Fluid and Mechatronic Systems
at Linköping University

Petter Krus

CONCEPT REALISATION LABORATORY

Increased Intelligence in Products

- New products tend to have more intelligence than before. This apply to a wide range of products. This is particularly true for:
  - Cars
  - Aircraft
  - Construction Machinery
- This is in response to increased requirements for efficiency, driven by economics , safety, and environment.

Technologies

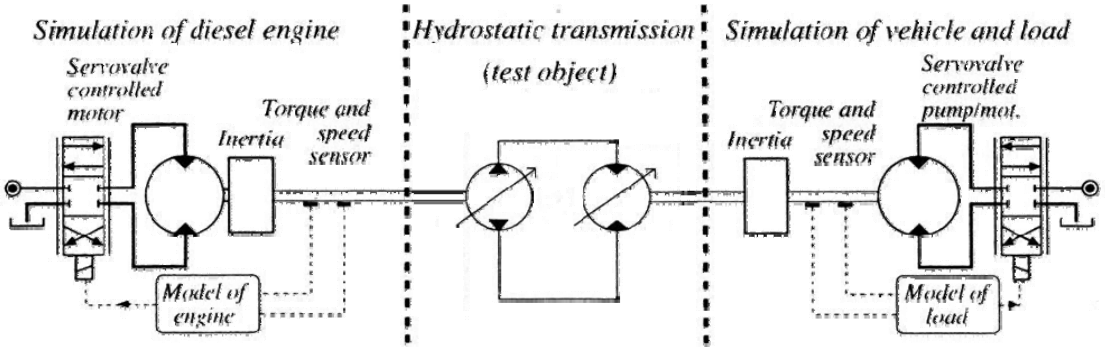
- Systems that are characterized by a close coupling between:
  - Mechanical system
  - Power transmission/Actuation system
  - Sensors
  - Control System
- This requires, *Multidisciplinary co-design,* i.e. Mechanical design and control system co-design where modelling and simulation are central

Partner Companies with Ongoing Projects

- Atlas Copco (Mining equipment, rock drills)
- CybAero (Unmanned helicopters)
- National Instruments (Measurement and control)
- Parker (Fluid power)
- Prevas (Testing systems)
- Saab AB (Aircraft)
- Scania AB (Trucks)
- Volvo CE (Construction Machinery)

Energy Efficient Transmissions for Construction Machinery

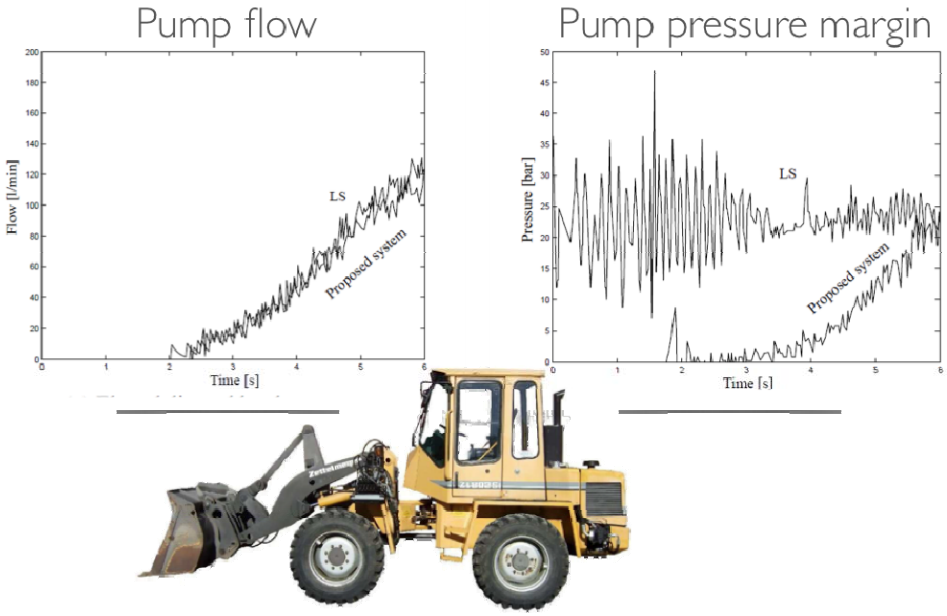
- Flumes/VCE project
- Hydromechanical transmission
- Hardware-in-the-Loop testbench

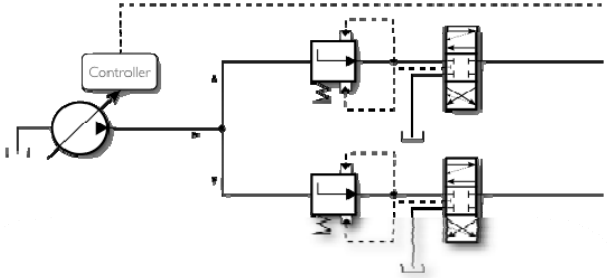


Björn Eriksson
Mikael Axin

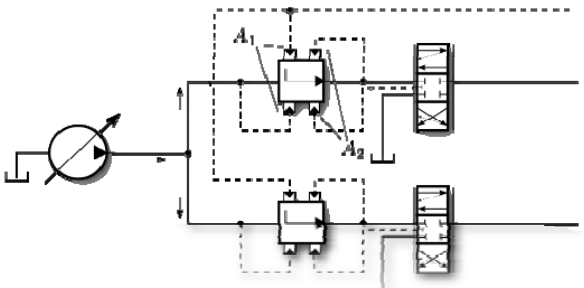
Energy Efficient Hydraulic Systems

- Project sponsored by Parker Hannifin-Hannifin, USA





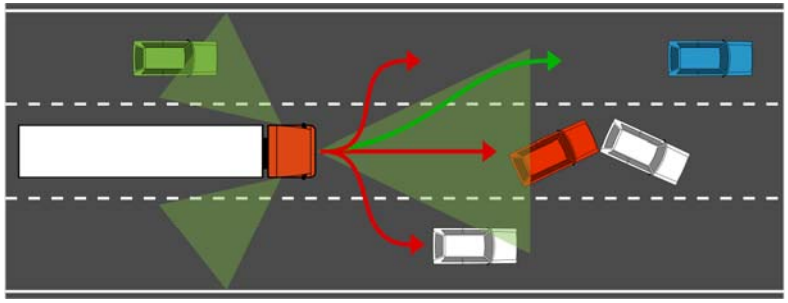
Original Load Sensing system (LS) with closed loop controlled pump

