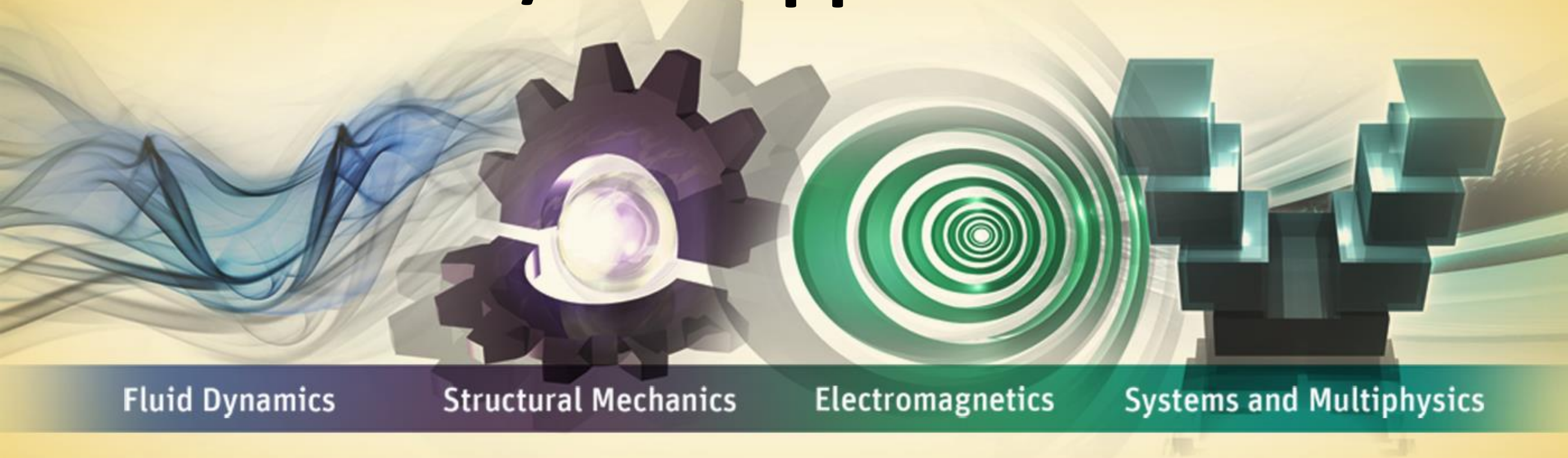
ANSYS

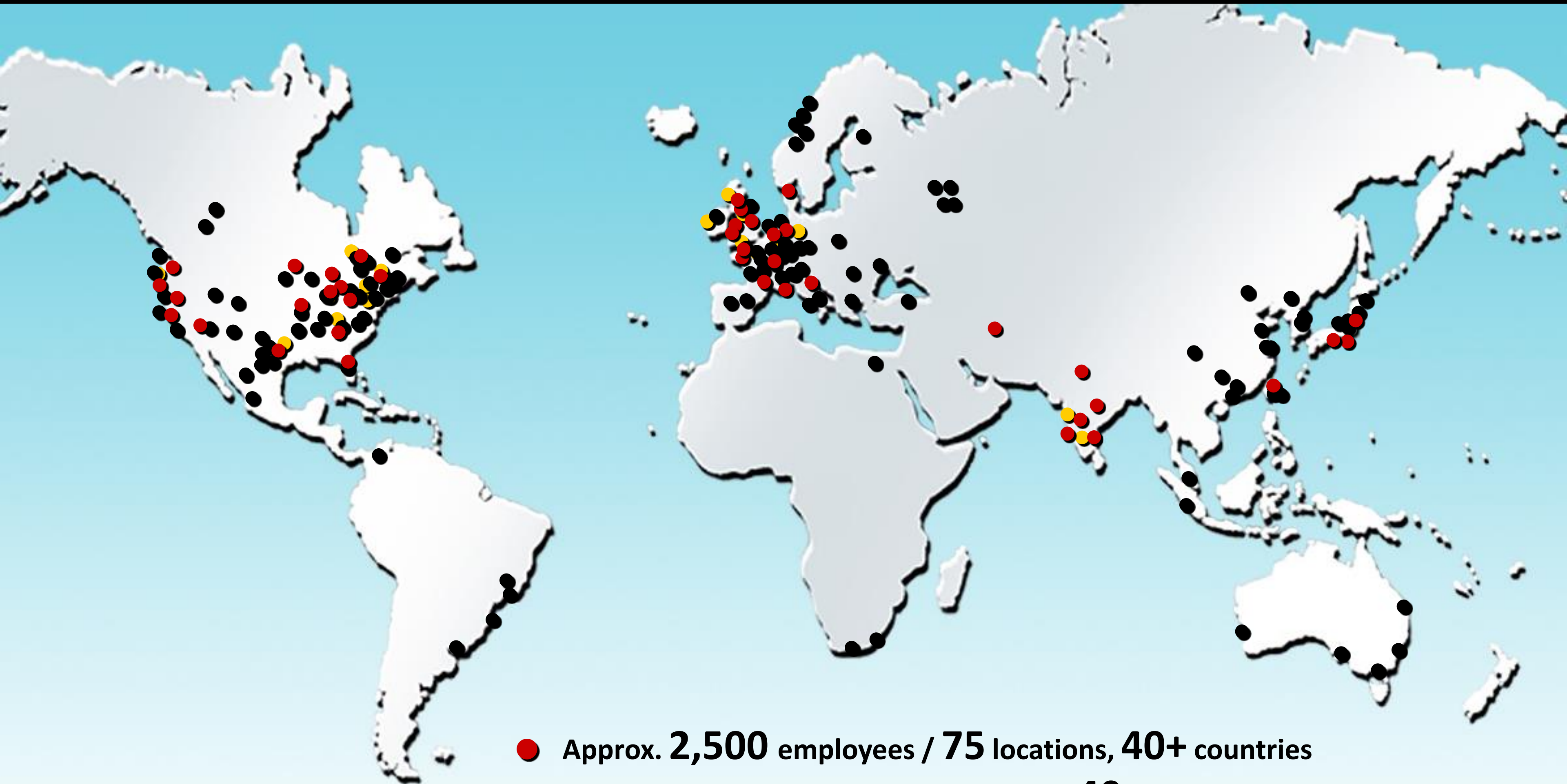
Realize Your Product Promise™

Advanced Simulation Technology in EV/HEV Application



ANSYS Team

ANSYS: World's *Largest* Simulation Community



● Approx. **2,500** employees / **75** locations, **40+** countries

● Network of sales channel partners in **40+** countries

● **21** major R&D centers on **3** continents

Our Focus: engineering simulation

ANSYS is dedicated **exclusively** to **engineering simulation** and is the world's **leading** software provider. Product innovators in the most demanding markets have **trusted** us for over 40 years.

"One of the things that we really pride ourselves in is creating innovative products. We're a world leader in most of our markets and so to stay there, we really need to keep cutting-edge innovation. We use tools like ANSYS to really help us do that."

Tom Chimner
Eaton Corporate

Our Products Overview: Leaders in the Field

ANSYS provides market-leading depth and breadth of capabilities in one discipline, while allowing for integrated simulation across all disciplines

Systems

ANSYS Simplorer
ANSYS SCADE
ANSYS HPC
ANSYS Engineering Knowledge Manager
ANSYS DesignXplorer

Fluids

ANSYS Fluent
ANSYS CFX
ANSYS Polyflow
ANSYS Icepak

Structures

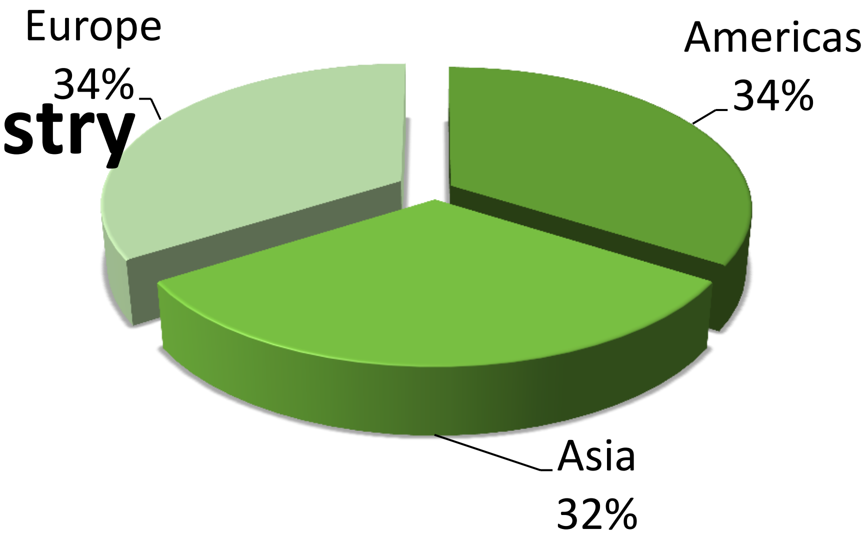
ANSYS Mechanical
ANSYS Autodyn
ANSYS LS-DYNA
ANSYS nCode

Electronics

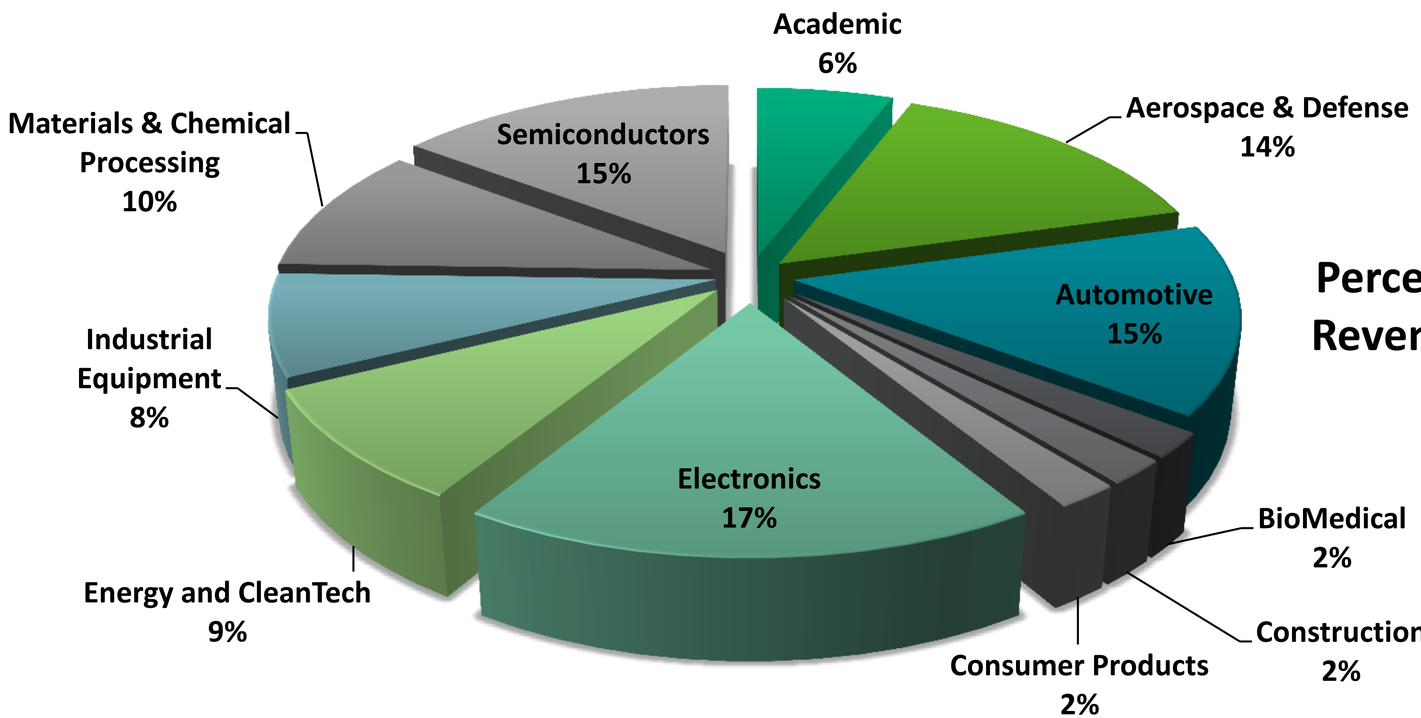
ANSYS HFSS
ANSYS Maxwell
ANSYS Designer
ANSYS RedHawk

ANSYS

Our Balance: Geography & Industry



Consolidated Company Geographic Revenue



Percent of Net Sales Revenue by Industry

Our Customer: Top Automotive Companies

Auto Makers

Toyota
General Motors
Volkswagen
Ford
Hyundai
PSA
BMW
Honda
Renault
Tata Motors
SAIC
Volvo
Chrysler

Auto Suppliers

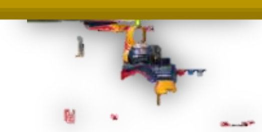
Bosch

Truck/Bus & Off-Highway

Caterpillar

Motorsports & Two-Wheelers

Red Bull

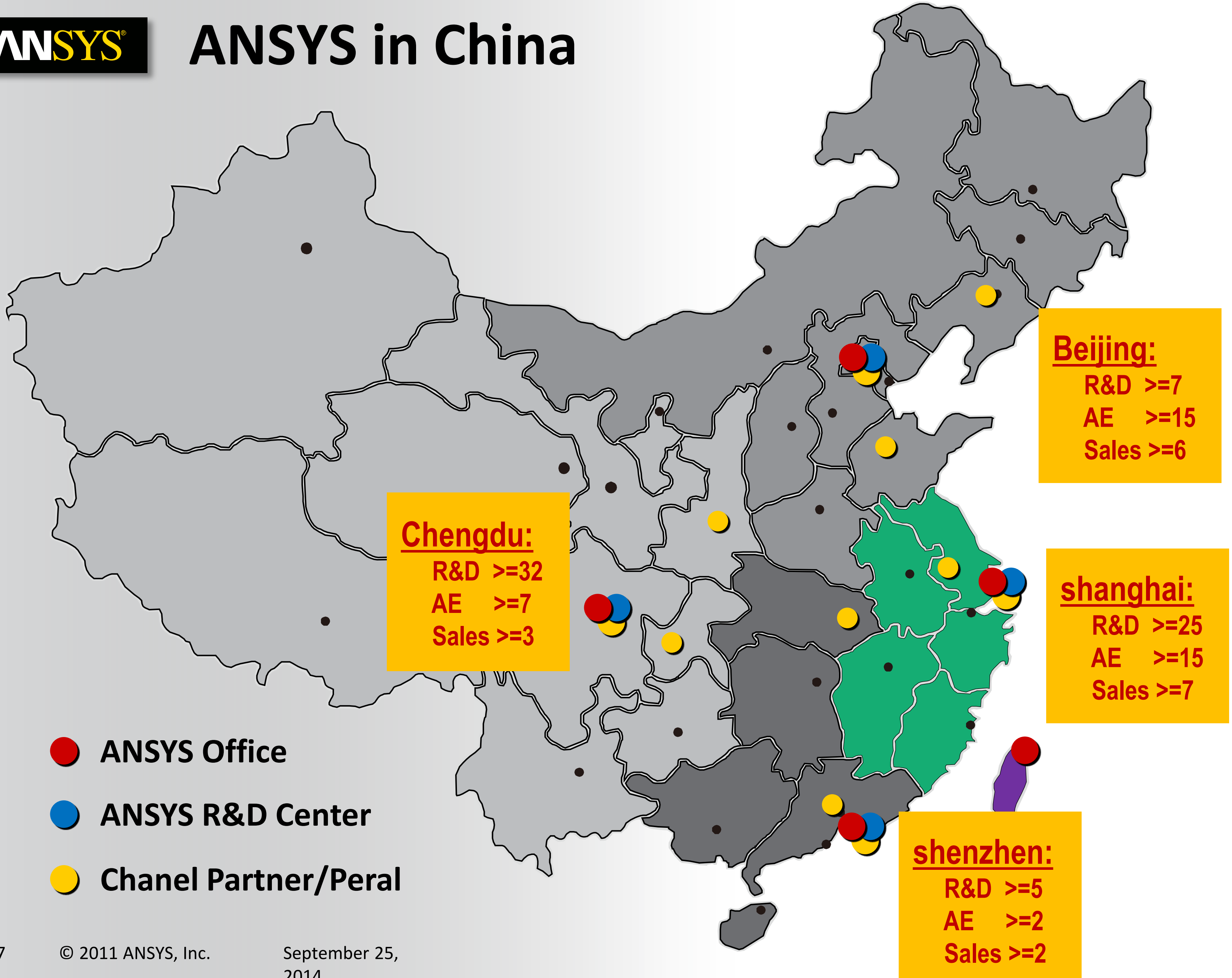


Other Ground Transportation

Alstom Transport
...mbardier
...nsportation
...tsche Bahn
...tromotive
...el
...way Technical
...earch Institute
...n
...zhou Electric
...omotive

- > 15,000 Total Customers
- > 200,000 Commercial Seats
- > 200,000 University Seats
- > 200 Channel Partners
- > 150 Industry Partners

