Multi-disciplinary challenges of Modelling and Simulation in Finnish Industry

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Tekes-MASI technology program

Business from technology

Modelling and simulation is related to all engineering and everything in engineering

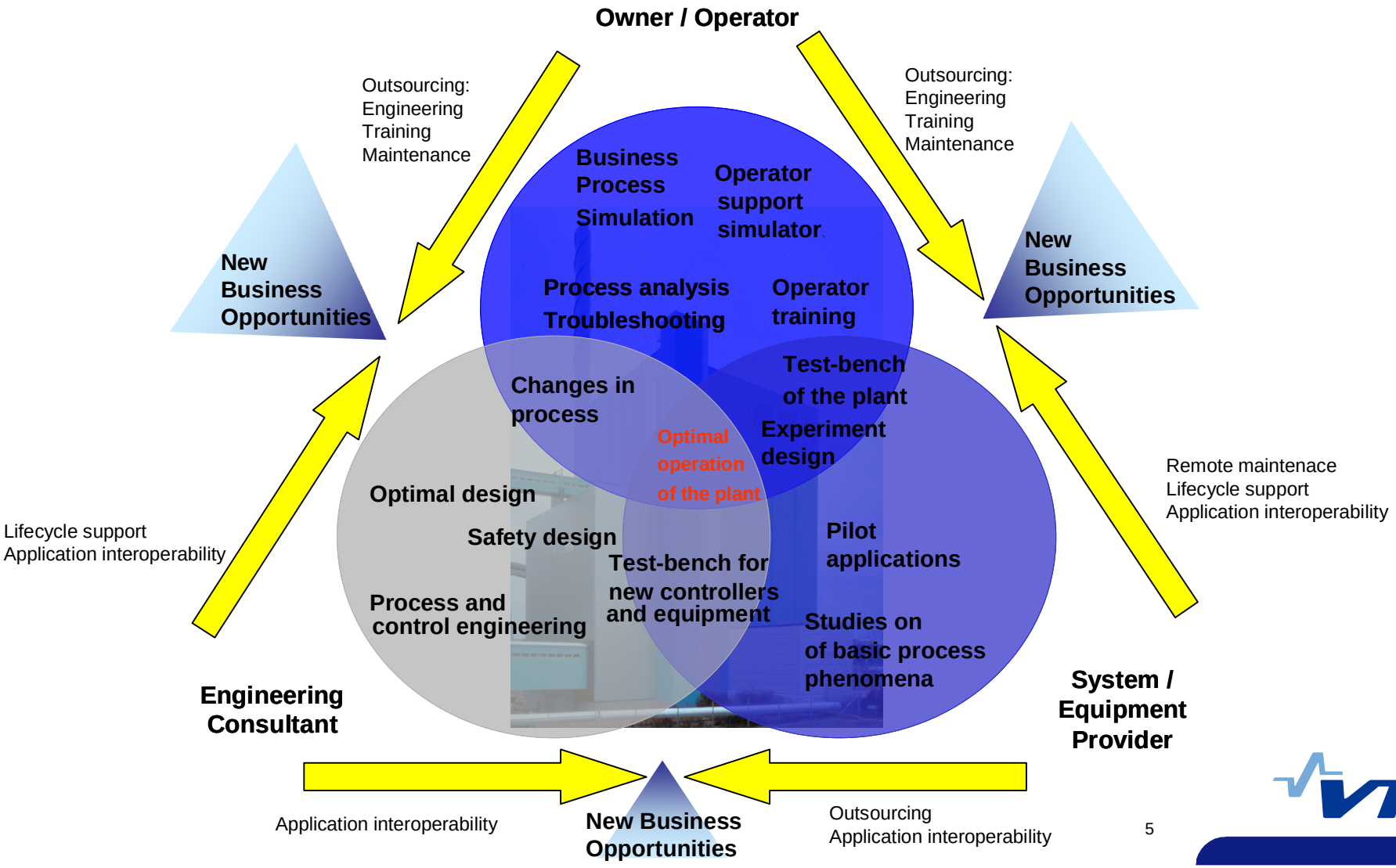
- **Process industry**
  Pulp & paper, metallurgy, chemical, petrochemical, energy production, nuclear
- **Machine industry**
  Marine, vehicles, working machines, process equipment
- **Manufacturing, production, logistics, project business**
- **Electronics industry**
  Mobile phones, telecommunication networks, measurement systems
- **Buildings, built environment, energy networks, traffic**
- **Biotechnology**
- **Material science**
  Metals, semiconductors, polymers, composites, fibres, nanomaterials
- **Environmental impacts**
- **Military applications**

Finnish industry profile is also different!

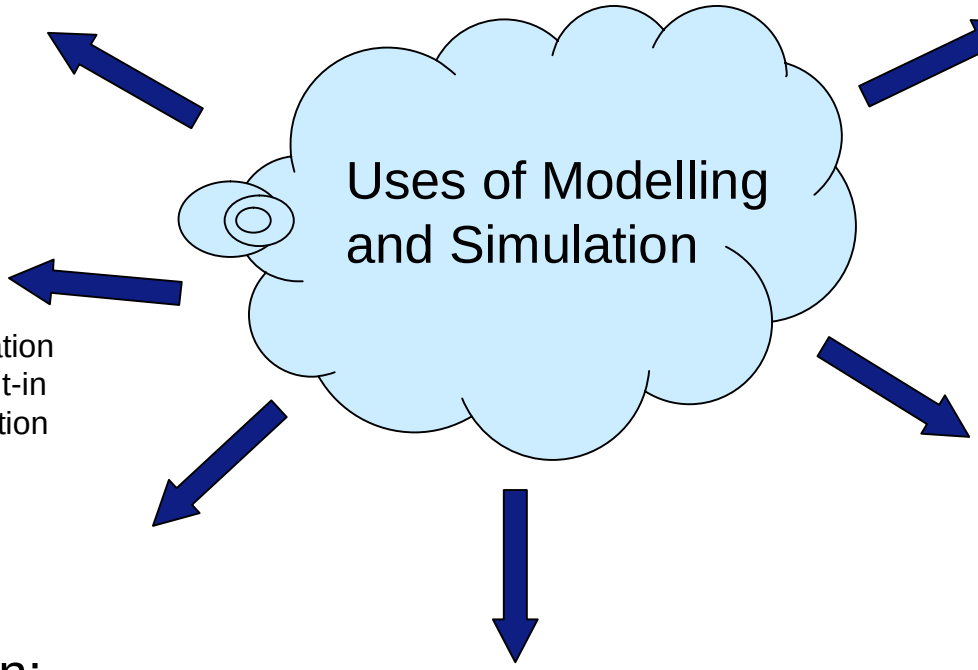
- A significant role in **forest, energy, and metallurgical** industry, less in chemical or petrochemical industry which are the leading sectors in global industries
- Relatively strong in working or mobile **machines**, less in car industry that invests much more in M & S globally
- Not much aviation or space industry
- **Mobile phones**, etc.: a major share of domestic R&D resources
- Finnish research is **industry driven**, not military driven

Process Industry

PROCESS INDUSTRY:
Applications of M & S in process plant life cycle



PROCESS INDUSTRY: Future directions



Multi-level simulation:
Seamless support for simulation in different levels of details

Trends from software Business:
Software as a service
Social media / Web 2.0
Open Source

Model quality improvement:
Support for validation and verification of simulation models will be a built-in feature in a modelling and simulation frameworks

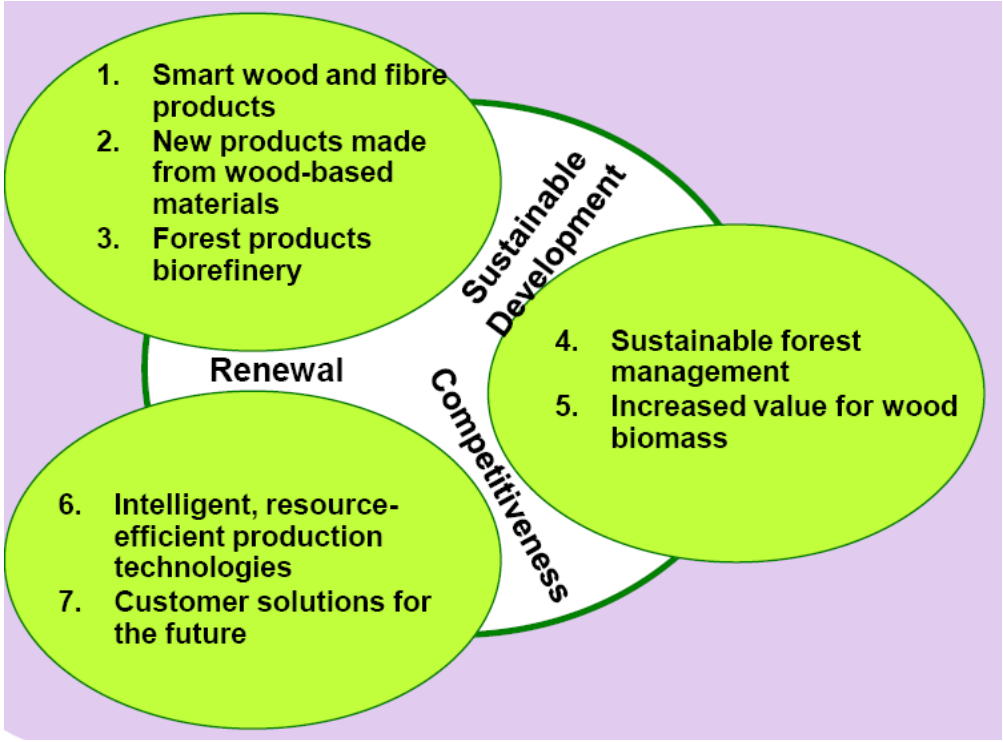
Simulation and design tool Integration:
Links from simulators to different engineering applications

Heterogeneous system simulation:
Support for multi-domain and multi-physics simulation

Distributed modelling and simulation:
Distributed simulation model configuration and usage including version and access control

PROCESS INDUSTRY: Action map

- **Tekes**
  - Modeling and Simulation 2005-9
  - Digital product process 2008-12
  - Other programs
- **Forestcluster Ltd**
  (Strategic Centre of Science, Technology and Innovation for the forest cluster)
  - Intelligent, resource-efficient production technologies
    - **WP2 - Modelling and measurements**
  - Future Biorefinery
  - Customer solutions for the future



Action map: Cleen Ltd
(The Strategic centre for science, technology and innovation of the Finnish energy and environment cluster)