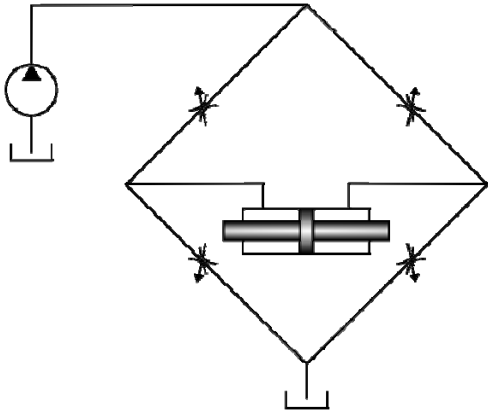


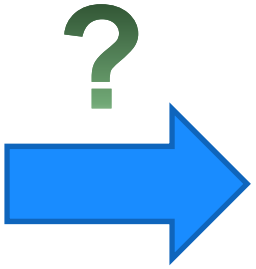
Flow sharing system with open loop controlled pump

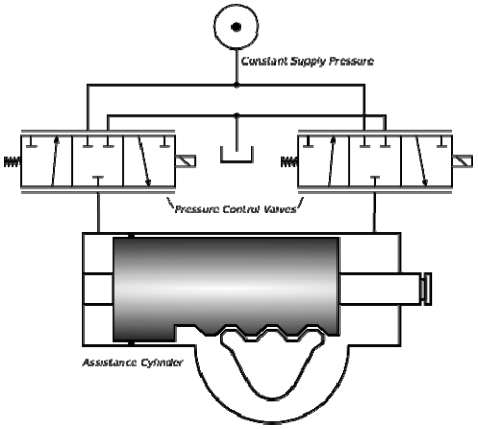
Autonom Styrning av Tunga Fordon (FFI,Scania)

- Aktiv styrning
- Genering av nytt koncept för servostyrning
- Minskad bränsleförbrukning
- HWIL
- Validera i rigg och lastbil



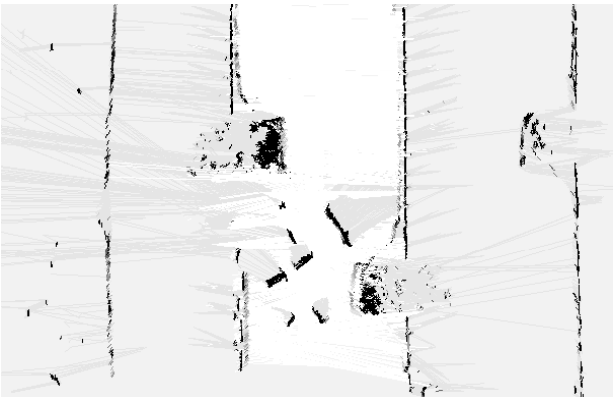
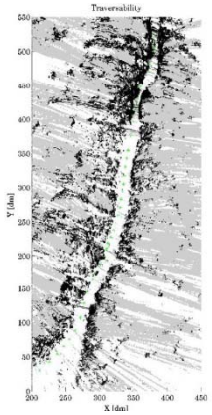