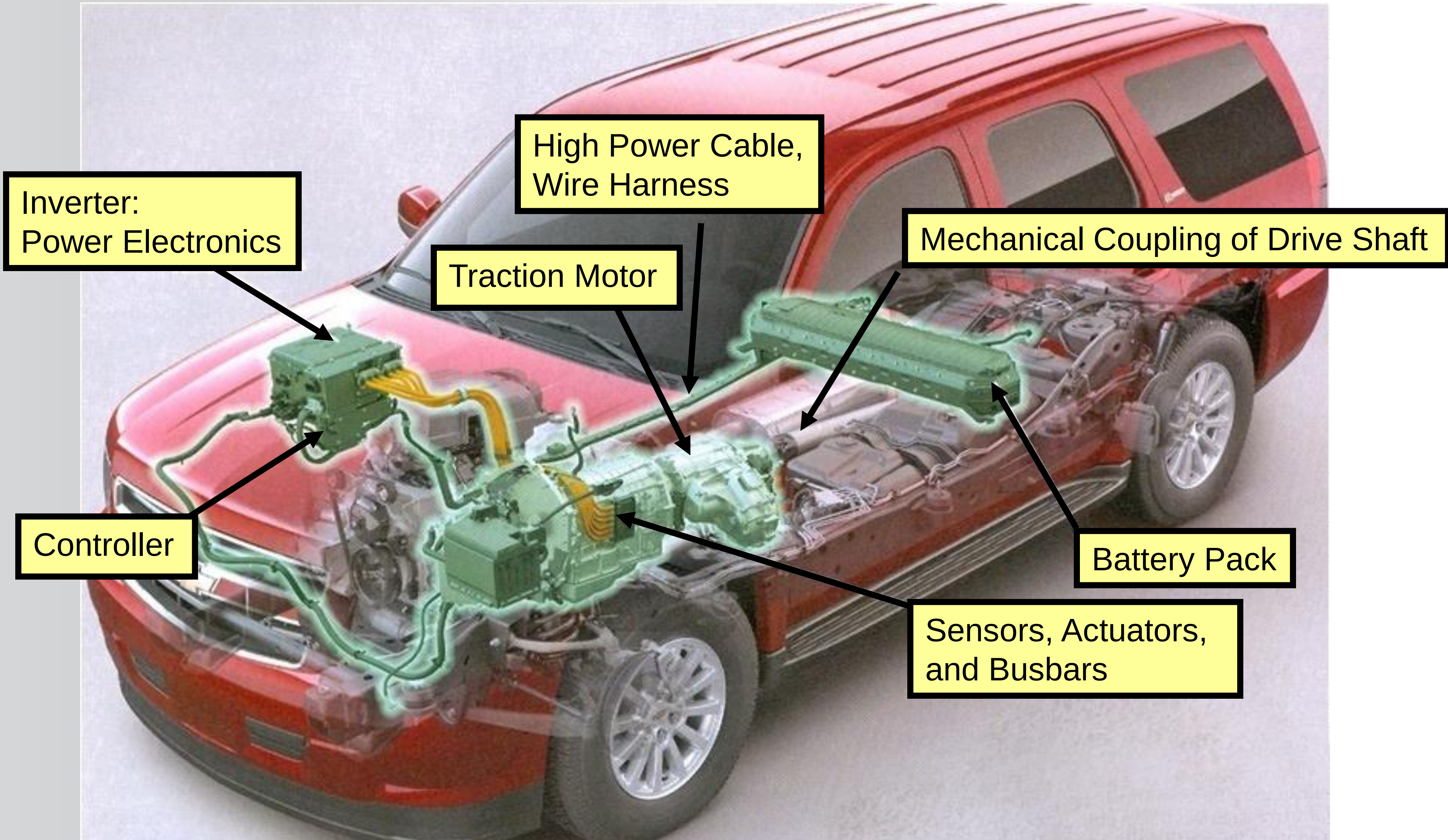
ANSYS in China



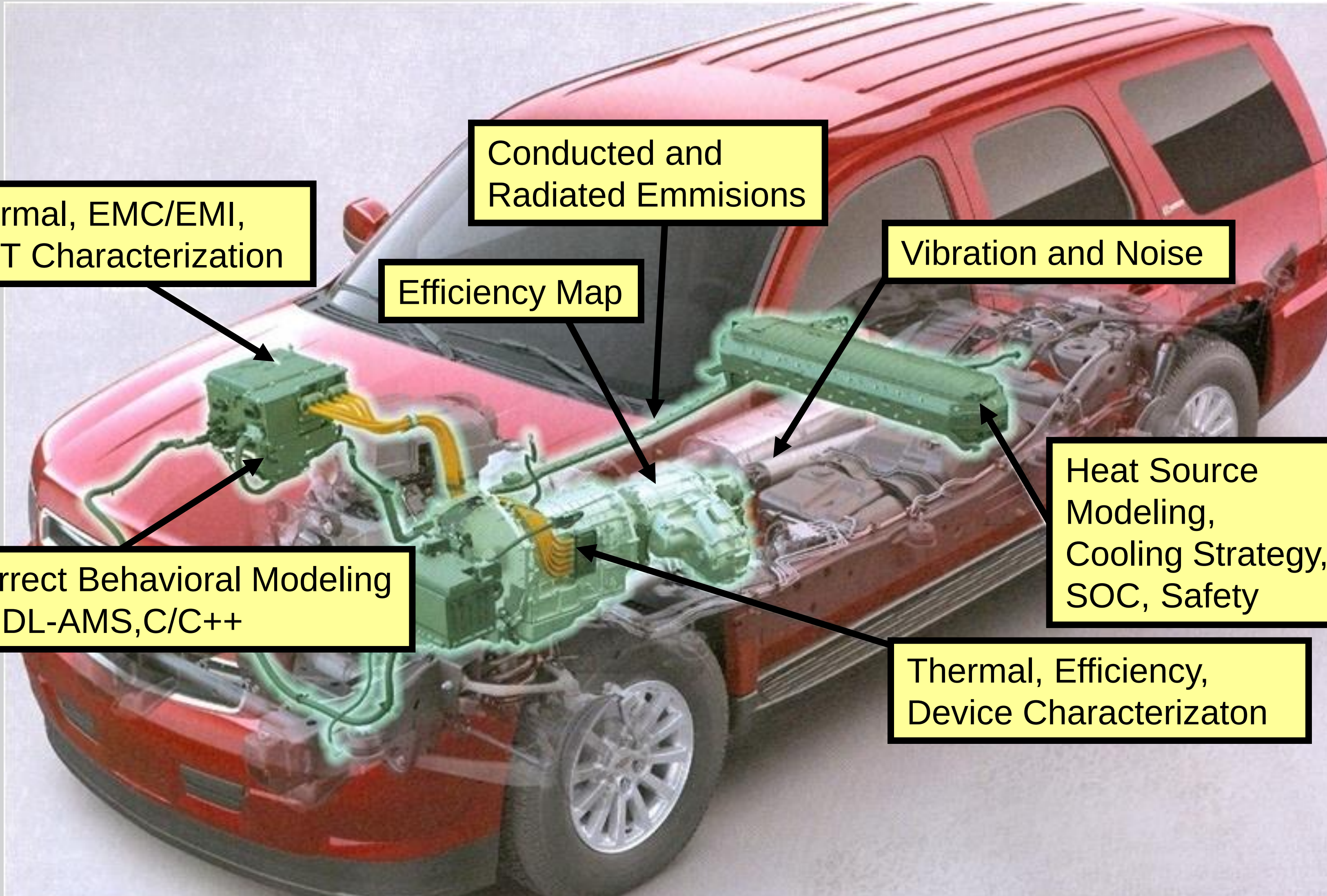
EV/HEV Customers in China

More than 200 EM Customers in China

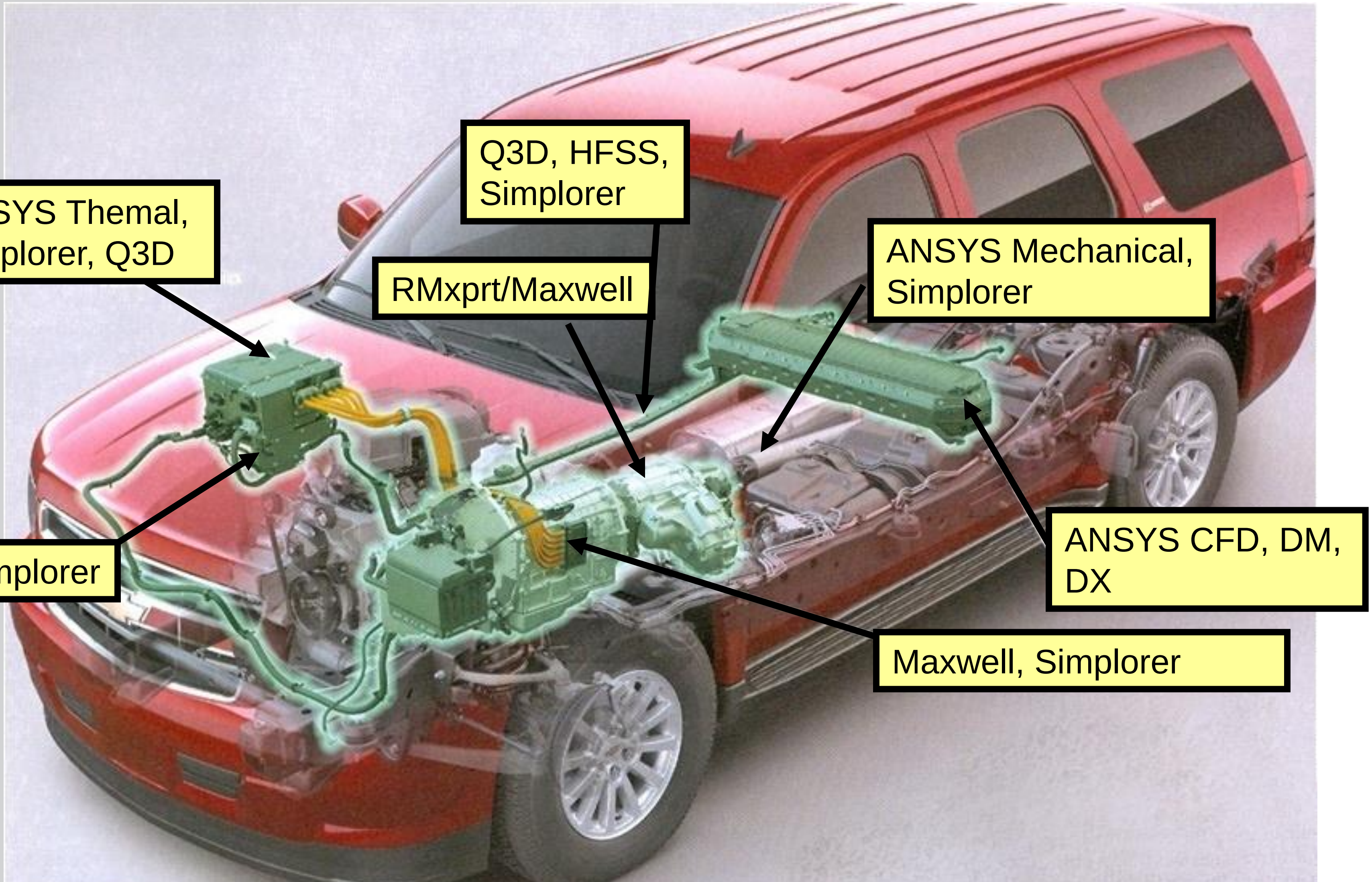
Applications in HEV/EV



Issues


Thermal, EMC/EMI,
IGBT Characterization
Conducted and
Radiated Emmisions
Efficiency Map
Vibration and Noise
Heat Source
Modeling,
Cooling Strategy,
SOC, Safety
Correct Behavioral Modeling
VHDL-AMS,C/C++
Thermal, Efficiency,
Device Characterizaton

Products

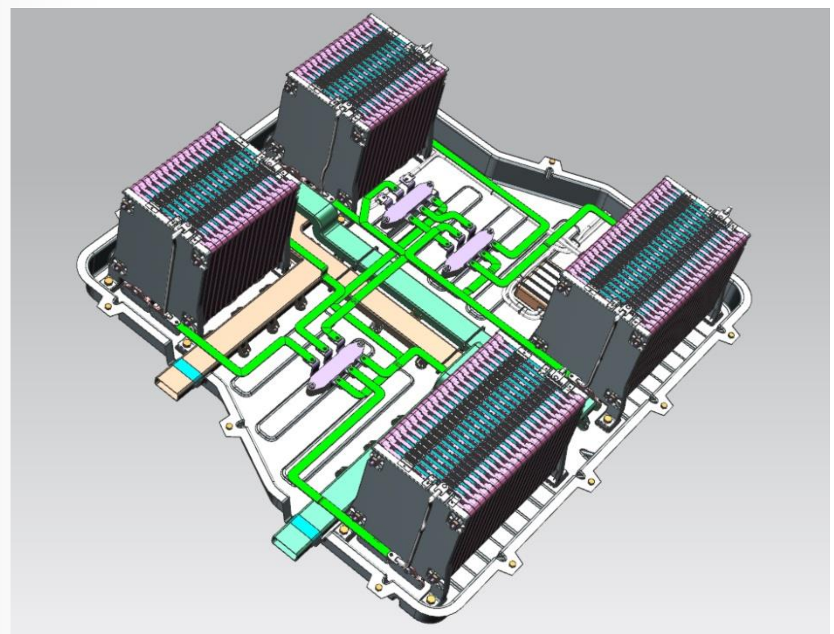

Q3D, HFSS,
Simplorer
ANSYS Themal,
Simplorer, Q3D
RMxprt/Maxwell
ANSYS Mechanical,
Simplorer
Simplorer
ANSYS CFD, DM,
DX
Maxwell, Simplorer

ANSYS

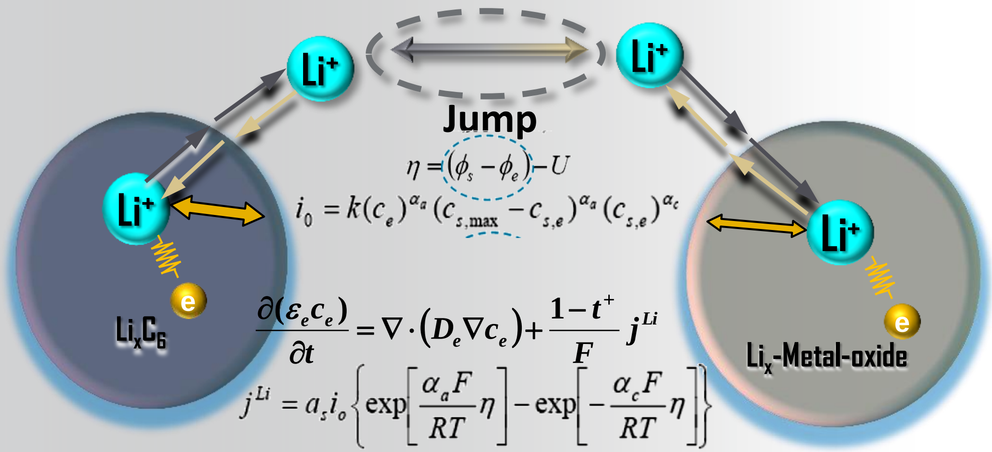
Power Source

Power Source ⟷ Power Electronics ⟷ Electric Machine ⟷ Mechanical Component

- **Electrical chemistry**
  - Life, SEI
- **Electric circuit model**
  - System performance
- **Thermal Management**
  - Thermal run-away.
- **Mechanical Abuse**



Newman's 1D Electrochemistry Model



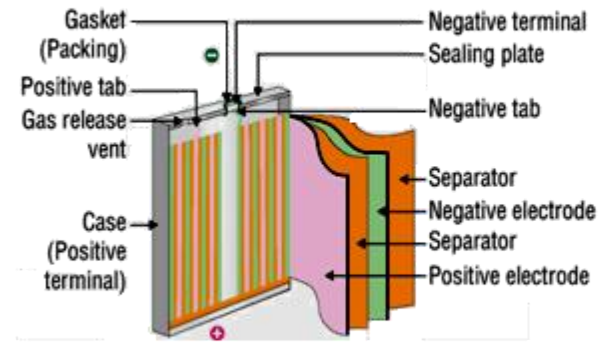
$$\eta = (\phi_s - \phi_e) - U$$

$$i_0 = k(c_e)^{\alpha_a}(c_{s,\max} - c_{s,e})^{\alpha_a}(c_{s,e})^{\alpha_c}$$

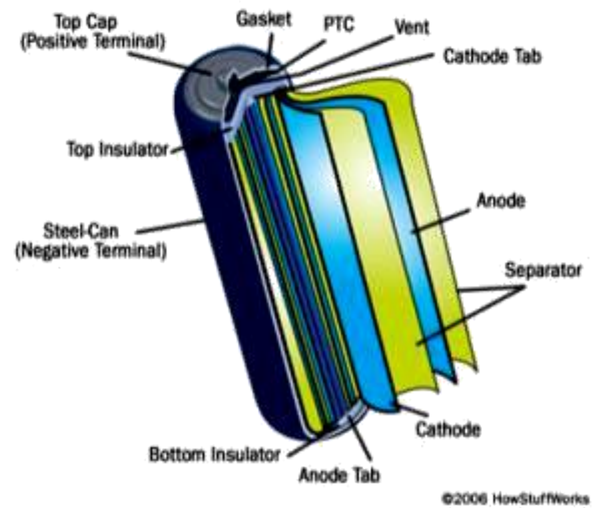
$$\frac{\partial(\varepsilon_e c_e)}{\partial t} = \nabla \cdot (D_e \nabla c_e) + \frac{1-t^+}{F} j^{Li}$$

$$j^{Li} = a_s i_o \left\{ \exp\left[\frac{\alpha_a F}{RT}\eta\right] - \exp\left[-\frac{\alpha_c F}{RT}\eta\right] \right\}$$

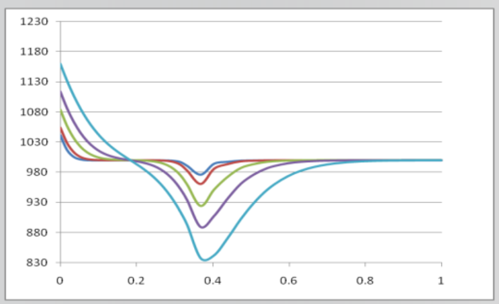
Lithium Ion Batteries



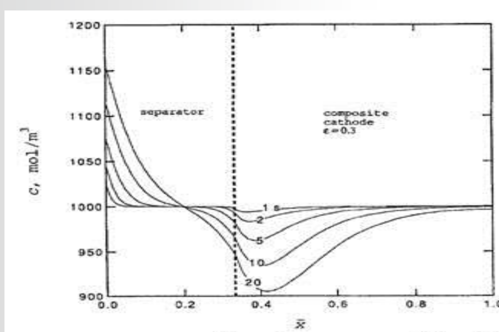
$$Li_{(1-x)}CoO_2 + Li_xC \rightleftharpoons LiCoO_2 + C$$



- Electrochemical Kinetics
- Solid-State Li Transport
- Electrolytic Li Transport
- Charge Conservation/Transport
- (Thermal) Energy Conservation



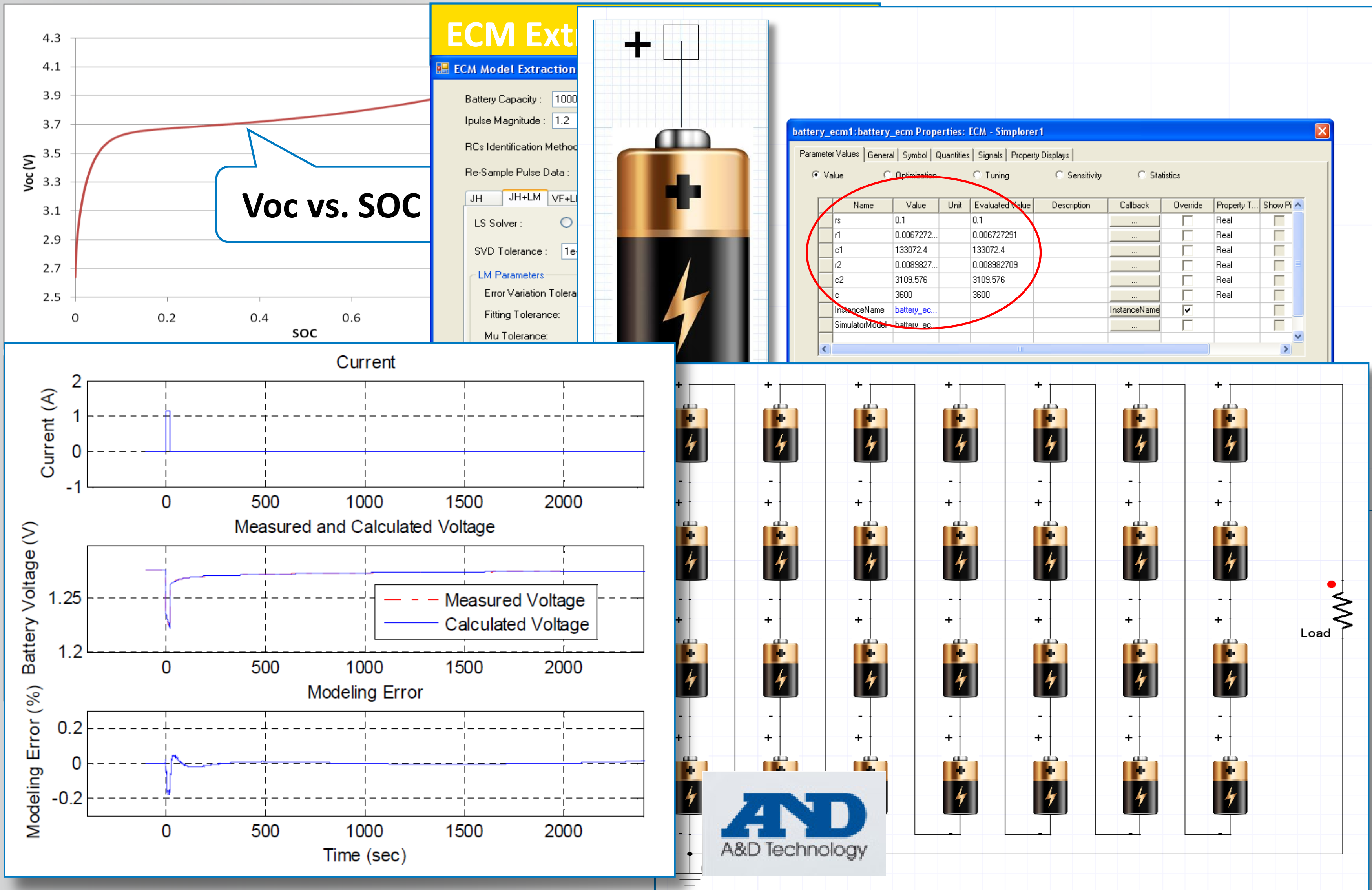
Simplorer Results



Newman's Results

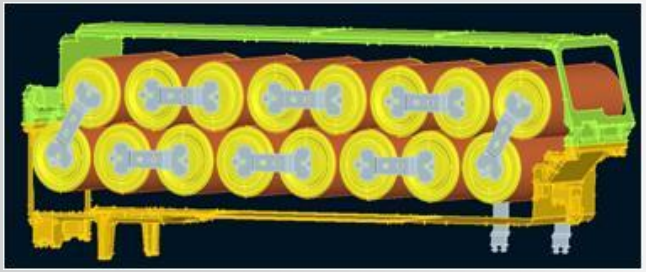
[1] X. Hu, S. Stanton, L. Cai, R.E. White, J. Power Sources 214, 40-50, 2012.
[2] X. Hu, S. Stanton, L. Cai, R.E. White, J. Power Sources 218, 212-220, 2012.