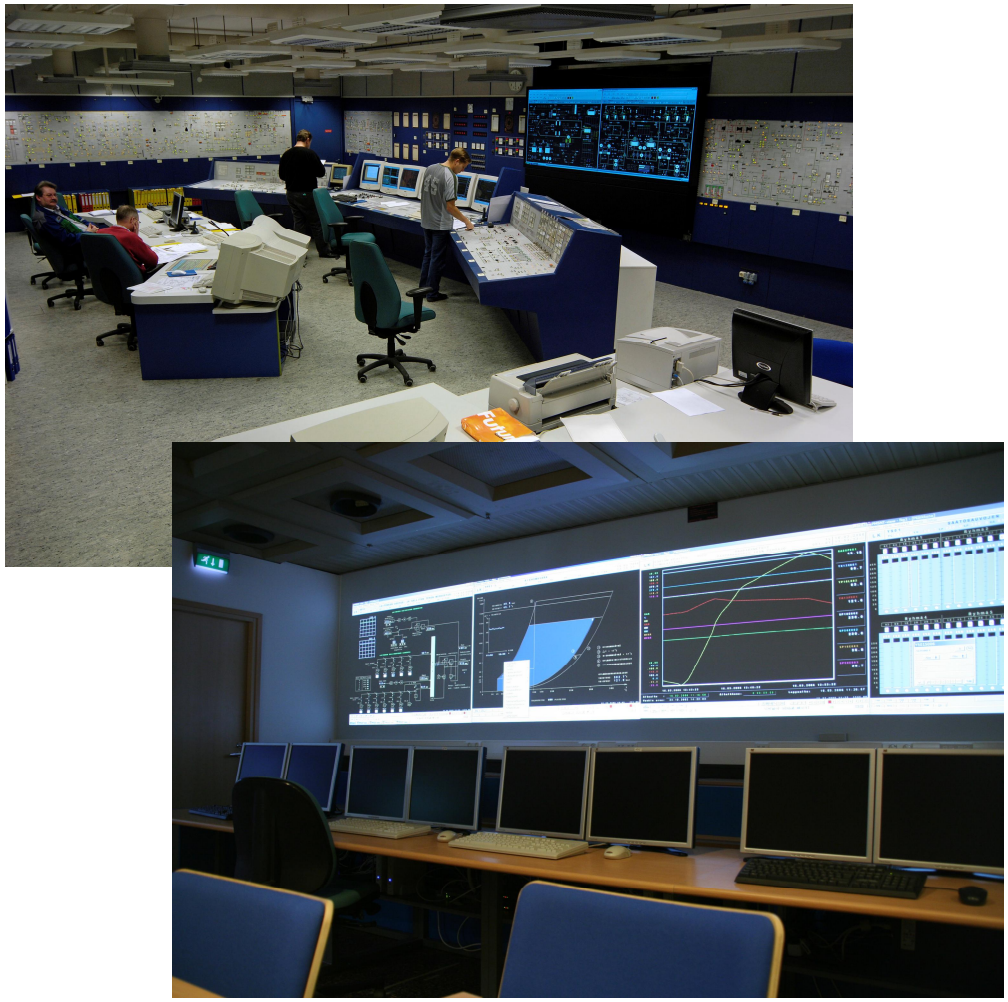
Main areas:

- Carbon neutral energy production
- Distributed energy systems
- Sustainable fuels
- Energy market and smart grids
- Efficient energy use
- Resource efficient production technologies and services
- Recycling of materials and waste management
- Measurement, monitoring and assessment of environmental efficiency

Cross-cutting issues

- Forecasting energy and environmental policies and how technologies are developing.
- New business models.
- Understanding of combustion processes by **modelling** and experimental work.
- New materials for power plants and components, **modelling** and characterisation.
- New measurement technologies for emissions and process control.
- **Generic tools for simulation, modelling, process optimisation**.
- **Tools for life cycle assessment, LCA services and LCA of processes**.
- Etc.

PROCESS INDUSTRY Example:
Loviisa Automation Renewal - Training Simulator (Fortum Power and Heat)

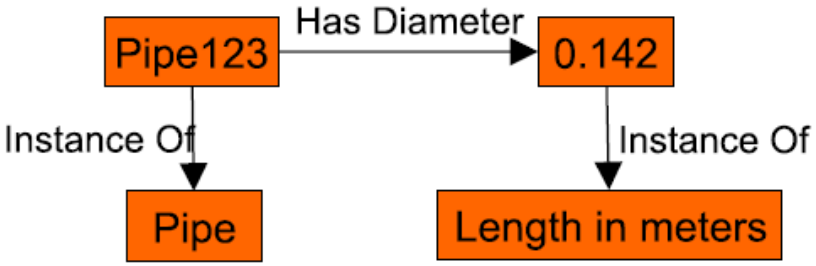


- Full scope training simulator with a replica Main Control Room
- Real displays and virtual controls
  - Siemens T2000 incl. OM690 displays
  - Areva TXS and QDS displays
- Training Station instructor's tool
  - Simulation control
  - Additional graphical displays for malfunction management and field operations
  - Simulation sequences for management of lessons and initial conditions

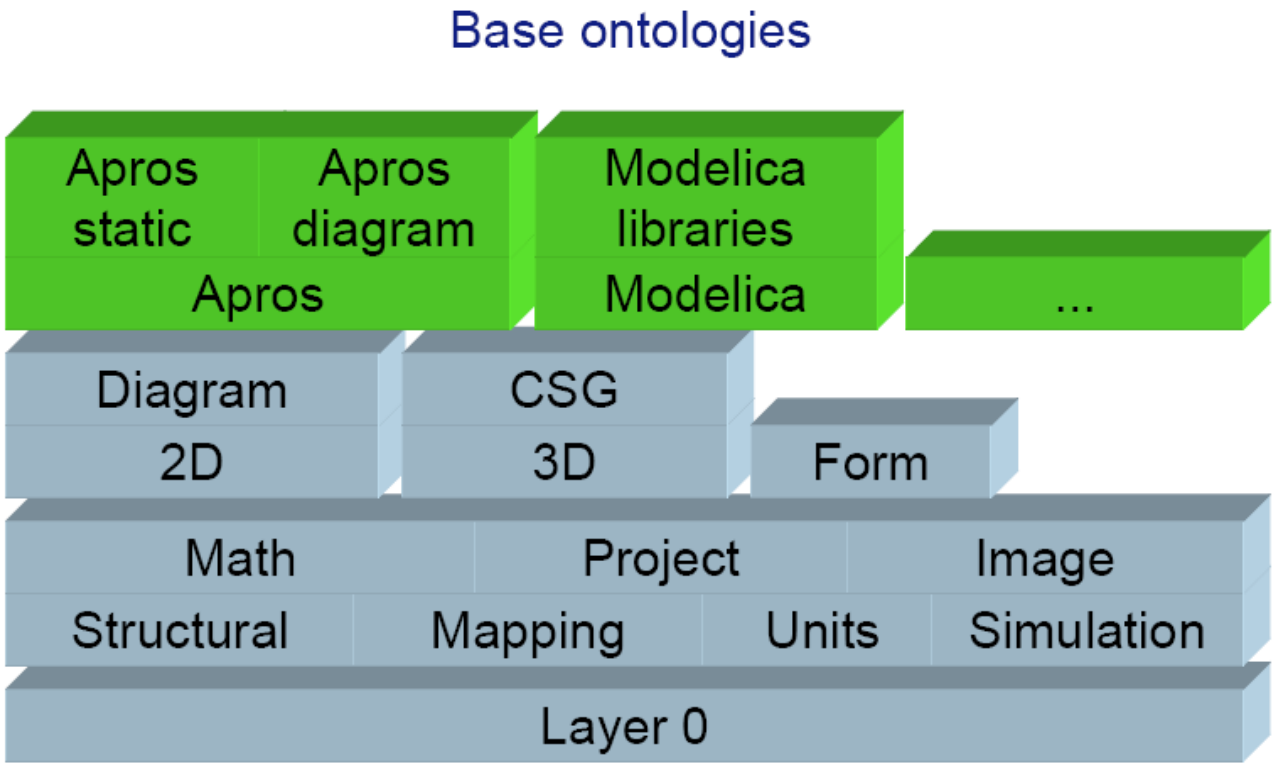
Many interconnectivity problems can be solved semantically

Semantic graph

- Data consists of resources, statements and literals.
- Resource: a node of the graph. A resource has a unique identity.
- Statement: an edge of the graph. A statement consists of three resources: subject, predicate (relation), object.
- Literal: any binary data attached to a resource.



VTT SIMANTICS
An ontology-based middleware



VTT activity: Simantics Plug-in Architecture for Modelling and Simulation

Plug-in (*
APROS simulation engine

Plug-in (*
OpenFOAM CVM CFD simulation environment

Plug-in (*
Elmer FEM multi-physics simulation environment

Plug-in (*
OpenSceneGraph visualisation environment

Plug-in (*
BALAS simulation engine

Simantics Platform

- *Eclipse* based application framework
- *Open CASCADE* 3D geometry kernel
- *Apache Batik* 2D diagram framework
- …
- Editors (text, 2D diagram, 3D geometry)
- Structural data handling and mapping
- Project/team management tools
- Distributed modelling and simulation facilities
- …

Plug-in (*
OpenDX and *ParaView* post-processing and visualisation tools

Plug-in (*
VTT-Talo building simulation environment

Plug-in (*
Octave mathematical language environment

Plug-in (*
OpenModelica system simulation environment

ProCore triple engine Modelling database management

Historian Simulation results database management

Plug-in (*
…

*) Plug-ins are examples what could be connected to the Simantics platform

Machine Industry

MACHINE INDUSTRY: Applications of Modelling & Simulation

- M & S of mechanical properties
  (mechanical loads, dynamics, states and trajectories, etc.)
- Control design, integration of control and mechanics, optimization, testing
- Vibration and sound/noise control (rotating machines, fans, generators, vehicles, working machines)
- Estimation of thermal loads, e.g., in engine components
- Hydraulics and pneumatics
- Special conditions: failure conditions, tilting, accidents, driver safety, maintainability, etc.