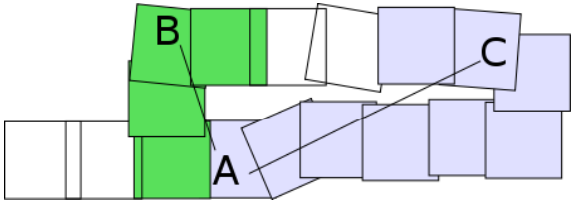


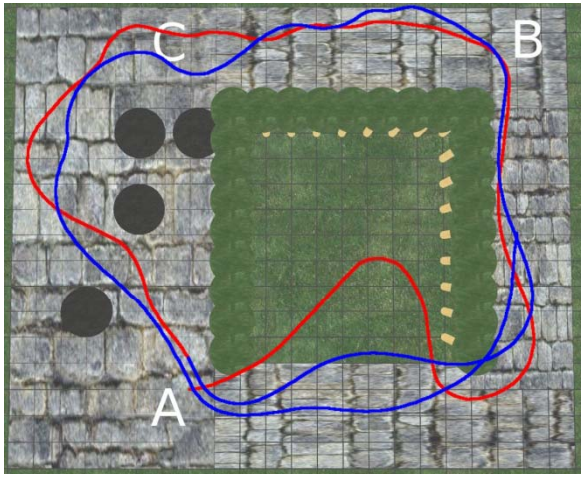
Peter Nordin
Lars Andersson

Mobile Robotics
Traversability Mapping

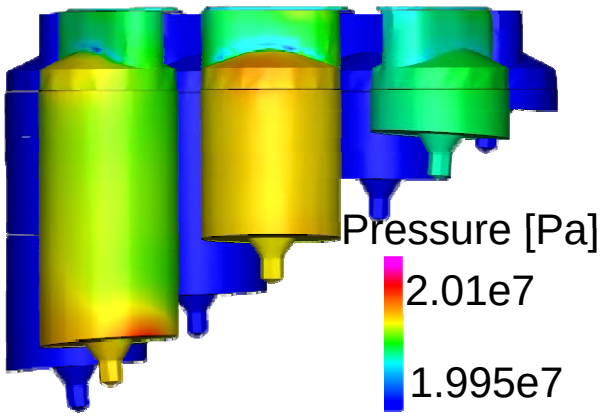





Map Reuse for Path-Planning

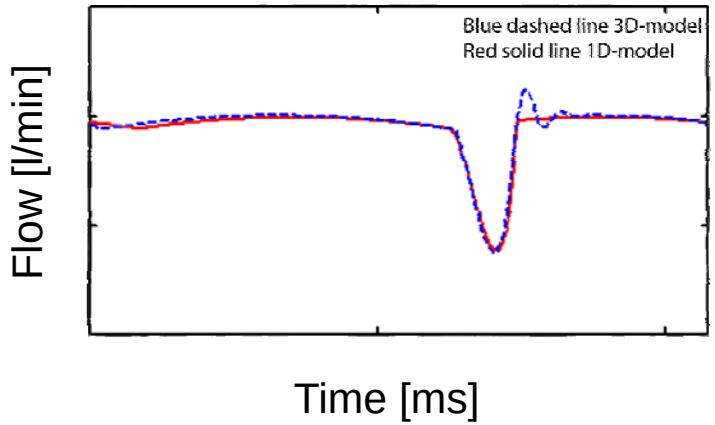




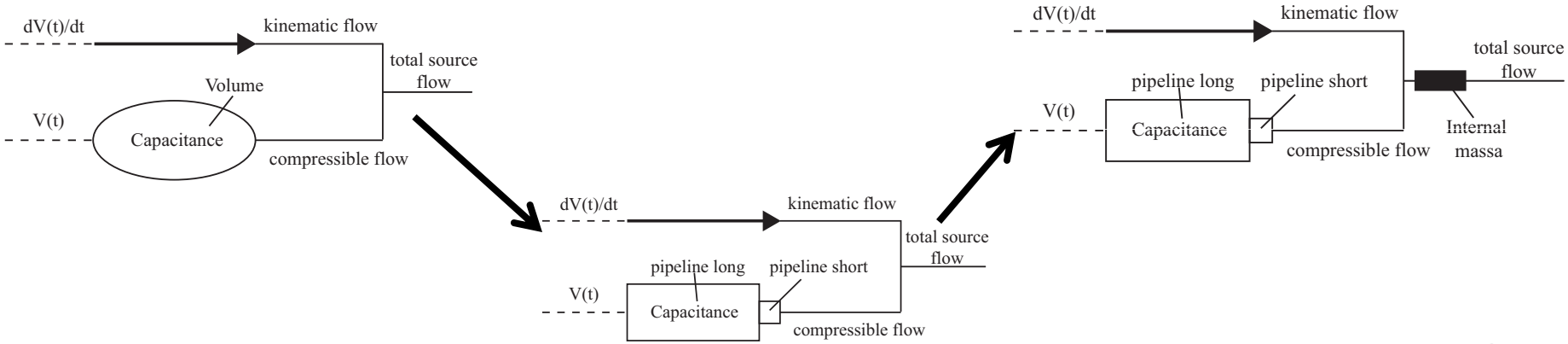
3D CFD-model vs. 1D model for Fluid Power Machines



Simulations can be in different shapes and comprehensive level with there own pros and cones.

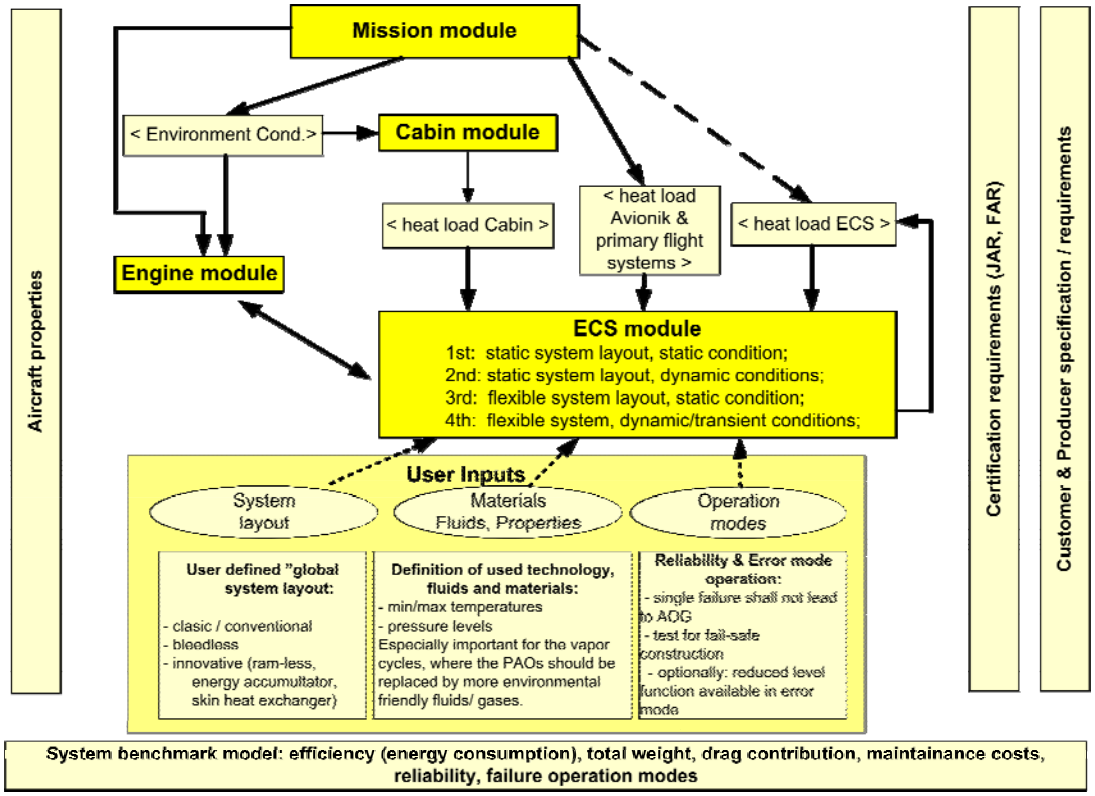


With the knowledge from the CFD simulations and measurements, the accuracy of the fast 1D model can be increased.



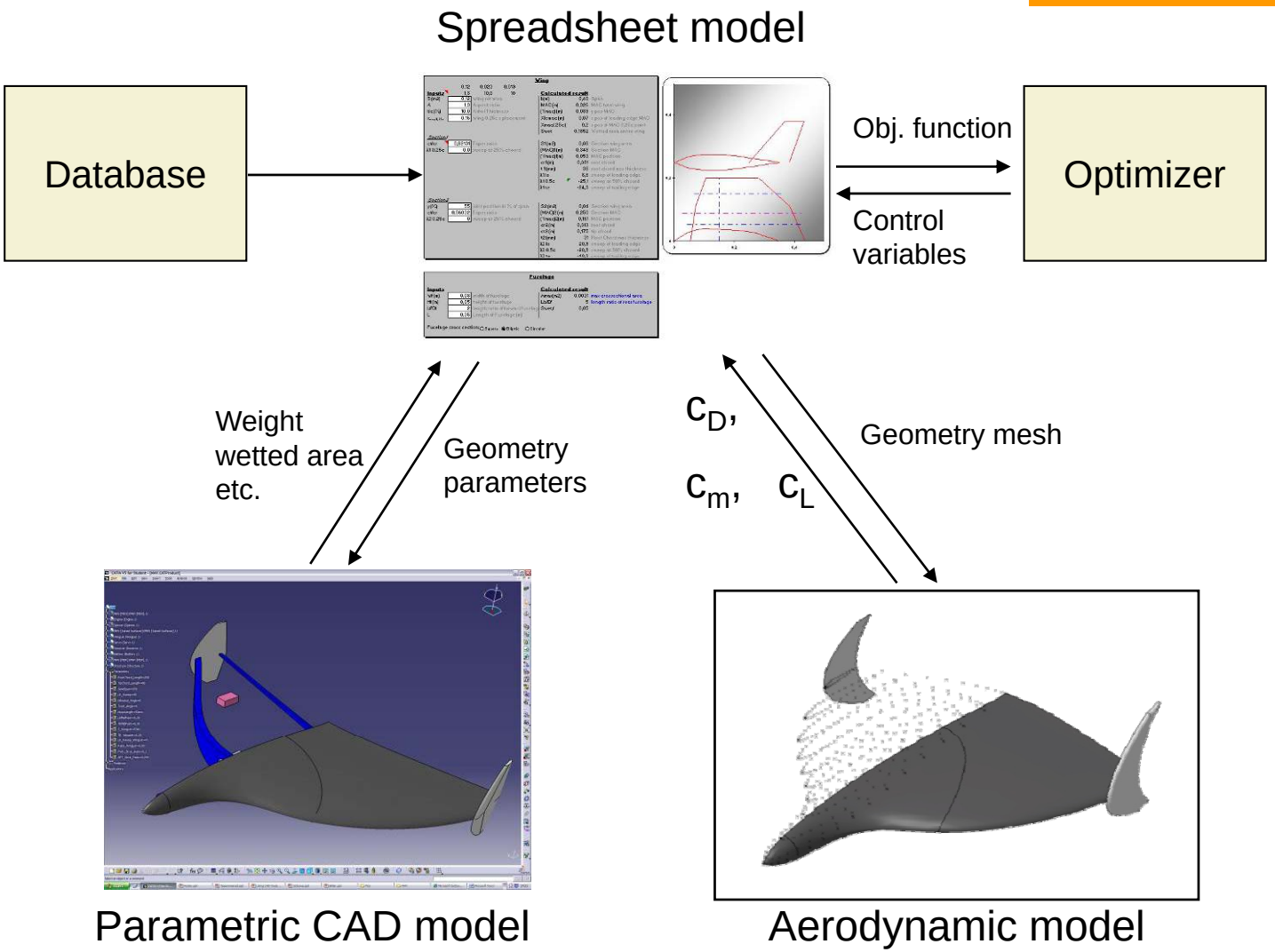
FLUD/Vinnova, Saab AB
Aircraft Environmental Control System

