



Skandinaviens nordligaste tekniska universitet  
**Forskning & utbildning i världsklass**

# Automatic Control

## Research tracks

Thomas Gustafsson



# Automatic Control

**Richard Feynman** (Nobel prize 1965)

*Physics is mathematics constrained by reality.  
Engineering is physics constrained by money.*

Automatic  
Control

## Control Theory

Generalized **mathematical** theory  
Illustrated in simulation  
Usually not directly applicable

Mathematics

## Control Engineering

Makes theory **practically useful**  
Verified in **reality**.  
Generates need for new theory

Applications

# Automatic Control

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- Automatic control is built on mathematics and is application agnostic
- Our research focus is to develop theories and methods for
  - designing robust adaptive low complexity optimal feedback control systems for large complex and data-rich systems
  - modelling of large dynamical systems based on data and/or first principles
  - modelling of (statistical) properties for disturbances
  - estimation and classification of system properties from large data sets.
- As a control engineering subject, we always apply and verify methods in real life

# First publication

## High-Accuracy Sounding Rocket Attitude Estimation Using Star Sensor Data

BENGT SCHMIDTBAUER  
University of Luleå, Sweden

### Abstract

A three-axis attitude reconstitution scheme for spin stabilized sounding rockets is presented, using star transit pulse information from a single slit all solid state star sensor. The method, based on Kalman filtering and smoothing, gives accuracies in the arcminute range and has been successfully tested on four different missions in the Swedish sounding rocket program.

### I. Introduction

For many sounding rocket attitude time history is needed in a convenient manner. In the common large attitude deviations conditions, unpredictable vibrations, etc. Thus the attitude angles, which can be done, meters, infrared sensors, su

High-precision attitude; however, the extreme acceleration phase of powered flight needs high quality components to initial alignment requirements. Strains on flexibility in the gimbal freedom, alternative feedback, is generally needed offsets and coning amplitudes.

No precision measurements use of magnetometers, due to reference (geomagnetic) disturbance. Measurements are exercised in the rocket more, as in the sun sensor undetermined, since only available.

The stars and planets off reference directions with a craft attitude reference objects. Truly practical attitude measurements, one needs the

- 1) A sensor—a solid state star sensor—has several advantages in terms of reliability; due to the transit times the signal parameter in the design.
- 2) A reconstitution scheme of pulses at instants of attitude being non-linear requires computer utilization of the star

This paper describes a reconstitution scheme for the Swedish sounding rocket program on the Nike-Tomahawk missile at Esrange, Kiruna, in January 1978.

Manuscript received  
Author's address: Un  
Wisconsin, Dept. of E  
0018-9251/78/11004

IEEE TRANSACTIONS



Bengt A. Schmidtbauer was born in Berlin on May 8, 1939. He received the Civ. Eng. degree in physics from Chalmers University of Technology, Göteborg, Sweden, in 1961 the S.M. degree from M.I.T., Cambridge, Mass., in 1965, and the Ph.D. degree in control from Chalmers University of Technology in 1973.

From 1962 to 1974 he was with the SAAB-SCANIA Company in Sweden working on guidance and control problems in aerospace and other areas. Since 1974 he has been a lecturer in control and industrial electronics at the University of Luleå in Luleå, Sweden.

During the current academic year he is visiting associate professor at the University of Wisconsin-Madison, Department of Mechanical Engineering.

Publikationsdatabasen

Sök i hela Publikationsdatabasen

Publikationer  
Forskningsprojekt  
Aktiviteter  
Doktorsavhandlingar  
Licentiatuppsatser  
Dataset

Forskningsämnen  
Disputationer & lic. seminarier  
Statistik

Examensarbeten  
Sök  
Lägg in  
Gör så här  
Länkar

Reglerteknik

Översikt Forskare Publikationer Forskningsprojekt

501 - 503 av 503 Vy: Standard Sortera enligt: Utgivningsdatum

1979

Belastningscykel hos dieseldrivna fordon under jord för renare avgaser: Slutrapport Publicerad  
Rehnberg, O. & Schmidtbauer, B. 1979 Luleå: Högskolan i Luleå. 36 s. (Teknisk rapport / Högskolan i Luleå; Nr 1979:01T).  
Publikation: Forskning > Rapport

Report on engine system and microprocessor activities at the University of Wisconsin, Madison 1978-79 Publicerad  
Schmidtbauer, B. 1979 Luleå. 7 s. (STU-rapport; Nr 78-3326).  
Publikation: Forskning > Rapport

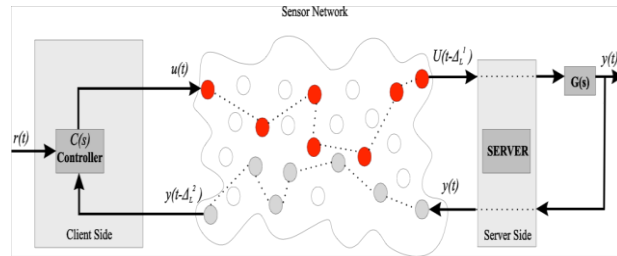
1978

High-accuracy sounding rocket attitude estimation using star sensor data Publicerad  
Schmidtbauer, B. 1978 I: IEEE Transactions on Aerospace and Electronic Systems. 14, 6, s. 891-898 8 s.  
Publikation: Forskning - peer-review > Tidskriftsartikel

Föregående 1 ... 47 48 49 50 51 Nästa

### II. The Sensor

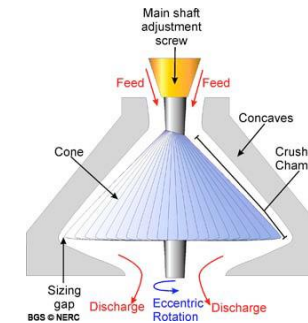
# Many application areas – Same methods (almost)



