Workshop InS3PECT

ANSYS Simulation Platform Overview

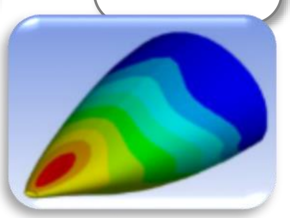
From Comprehensive Component-Level Design & Simulation …

FLUIDS

STRUCTURES

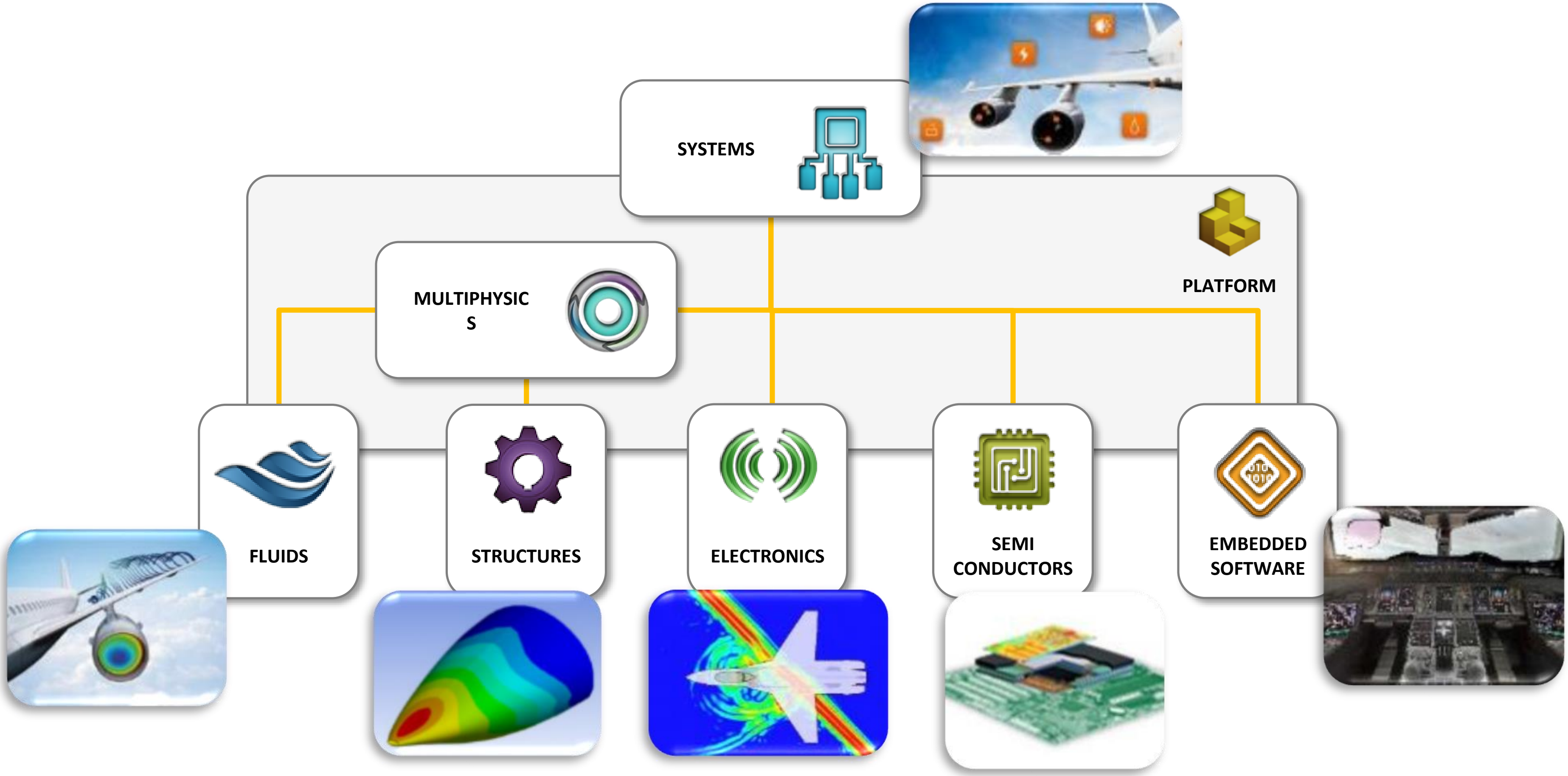
ELECTRONICS

SEMI CONDUCTORS

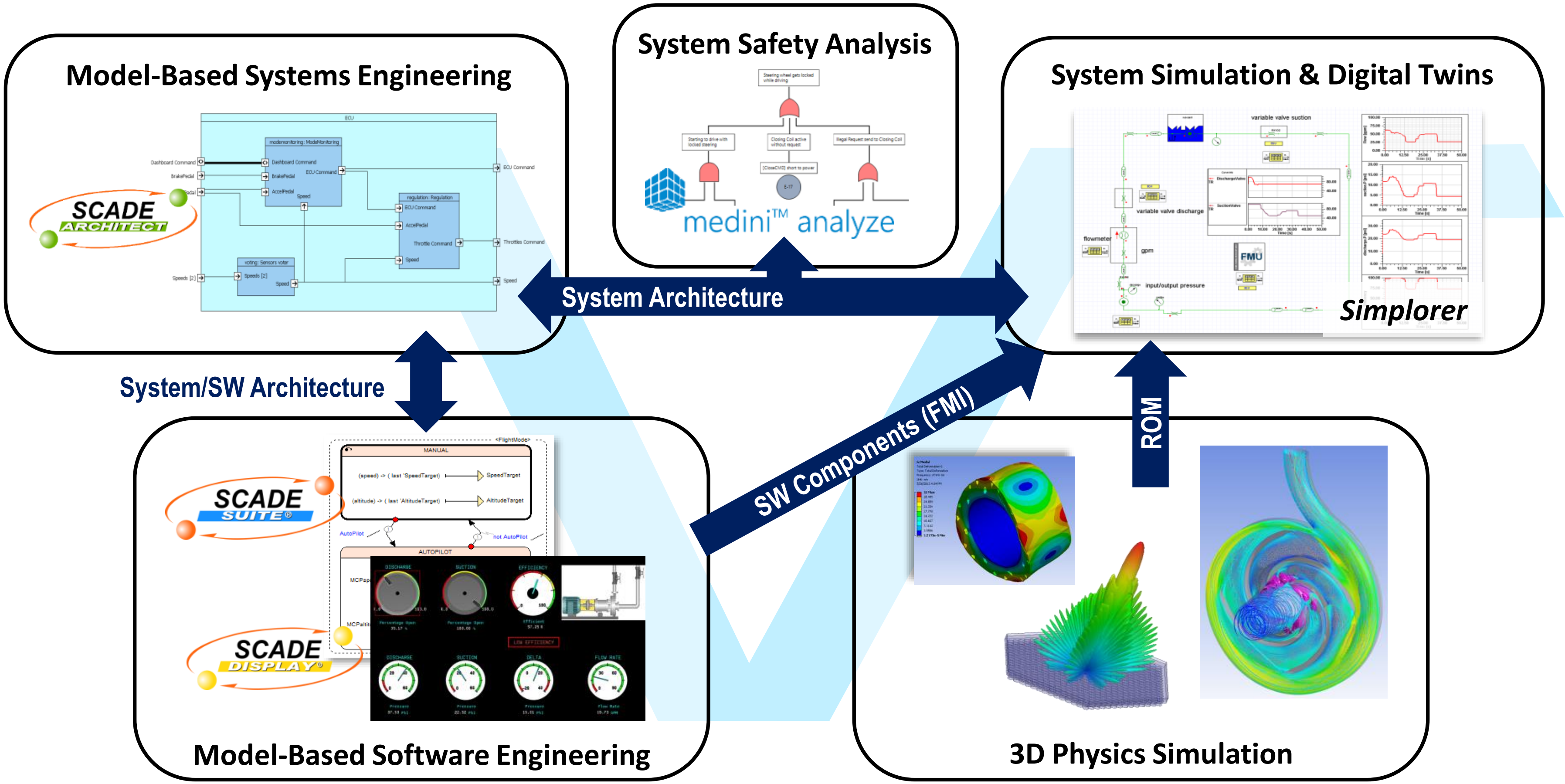


ANSYS Simulation Platform Overview

… To Complete Systems Simulation



ANSYS Systems & Embedded Software Capabilities

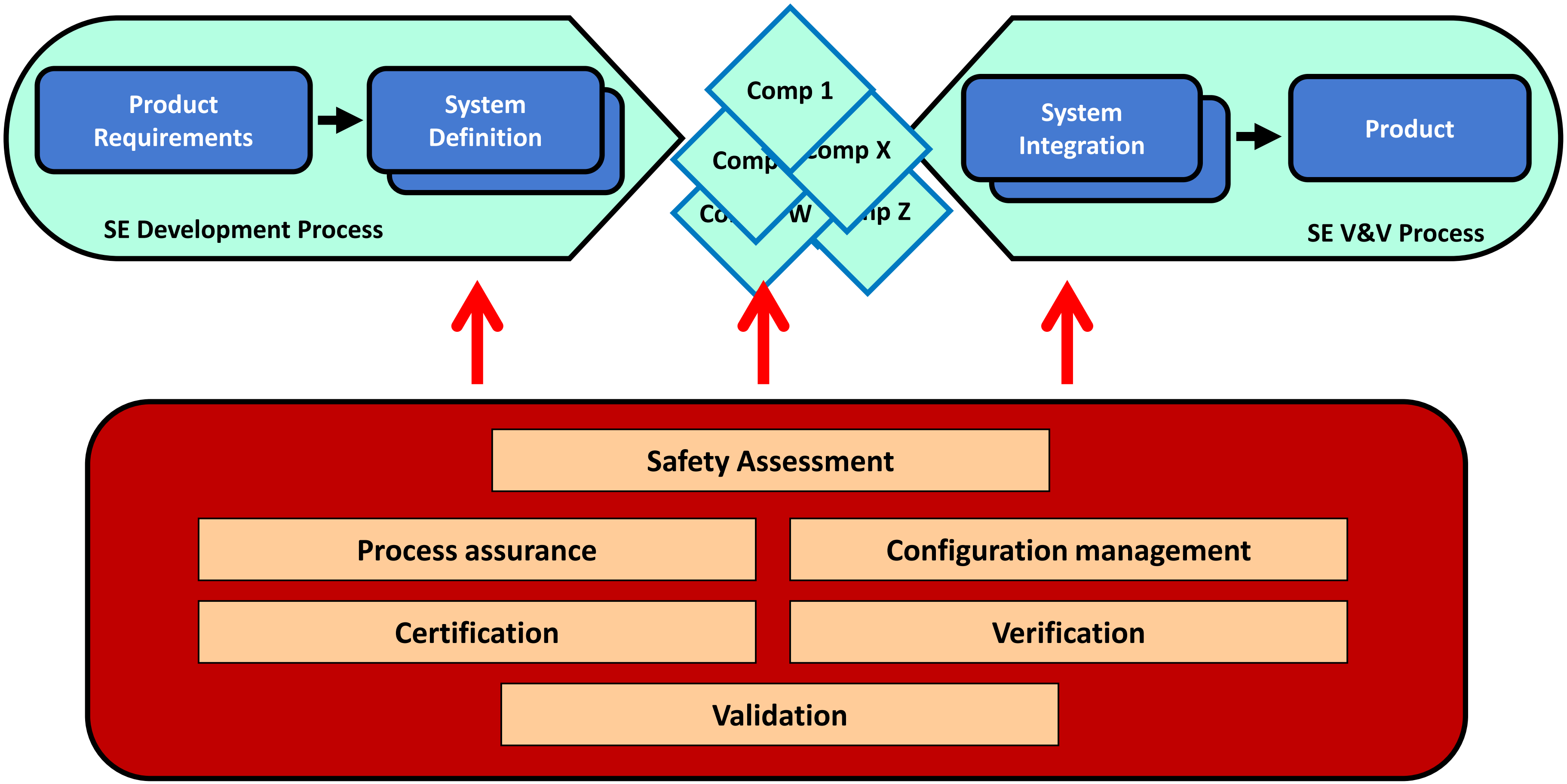


Realize Your Product Promise®

Virtual Prototyping along the V-Cycle

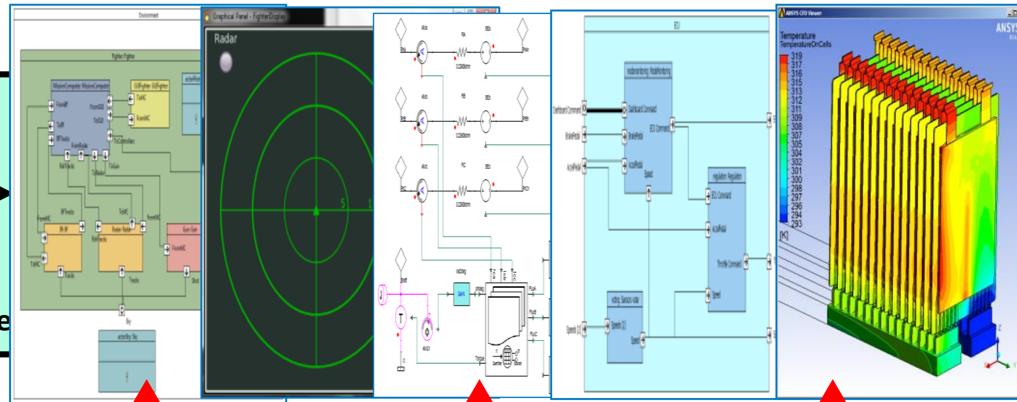
Jair Gonzalez, PhD
Jair.Gonzalez@ansys.com
Technical Director

Main Risk of the System Engineering process: Gap between the Development and the V&V Processes



Ansys Approach to Bridge the Gap: MBSE along the V-Cycle

Product Requirements → [SE Development Process]