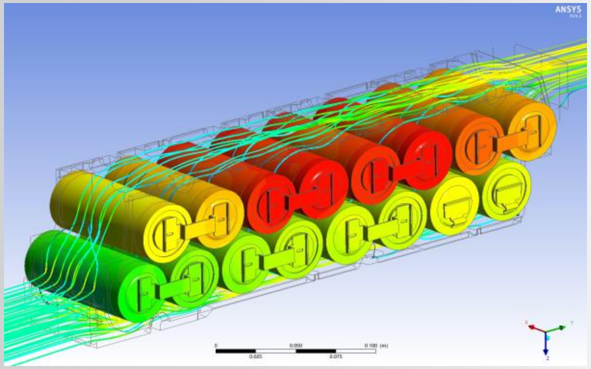
Battery Equivalent Circuit Model

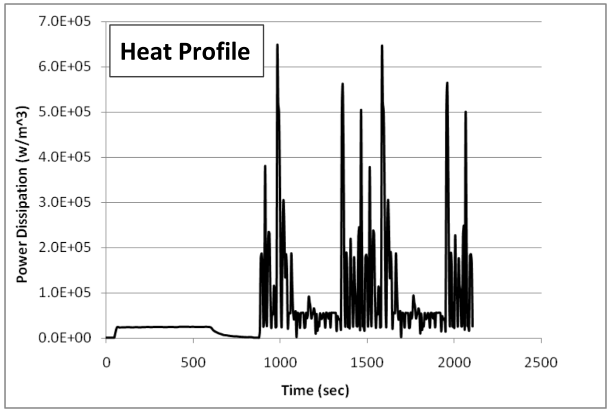


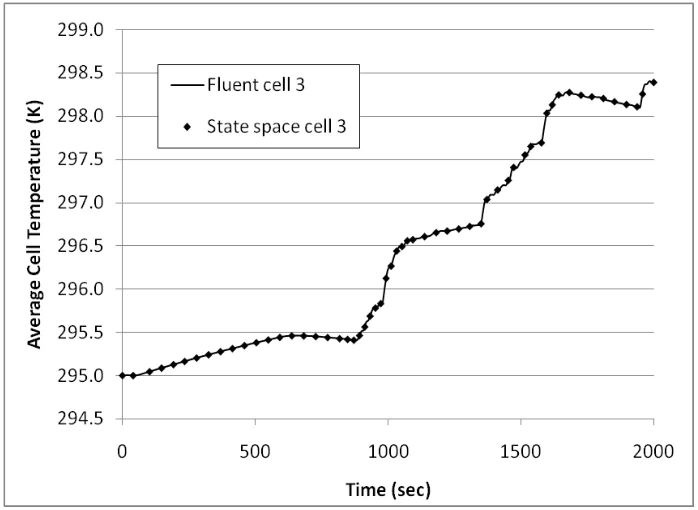
X. Hu, L. Collins, S. Stanton, S. Jiang, "A Model Parameter Identification Method for Battery Applications", SAE 2013-01-1529.

Battery Thermal Management : A GM Battery





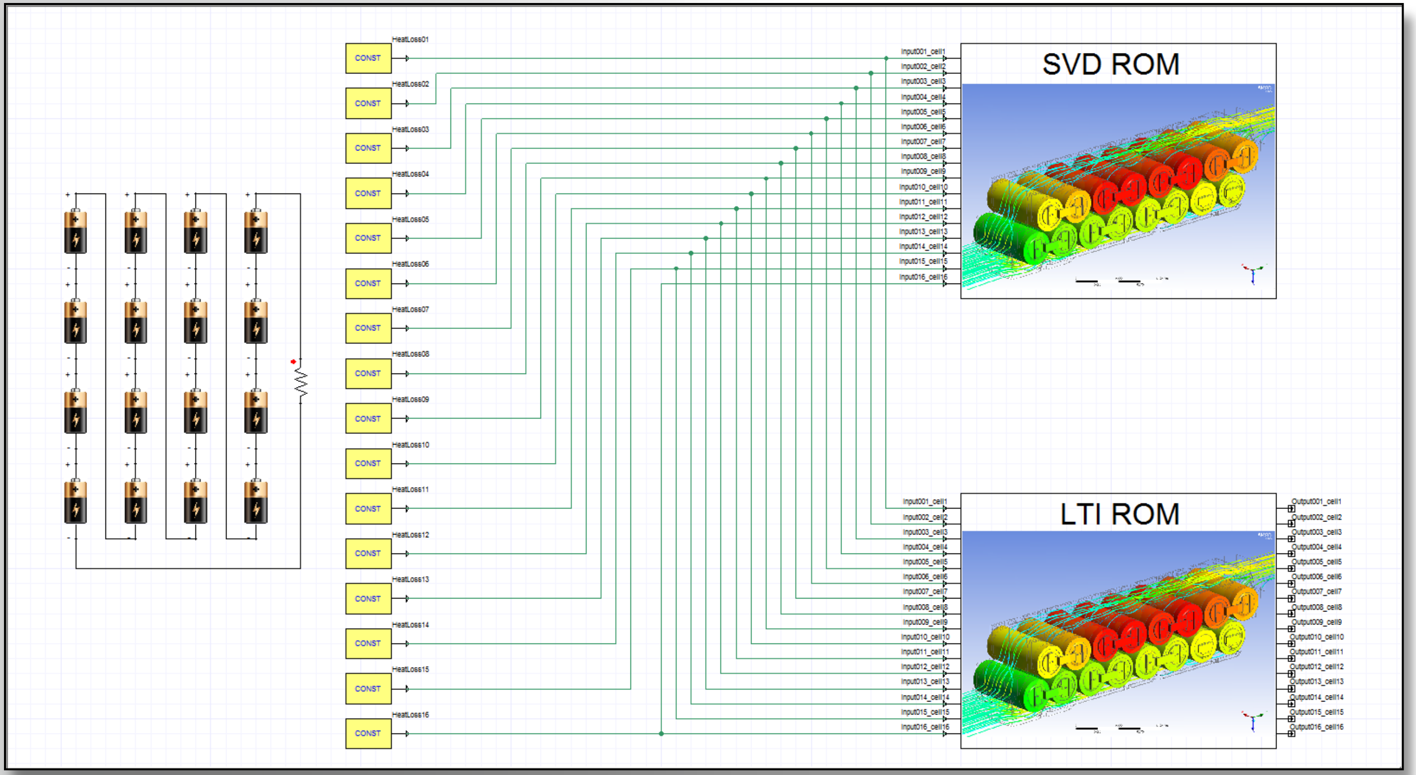




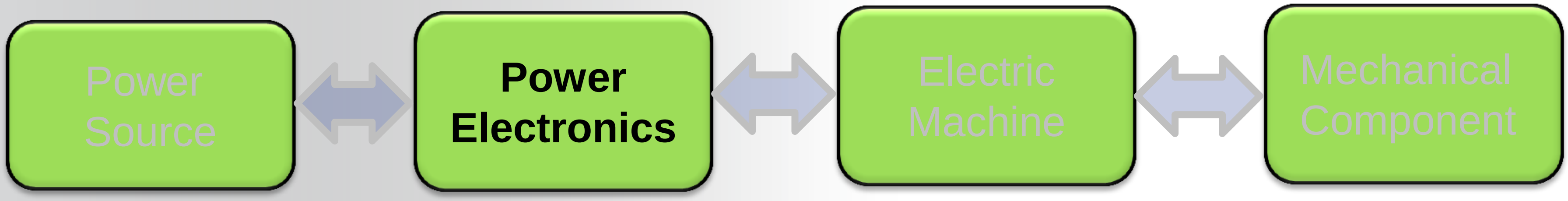
X. Hu, S. Lin, S. Stanton, W. Lian, "A Foster Network Thermal Model for HEV/EV Battery Modeling," IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 47, NO. 4, JULY/AUGUST 2011
X. Hu, S. Lin, S. Stanton, W. Lian, "A State Space Thermal Model for HEV/EV Battery Modeling", SAE 2011-01-1364

GM Battery Module – ECM Coupled with ROMs

- ECM calculates heat source and sends it to the two ROMs.
- LTI ROM calculates average temperature and sends it to ECM.
- SVD ROM *calculates* temperature distribution.



Power Electronics: IGBT



High Power System Design Concept

- **Electro-Thermal Model: Average and Dynamic**
- **Package Thermal Model Extracted from CFD**

Mechanical Stress Analysis

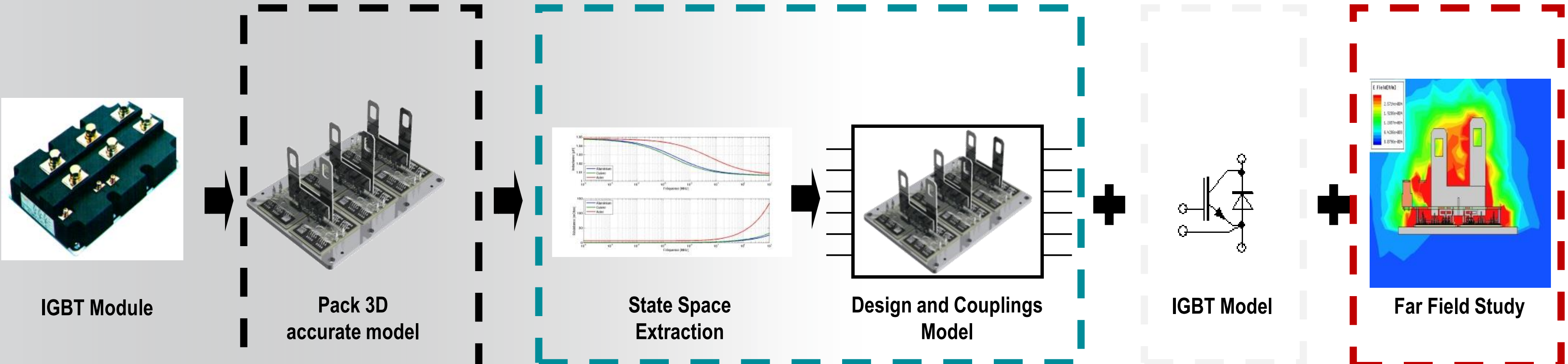
- **Thermal Stress**
- **Electromagnetic Forces**

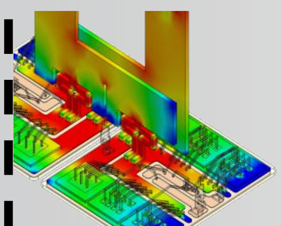
EMC/EMI Analysis

- **Parameter Extraction: R, L, C, G**
- **Radiated Emissions – Full Wave Effects**

Component Level Modeling

Example of EMC/EMI Oriented Model design developed at **Alstom** *





- **Tridimensional IGBT pack model and EM study**
- **State space extraction**
- **IGBT circuit model**
- **Far Field Study for Electric Field EM**

** Emmanuel Batista, Vincent Delafosse, «Simulating EMC/EMI Effects for High Power Inverter Systems », Ansoft Inspiring Engineering, 2008*

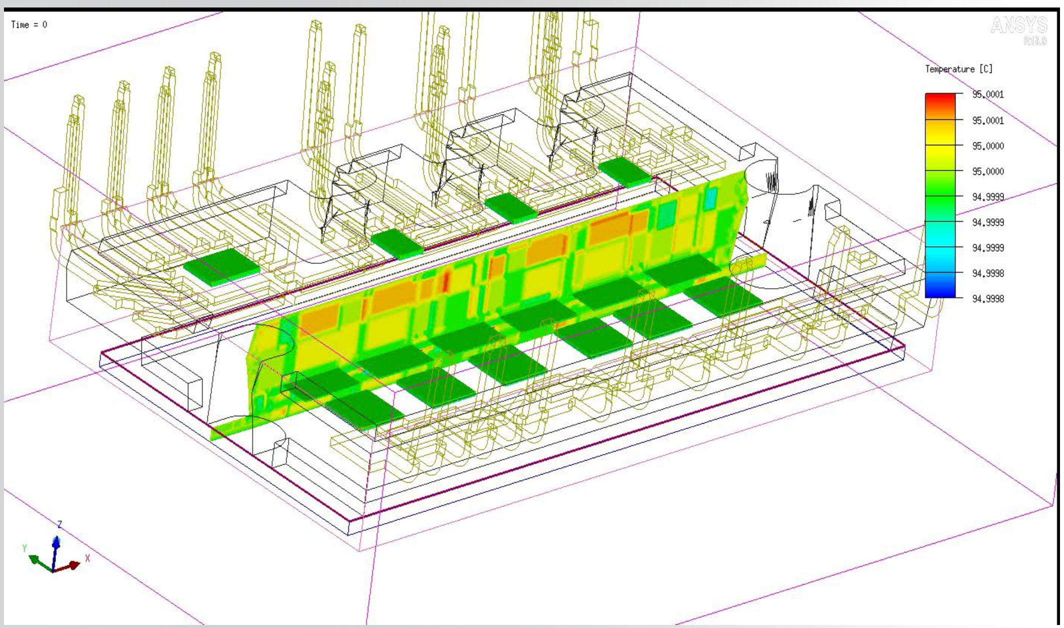
3-Phase Inverter 3D Simulation

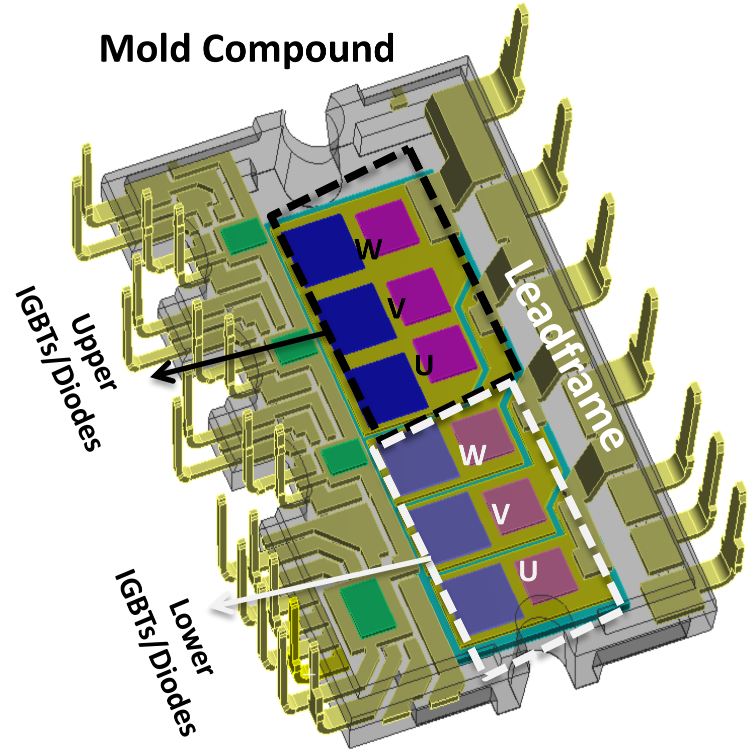
3-Phase inverter power module

Thermal-fluid analysis within Workbench

Model includes many details

Solving conjugate heat & mass transfer



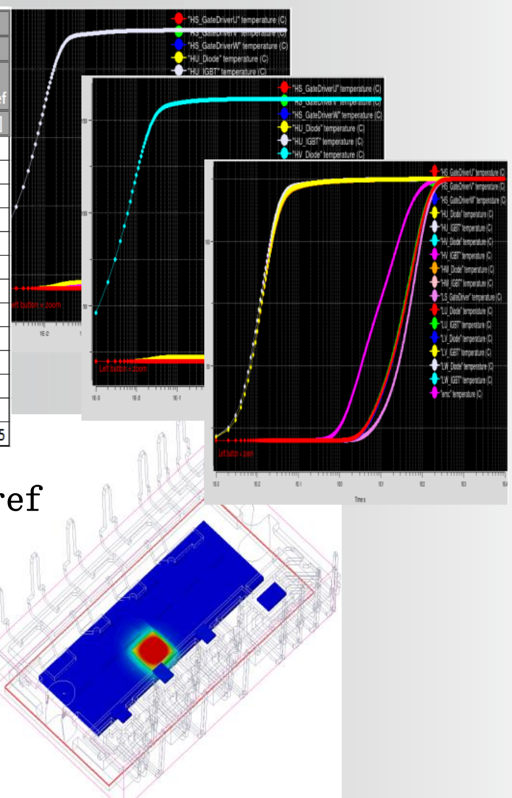


ROM Generation Process

ANSYS | FAIRCHILD

System step response	ROM Extraction	ROM

Trial No.	Upper U D	Upper U I	Upper V D	Upper V I	Upper W D	Upper W I	Lower U D	Lower U I	Lower V D	Lower V I	Lower W D	Lower W I	Tref
	[W]												[C]
1	300	0	0	0	0	0	0	0	0	0	0	0	0
2	0	300	0	0	0	0	0	0	0	0	0	0	0
3	0	0	300	0	0	0	0	0	0	0	0	0	0
4	0	0	0	300	0	0	0	0	0	0	0	0	0
5	0	0	0	0	300	0	0	0	0	0	0	0	0
6	0	0	0	0	0	300	0	0	0	0	0	0	0
7	0	0	0	0	0	0	300	0	0	0	0	0	0
8	0	0	0	0	0	0	0	300	0	0	0	0	0
9	0	0	0	0	0	0	0	0	300	0	0	0	0
10	0	0	0	0	0	0	0	0	0	300	0	0	0
11	0	0	0	0	0	0	0	0	0	0	300	0	0
12	0	0	0	0	0	0	0	0	0	0	0	300	0
13	20	20	20	20	20	20	20	20	20	20	20	20	125