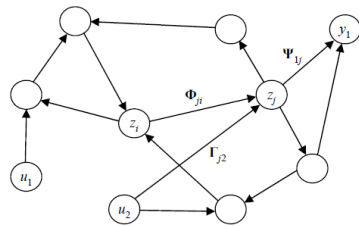
**Distributed Estimation & Control**



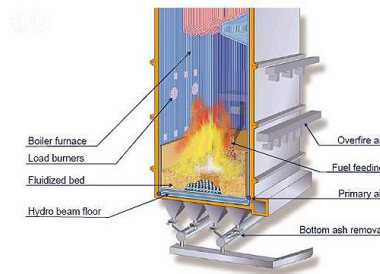
**Pulp & Paper**



**Mining**



**Structural Analysis**



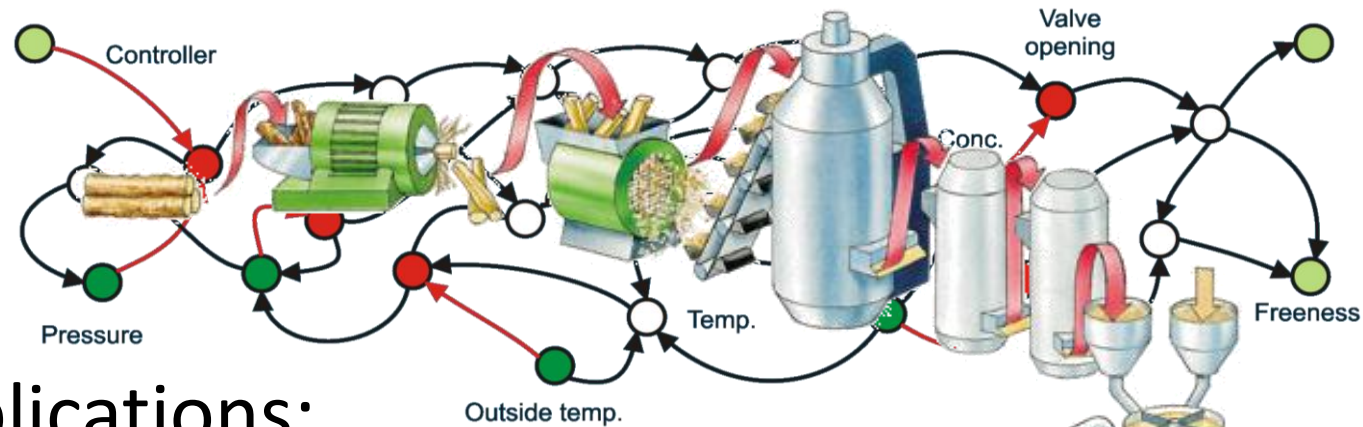
**Sustainable Energy and Environment**



**Field Robotics - Autonomous vehicles**

# Process industries are large scale and complex

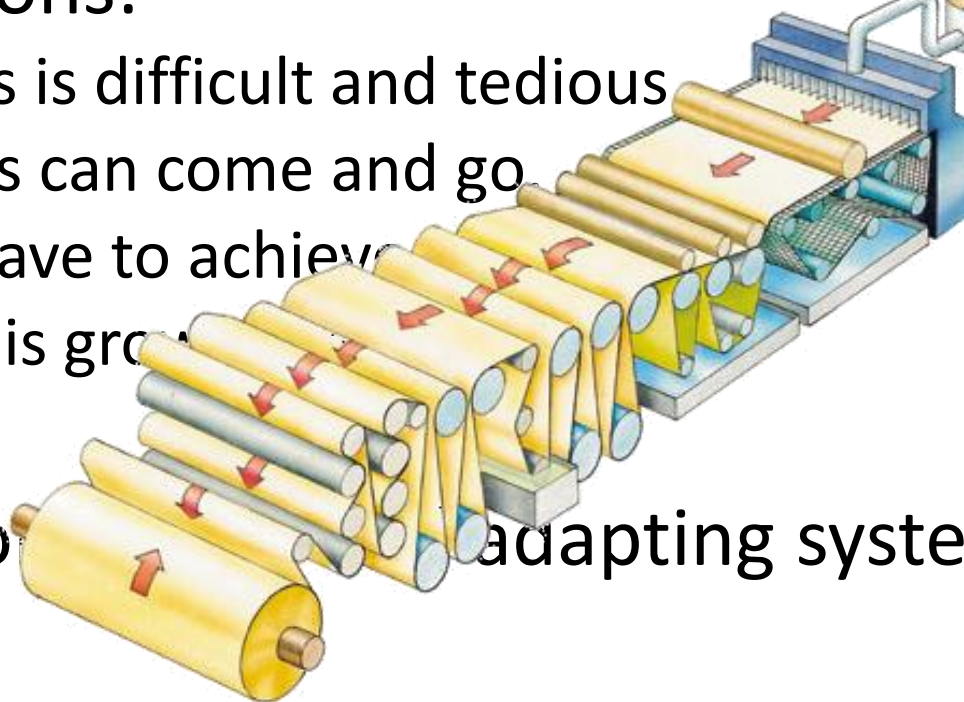
- We need to deal with large scale complex systems



- Some complications:

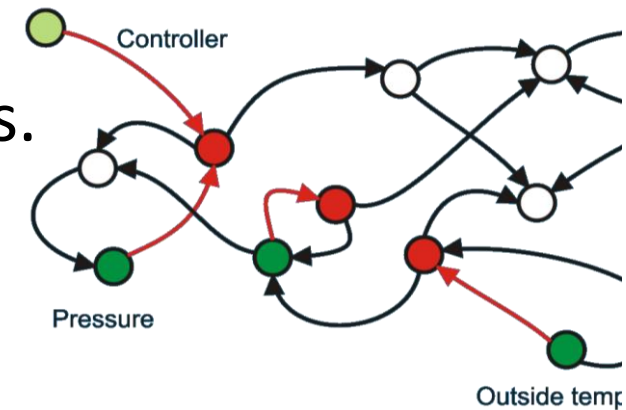
- Creating models is difficult and tedious
- The connections can come and go
- Fewer people have to achieve
- The population is growing

- Needed: Trustworthy adapting systems

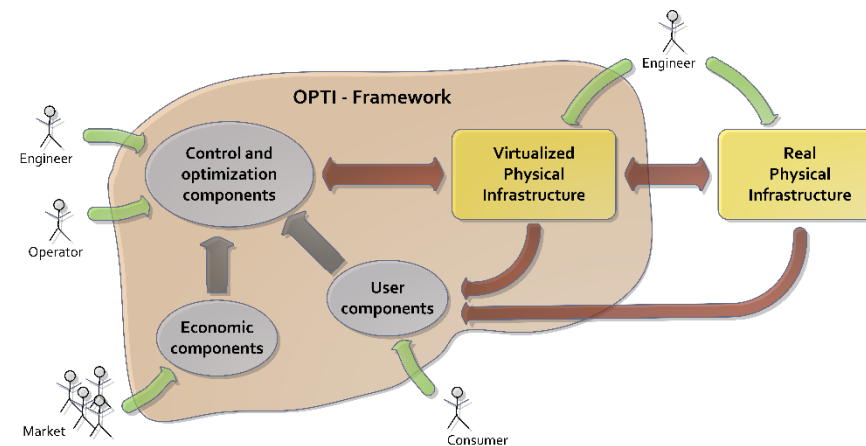
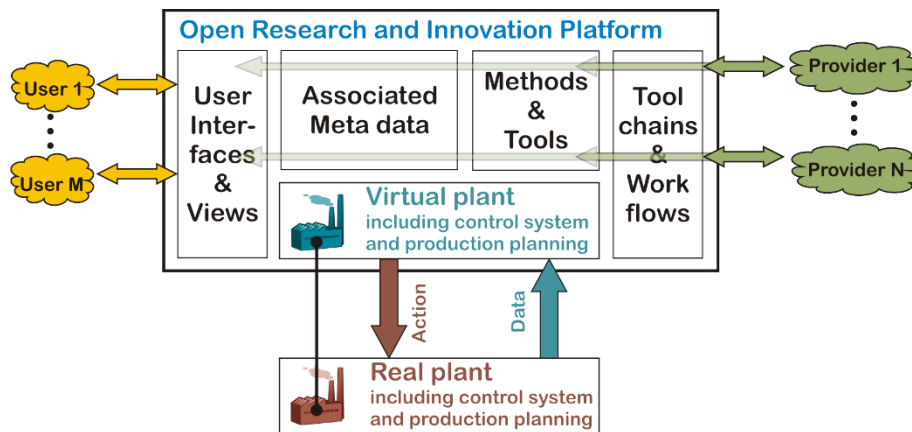


# Efficient design of control strategies

- Reconfiguration of control systems.
- Data-driven decision making on control structures.
- Robustness of control structure selection.