→ Product

SE V&V Process

Safety Assessment

Process assurance

Configuration management

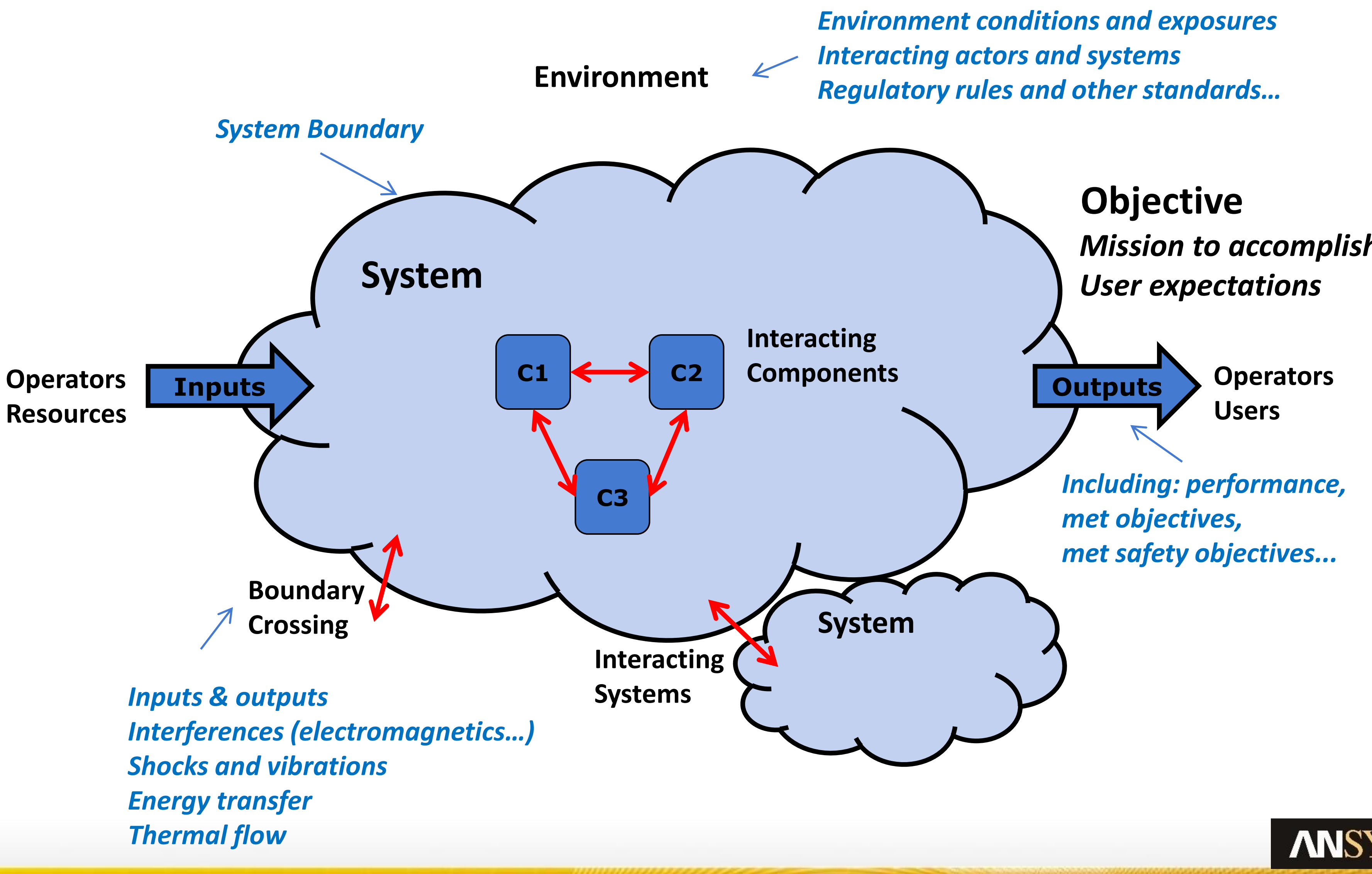
Certification

Verification

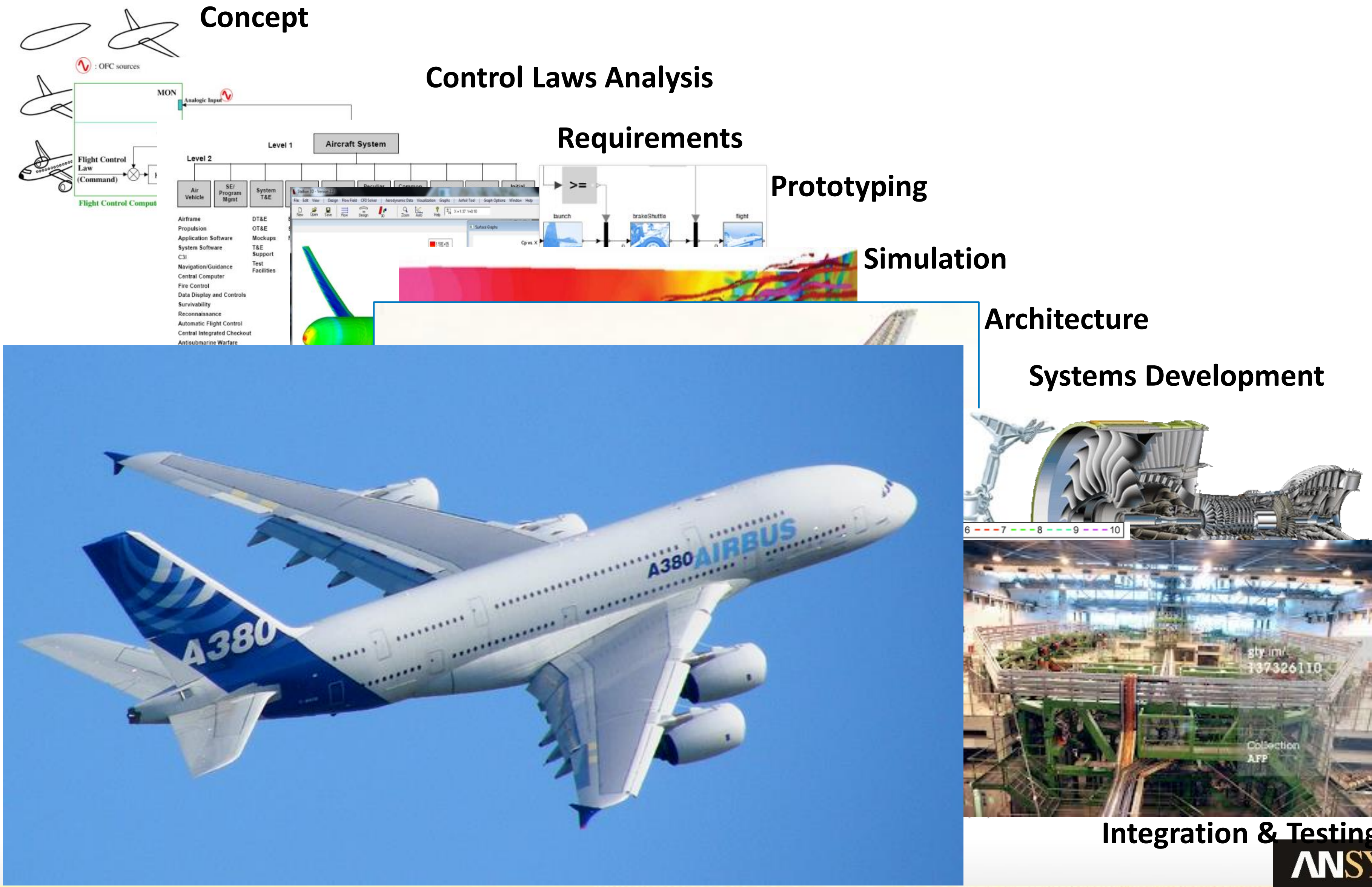
Validation

What is a System?

What is a System?



What is Systems Engineering?



What is Systems Engineering? INCOSE Definition

- *"Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems.*
- *It focuses on defining customer needs and required functionality early in the development cycle,*

✓ *documenting requirements,*

✓ *and then proceeding with design synthesis and system validation*

✓ *while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal.*

- *Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs."*

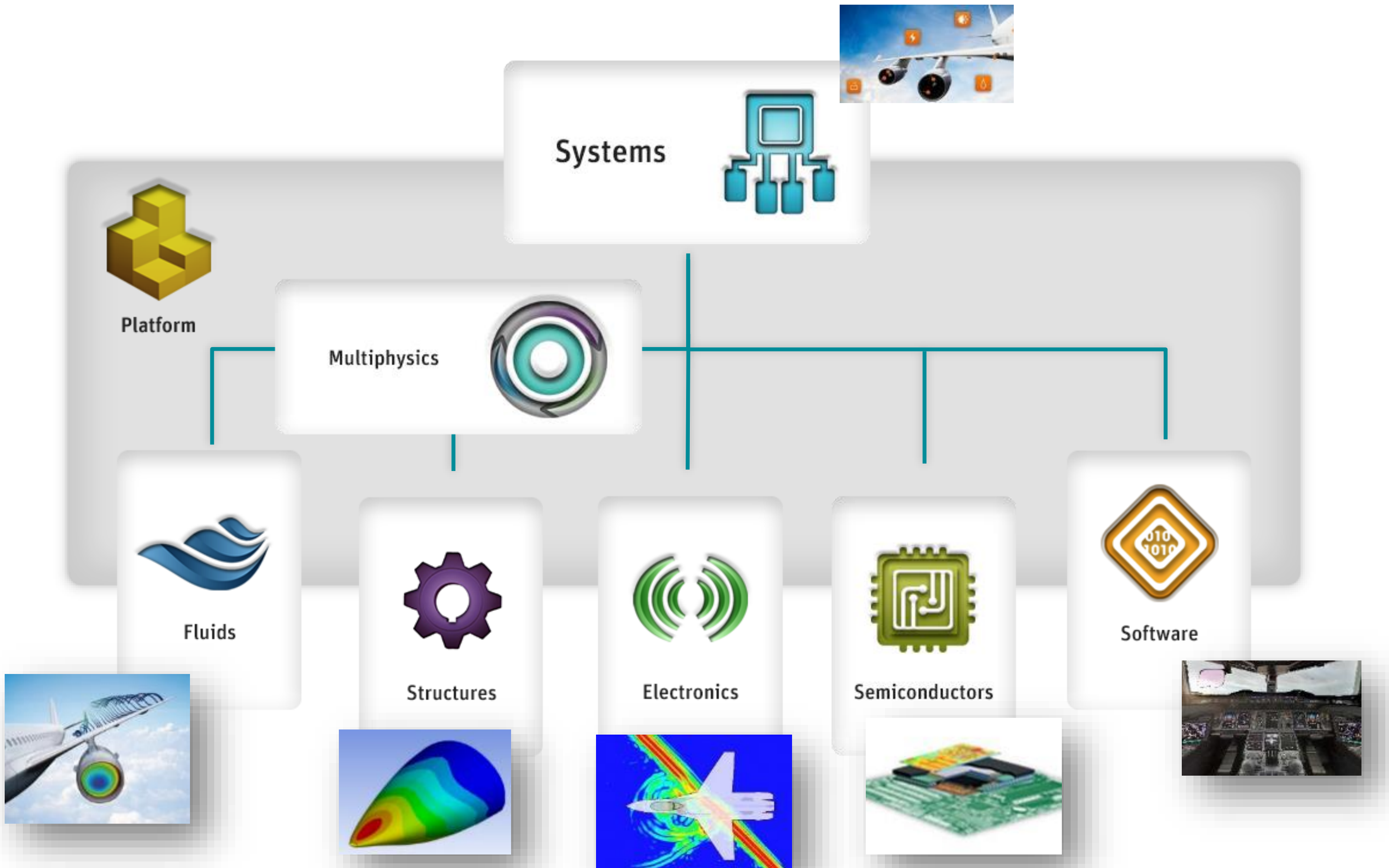
Systems Engineering… *in one single slide*

- Both a technical and a management process
- Organizing the technical efforts in the appropriate lifecycle
- Iterative and incremental
- Managing complexity
- Problem Solving oriented and Decision Making centered
- Constantly looking to increase the probability of success
- Reducing risks
- Managing safety and reliability
- Optimizing the global life cycle cost

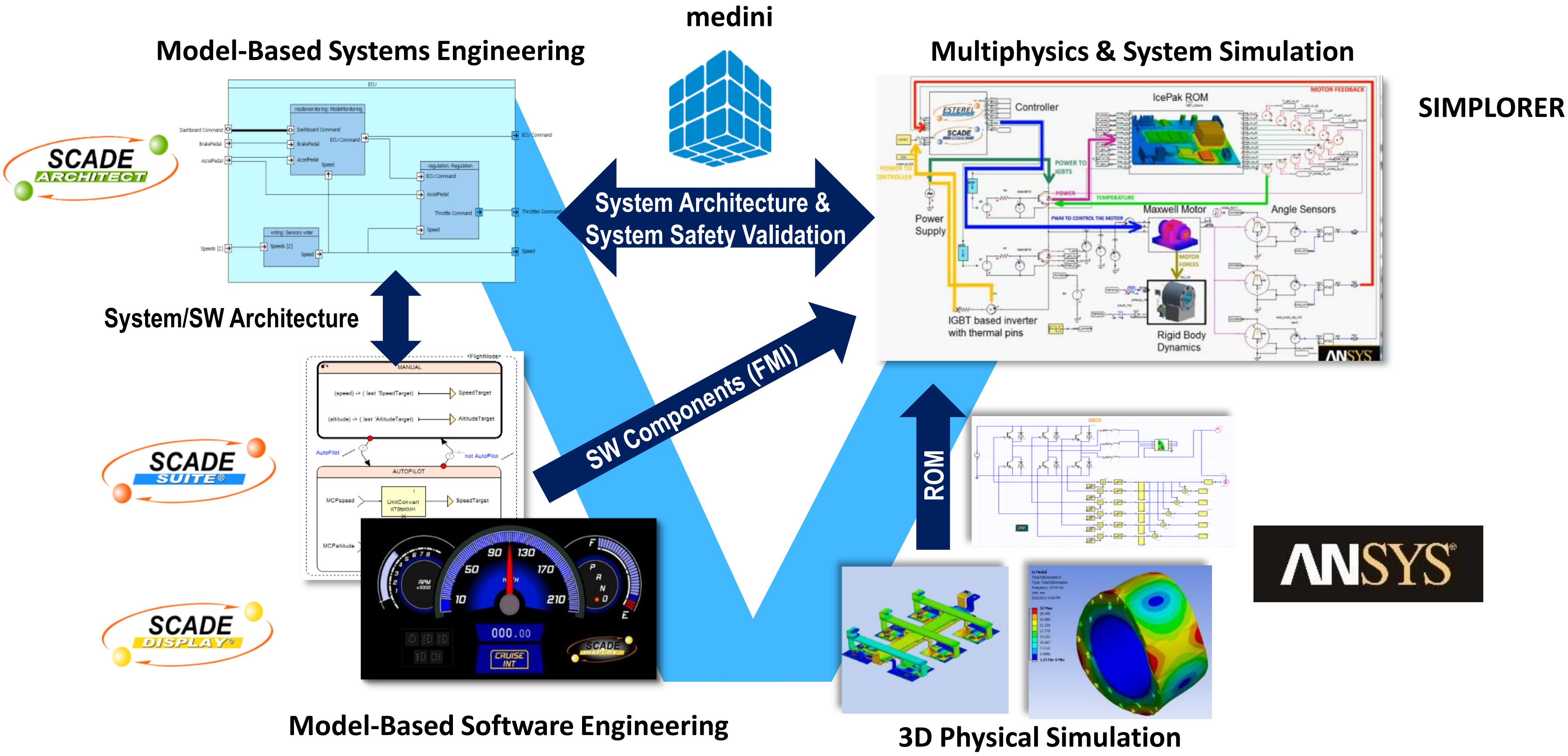
Realize Your Product Promise®

ANSYS Systems simulation: a unifying perspective

ANSYS Simulation Platform Overview

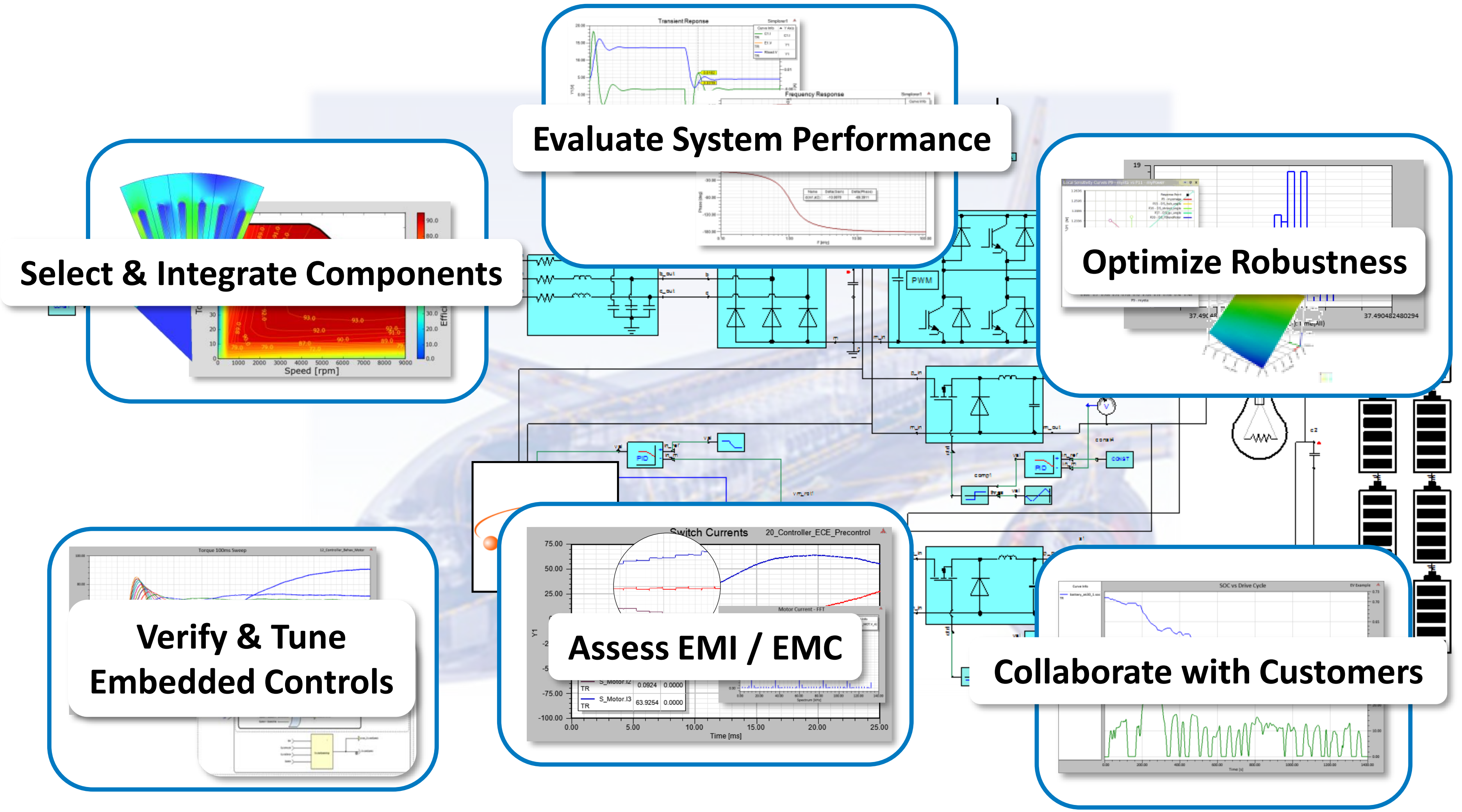


The Power of System Simulation with ANSYS



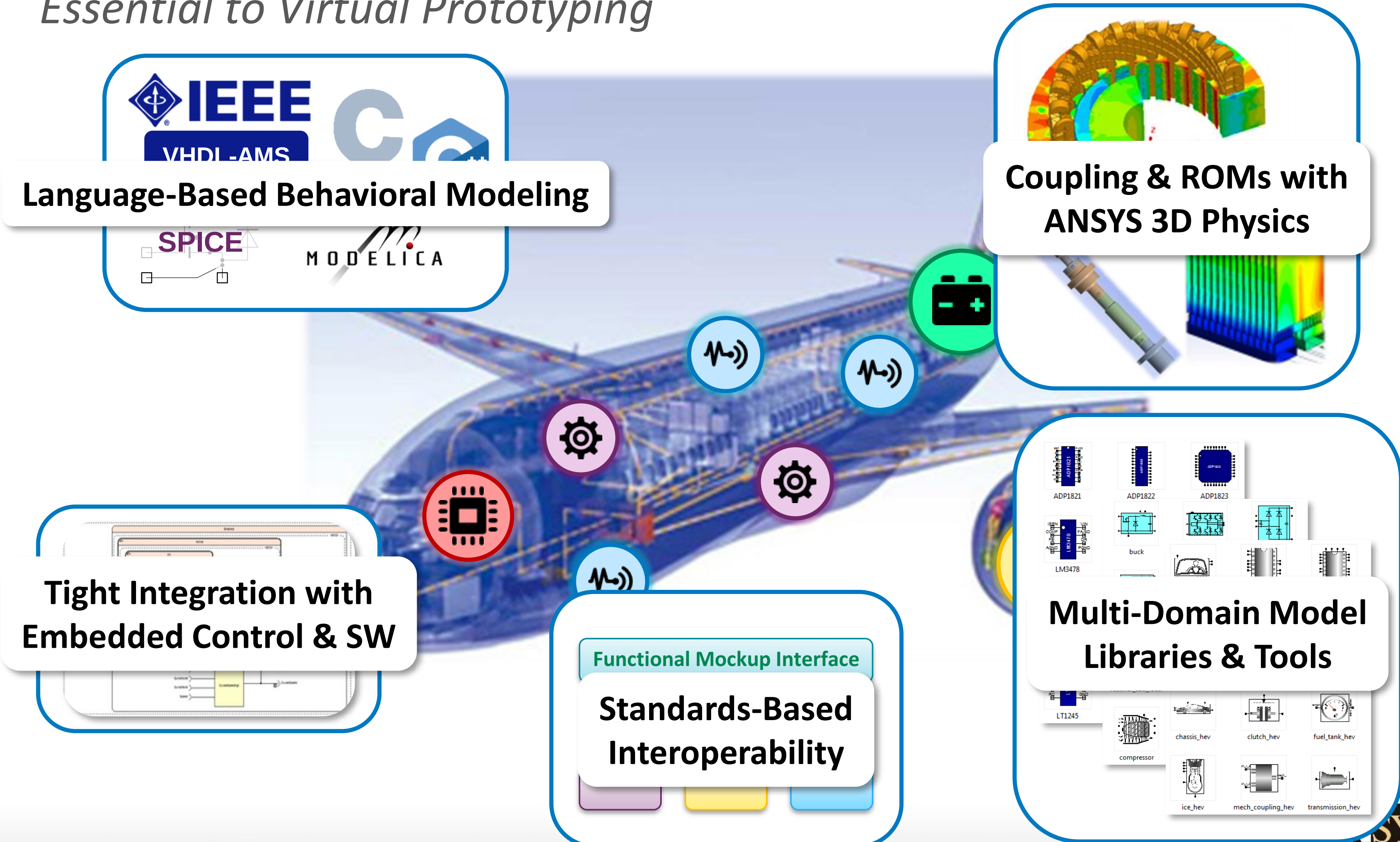
ANSYS

Goal: Assemble & Analyze Complex, Multi-Domain Interactions



ANSYS Simplorer: Multi-Domain System Simulation
Modeling Flexibility, Reusability, Interoperability