- Produce models for concept selection if aircraft environmental control system



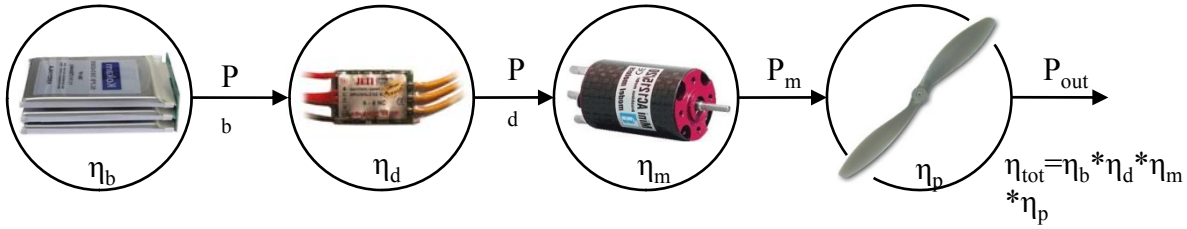
David Lundström
Patrick Berry
Kristian Amadori
Christopher Jouannet

Design Framework



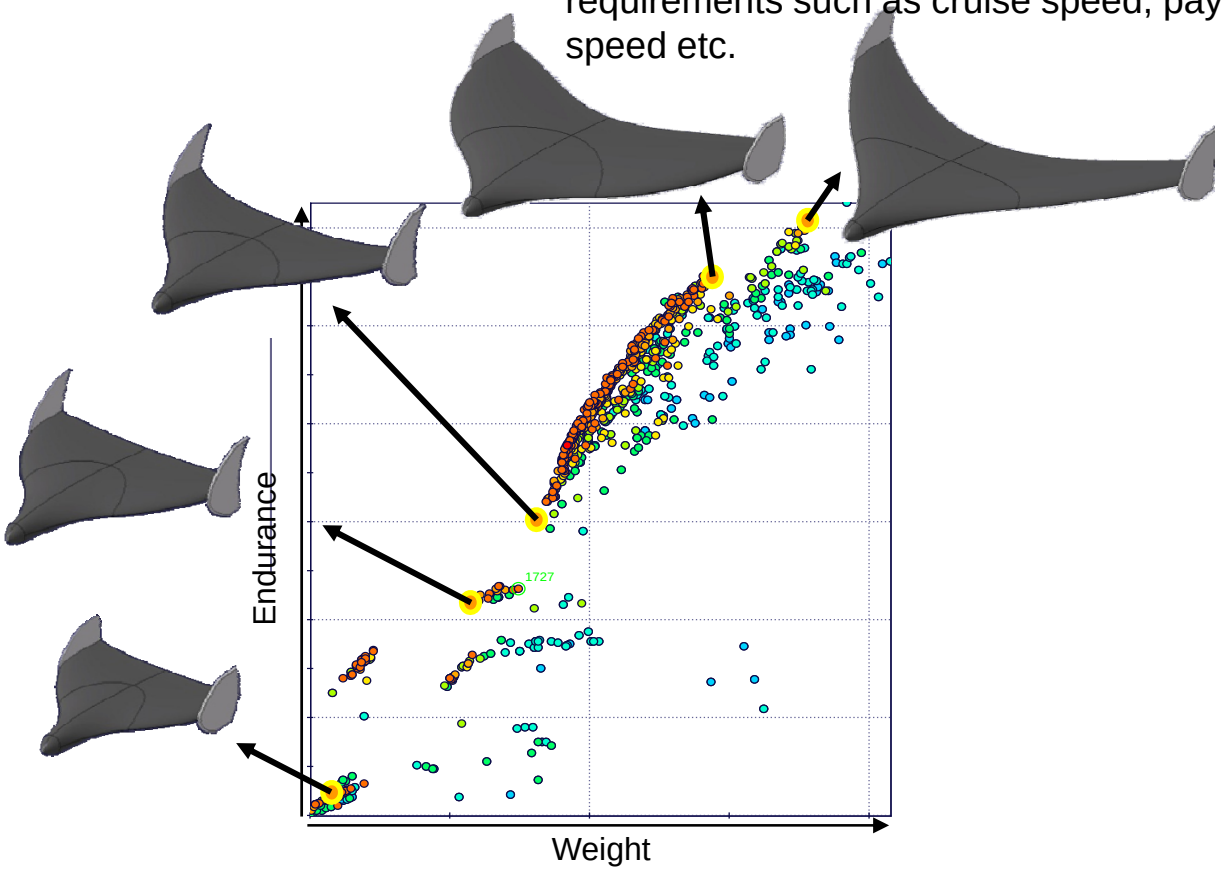
Closing the Loop - MAV Prototyping

- FDM type 3D printer
- Test: 270mm MAV
- Weight: 90g
- Benefits
  - Allows easy validation
  - No ”craftsmanship” is needed
  - Geometric complexity does not ad cost
  - Good accuracy and repeatability



Design Framework

Example MAV optimization. Pareto optimal front showing how endurance relates to weight. Each dot in the figure represents a full CAD design, optimal propulsion system combination, while meeting mission related performance requirements such as cruise speed, payload capacity, stall speed etc.