- Towards system autonomy: Digital twins.



# Past projects in pulp and paper

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- **SCOPE**

Collaboration of major pulp & paper industries in the north. Both long term and short term activities

- **MeSTA – Methods for structural analysis**

Project that created methods to determine control strategies for processes. Open Source tool ProMoVis.

- **EQoRef – Energy efficiency of pulp refiners**

Model based approach to understand and improve refiner operation. Mainly together with Mondi Dynäs



# On-going Activities

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- **OPTi project**

Optimisation of district heating and cooling systems. Treated as a process industry plant.



- **PiiA-WARP (VINNOVA PiiA)**

Reconfiguration of processes using wireless components

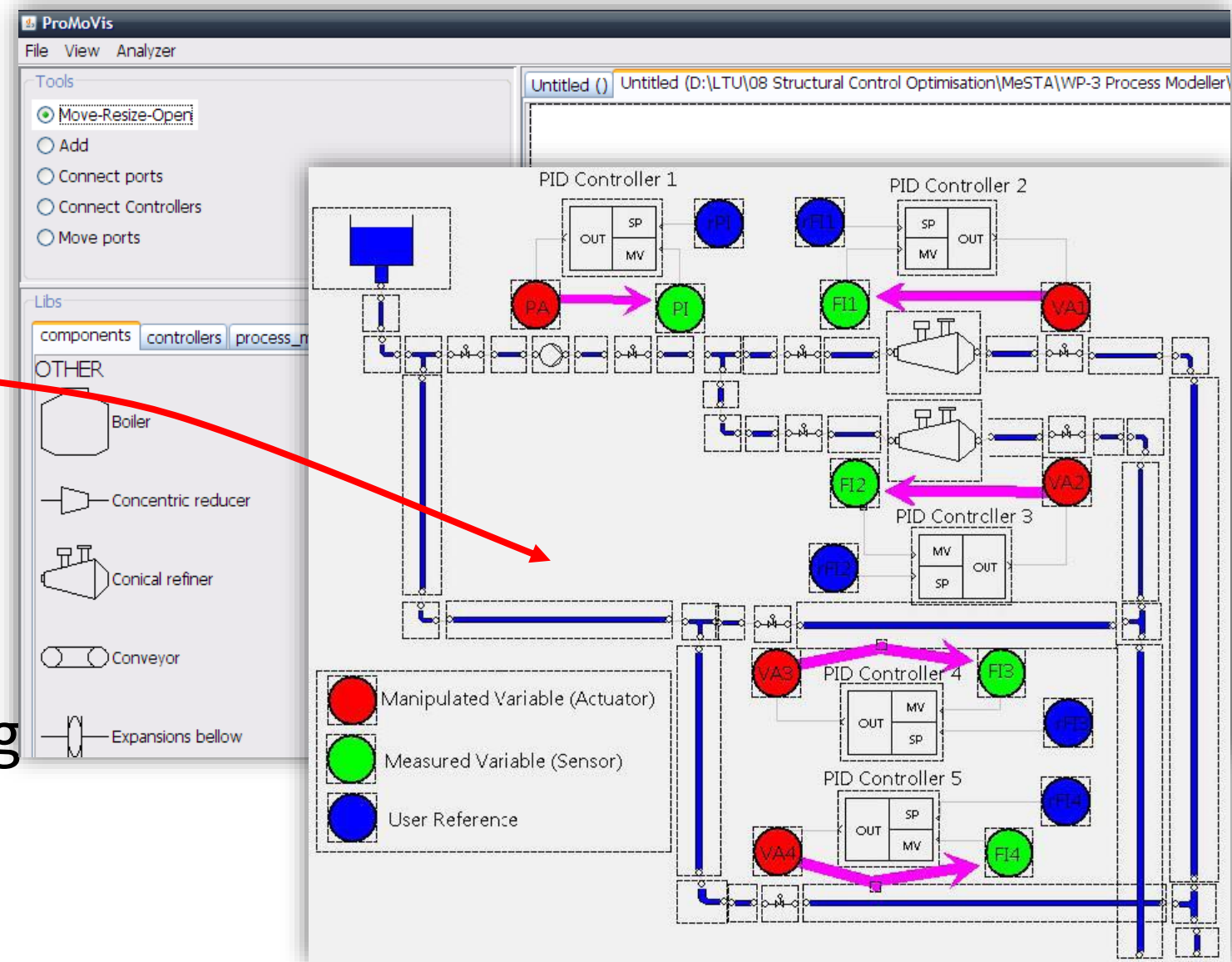
- **AutoMod-Pre (VINNOVA PiiA)**

Automated model generation of process industry plant. At the moment together with SSAB.

# Open Source tool ProMoVis

## Tested on several cases in P&P:

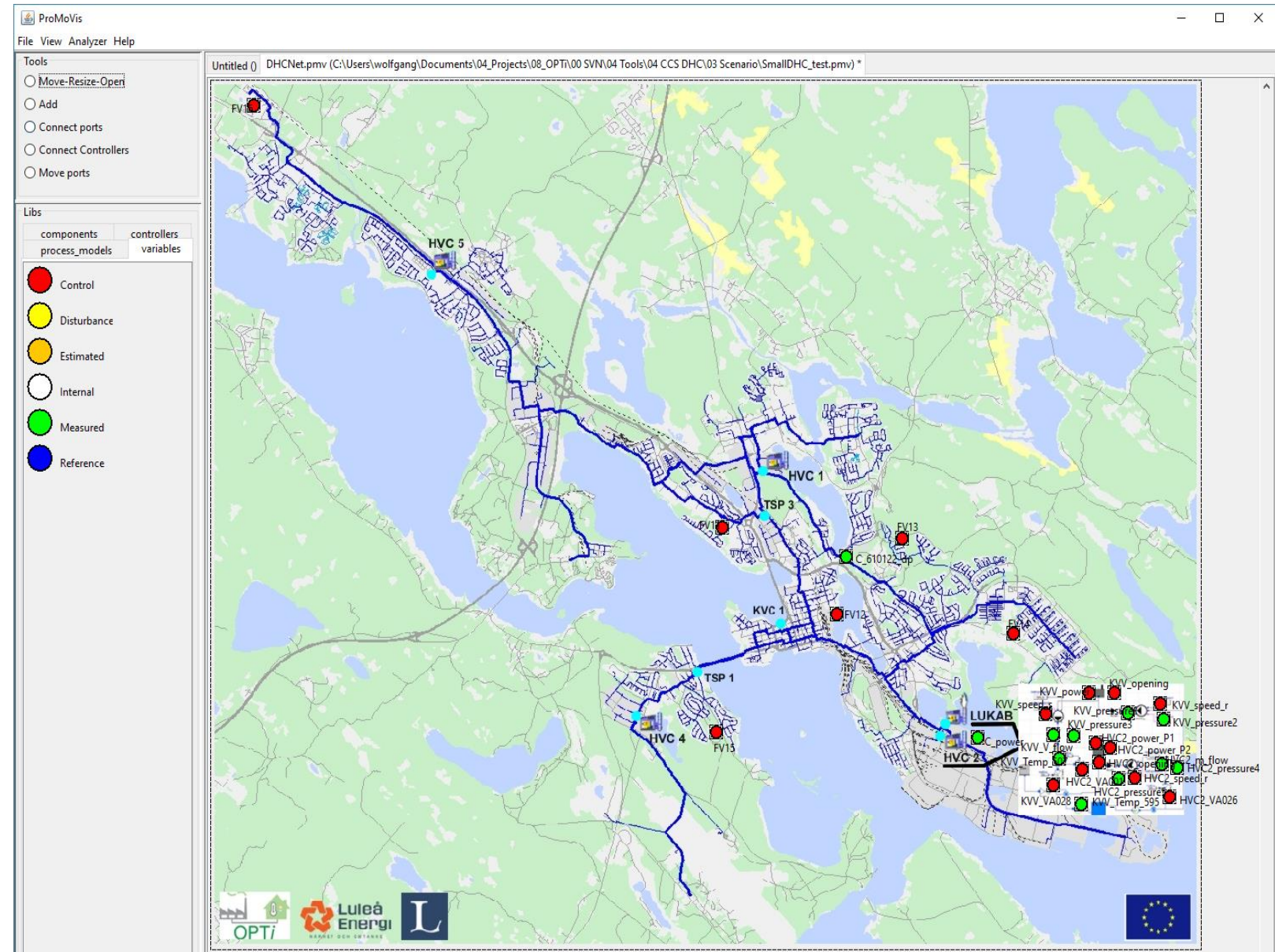
- Stock preparation plant at SCA Obbola
- Bark boiler at SCA Obbola
- Secondary heating at Billerud Karlsborg