Essential to Virtual Prototyping



Assembling System Models

Flexibility, Reuse, Interoperability

Language-Based Modeling | **Multi-Domain Model Libraries** | **Coupling with 3D Physics** | **Reduced Order Modeling** | **Embedded Software Integration** | **3rd Party Interoperability**

KEY INITIATIVES

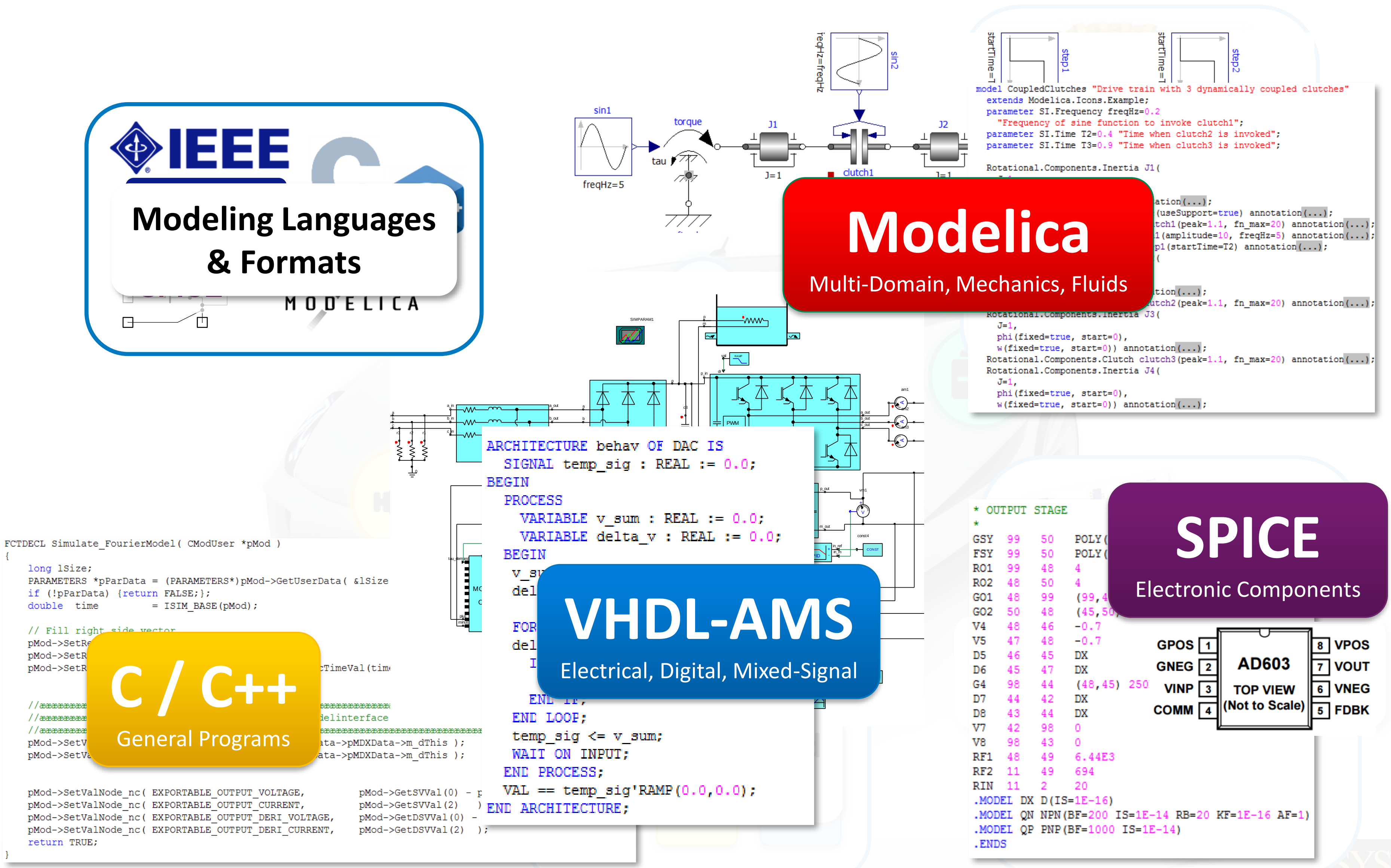
ROM Interfaces

FMI
Functional Mock-up Interface

MODELICA

ANSYS

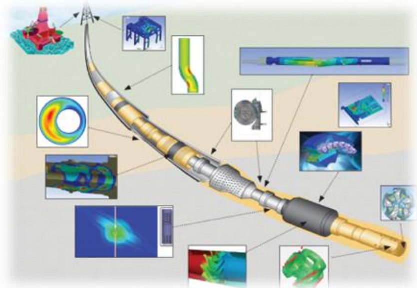
Languages Common to Design Disciplines

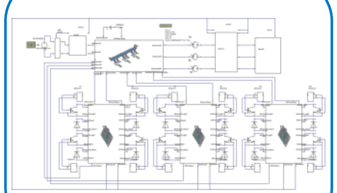


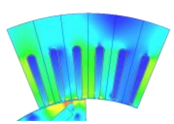
The Functional Mockup Interface (FMI)

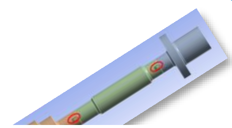
Standard for Connecting Simulation Models

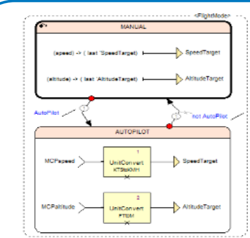
Integrated System Simulation











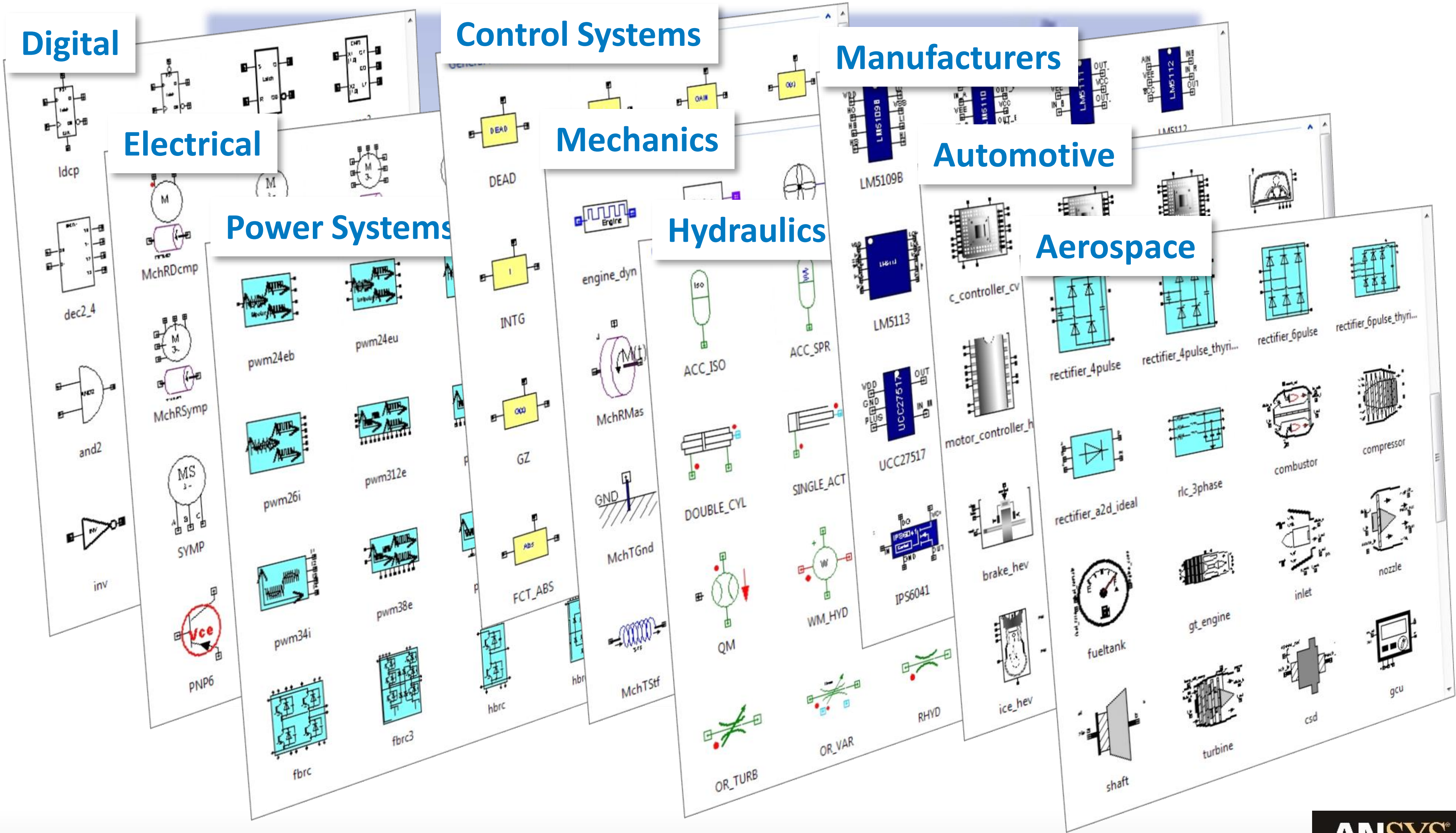
Developed to Enable:

MODEL PORTABILITY

TOOL INTEROPERABILITY

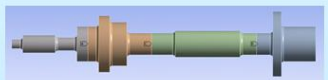
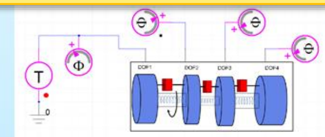
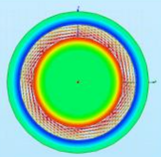
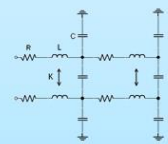
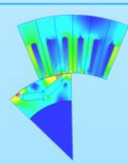
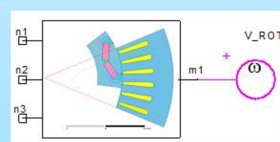
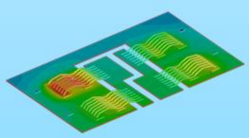
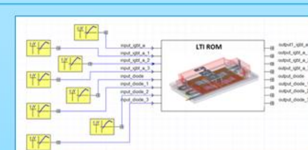
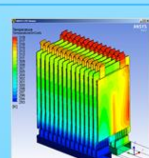
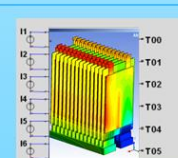
ENTERPRISE DEPLOYABILITY

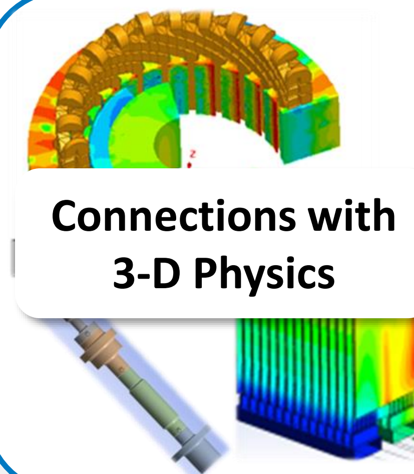
Model Libraries for Multiple Domains, Applications



Reduced-Order Modeling (ROM) Interfaces

- Preserves essential accuracy
- Simulates in a fraction of the time required by 3D
- Techniques for all ANSYS physics

Mechanical		
Electrical		
Electromagnetic		
Thermal		
Fluid		

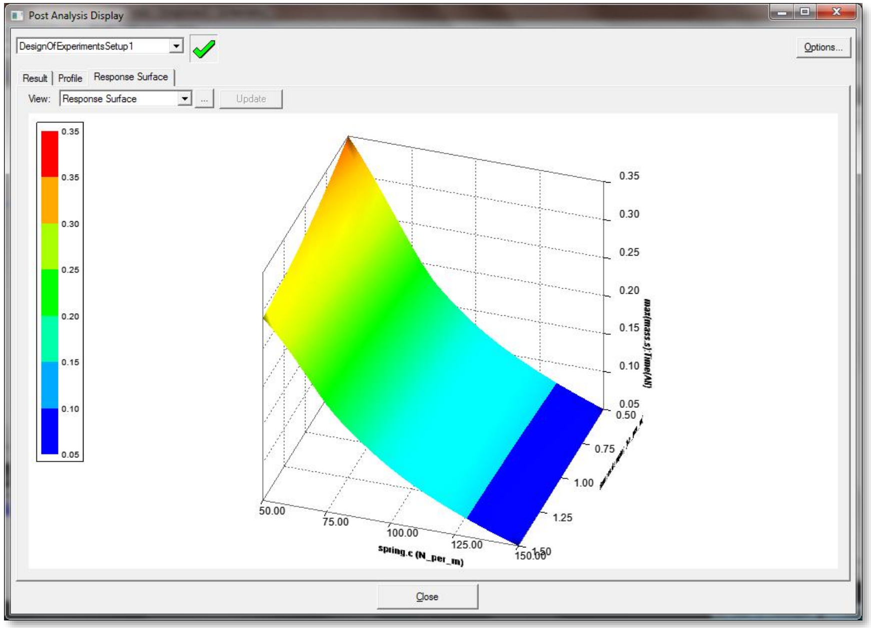


Connections with 3-D Physics

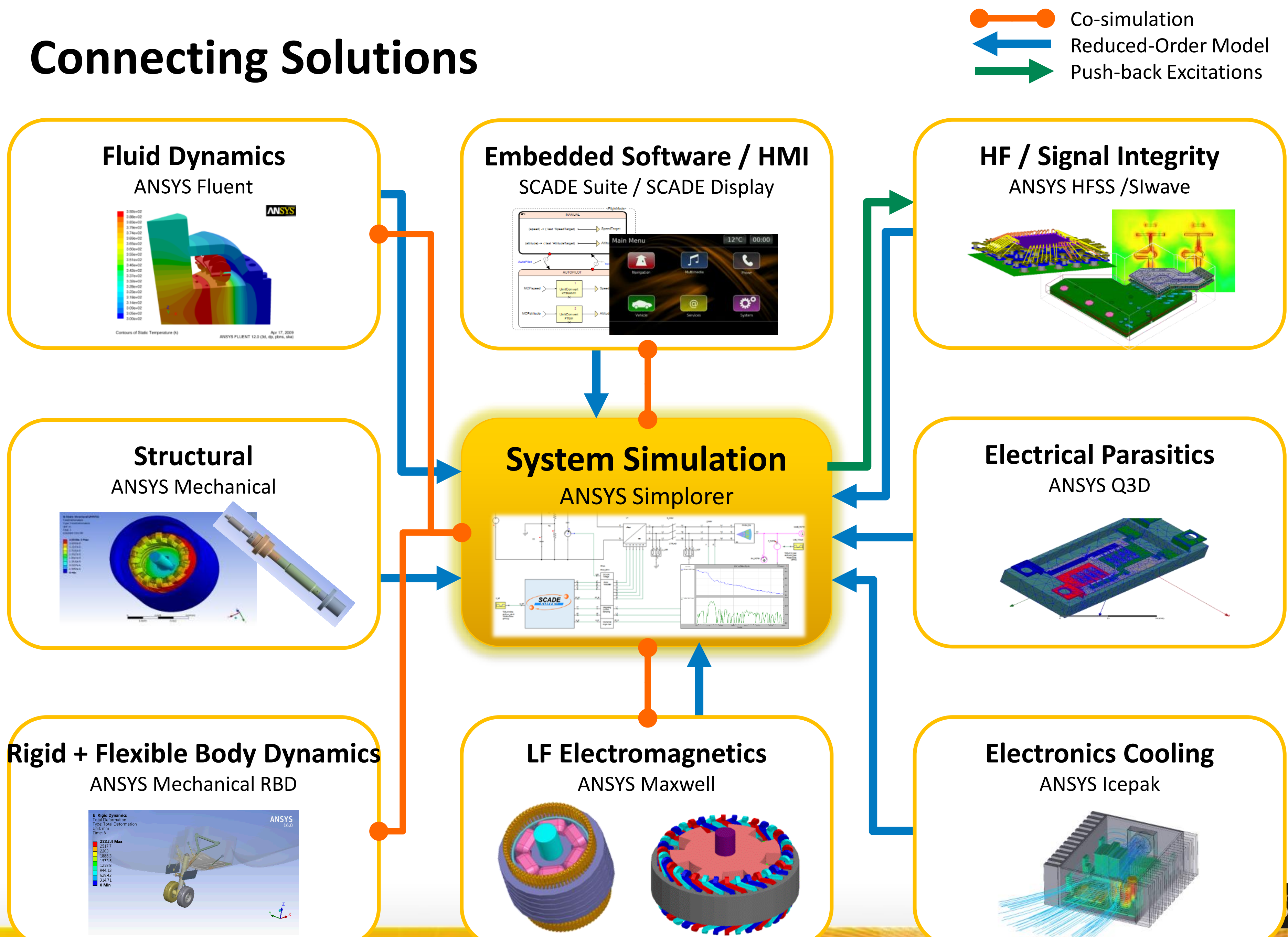
Multi-Domain Component Libraries

System Analysis: Design of Experiments

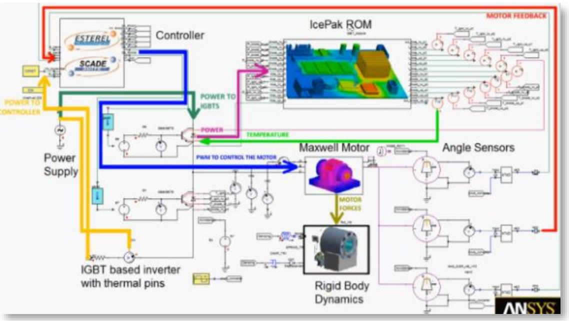
- New built-in **Design of Experiments** analysis helps understanding of how design factors affect system response
- Interactively explore the design space prior performing optimization
- Use Response Surface Model as a surrogate in system-level analyses



