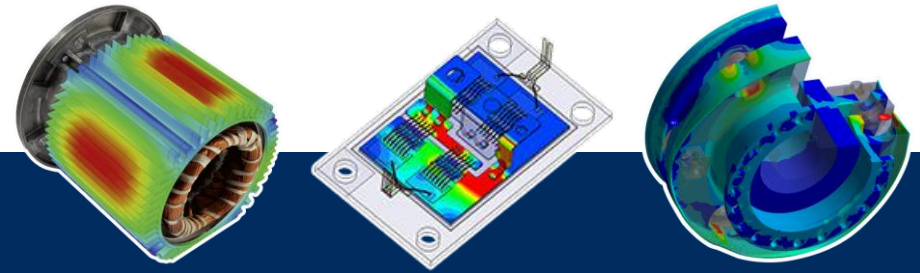




Simulation ist mehr als Software®



# An integrated Workflow for the Simulation-Driven Development of Electric Motors and Generators

René Fuger CADFEM (Austria) GmbH

## From the Idea to the Operation

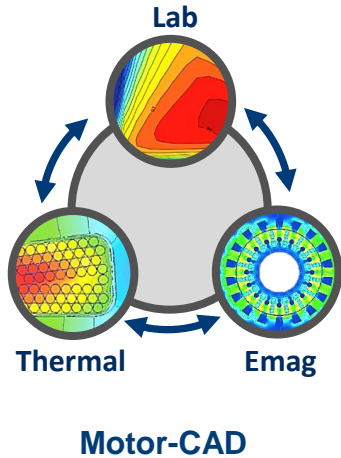
Design

Analysis

Operation

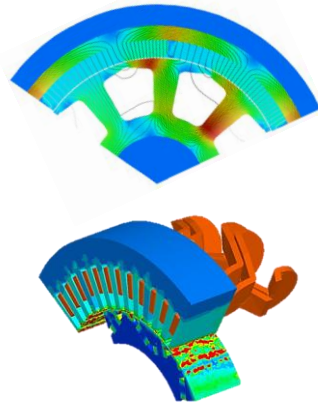
### Design

Efficient Motor Design Toolkit



### 2D & 3D Analysis

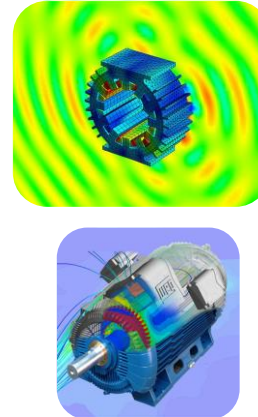
Advanced Magnetics Modelling



Maxwell 2D & 3D

### Coupled Analysis

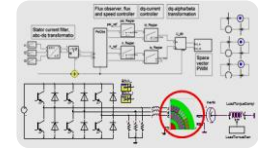
NVH, Cooling, ...