MACHINE INDUSTRY:
Modellling & Simulation Solution Concepts

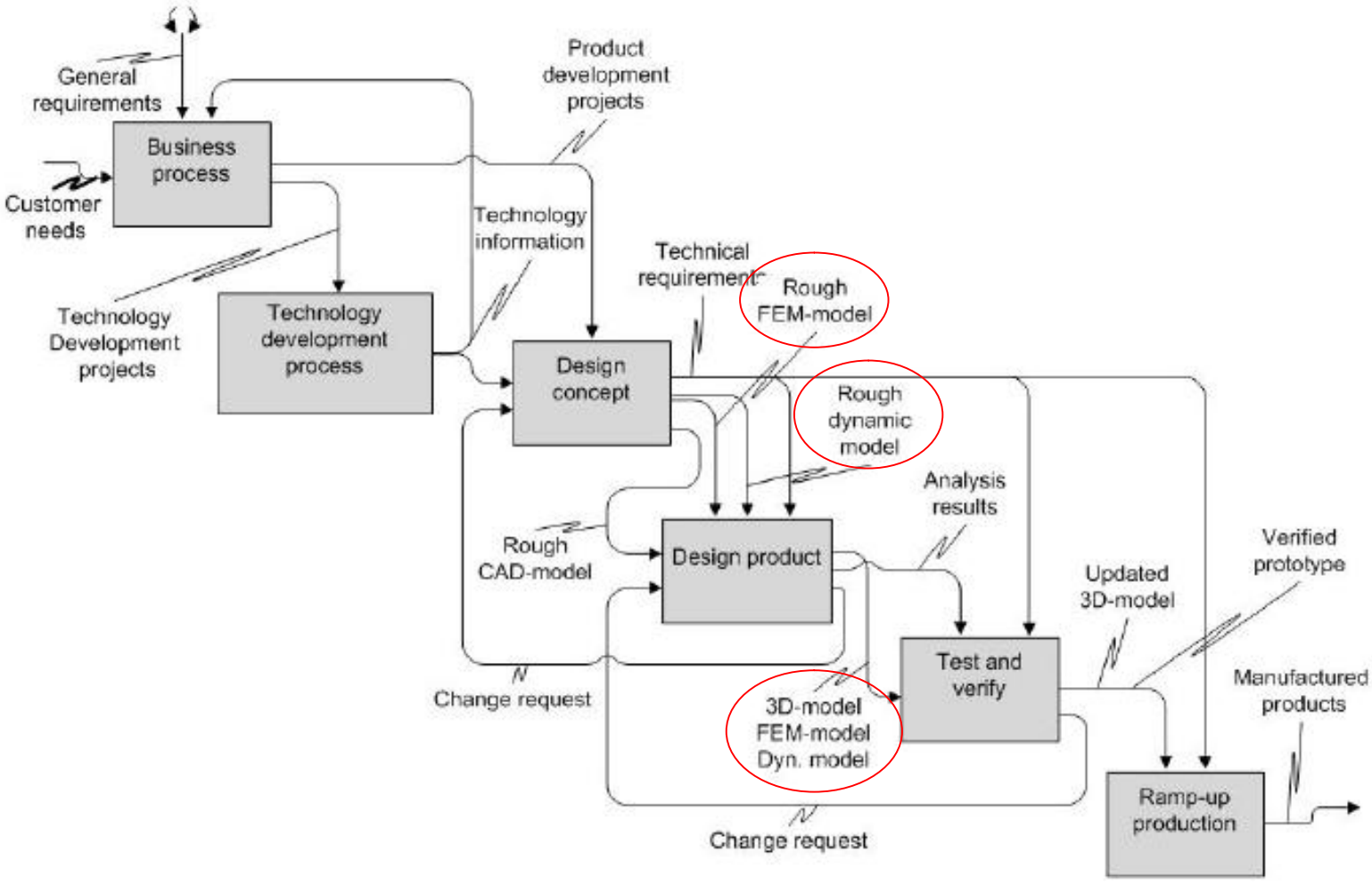


Figure 2.8. The simulation-based design process. The topmost level includes six phases.

MACHINE INDUSTRY:
Modellling & Simulation Solution Concepts

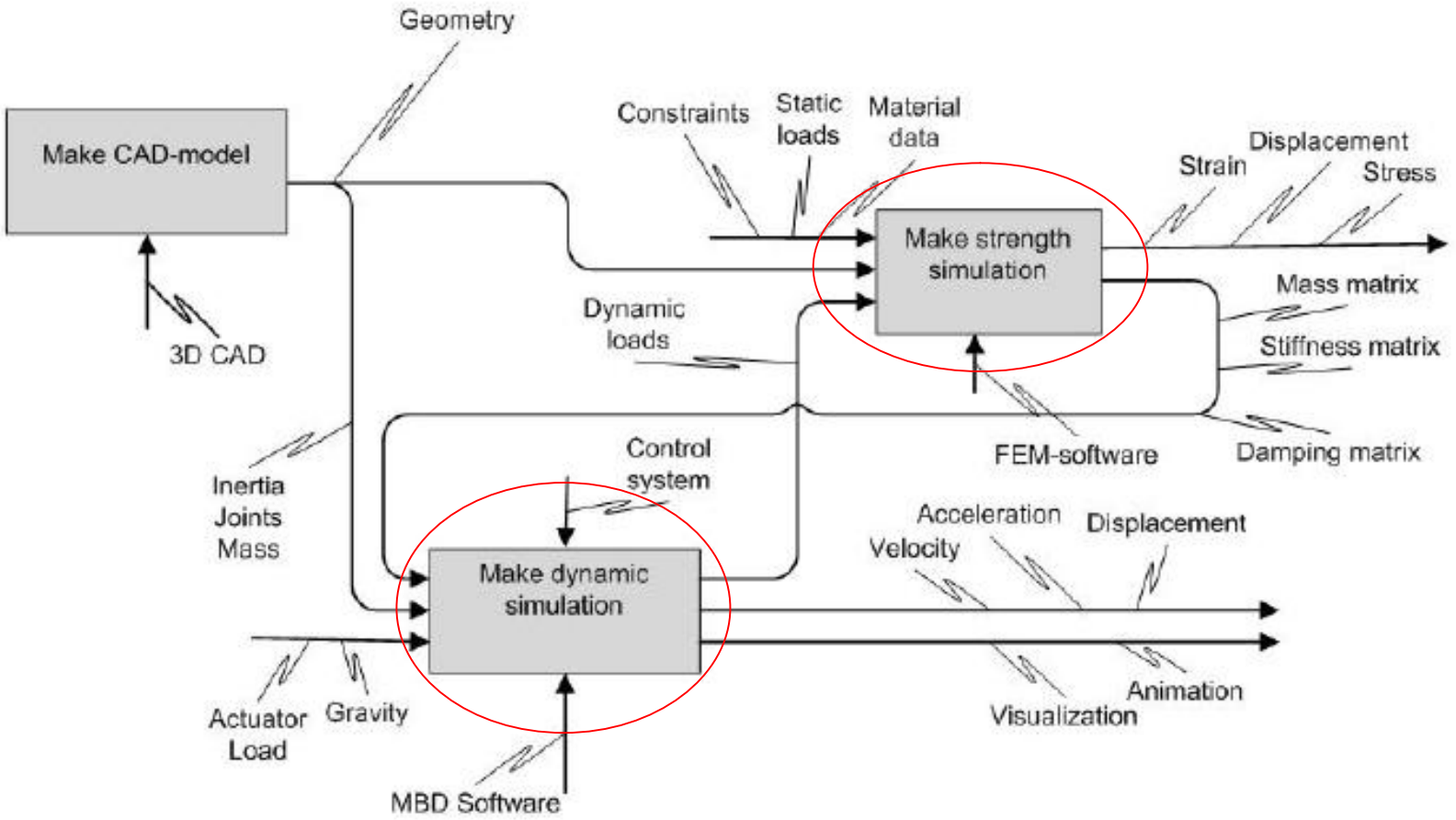


Figure 2.10. The dynamic simulation loop.

MACHINE INDUSTRY:
Modellling & Simulation Solution Concepts

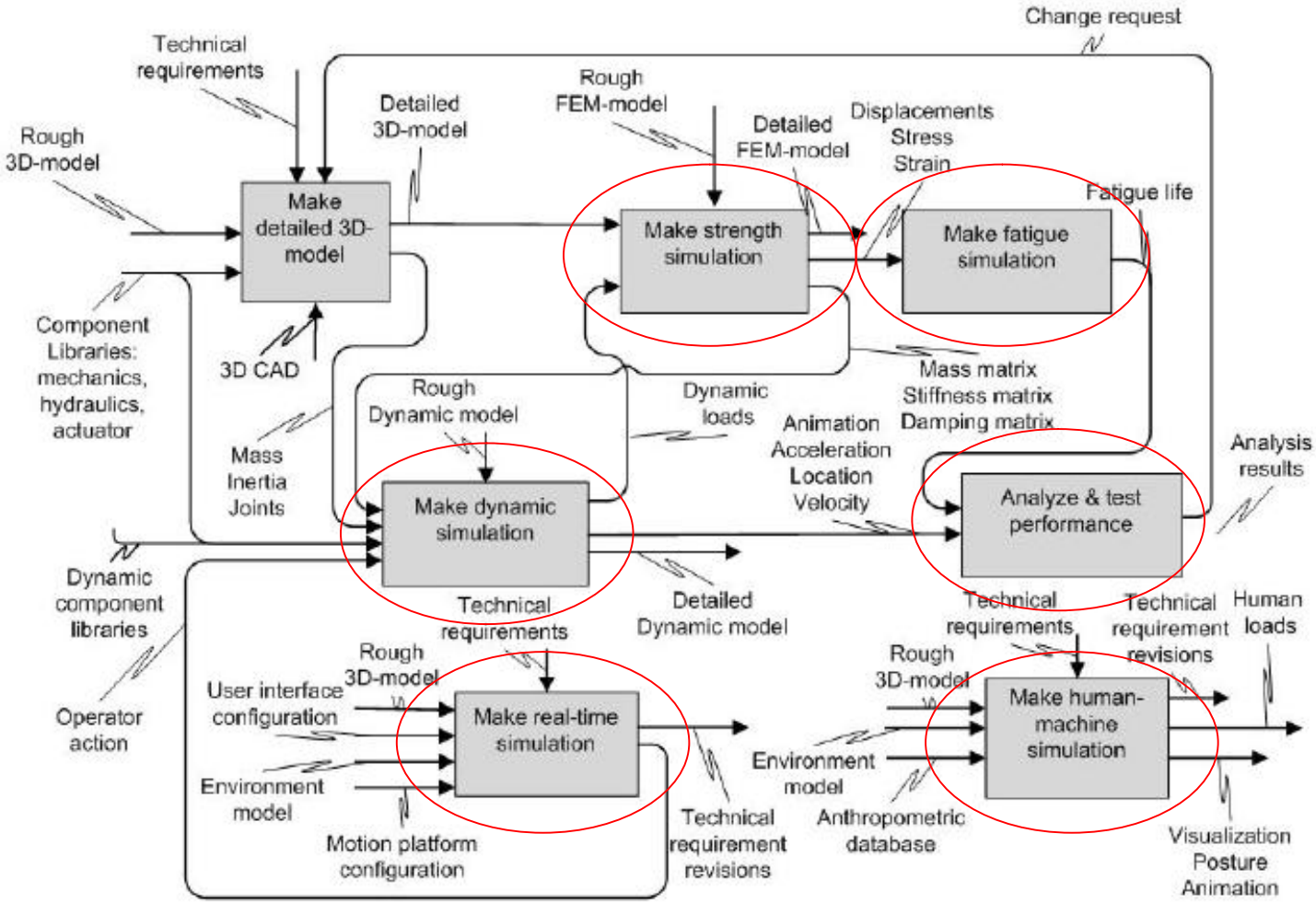
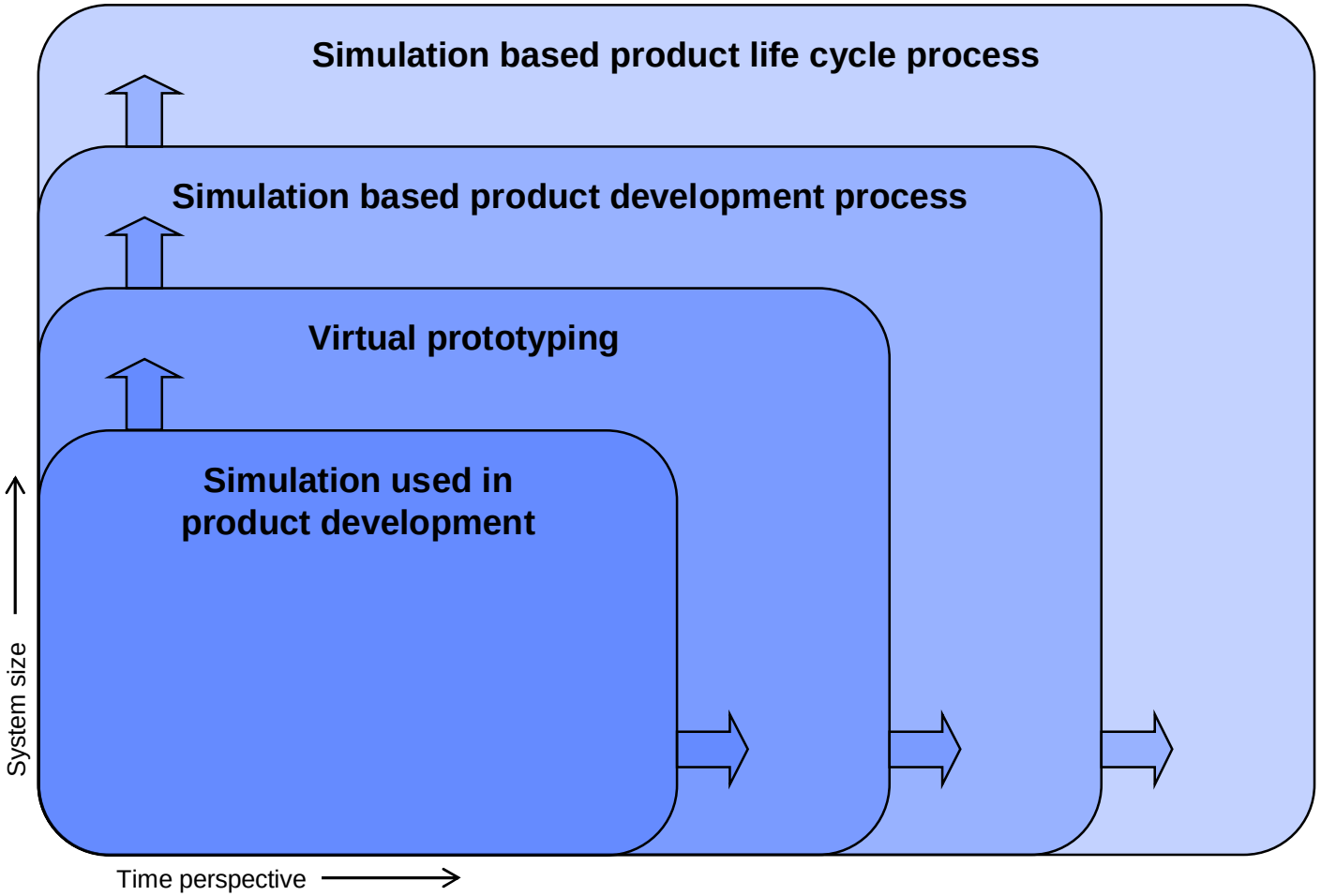