Connecting Solutions

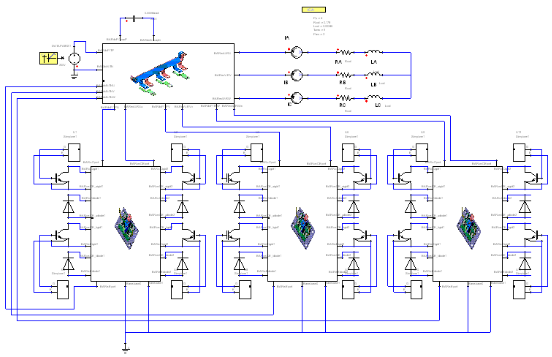


Simplorer: Multi-Domain System Simulation



A Platform for Virtual System Prototyping

Model, simulate, and analyze complex, software-controlled, multi-domain systems

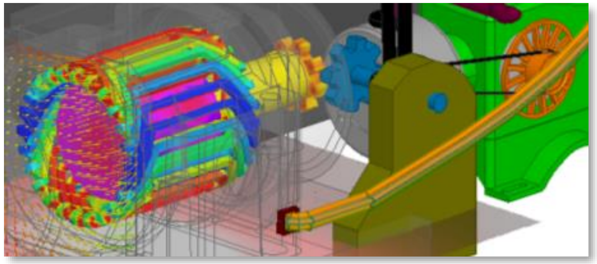


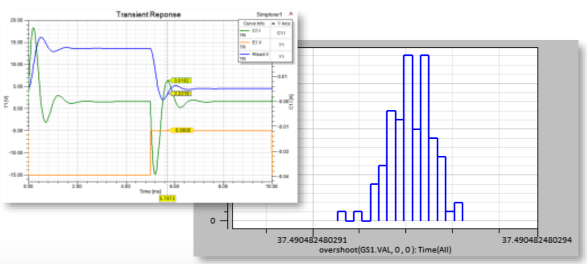
Pedigree in Power Electronics

Rich feature set and libraries designed for high-performance power electronics and electromechanical simulation

3-D Precision When You Need It

Reduced-Order Modeling (ROM) and Cosimulation with 3-D solvers captures detailed physics when precise system verification is required



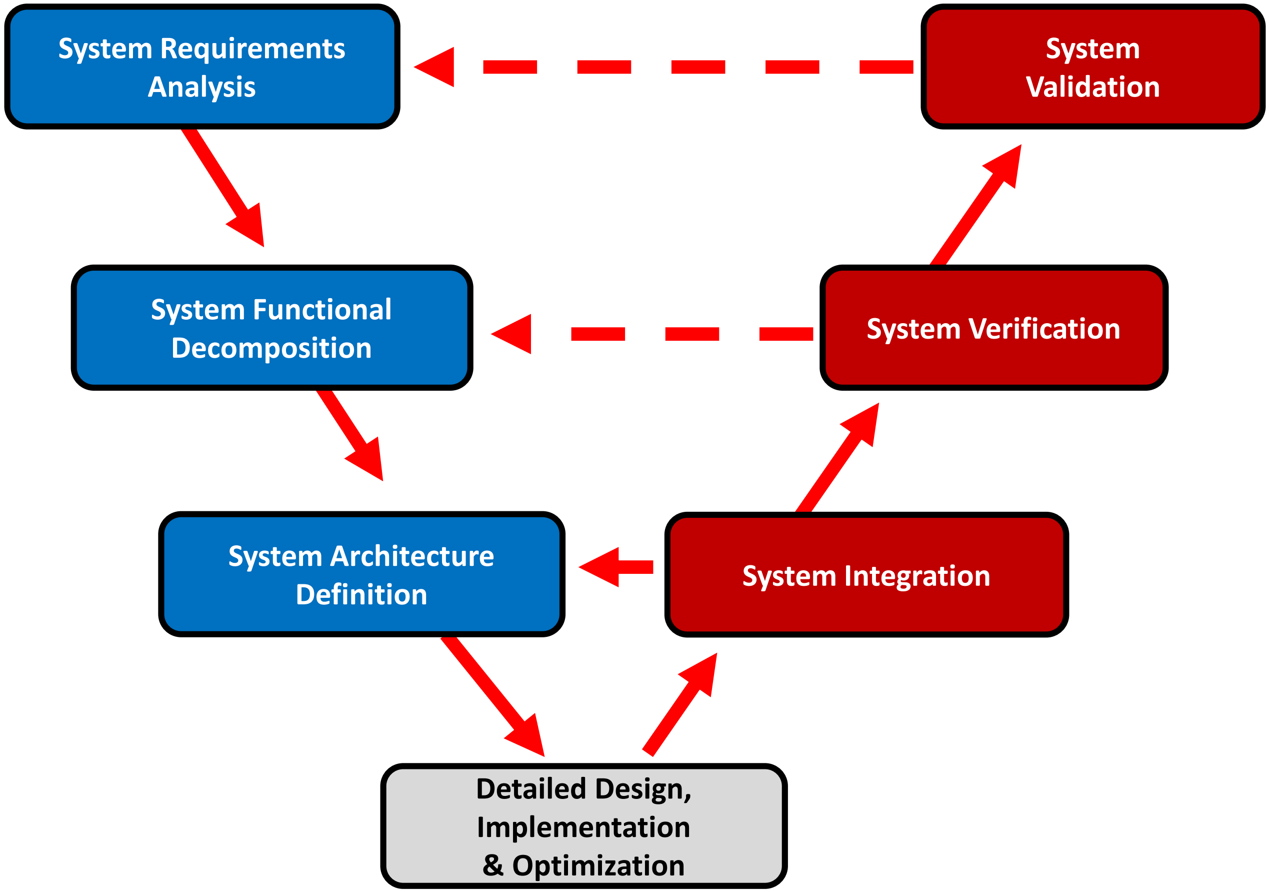


Simulation-Based Testing

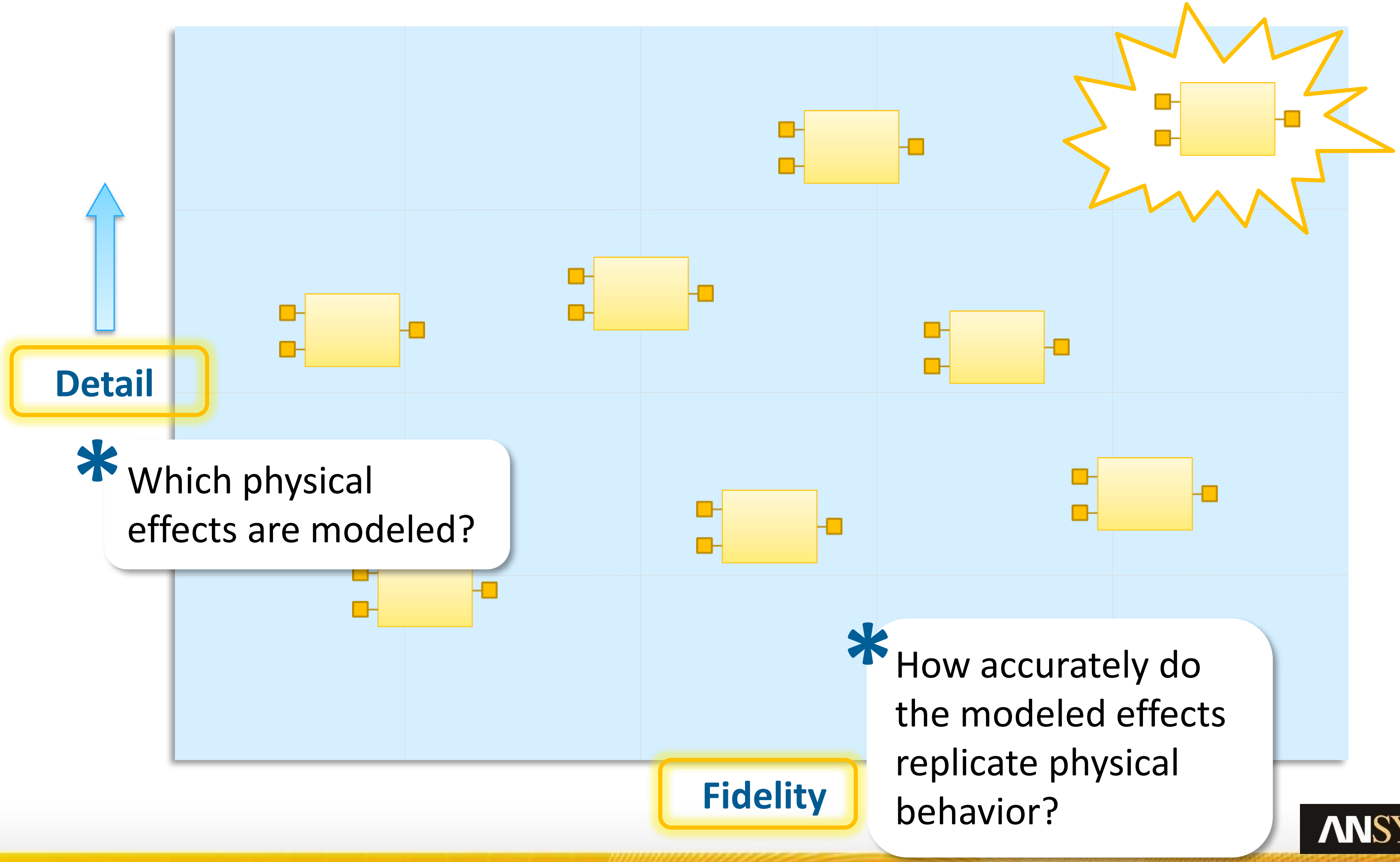
Verify and optimize system performance throughout the design process with robust, high-perfoming solvers and powerful post-processing

