

ANSYS®



仿真
新时代

2017 ANSYS用户技术大会

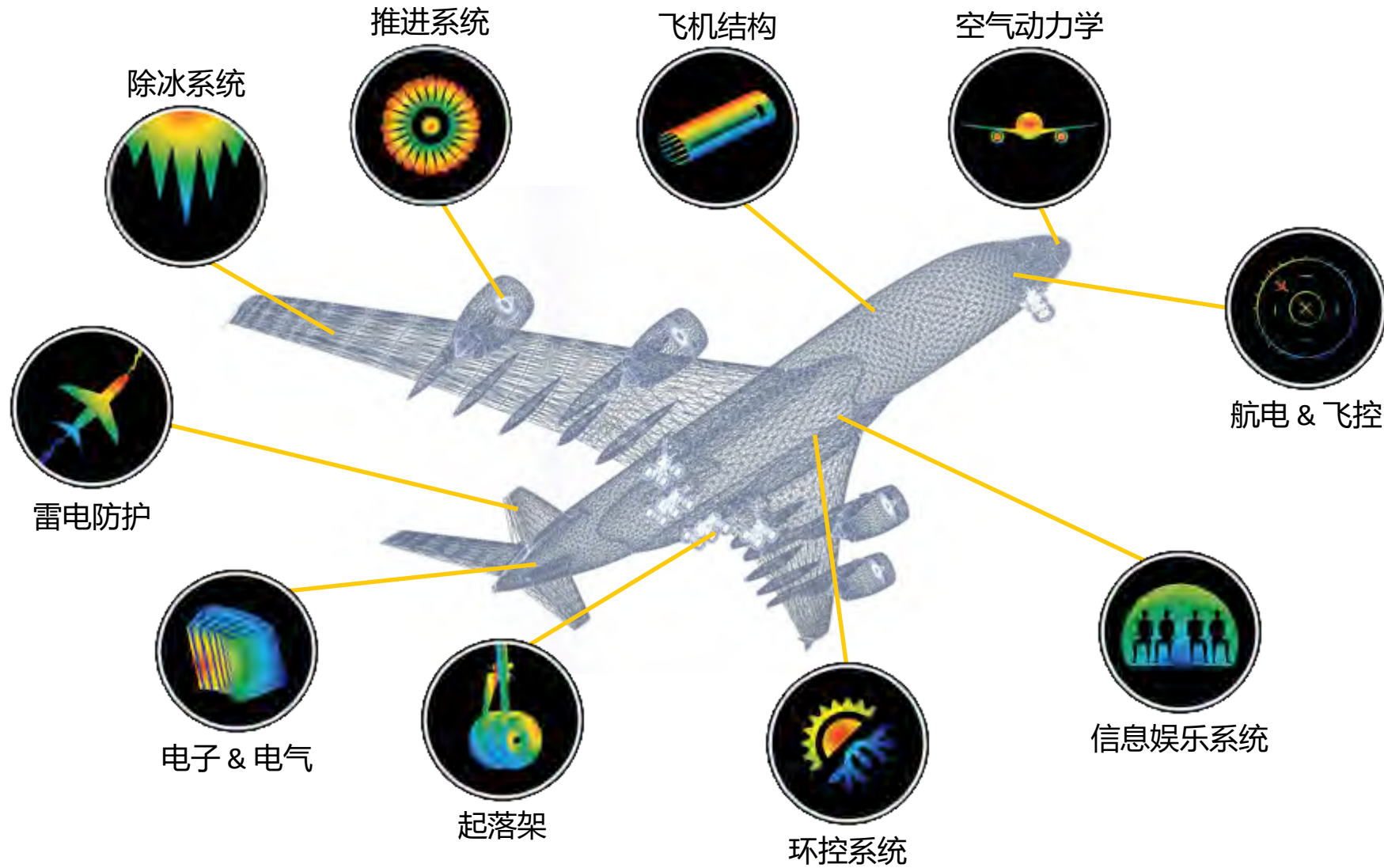
中国·烟台

航空航天中的系统仿真方法及应用实践

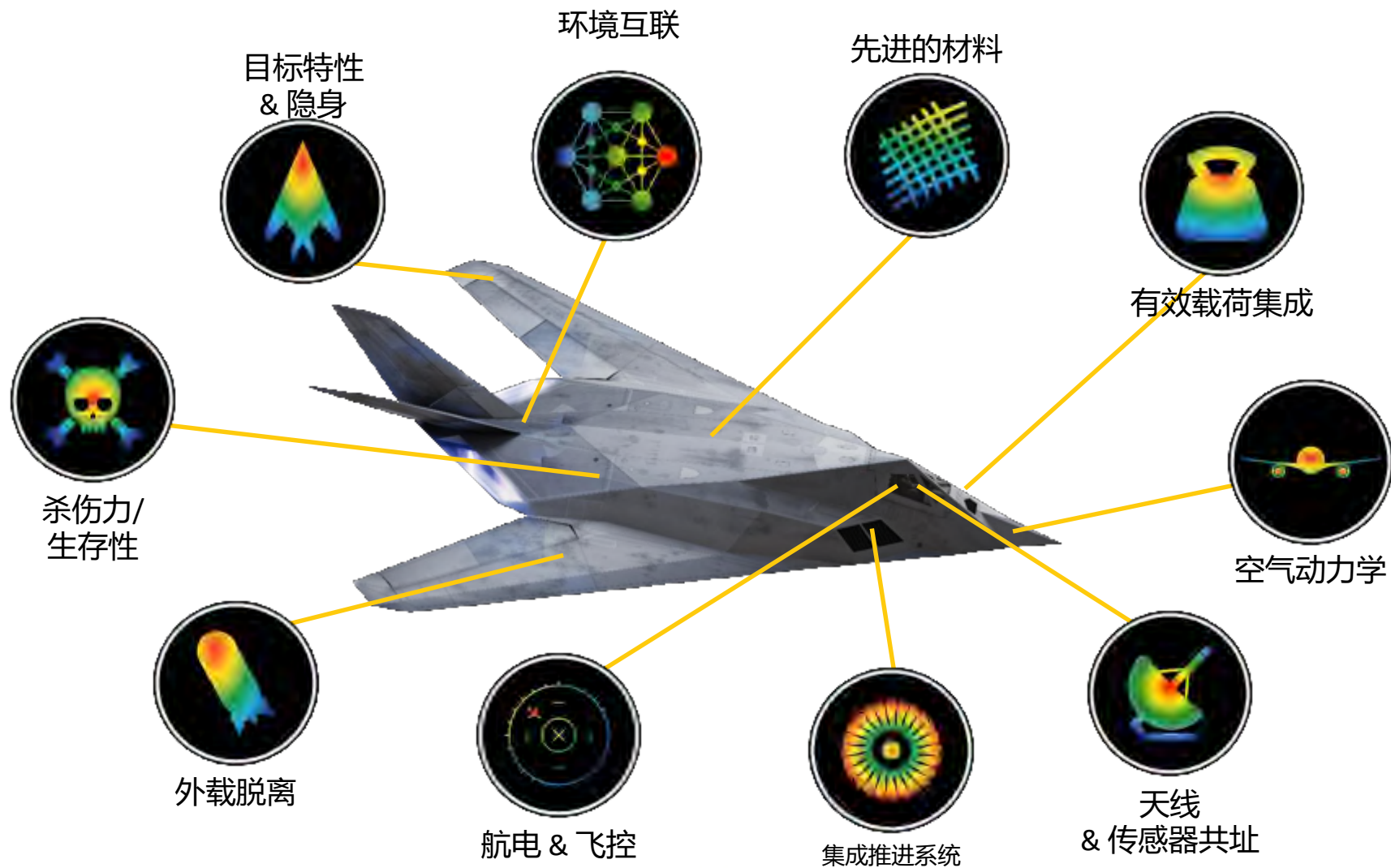
袁勇 博士

ANSYS北区技术经理

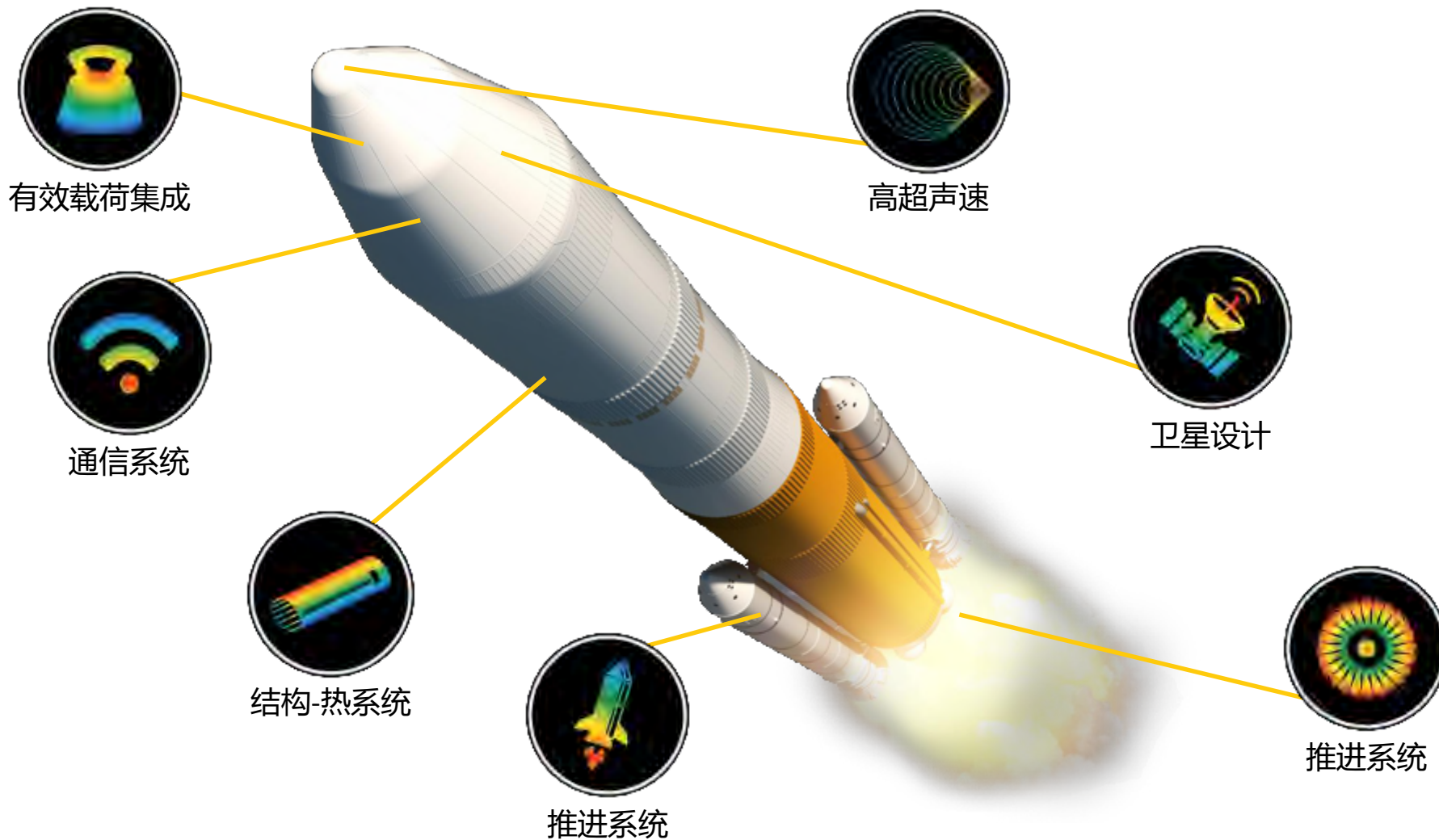
ANSYS 提供无缝集成的工具，全方位仿真复杂系统



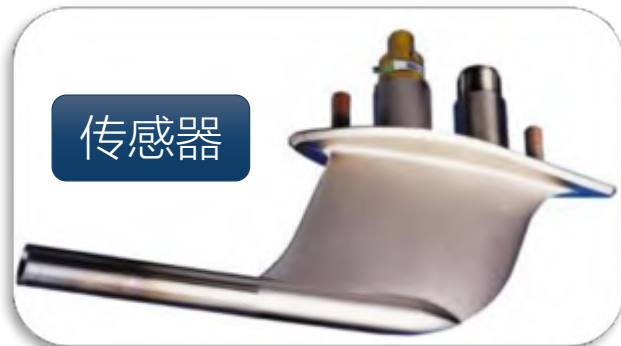
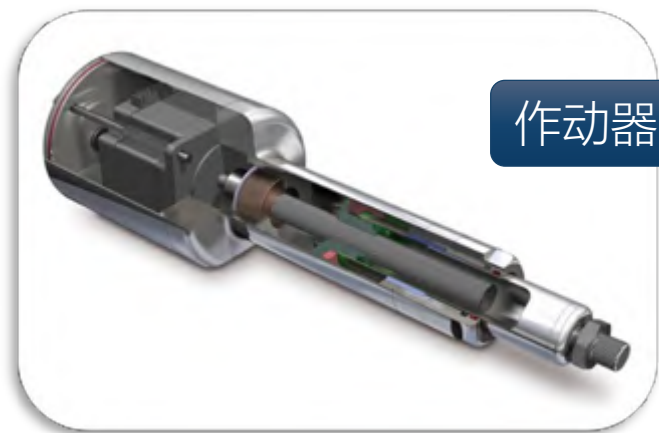
ANSYS 提供无缝集成的工具，全方位仿真复杂系统



ANSYS 提供无缝集成的工具，全方位仿真复杂系统



在设计师的眼里...