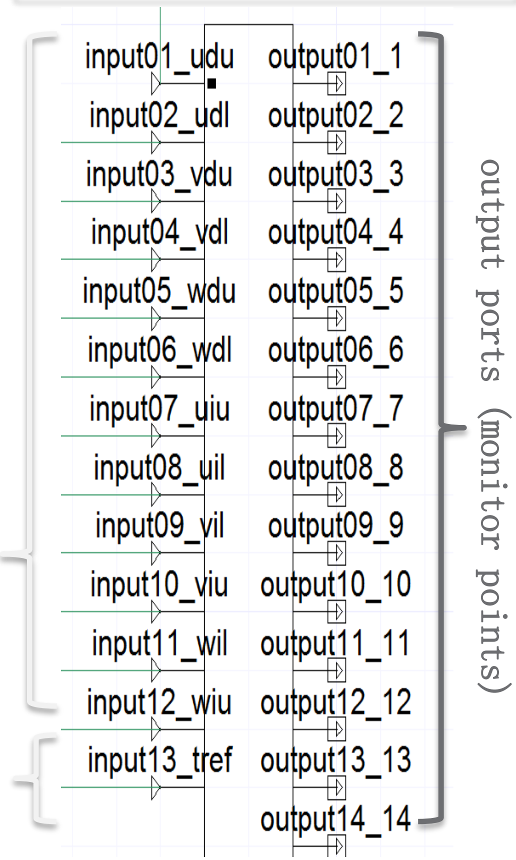
6 IGBT, 6 Diode, Tref

13 Analyses ≈ 26 h

- Frequency Domain
- Vector Fitting

Input ports Si die power dissipation

Input port for heat sink temperature



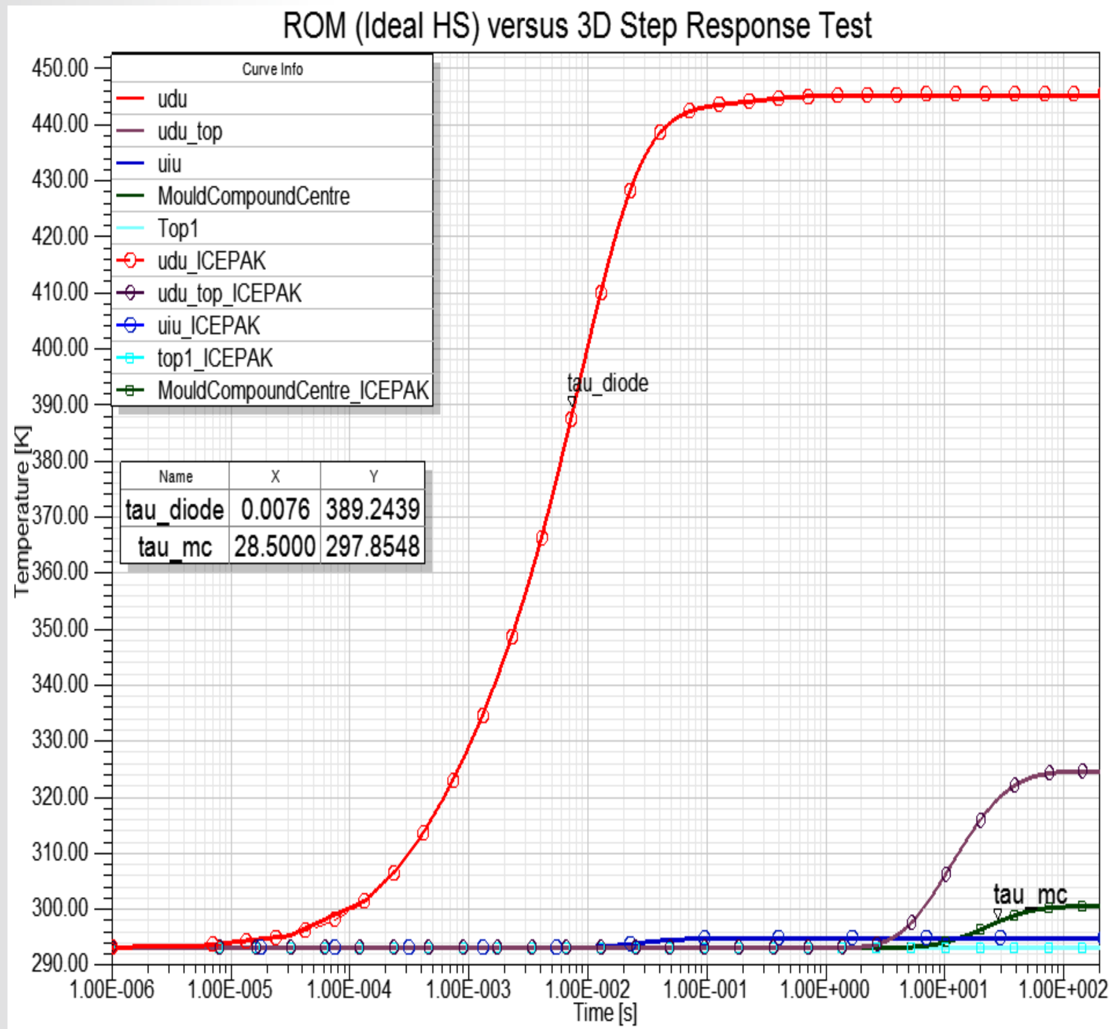
  September 25, 2014

ROM vs. 3D Analysis

High accuracy (ΔT < 0.3 K)

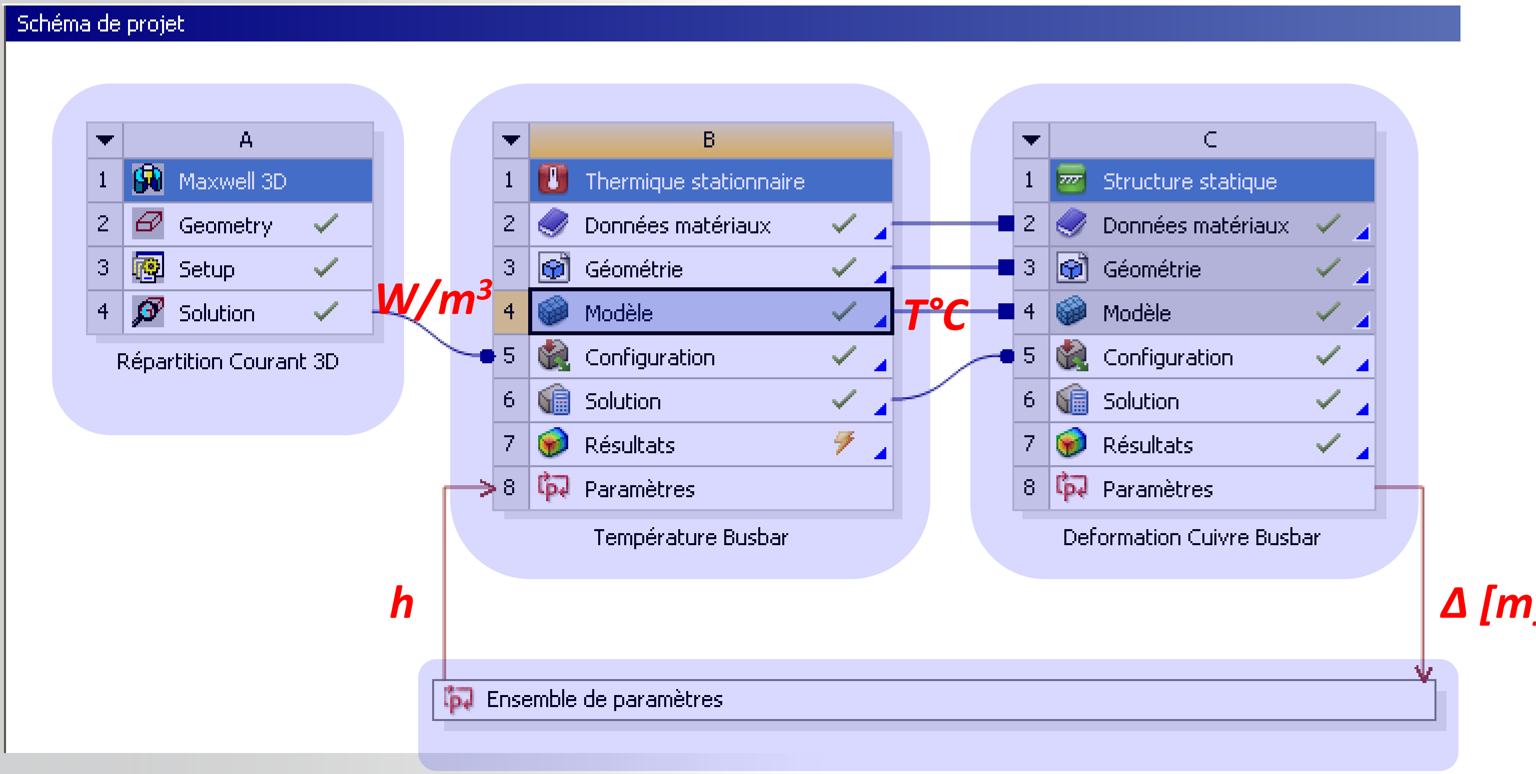
Required Solver Time

3D ≈ 2 h ⇔ ROM ≈ 1 min



Multiphysics Modeling

Workbench enables a seamless 3D coupling flow.

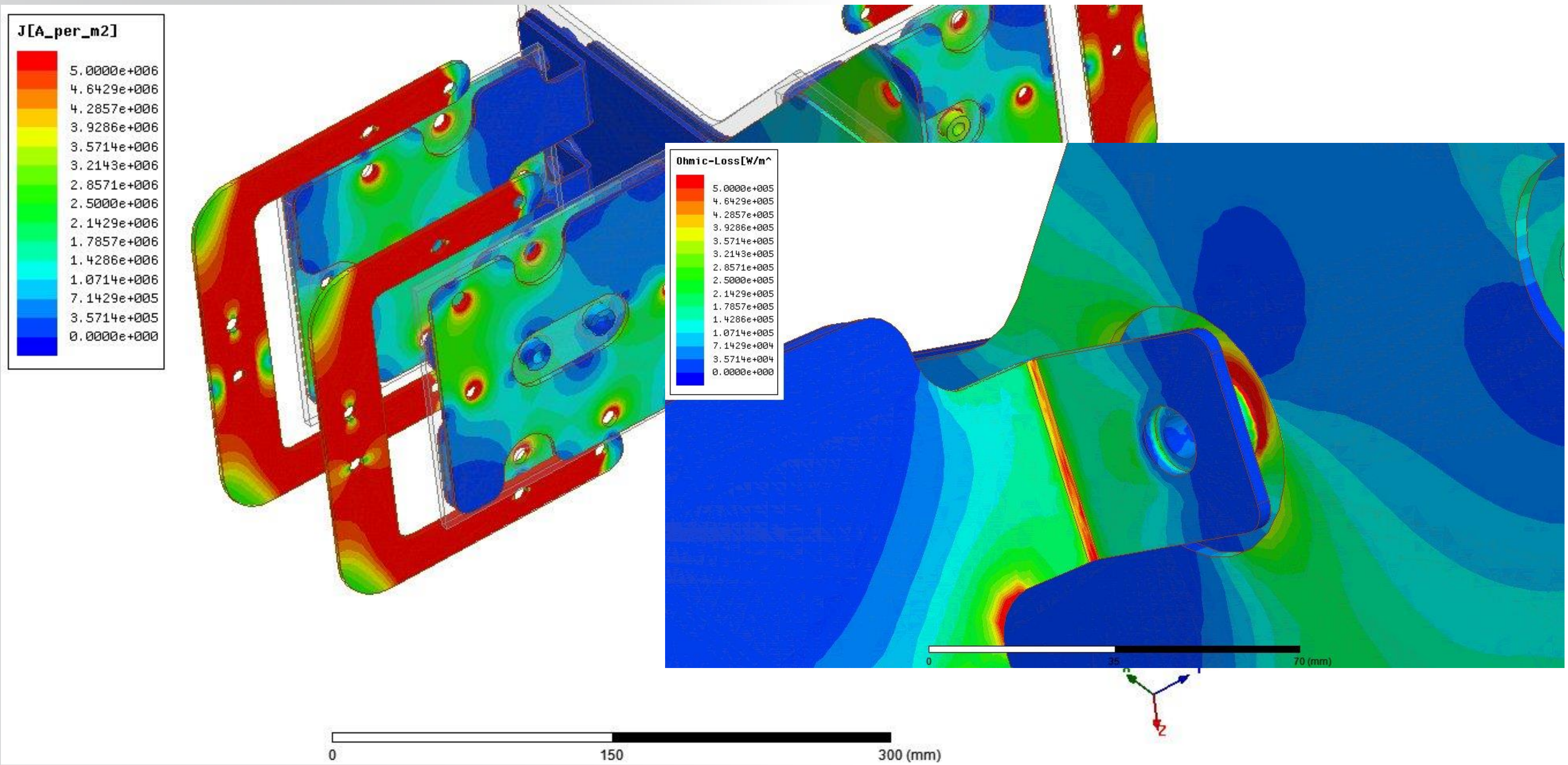


A parameter Analysis is used to determine what insulation material is needed to achieve a maximum displacement level

Multiphysics Modeling

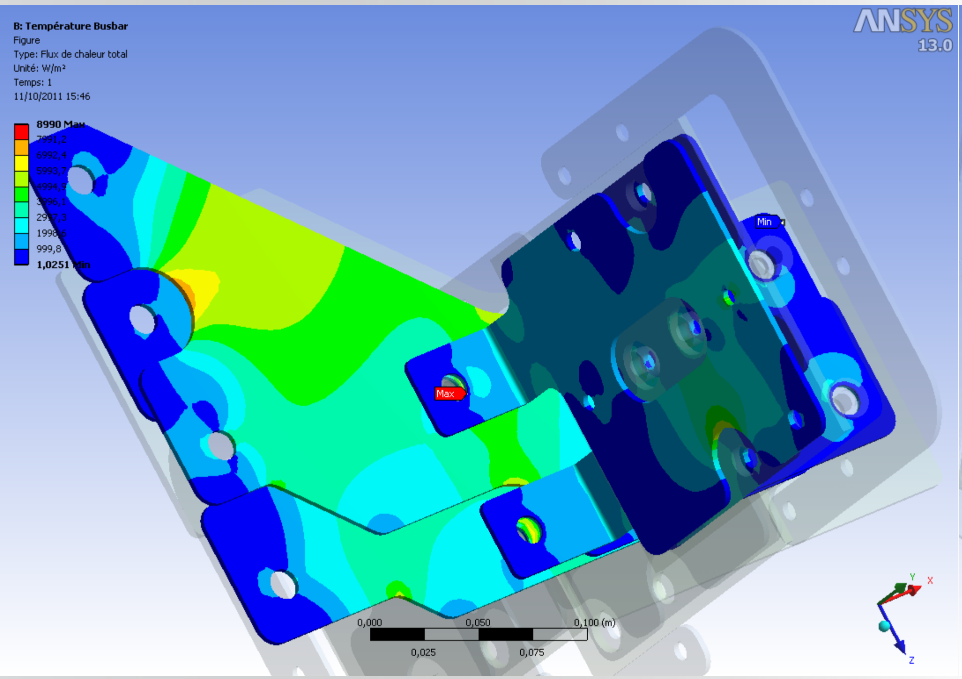
Maxwell 3D simulation: Current Calculation

- **Input: average current that is computed in the system simulation in Simplorer**
- **Output: Ohmic losses are calculated based on the volumic current calculations.**