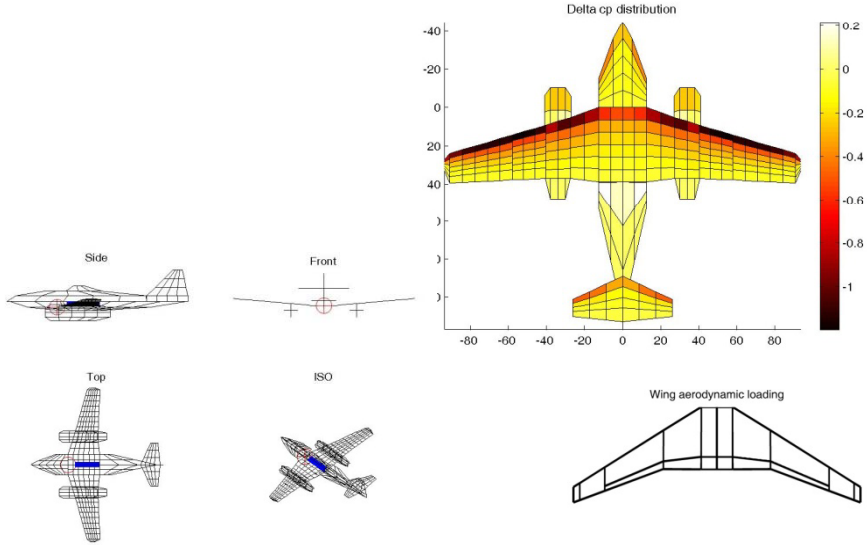


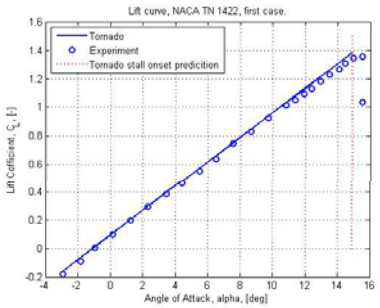
Eco Sports plane

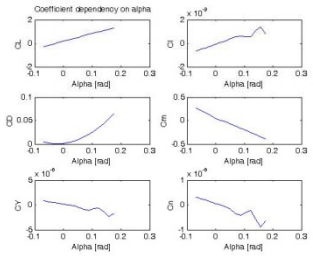
Tornado

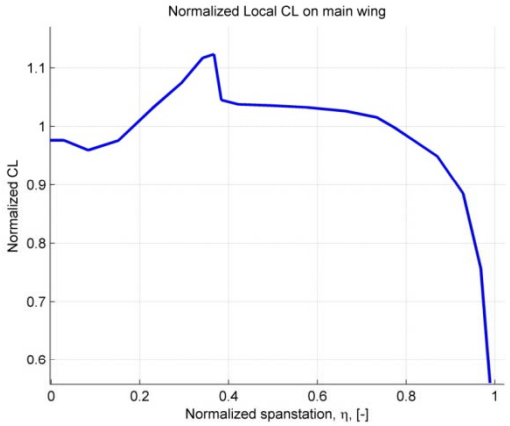
a Vortex Lattice Method implemented in Matlab

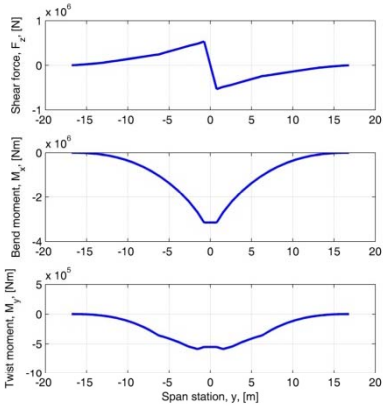
Tornado is an aerodynamic modelling software which allows for almost instantanious computation of the aerodynamic properties of an aircraft











Tornado Computation Results

JID:	q1	Downwash matrix condition:	15.6925		
Reference area:	356.3147	Supersonic flow warning:	0		
Reference chord:	6.6941	Reference point pos:	10.2345	0	-0.9
Reference span:	56.4	Center of gravity :	0 0 0		

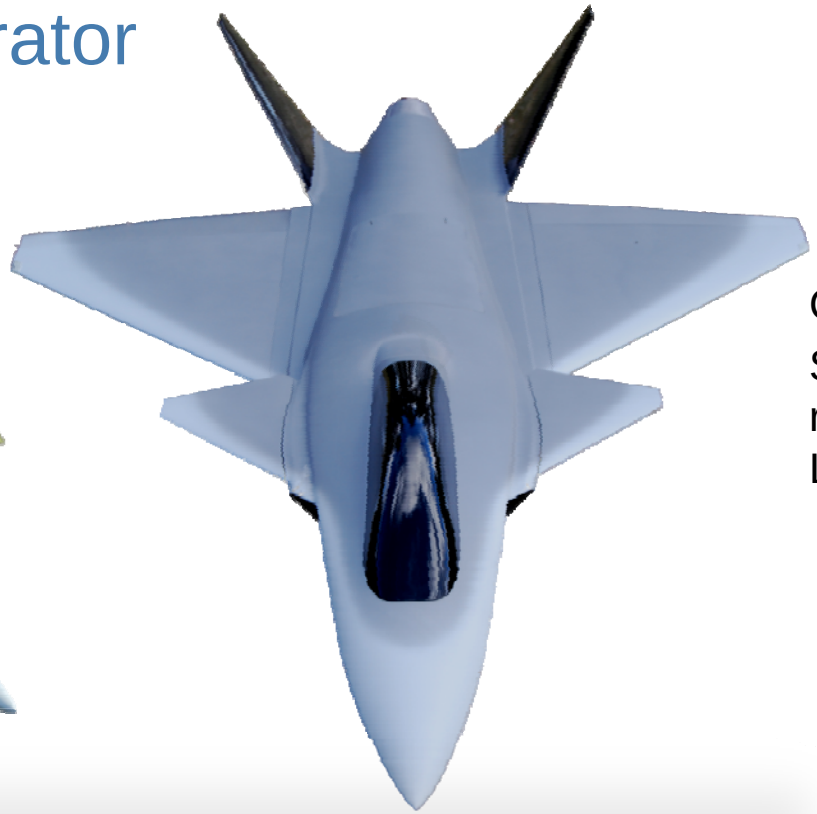
Net Wind Forces: (N)		Net Body Forces: (N)		Net Body Moments: (Nm)	
Drag:	16943.0468	X:	-36672.9444	Roll:	0.035674
Side:	-0.0082944	Y:	-0.0082944	Pitch:	-482588.9878
Lift:	1024014.3716	Z:	1023497.726	Yaw:	-0.1792

CL	0.4778	CZ	0.47756	Cm	-0.033698
CD	0.0079056	CX	-0.017111	Cn	-1.4825e-009
CY	-3.6701e-009	CC	-3.6701e-009	Cl	2.9513e-010
$CD_{trefftz}$	N/A				

STATE:

α [deg]:	3	P [rad/s]:	0		0 0
β [deg]:	0	Q [rad/s]:	0	Rudder setting [deg]:	0 0
Airspeed:	177.922	R [rad/s]:	0		0 0
Altitude:	10660	PG Correction:	1		
Density:	0.38001	Mach:	0.6		