特定领域，以组件为中心

...成为最终系统的一部分



电子控制



安全性需求



作动器



嵌入式软件



运行剖面

传感器



运行条件

...存在复杂的相互作用



关键问题:

系统是如何运行的？

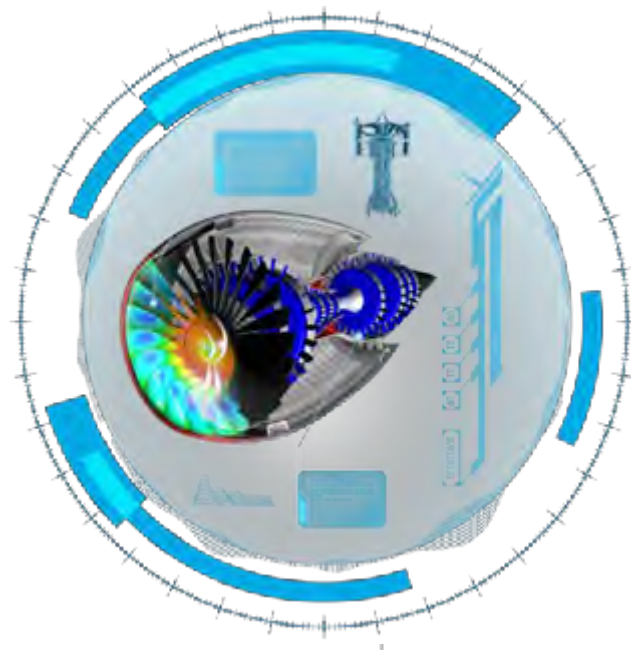


系统如何才能符合标准？

基于模型的工程（MBE）与数字延续性



**DIGITAL
EXPLORATION**

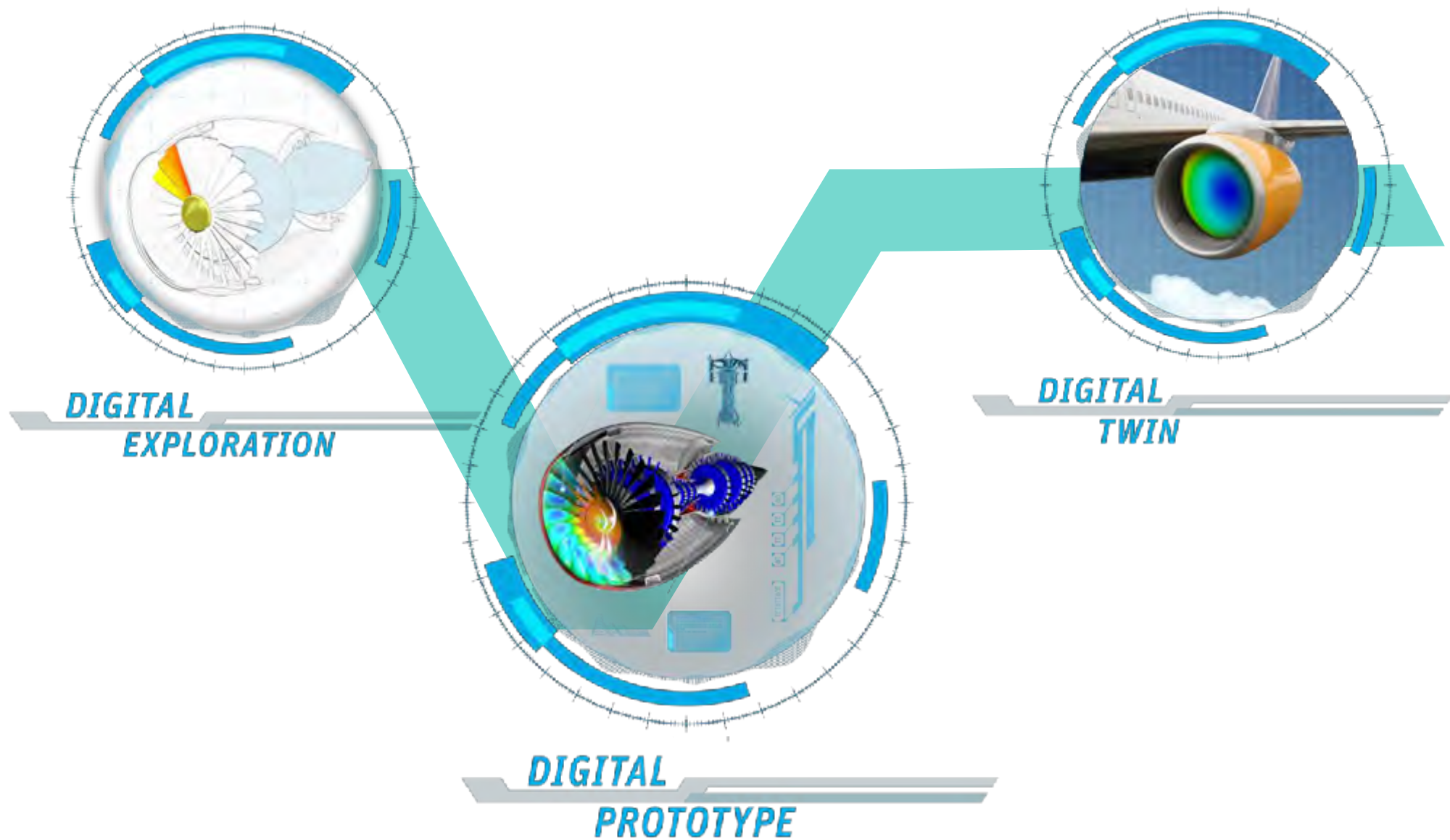


**DIGITAL
PROTOTYPE**

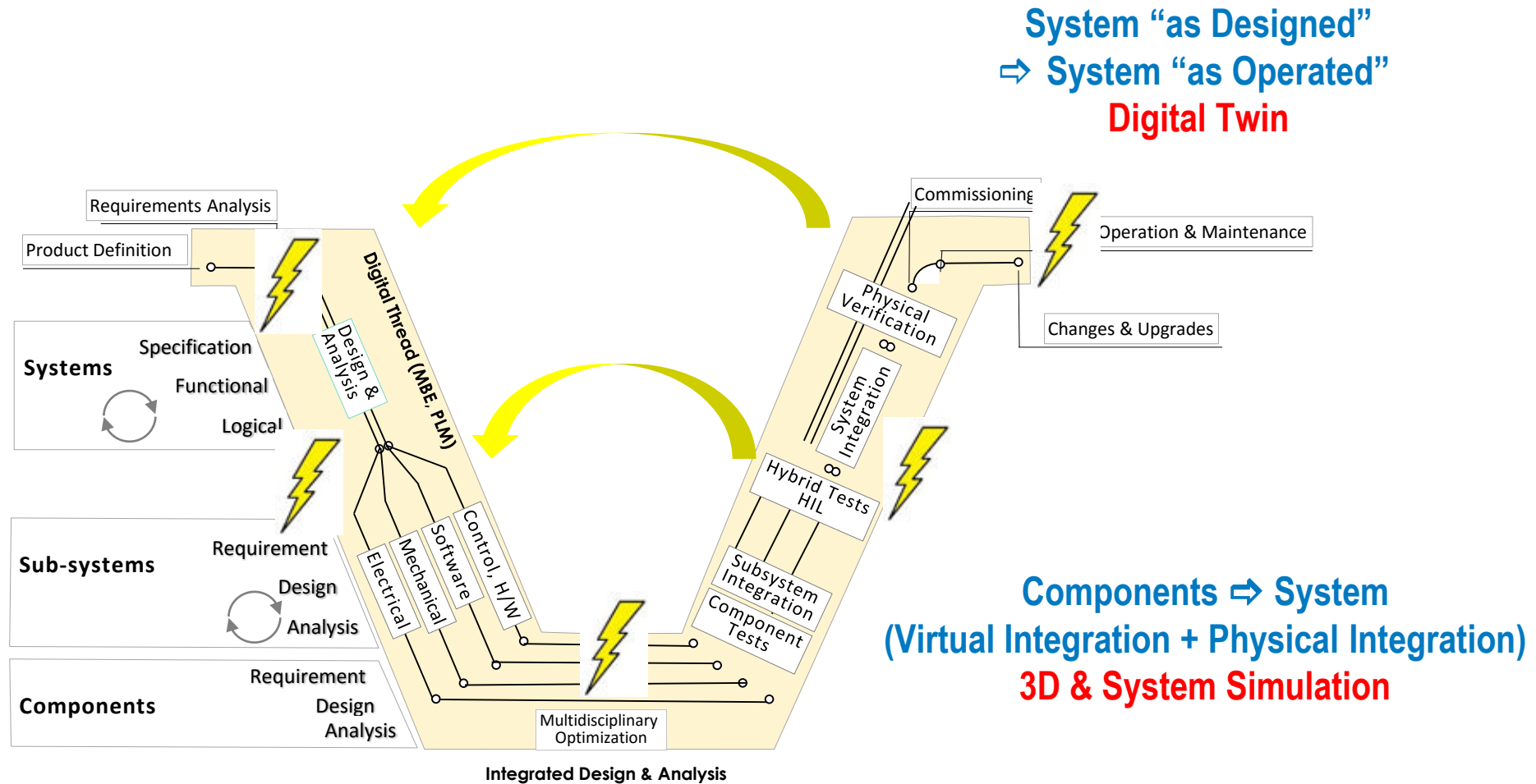


**DIGITAL
TWIN**

从系统 v 流程角度看..



但往往存在无法延续的状况...



Requirements => System => Components (3D, Software, E/E)
Model Based System & Software Engineering

系统开发中的挑战

管理设计复杂度

确保功能安全性

优化系统整体性能

减少软件开发成本

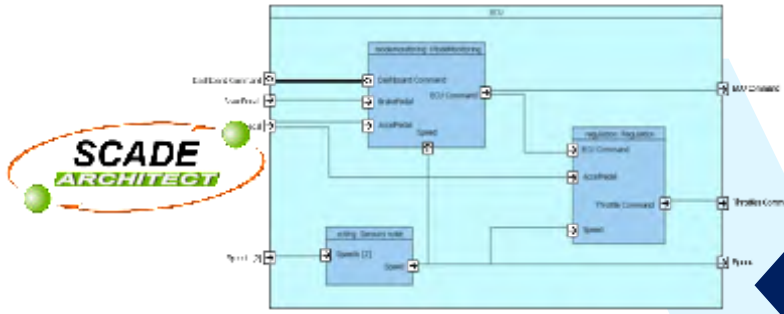
减少物理验证成本



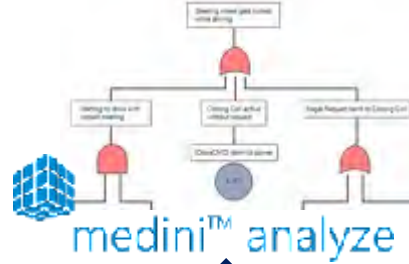
需求管理 & 产品线工程



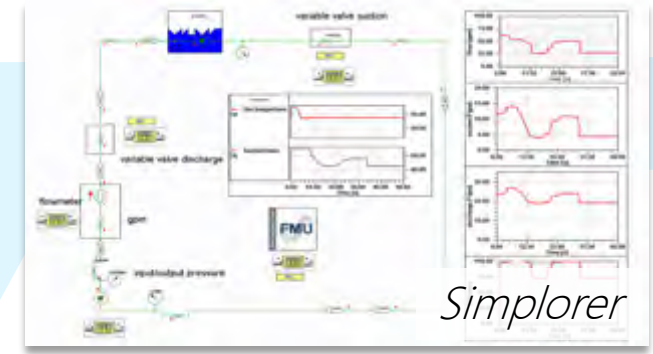
MBSE 基于模型的系统工程



系统安全性分析

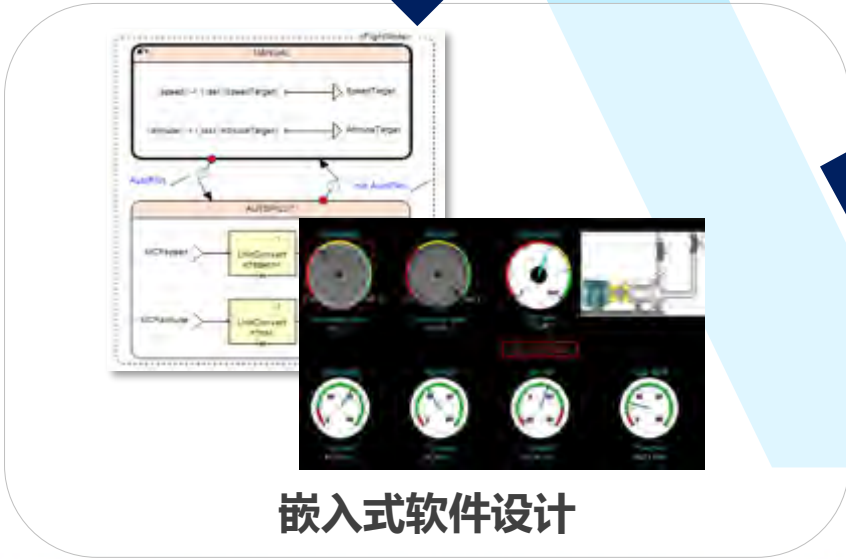


系统虚拟集成验证 & Digital Twins



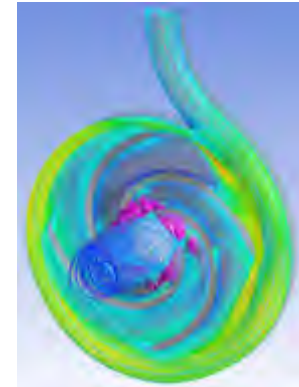
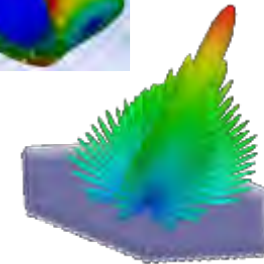
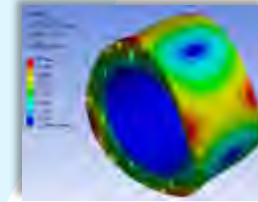
系统架构