The process

A Generic Systems Engineering Process V-Cycle



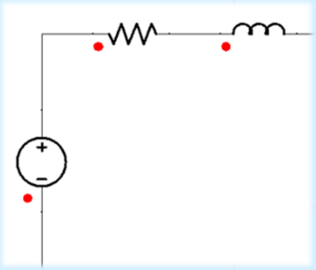
Model Detail & Fidelity



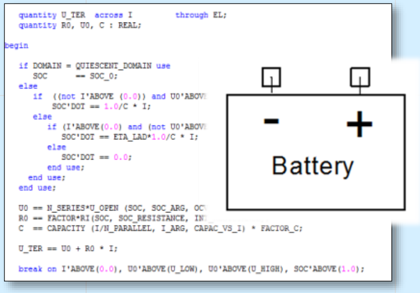
Modeling the Drive System

Power Source

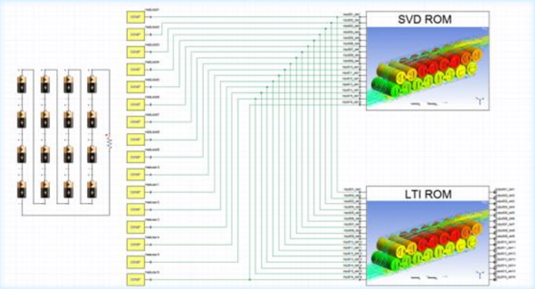
Detail



Basic Equivalent Circuit



VHDL-AMS Behavioral Model

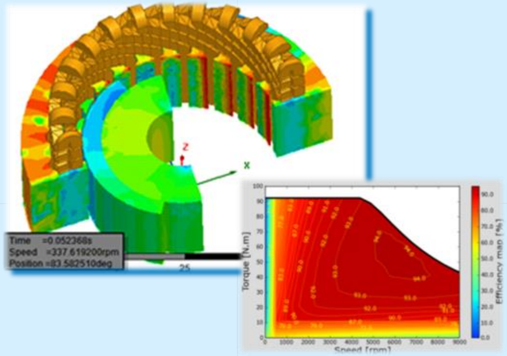


Equivalent Circuit Model + CFD ROM

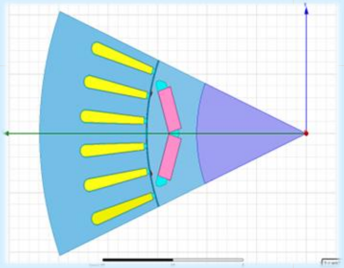
Fidelity

Modeling the Drive System

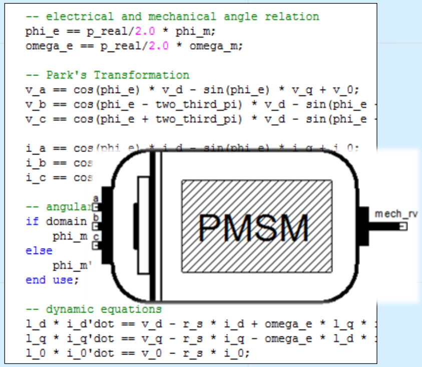
Motor



Co-simulation with 2D/3D FEM



Electric Circuit Equivalent ROM



VHDL-AMS Behavioral Model

Detail

Fidelity

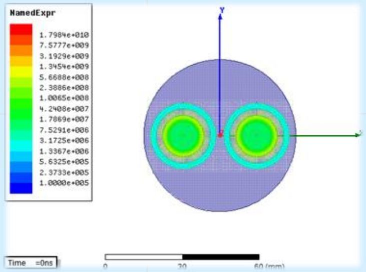
ANSYS

  December 12, 2017 ANSYS Confidential

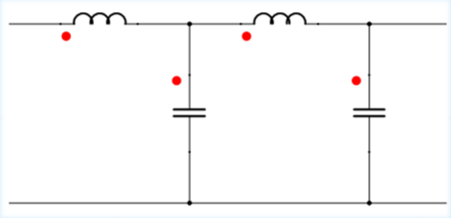
Modeling the Drive System

Power Cables

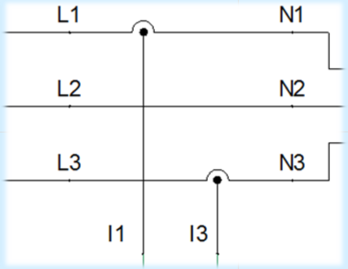
Detail



S-Parameter ROM
for Distributed Tx Lines



Lumped Element
Lossless Model



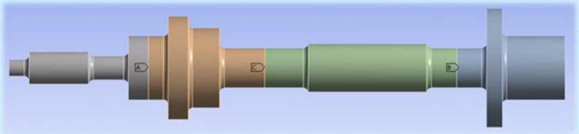
Ideal Connections

Fidelity

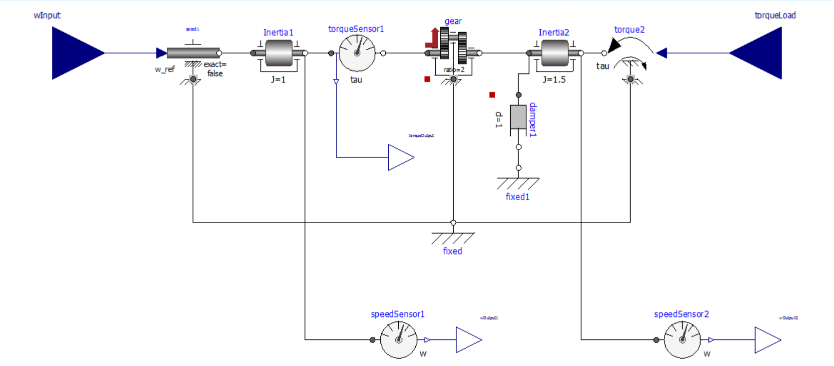
Modeling the Drive System

Mechanical Dynamics

Detail



Mechanical ROM of Flexible Shaft



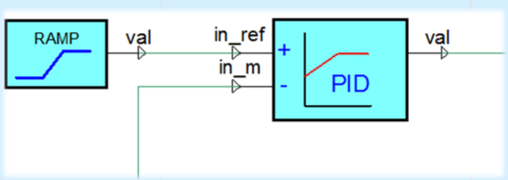
Modelica Behavioral Model

Fidelity

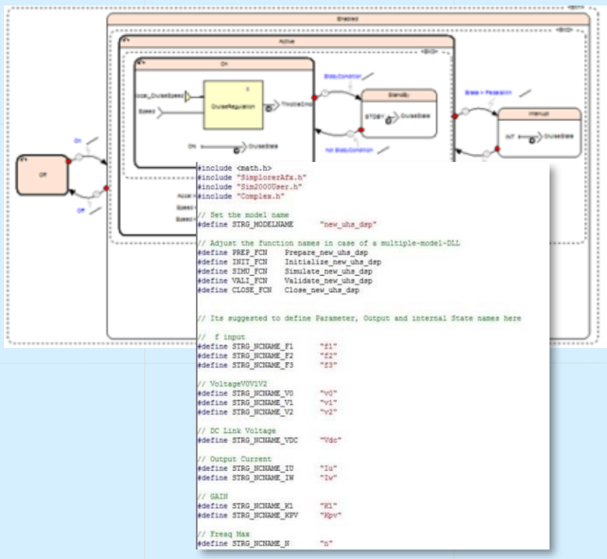
Modeling the Drive System

Embedded Control

Detail



Ideal Control Blocks

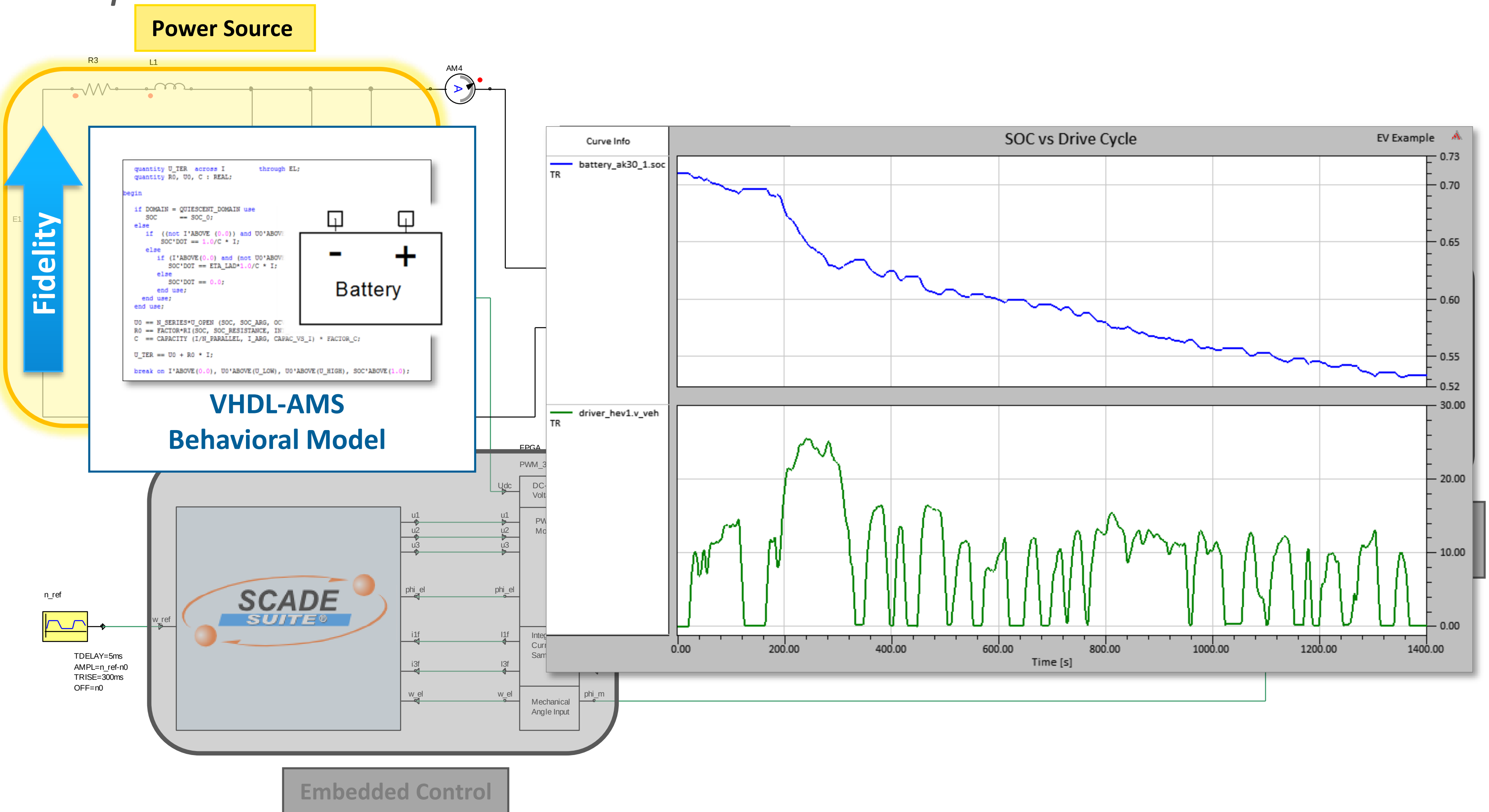


Generated Control Application Code

Fidelity

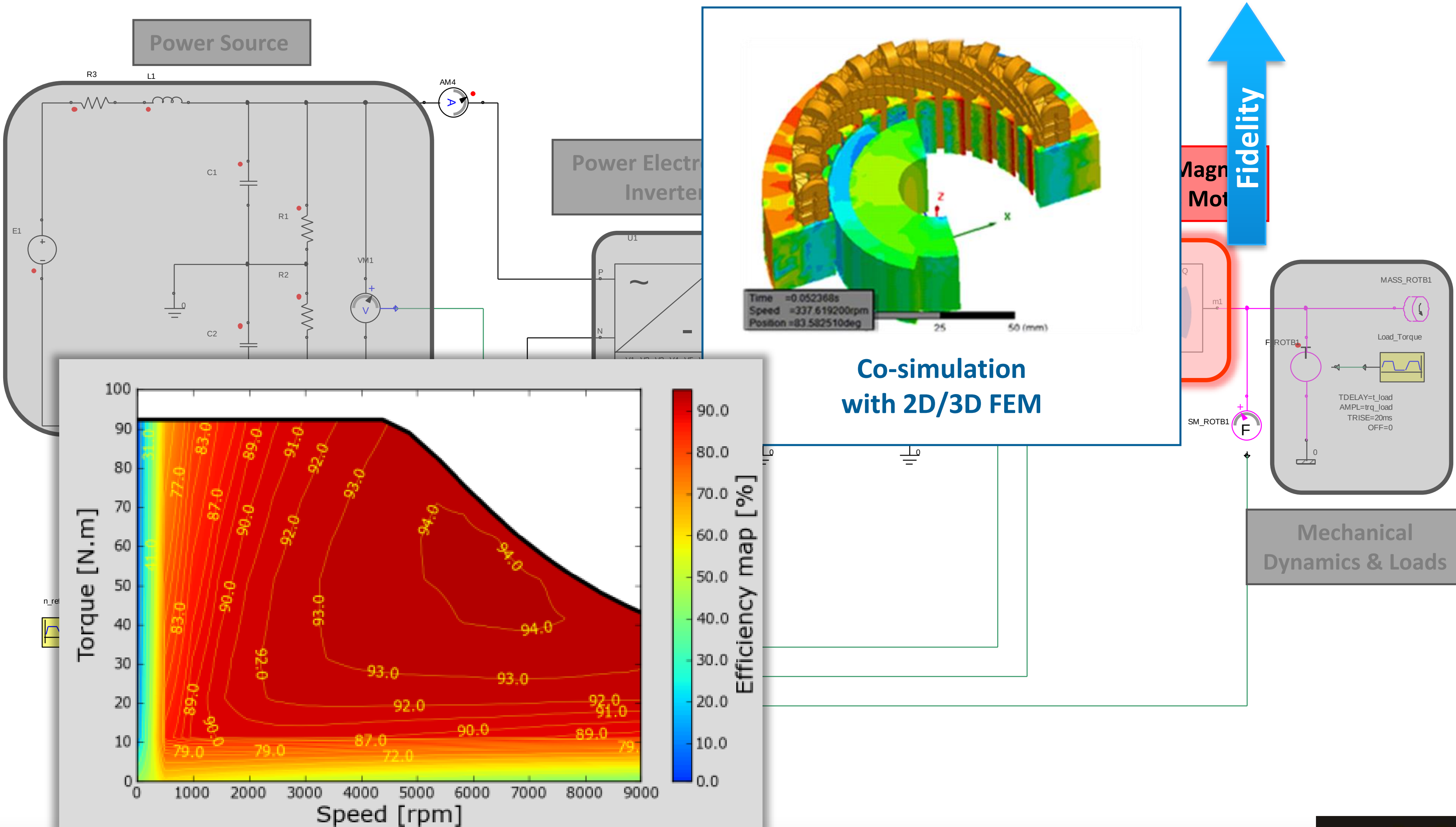
Assembling & Analyzing the System

Goal: Evaluate System Architecture, Size Key Components



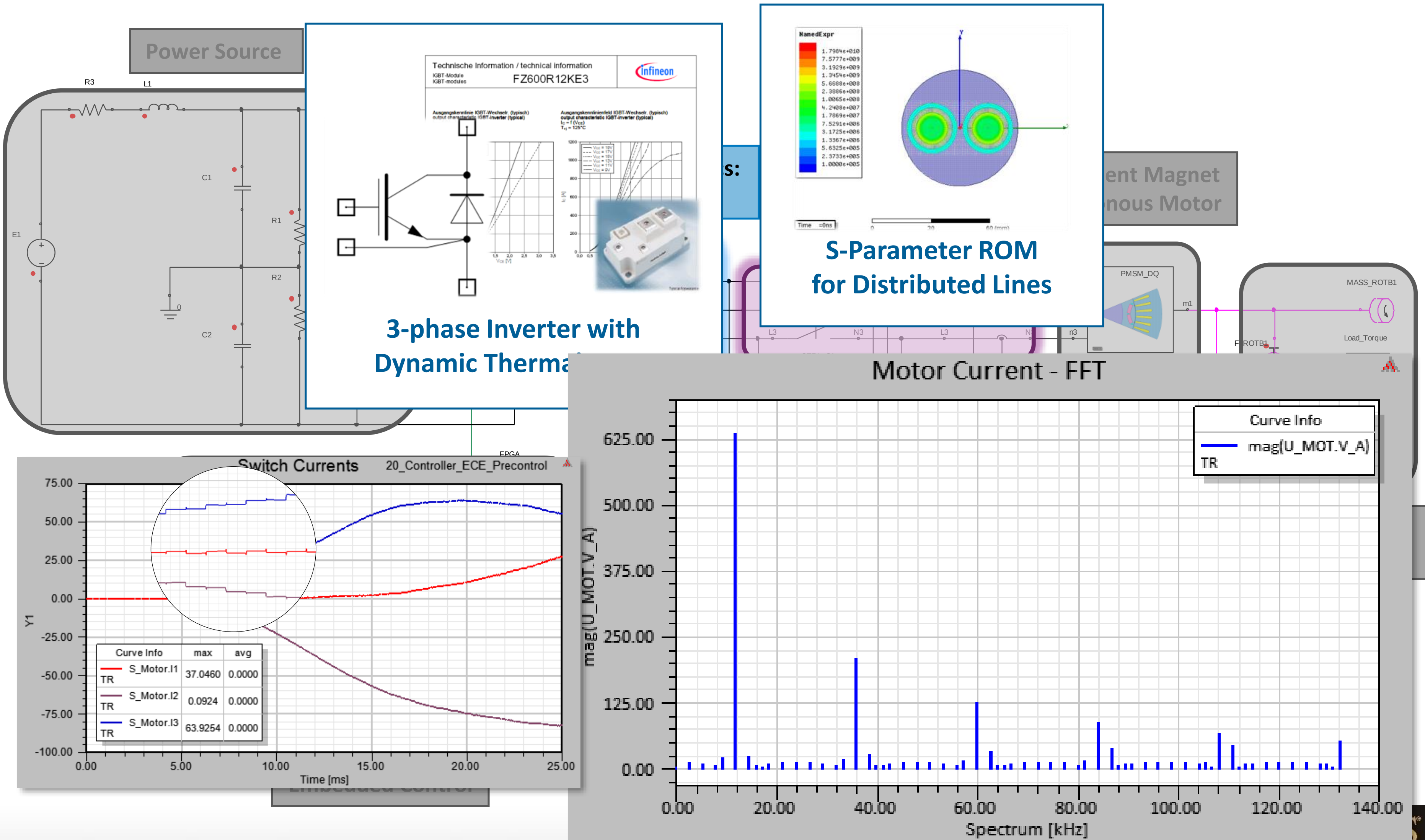
Assembling & Analyzing the System

Goal: Characterize Motor Losses



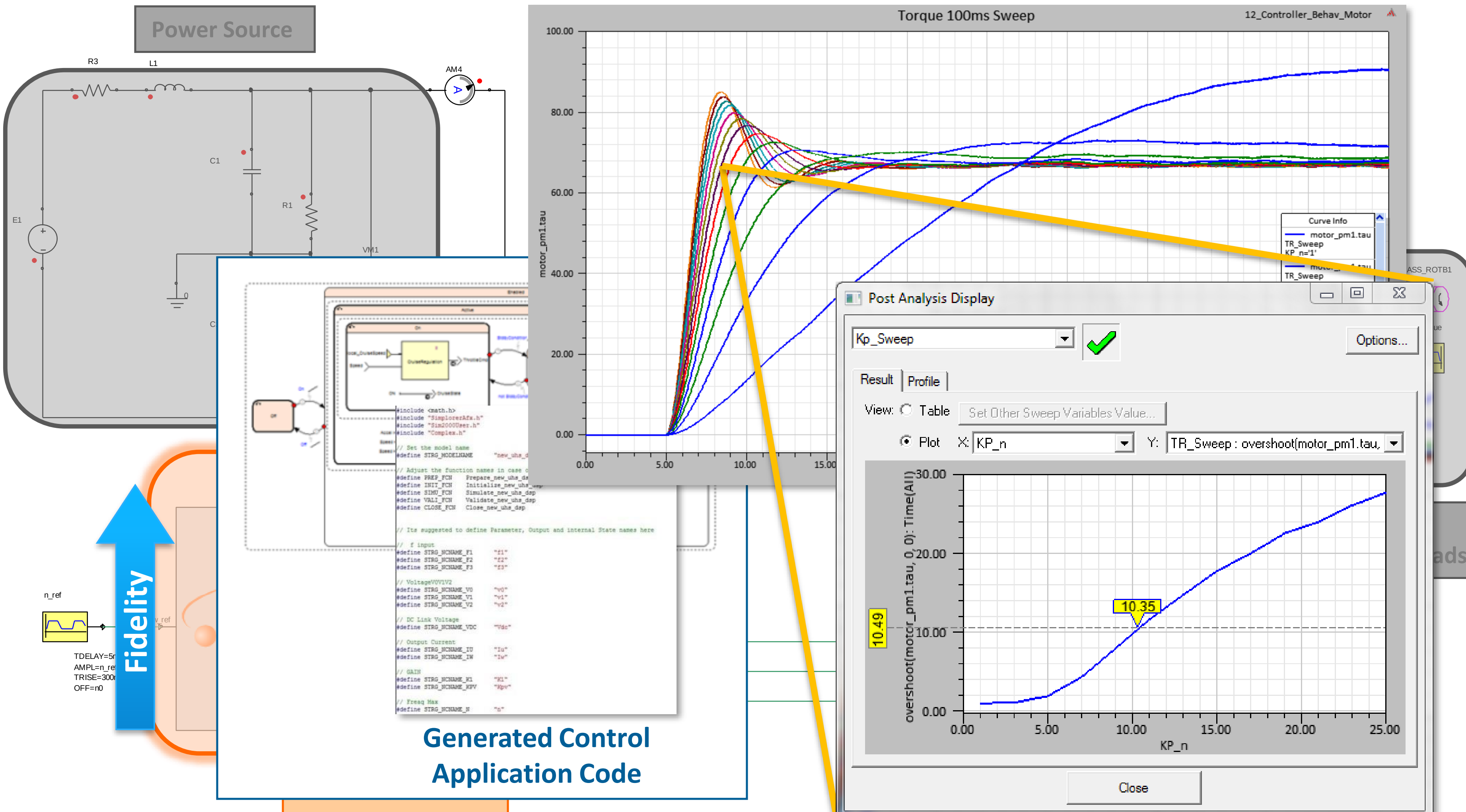
Assembling & Analyzing the System

Goal: EMC Prediction



Assembling & Analyzing the System

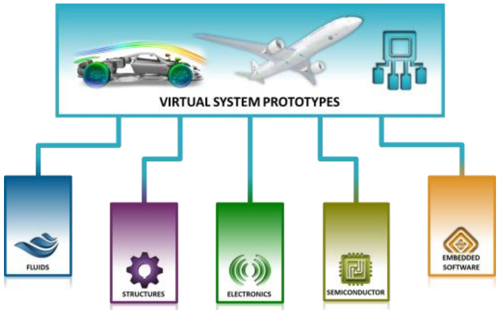
Goal: MiL, SiL Testing / Calibration & Tuning

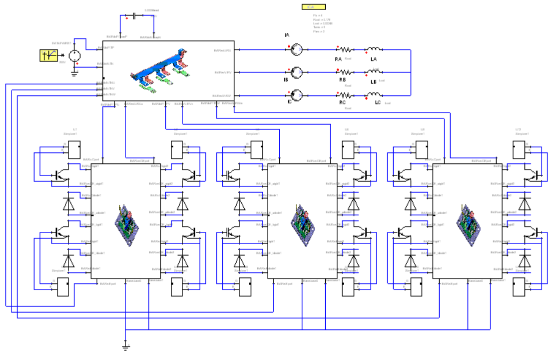


Simplorer: Physical System Modeling & Simulation

A Platform for Virtual System Prototyping

Model, simulate, and analyze complex, software-controlled, multi-domain systems





Pedigree in Electrified Systems

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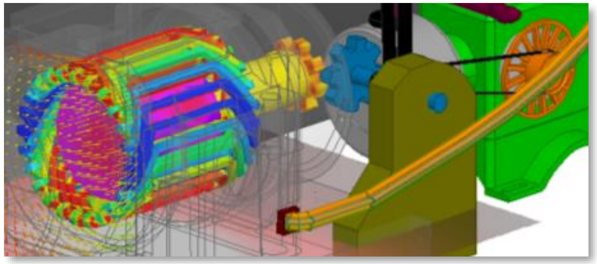
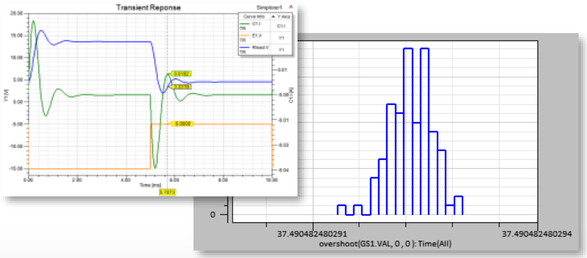
3D Precision When You Need It

Reduced-Order Modeling (ROM) and Co-simulation with 3D solvers captures detailed physics when precise system verification is required





Comprehensive Simulation-Based Testing

Verify and optimize system performance throughout the design process with robust, high-perfoming solvers and powerful post-processing

ANSYS

ANSYS®

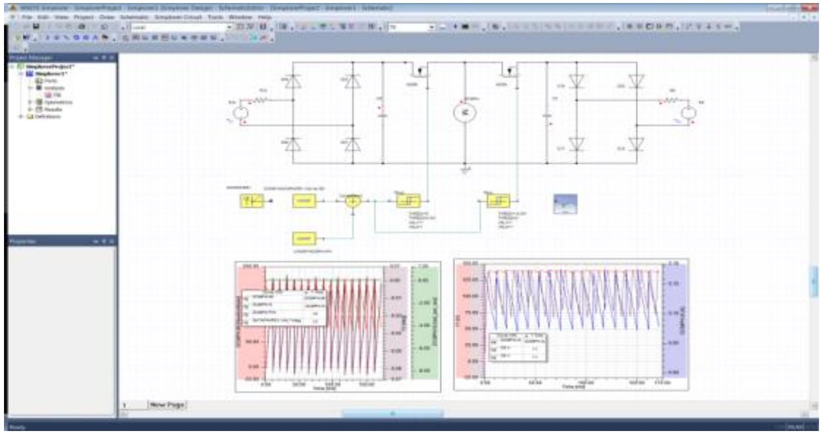
Multiphysics Use cases in Simplorer

- Flexible body dynamics: Landing gear
- Environmental Control System
- Electromechanical Flight Controls
- Modeling of a water pumping system using Modelica
- Complete Electro-Hydraulic Actuator modeling
- Electrical analysis of HVDC bus for power converter