Mechanical & CFD

### System Validation

Control logic, software



3D Physical Validation

Twin Builder

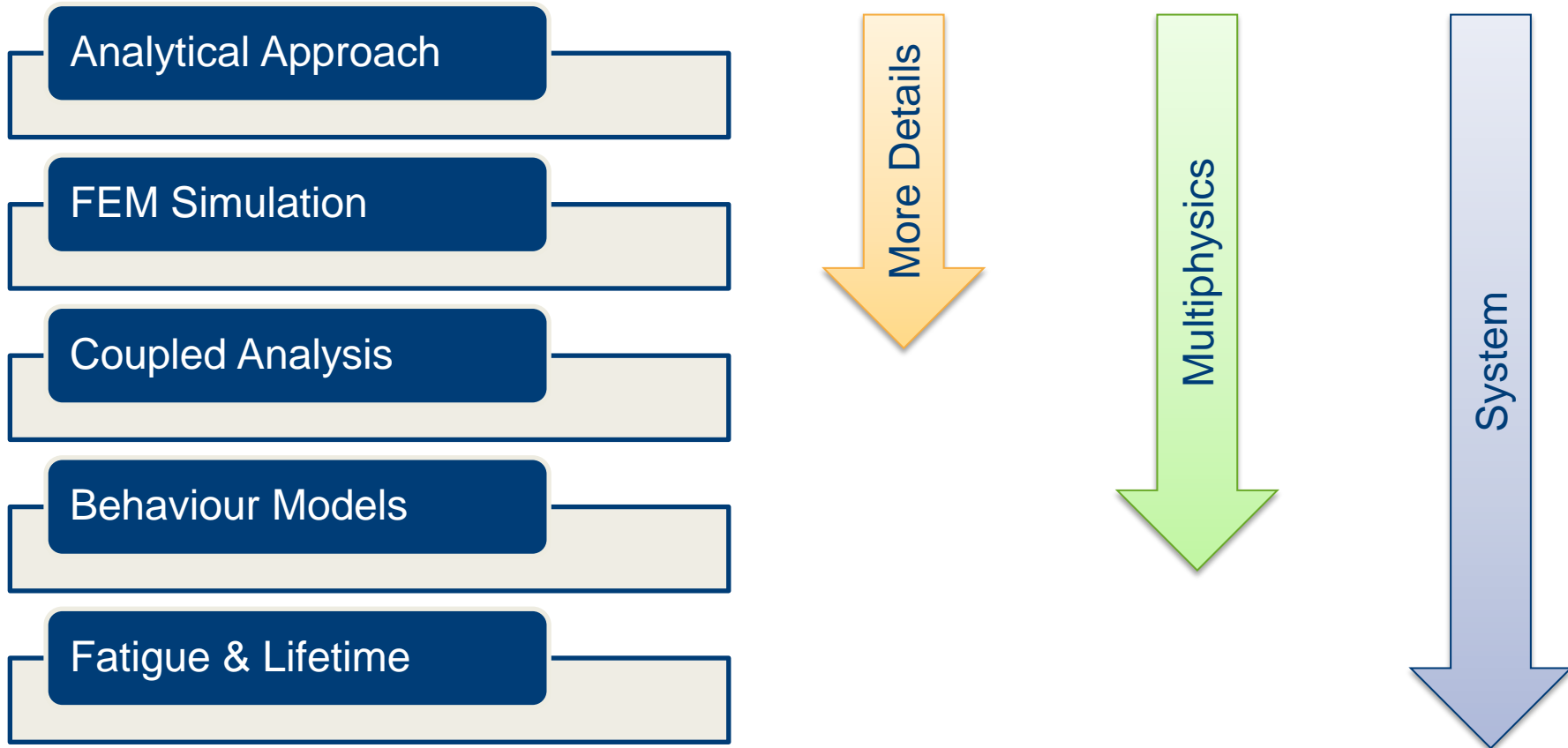
## Motivation

### New challenges in the development of electric drive systems

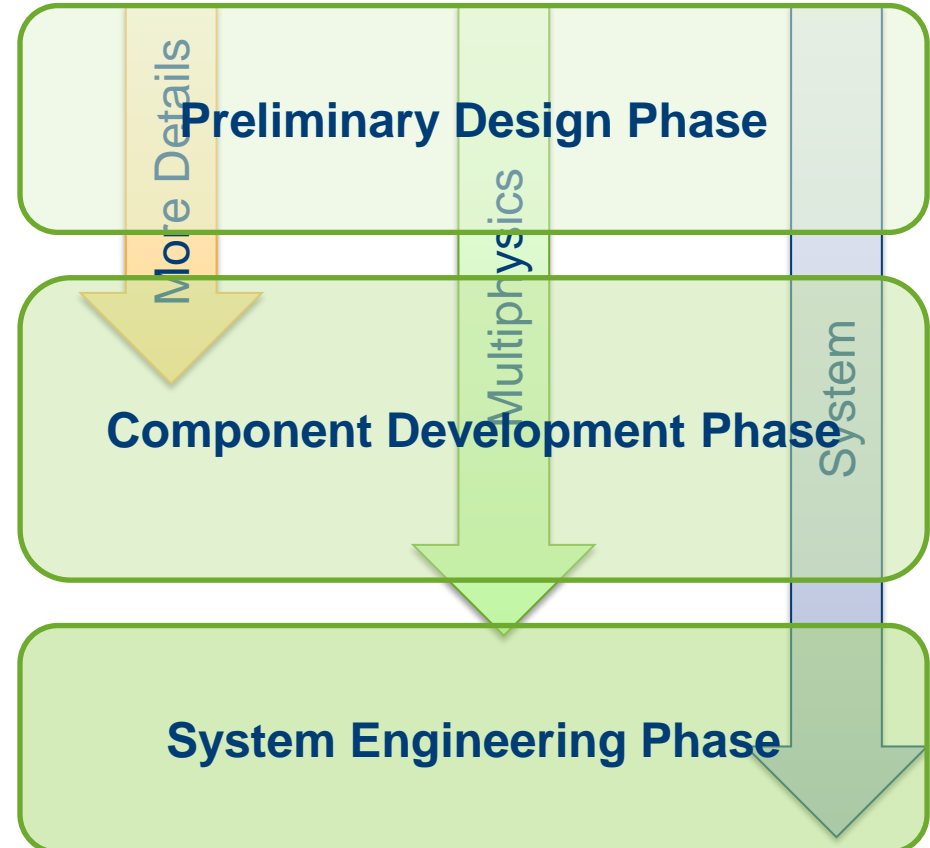
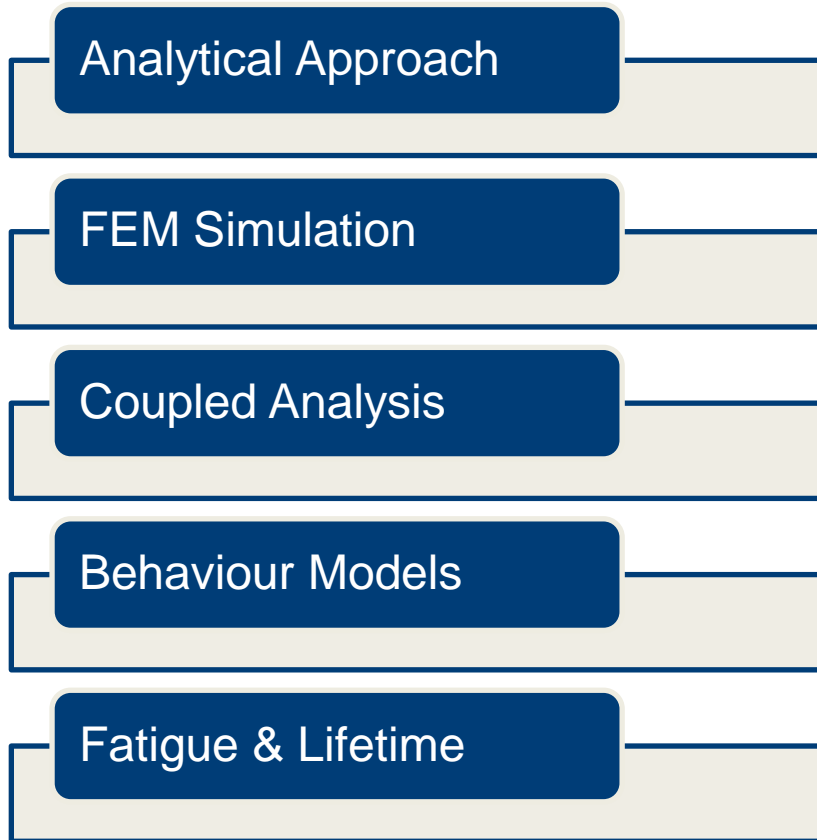
- Application specific requirements getting more restricted
- Faster response times to customer inquiries and shorter development times
- Different motor designs available and more competitors on the market
- System performance map required during tendering stage
- ...



