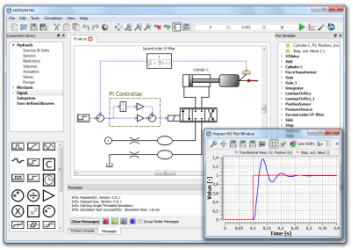
Fluid and Mechatronic Systems, Flumes activities in MODPROD

Petter Krus
Linköping University, Sweden



Flumes Research Areas

Aircraft Systems

Aircraft design

Onboard systems

Subscale flight testing

Fluid Power

Hydraulic system and component design

Mobile systems

Measurement and control systems

Noise and vibrations

Modelling and simulation

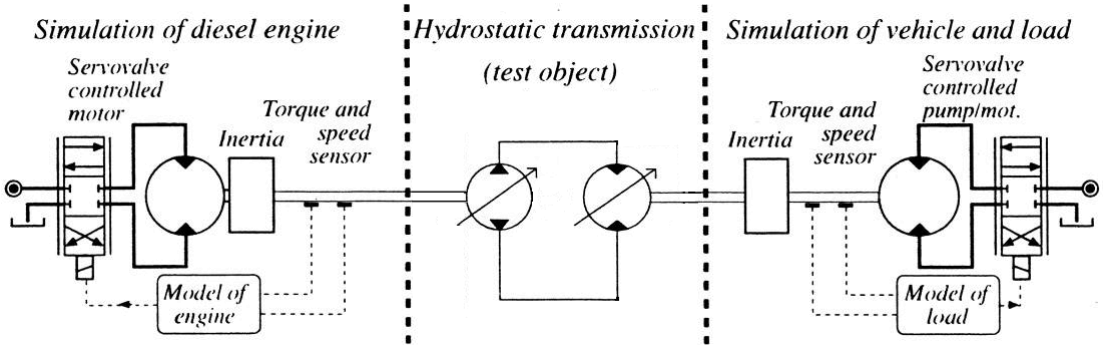
Systems Engineering

Mechatronics

Design analysis and optimisation

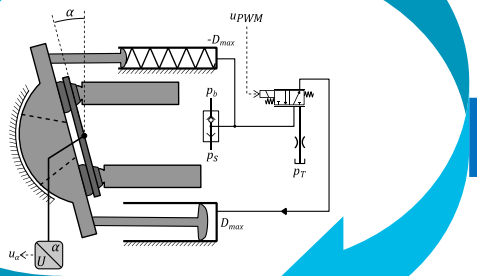
Energy Efficient Transmissions for Construction Machinery

- Flumes/VCE project
- Hydromechanical transmission
- Hardware-in-the-Loop testbench