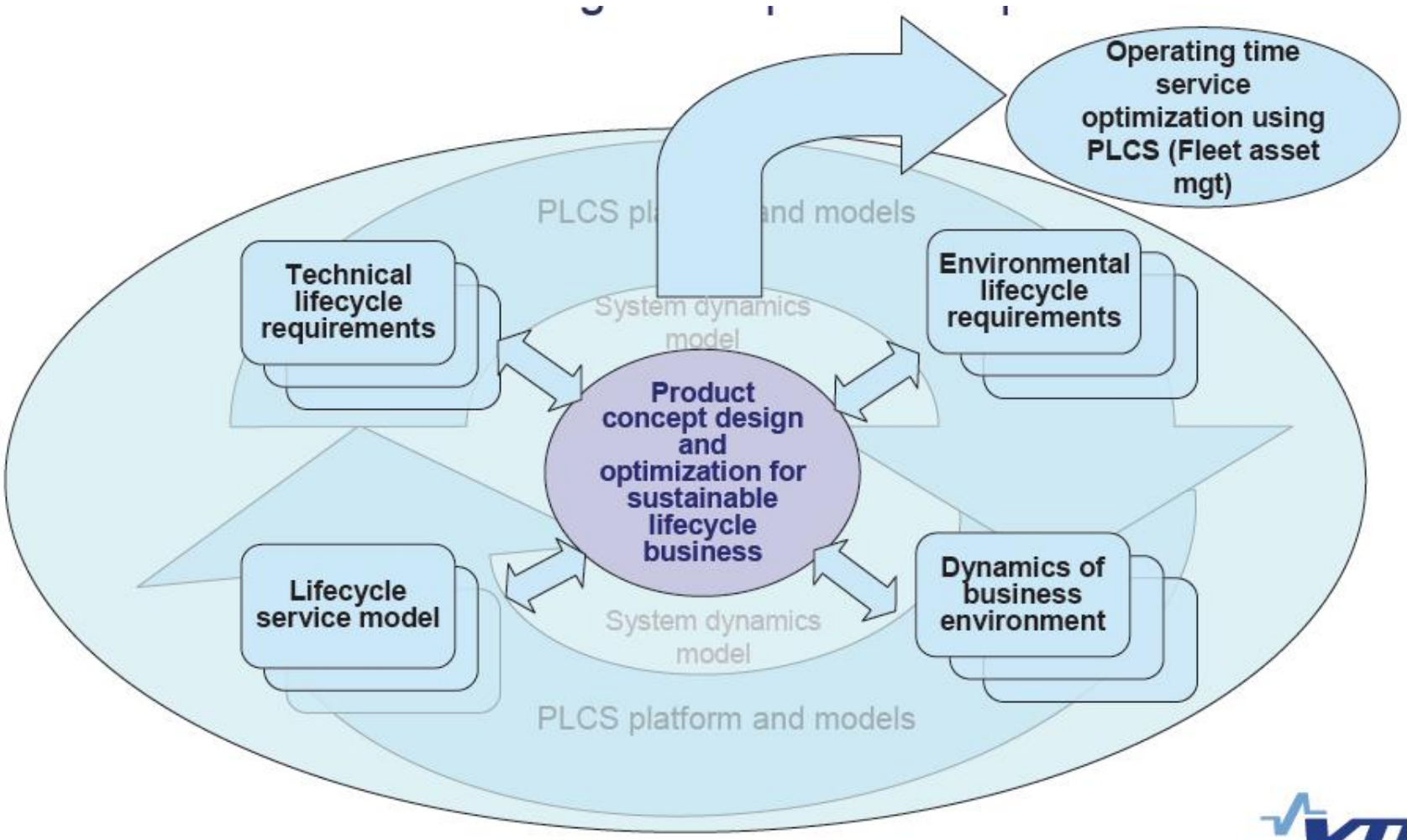
Figure 2.11. Design product phase.

MACHINE INDUSTRY: Widening the View of Modelling & Simulation

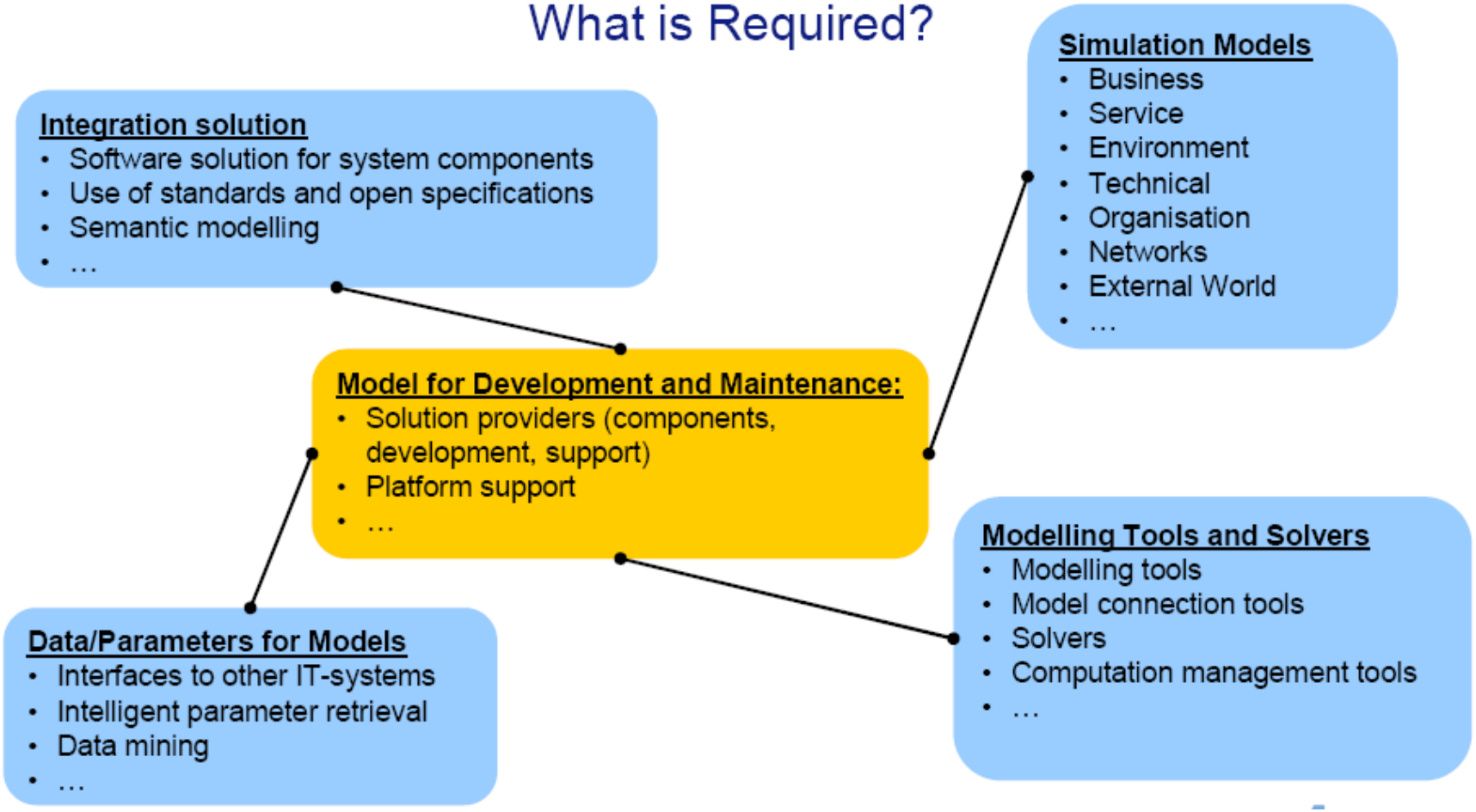


- From local detailed simulation to overall simulation-based product life cycle management
- Scaling both in system size and time perspective
- Challenges:
  - Many data formats
  - Heterogeneous data, both in shape and meaning
  - Massive amount of data
  - Easy-of-use despite of complex data environment
  - Many closed software systems

MACHINE INDUSTRY: Life-cycle simulation



What is Required?