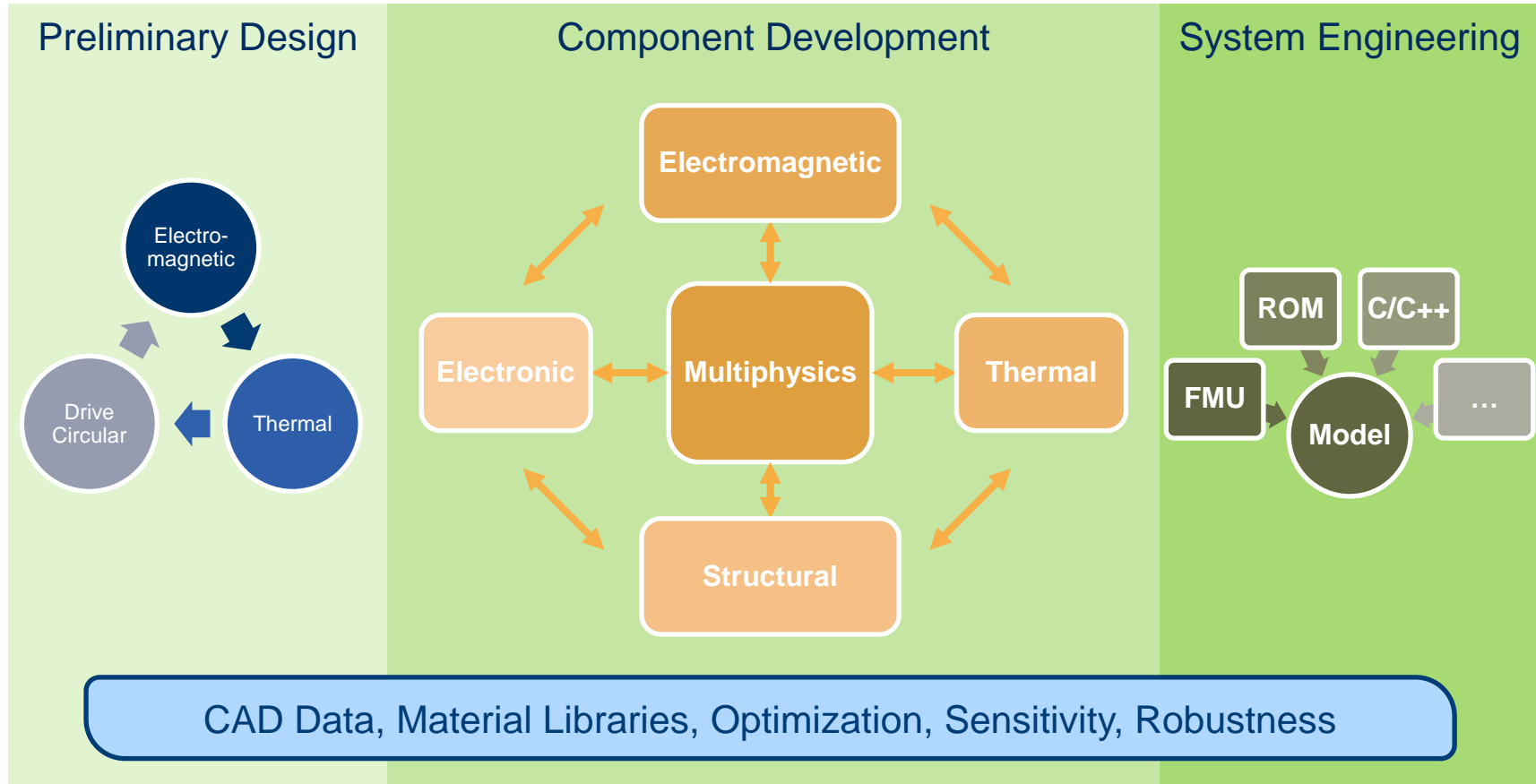
## Simulation Depth



## Simulation Depth

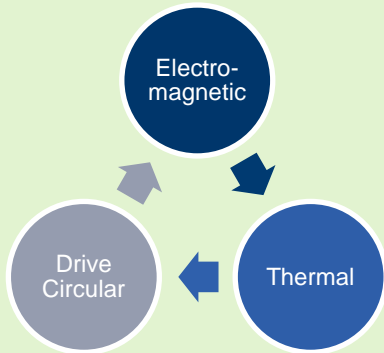


## Simulation Requirements



## Preliminary Design

### Preliminary Design



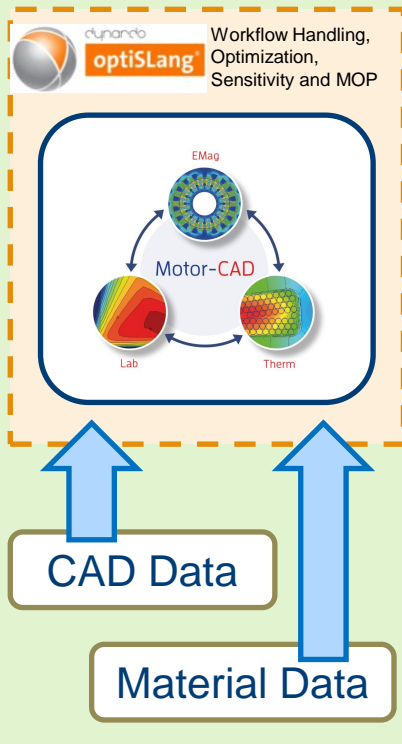
### Objectives

- Investigation of the possibilities
- Fast evaluation of different designs
- Coupled preliminary electromagnetic and thermal analysis
- Fast evaluation of performance maps and duty circles



## Preliminary Design

### Preliminary Design



### Objectives

- Investigation of the possibilities
- Fast evaluation of different designs
- Coupled preliminary electromagnetic and thermal analysis
- Fast evaluation of performance maps and duty circles



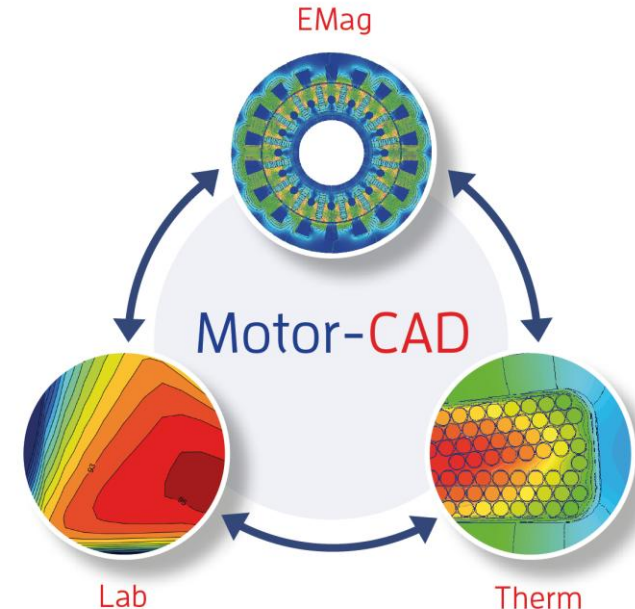
### Requirements

- Software to evaluate fast and accurate electromagnetic and thermal behaviour
- Capability for preliminary optimization and sensitivity analysis
- Automated workflows for data exchange

## Motor-CAD Software

- Motor-CAD **EMag**, **Therm** and **Lab** modules are developed to enable fast and accurate analysis in one integrated software
- **EMag**: A fast 2D finite element module for accurate electromagnetic and electrical performance predictions.
- **Therm**: Combines a lumped circuit and finite element thermal calculation for optimising the cooling system of a machine.
- **Lab**: Provides efficiency mapping and duty cycle / drive cycle transient outputs within minutes

*Written by motor design experts in the language of the motor designers so very easy to use.*