Simulation Aided Control Design for a Displacement Actuator

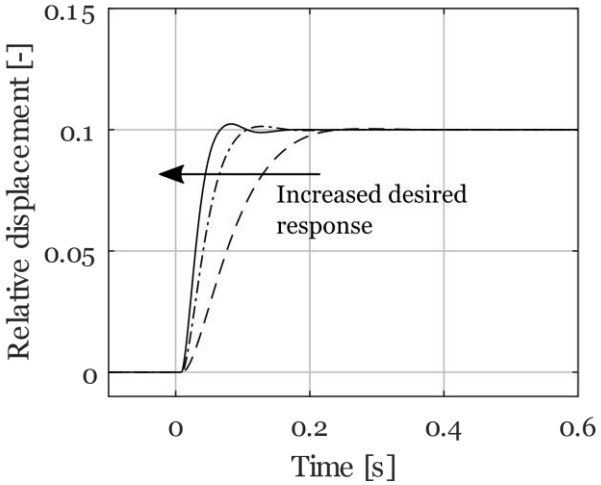
Model

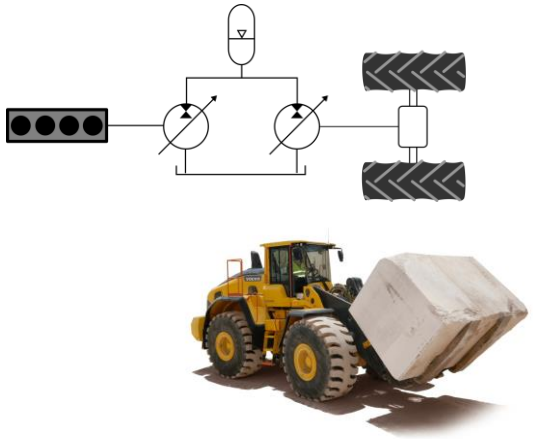


Control strategy

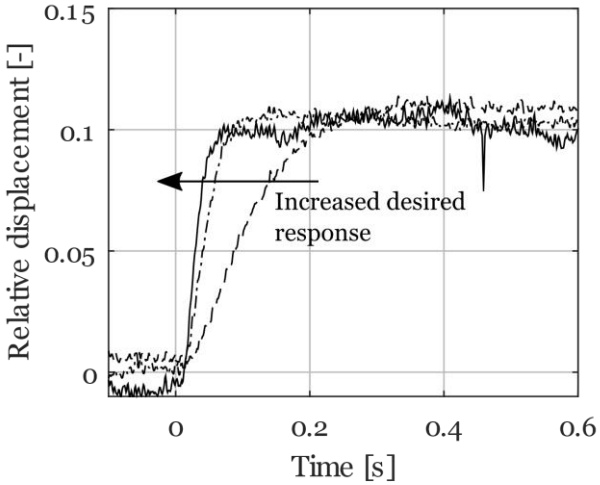
Hardware

Hopsan Simulation

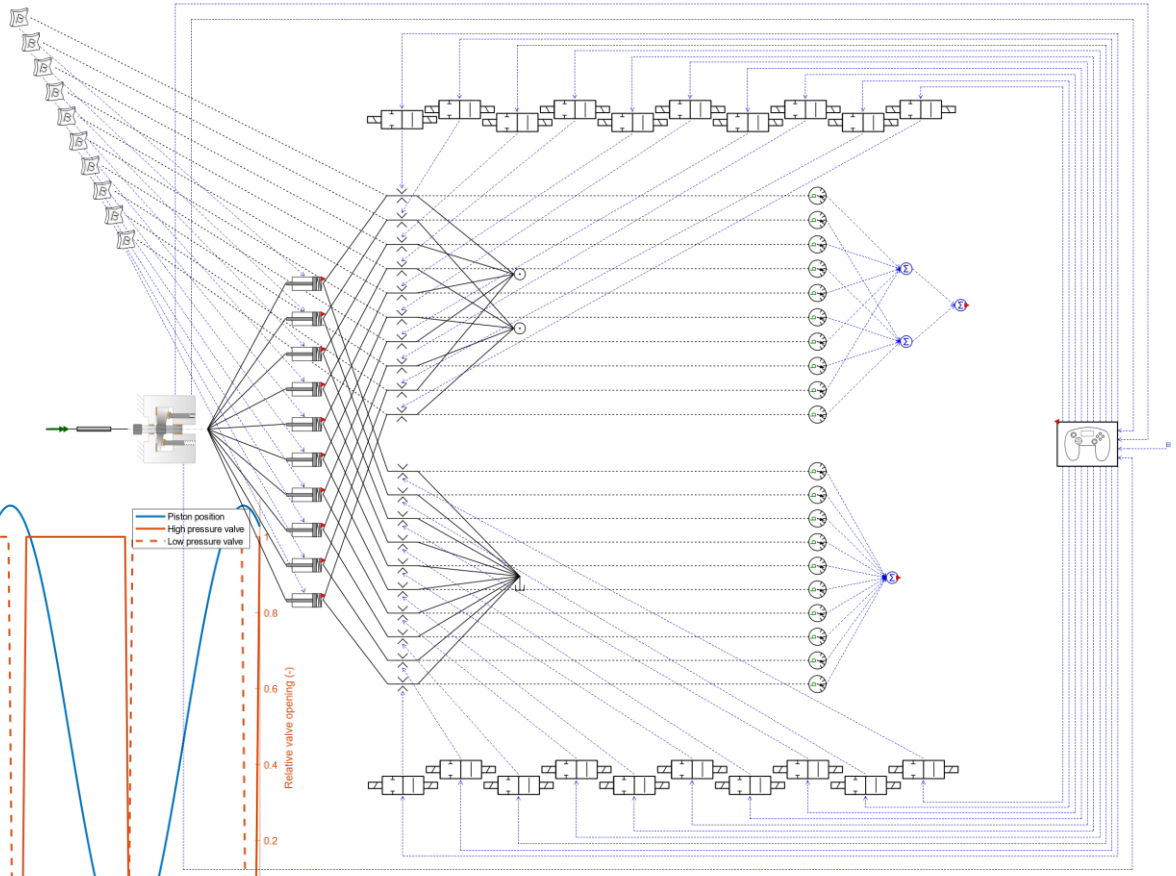




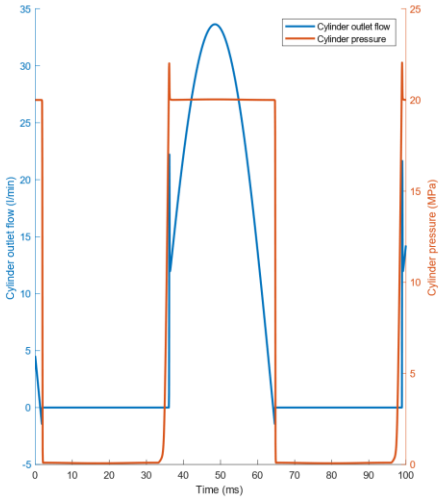
Measurement



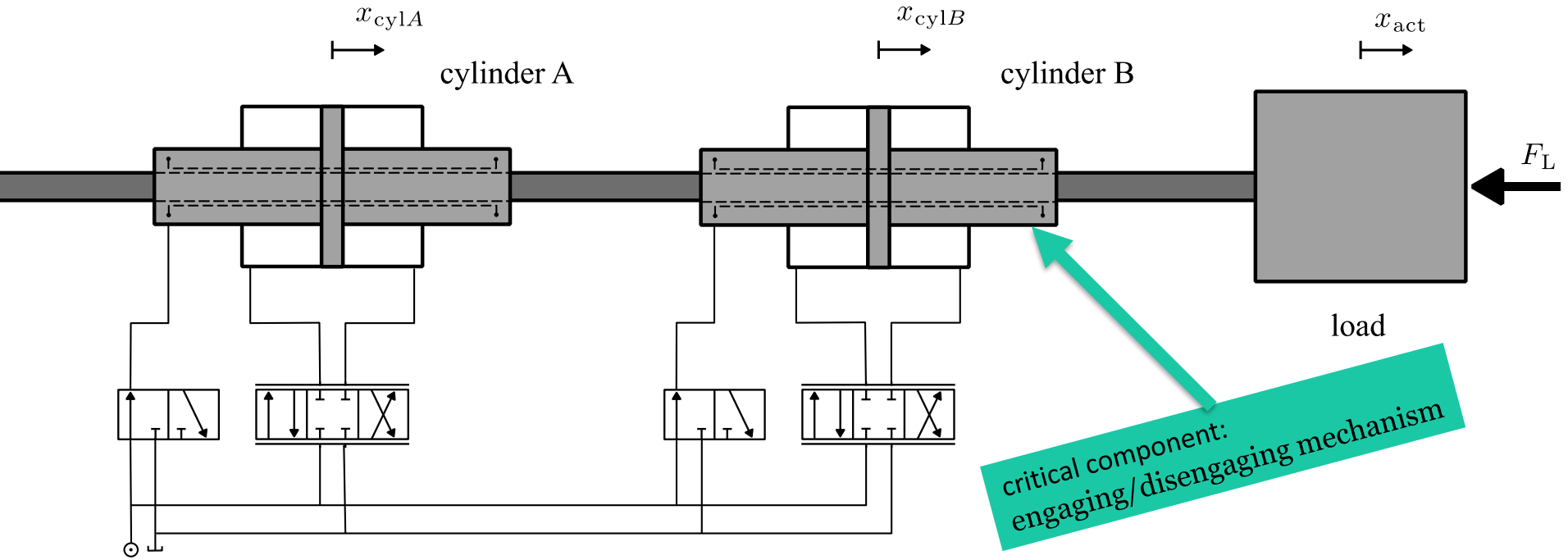
Hydraulic Pump Simulation: Digital pump with 10 pistons



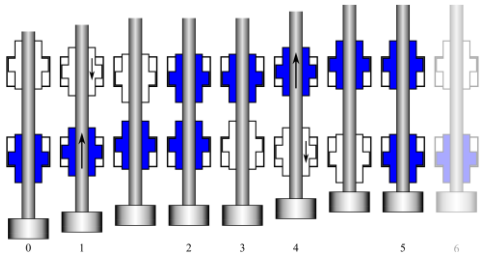
Analysis on piston level

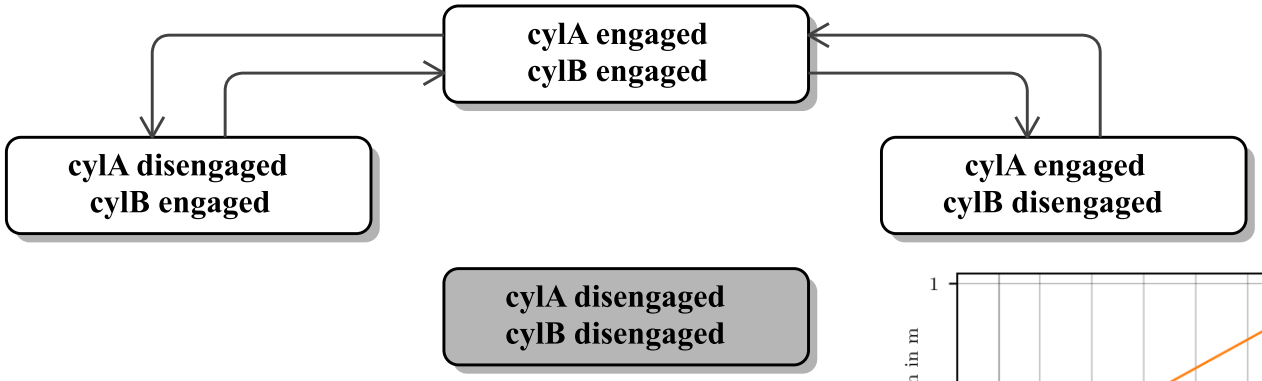


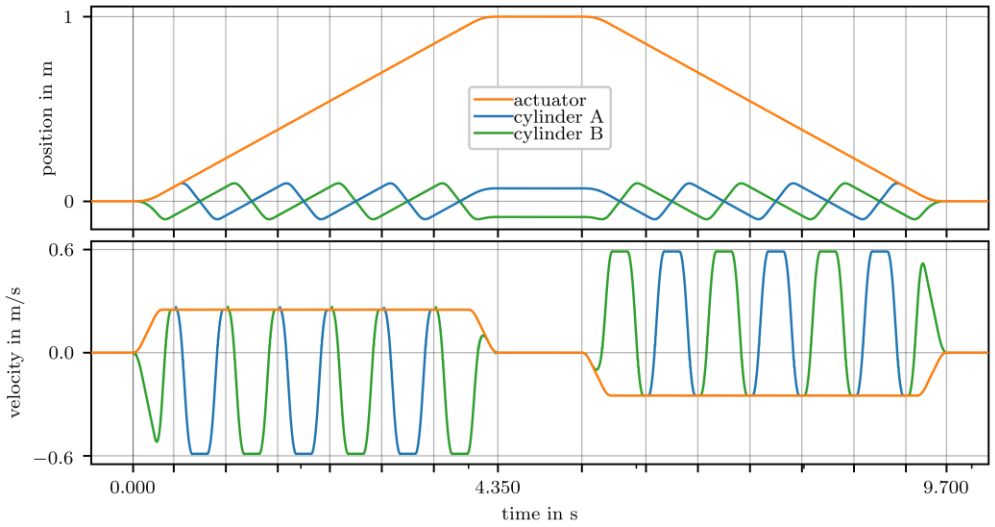
Linear Incremental Hydraulic Actuator



Gait -- Smooth Motion

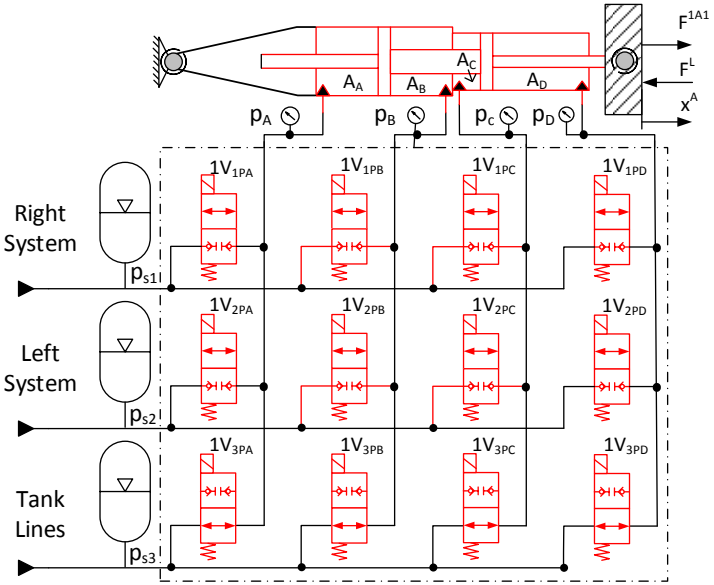


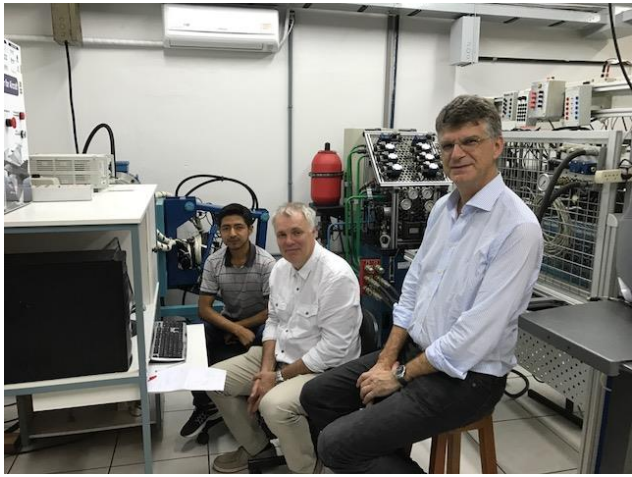


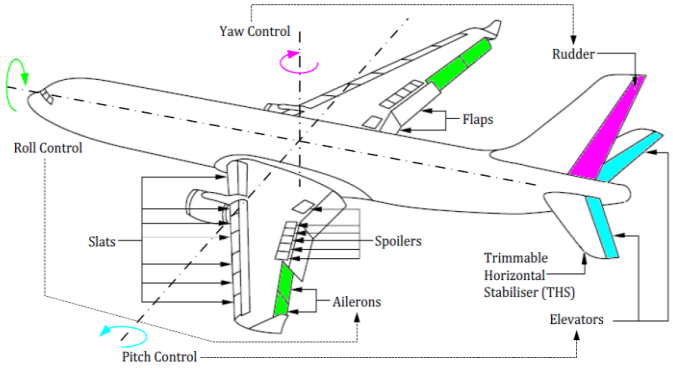


RQ2 [I, III]