MACHINE INDUSTRY: Action map

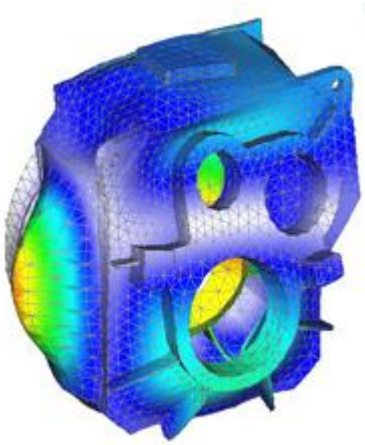
- **Tekes**
  - Digital product process 2008-12
  - Other programs
- **FIMECC Ltd** - Finnish Metals and Engineering Competence Cluster
- Main themes
  - Service Business
  - User Experience
  - Global Networks
  - Intelligent Solutions
  - Break-through Materials
- FIMECC Ltd / Modeling & Simulation
  - Modeling and simulation are **deeply connected with several topics**
  - Design, implementation and use of process automation systems and networks would all benefit of **easier-to-use and cost effective modeling and simulation tools**.
  - One of the key challenges in this area is to **enable easy and intuitive modeling**, preferable as a side product of other manual work or as a fully automated feature.
- FIMECC Ltd / Modeling & Simulation (cont'd)
  - Another important issue is **better integration of simulation tools** and daily user tools as well as lowering skills required to perform simulations.
  - Extending the use of simulators to various directions brings the need of **multi-technology simulation, multi-accuracy simulation or multi-purpose simulation** which hasn't become a practical reality so far.
  - **Automated testing trough simulation / emulation** is also a growing demand in industry, because products become more and more complex.
  - **Modeling and simulation of metallurgical and metal-working processes** need special skills and knowledge. That is of crucial importance especially in those situations, where the basic phenomena are difficult to measure, and will decrease sampling and inspection.

Example: Next Generation Gearbox Technology

Moventas Wind Oy – Windmill Gearboxes

- Moventas Wind Oy and VTT develop and apply new methods to better manage windmill gearbox development, manufacturing and condition monitoring
  - Virtual prototyping and computational methods are applied to understand complex dynamics in the chain from wind to electric network
  - New analysis and simulation tools and methods are used to boost development and design process
- The objective is to better manage the whole product life cycle process of a windmill gearbox

Courtesy: Moventas Oy

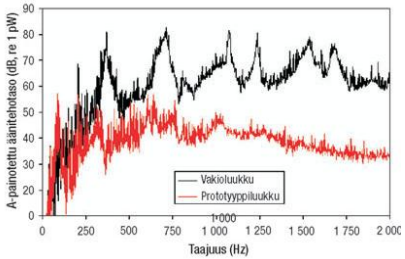


Courtesy: Moventas Oy

Example: Simulation Based Noise and Vibration Reduction

Wärtsilä – Diesel-Electric Power Plants

- Increase the understanding of complex coupled phenomena of noise and vibration
- Deployment of computational methods, simulation and analysis for noise and vibration reduction in diesel-electric power plants
- The objective is to optimise products taking into account technical requirements as well as the environment and to ensure lifetime reliability
- Wärtsilä and VTT have a long time research partnership



Ref. *Masina – Koneenrakennuksen teknologiaohjelma 2002–2007, loppuraportti*, p. 51.

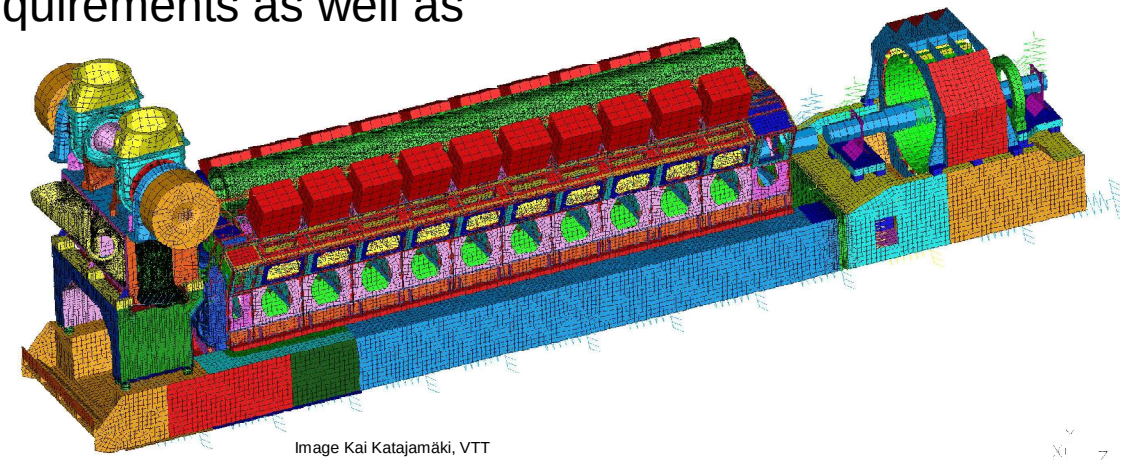


Image Kai Katajamäki, VTT

Energy Systems, environment

Energy Systems and Environment

Applications of M & S

- Estimating the trends of energy systems, constructing scenarios (Finland, Europe, World wide)
- M&S of energy markets (electric energy, oil, gas, emission trading)
- Lifecycle assessments of products and systems w.r.t. energy, emissions, ecological impact

Driving forces, regarding M & S

- Liberation of energy markets
- Policies due to climate change
  - Emission trading, feed-in tariffs, subsidies

Energy Systems and Environment: M & S related solution concepts

M & S related solution concepts

- Energy balance models
- Actors behaviour models
- Profitability models of technical systems
- Static lifecycle models
- Dynamic models
    - Green house gas emissions
    - Carbon cycle
    - Atmospheric lifetimes of substances
    - Radiation absorption
    - Albedo change
- Model uncertainties, stochastic modelling

Benefits

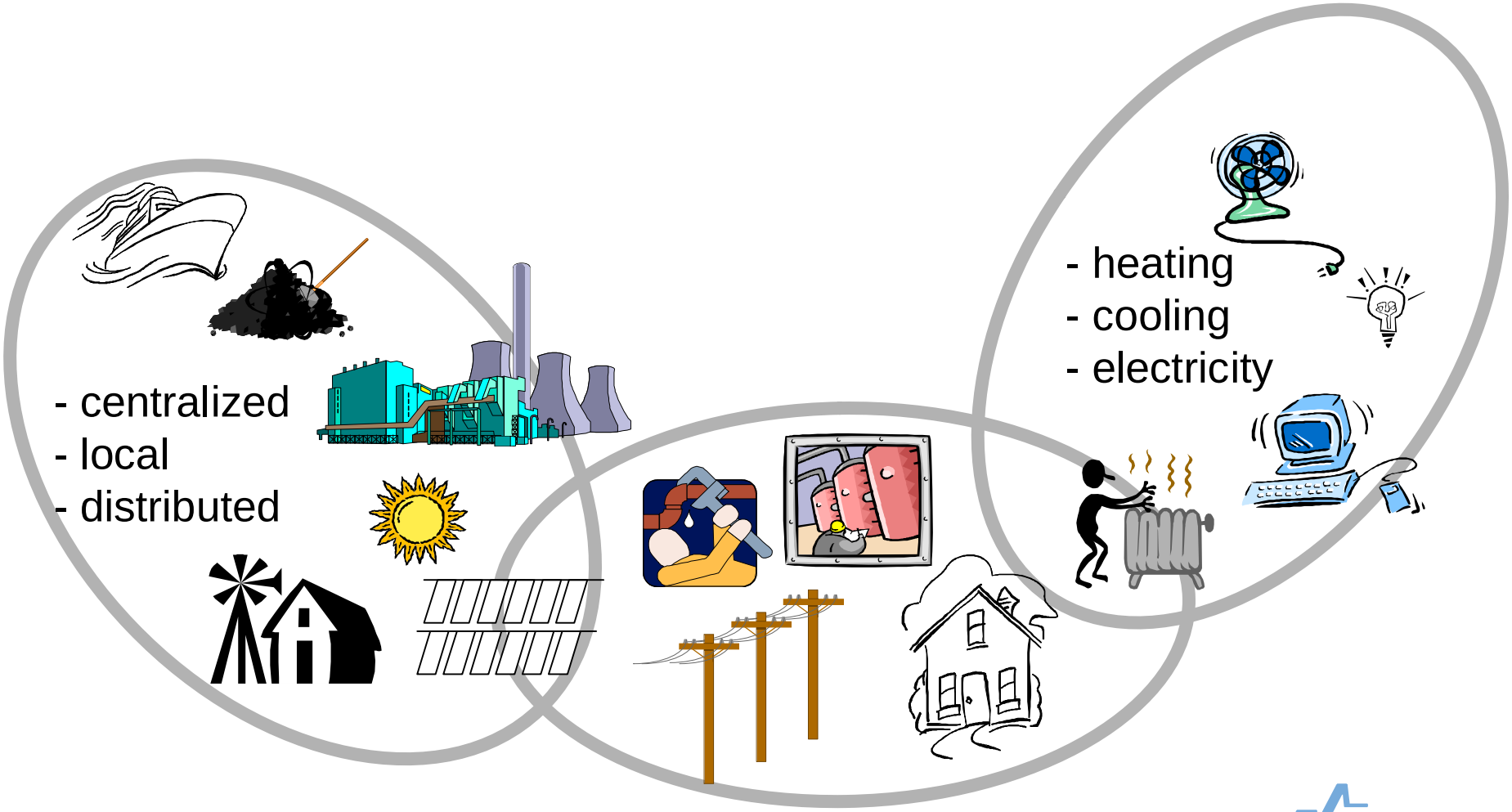
- Assessments of future operational environment
    - Dependence on energy sources
    - Energy costs
    - Green house gas emissions
- Strategic decision making