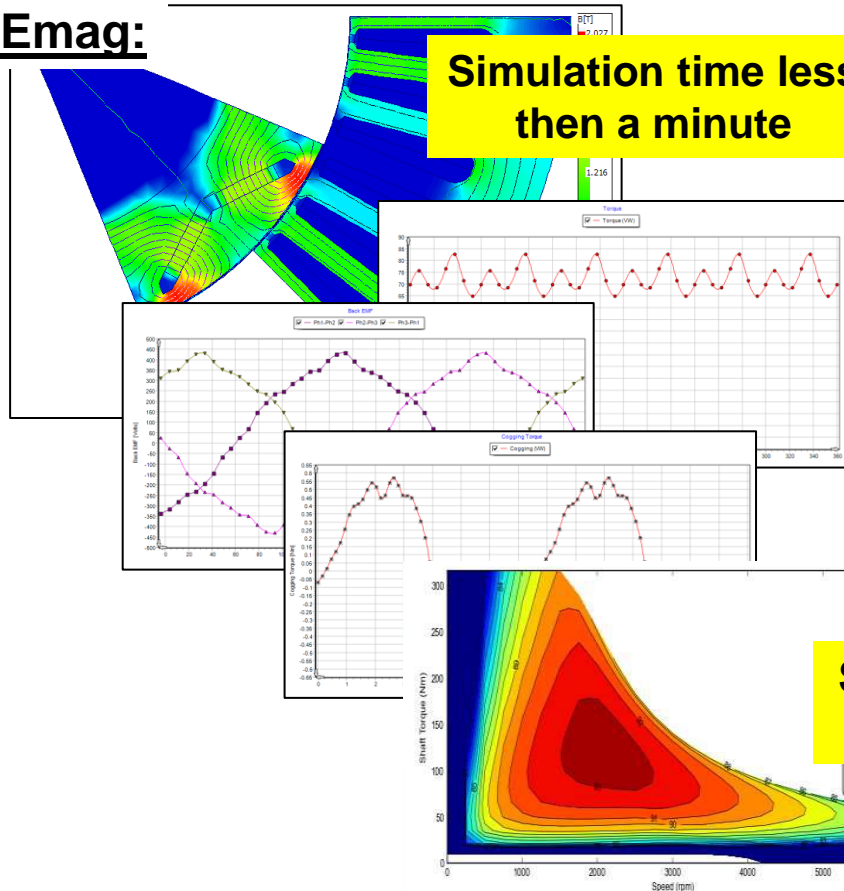




## Data Evaluation

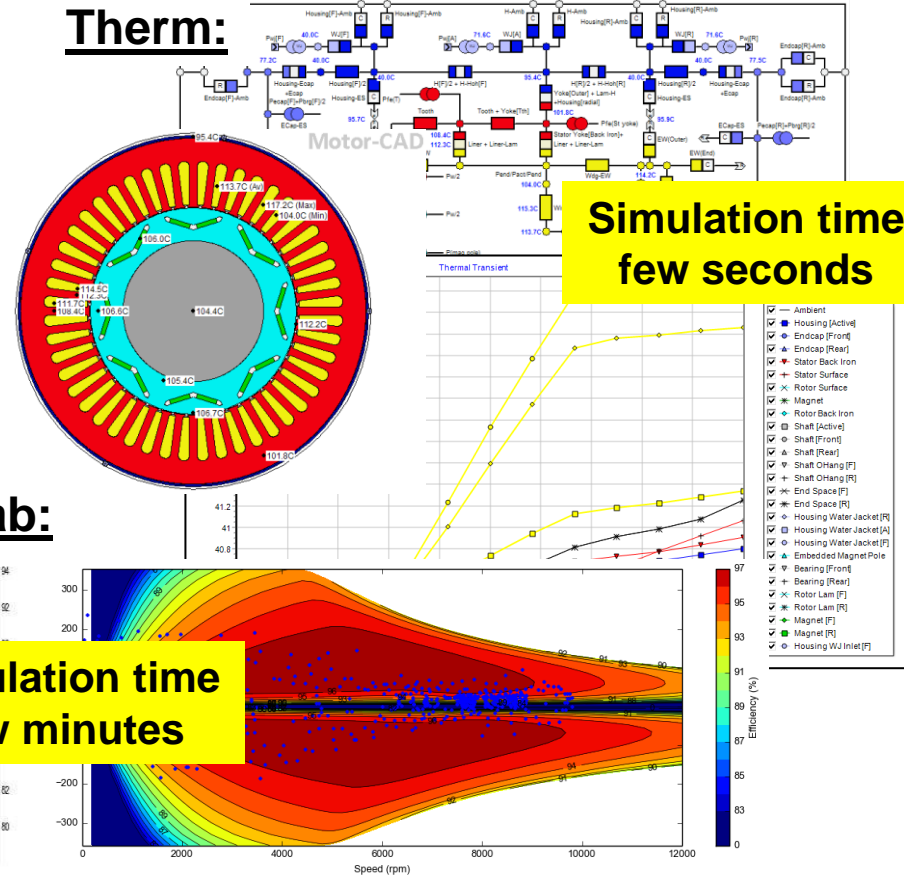
### Emag:

Simulation time less  
then a minute



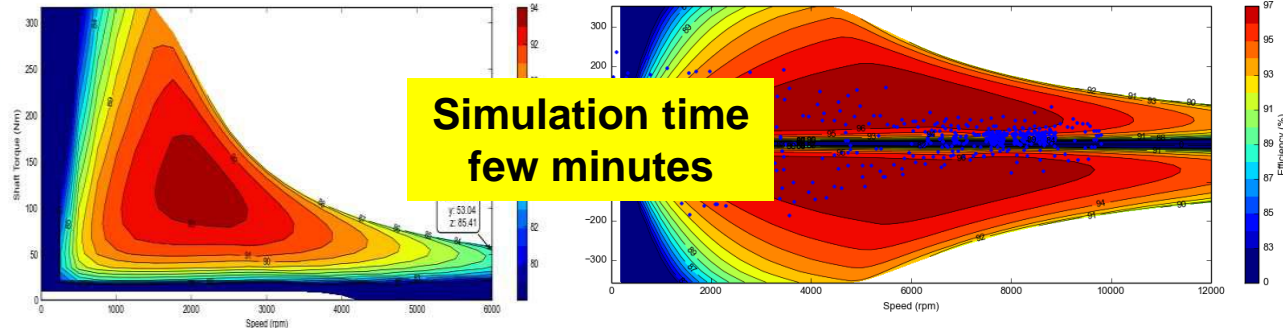
### Therm:

Simulation time  
few seconds



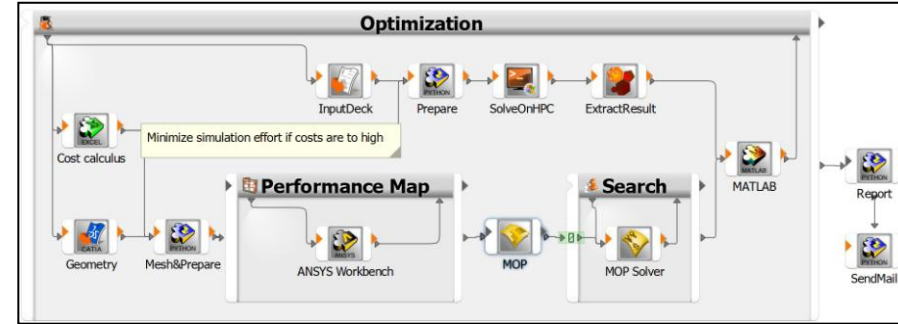
### Lab:

Simulation time  
few minutes



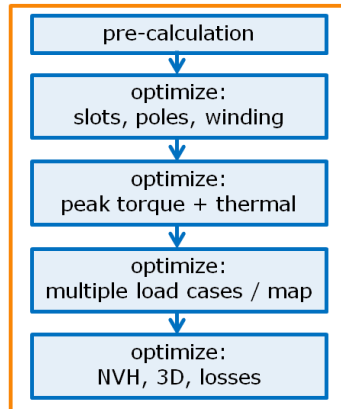
## Automation of Workflow and Optimisation

- Graphical programming, based on templates, wizard-based derivatives
- Post-Processing: visualization, main info at a glance, investigation when needed
- State-of-the-art sensitivity analysis + MOP + Robust Design Optimization



© Dynardo GmbH

### fully automatic

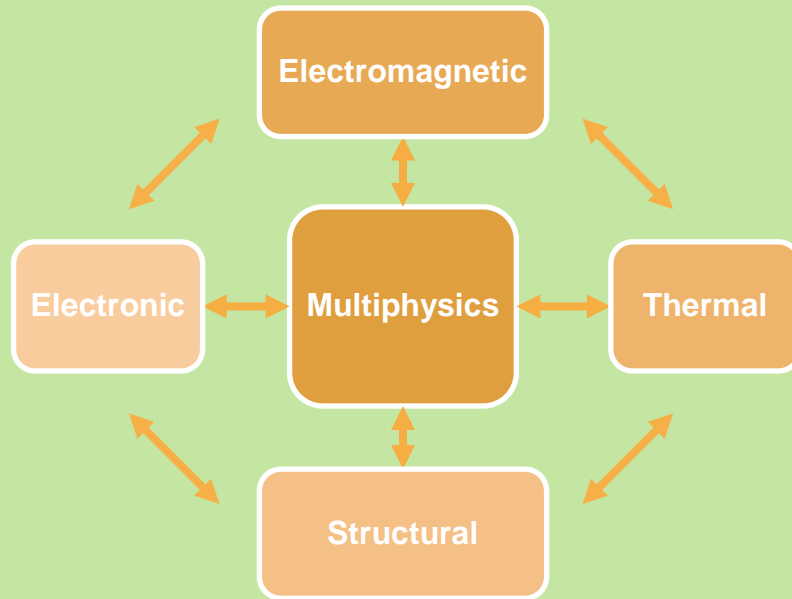


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- Investigative research → gain insight & understanding
- Establish workflows → benefit from your (codified) competence
- Integrated Workflows → optiSLang connects