Digital Hydraulics with UFSC, Brazil



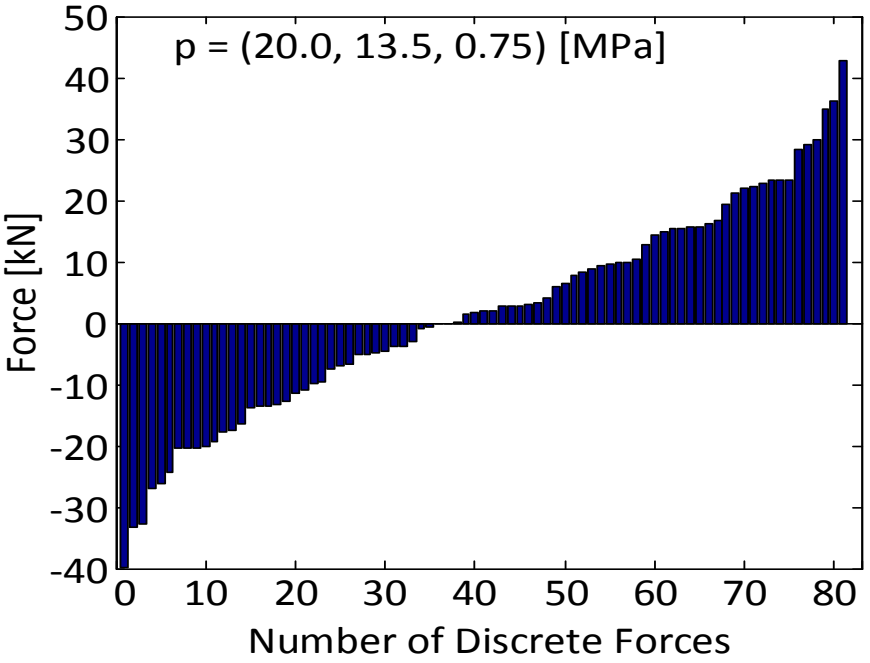


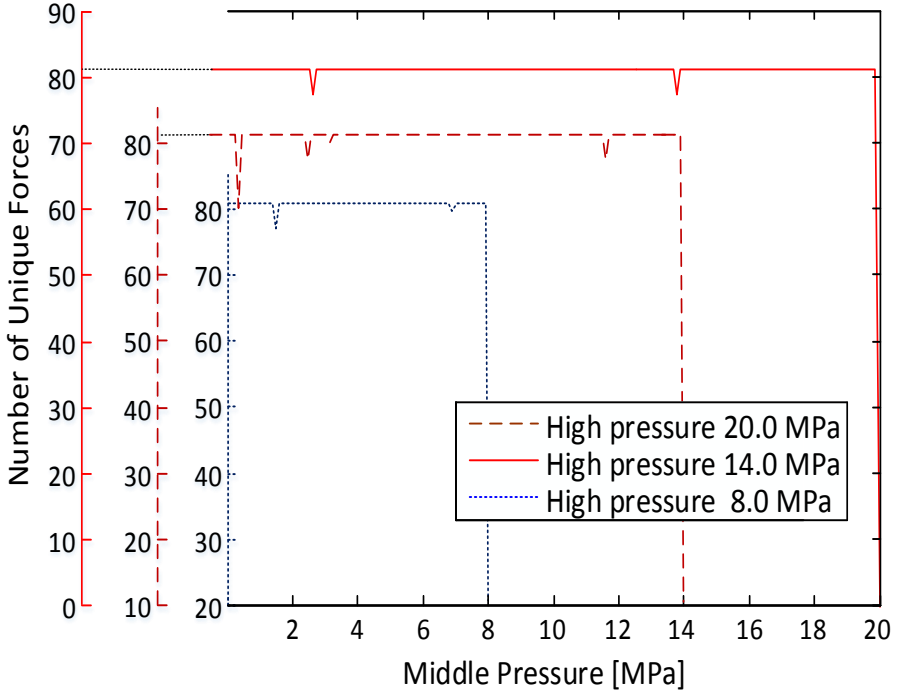


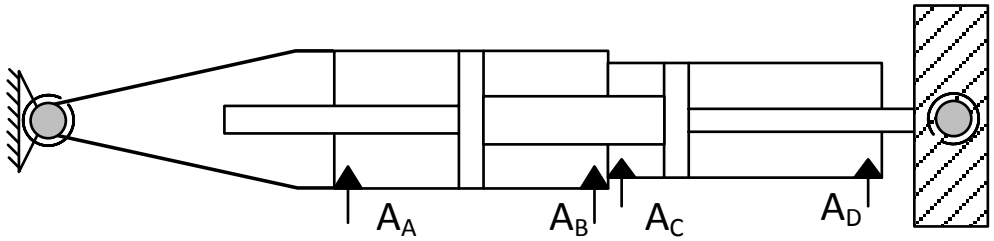
Fluida och Mekatroniska System
FluMeS
Fluid and Mechatronic Systems

LASHiP
HYDRAULICS & PNEUMATICS

Introducing digital hydraulics with more similar size piston areas





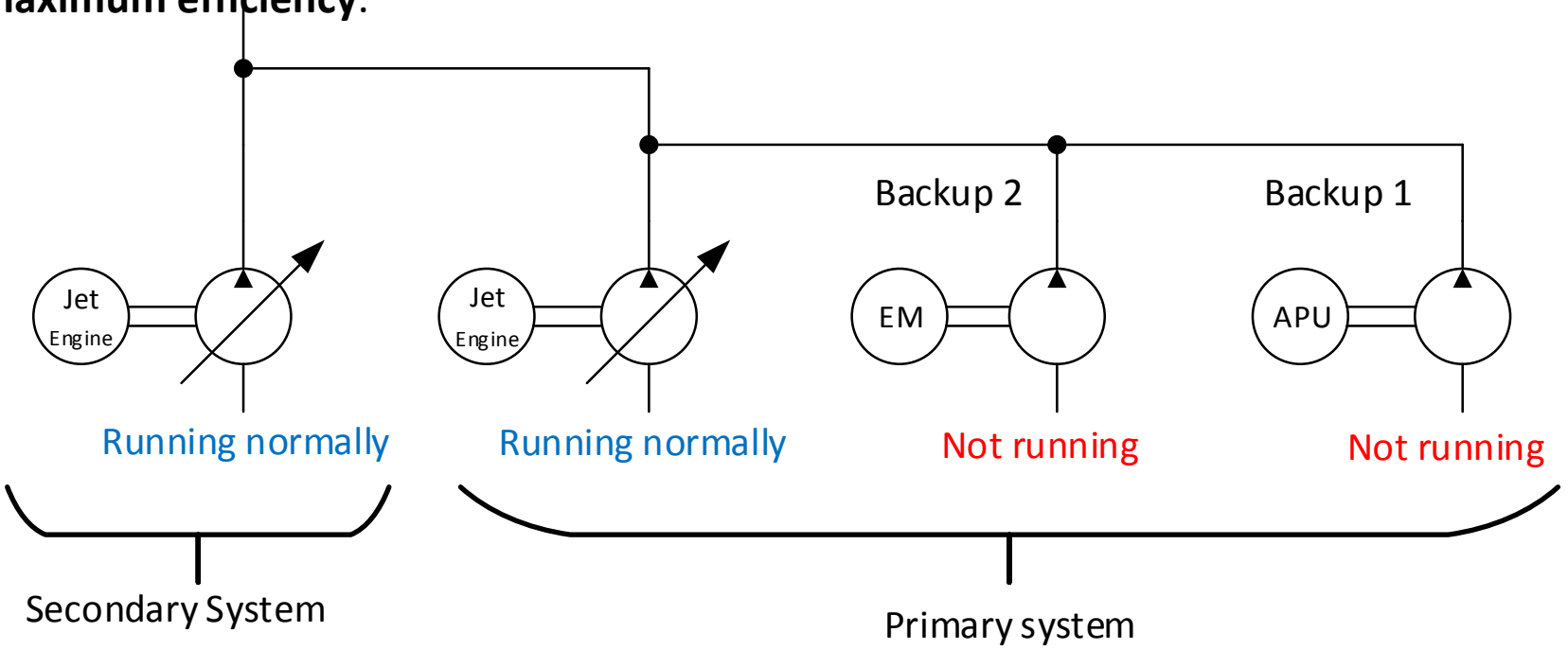


Areas: $A_A = 12.1$; $A_B = 10.6$; $A_C = 10.0$ and $A_D = 10.1$ (x10^{-4} [m^2])

Hydraulic Power Management, UFSC

The **simplify circuit** of an aircraft is represented below. The main idea of this work is to propose **new solutions to increase the efficiency on the aircraft based on hydraulic pumps**.

The solutions is based in the operation of the hydraulic pumps in the **region of maximum efficiency**.