系统/软件架构



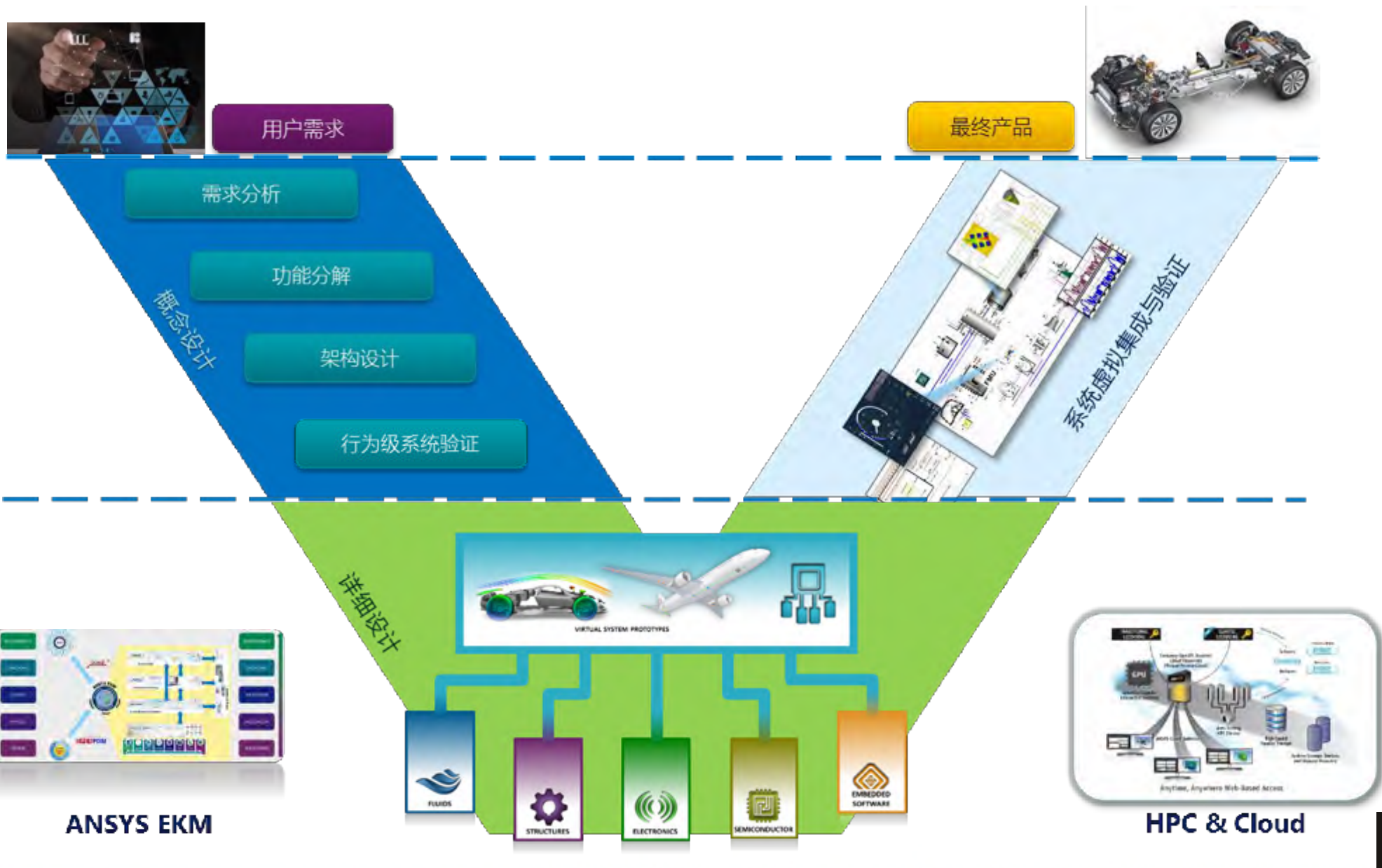
嵌入式软件设计

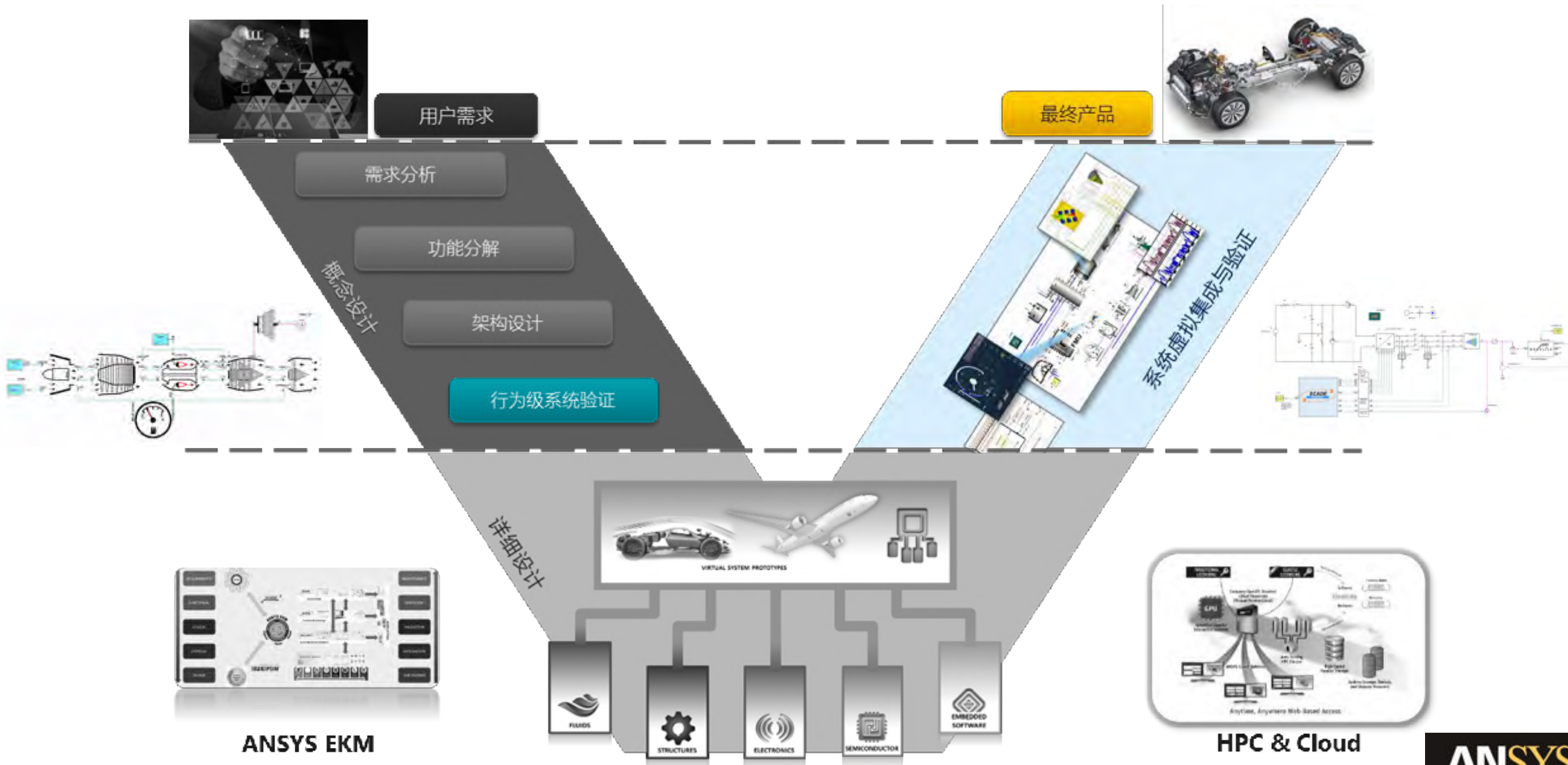
软件组件 (FMI)