## Component Development

### Component Development



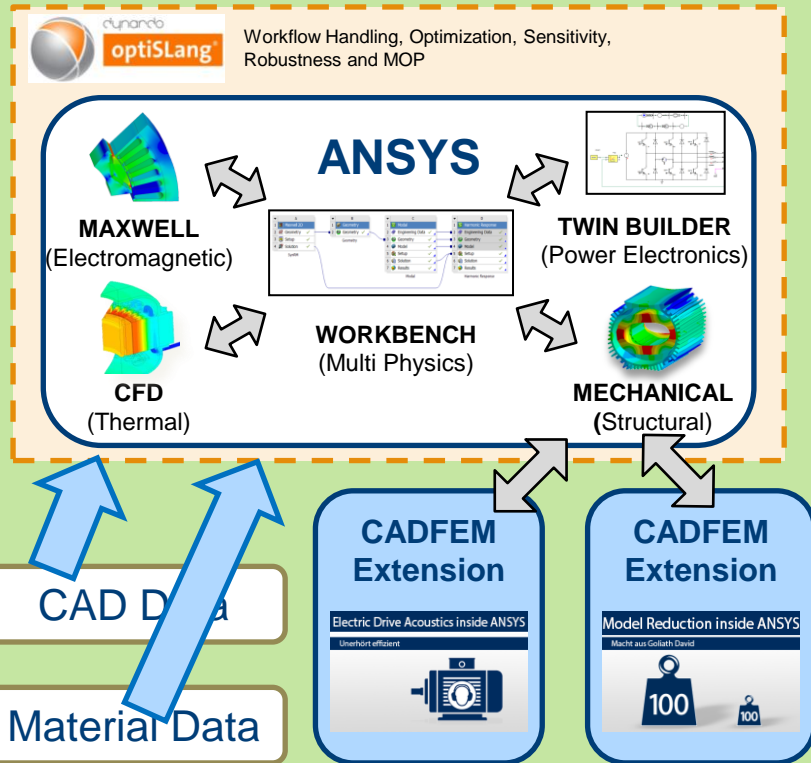
### Objectives

- Detail analyses of the electric drive
- Investigation of transient or three dimensional effects on the electromagnetic behaviour
- Coupled and uncoupled structural, thermal and power electronics simulations
- Generating deeper physical understanding and there dependence on the electric drive system
- Acoustics simulations (NVH)



## Component Development

### Component Development



### Objectives

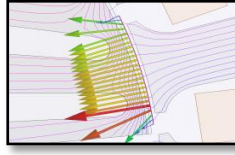
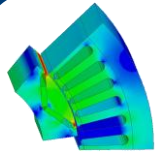
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### Requirements

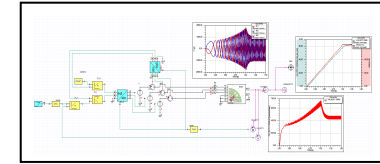
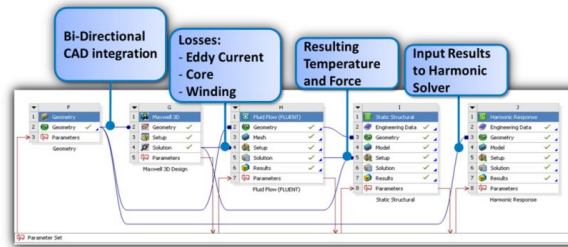
- High-end simulation tools for the different physical domains
- Easy coupling between the results from different domains (Simulation Platform)
- Sensitivity and robustness analysis over different tools and many parameters
- Workflow automation and file data handling

## Simulation Platform



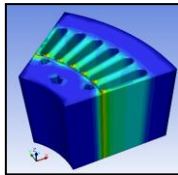
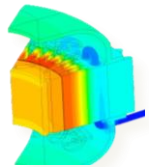
### MAXWELL

- Electromagnetic Fields
- Induced Voltage
- Induction Matrix
- Forces & Torques
- Losses



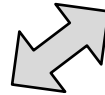
### Twin Builder

- Control Parameters
- System Behaviour
- Power Electronics



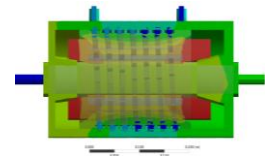
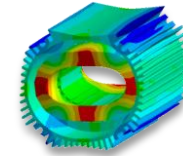
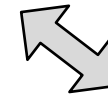
### CFD

- Heat transfer Coefficient
- Temperature Distribution
- Flow Characteristics



### WORKBENCH

- Simple Exchange of Data
- Connecting by Drag and Drop
- All Physics Domain in one GUI
- Coupled Optimisation

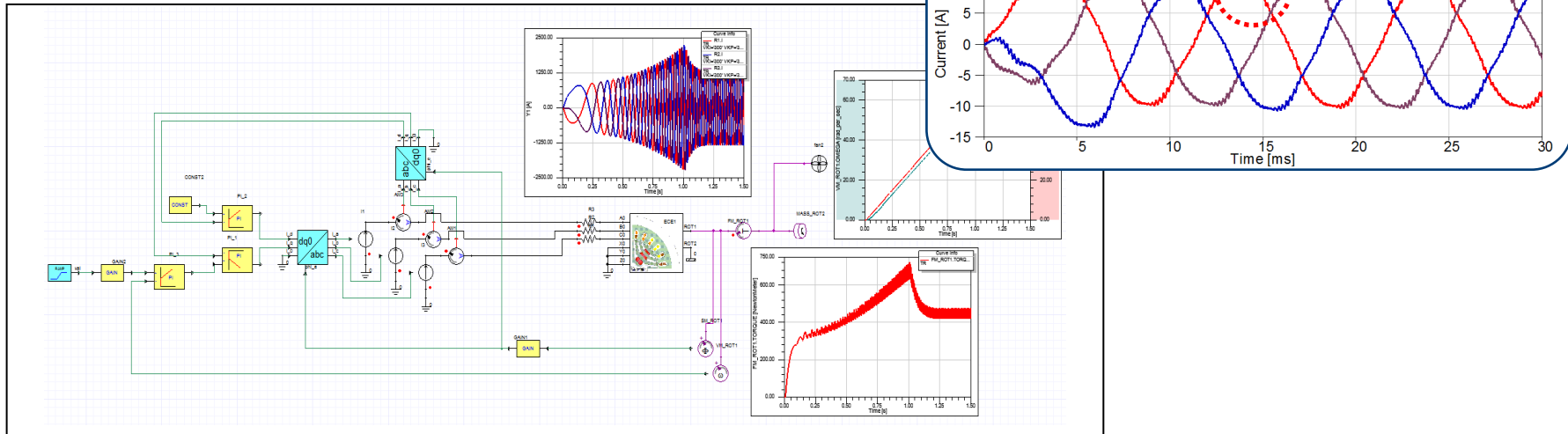
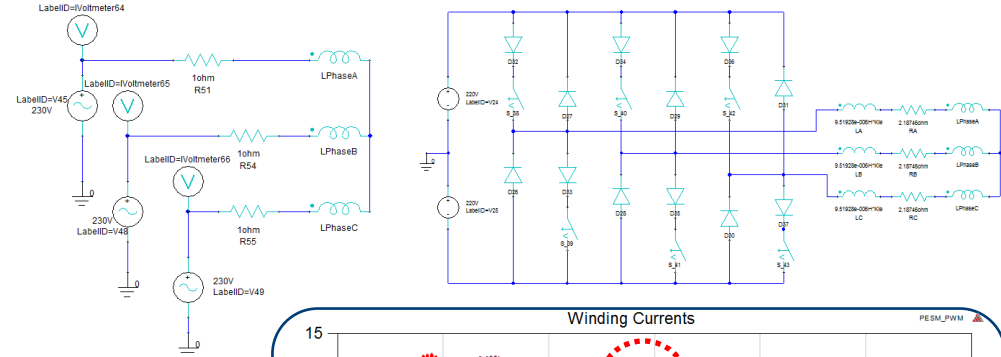