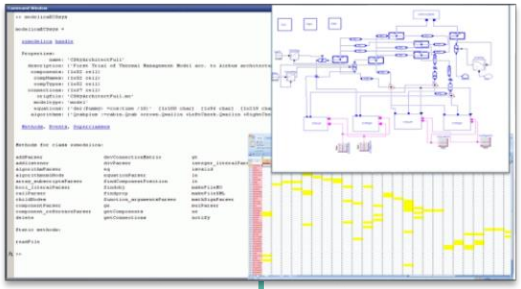


Conceptual Aircraft Design (Saab)

SIZING AND AERODYNAMICS

Matlab

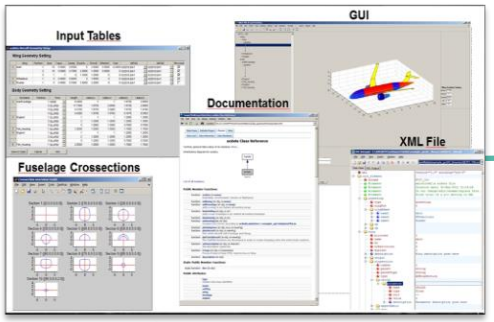
- **Tango -** Aircraft sizing
- **Tornado**- Aerodynamics



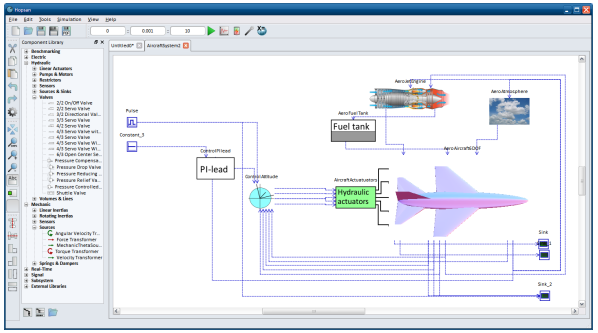
Modelica (Dymola)

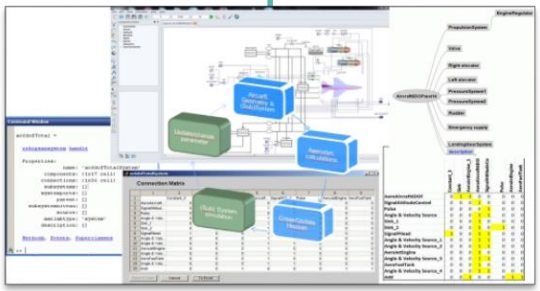
CATIA

RAPID

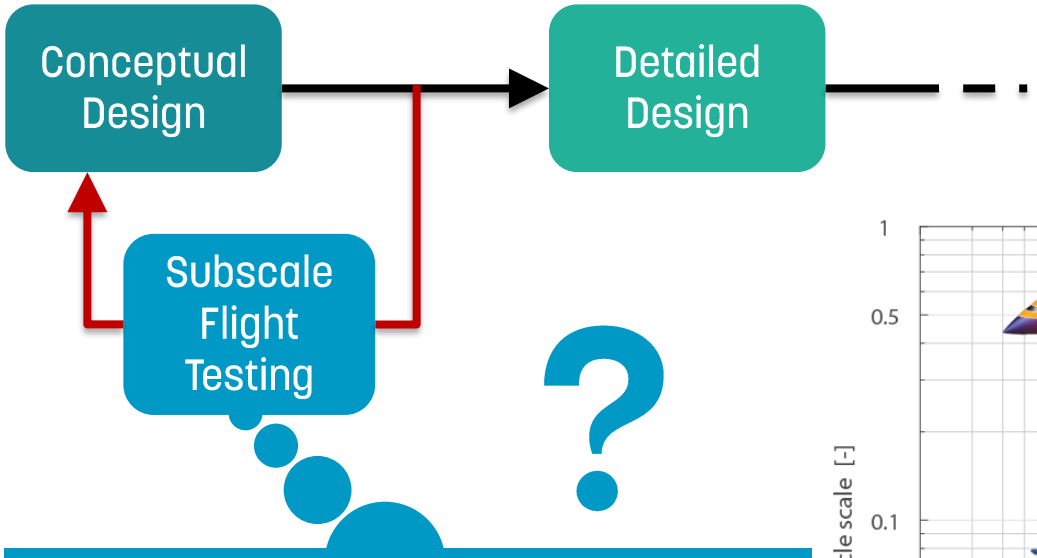


Hopsan

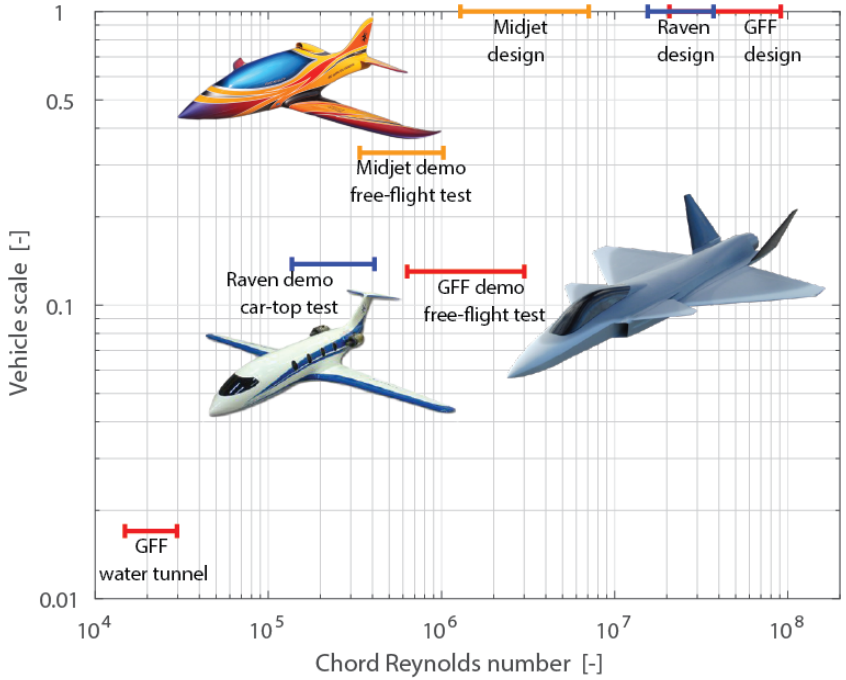




Subscale Flight Testing in Aircraft Conceptual Design



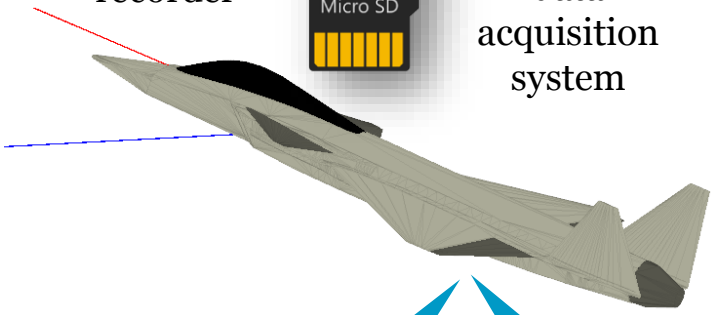
- How to choose the scaling method?
- How to acquire the right data?
- How to extrapolate the results?

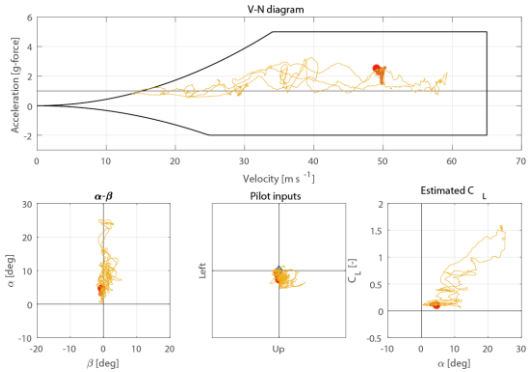


Subscale Flight Testing in Aircraft Conceptual Design

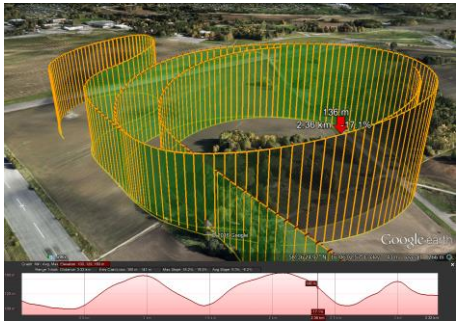
Onboard video recorder

Miniaturised data acquisition system





Tools for flight test analytics

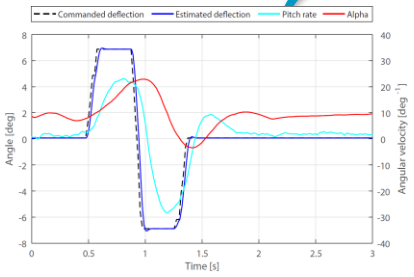


Flight test design for very confined airspace

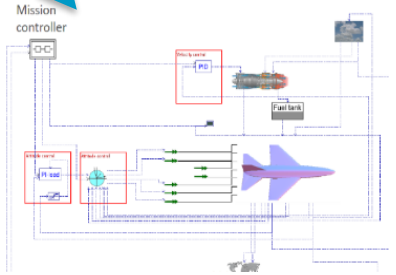
Bi-directional low-latency control link (RC equipment)

Bi-directional telemetry link (ground station)