Use case 1: Multi-body dynamics

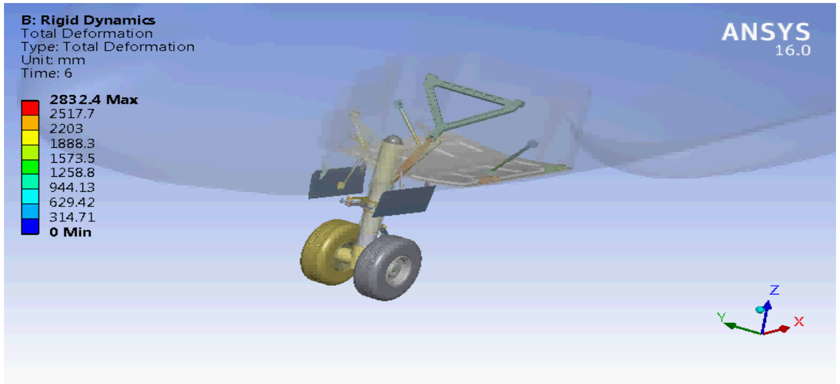
System-Level Objectives

- Integration of embedded software, 0D, 1D, 2D and 3D multi-disciplinary simulation components into a system representation
- Rapid generation of certified embedded code
- **Peak load determination during dynamic events**



Key System-Level Models

- ***ANSYS Mechanical RBD***: multibody dynamics
- ***ANSYS SCADE***: control software - Auto generation of certified code (DO 178B&C, ARINC 661)
- ***ANSYS Simplorer***: External conditions, mission profiles



CRANE AEROSPACE & ELECTRONICS

ANSYS

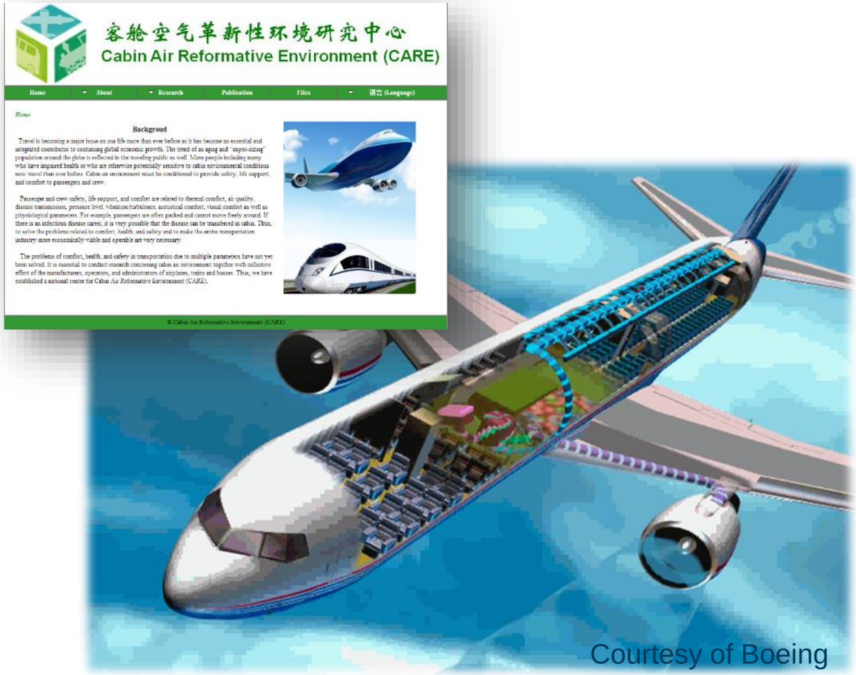
Use case 2: Aircraft Environmental Control

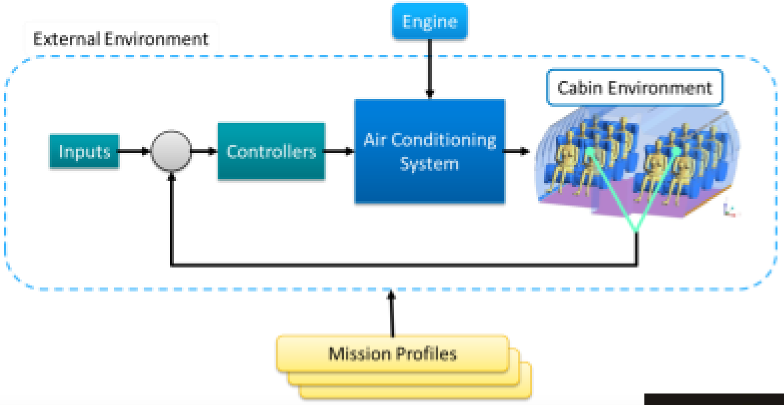
System-Level Objectives

- **Optimize component selection, sensor placement, and control strategies to improve fuel efficiency (lower emissions)**
- Tune & optimize controller parameters to improve passenger comfort across a range of mission profiles and conditions

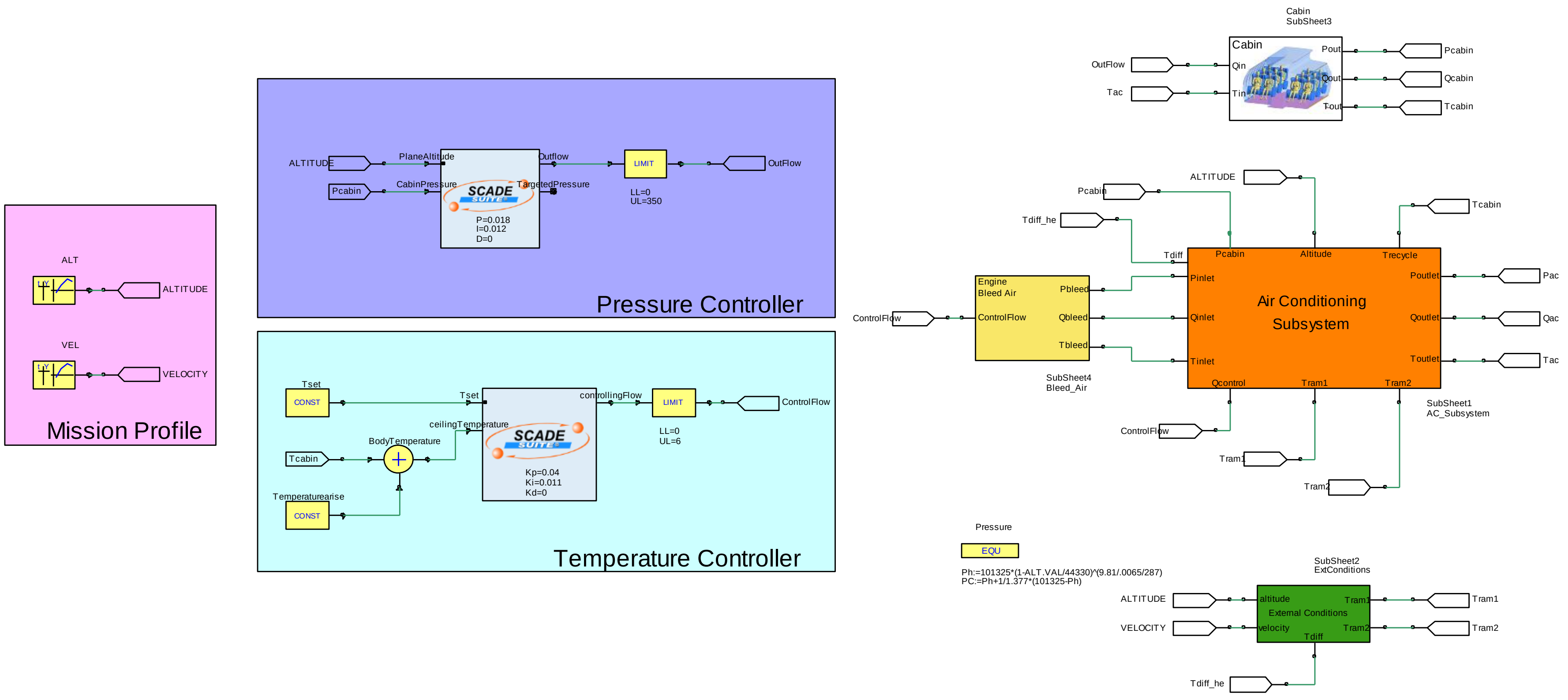
Key System-Level Models

- ***ANSYS Fluent***: Detailed cabin airflow model
- ***ANSYS SCADE***: Cabin pressure / temperature control software
- ***ANSYS Simplorer***: External conditions, mission profiles
  - ***Modelica in Simplorer***: A/C system components (actuators, sensors, etc.)





ECS System Model
With ANSYS Simplorer

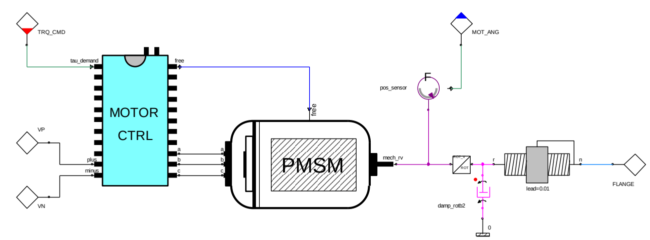


Use case 3: Electromechanical Flight Controls

Mechanics + Electronics + Embedded Control operating in a Fluids environment !

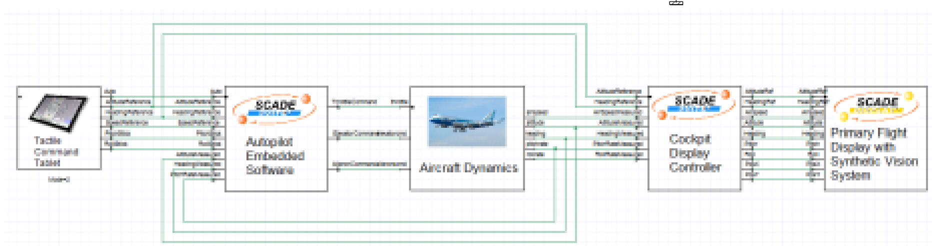
System-Level Objectives

- Verify control strategies and calibrate control parameters
- **Optimize performance and robustness to external disturbances**
- **Assess system reliability (worst-case analysis, fault injection)**



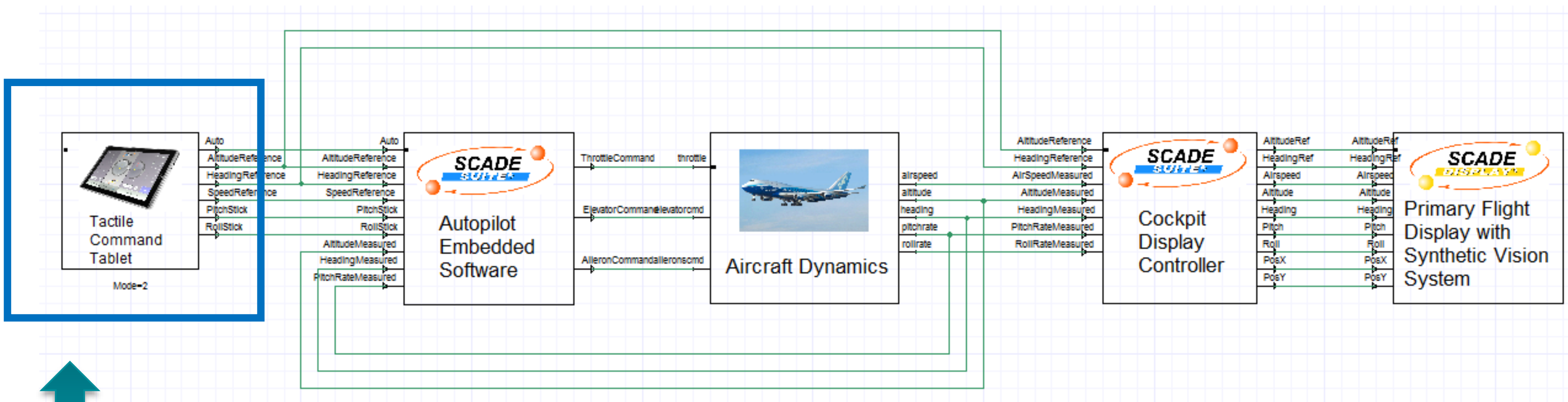
Key System-Level Models

- ***ANSYS Maxwell***: Permanent magnet synchronous machine extracted as ROM
- ***ANSYS SCADE***: Autopilot control software, cockpit display
- ***ANSYS Simplorer***: Power electronics, behavioral multi-domain sensors, mechanical assemblies



Multi-Disciplinary Modeling

Coupling Software, Systems and Physics



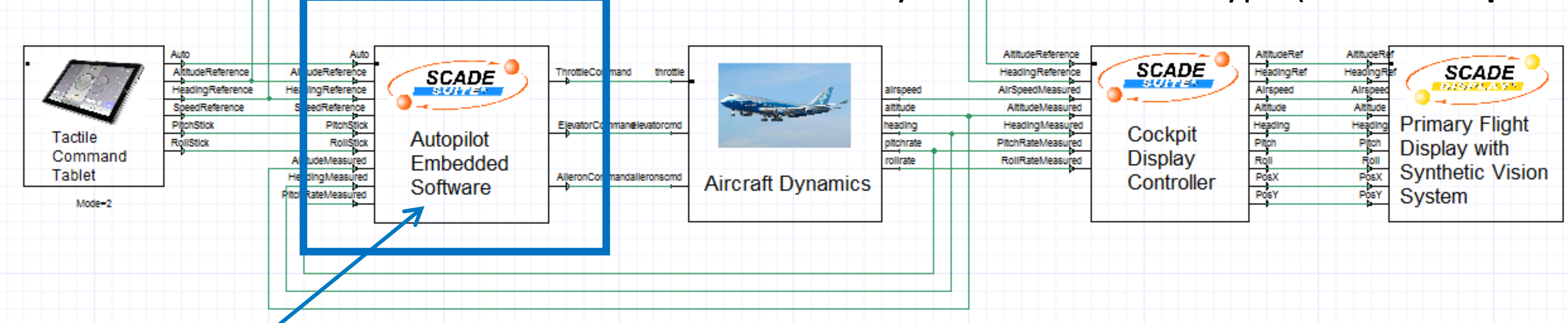
System Simulation Dashboard

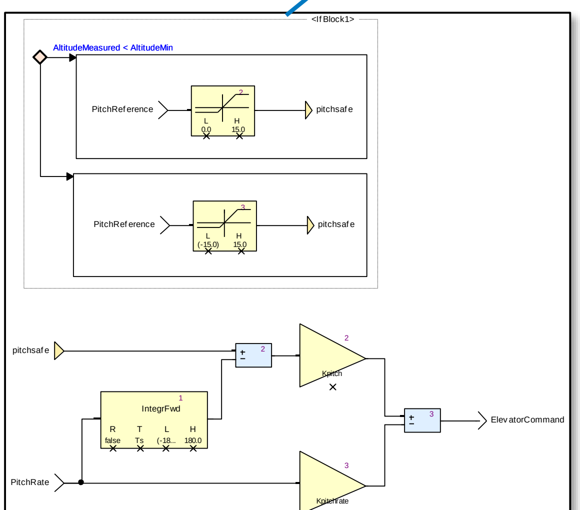
- Option#1: **Pre-defined Simulation Scenarios**
  Sinusoidal/rectangular inputs for target speed, altitude, heading
- Option#2: **Tactile Tablet to Fly the Aircraft**
  Graphical interactive dashboard (for live simulation)
- **SCADE LifeCycle Rapid Prototyper**

Multi-Disciplinary Modeling

Coupling Software, Systems and Physics

Aircraft System Virtual Prototype (**ANSYS Simplorer**)





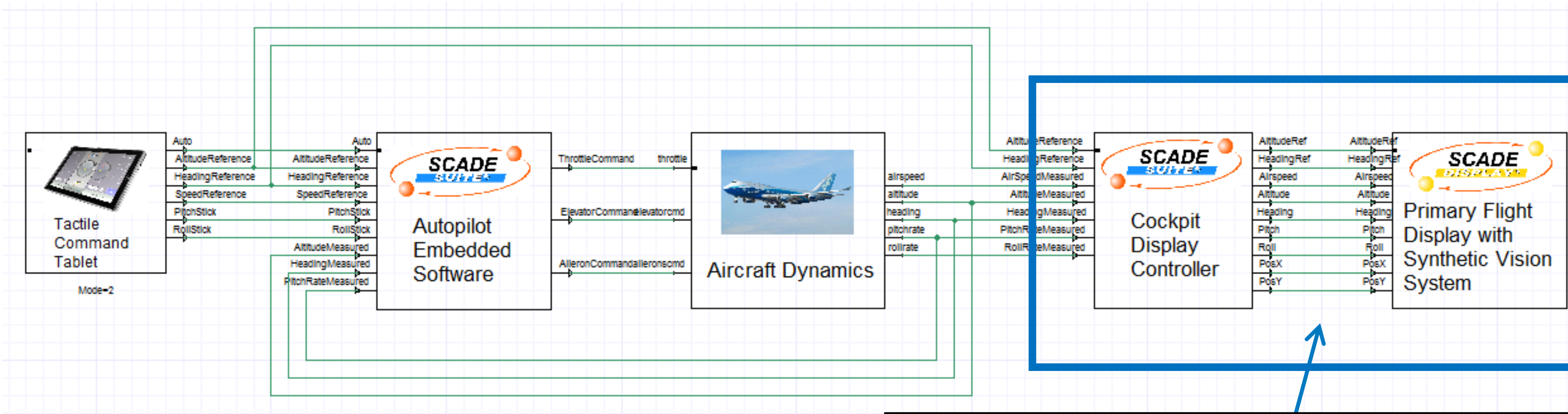
Embedded Flight Control / Autopilot Software

SCADE Suite

- Model-Based Control Software Design
- Simplorer Coupling via Functional Mockup Interface (FMI)
- Automatic Embedded C & Ada Code Generation
- DO-178B&C Level A Certification