# Open Source tool ProMoVis

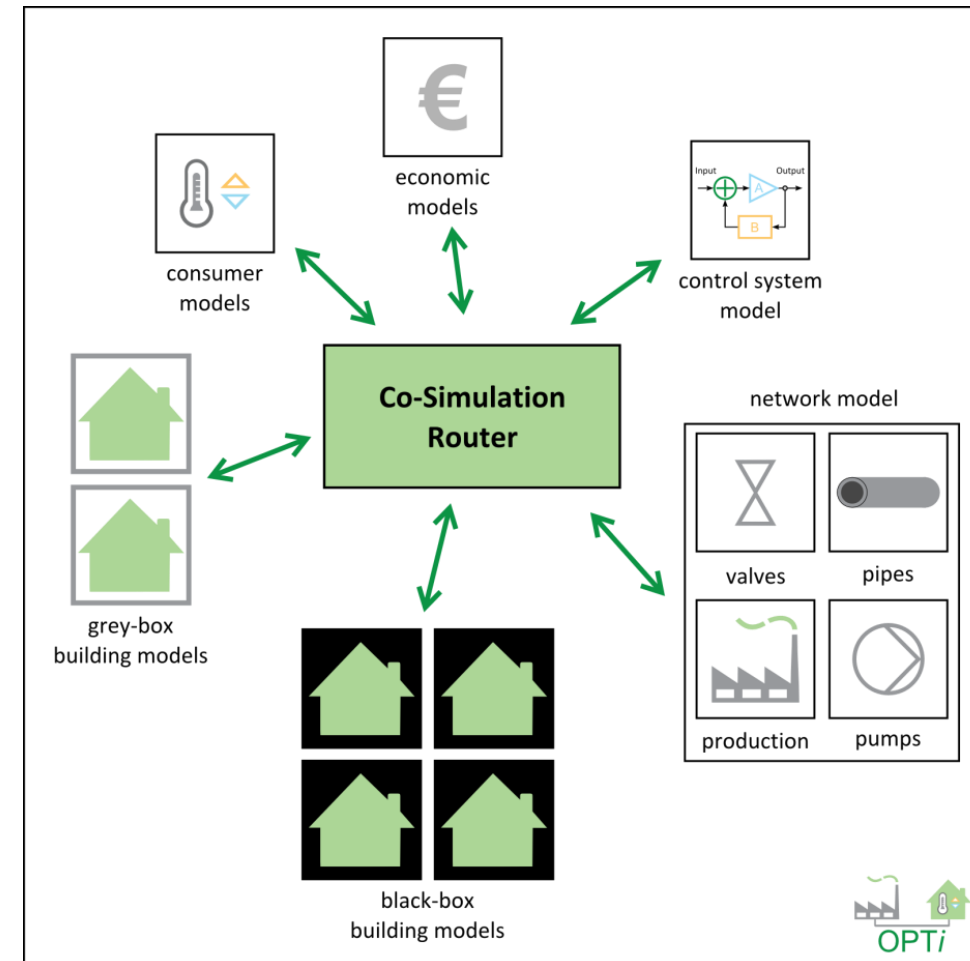
## District heating in Luleå:

- 46000 pipes
- 800km in length
- 4 production units
- Large number of valves, pumps, HEX.
- Ongoing!