Parameter estimation

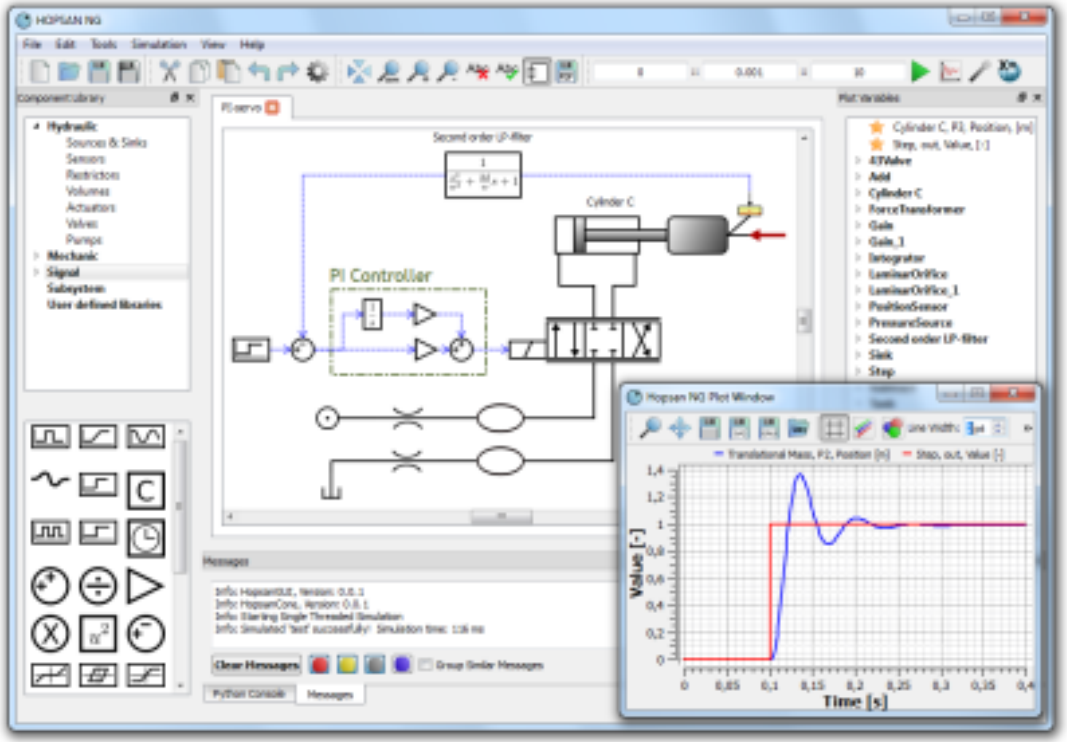


Simulation model improvement



HOPSAN

- Bidirectional delay-lines (TLM)
- Open source that can be downloaded from http://www.iei.liu.se/flumes/system-simulation/hopsanng



System simulation

- Distributed models, no centralized solvers
- Parallelization of simulation models for multi-core processors
- Hardware in the loop simulation
- FMU support
- Using bilateral delay line (transmission line modelling, TLM) for model partitioning

$$p_1(t) = p_2(t - T) + \frac{T}{C}[q_1(t) + q_2(t - T)]$$

$$p_2(t) = p_1(t - T) + \frac{T}{C}[q_2(t) + q_1(t - T)]$$

Hopsan Development

- Software for system simulation. Hydraulic, mechanical, electrical, control systems, thermal, etc.
- Work on first Hopsan (in Fortran) began in late 1970s at Linköping University
- Used by industry and for research
- Development of new version called Hopsan NG (in C++) began in 2009
- Longest running simulation software with continous development *in the world* (?)

Atlas Copco: Rock drill Simulation and Optimization using the HOPSAN simulation package

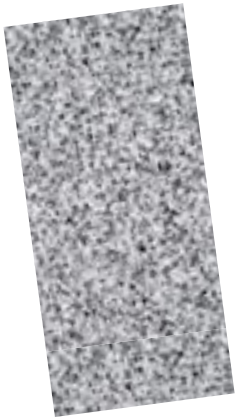
Atlas Copco has 45% of the world market in rock drill equipment

