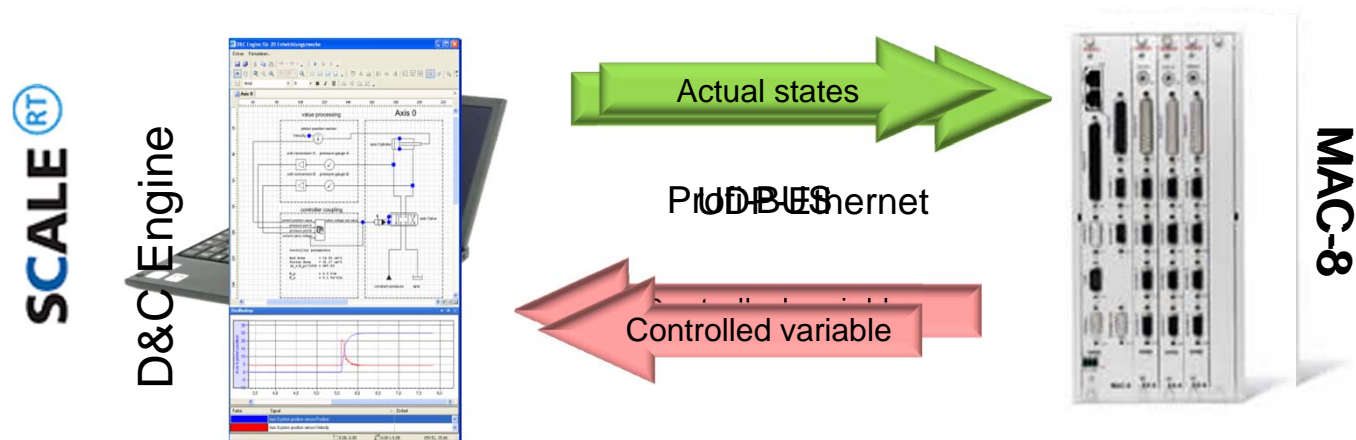
Project Explorer:

- Model (1)
 - Sheet (1)
 - Constant Pump (1)
 - Accumulator (1)
 - Constant (1)
 - Revolution (1)
 - Accu-Valve
 - Profile-SE (1)
 - Pressure Reducing Valve DB (1)
 - q_Pumpe
 - p-P
 - p-P
 - Product (Bipol) (1)
 - Leistung-act
 - I-Controller (1)
 - Check Valve (1)
 - Accu-Valve (1)
 - Hydraulic node (1)
 - Greater Than (1)
 - Constant (2)
 - B/A-Converter (1)
 - Constant (3)
 - p-P (1)
 - Tank (2)
 - Form1
 - Wagen1
 - Tank (1)
 - Dorn1
 - Stanzel
 - WDS
 - ExtruderNicken
 - Dorn2

- Plot (1)
- X axis
 - Simulation time
- Y axis
 - Constant Pump (1).Flow rate A
 - Wagen.Flow Rate
 - SE.Flow Rate
 - Accumulator (1).Pressure
 - Accu-Valve.Spool position
 - Pressure Reducing Valve DB (1).Flow Rate
 - Leistung-act.Output
 - p-P.Pressure
 - I-Controller (1).Output
 - Greater Than (1).Output
- System
- X axis
 - Simulationszeit
- Y axis
 - Pumpe, konstant (1).Volumenstrom A
 - p-P.Druck