Gaps, critical needs to be addressed

- Development of models
- International cooperation

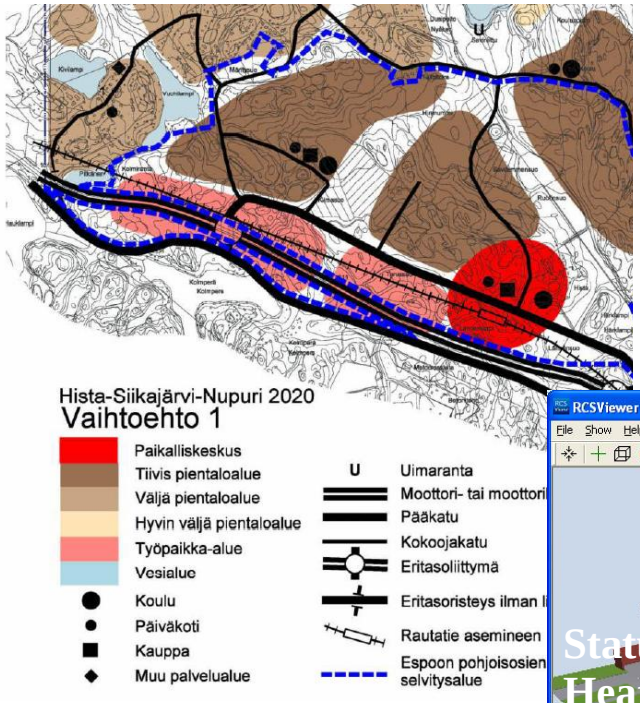
Built environment

Energy chain: Production - Distribution – Use /Storage

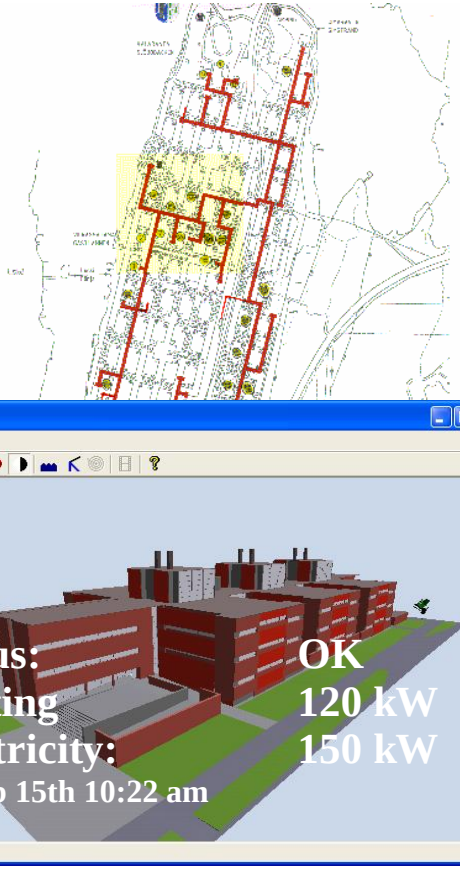


District heating, building simulations

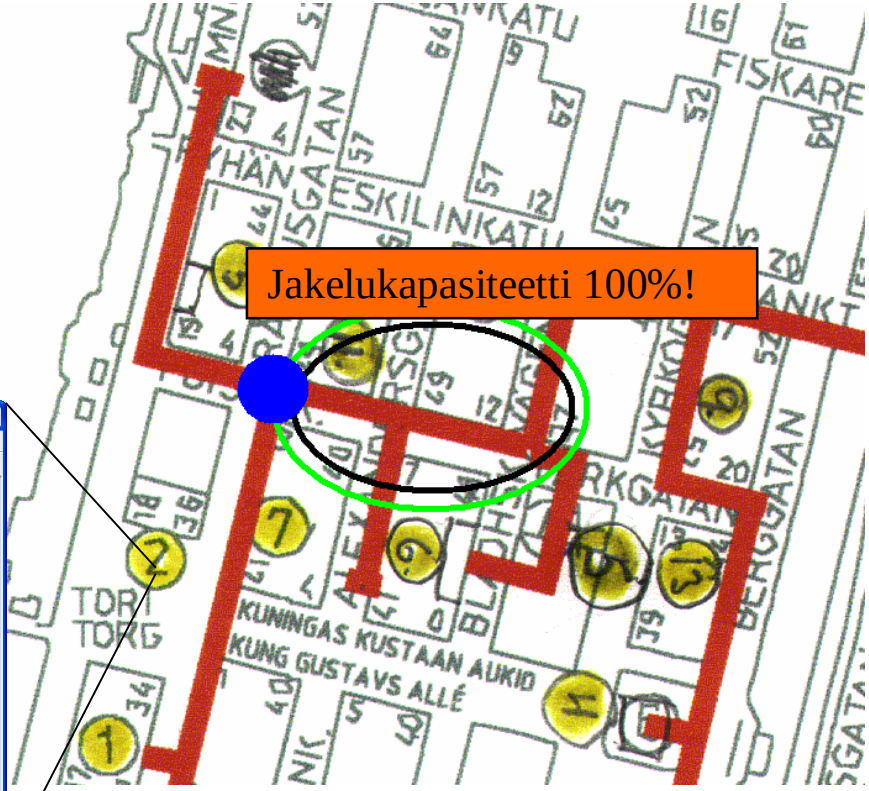
Preplanning



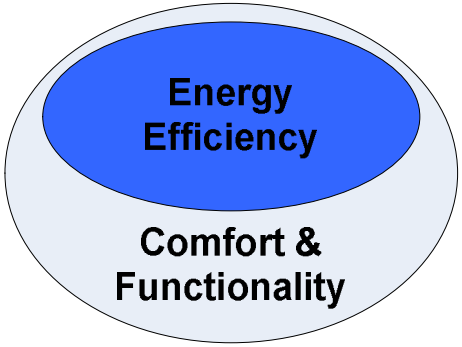
Planning

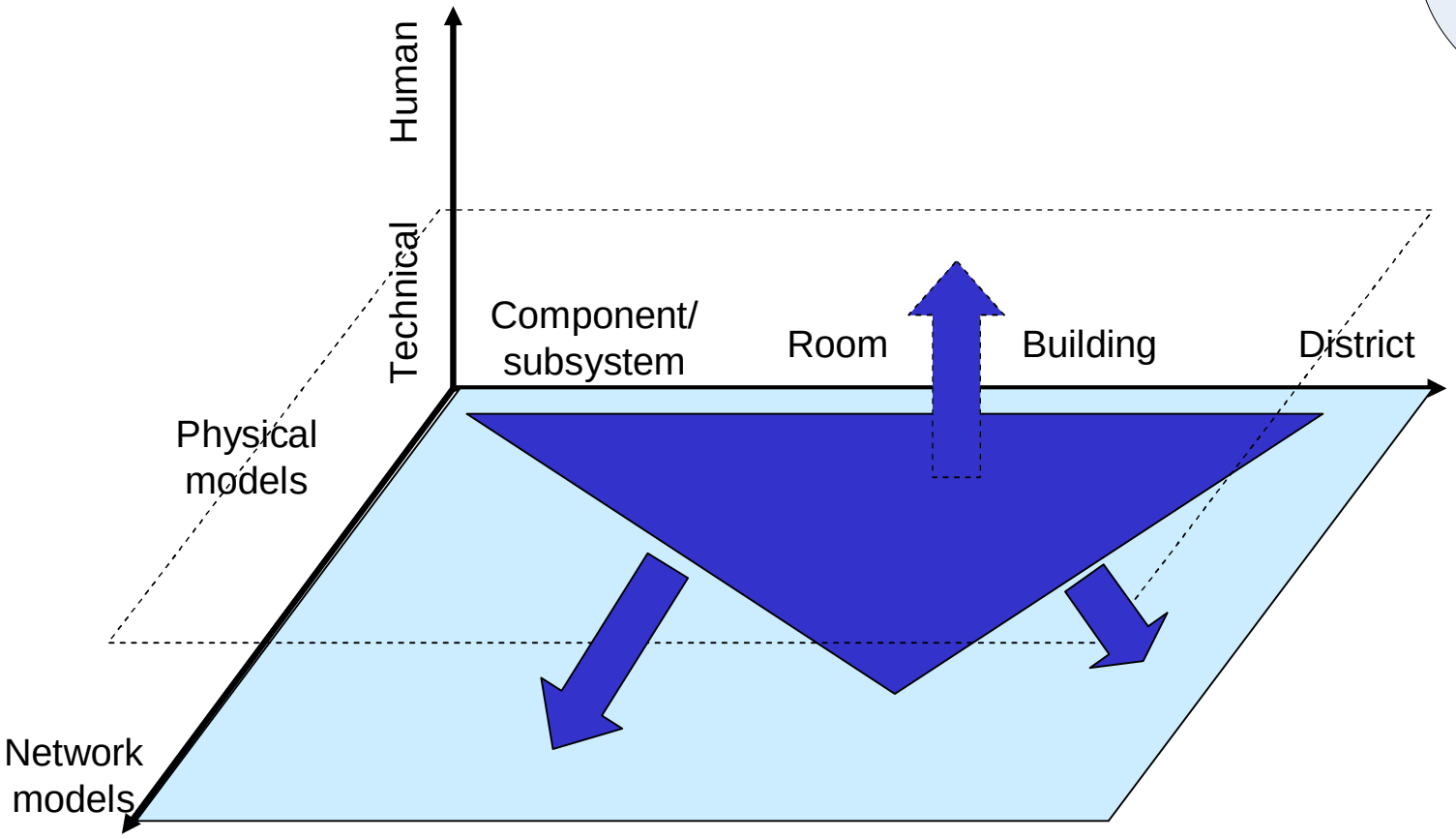


Operational



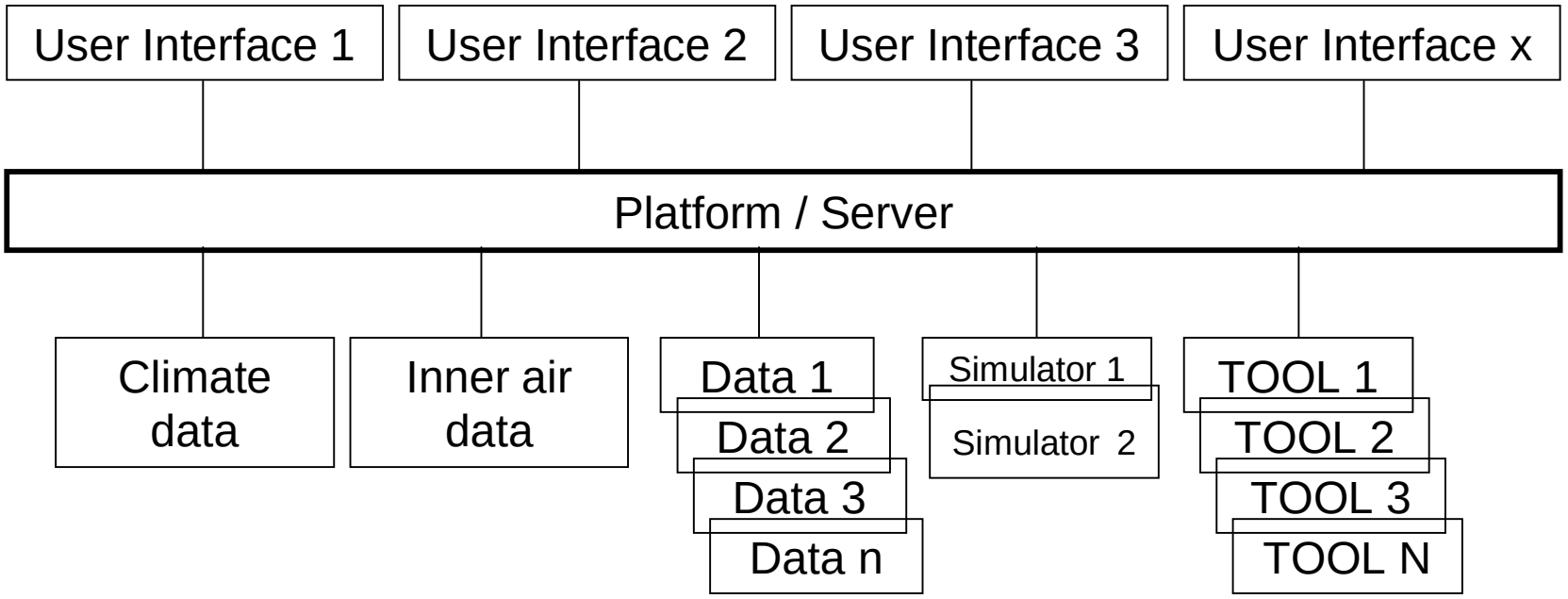
Scoping





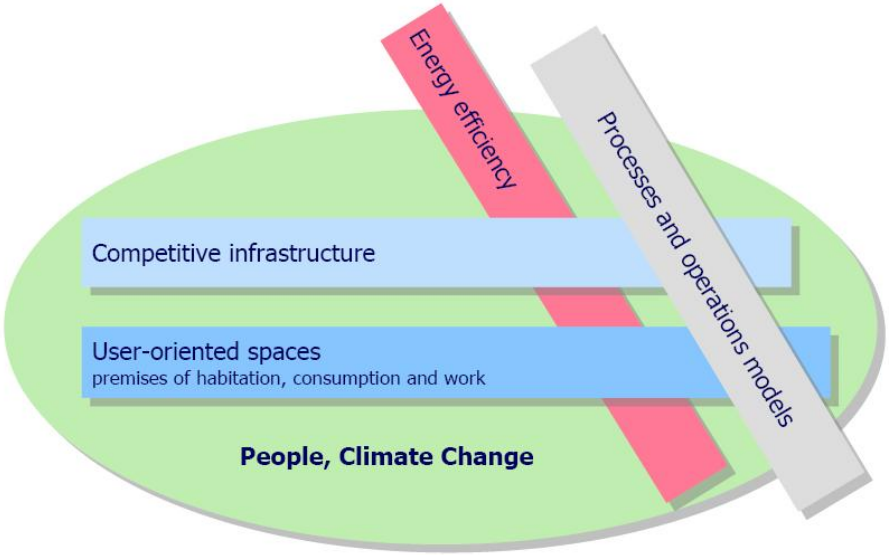
- **Flows**
- **Heat, cool, energy**
- **Concentrations**
- **Humidity**
- **Lighting**
- **Sound, acoustics**
- **Automation**
- **Fires**
- **Exposures on climate conditions, etc.**
- **Aging, maintenance, etc., of structures**

M & S related solution concepts



Action map:
Strategic Centre for Science, Technology and Innovation for Built Environment

- **Energy-efficiency**
  - Operational environment
  - Business and commersialization
  - **Life-cycle processes**
  - Concepts, services and products
  - **Production, distribution and storage of energy**
- **Processes and operations models**
  - Operations and business models
  - **Management of supply networks**
  - **Productivity and effectiviness**
  - **Information models and interfaces of data transfer**
  - **Digitalisation of the existing built environment**
- **Competitive infrastructure**
  - Concepts of communities
  - Eco-efficient solutions for water supply and sewage
  - **Management of real property and life-cycles**
  - Material and structural technologies
- **User-oriented spaces**
  - **User-oriented development of spaces**
  - Concepts of spaces
  - Residential solutions for elderly
  - **Management of indoor conditions**
  - Life-cycle of a space



Project AR4BC

Augmented Reality for Building and Construction

- Industrial partners incl. Pöyry, Tekla, Skanska, Buildercom, DeskArtes, Adactive

Augmented on-site visualization