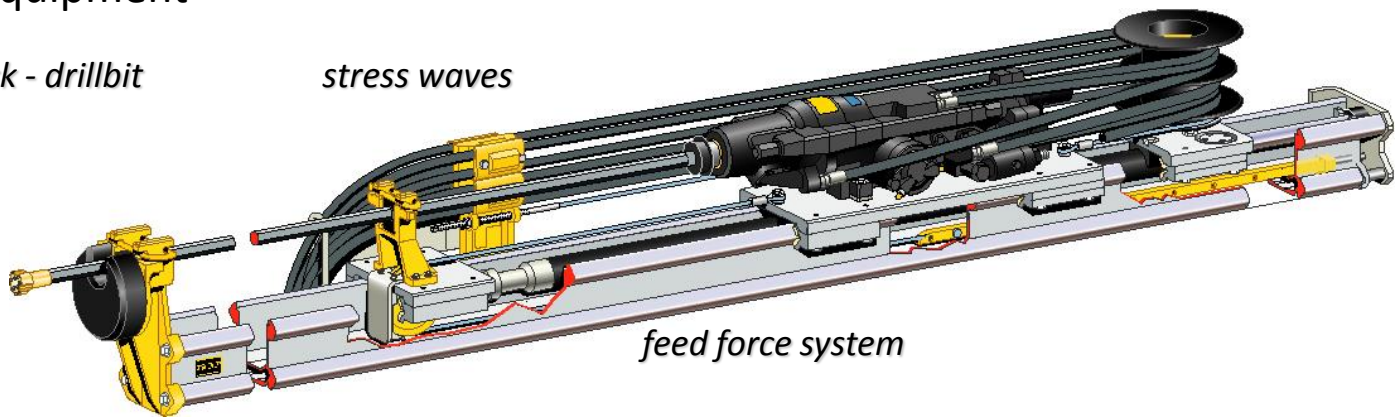
rock drill systems

supply system

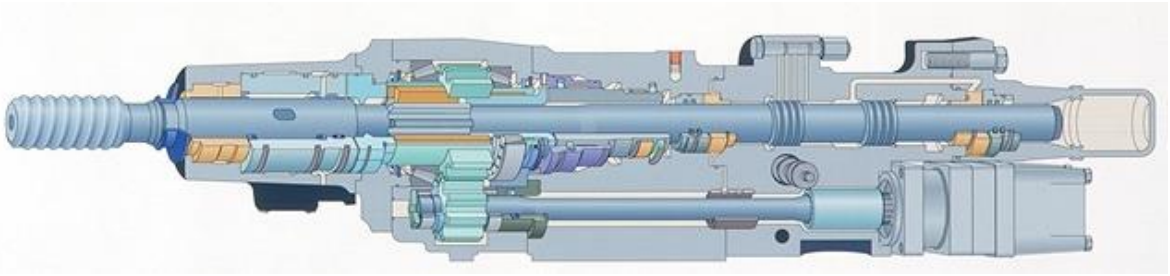
rock - drillbit

stress waves





feed force system



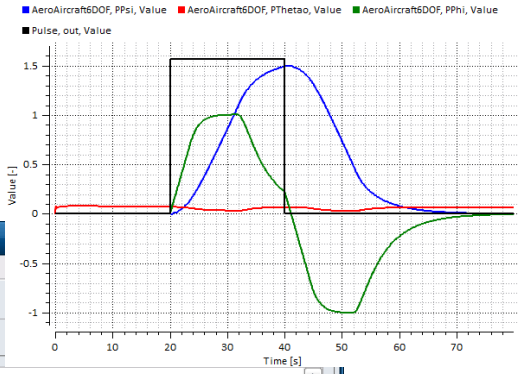
stress wave

rotation

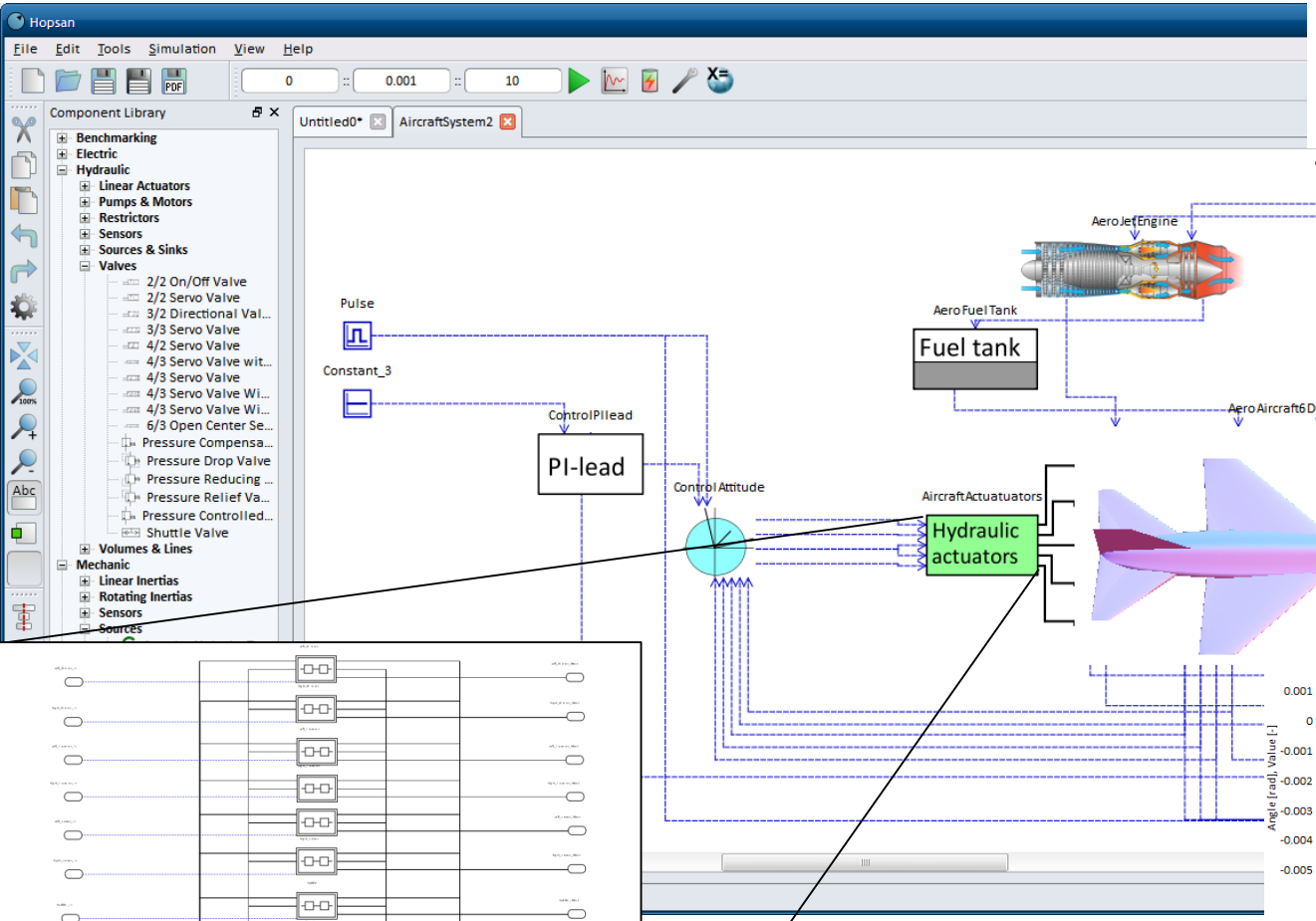
feed force tranfer and damping

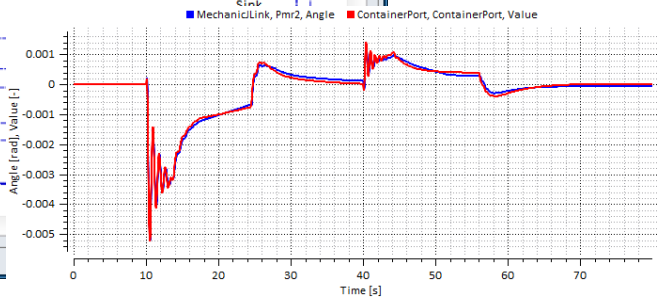
percussion

Example: Aircraft System



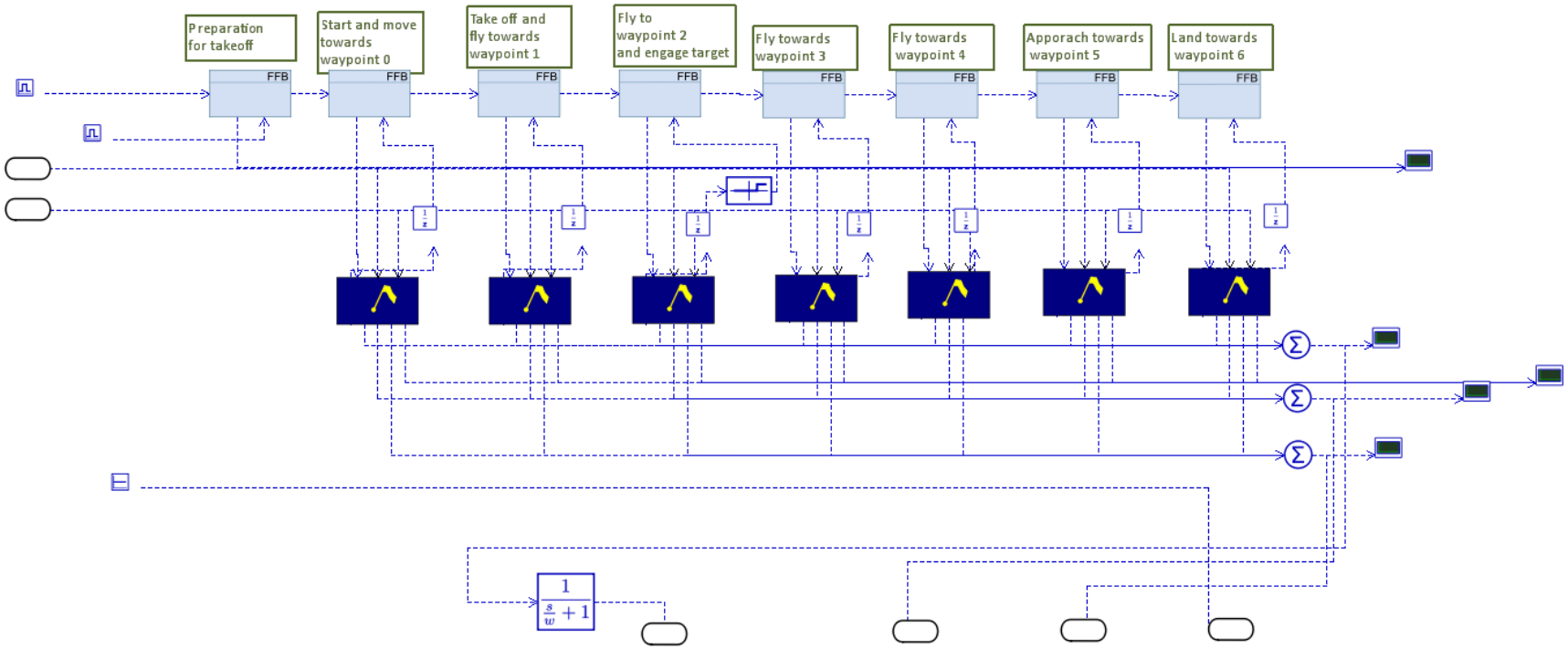
The aircraft attitudes during an S-maneuver.



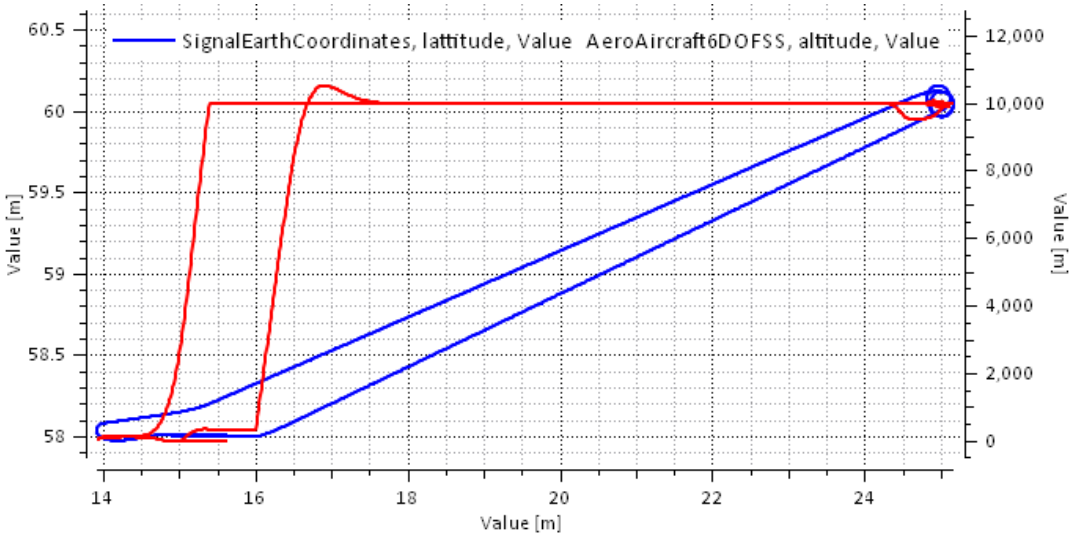


Angular position and reference position of the rudder actuator

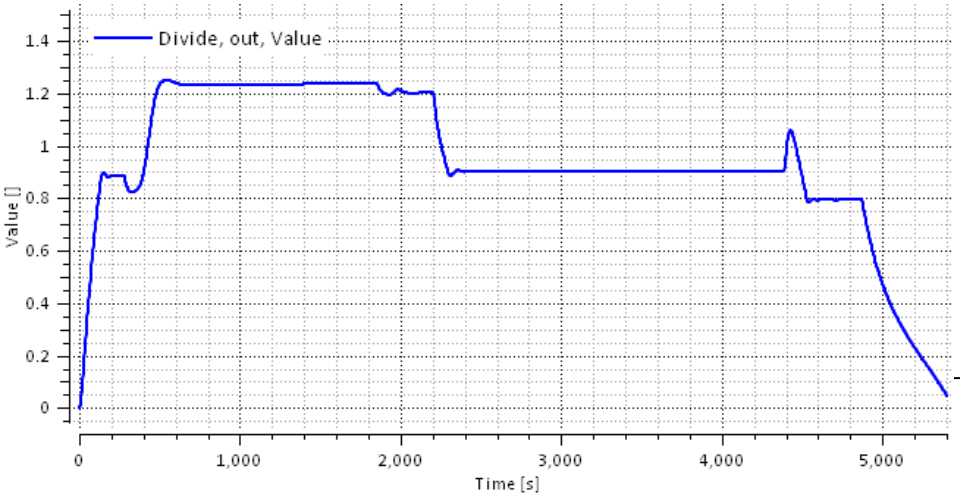
Mission Controller



Mission Simulation Results



Flight trajectory



Velocity profile

Simulation time 5400 sec in 24 seconds
216 times real time
(73 times real time including actuation system)