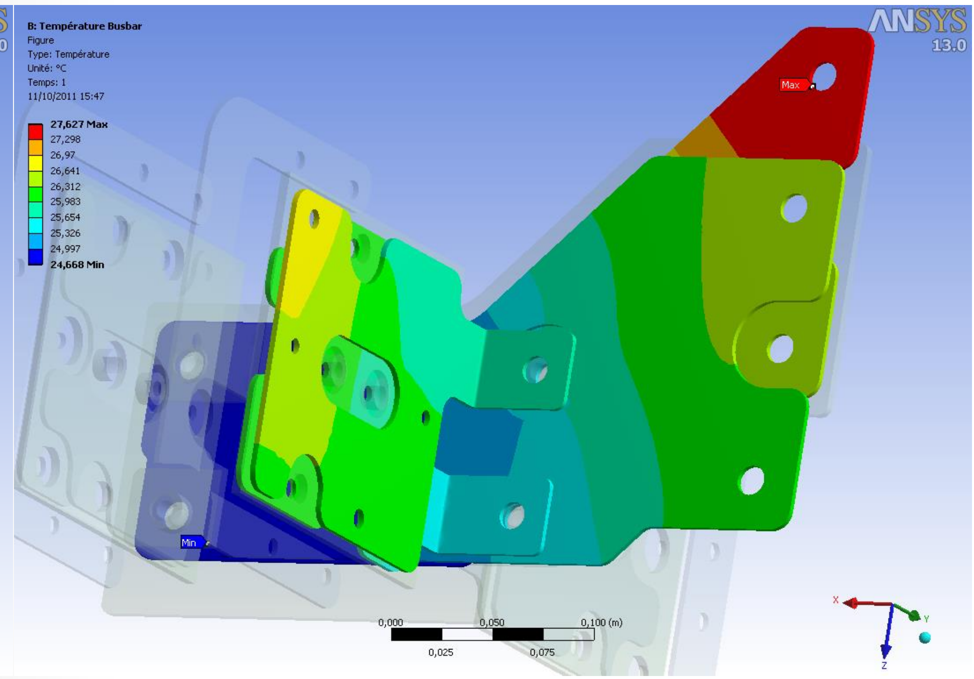


Multiphysics Modeling

Static Thermal Module of ANSYS: Temperature distributions



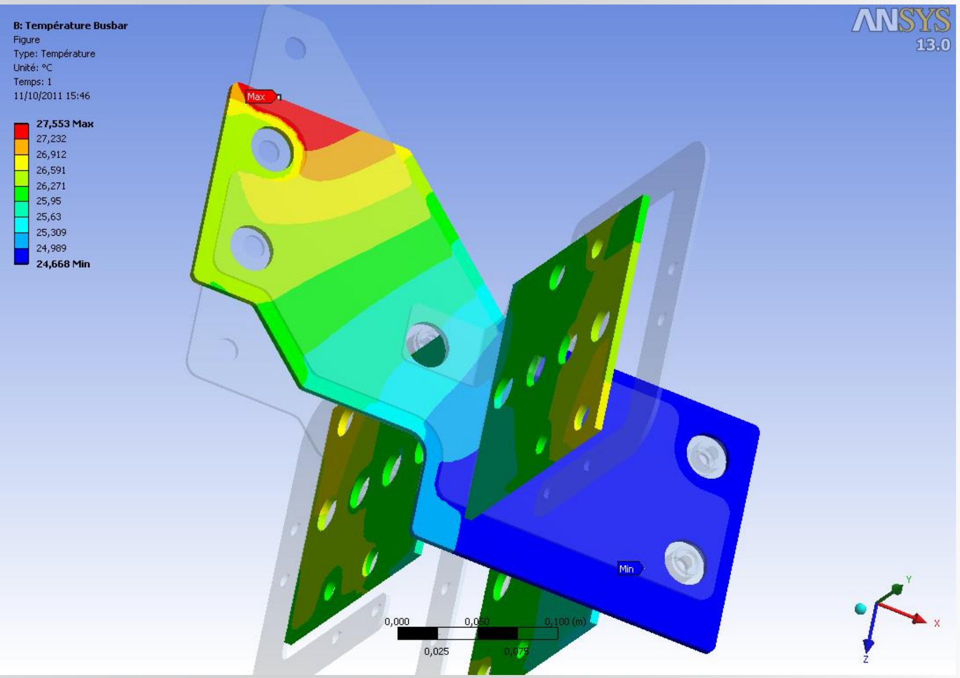
Heat Flux on Copper parts



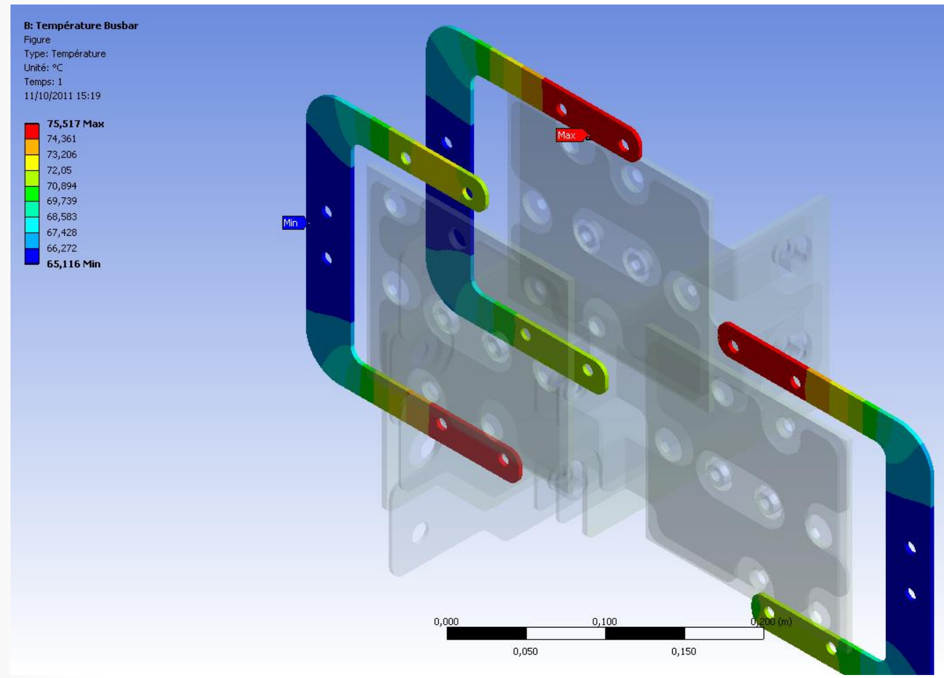
Maximum temperature on Copper parts

Multiphysics Modeling

Static Thermal Module of ANSYS: Temperature distributions

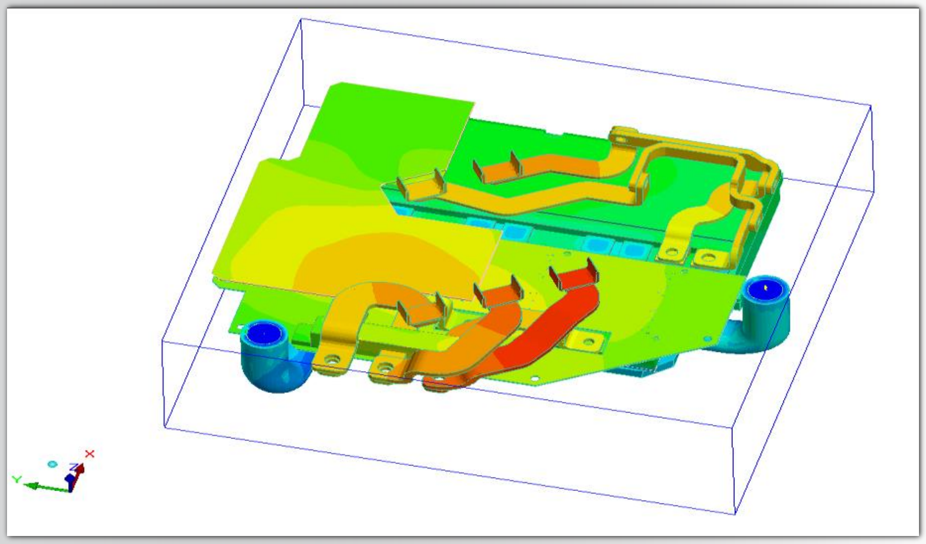


Insulation part Temperatures

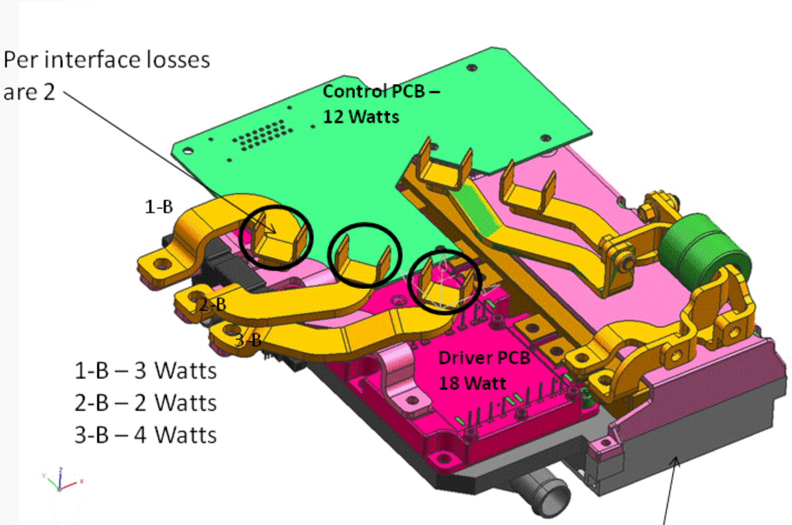


Phase Conductors Temperatures

Power Electronics Thermal Management



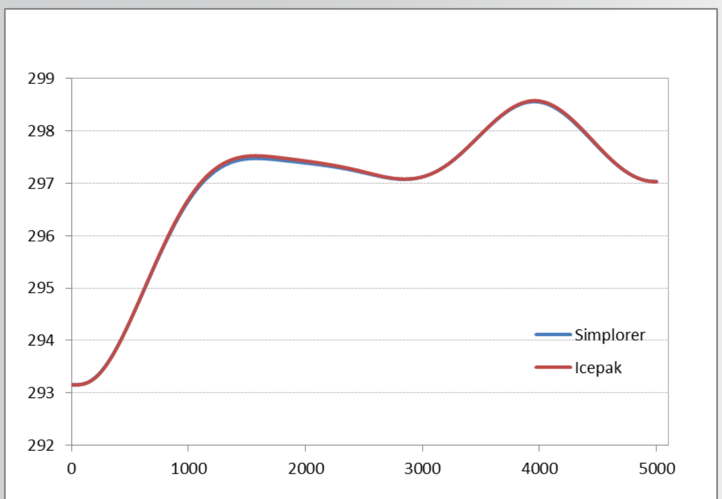
Per interface losses are 2

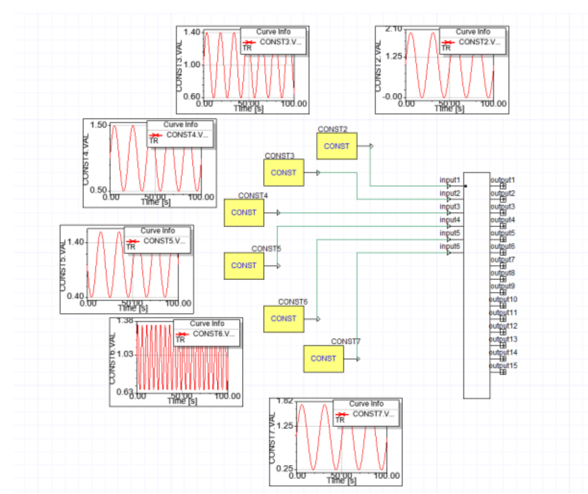


1-B – 3 Watts
2-B – 2 Watts
3-B – 4 Watts

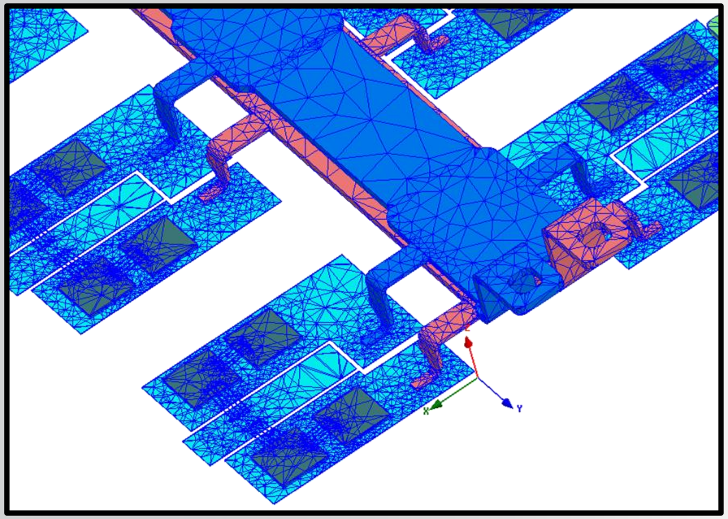
Top plate and housing – Aluminum die cast
Coolant temperature – 75 oC
Outside ambient – 105 oC

Coldplate – Aluminum





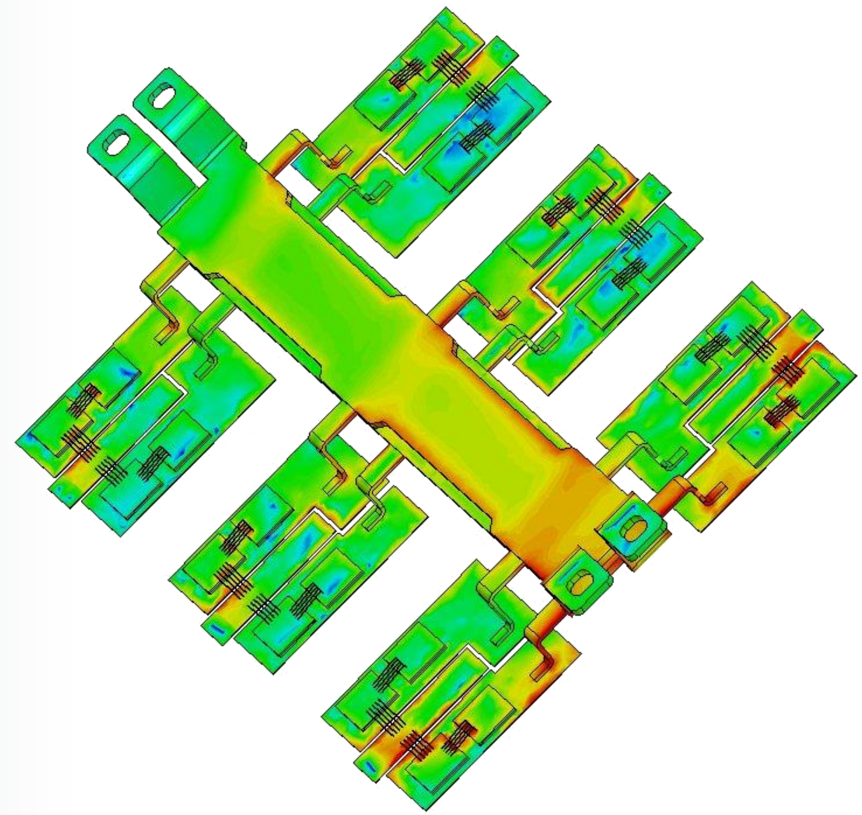
EMI/EMC: Automatic L,R,C Extraction and Network Model



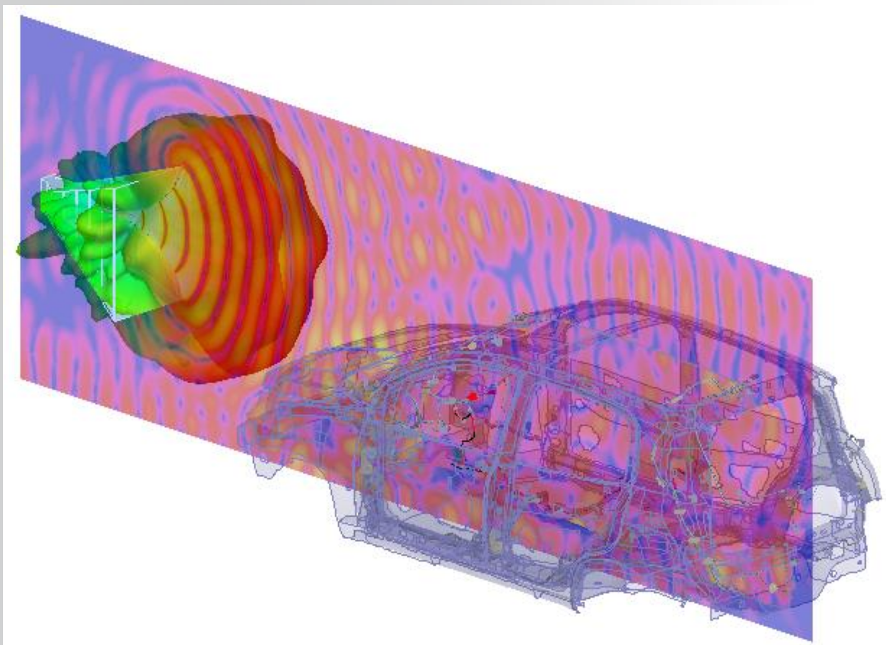
The structure is meshed using automatic and adaptive meshing

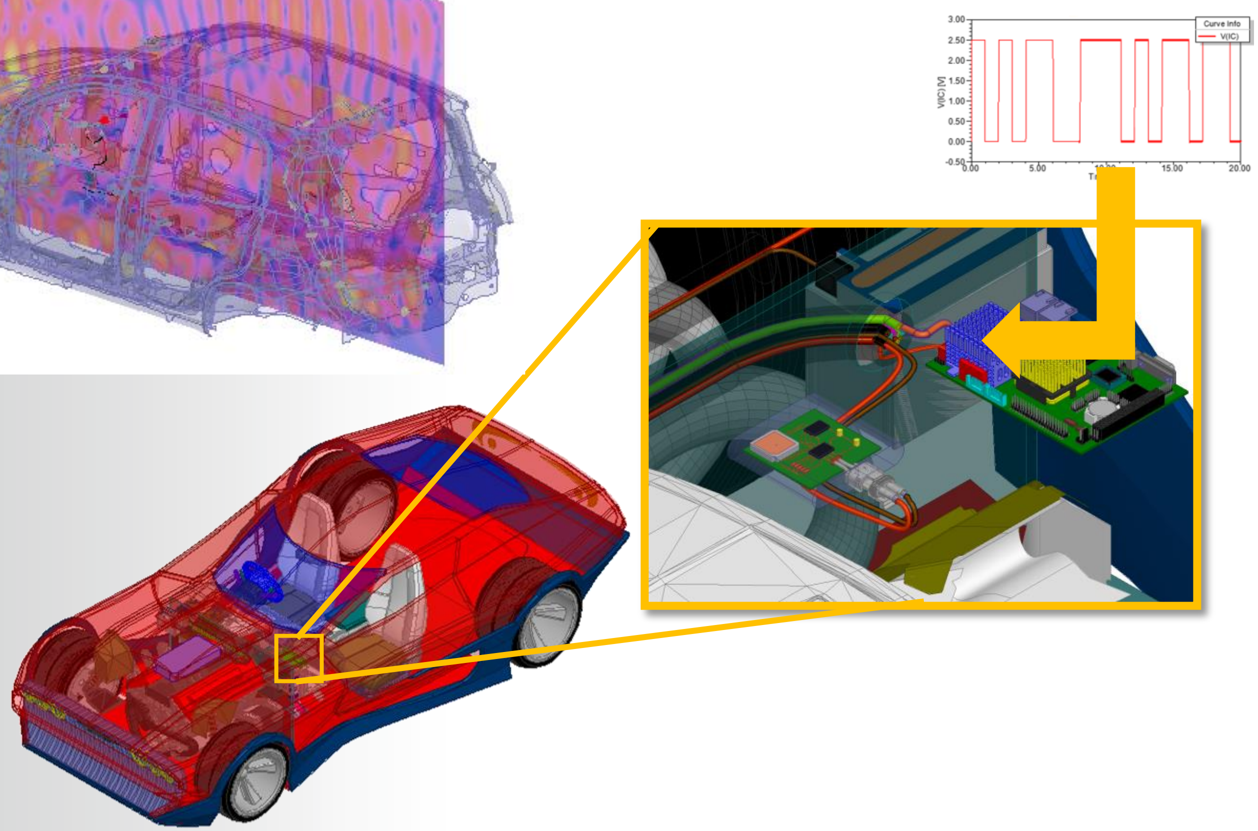
Pass	Type	# Triangle	DeltaR	DeltaL
1	C	11558	N/A	N/A
2	C	15269	4.2826	N/A
3	M	20267	2.6867	N/A
4	M	27011	2.5257	6.1143
5	M	35472	0.36587	2.0524

Current Distribution

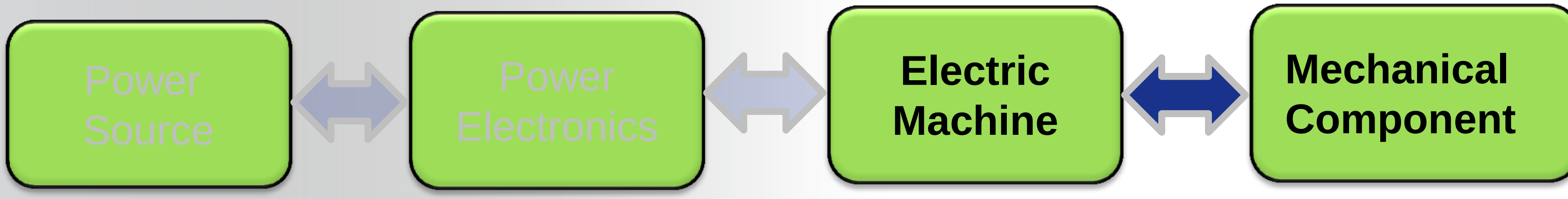


Automotive EMI/EMC is a System Issue





Electric Machine Design



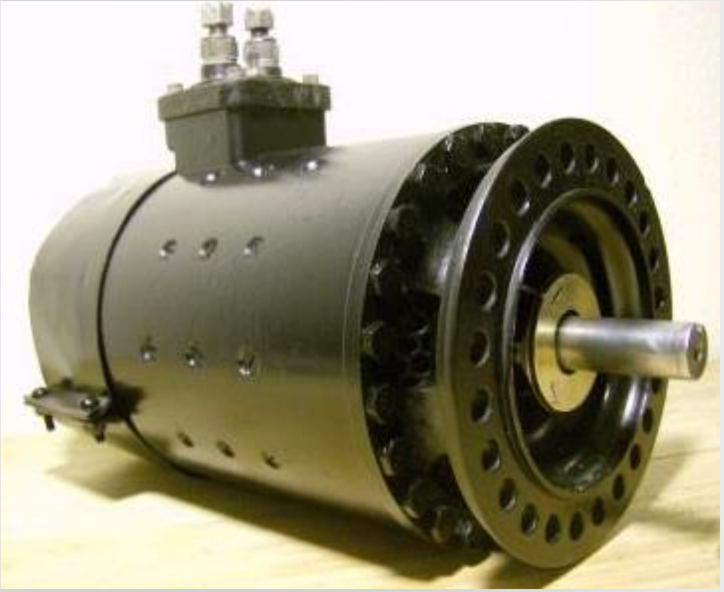
Coupled Electromagnetic and Thermal Solution

Detailed Transient Analysis

Coupled with Drive Electronics

Technology: Yesterday vs. Today

1980's DC Machine used for Military Aircraft



Size: 6.25 in X 11.0 in
Weight: 70 lbs
Rated Power: 13.4kW
Rated Torque: ~100Nm

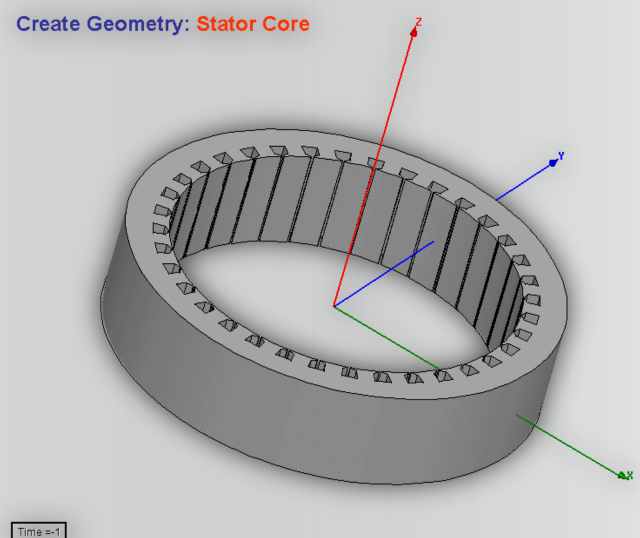
2004 Toyota Prius
Interior Permanent Magnet Machine