### MECHANICAL

- Stress, Stiffness and Deformation
- Eigenmode
- Temperature Distribution

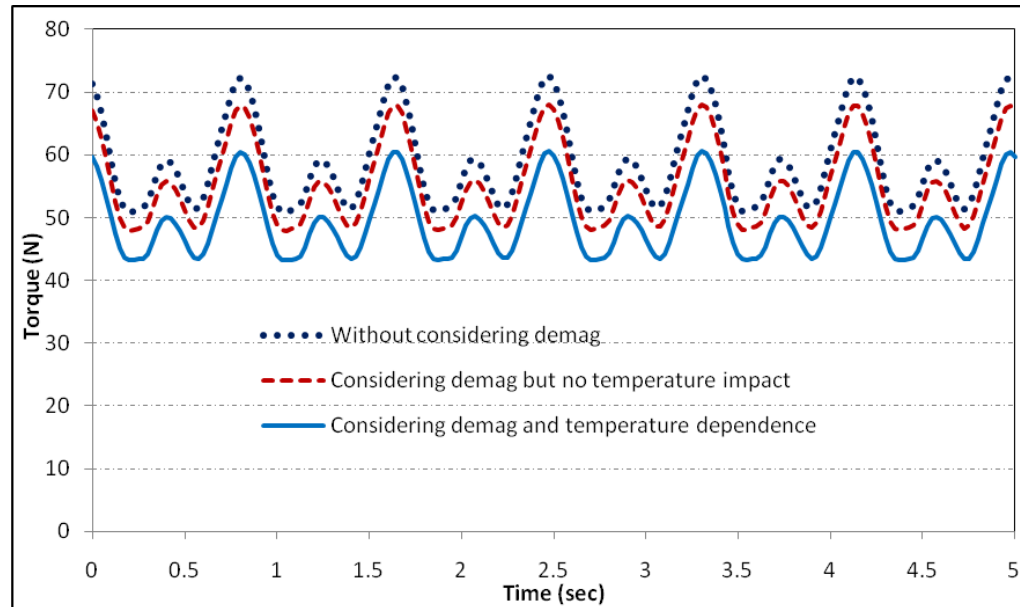
# Electronic-Electromagnetic Coupling

- Influences of power electronics
  - Sinus vs. PWM excitation
  - Additional Losses
- Control loops
  - Optimization



# Electromagnetic-Thermal Coupling

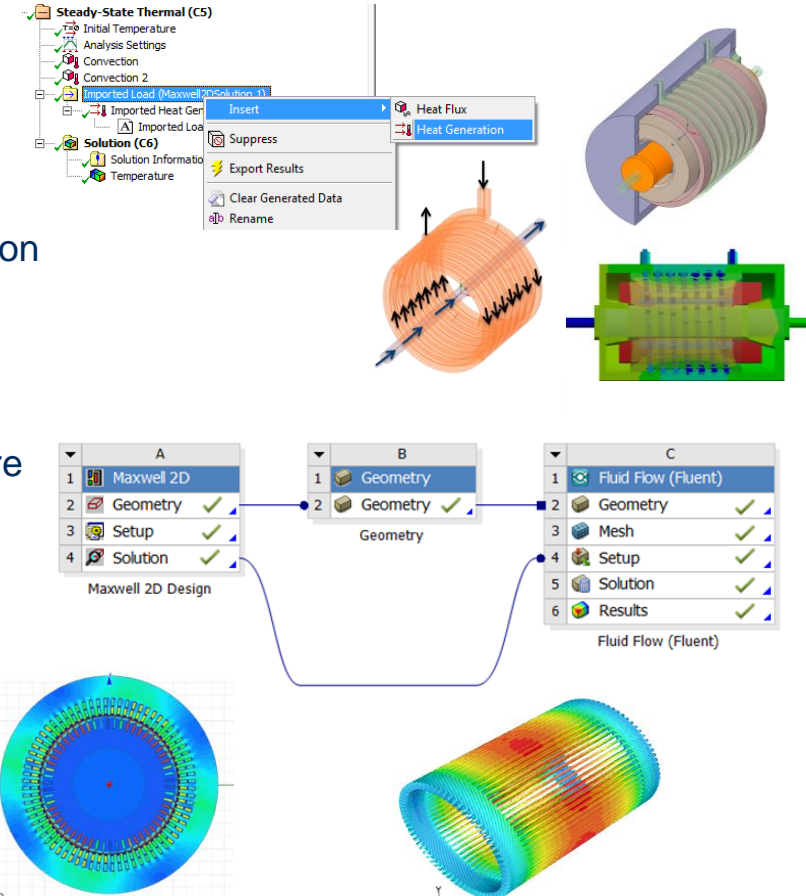
## Why coupling?



## Electromagnetic-Thermal Coupling

The losses obtained by EM-Simulation are used as realistic loads.

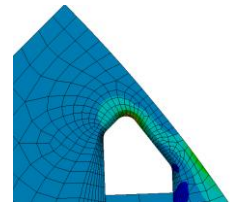
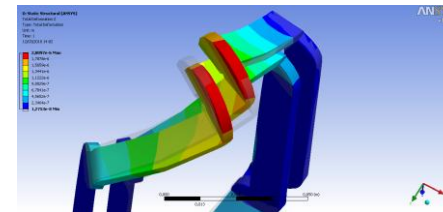
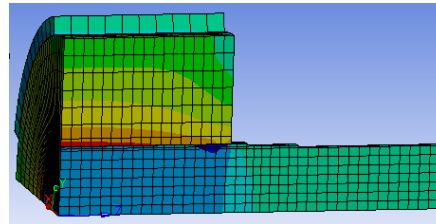
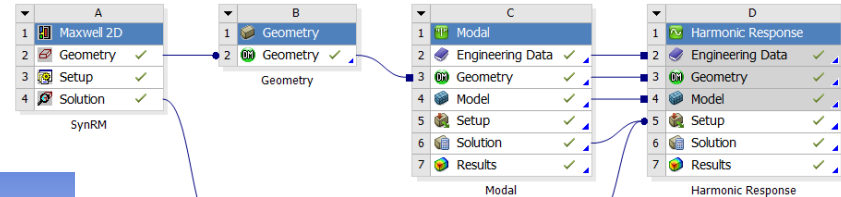
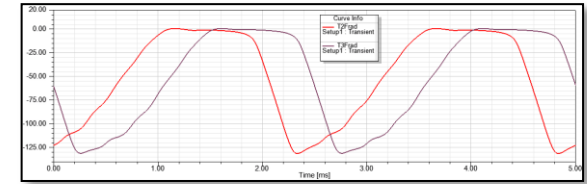
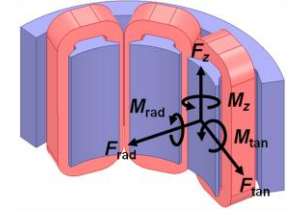
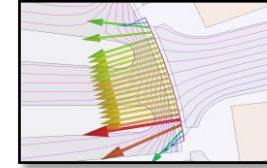
- Thermal analysis without fluid dynamics
  - Conduction, diffusion, advection, convection and radiation
  - Special elements for advection
  - Solves faster due to smaller project size
  - Convection has to be defined by boundary condition
  - Thermal Heat Coefficients has to be taken from literature
- Thermal analysis with fluid dynamics
  - Solves for heat transfer coefficient
  - Higher accuracy for fluid problems
  - Setting up of the model is more complex



## Electromagnetic-Structural Coupling

### Automated load transfer from magnetic field analysis

- Uncoupled or Coupled Simulations
- Static Simulation
  - Stresses (E-Steel, Housing)
  - Deformation
  - Resonance Frequencies
- Dynamic Simulation
  - Harmonic response based on magnetic forces
- Transfer of transient magnetic loads to frequency domain by DFT