Generic Future Fighter (GFF) Subscale Demonstrator



Concept developed by Saab

Subscale demonstrator build on request from FMV and Saab at Linköping University

Real Jet Engine with
170 N thrust a
Length 2.4 m
Span 1.5 m
Weight 15 kg
13% scale

Project Goals

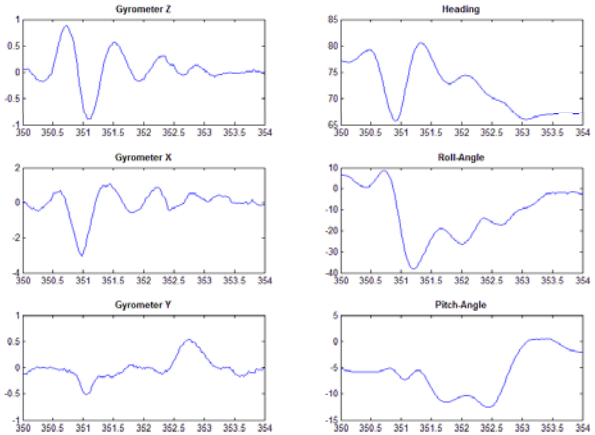
- Show a cost effective way, with short lead time, to design and manufacture a flying demonstrator of a concept, that can be used already in preliminary design, for project risk mitigation.
- Evaluate the usage of scaled demonstrators as a tool for aircraft development, e.g. as "flying wind tunnel".

Subscale Flight Testing

- Methodology and instrumentation is developed on jet powered Rafael model.
- Subscale flight testing as *flying wind tunnel*

Tufting for flow visualisation in flight

In flight step response: Rudder deflection



Full Mission Simulation for Aircraft Design

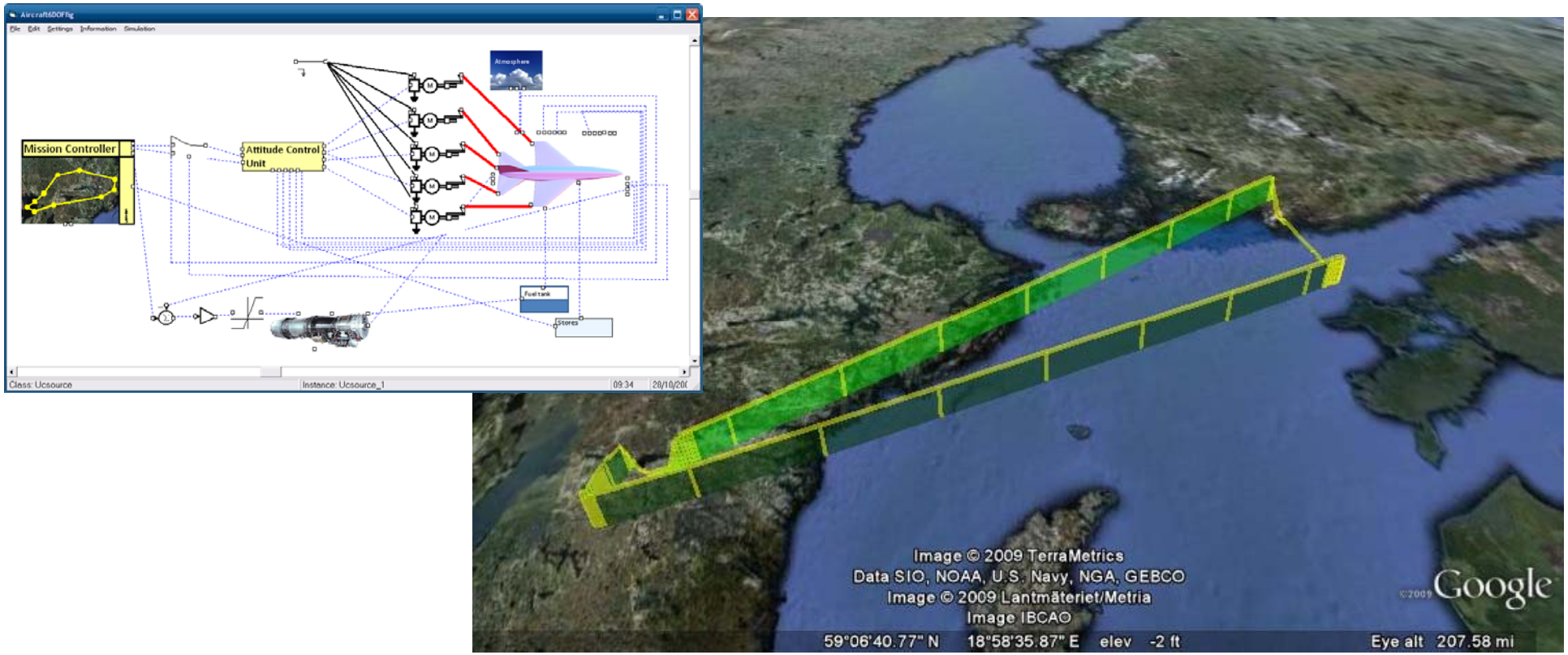
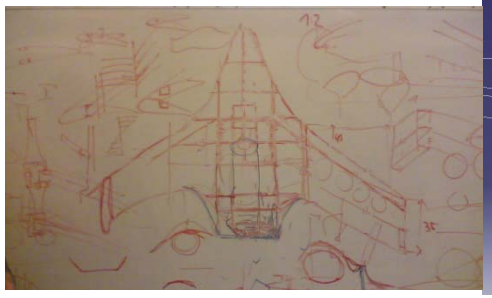


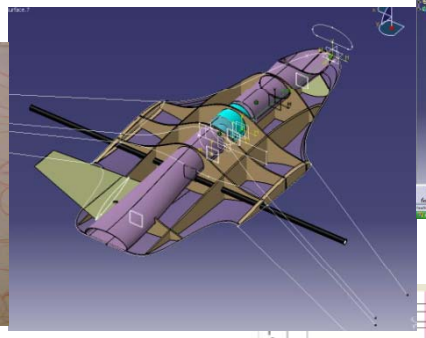
Figure 5. Simulated flight path (Furthest distance about 45 km from start point). Altitude scale is amplified 20 times for the plotting.