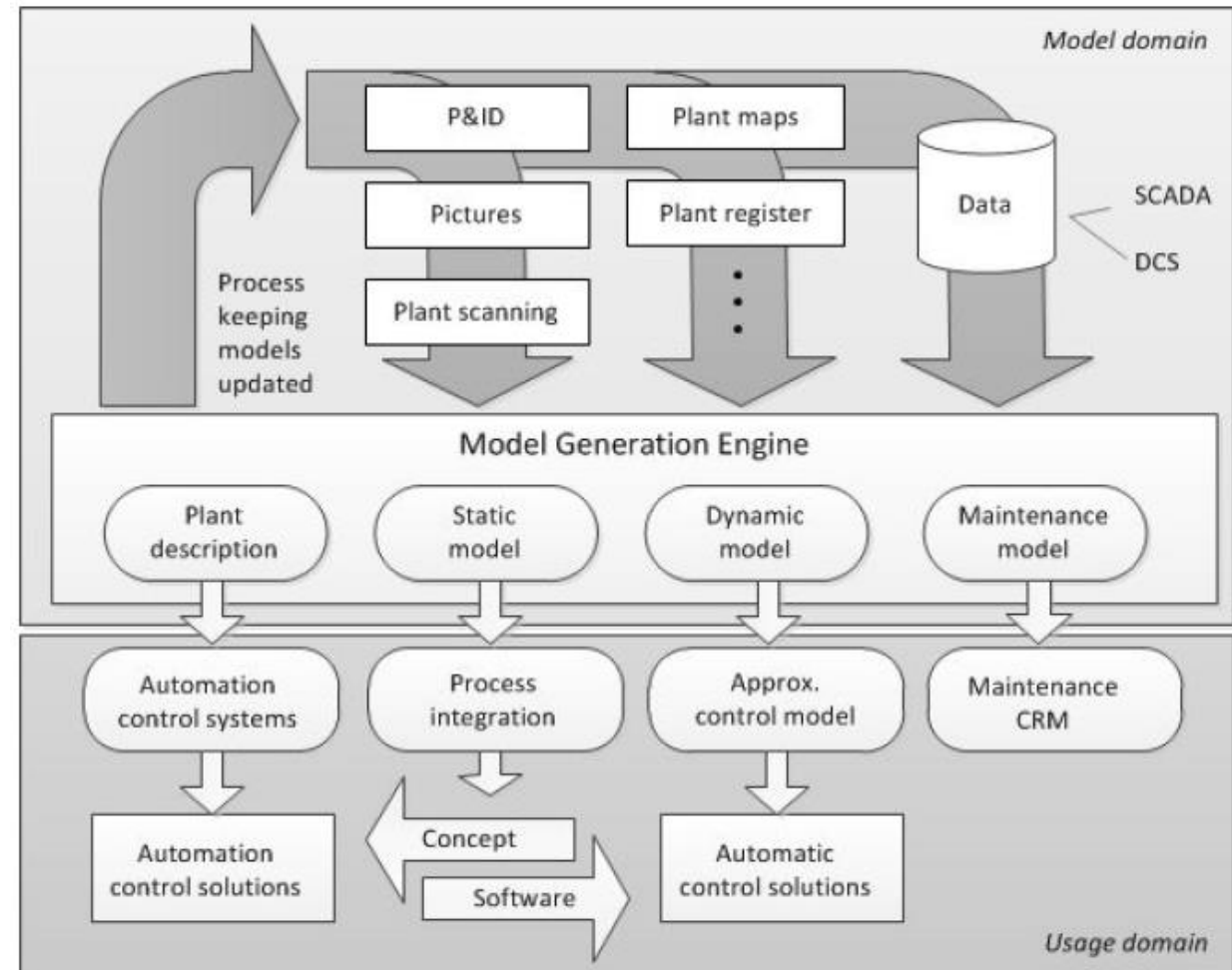
# Modeling and simulation of Large scale systems

- Models are the basis for advanced control and monitoring solutions
- In OPTi the complete grid was modelled in an automated fashion.
- A digital twin was build where building models were created using machine learning methods



# Automated model generation

- Models need to be generated and re-generated automatically!
- Use-cases:
  - Simulation study for better operation
  - Training simulation
  - Control (re-)design
  - Condition base monitoring
  - Predictable refurbishment
  - etc.



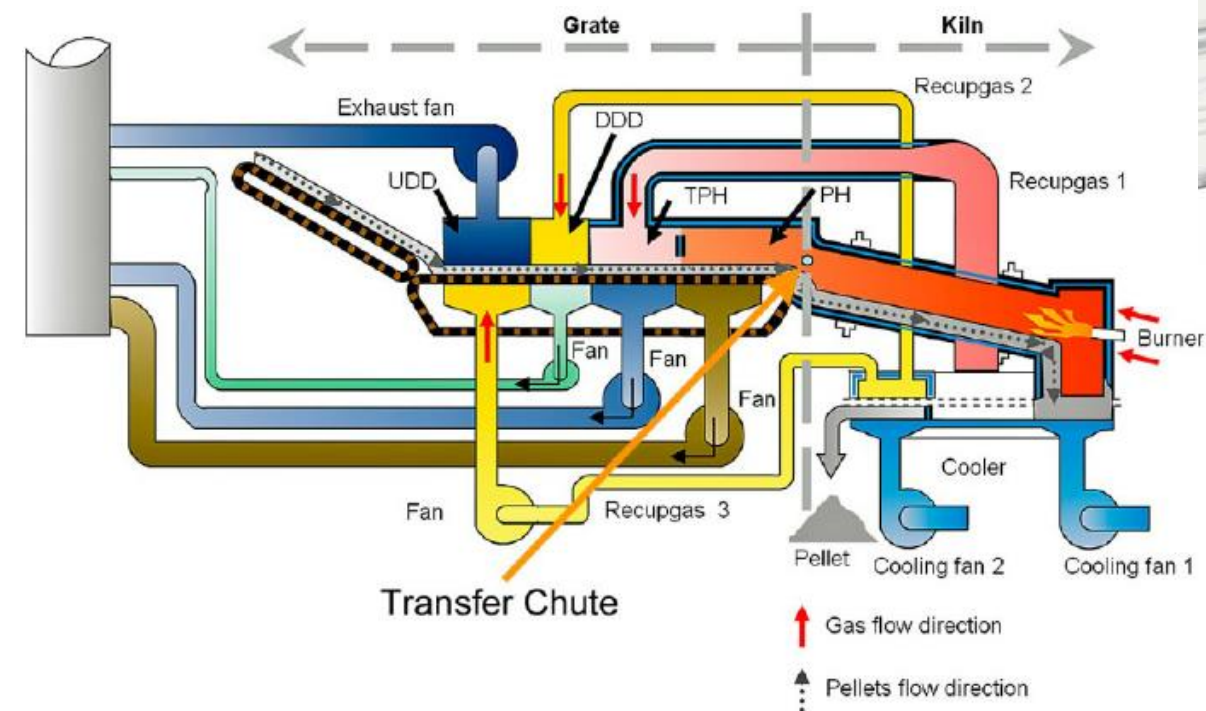
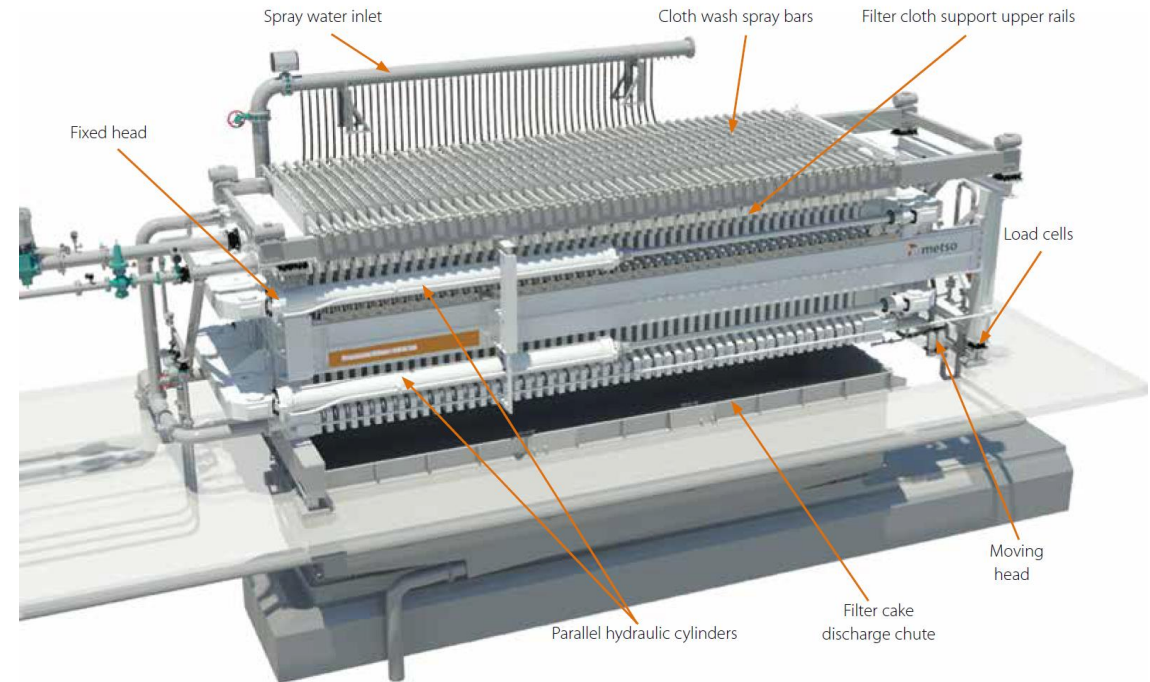
# Condition based maintenance methods