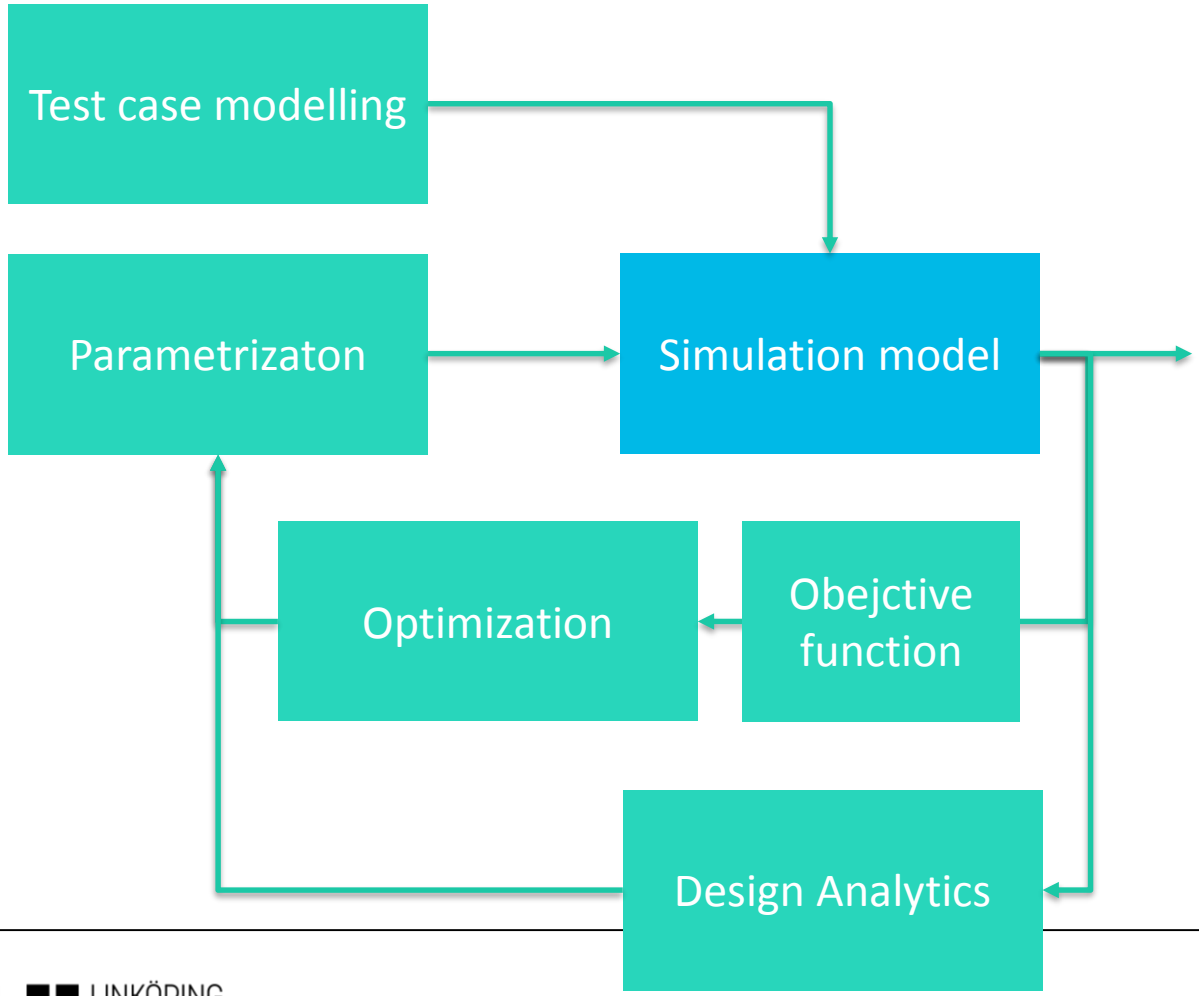
Model Based Systems Engineering

- Closing the design loop with modelling and analysis, e.g. through model execution (simulation).
- Simulation model is used as the basis for design optimization and for design analytics

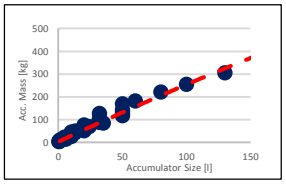
Extended System Simulation

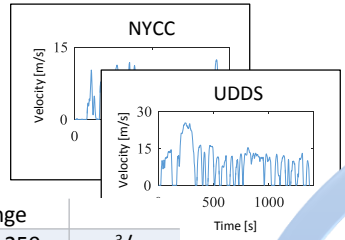
- Connectivity, co-simulation, multi-core, FMU etc.
- Simulation based optimization
- Design analytics
  - I.e. sensitivity analysis, correlation analysis, robustness, complexity metrics, etc.
  - Methods for experimental validation
- Parametrization for design.
  - Analytic parametrization, and reduction
- Test case modelling

Extended System Simulation



Simulation-Based Optimization Framework for Series Hydraulic Hybrid Vehicles (SHHV)

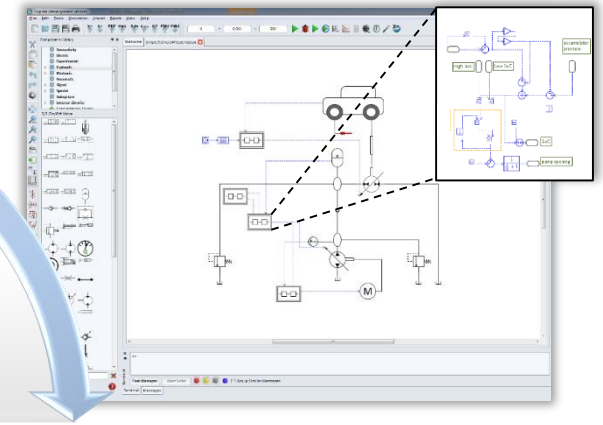




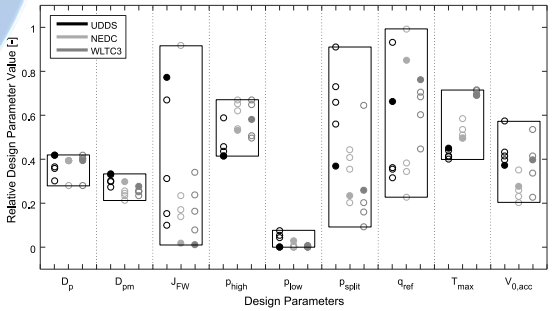
Design parameter	Range	
Pump size	25 … 250	cm³/rev
Pump/motor size	25 … 250	cm³/rev
Upper SoC limit	15.0 … 45.0	MPa
Lower SoC limit	12.5 … 44.0	MPa
Diesel engine size	75 … 400	Nm
Accumulator size	10 … 100	l