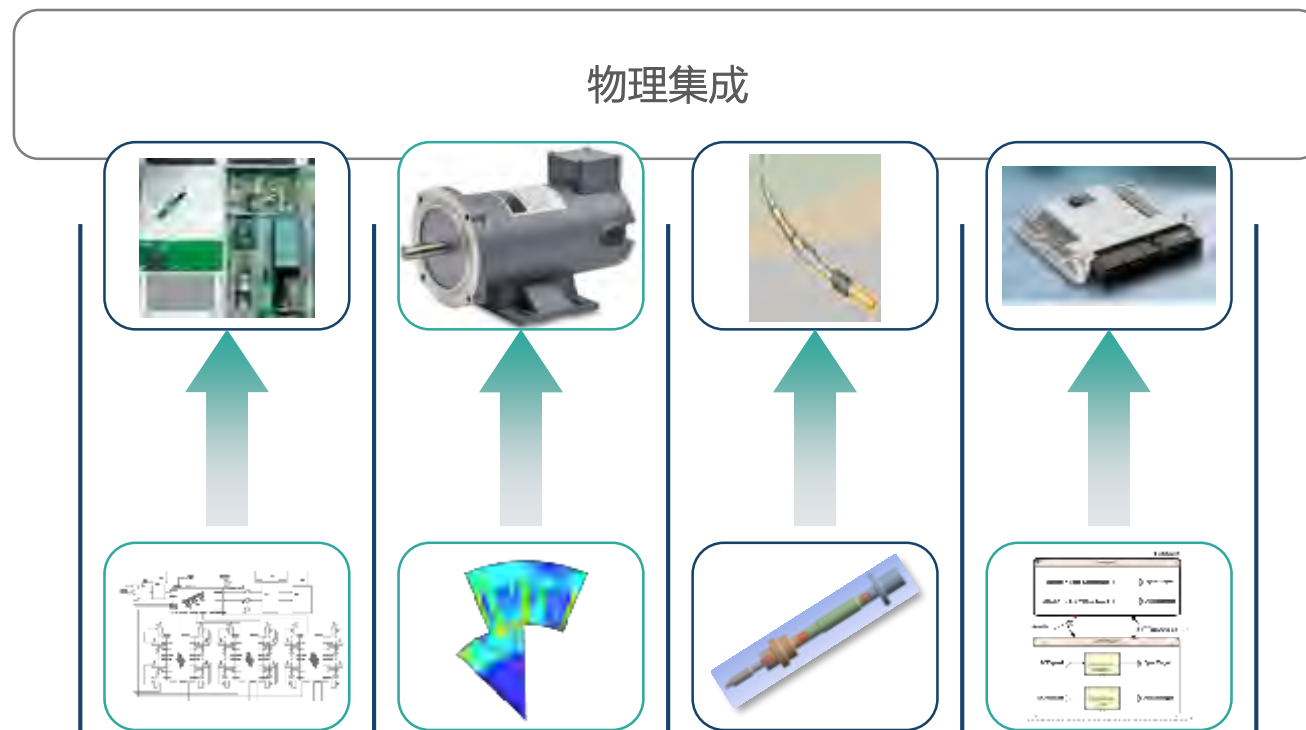
3D 物理仿真

ROM

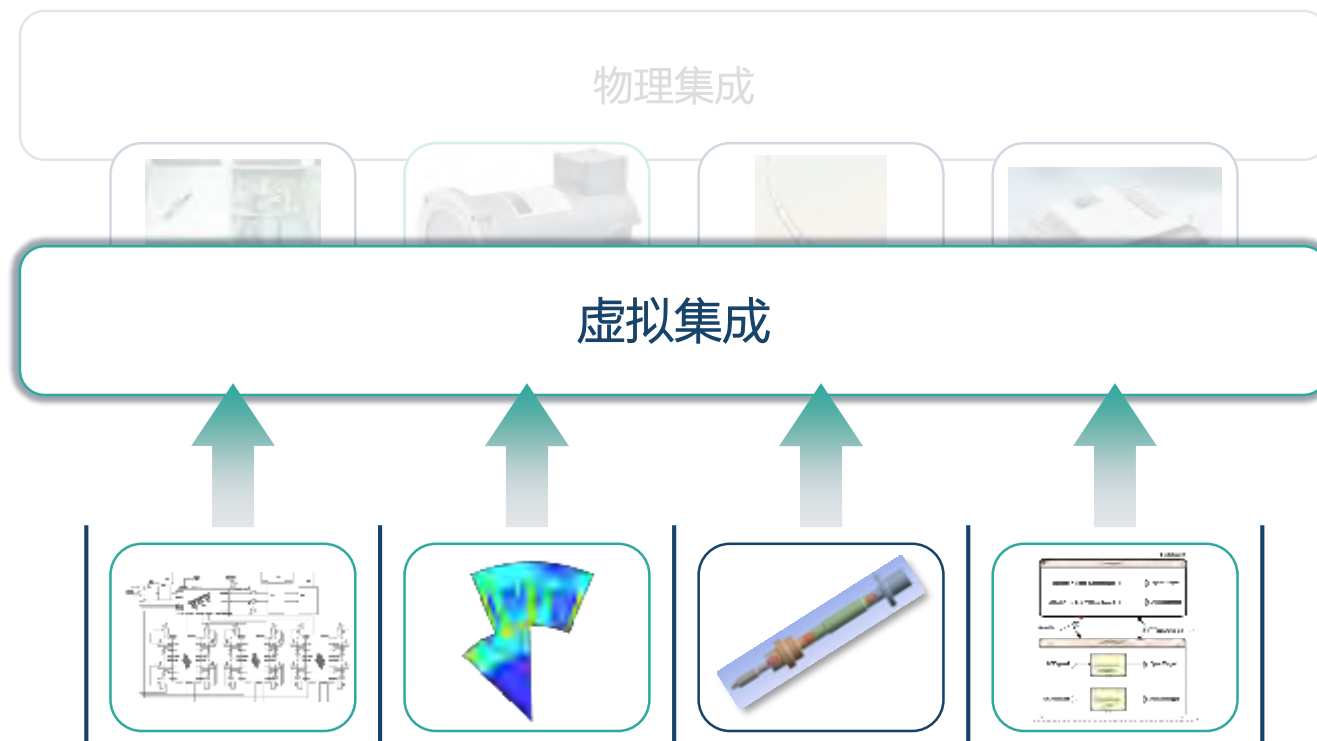




产品开发中的管道现象

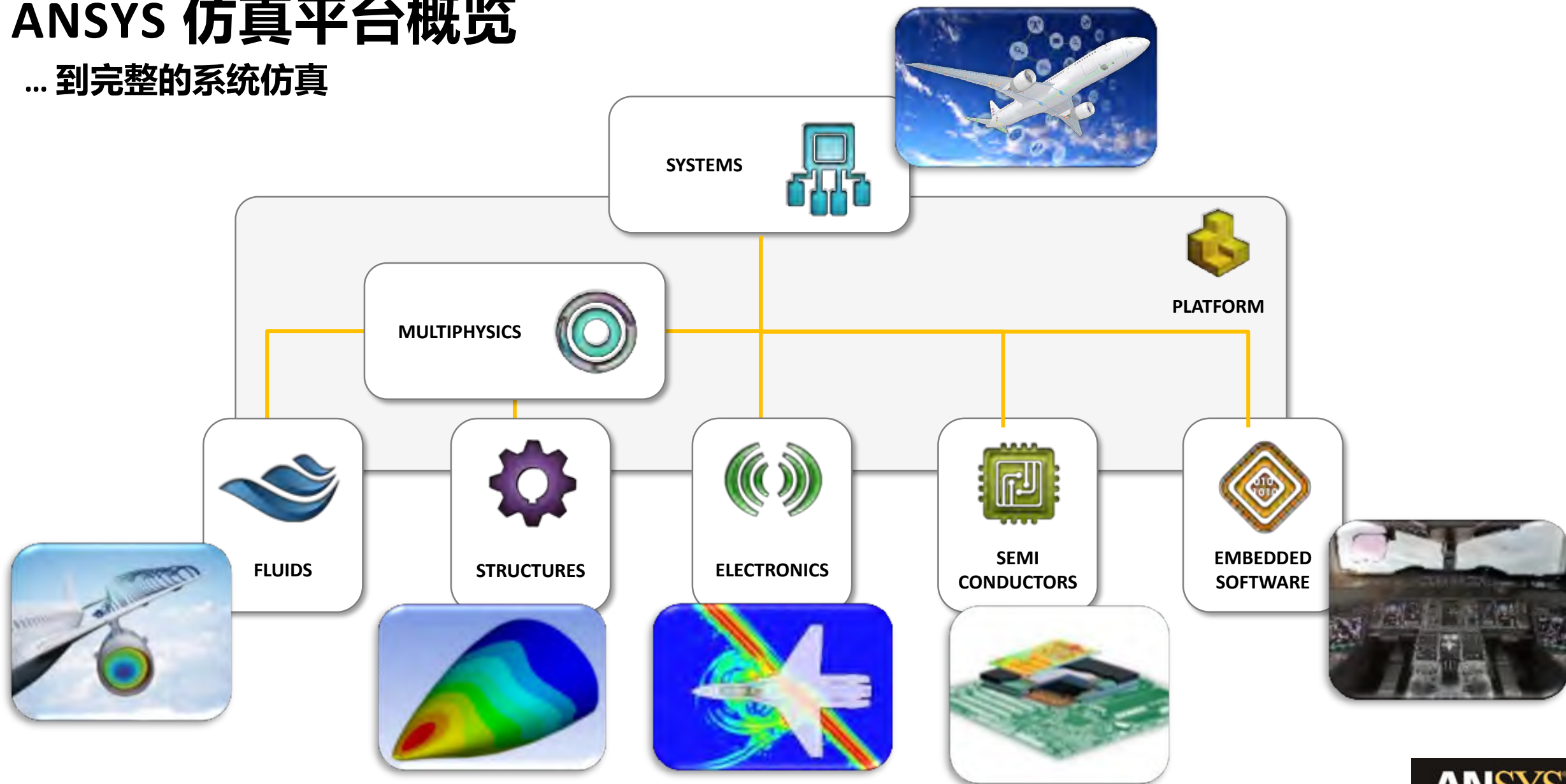


系统装配与仿真

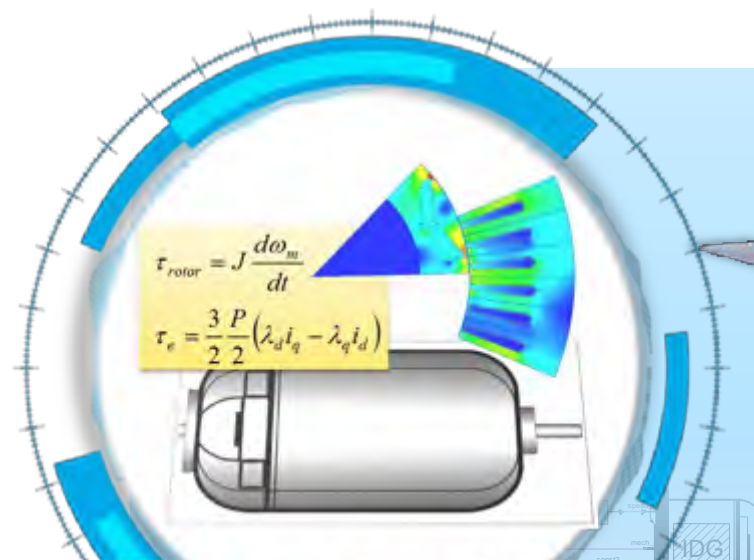


ANSYS 仿真平台概览

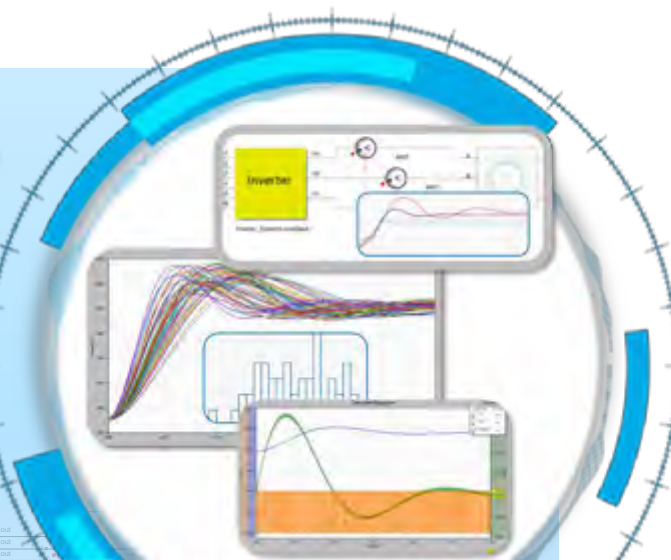
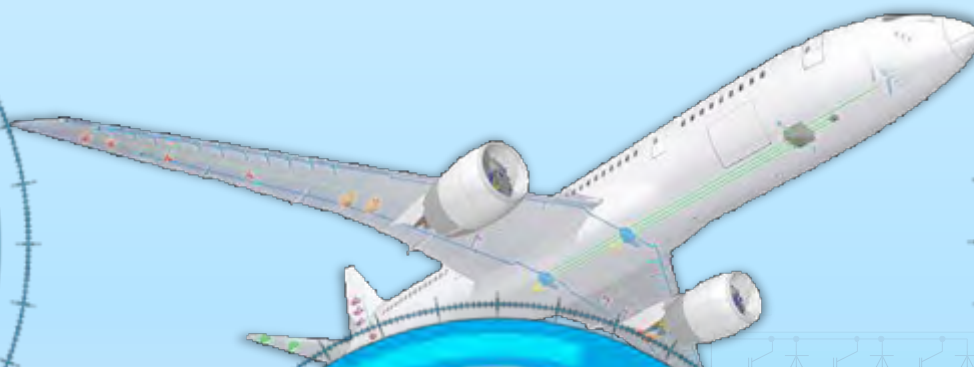
... 到完整的系统仿真