- Comparing project plans (4D BIM) with actual situation on site

Augmented site journaling

- Mobile feedback to BIM system
- Attach images, tags etc. to components in BIM model
- *Augmented Virtuality*

Telecommunications

Business from technology

Telecommunications: Applications of M & S

Analyse operations, functions of telecommunication networks

- Physical channel, analog components
- Modulation, coding, error-correction
- Protocols on various levels
- Elements and nodes of the network

Analyse performances, reliability, complexity of telecommunication networks

- Throughput, delays, error-ratios
- Spectral efficiency, energy efficiency
- Availability, reliability, costs
- Measure performances of algorithms
- Network capacity, coverage modelling
- Dimensioning, design of networks
- Propagation medium, disturbances
- Locations of network devices
- Configuration management, diagnostics
- Services, quality, user experience
- Sensor networks

Telecommunications: M & S related solution concepts

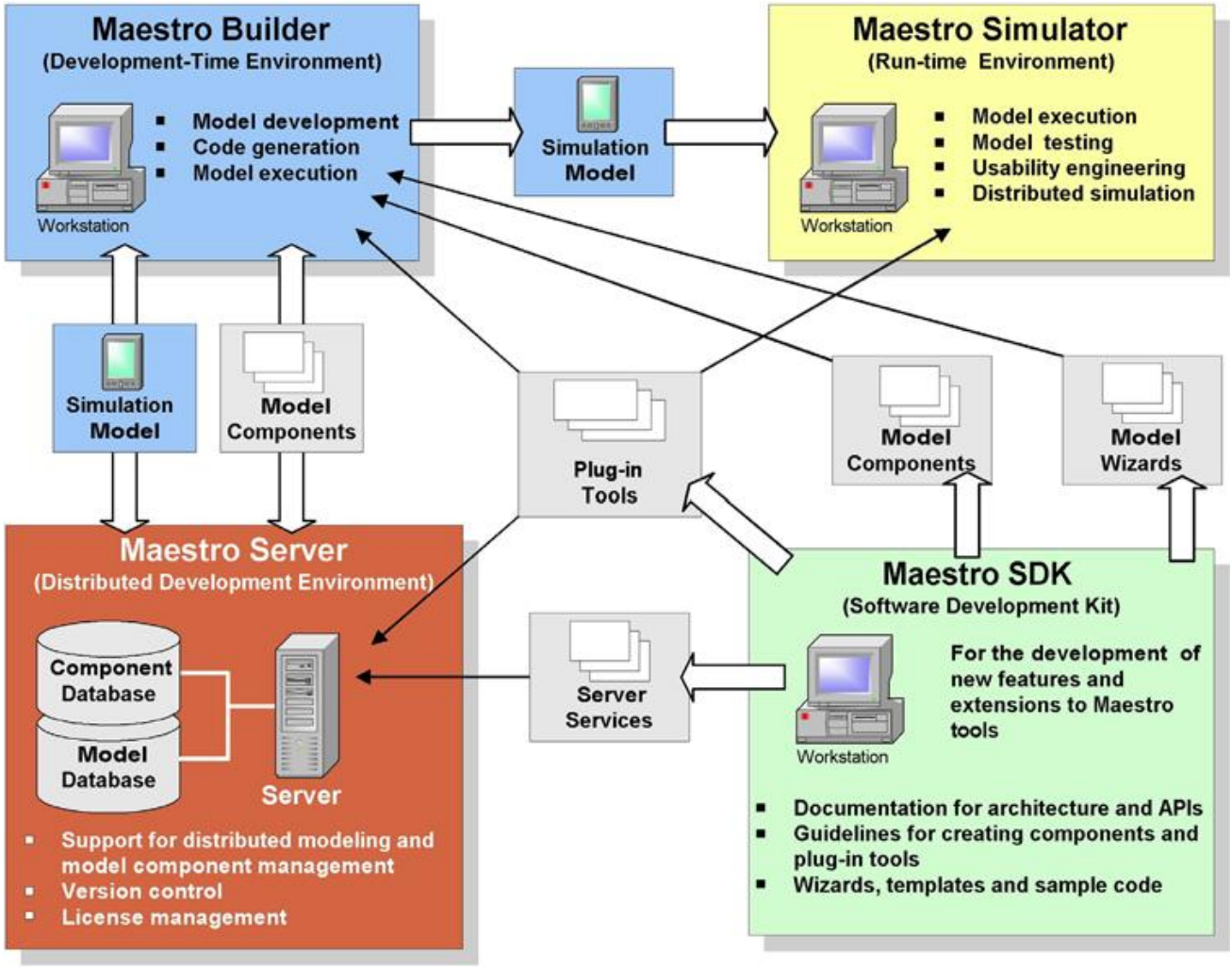
Concepts:

- Integration of several simulation systems
- Integration of simulators and hardware
- Needs for data-mining in simulation
- Standardization of simulation
- Multi-accuracy models (critical vs. less important)

Benefits:

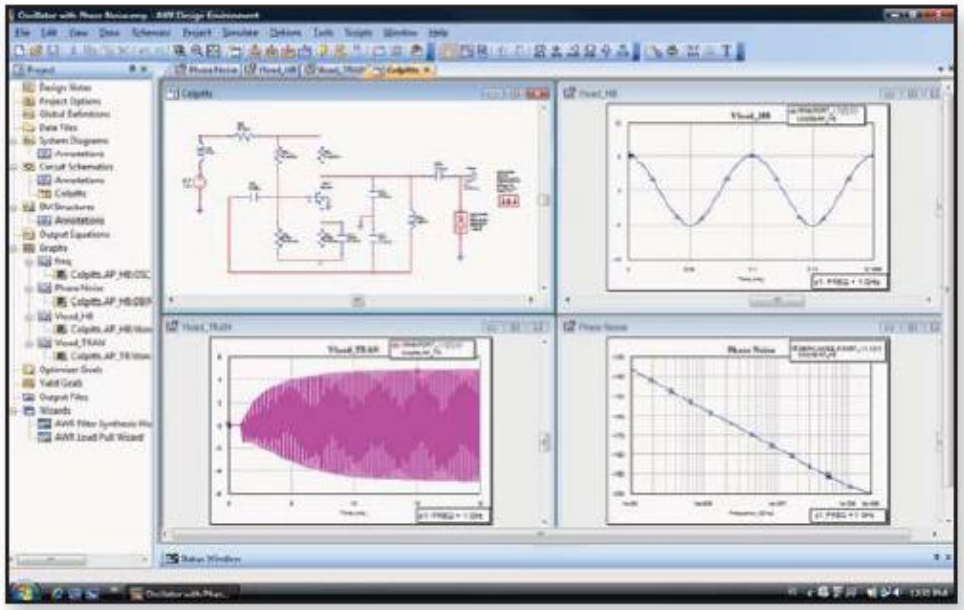
- Faster R&D, faster idea testing
- Early comparison of solution alternatives, vulnerabilities, etc.
- Virtual prototyping before actual product
- Hardware in the loop simulation
- Change management of complex systems

Virtual design of a product



APLAC simulator

- The APLAC simulator offers multi-level analyses which includes:
  - DC operation point
  - Linear frequency domain
  - Time domain
  - Harmonic balance
  - Phase noise
  - Linear/non-linear noise including AC noise contributors, temperature
  - Yield predictions and optimization



APLAC oscillator analysis utilizes optimization to find oscillation frequency. Both HB and transient simulation results are studied.