# CADFEM ANSYS Extension - Electric Drive Acoustics inside ANSYS

## Workflow:

External computation  
of excitation loads

**Electro-  
magnetic  
Analysis**

**ANSYS Mechanical with Electric Drive Acoustics  
inside ANSYS**

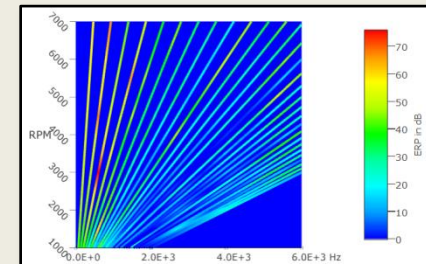
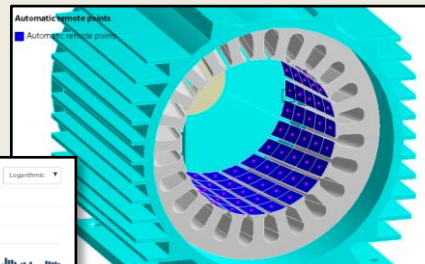
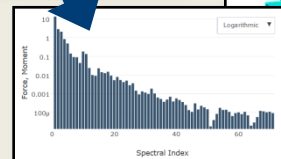
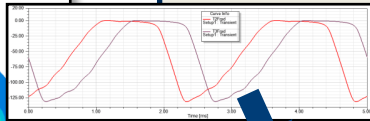
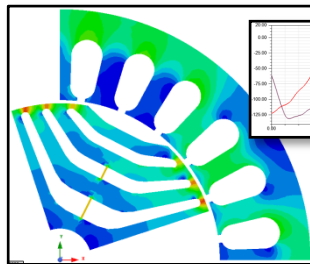
E.D.A. inside ANSYS

**DFT**

**Excitation  
Loads**

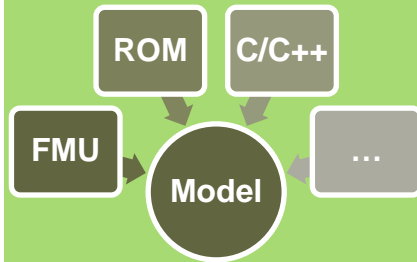
**Harmonic  
Vibration  
Analysis**

**Oscillation,  
ERP,  
Waterfall Plot**



## System Engineering

### System Engineering



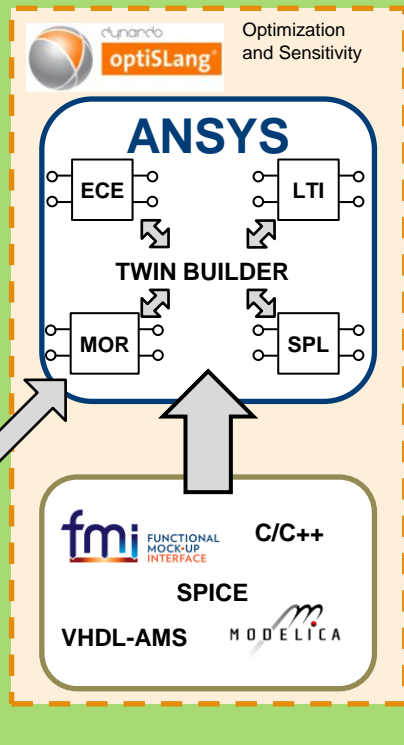
### Objectives

- Analysis and optimization of a system without extensive coupled FEM simulation
- Generating accurate behavior models from the component analysis
- Implementation of third party behavior models
- Fast evaluation of performance maps and duty circles on a system level



## System Engineering

### System Engineering



### Objectives

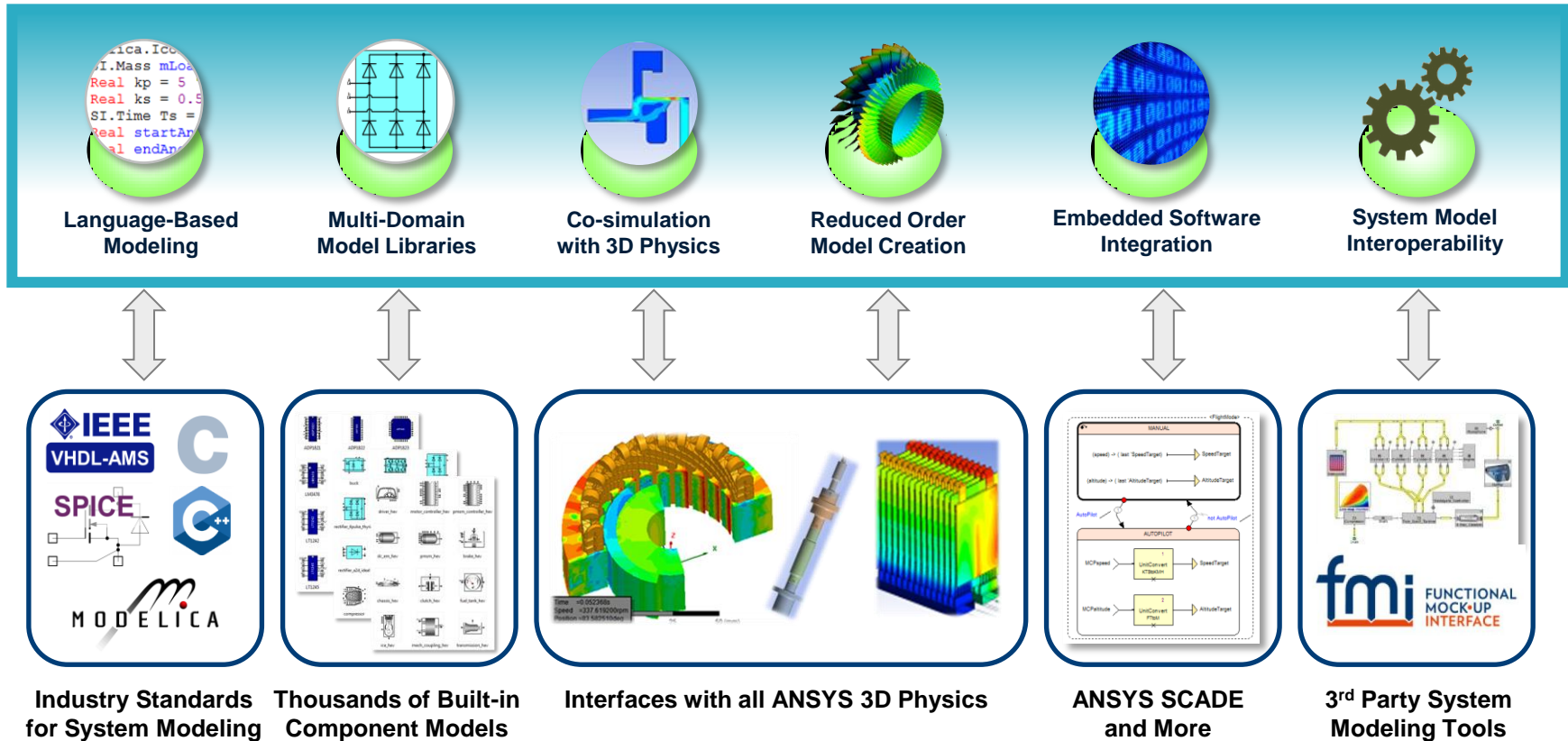
- Analysis and optimization of a system without extensive coupled FEM simulation
- Generating accurate behavior models from the component analysis
- Implementation of third party behavior models
- Fast evaluation of performance maps and duty circles on a system level