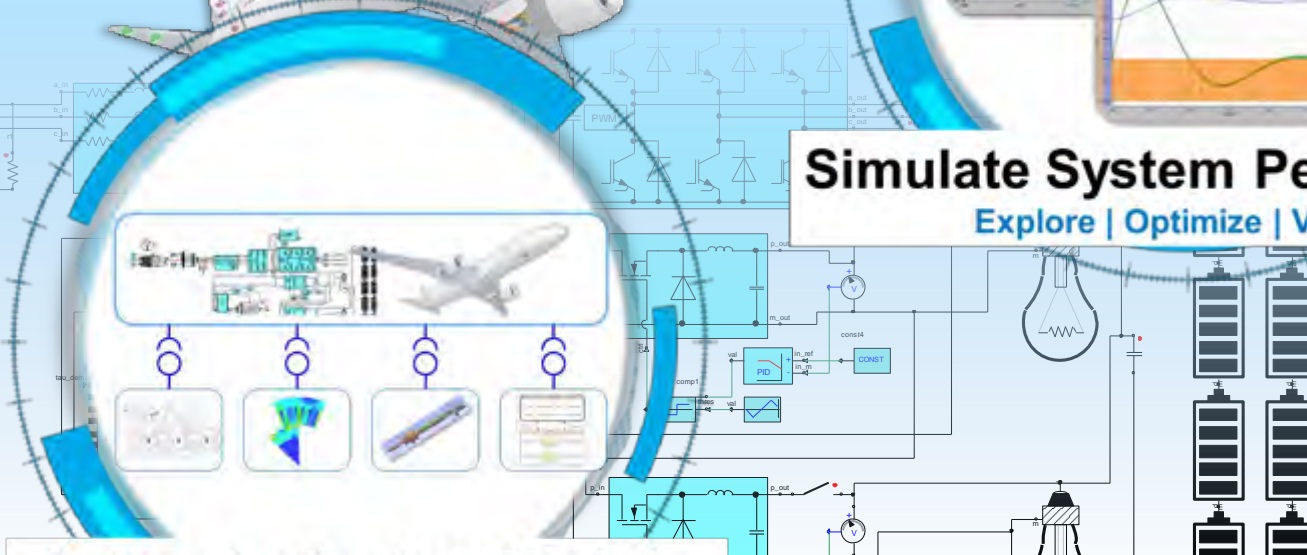
ANSYS 多学科系统仿真平台工具——Simplorer



Model Component Dynamics
Physics-Based | Equations | 3D



Simulate System Performance
Explore | Optimize | Validate



Integrate System Models
Physical Components | Controls & Software

在电气化系统中广泛应用



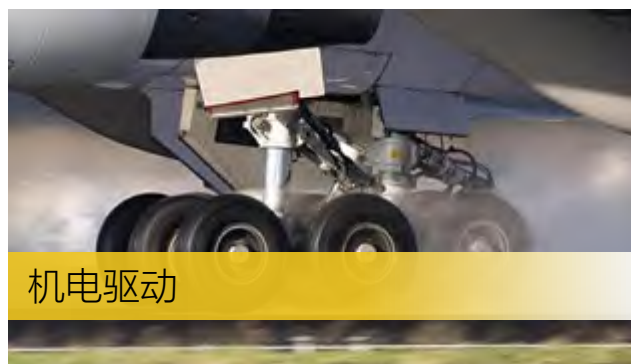
电源分配



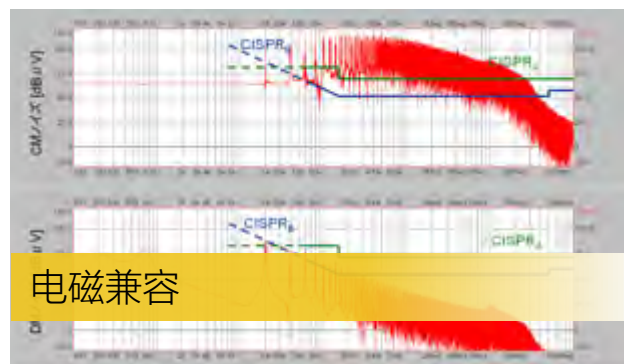
功率变换



发电 & 储能



机电驱动



电磁兼容

Simplorer 系统仿真

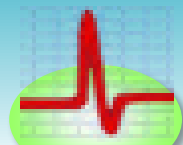
基于仿真的试验



稳健的高性能求解器



仿真同步器



基于仿真的试验分析



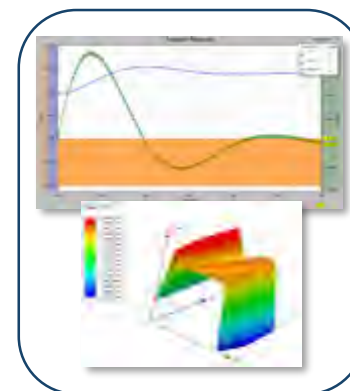
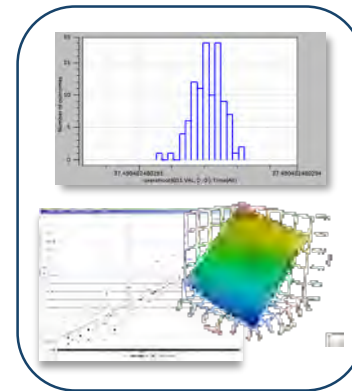
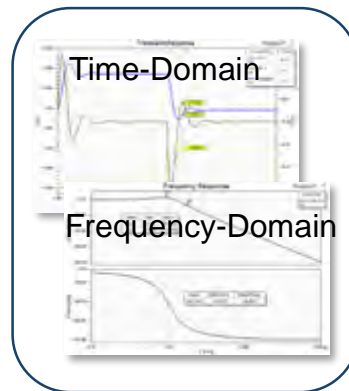
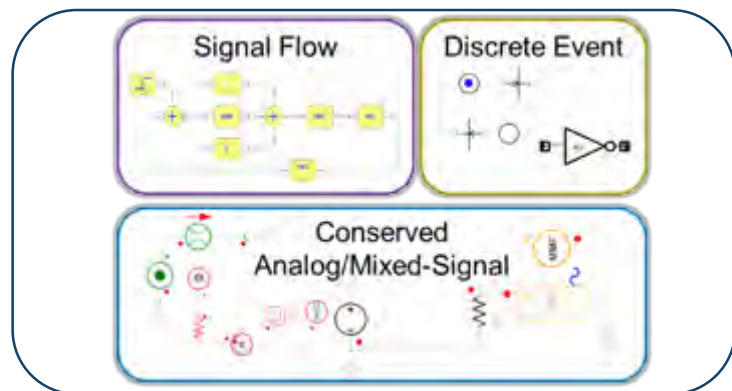
优化、稳健性
与可靠性分析工具



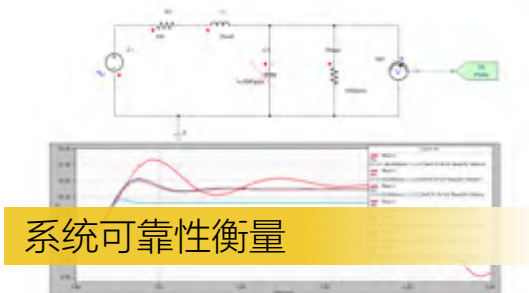
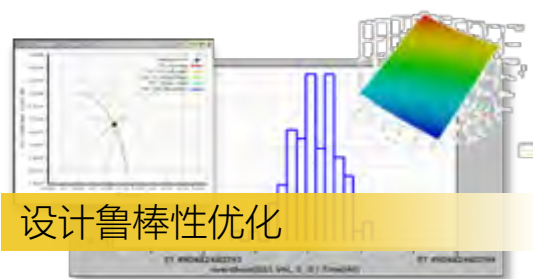
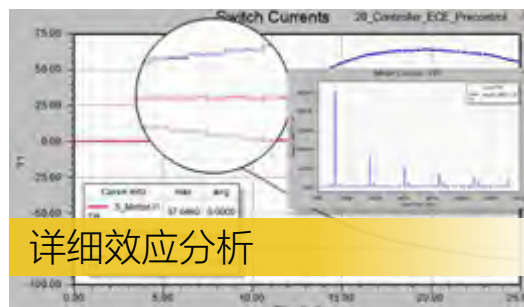
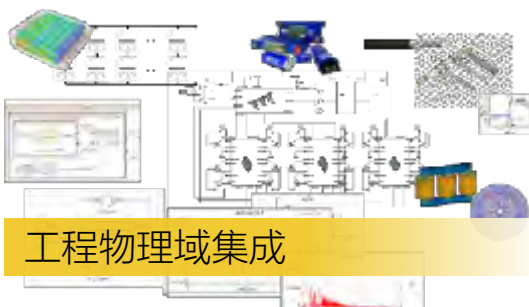
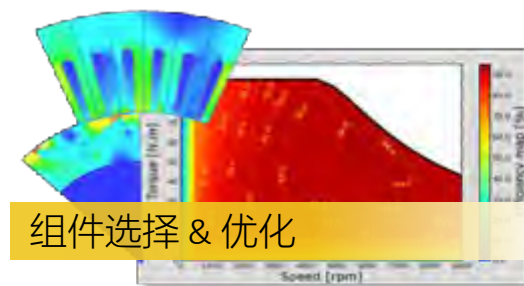
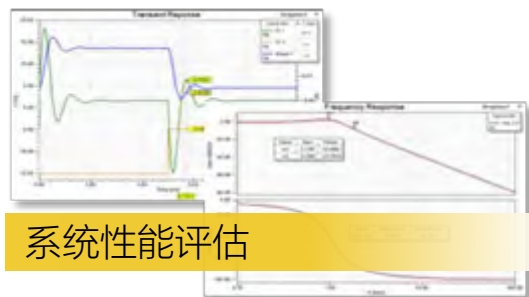
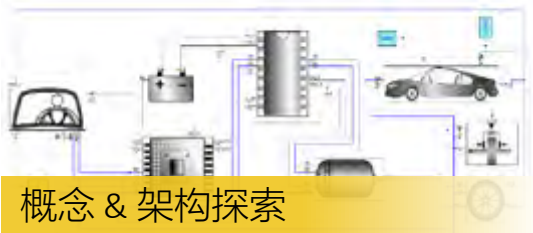
波形和数据后处理



报告、脚本与自动化

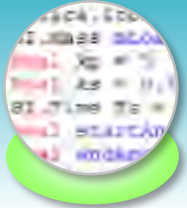


复杂系统基于仿真的试验



Simplorer 系统建模

模型生成、装配、与重用



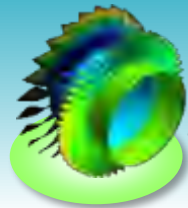
基于语言的建模



多域模型库



3D物理场协同仿真



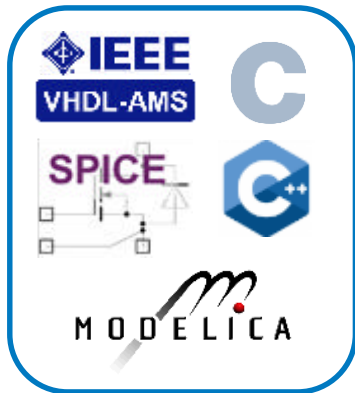
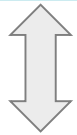
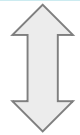
降阶模型建立



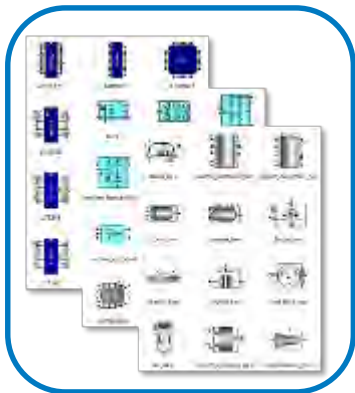
嵌入式软件集成



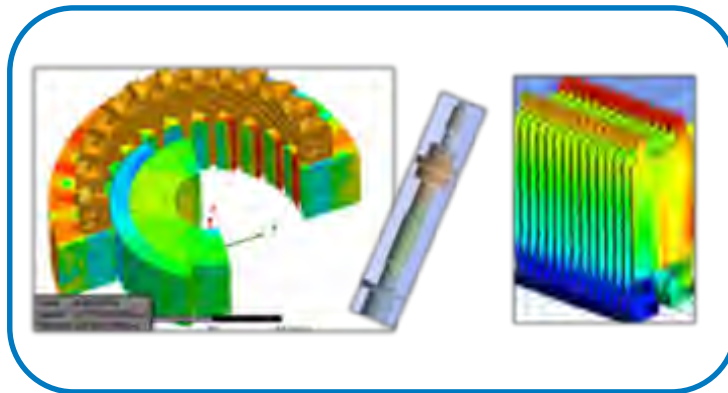
系统模型互操作



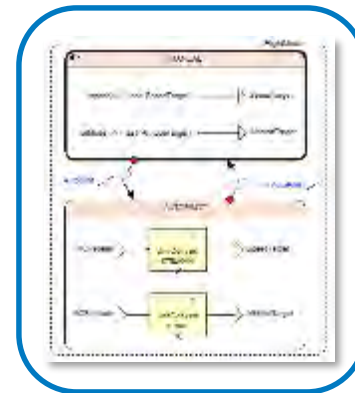
支持系统建模行业标准



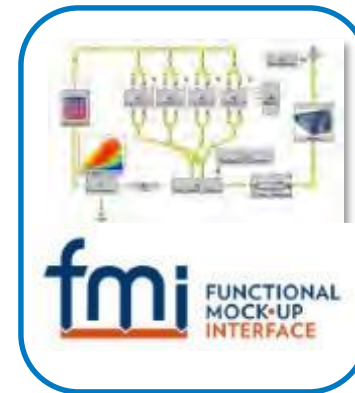
数千种内置部件模型



与 ANSYS 所有 3D 物理场的接口



ANSYS SCADE



第三方系统建模工具

Simplorer 系统建模

模型生成、装配、与重用



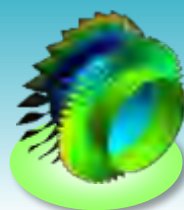
基于语言的建模



多域模型库



3D物理场协同仿真



降阶模型建立



嵌入式软件集成



系统模型互操作

关键措施：

FMI

功能模型接口



ROM
降阶模型

利用FMI集成第三方模型

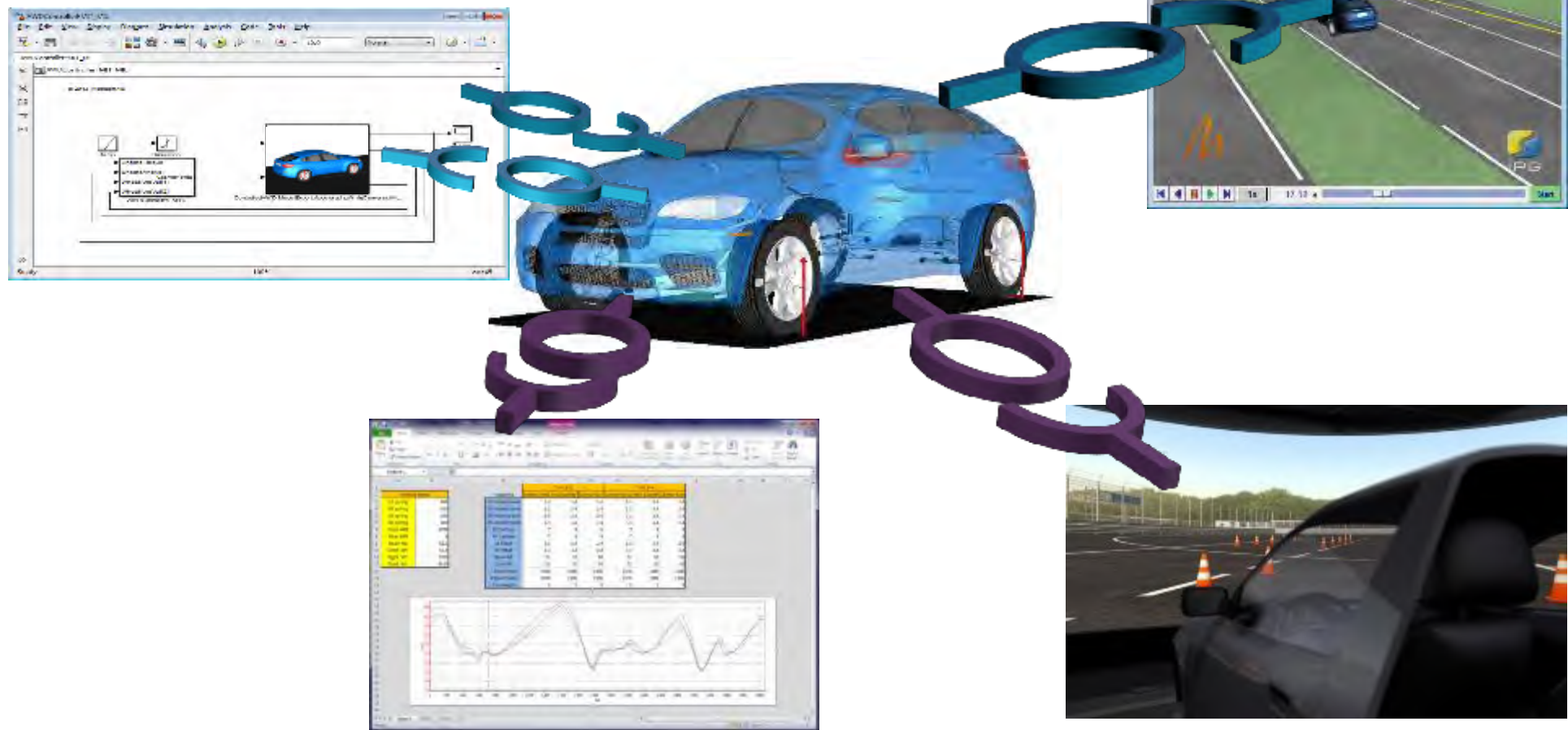


Simplorer FMI 支持:

- 导入 FMUs 实现模型交换
- 与 Slave FMUs 耦合，实现协同仿真 **NEW in R18!**
 - GT-SUITE, Amesim, CarSim, more...
- 导出 Modelica subsystems 实现模型交换

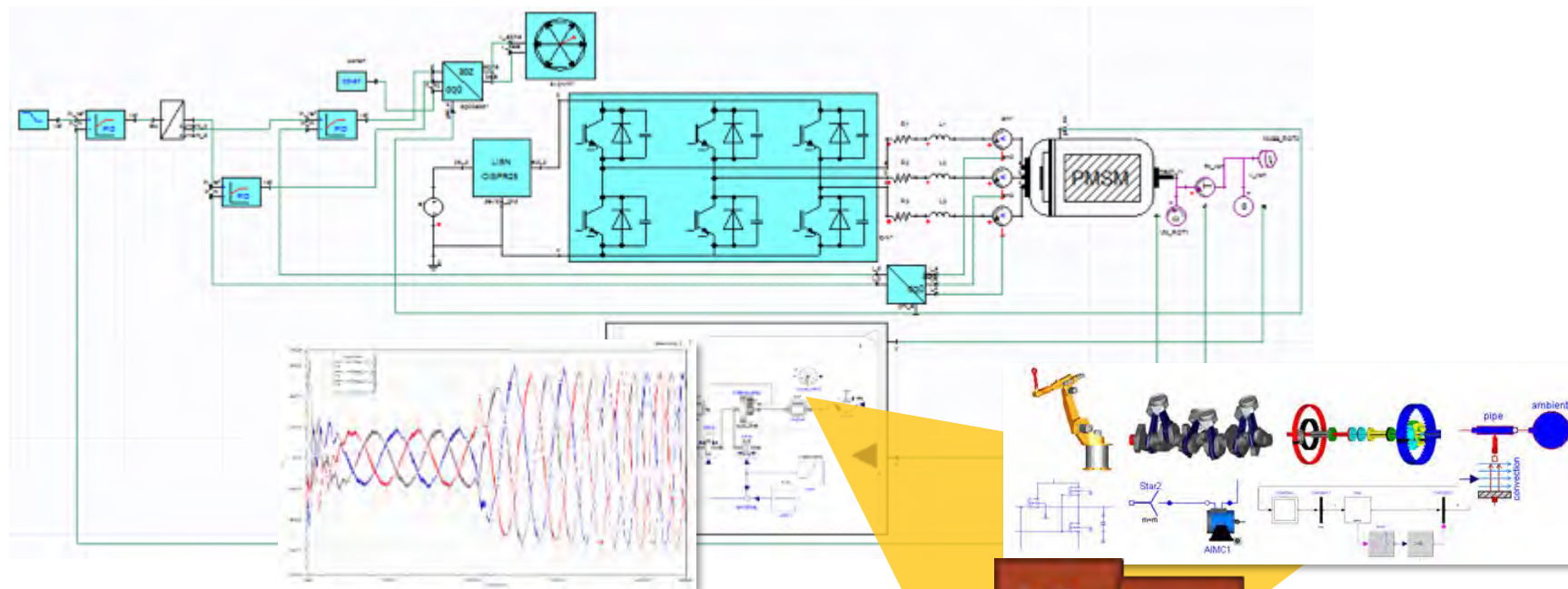
FMI兼容工具请查看：www.fmi-standard.org/tools

实现不同应用模型的集成

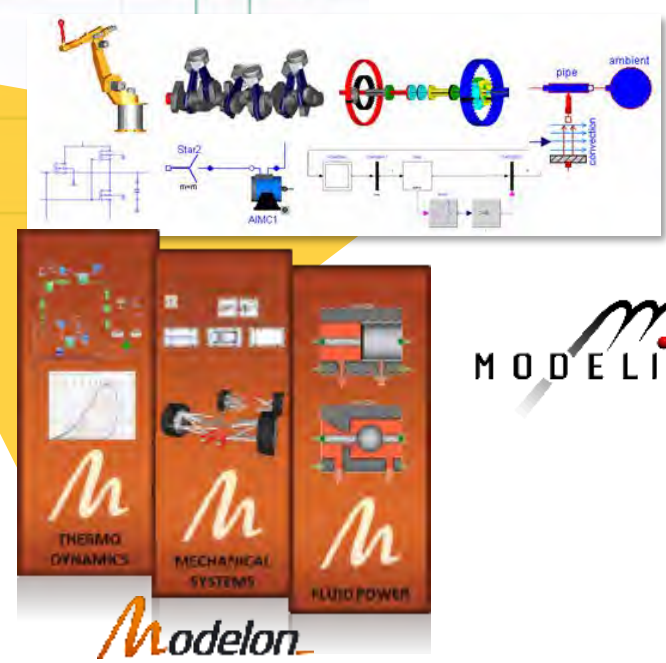


Modelica in Simplorer

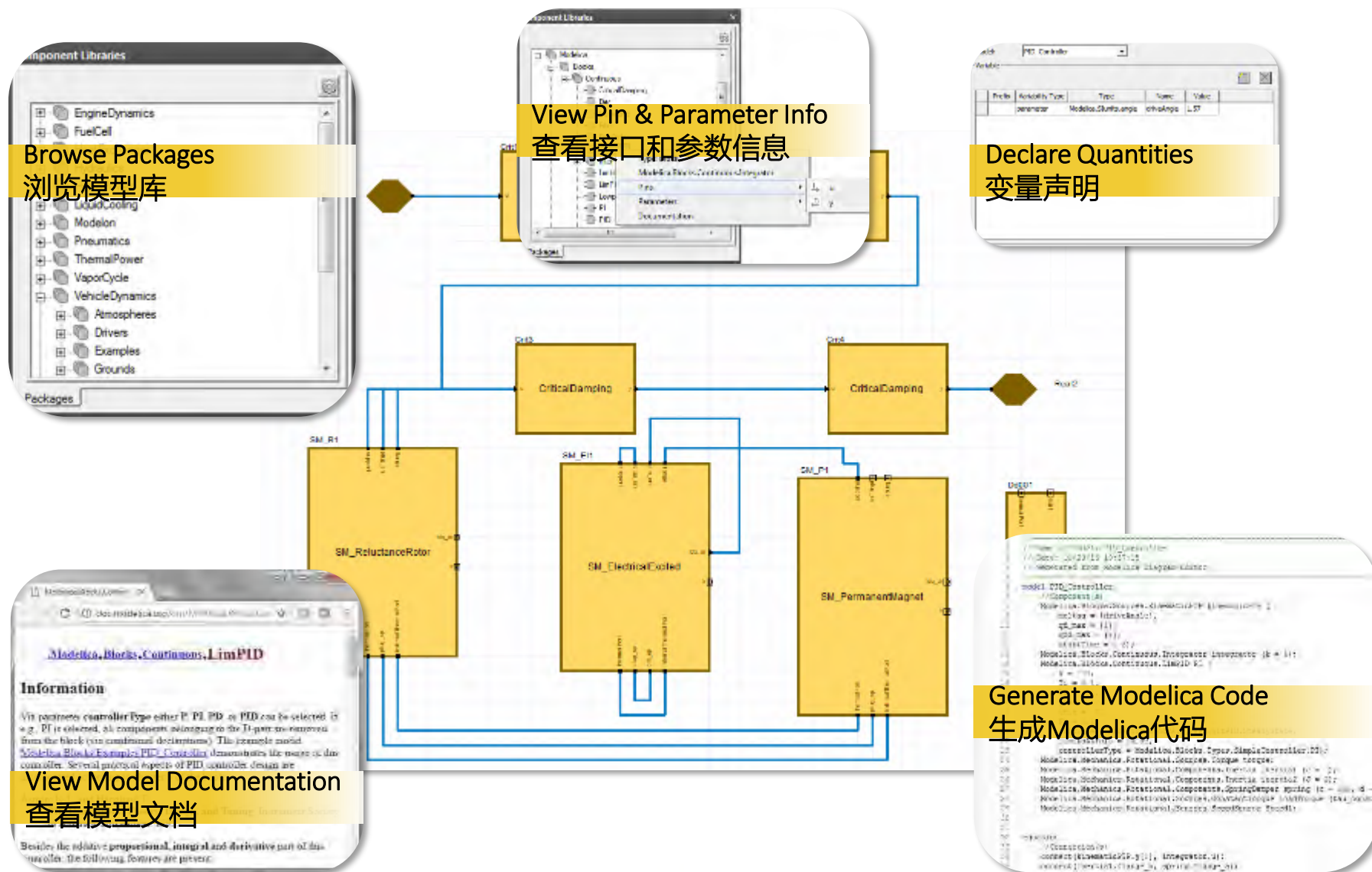
扩展系统建模的覆盖领域



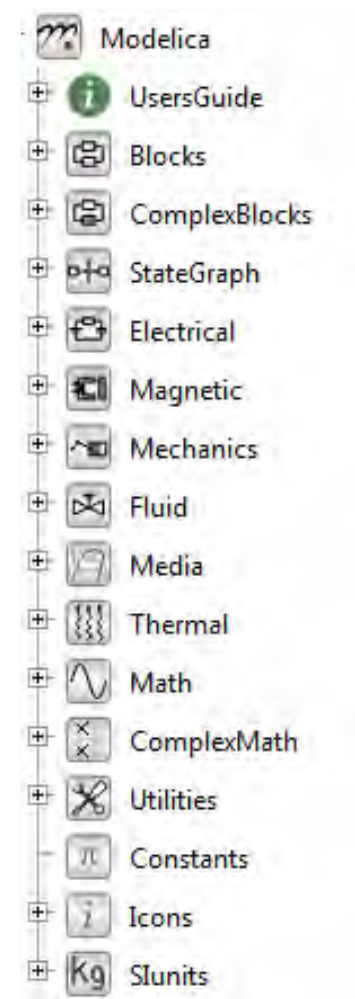
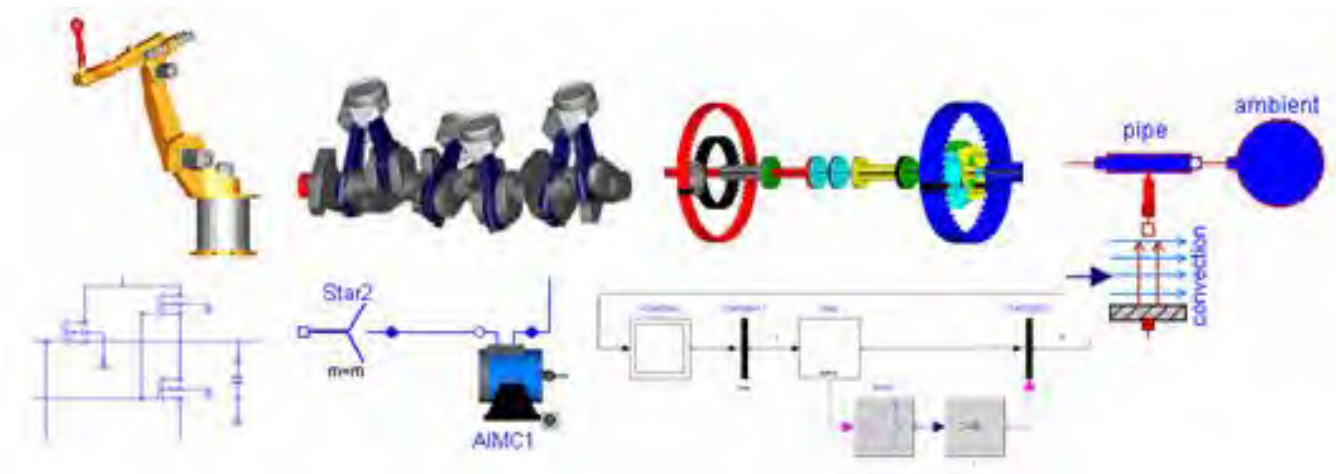
建立并重用Modelica模型
+电气化系统领先的精度和性能