Multi-Disciplinary Modeling

Coupling Software, Systems and Physics



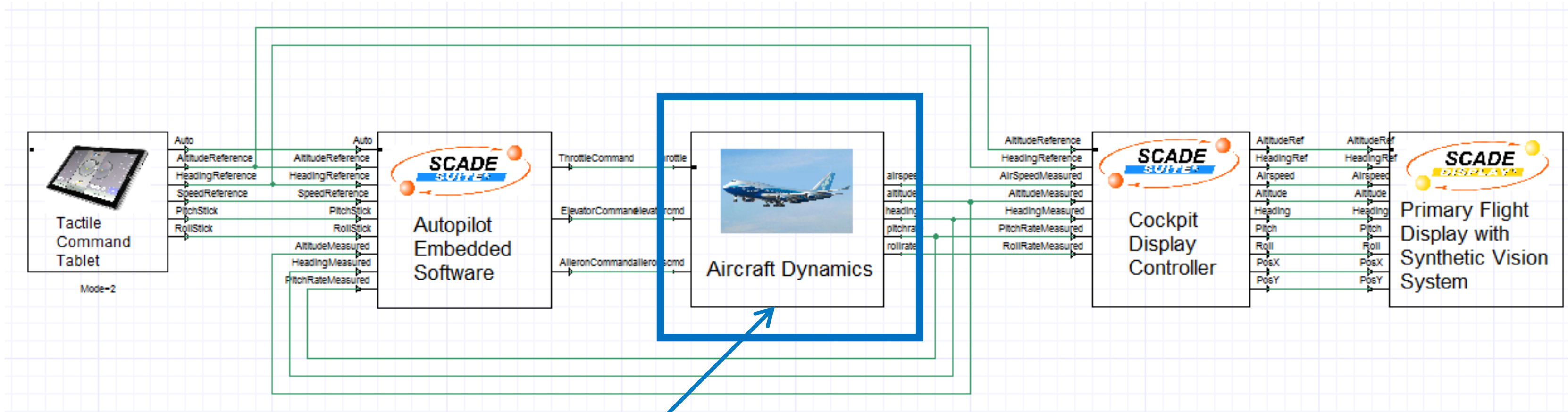
Embedded Cockpit Display Software

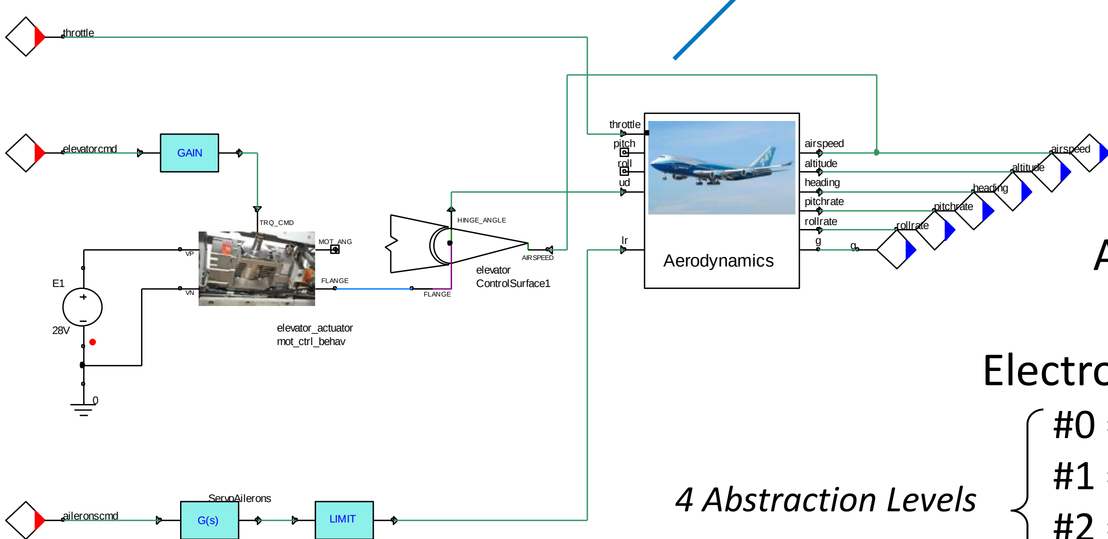
SCADE Suite/Display + Synthetic Vision System

- Model-Based HMI Software Design
- Simplorer Coupling via FMI
- Automatic Embedded C Code Generation
- Compliance with OpenGL SC and ES2
- DO-178B&C Level A Certification

Multi-Disciplinary Modeling

Coupling Software, Systems and Physics





Aircraft Dynamics

ANSYS Simplorer

Aircraft Aerodynamics (VHDL-AMS)

\+

Electromechanical Actuation for Elevator

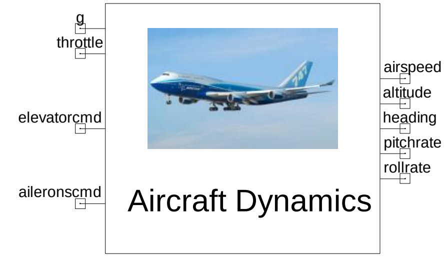
4 Abstraction Levels

- #0 = Ideal Actuator Dynamics
- #1 = Behavioral Actuator Dynamics
- #2 = ROM from 2D Analytical Model
- #3 = ROM from 2D Finite Element Model

Modeling Aircraft Dynamics

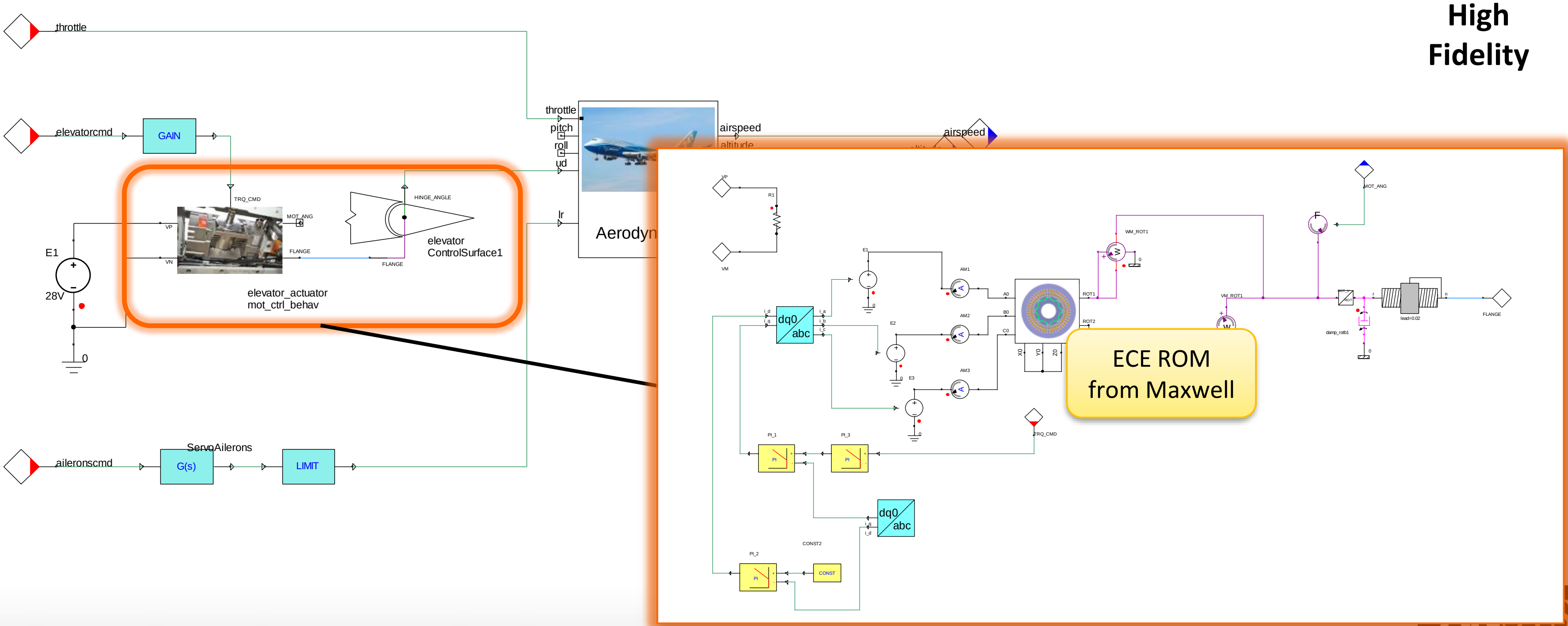
Level #3: ECE ROM

Next: CFD ROM



- **Latitudinal / longitudinal aerodynamics implemented using VHDL-AMS**
- **Fidelity of elevator dynamics enhanced with analytical ROM from ANSYS Maxwell**

Very High Fidelity



  December 12, 2017

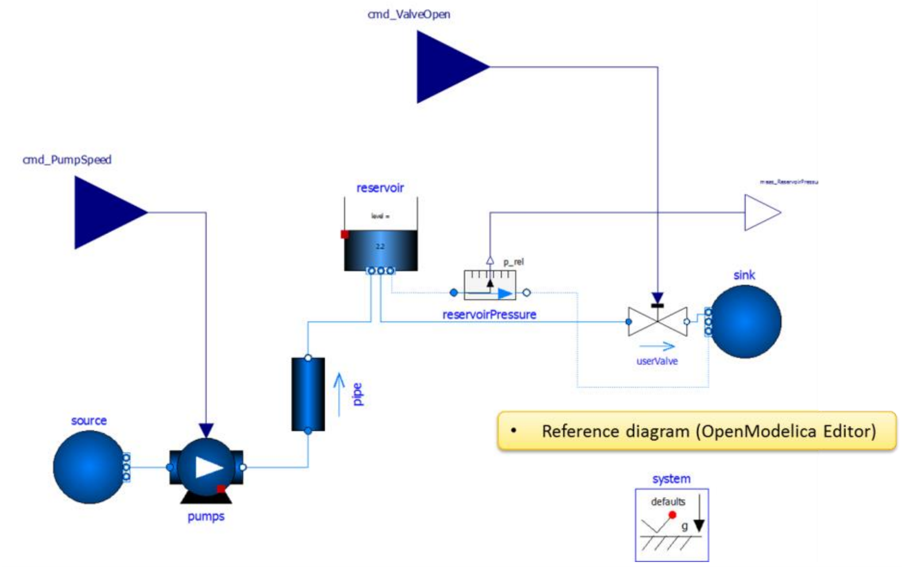
Use case 4: Water pumping system

System-Level Objectives

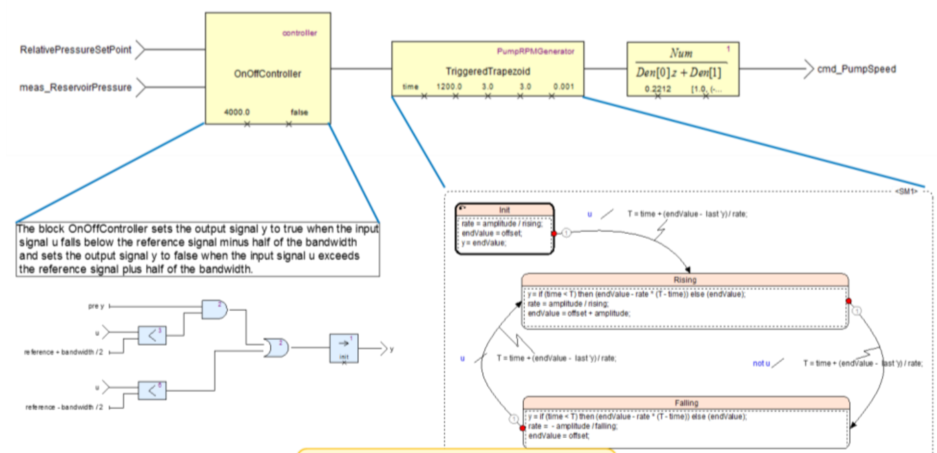
- Integration of embedded software, with complete hydro-mechanical subsystem for system behavioral modeling
- Rapid generation of certified embedded code
- **Tank pressure control monitoring during process**

Key System-Level Models

- ***ANSYS SCADE***: control software - Auto generation of certified code (DO 178B&C, ARINC 661), interactive control & monitoring panel
- ***ANSYS Simplorer***: External conditions, mission profiles
  - ***Modelica in Simplorer***: Pumping plant system (hydraulics network, pump, valves, etc.)

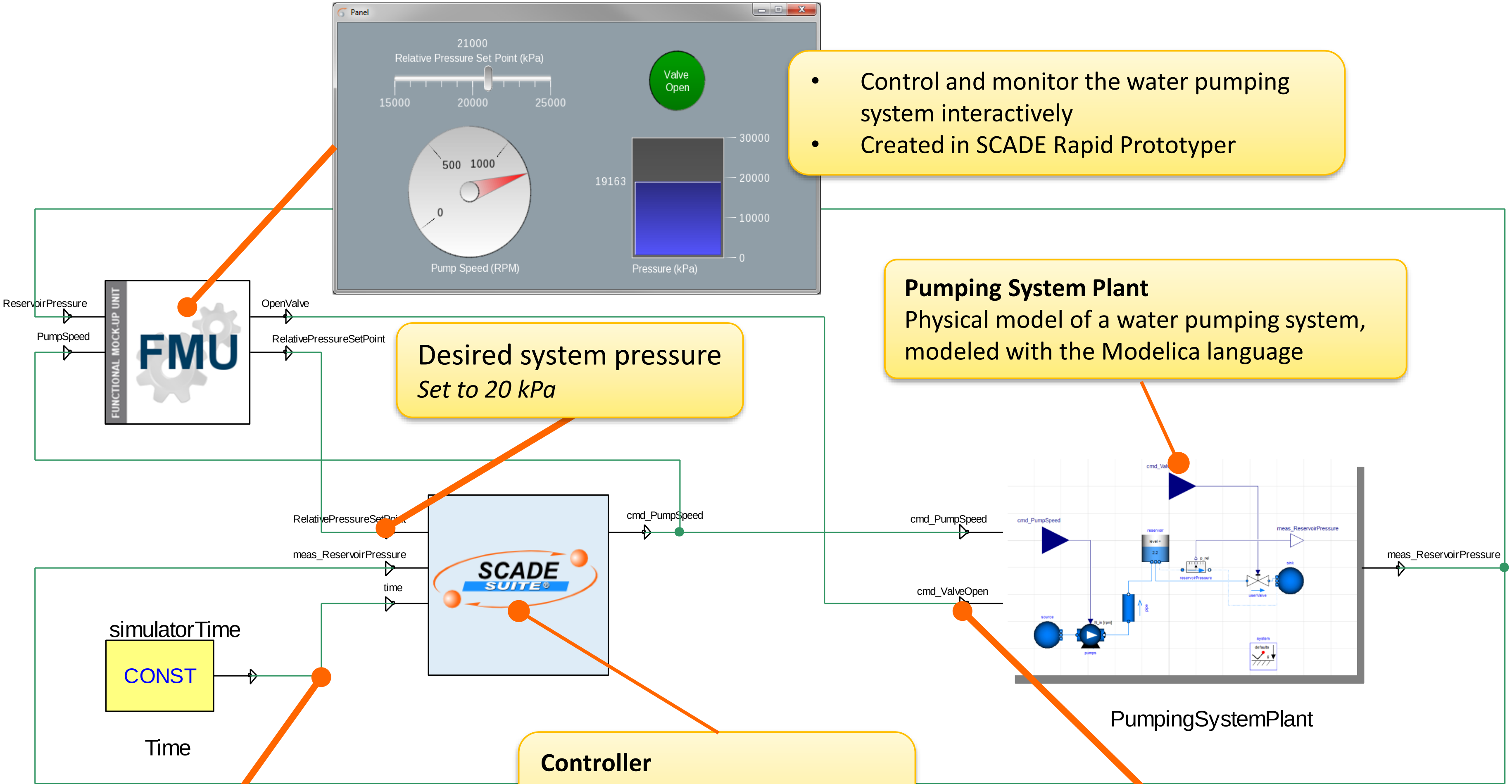


- Reference diagram (OpenModelica Editor)



- Implemented in ANSYS SCADE Suite
- Imported into Simplorer as FMU

Water pumping system



- Control and monitor the water pumping system interactively
- Created in SCADE Rapid Prototyper

Pumping System Plant
Physical model of a water pumping system, modeled with the Modelica language

Desired system pressure
Set to 20 kPa

Controller
Embedded Software Controller created in ANSYS SCADE Suite

Simulator time
For scheduling controller execution

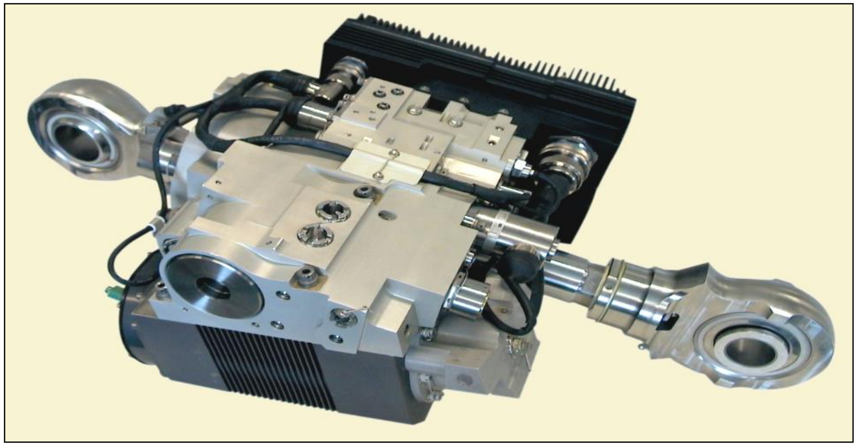
Tank drain valve switch
Opens at 200 seconds

Use case 5: Electro-Hydraulic Actuator modeling

System-Level Objectives

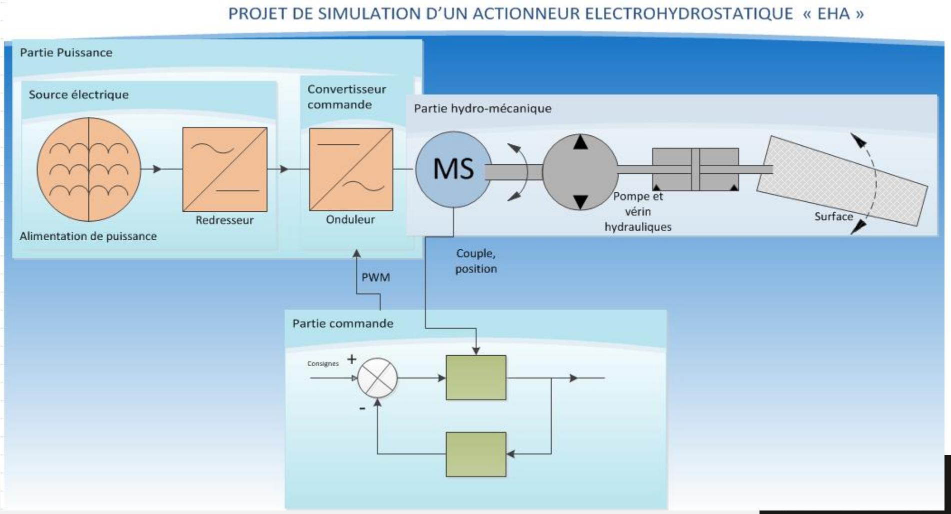
- **Analysis and predictive global thermal performance**
- **Analysis and potential weakness detection early in the design process**
- **Customer requirement of product optimization : Multiphysics simulation is mandatory**