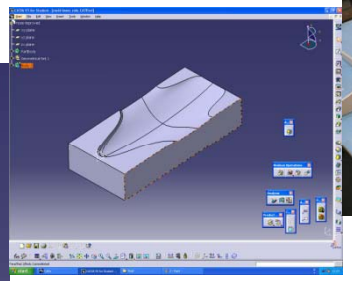
(6000 sec simulated in 105 seconds (normal PC), time step 0.01 sec)

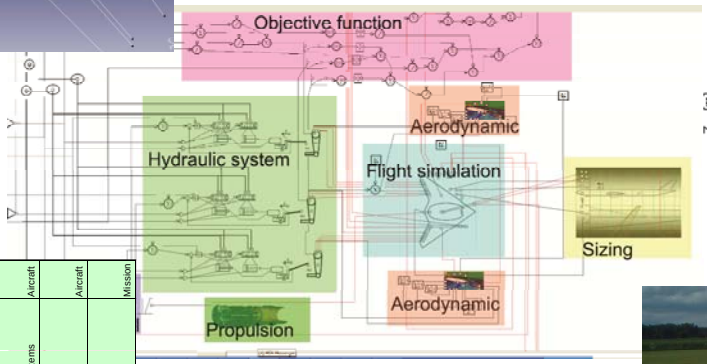
GFF Project Team

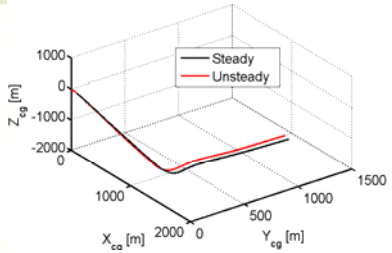
Student Projects:
From sketch to physical prototype in 5 months



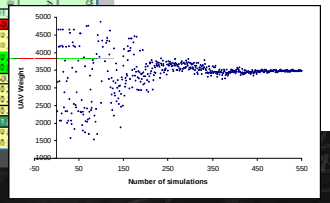








				Aircraft	Aircraft	Aircraft	Aircraft	Aircraft	Aircraft	Aircraft	Aircraft	Aircraft	Aircraft	Aircraft	Mission
				Structure	Structure	Structure	Structure	Structure	Structure	Structure	Airframe	Propulsion system	Systems		
				Wing	Wing	Wing									
				B	Cr	Ct									
System characteristics	Unit	Target value	Actual value	20,00	6,89	2,07									
Range	km	5000,00	5490,87	-0,09	-0,45	-0,10									
Liftoff distance	m	500,00	393,93	-1,46	-0,37	-0,17									
Landing distance	m	500,00	104,18	-0,37	-1,32	-0,32									
Takeoff weight	N	60000,00	85865,23	0,00	0,00	0,00									
Required weight quotient		1,00	0,98	0,08	-0,03	-0,01									
Optimal cruise speed	m/s	100,00	146,68	-0,68	-0,11	-0,07									
Landing speed	m/s	70,00	25,48	-0,50	-0,38	-0,12									
Liftoff speed	m/s	70,00	30,33	-0,50	-0,38	-0,12	0,00	0,00	1,00	1,00	0,25	0,19	0,00	1,43	0,00
Stall speed	m/s	80,00	50,55	-0,50	-0,38	-0,12	0,00	0,00	1,00	1,00	0,25	0,19	0,00	1,43	0,00
Emissions		10000,00	18869,74	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00	1,00	0,00
MTBF	hour	1000,00	7324,98	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,27	0,00	1,00	5,27	0,00
Cost	kEUR	40000,00	57060,64	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,77	0,24	0,02	1,02	0,00



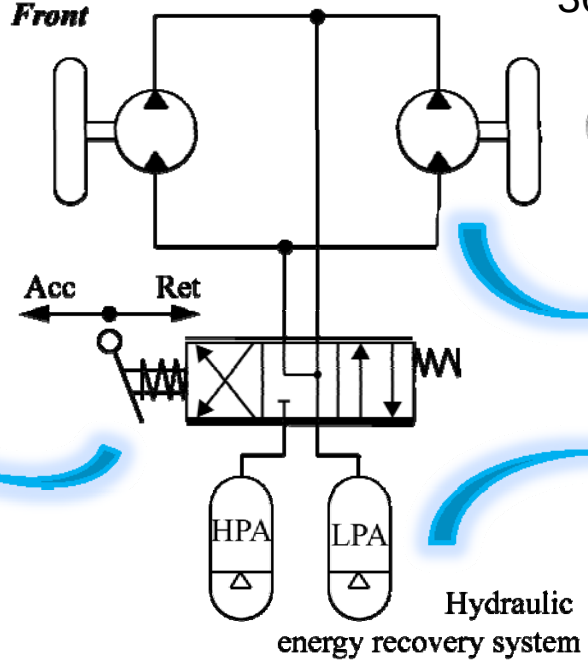
Some Previous Student Projects

2007 *Modulith*

Modular light electric utility vehicle for

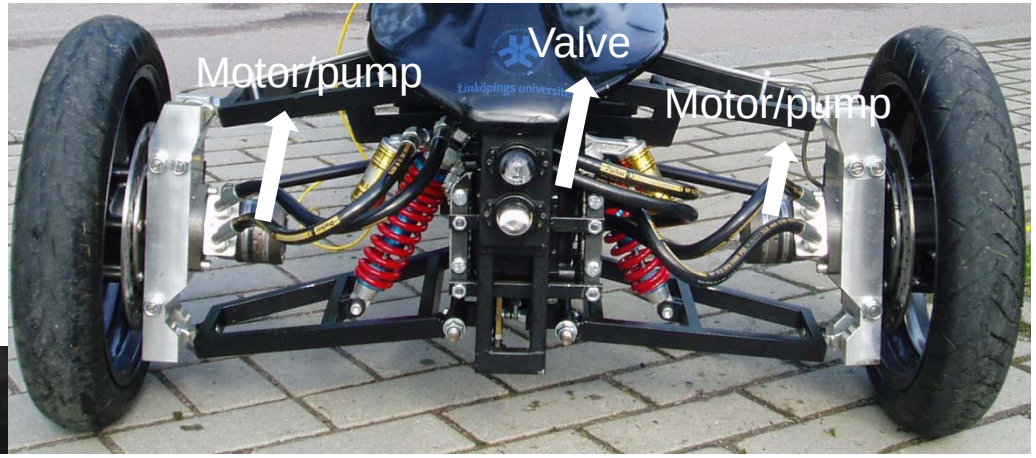
Formula ATA Electric and Hybrid Vehicles, Class 2, Rome 2009.