利用Modelica框图实现多域建模



完全兼容Modelica标准库

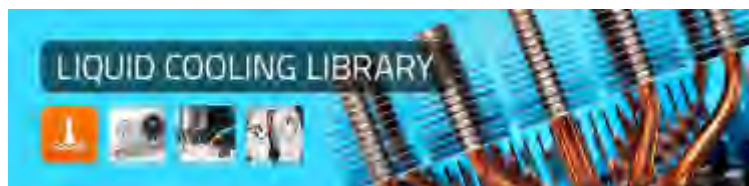


Modelica标准库 (MSL) 是来自Modelica协会的免费库，包含有超过1,500个部件，可对机械、电气、热、流体及控制系统进行建模。

在Simplorer中:

- 通过MSL模型建立框图
- 导入用MSL模型创建的子系统

兼容 Modelon 库



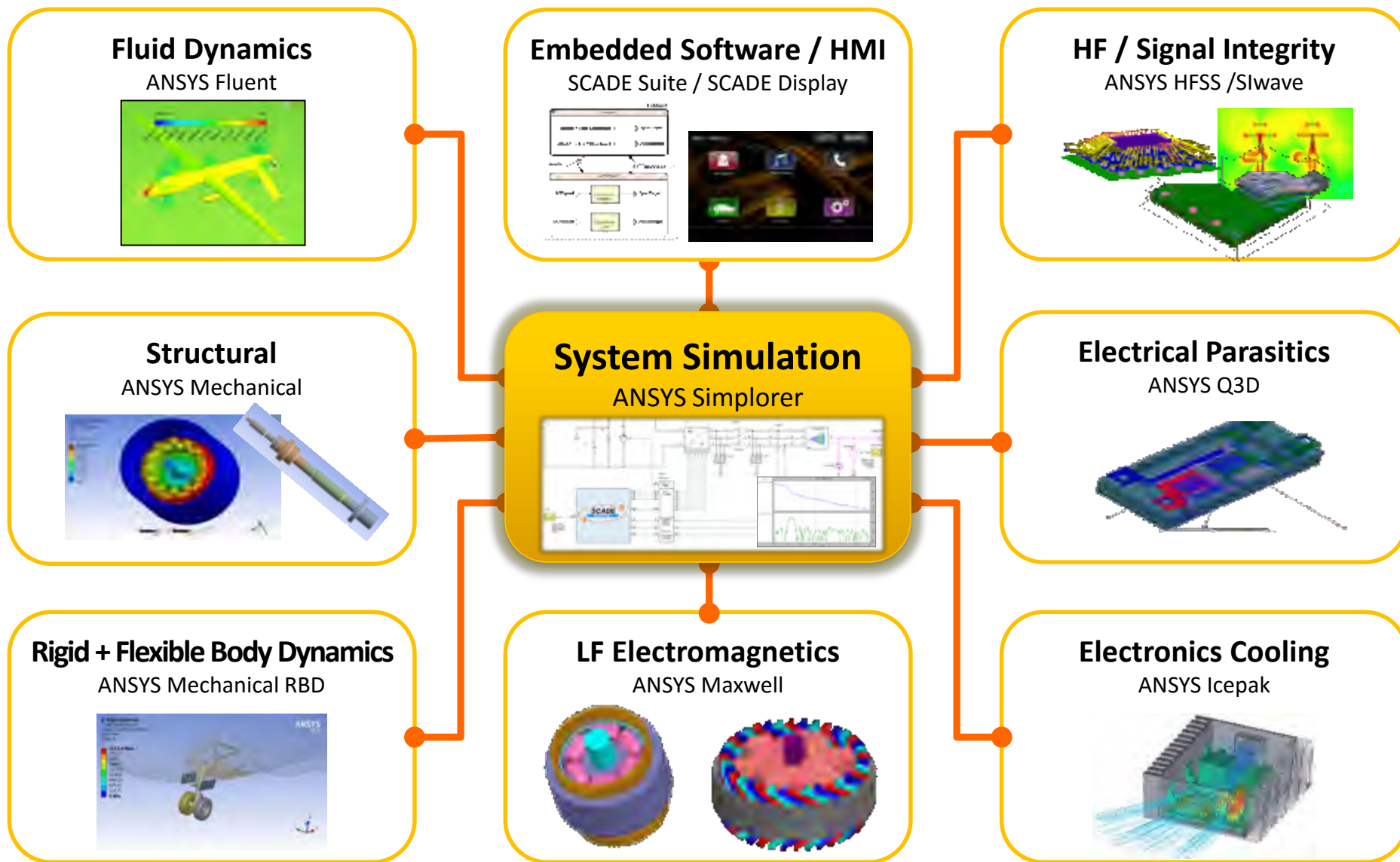
| | |
|--------|-------|
| 发动机动力学 | 液冷系统 |
| 燃料电池 | 气动力学 |
| 热交换器 | 火力发电 |
| 液压系统 | 蒸汽循环 |
| 水力发电 | 车辆动力学 |

Modelon

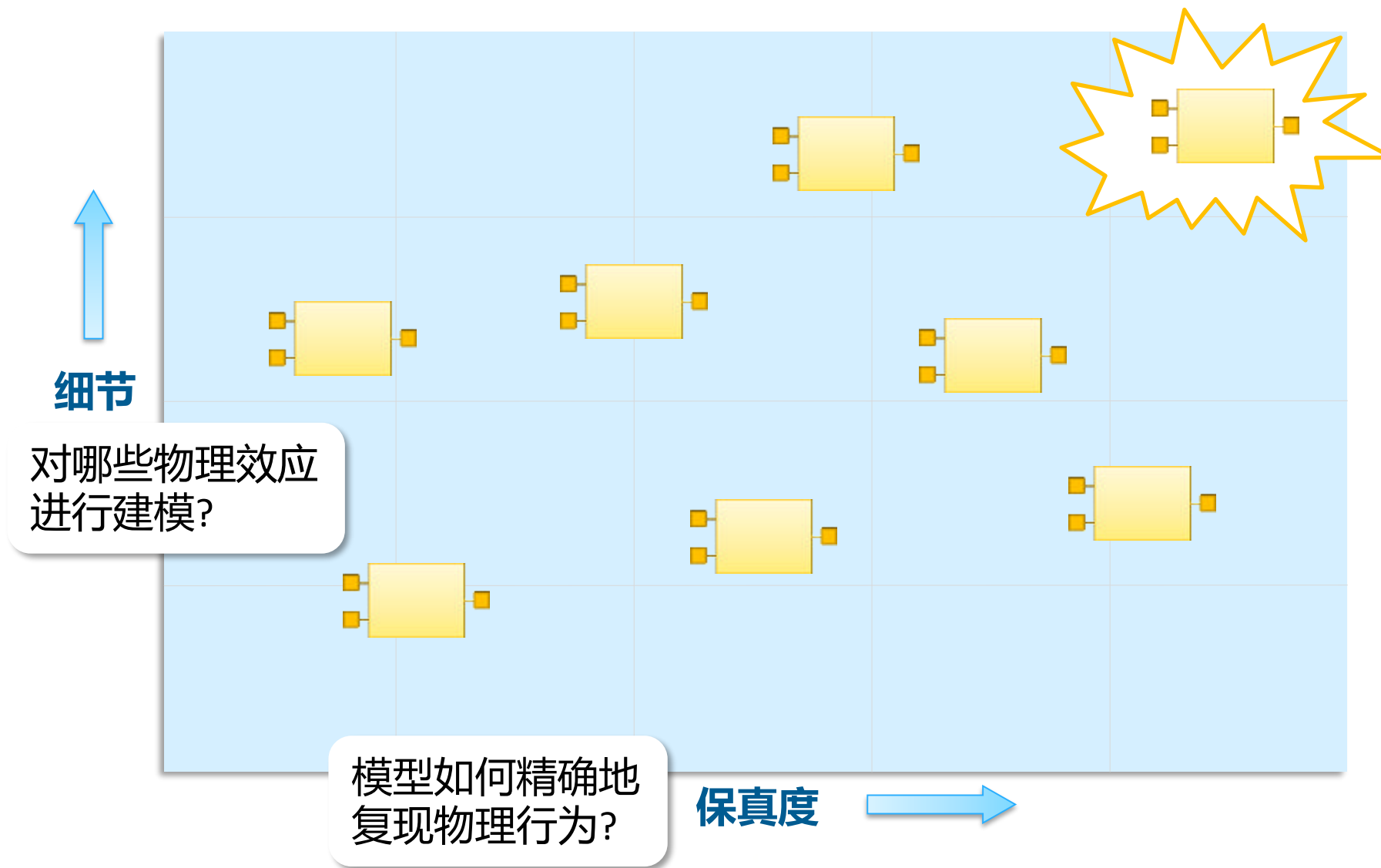
ANSYS

* Modelon libraries are provided by Modelon AB / Inc.

连接ANSYS仿真工具



系统仿真的不同阶段对细节和保真度的要求不同

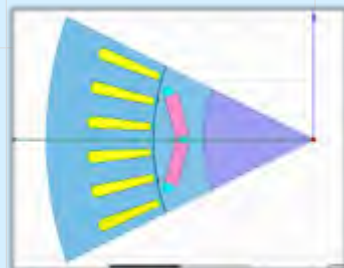


系统仿真的不同阶段对细节和保真度的要求不同

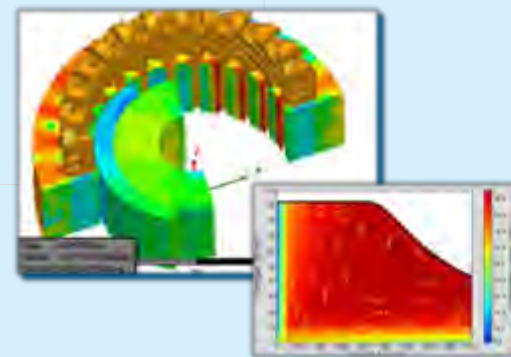
↑
细节

```
-- electrical and mechanical finite element  
phi_e = p_2nd/2.0 * phi_m  
omega_e = p_2nd/2.0 * omega_m  
  
-- flux transformation  
r_a = cos(phi_e) * r_d - sin(phi_e) * r_q + r_0r  
r_b = cos(phi_e - two_third_pi) * r_d - sin(phi_e - two_third_pi) * r_q + r_0r  
r_c = cos(phi_e + two_third_pi) * r_d - sin(phi_e + two_third_pi) * r_q + r_0r  
  
L_d = cos(phi_e) * L_d0 + sin(phi_e) * L_q0  
L_q = cos(phi_e) * L_q0 - sin(phi_e) * L_d0  
  
-- angular velocity  
if done_e  
  phi_e  
else  
  phi_e  
end if  
  
-- system equations  
r_d + L_d1dot = r_d - r_q + L_d0 * omega_e + L_q1 * i_qdot  
r_q + L_q1dot = r_q - r_d + L_q0 * omega_e + L_d1 * i_ddot  
L_d1dot = r_d - r_q + L_d0 * omega_e + L_q1 * i_qdot  
L_q1dot = r_q - r_d + L_q0 * omega_e + L_d1 * i_ddot
```