UTC Aerospace Systems

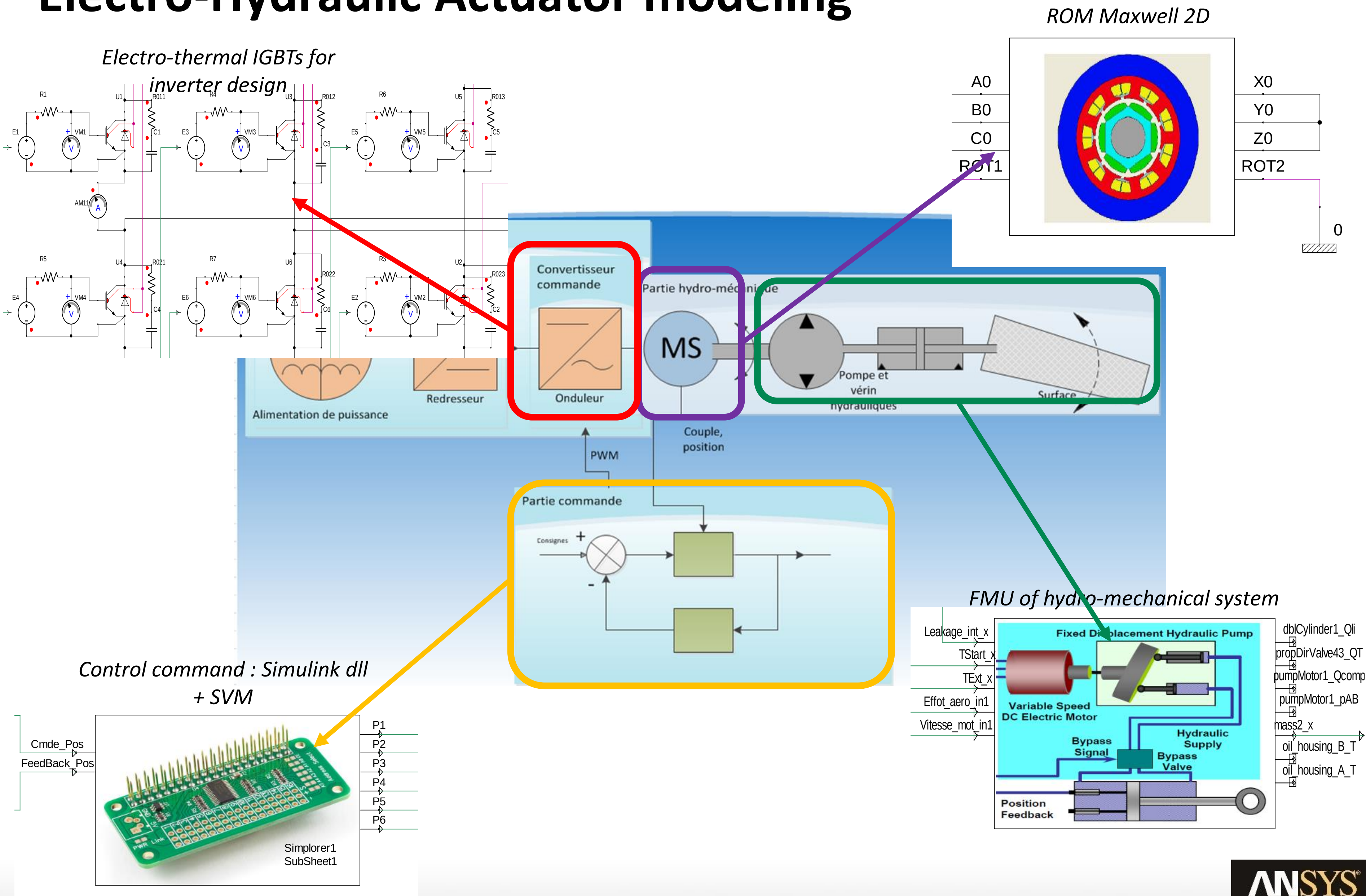


Key System-Level Models

- ***ANSYS Simplorer***: Power Electronics design, multi-domain system integration
- ***ANSYS Maxwell***: Analysis of performance and design of electrical machine
- ***ANSYS Icepak***: Thermal modeling of housing and electronics cooling system
- ***ANSYS DX***: Surrogate model (response surface) of EM losses depending on (Imax, w, angle)
- ***3rd party tool***: Hydro-mechanical circuit and control command

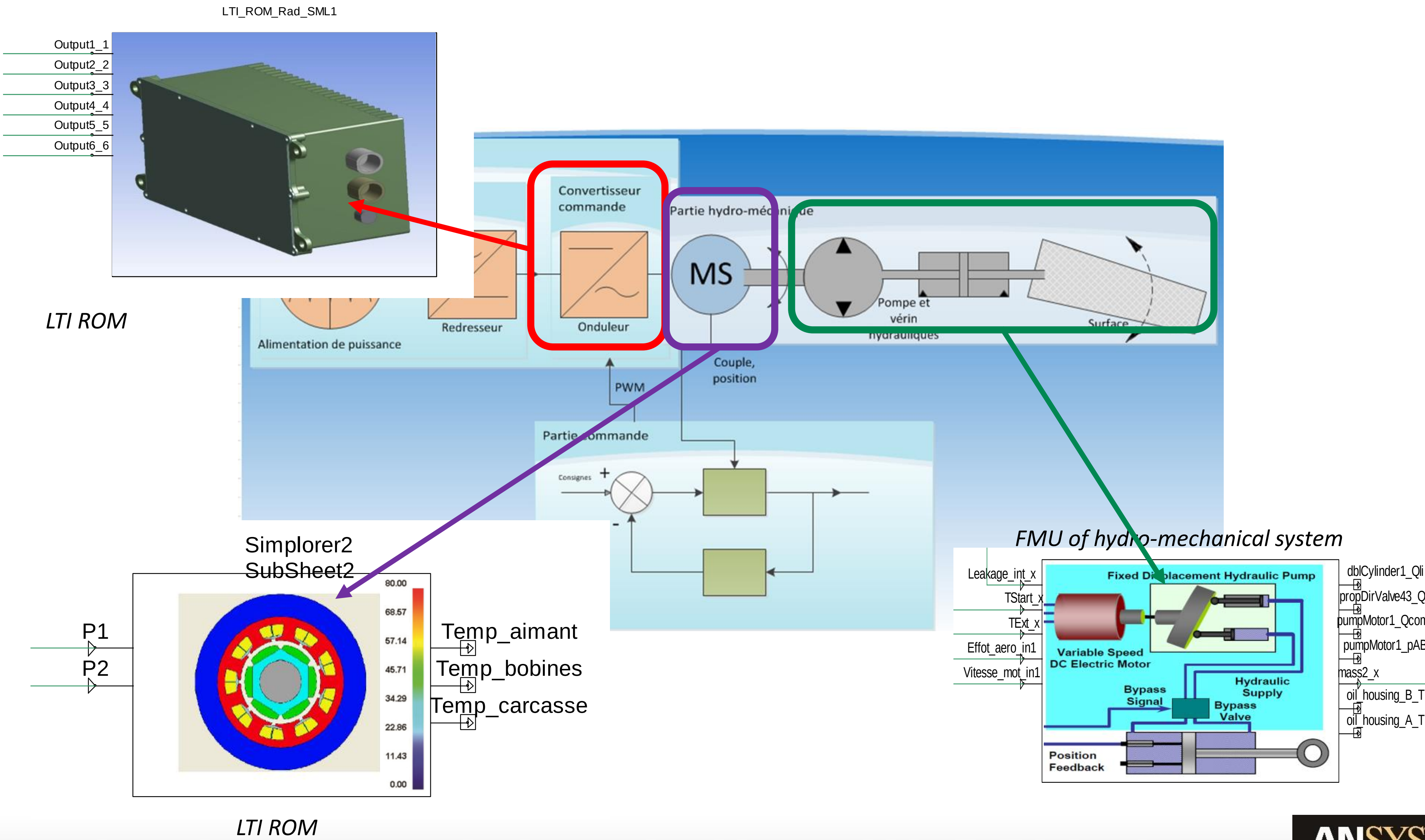


Electro-Hydraulic Actuator modeling

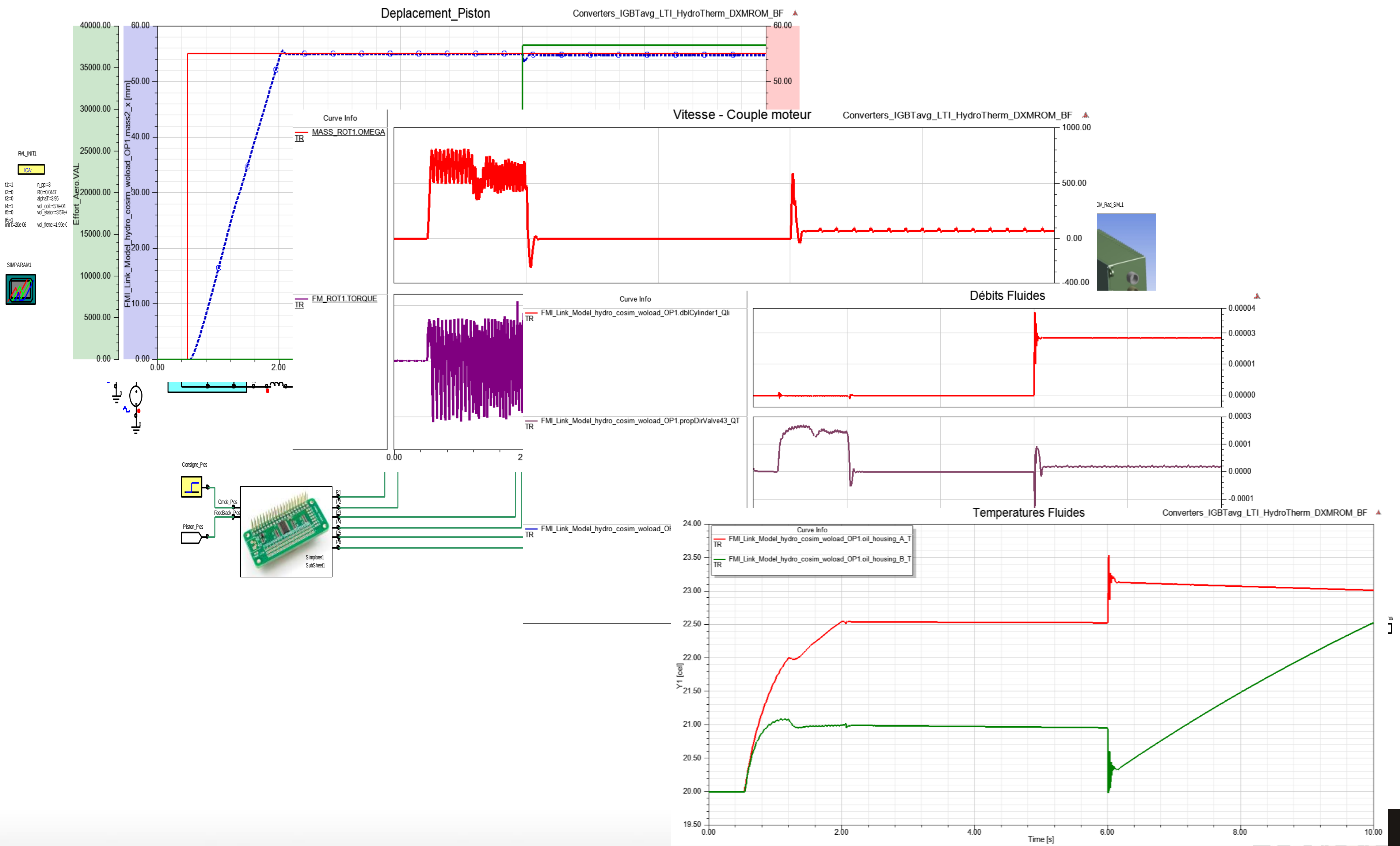


Electro-Hydraulic Actuator modeling

Thermal consideration



Electro-Hydraulic Actuator modeling



Use case 6: Electrical analysis of HVDC bus stability

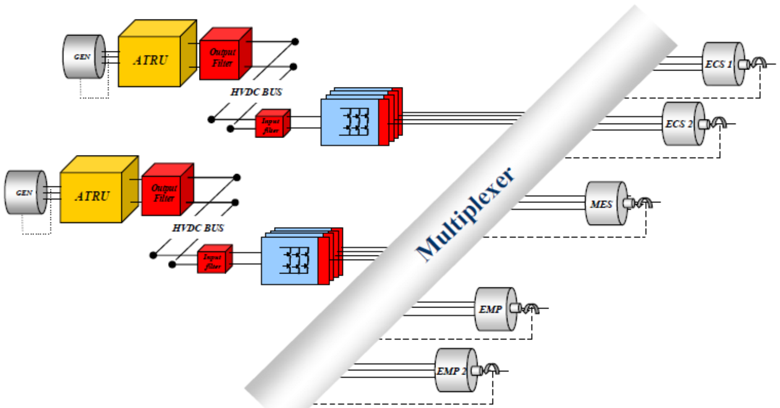
System-Level Objectives

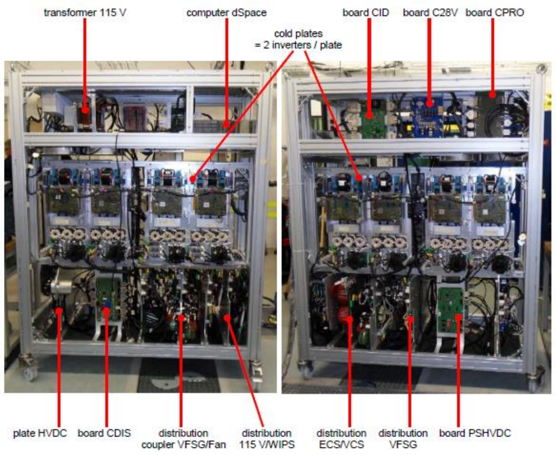
- Weight and volume reduction of the overall electrical system
- Architecture, system topologies studies, including redundancy, for creating modular and reconfigurable designs.
- **Optimizing overall performance and power source stability**

Key System-Level Models

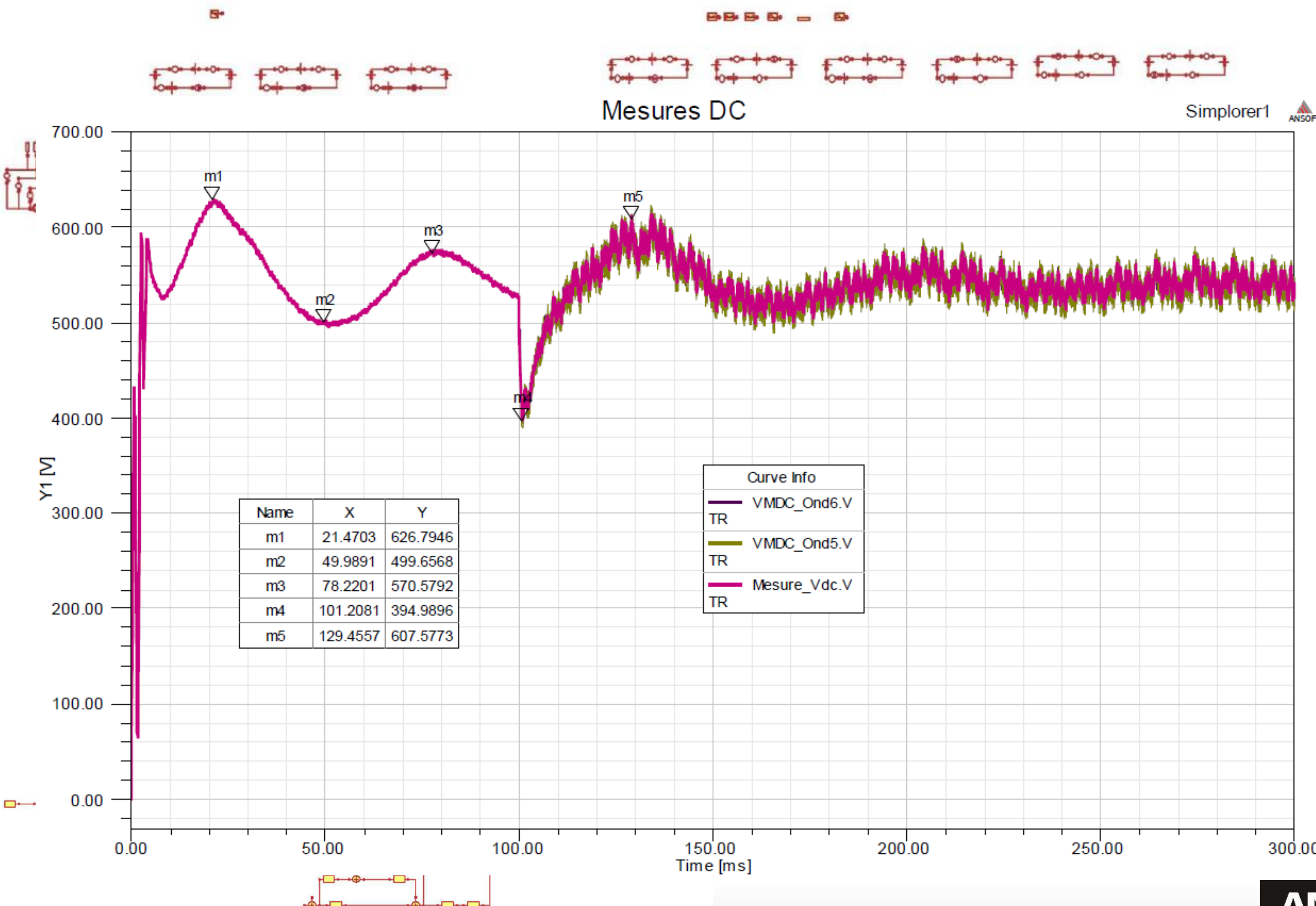
- ***ANSYS Simplorer***: Power electronics circuit, hierarchical models and subcircuit, vector control, tests of different configurations and operating points

THALES





Electrical analysis of HVDC bus stability



Name	X	Y
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m2	49.9891	499.6568
m3	78.2201	570.5792
m4	101.2081	394.9896
m5	129.4557	607.5773

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Q&A