### Requirements

- Physical based system simulator with the possibility to generate State Space Model, Reduced Order Models, MOP, ...
- Implementation of 3<sup>rd</sup> party models
- Optimization, sensitivity and robustness analyses

## Twin Builder (Simplorer)



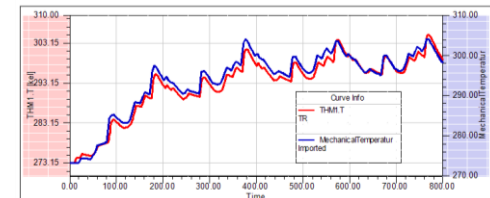
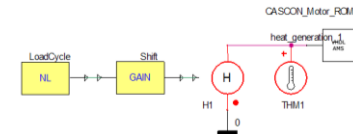
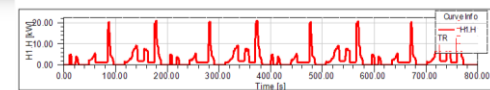
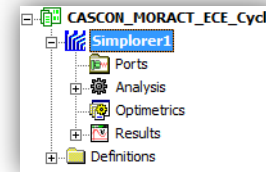
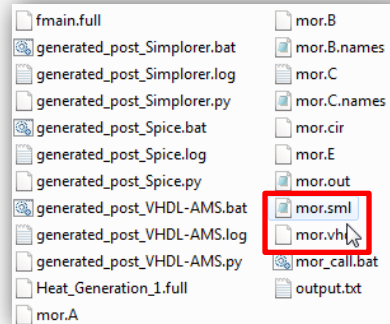
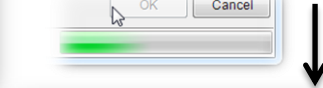
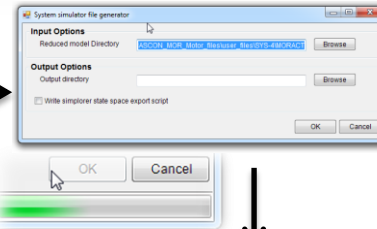
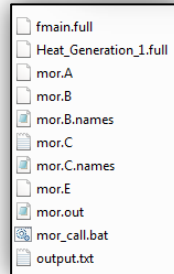
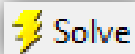
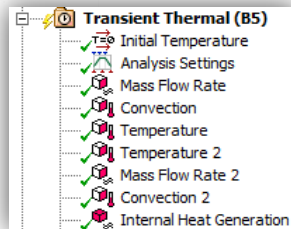
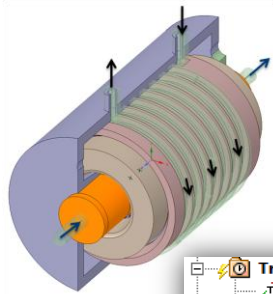
# CADFEM ANSYS Extension – Model Reduction inside ANSYS

## Model Reduction in ANSYS Mechanical with CADFEM MOR-ACT

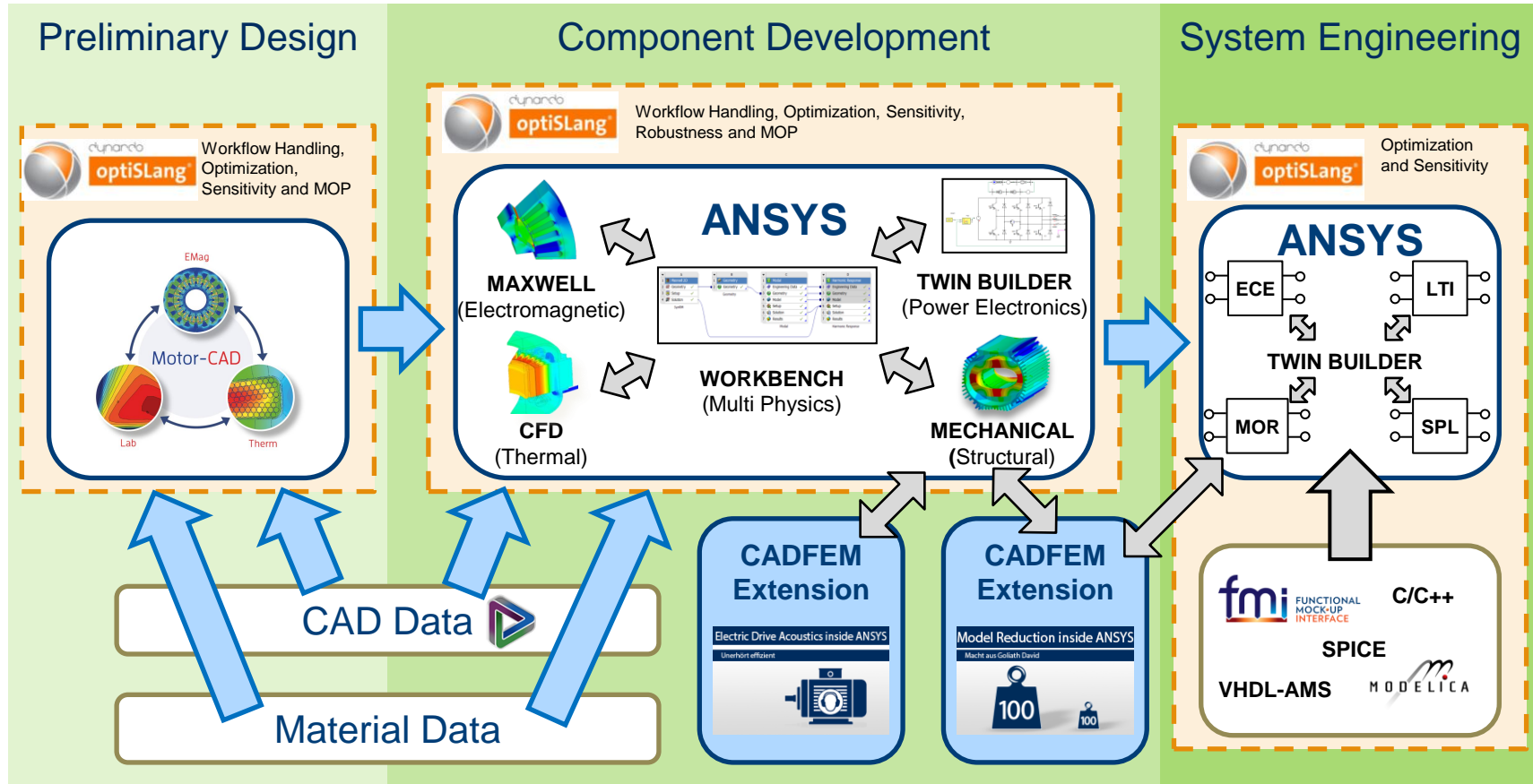
Mechanical  
*Transient Thermal*

Generate ROM

Twin Builder  
*Transient System*



## Summary - Workflow Overview



## Summary

- An integrated workflow for the simulation-driven development of electric motors was presented.
- The importance of an compact and fast simulation tool chain for the preliminary design phase was highlighted.
- Easy coupling of different physical domains is important to get realistic loads and accurate results.
- The development process have to be accompanied by optimization and sensitivity studies.
- Parts of the workflow was already implementation in the development process from our customers



**Simulation ist mehr als Software®**

# Simulation macht vieles möglich

Gemeinsam holen wir das Beste heraus