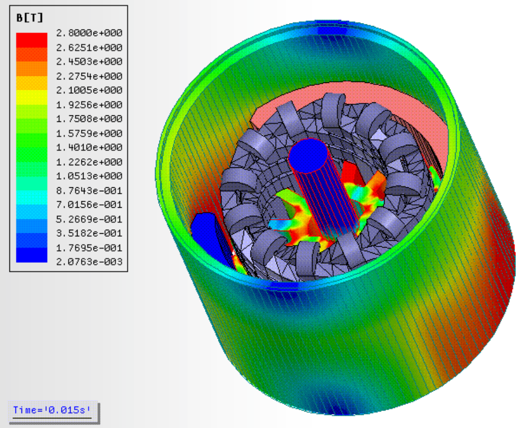
Outer Diameter: 6.315 in
Stack Length: 3.29 in
Weight: 22.5 lbs
Rated Power: 50kW
Rated Torque: 400Nm

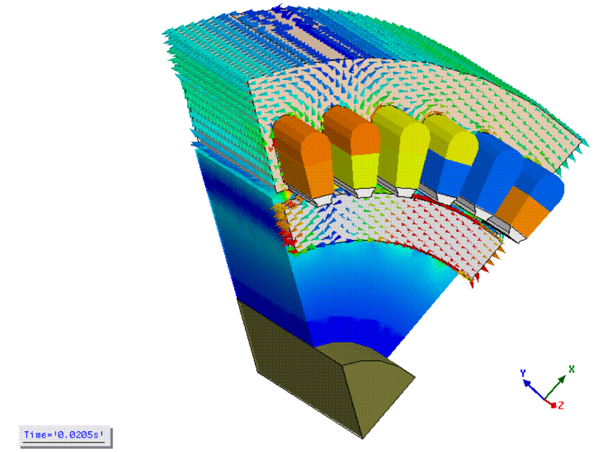
Smaller, Lighter, More Powerful, More Advanced Controls

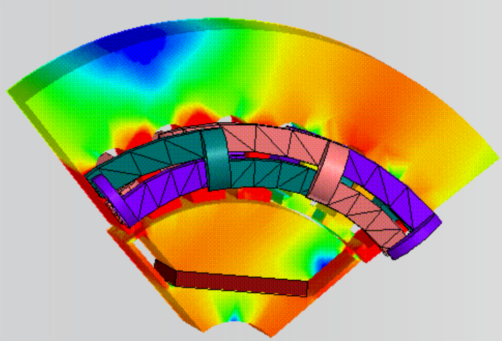
Electromagnetic Design and Optimization

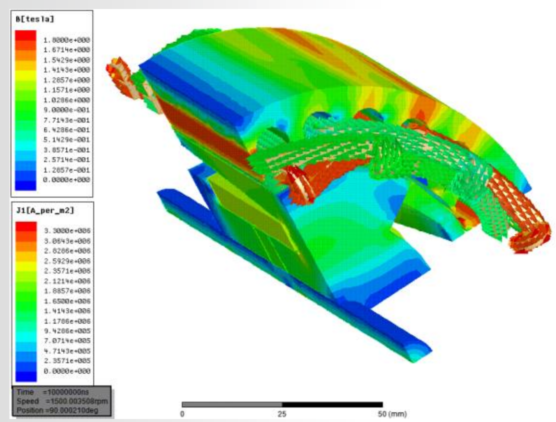
Exactly simulating and optimizing the transient performance of EM on normal or fault conditions, such as start, variable load, short circuit.

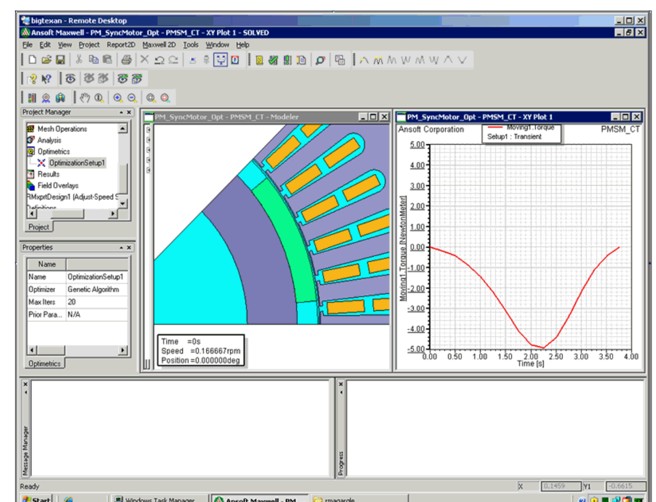




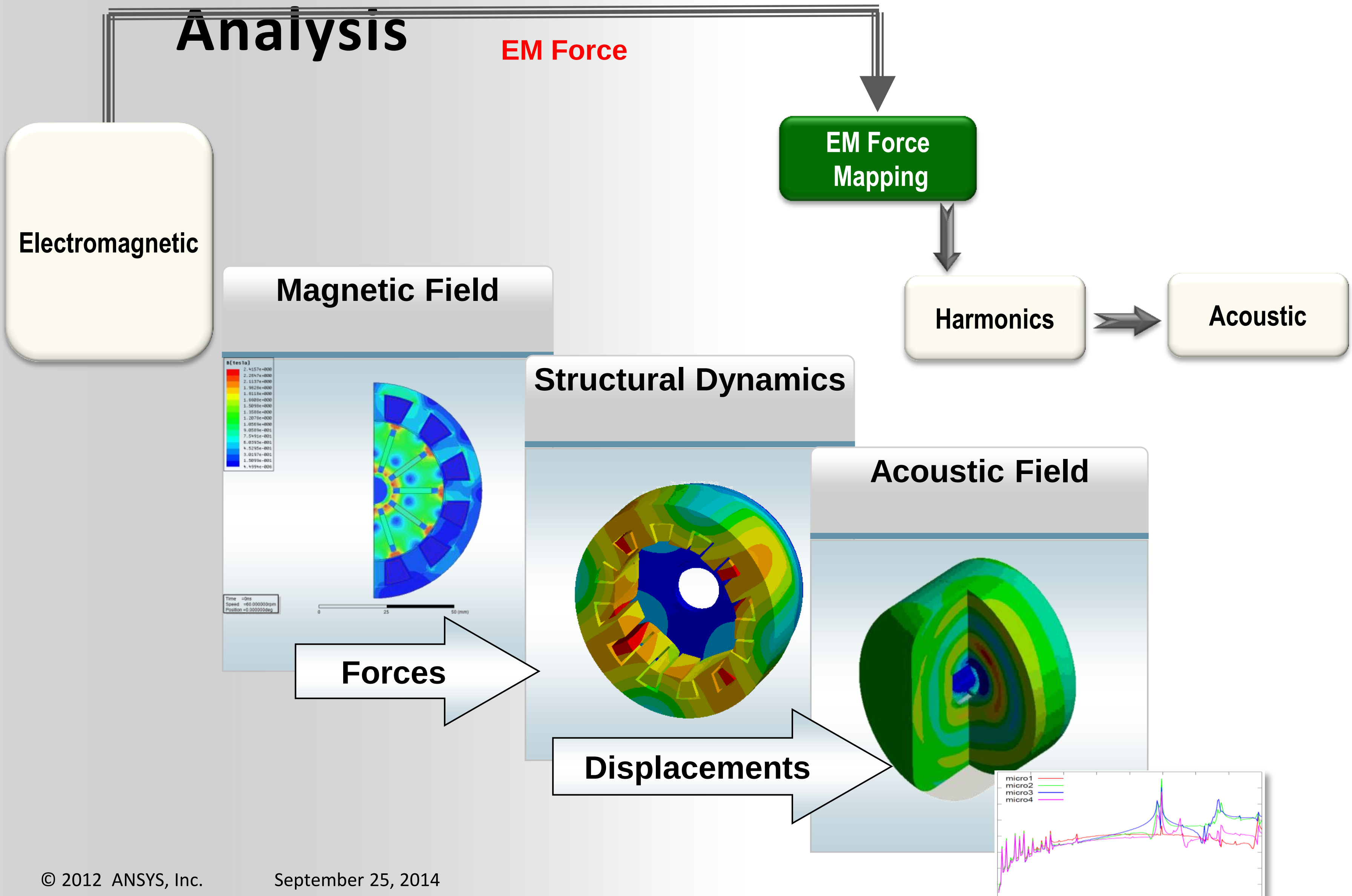








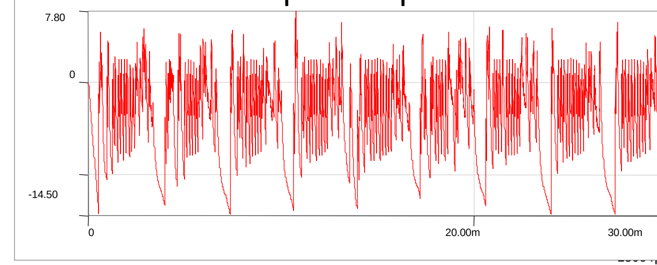
Automatic coupling Design Flow for Electric Machine EM, Vibration, Acoustic Analysis

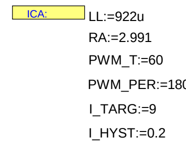


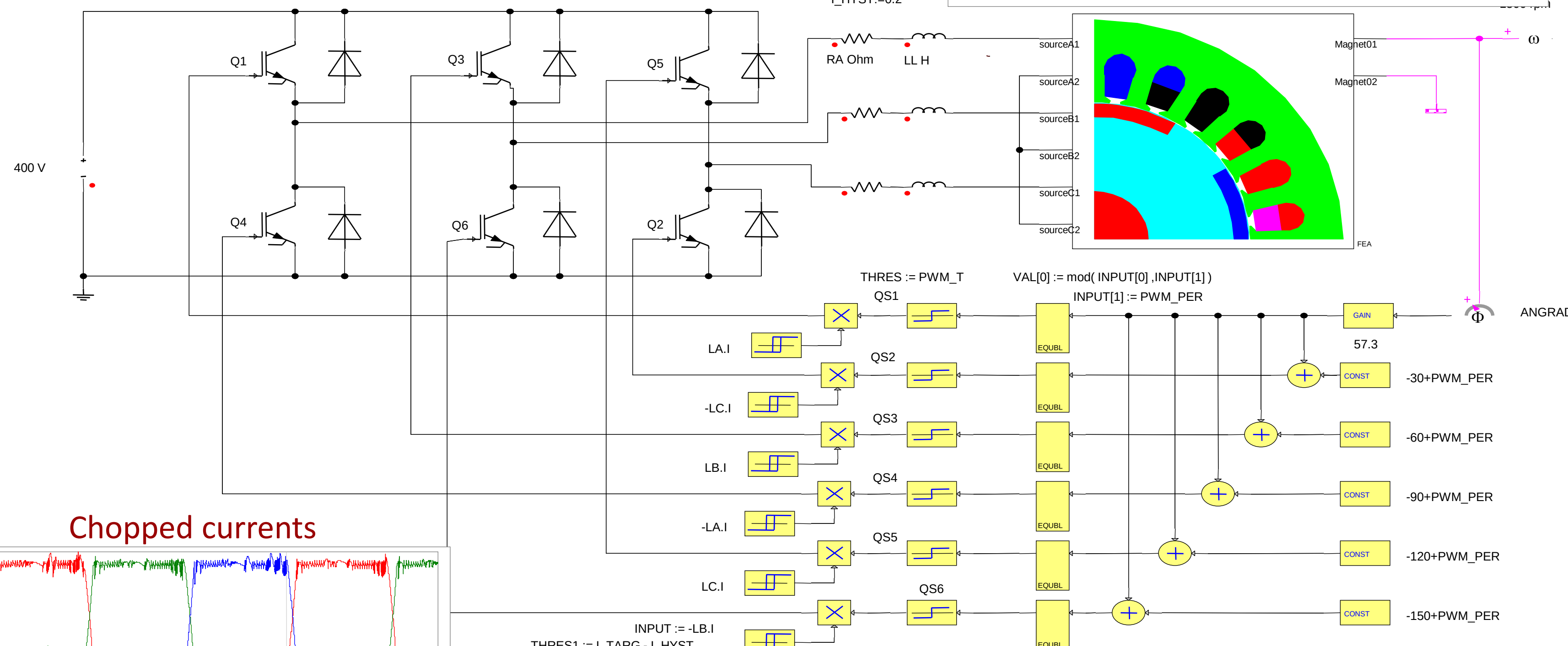
BLDC motor FEA Coupled with Simplorer

- Inverter fed three phase BLDC motor drive
- Chopped current control

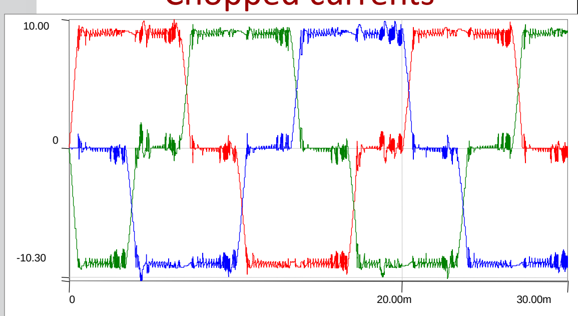
Output torque

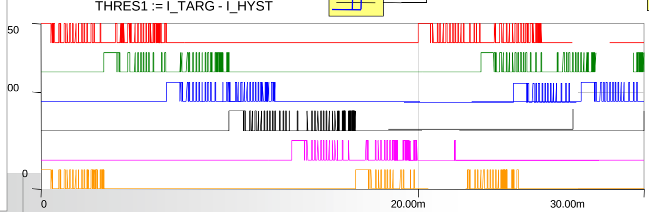


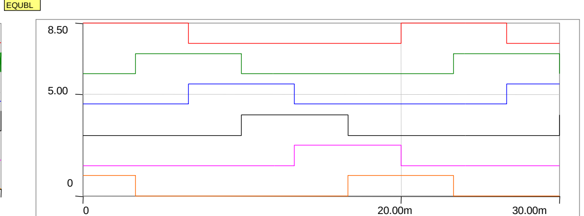




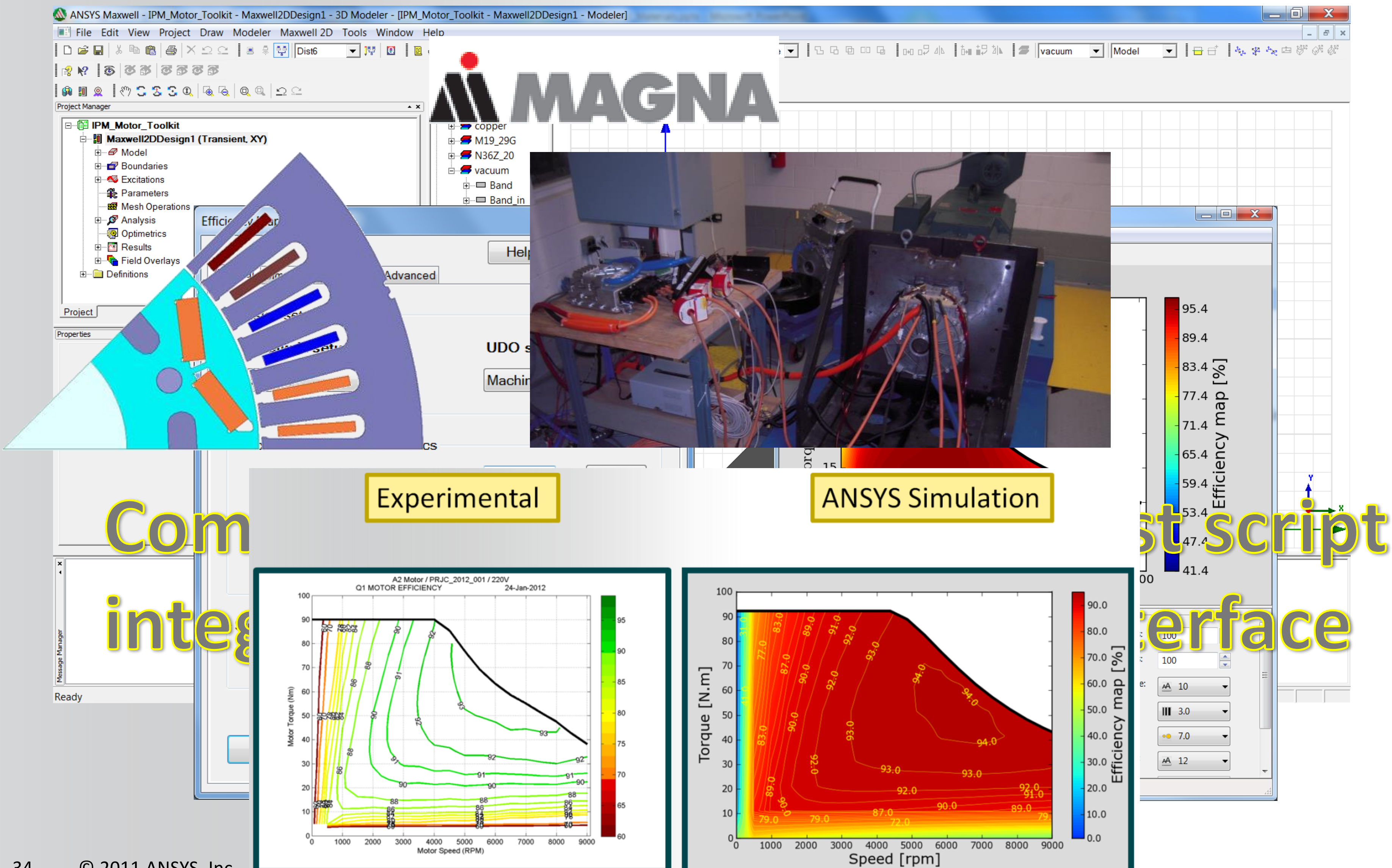
Chopped currents







Electric Machines Design Toolkit



Design Speed Improvement: Distributed Solver Option

16X Speedup in ANSYS Maxwell DSO on 32-Core High-Performance Compute Farm Doubles Traction Motor Design Productivity at General Motors

By Dr. Bradley Smith
HPC Architect
General Motors Corporation

Optimizing the design of traction motors used to drive electric vehicles (EVs)

Microsoft Windows

Microsoft Windows xp Professional x64 Edition

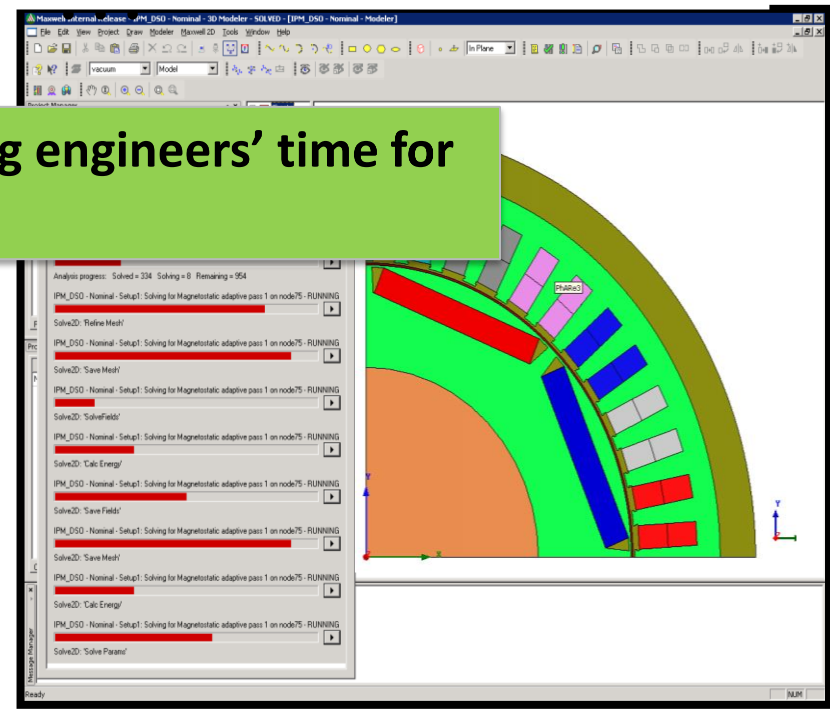
Let computers work 24/7, freeing engineers' time for other important tasks