The Electric and Hydraulic Propulsion Systems



36 cm^3/rev Gerotor

2.5 litres gas bladder accumulator



SSF/ProViking. Hi Performance Simulation for System Design and Operation – HiPO

-*Using the same models throughout the lifecycle*

System level design

- System simulation for design optimization and analysis
  High Speed Simulation HSS
- Human in the loop simulation, *Real time simulation RTS*

Subsystem design

- System simulation for design *HSS*
- Hardware in the loop simulation *HWIL, RTS*

Prototype testing and evaluation

- Dynamic testing using HWIL, *RTS*

Operation

- Training simulators, *RTS*
- Embedded simulation models for condition monitoring and control
  RTS and faster than real time simulation, FRTS
- Mission planning
  Faster than real time simulation, FRTS

HiPO - Research Areas

- Real-time Simulation (RTS), and Faster than Real Time Simulation (FRTS) Technologies
  - Distributed modeling
  - Parallelization of simulation models for multi-core processors
  - Hardware in the loop simulation
- Model fidelity and management
- Using bilateral delay line (transmission line modelling, TLM) for model partitioning

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

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

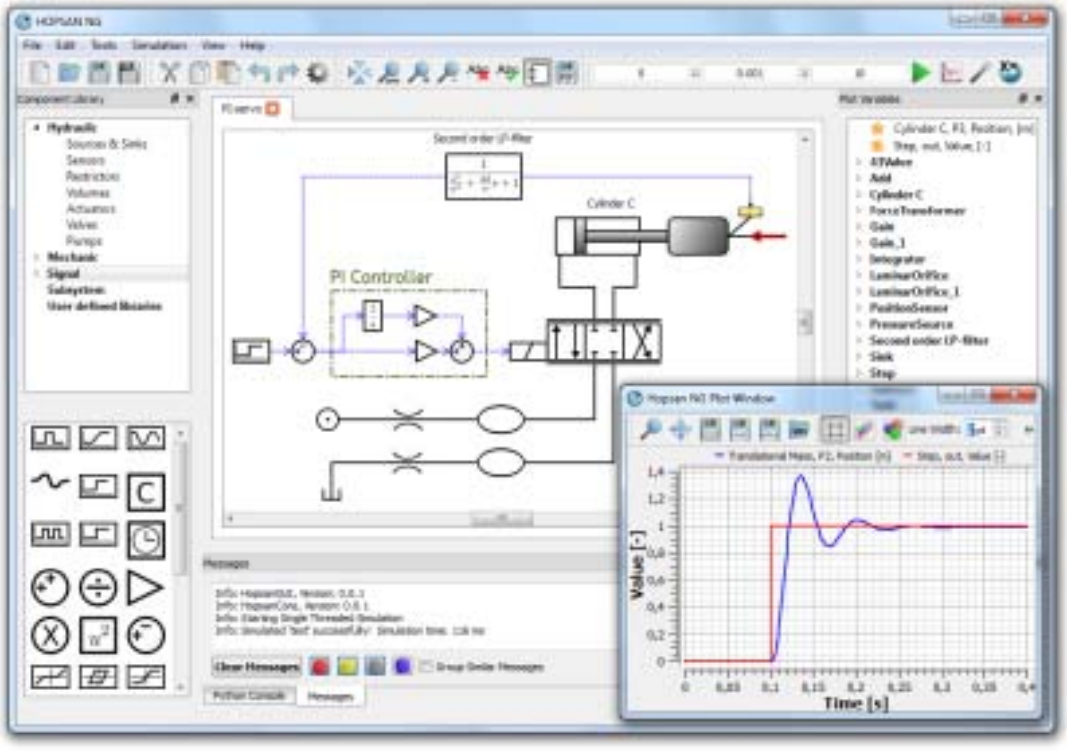
Drivers for this Project

- Mainstream simulation technologies assume single solver strategies, which is may give efficiency and instability problems for multi domain systems, such as mechanical, hydraulic, and electric.
- High fidelity simulation in real time is not possible for other than simple systems
- Multi core architectures are not used effectively
- Present technologies requires central solvers and do not allow the flexibility of each model component having its own solver.

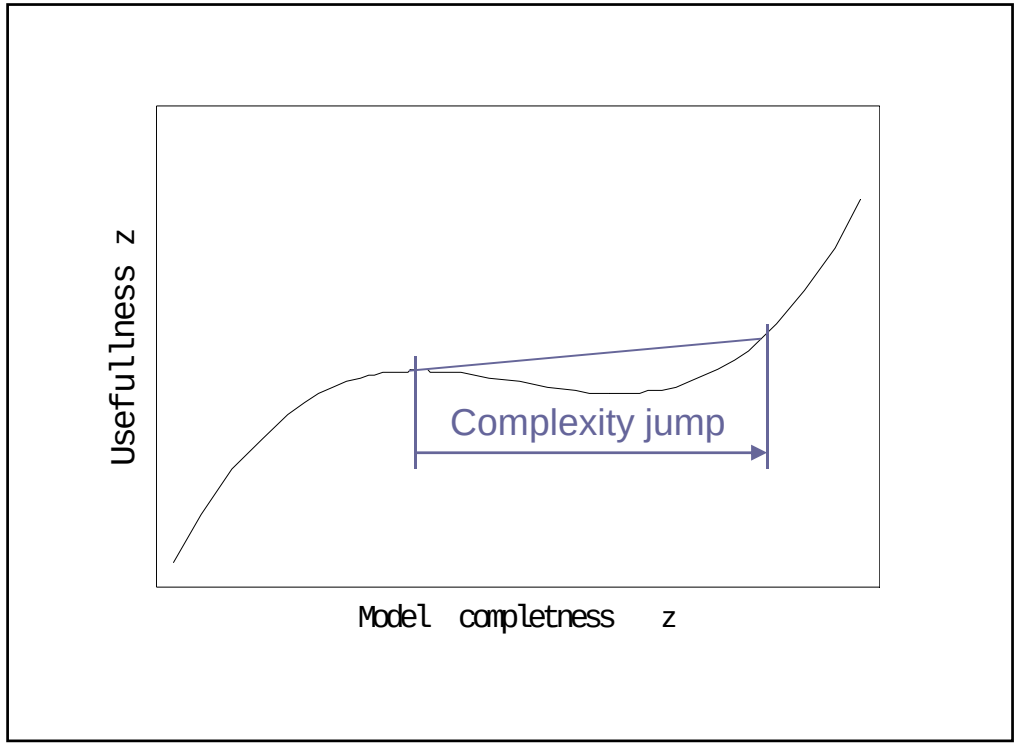
HOPSAN-NG (Next Generation)

- Bidirectional delay-lines
- Modelica support is under development
- Genuine team work
- Relased on this MODPROD workshop

Friday afternoon workshop= “happy hour”



The usefullness of simulation



Simulation is going through a rapid transition from simple problem dependent models, to highly complex, multi domain, problem independent models

Development in modelling and simulation in complex mechanical systems

- Modelling and simulation of most of the Space Shuttle hydraulic system in the 70's. (HYTRAN).
- Hardware performance up 100 times/10years (that is 10,000,000 times in 35 years)
- System simulation development has been remarkably slow in progress.

System Simulation in a Context

- Maintain and develop laboratory resources
- Modelling and simulation technologies
- Design analysis and optimisation
- Applications: Mechatronics, hydraulics, construction machines, road vehicles, and aircraft.
- Keywords: System dynamics, and system efficiency
  - *Design – model – simulate –analyse – prototyping – evaluation and testing*

Linköping University
INSTITUTE OF TECHNOLOGY

FluMeS

Fluid and Mechatronic Systems

CRL
CONCEPT REALISATION LABORATORY