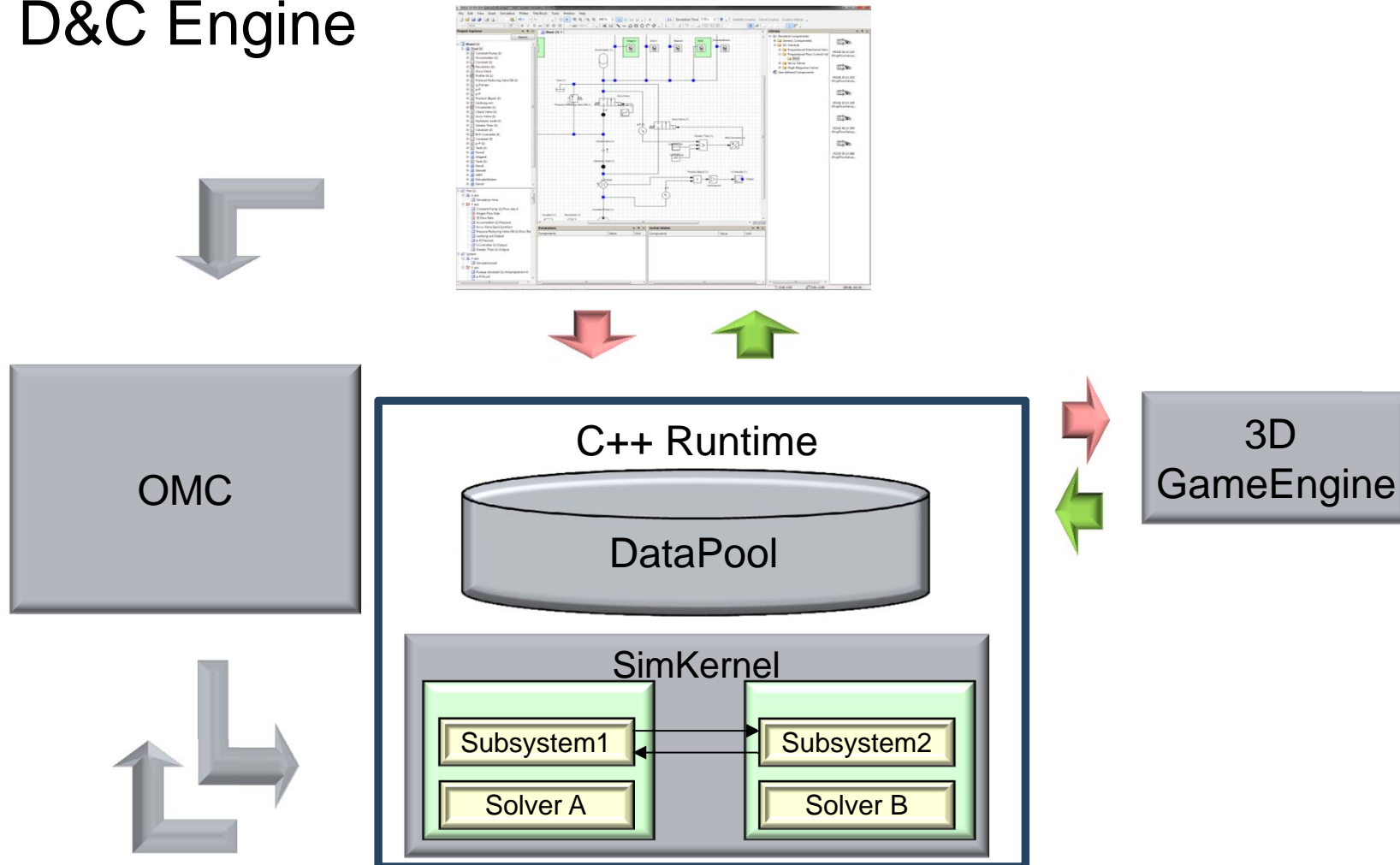
Communication with a PLC

Communication in Real-Time



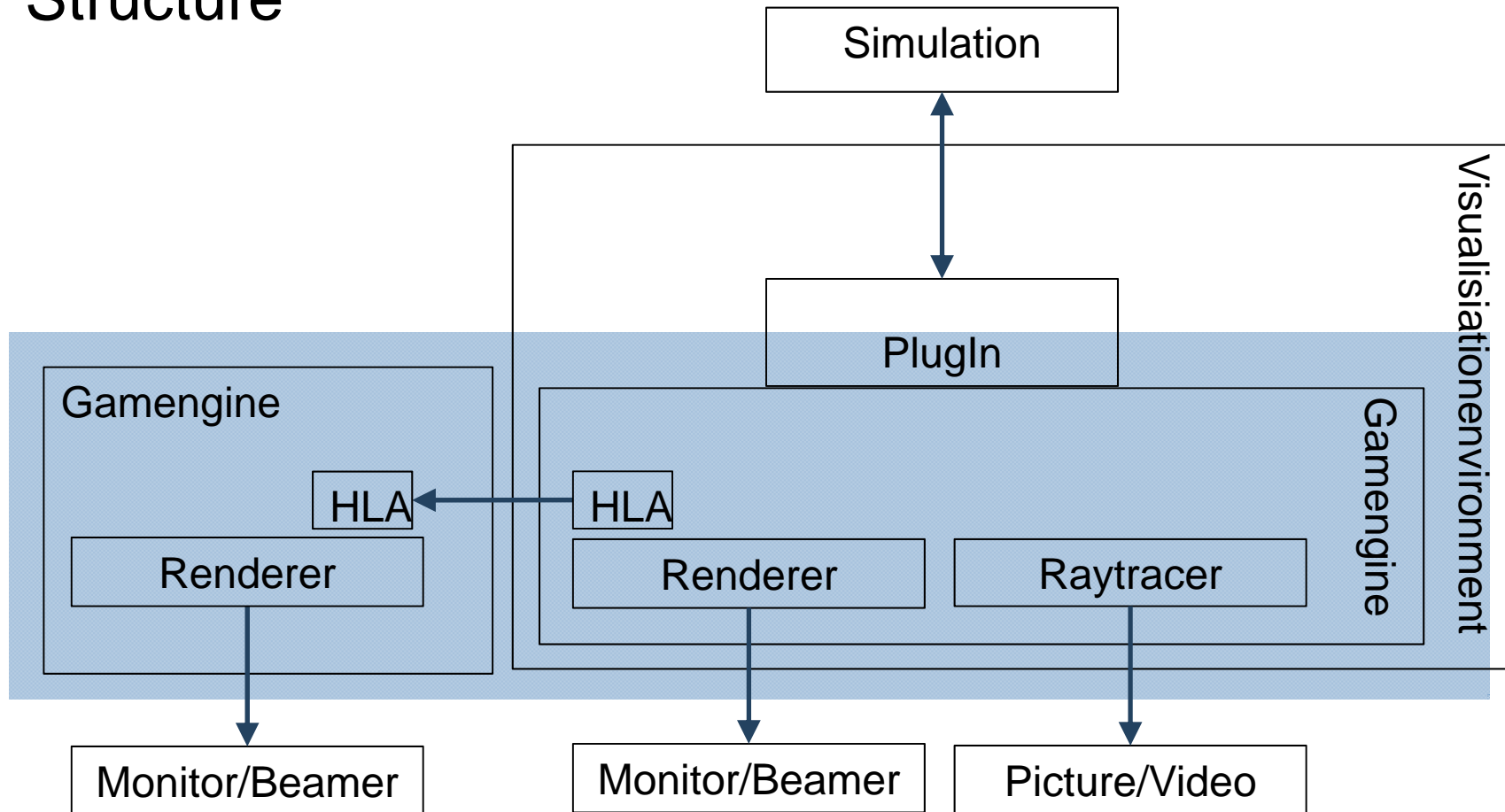
Visualization

D&C Engine



Visualization

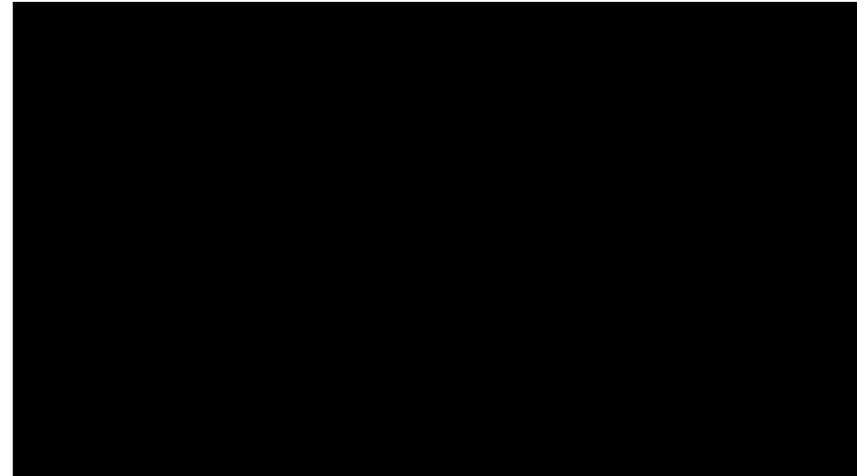
Structure



Visualization

Torque3D

- Commercial Game-Engine
- DirectX 10
- WYSIWYP Editor

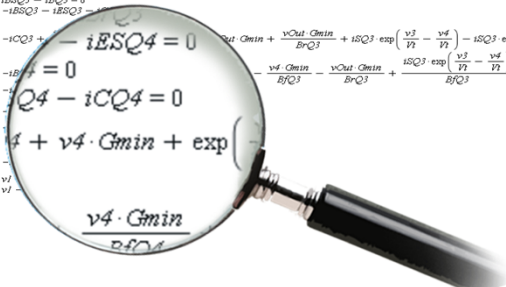


Application Example

Race against Time

- Model Reduction
 - Equation-Based Reduction Techniques
 - Manual simplification