Parametric variations: 1296

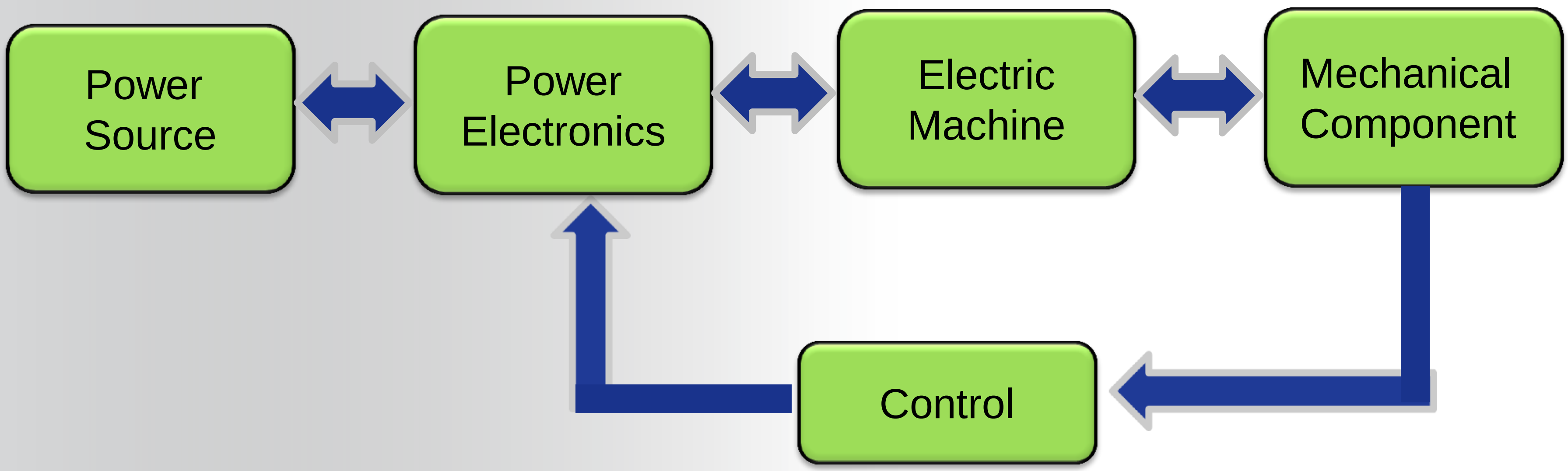
Solve time, one processor: 13 Hr 15 min

Solve time, distributed, 48 COREs: 18.4 min

Speed improvement: 43.3X



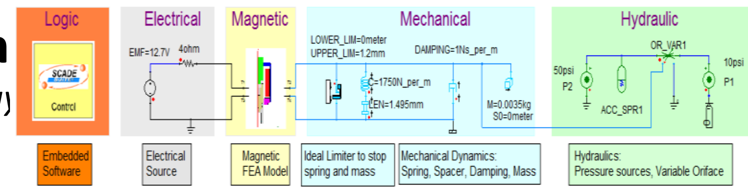
Electric Drivetrain Power Flow



ANSYS Simplorer Differentiation

Unmatched versatility for E/E Systems Simulation

Standard modeling languages, mixed digital and analog solver technology and standard co-simulation interfaces for simulation of electrical, electronics and embedded software systems.



$$\frac{\partial \rho}{\partial t}+\frac{1}{a}\nabla\cdot(\rho \boldsymbol{v})=0,$$

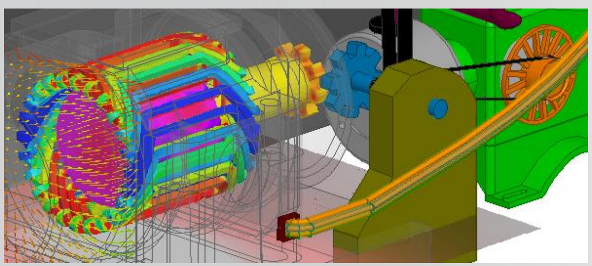
$$\frac{\partial(\rho \boldsymbol{v})}{\partial t}+\frac{1}{a}\nabla\cdot(\rho \boldsymbol{v}\boldsymbol{v}+p^{*}-\boldsymbol{B}\boldsymbol{B})=-\frac{\dot{a}}{a}\rho \boldsymbol{v}-\frac{1}{a}\rho\nabla\Phi,$$

$$+\frac{1}{a}\nabla\cdot[(E+p^{*})\boldsymbol{v}-(\boldsymbol{B}\cdot\boldsymbol{v})\boldsymbol{B}]=-\frac{2\dot{a}}{a}E-\frac{1}{a}\rho \boldsymbol{v}\cdot\nabla\Phi+$$

$$\frac{\partial \boldsymbol{B}}{\partial t}-\frac{1}{a}\nabla\times(\boldsymbol{v}\times\boldsymbol{B})=-\frac{\dot{a}}{a}\boldsymbol{B}$$

Adheres to physical laws

Behind every modeling component is a corresponding conservation law which ensures real-world physics are being respected.

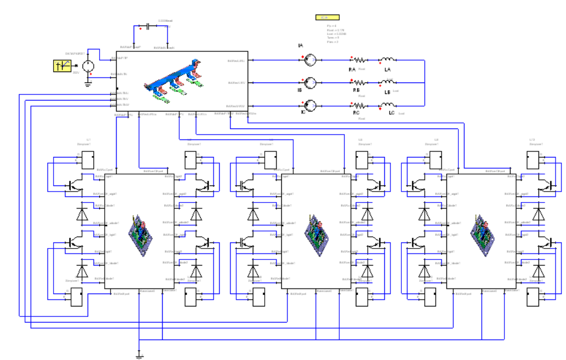


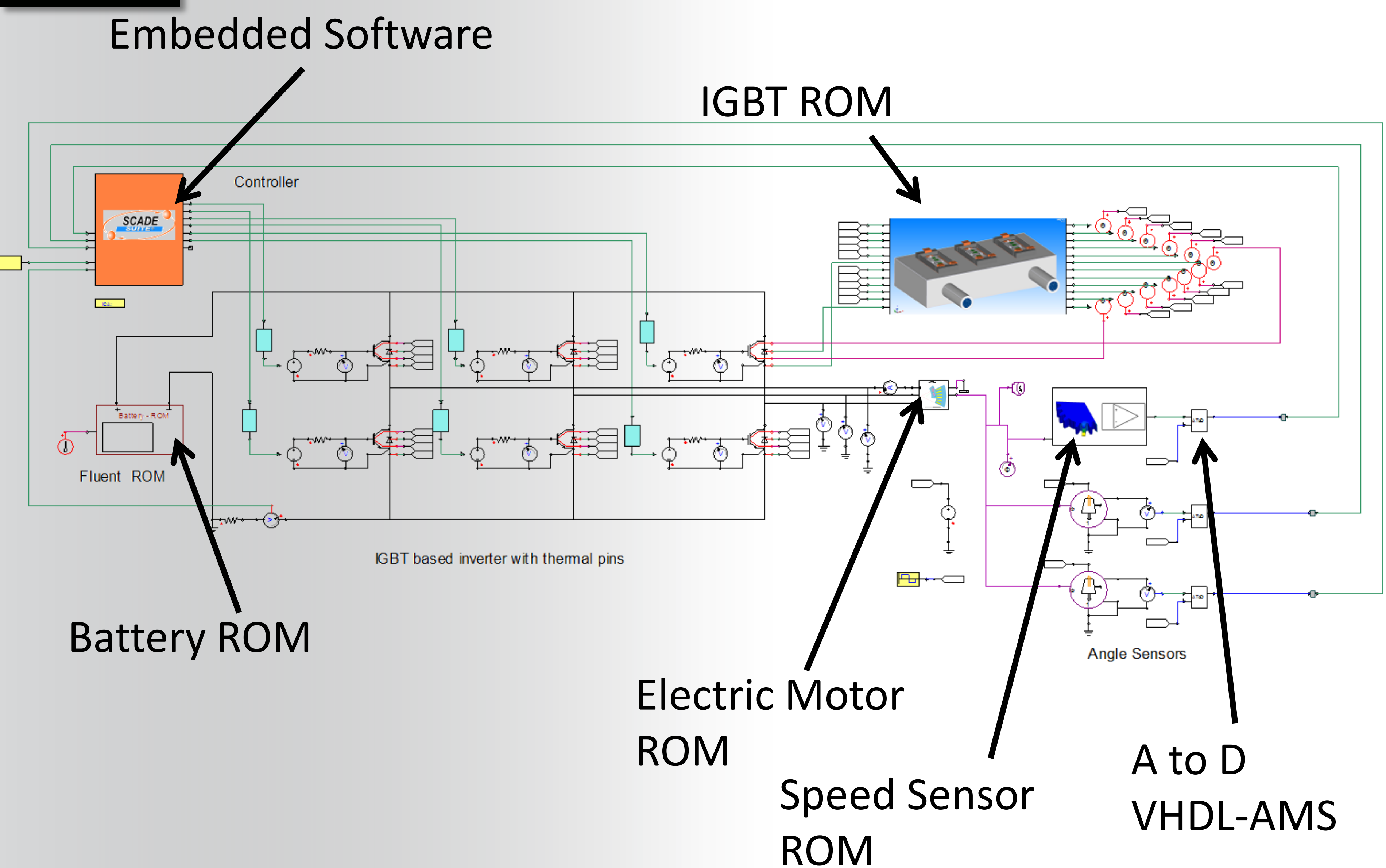
3D precision when you need it

Co-simulation with 3D solvers and reduced order modeling (ROM) captures complex multi-physics interactions when precise system verification is required.

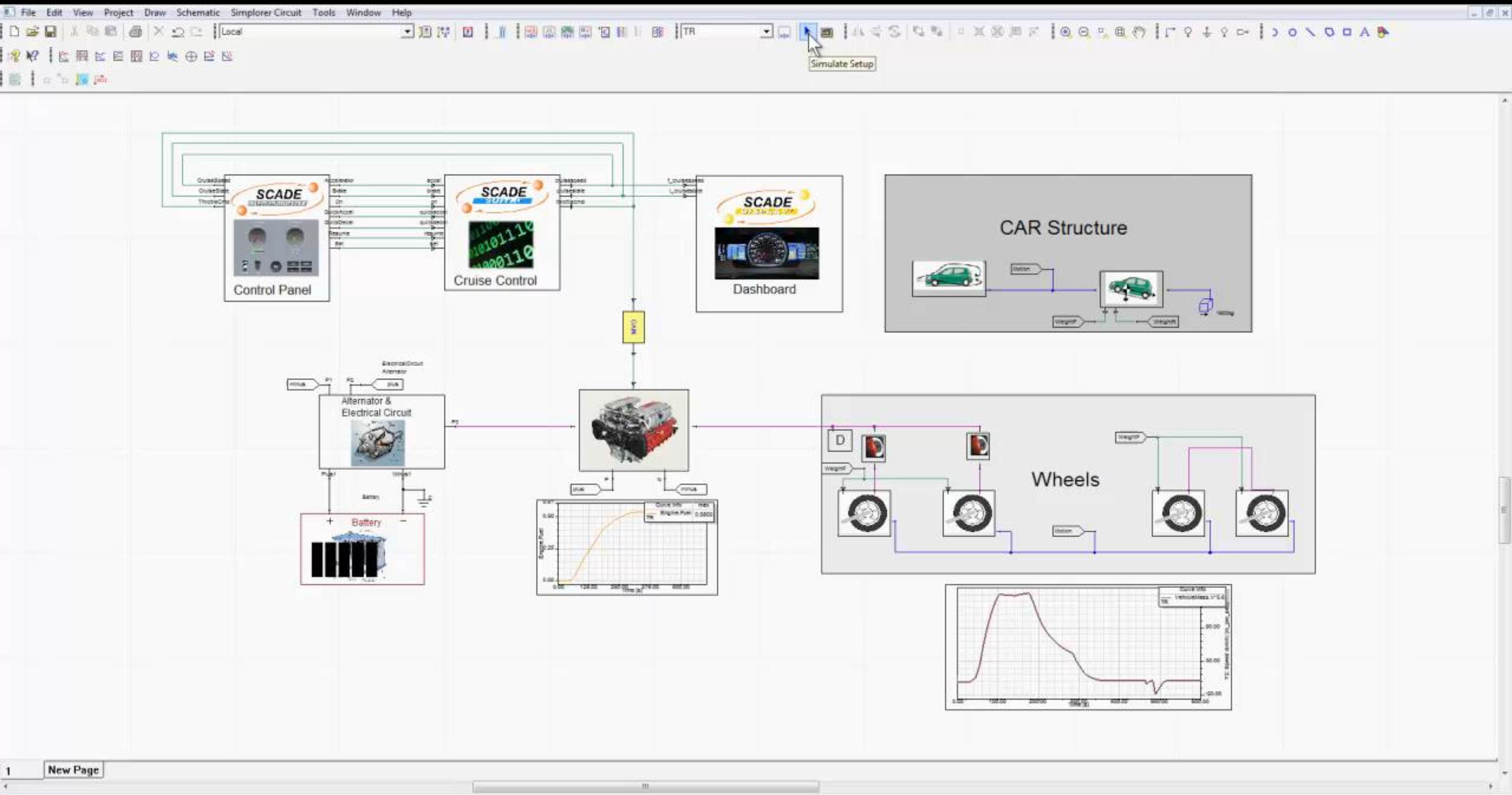
Leader in power electronics simulation

Rich modeling libraries and design automation designed especially for high performance power electronics and electromechanical simulation.



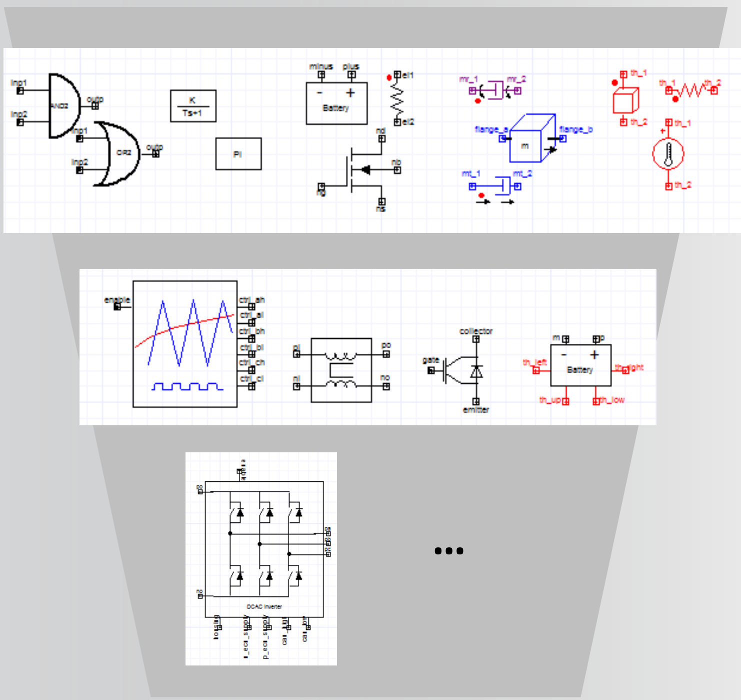


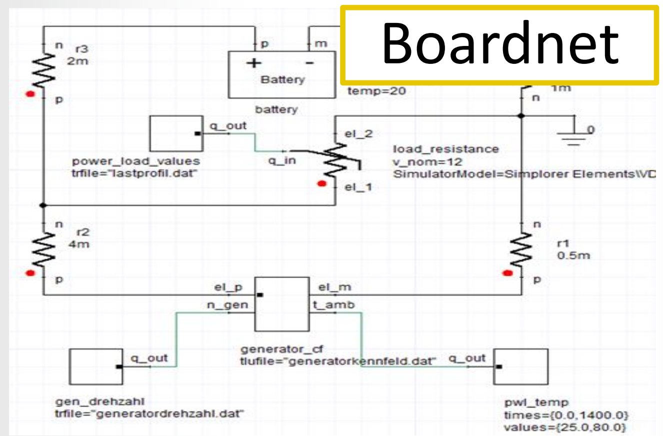
Embedded Software
IGBT ROM
Controller
SCADE SUITE
Battery - ROM
Fluent ROM
IGBT based inverter with thermal pins
Angle Sensors
Battery ROM
Electric Motor ROM
Speed Sensor ROM
A to D VHDL-AMS

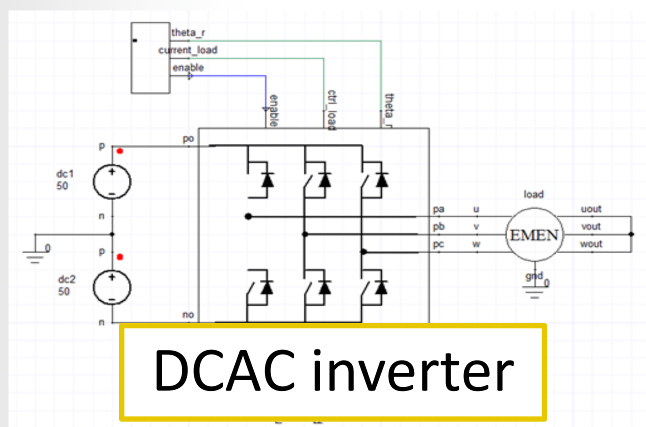

File
Edit
View
Project
Draw
Schematic
Simplorer Circuit
Tools
Window
Help
Local
TR
Simulate Setup
SCADE
Control Panel
SCADE
Cruise Control
SCADE
Dashboard
CAR Structure
Alternator &
Electrical Circuit
Battery
D
Wheels
1
New Page

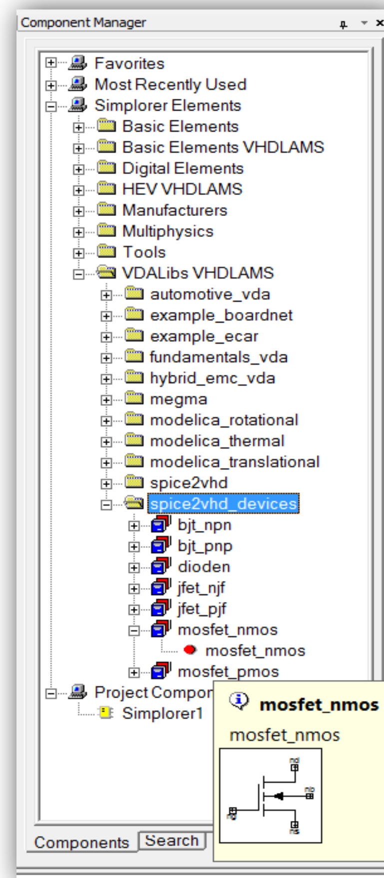
Simplorer 2014 includes the full VDA-FAT AK30 VHDL-AMS Library

- 500+ Models for automotive/controls
- Data driven, mostly lookup-table models with dynamics
- Includes custom Simplorer symbols