Design of production

VALOR COMPUTERIZED SYSTEMS (FINLAND) OY
Ruukinkatu 2
20540 TURKU
Puh. (02) 241 0201
www.valor.com

Manufacturing

Manufacturing: Applications of M & S

Products:

- Virtual prototyping
- Functional testing
- Testing for manufacturability
- Instructions generation
    - Assembly
    - Operations
    - Maintenance

Production and Manufacturing

- Manufacturing systems planning (device, phase, line, factory, company network, logistics)
- Assessing manufacturability, personnel training
- Simulation-based production automation testing
- Safety analyses
- System lifecycle (beginning/middle/end –of-life)
- Simulation-aided control and decision making (operators, production mgmt, company mgmt)

Manufacturing: Applications of M & S

- System and device vendors:
  - Marketing aids: simulated offer
  - Software development test environment
  - Business process optimization

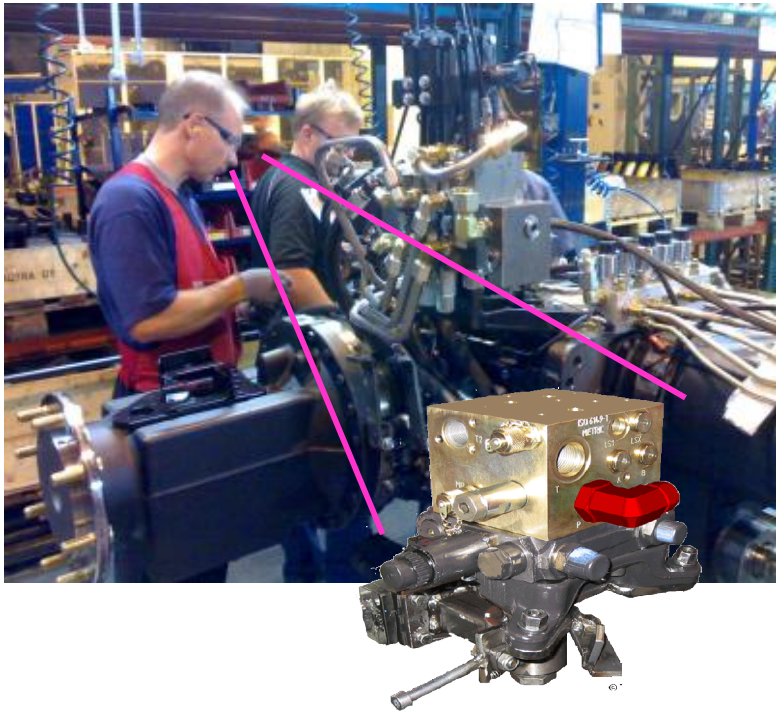
- Offering in Finland (engineering offices, software vendors, consulting, etc.)
  - Delfoi, http://www.delfoi.fi/web/en_GB/ , partly own development, Delmia repres.
  - SW Development, http://www.sw-development.com/en/index.php, partly own development based on Enterprise Dynamics -software
  - Visual Components, http://www.visualcomponents.com/, native development
  - IBM, Catia repres.
  - Ideal Engineering, http://www.ideal.fi/, Siemens PLM repres.
  - Artsicon Ky, Automod repres. http://www.artsicon.com/
  - ABB, also respective services
  - EP-Logistics, engineering

- Research (VTT, Helsinki & Tampere Univ. Tech., technical colleges)

Manufacturing: M & S related solution concepts

- Hardware-in-the-loop
  - (e.g. automation system or PLC operating on a simulated manufacturing line)
- Real-time simulations, on-line model editing, on-line manufacturing design
- Heterogeneous simulations (integrated in various levels of detail)
- Standardization
- Human-system integration
- Semantic knowledge management
- Early failure disclosure
- Virtual prototyping replacing expensive physical prototyping
- Shorter design cycles, shorter testing, ramp-up
- Better comprehension of complex systems
- Effective product tayloring

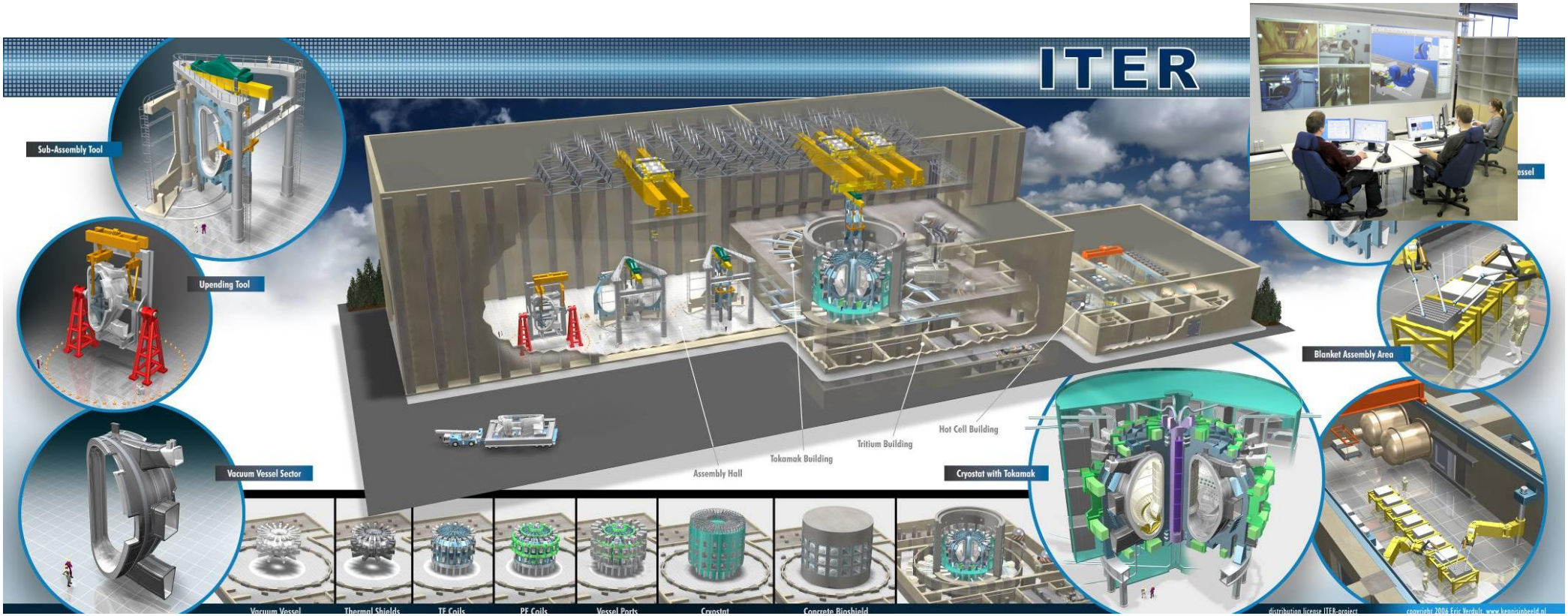
Valtra:
AUGMENTED REALITY FOR ASSEMBLY – INCREASING EFFICIENCY IN ASSEMBLY WORK



- Visual assembly information is superimposed on physical parts in order to assist complex assembly work
- Product data (STEP data protocol) from commercial CAD systems is linked
- Demonstrations for the assembly of a tractor assessory's power unit at Valtra Plc
- Less faults, shorter learning period
- Excellent for small series/product variations

ITER Maintenance - Virtual techniques

- Virtual techniques are used to define requirements and boundaries for the device
- Virtual prototyping of device kinematics and dynamics is elementary in design
- Virtual prototypes are used for device and control concurrent engineering
- Virtual model is used for robot programming, for task planning, for device control, condition monitoring, for operator training… all the robot life time



Conclusions

Major challenges for industrial modelling and simulation

- **Seamless support for simulation in different levels of details** i.e. conceptual level simulation at the beginning of the product life cycle, more detailed simulation in later phases and seamless moving between these levels.
- There should exist a way for software **component based simulation** i.e. model algorithms can be developed, added, removed and changed run time as part of the larger scale model.
- Support for **multi-domain and multi-physics simulation –** in spite of diverse, individual simulators in each domain or engineering discipline
- The simulation system should provide seamless exchange of model and simulation results data between different modules in the simulation process.
- **Model configuration has to be neutral** i.e. it should not be simulation tool specific.

Major challenges for industrial modelling and simulation (cont'd)

- There should be **general, unified model composing and modification tools** for different background tools.
- There should exist high level component modelling, meshing, model topology editing, simulation management and runtime adaptive tools.
- Need for **distributed simulation model configuration and usage** including version and access control.
- Simulation data **visualization** using suitable modern methods of computer graphics (2-D, 3-D, augmented reality) should be common for different models and different levels of details. This way results from these models can be visualized in a common and intuitive way.
- There should be better **links from simulators to different engineering applications**. Only this way simulation can find its way to the everyday engineering.
- Support for **validation and verification** of simulation models should be a built-in feature in a modelling and simulation framework.

Concepts of simulators

- A means to understand phenomena
  - A common part of modern science!
- A means to verify engineering
  - CAE, FEA/FEM, CFD, MES, optimization
  - Process analysis, troubleshooting, safety critical applications
- Operator training simulator
- Test bench for control, automation, and information systems
- Mixed physical-virtual
  - Hardware-in-the-loop
  - Mixed reality
- Geometries vs. physics modelling
- Integrated simulators
  - Multi-physics, multi-domain, multi-disciplines
  - Life-cycle simulators
- Simulation-based planning, simulation-based engineering

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VTT creates business from technology