- Choice of appropriate solution method
 - Real-Time Cycle
 - Multi-rate integration

$$\begin{aligned}
 & iCSQ2 + iVCC + iVLoad, iB = 0 \\
 & iBSQ2 + iBSQ3 + iCSQ1 - iB = 0 \\
 & iBSQ4 + iCSQ4 + iBSQ3 = 0 \\
 & iBSQ1 + iBSQ2 + iB = 0 \\
 & iCSQ1 - iVLoad = 0 \\
 & -iBSQ1 - iCSQ1 - iBSQ1 = 0 \\
 & iBSQ1 - iBQ1 = 0 \\
 & -iBSQ1 - iBSQ1 - iCQ1 = 0 \\
 & -iCQ1 + \frac{iSQ1}{BrQ1} + v3 \cdot Cmin + v3 \cdot \frac{Cmin}{BrQ1} - v3 \cdot \frac{Cmin}{BrQ1} + iSQ1 \exp(v3/V1) - iSQ1 \exp\left(-\frac{v3}{V1} + \frac{v5}{V1}\right) - \frac{iSQ1 \exp\left(-\frac{v3}{V1} + \frac{v5}{V1}\right)}{BrQ1} = 0 \\
 & -iBQ1 - \frac{iSQ1}{BrQ1} - \frac{iSQ1}{BrQ1} - v3 \cdot Cmin + v5 \cdot Cmin + \frac{iSQ1 \exp\left(\frac{v5}{V1}\right)}{BrQ1} + \frac{iSQ1 \exp\left(-\frac{v3}{V1} + \frac{v5}{V1}\right)}{BrQ1} = 0 \\
 & -iBSQ2 - iCSQ2 - iBSQ2 = 0 \\
 & iBSQ2 - iBQ2 = 0 \\
 & -iBSQ2 - iBSQ2 - iCQ2 = 0 \\
 & -iCQ2 + \frac{iSQ2}{BrQ2} + v1 \cdot Cmin + \frac{v1 \cdot Cmin}{BrQ2} - \frac{v3 \cdot Cmin}{BrQ2} - v5 \cdot Cmin - iSQ2 \exp\left(-\frac{v1}{V1} + \frac{v3}{V1}\right) + iSQ2 \exp\left(\frac{v3}{V1} - \frac{v5}{V1}\right) - \frac{iSQ2 \exp\left(-\frac{v1}{V1} + \frac{v3}{V1}\right)}{BrQ2} = 0 \\
 & -iBQ2 - \frac{iSQ2}{BrQ2} - \frac{iSQ2}{BrQ2} - \frac{v1 \cdot Cmin}{BrQ2} + \frac{v3 \cdot Cmin}{BrQ2} + \frac{v3 \cdot Cmin}{BrQ2} - v5 \cdot Cmin + \frac{iSQ2 \exp\left(-\frac{v1}{V1} + \frac{v3}{V1}\right)}{BrQ2} + \frac{iSQ2 \exp\left(\frac{v3}{V1} - \frac{v5}{V1}\right)}{BrQ2} = 0 \\
 & -iBSQ3 - iCSQ3 - iBSQ3 = 0 \\
 & iBSQ3 - iBQ3 = 0 \\
 & -iBSQ3 - iBSQ3 \\
 & -iCQ3 + \frac{iSQ3}{BrQ3} + vOut \cdot Cmin + \frac{vOut \cdot Cmin}{BrQ3} + iSQ3 \exp\left(\frac{v1}{V1} - \frac{v4}{V1}\right) - iSQ3 \exp\left(\frac{v3}{V1} - \frac{vOut}{V1}\right) - \frac{iSQ3 \exp\left(\frac{v3}{V1} - \frac{vOut}{V1}\right)}{BrQ3} = 0 \\
 & -iBQ3 = 0 \\
 & iCQ4 - iCQ4 = 0 \\
 & iCQ4 + v4 \cdot Cmin + \exp\left(\frac{v4}{V1}\right) \cdot \frac{v4 \cdot Cmin}{BrQ4} = 0
 \end{aligned}$$


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