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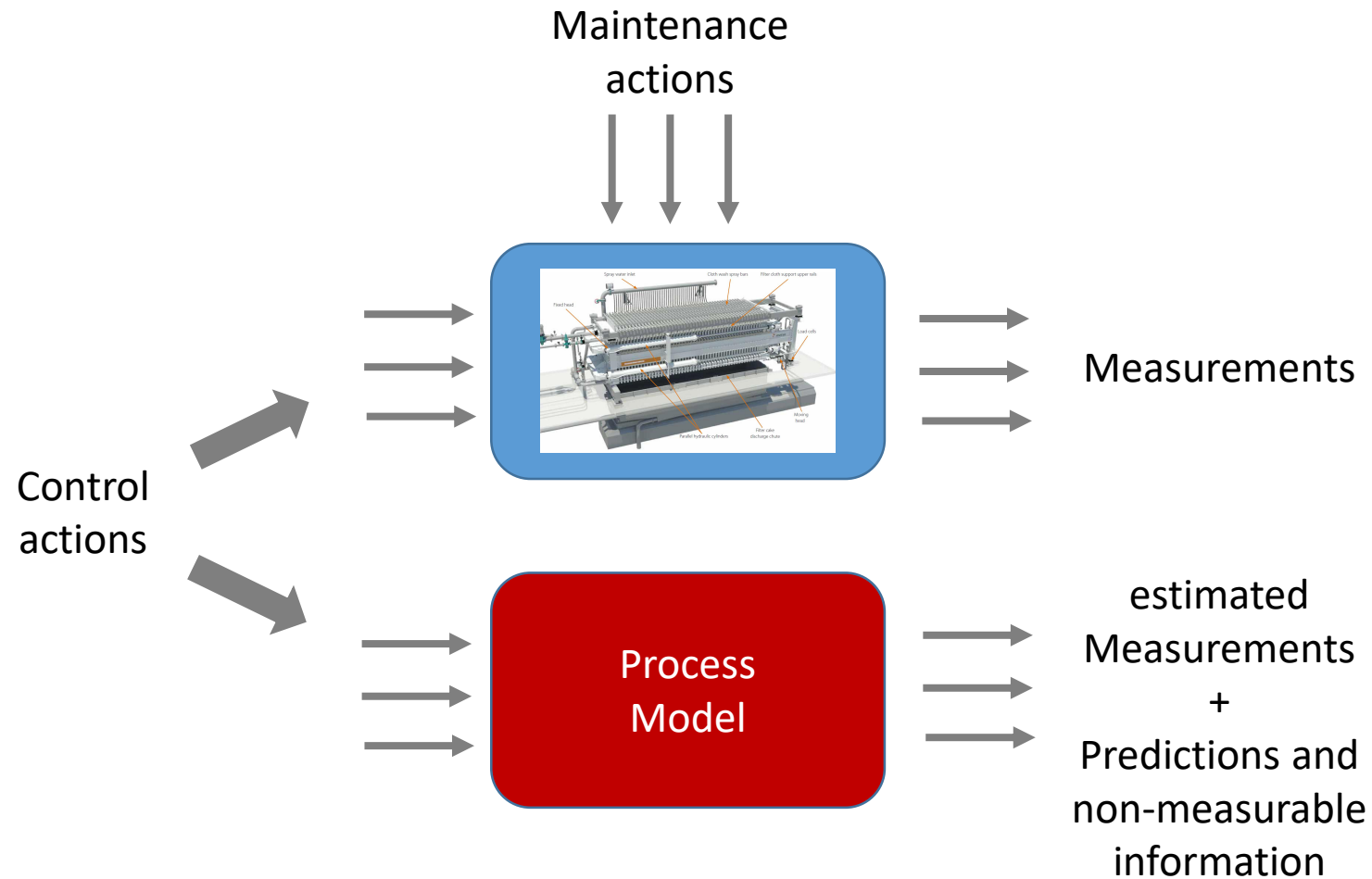
- Joint effort with
  - LKAB
  - LTU – Operation and Maintenance
  - LTU – Control Engineering Group
- Topic: Combine condition monitoring and eMaintenance methodologies for mining processes
- Goal: Make maintenance more effective and increase availability and productiveness of processes