SHHV, parameters, application

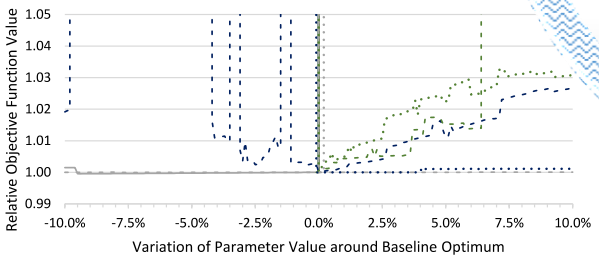
SHHV simulation model



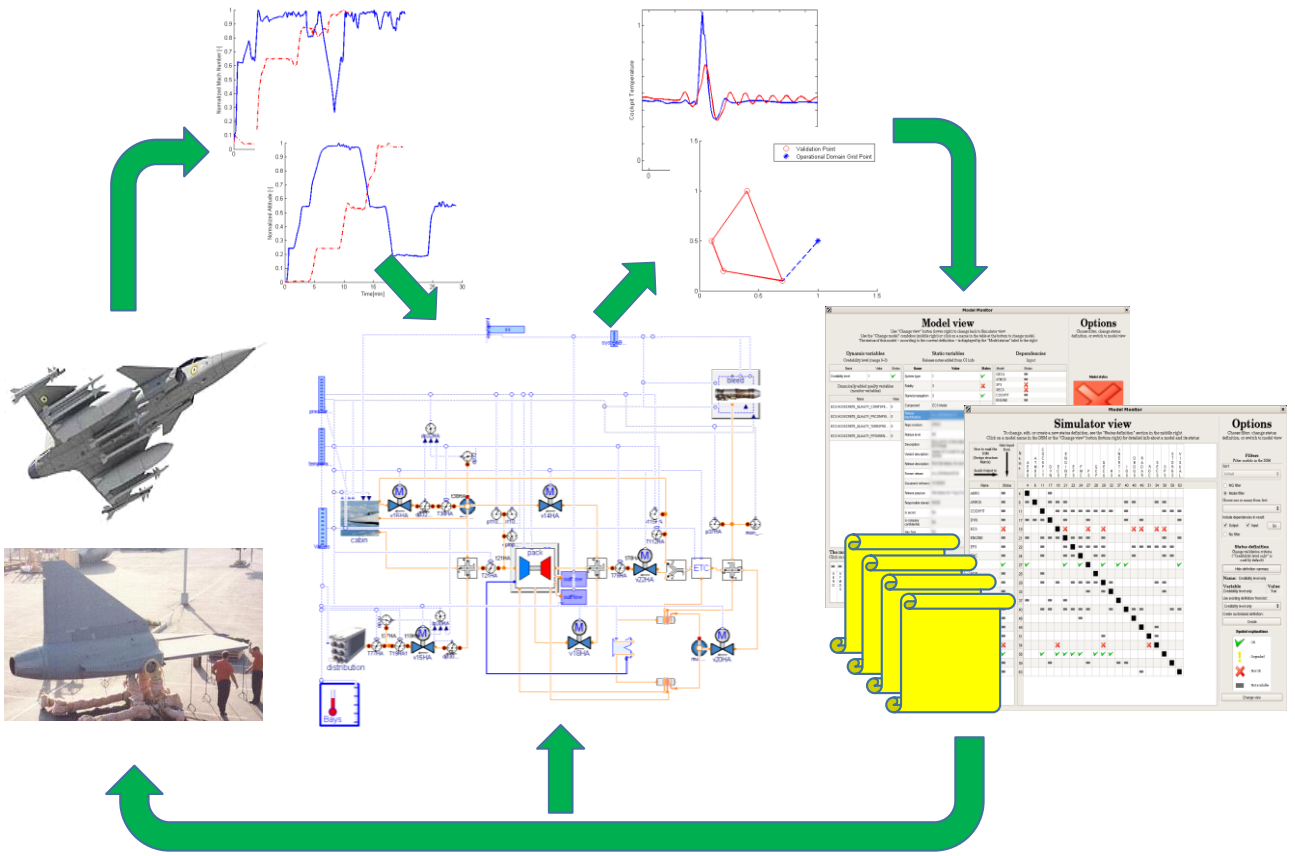
Design optimization



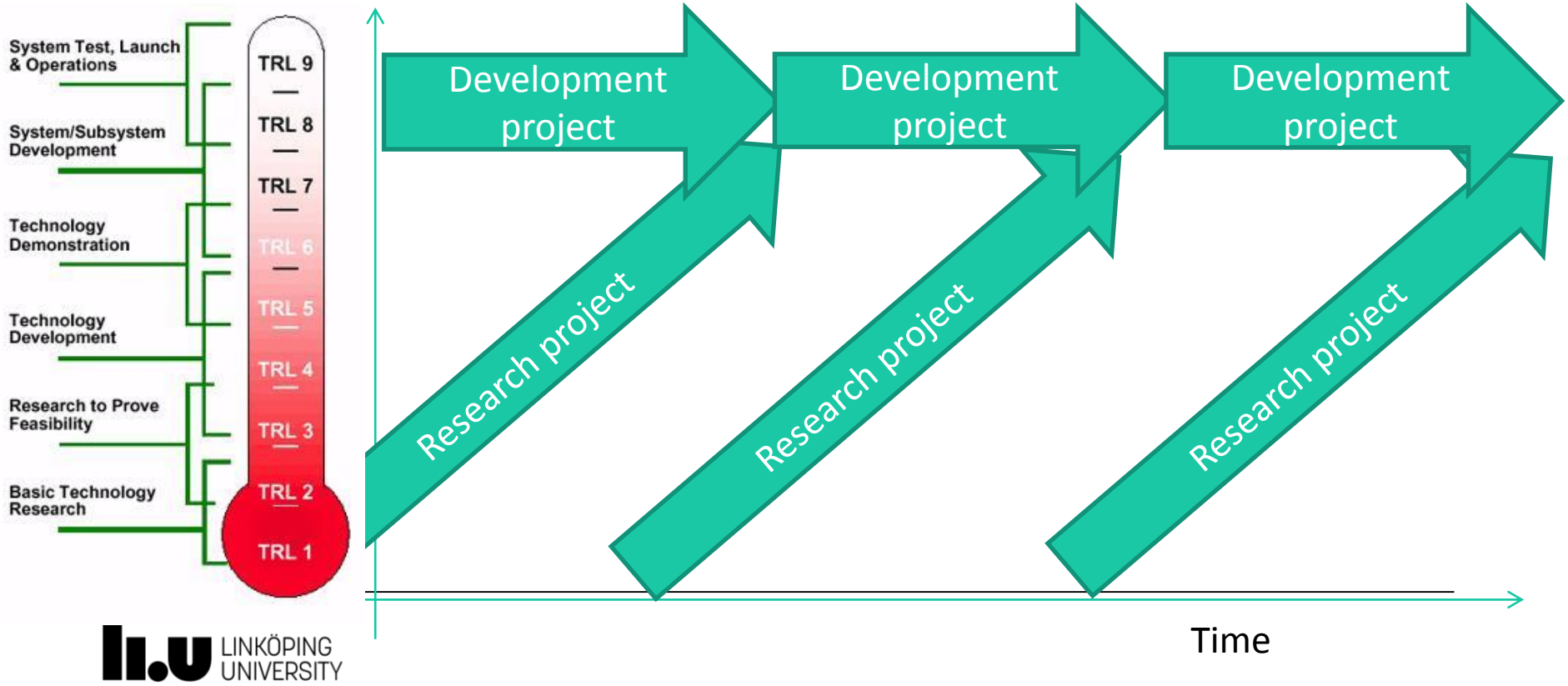
Analysis of optimization results



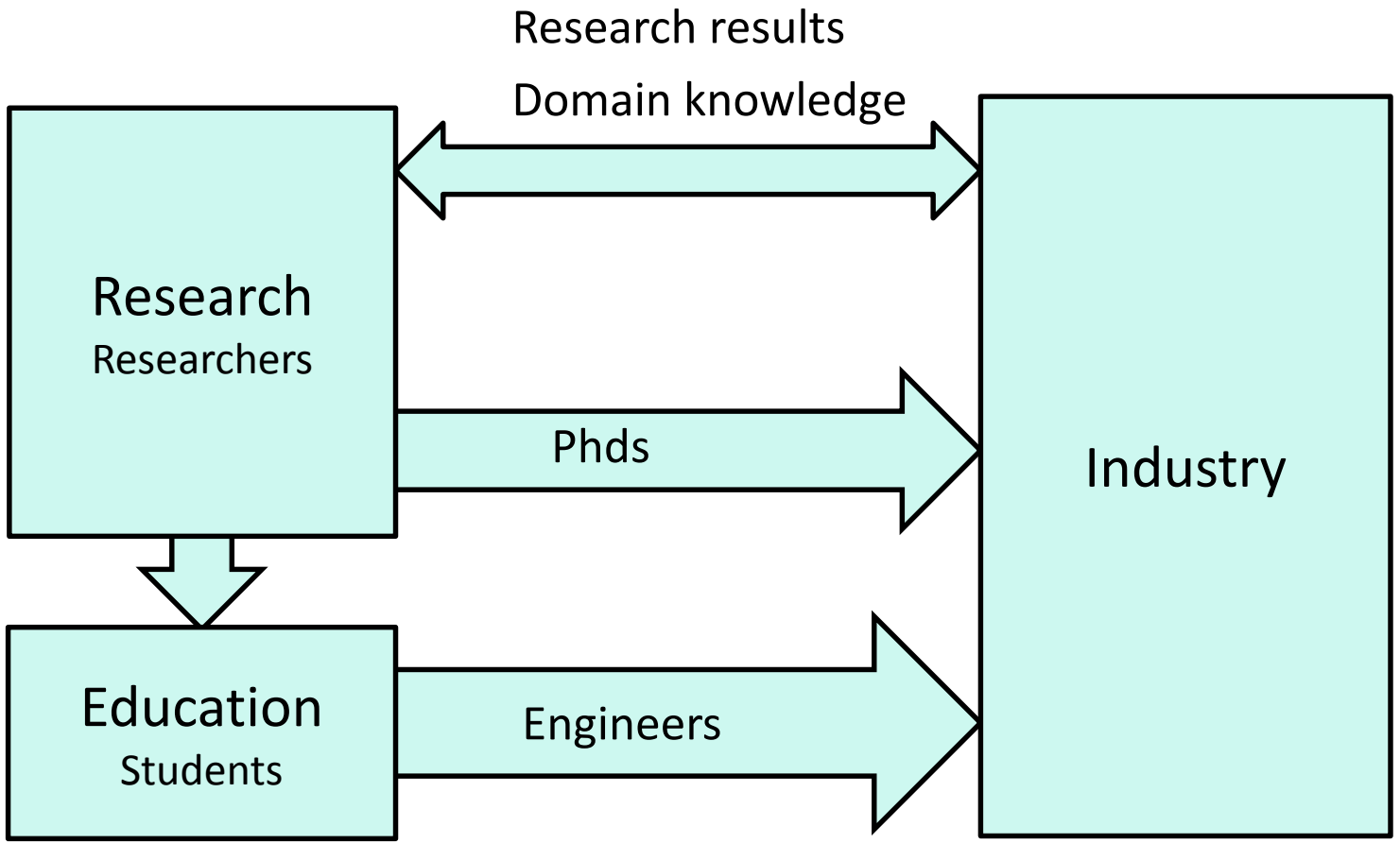
Methods for Automating Model Validation



Research and Product Developement



Applied University Research for the Generation of Excellent Engineers



Four PhDs during 2017