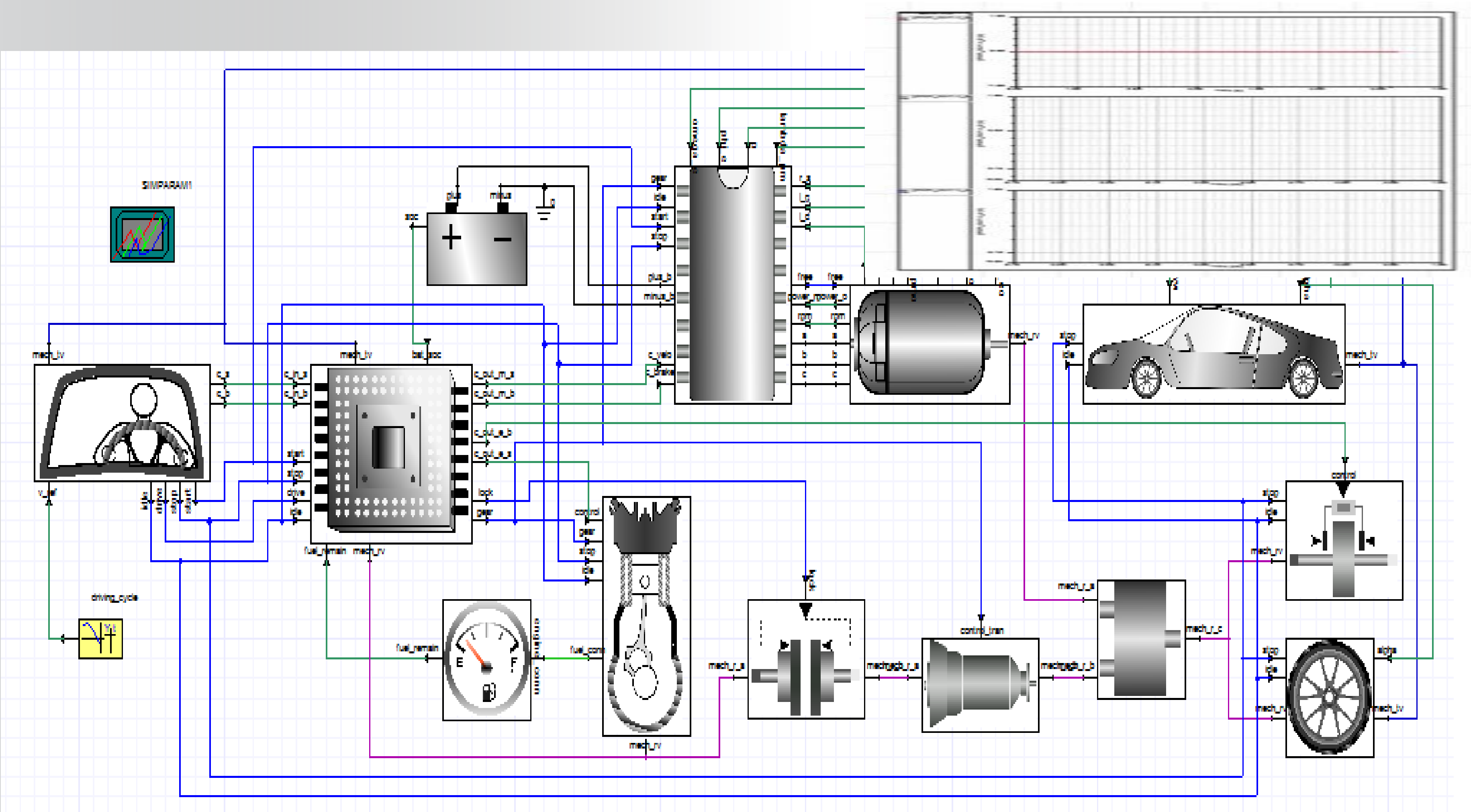




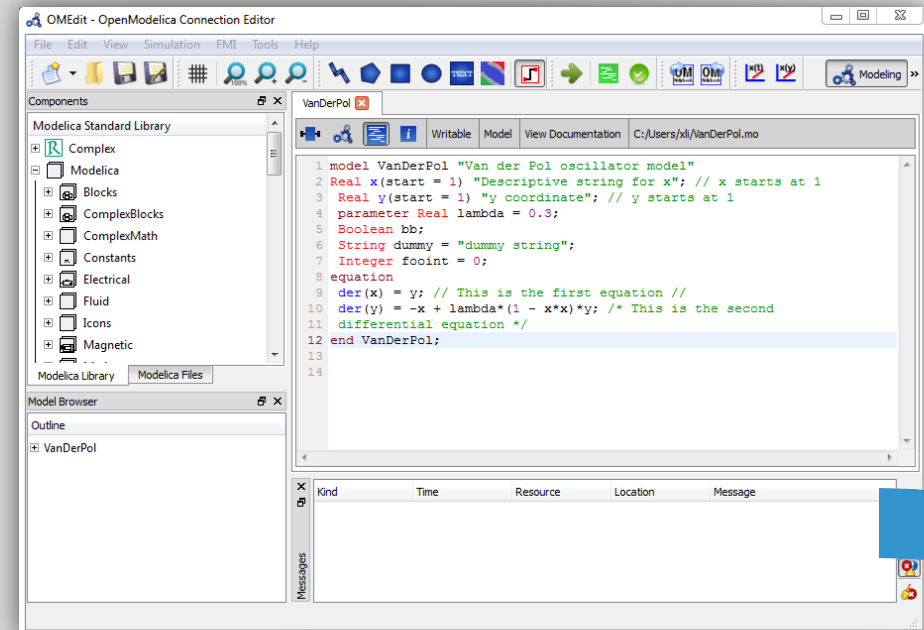


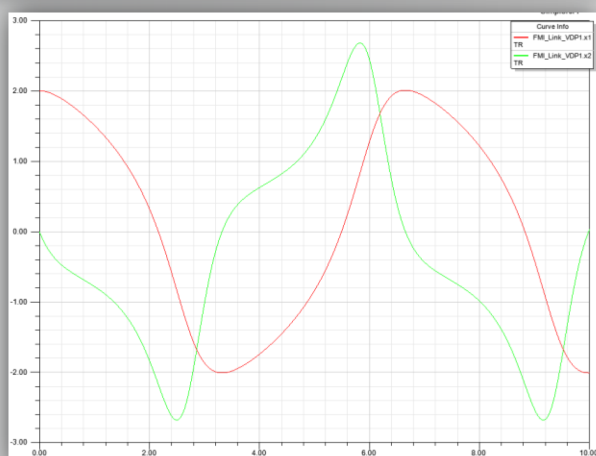


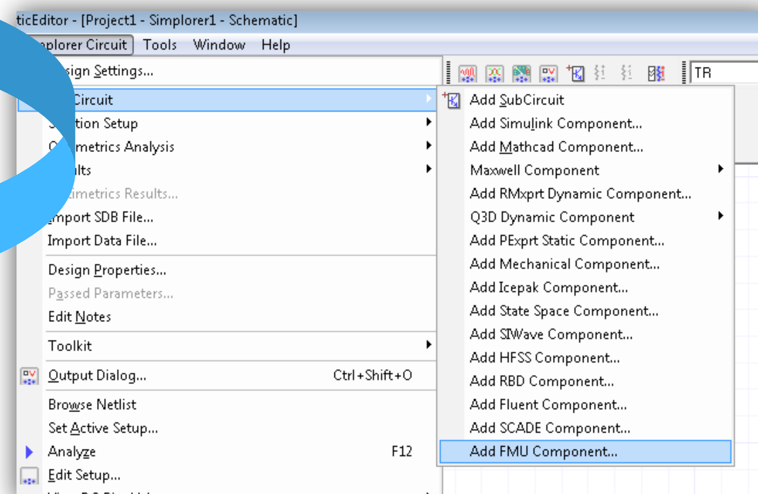
New VHDL-AMS HEV/EV Drive library allows easy prototyping of automotive systems



Co-Simulation capabilities with any Modelica or FMI-based Tool

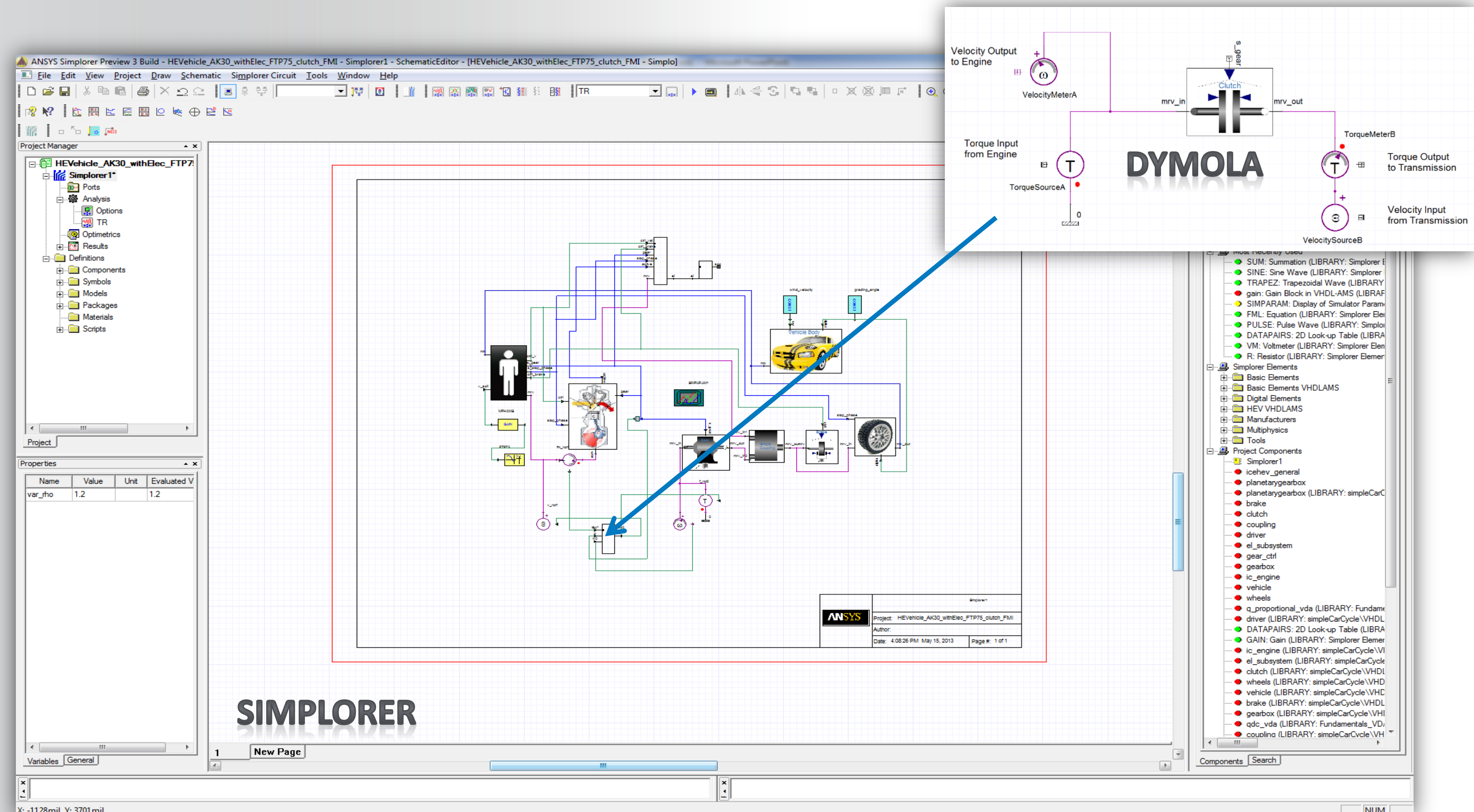




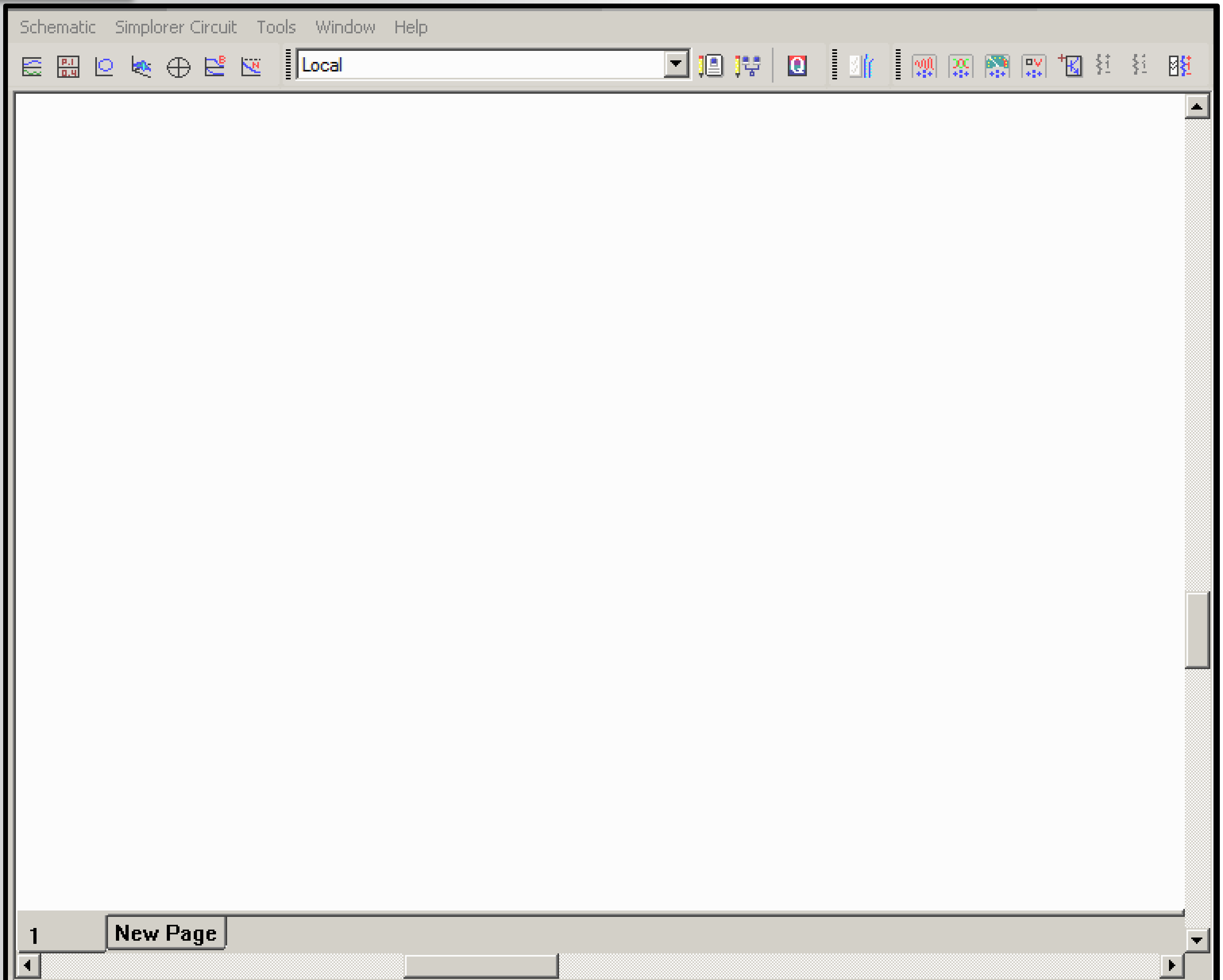


http://fast.wistia.net/embed/iframe/ak1gzr0g3s?popover=true
http://www.modelon.com/2013-detroit-fmi-day

FMI Support allows exporting models from Modelica tools to Simplorer



ROM, Co-Simulation Capability

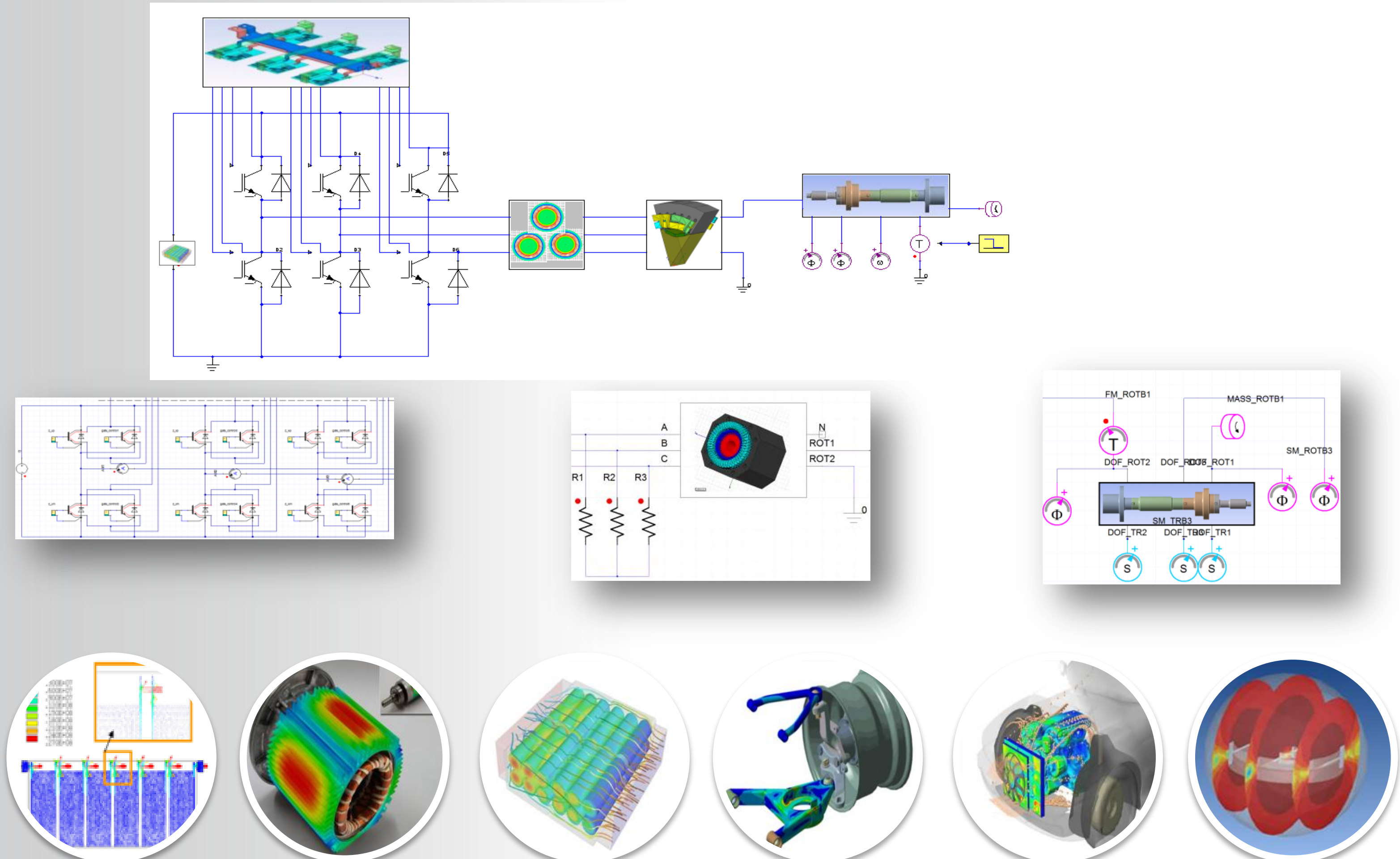


ANSYS Provides a Global Solution for HEV Development

System

Circuit

Component



Electrical Magnetic Fluid Mechanical Thermal Acoustic

Summary

- **In-depth physics for components.**
- **Coupled physics for interaction of components.**
- **System level simulation possible with Simplorer.**

Announcement

- **Automotive Simulation World Congress (ASWC)**