# Application cases:

- Vertical plate pressure filter
- Grate-Kiln

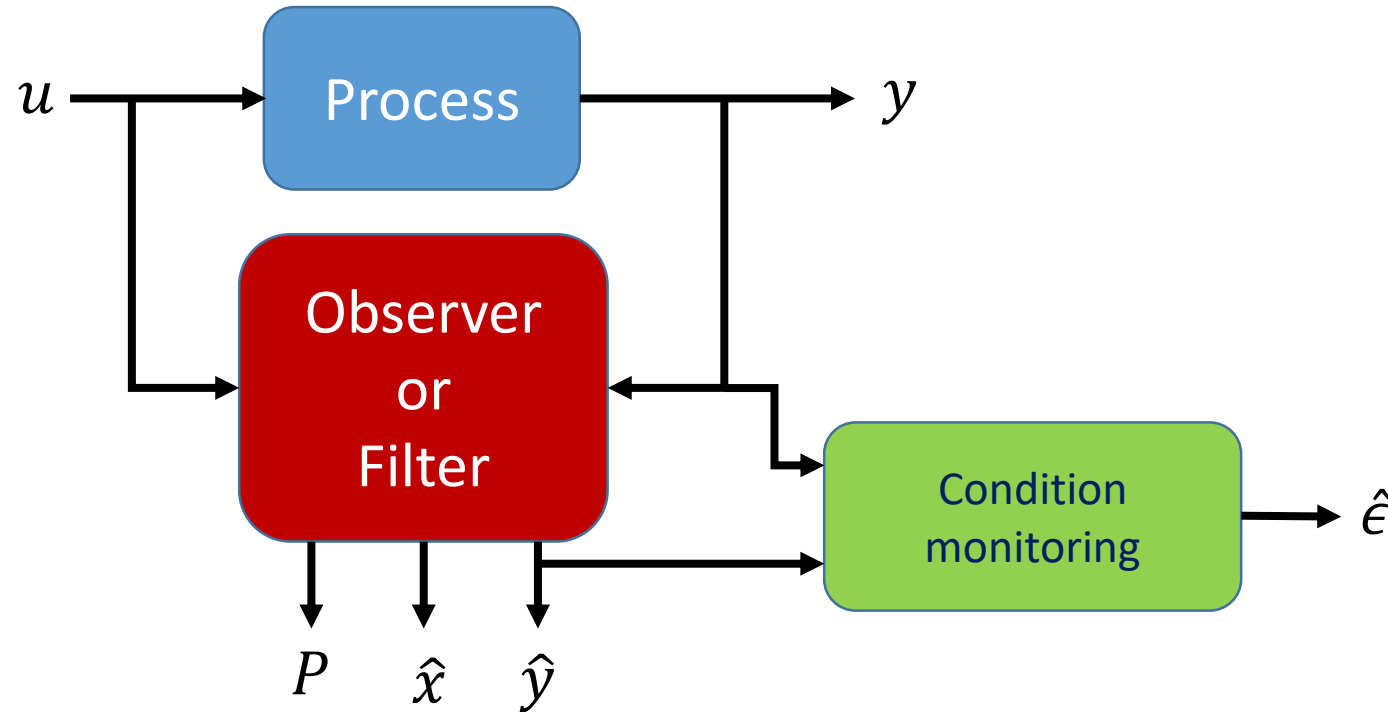


# A principle sketch





# Principle sketch (2/2)



- Needed:
  - Prognostics for maintenance
  - Prescriptive maintenance

# Collaborating Autonomous Aerial Vehicles



*The AEROWORKS robotic team will consist of multiple heterogeneous “collaborative Aerial Robotic Workers”, a new class of Unmanned Aerial Vehicles equipped with dexterous manipulators, novel physical interaction and co-manipulation control strategies, perception systems, and planning intelligence.*

# Collaborating Autonomous Aerial Vehicles

- **Exploration, localization and navigation** in unknown environment
- **Sensor fusion:** Vision, IMU, Accelerometers, ultrasound, **UWB 3D Localization**, Lidar, ....
- **Optimal control** for path following, obstacle avoidance, coordination and battery life



## Widefind kom med i nationell rymdsatsning

LULEÅ Widefind från Luleå är ett av åtta bolag i Sverige som har blivit utvalda att delta i den nationella rymdsatsningen, ESA BIC Sweden.



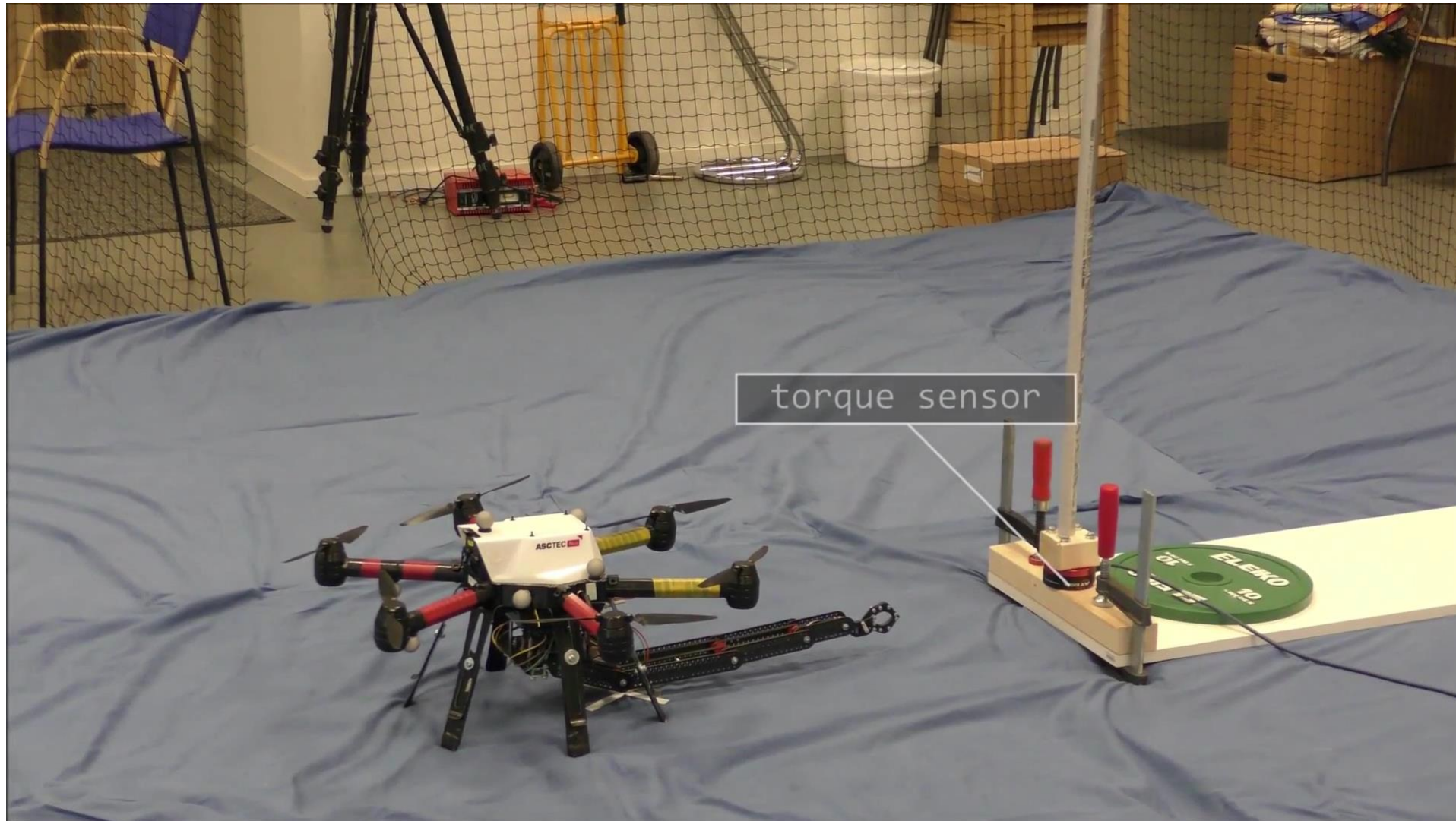
# Autonomous Aerial vehicles

## Framsteg inom Forskning och Teknik 2017



<https://www.svt.se/nyheter/lokalt/vasterbotten/sjalvkorandredronare-ska-hjalpa-vindkraften>

# Autonomous Aerial Workers

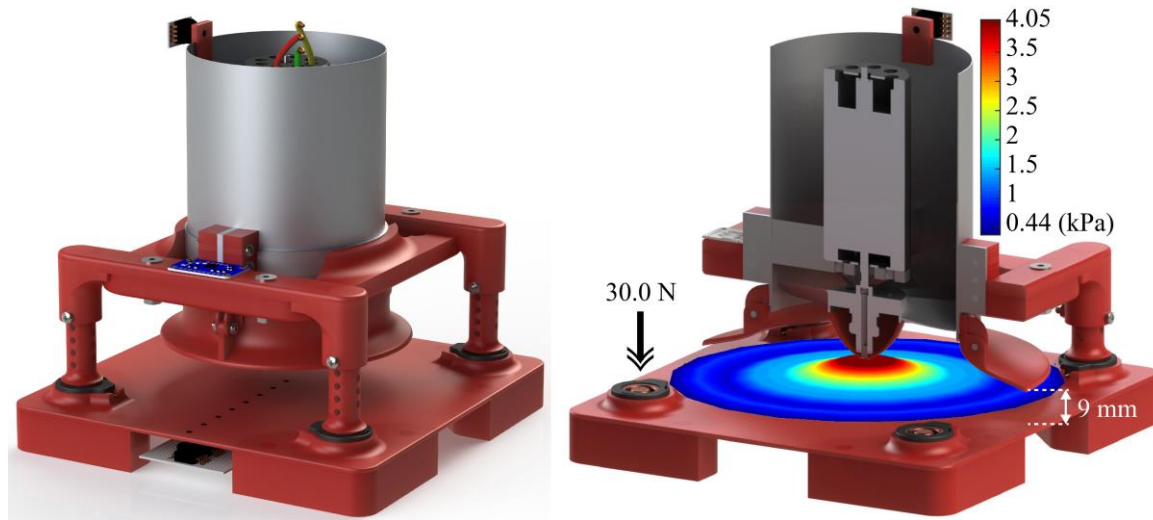


# Automation in mining



# Complnnova

An Advanced Methodology for the Inspection and Quantification of Damage on Aerospace Composites and Metals using an INNovative Approach



## Vortex propulsion and suction

- H2020-FETOPEN-2014
- 2.5 M€
- 5 Partners
- Coordinator: Cranfield University

# BART

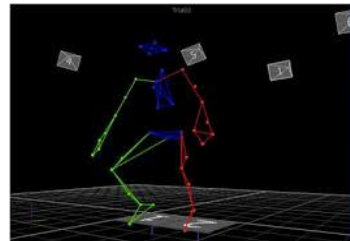


Falls and **fear of falling** pose major threats to health and independence among elderly people. Our objective is to gain further knowledge regarding **balance control** aspects on fall risk and fear of falling by

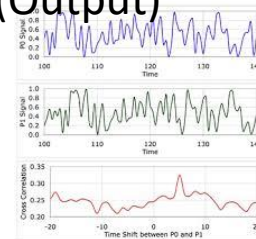
- assessing **postural sway** and **control mechanisms** in static and dynamic tests,
- creating a robotic humanoid with artificial muscles and electronic control systems
- establishing a mathematical formulation of balance control and experimentally evaluate it on the **robotic humanoid**.



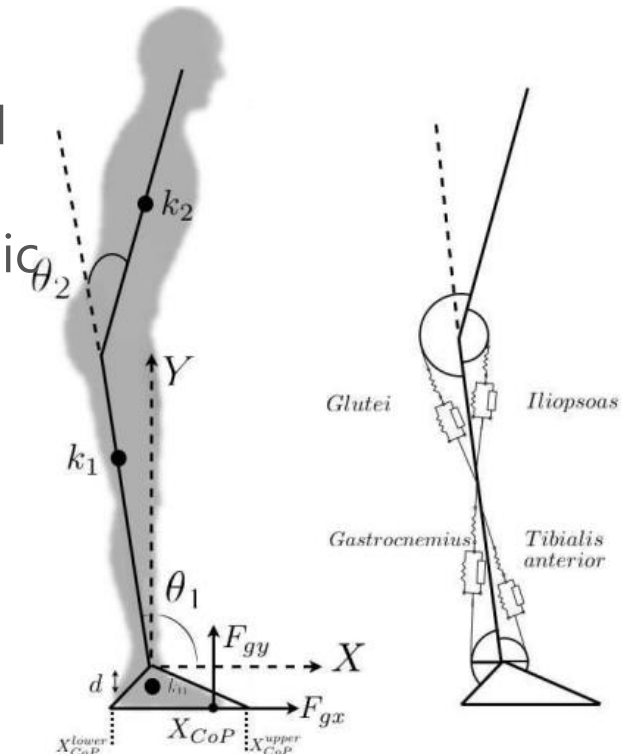
EMGs (Input)



Real Motion (Output)

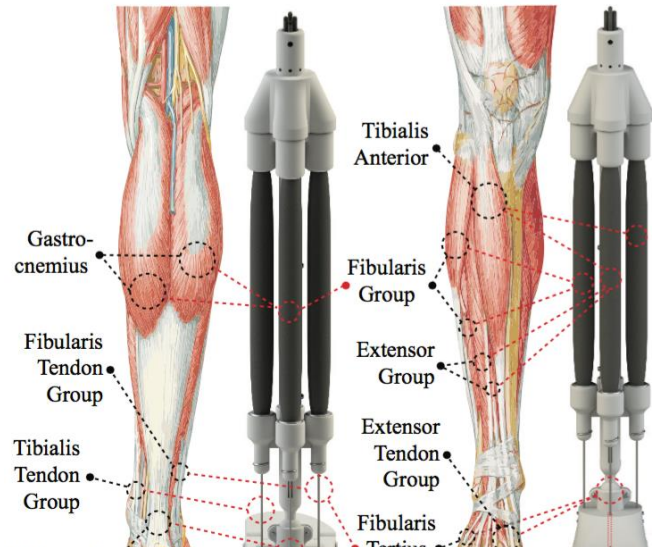


Musculoskeletal Model

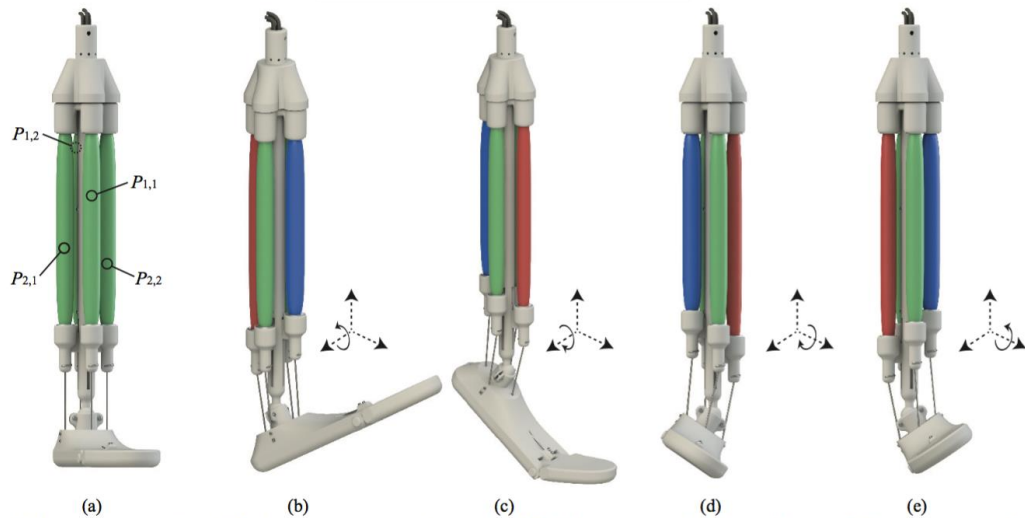




# Bio-inspired robotics



■ Idle   
 ■ Inflated   
 ■ Deflated



Graphical representation of the HURL movement strategy during: (a) Idle, (b) Dorsiflexion, (c) Plantar Flexion, (d) Eversion, and (e) Inversion.