VHDL-AMS
行为模型



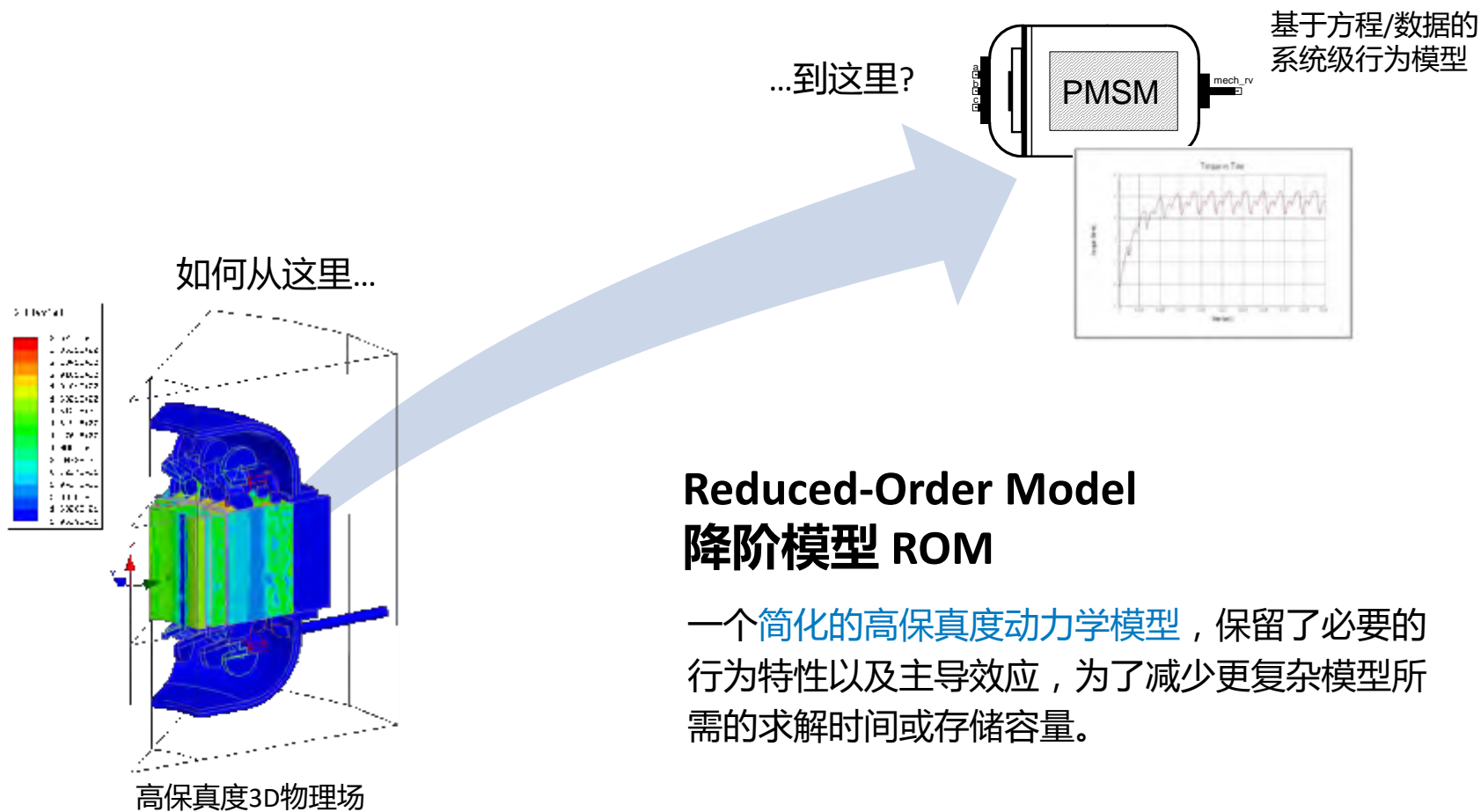
电路等效ROM



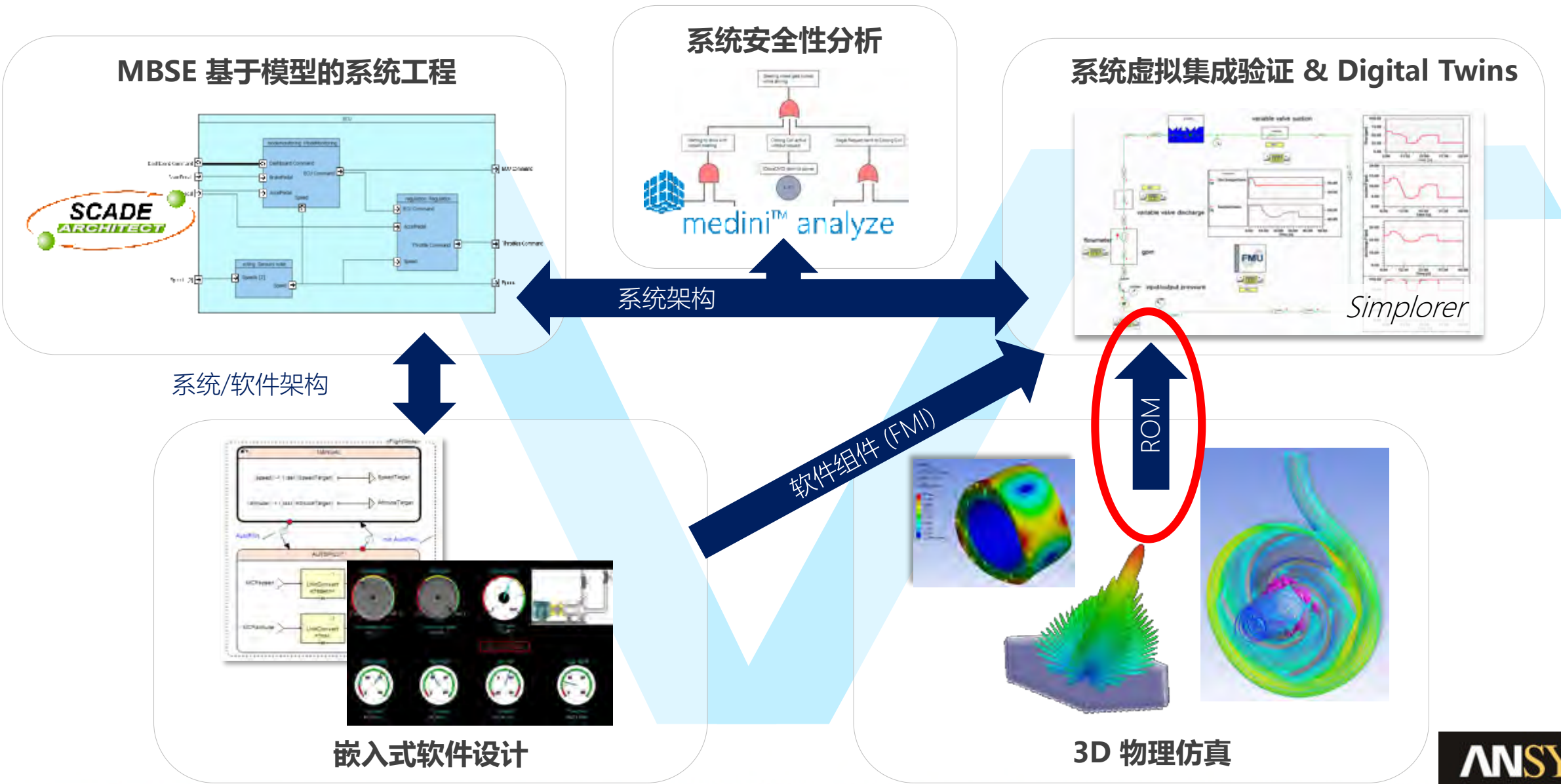
结合2D/3D FEM进行
协同仿真

保真度 →

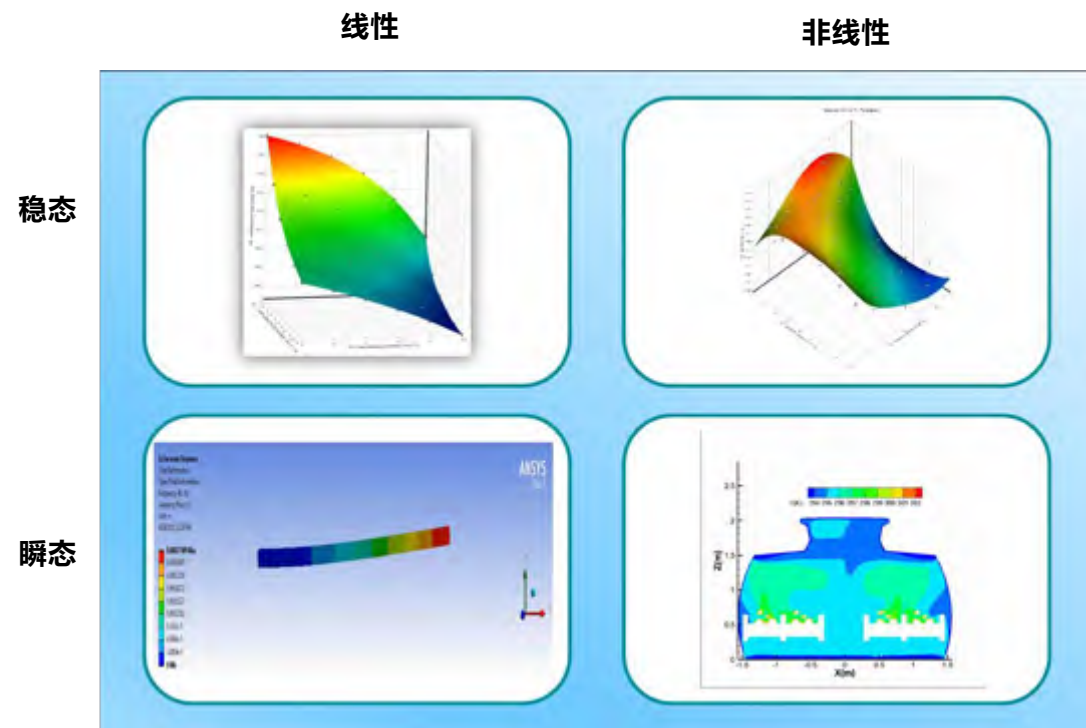
如何保持物理模型的保真度？



ROM 降阶模型连接3D与系统



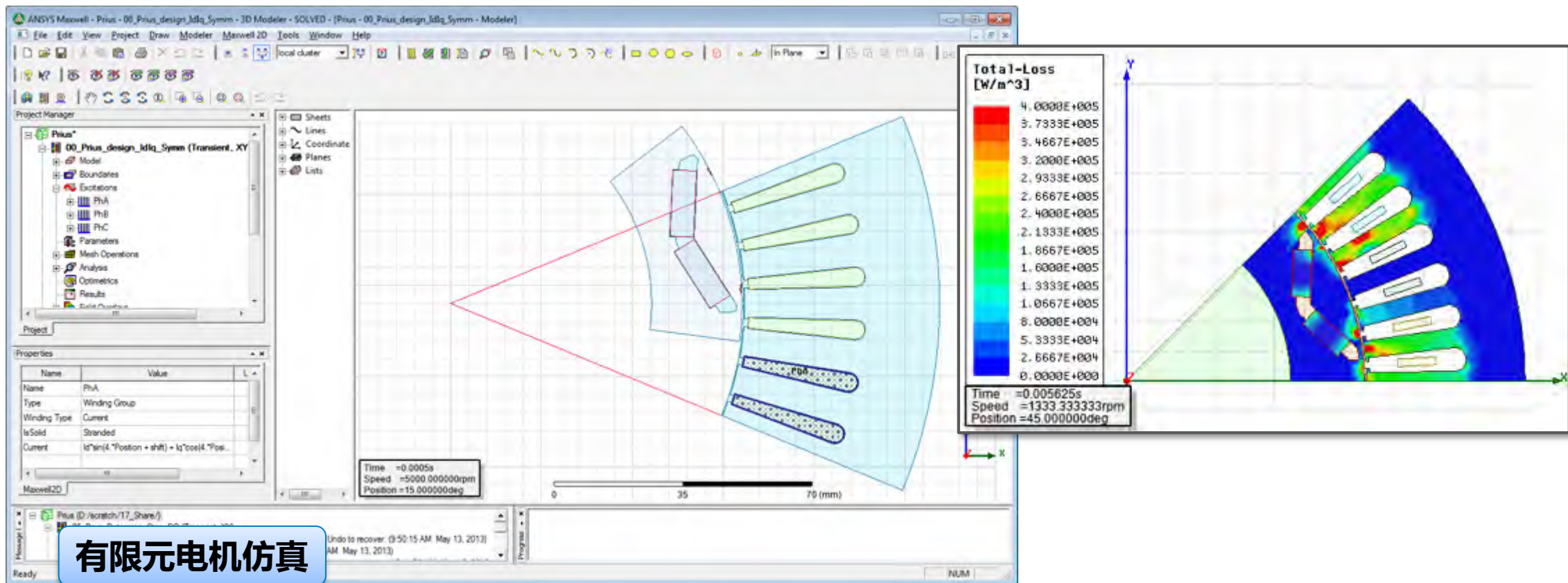
ANSYS 多种类型、多物理场的 ROM 模型



| | | |
|-----------------|--|--|
| Mechanical | | |
| Electrical | | |
| Electromagnetic | | |
| Thermal | | |
| Fluid | | |

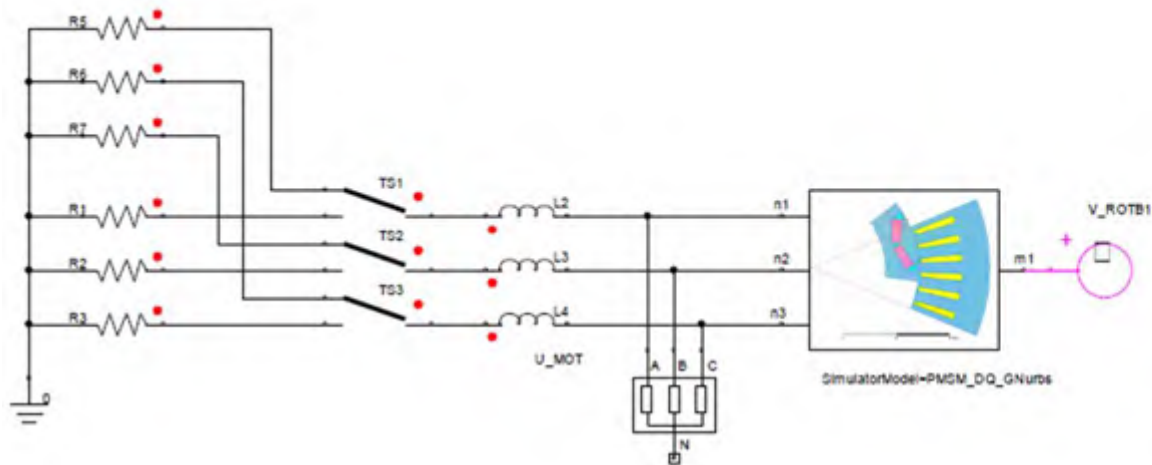
案例

电机 ECE ROM 提取



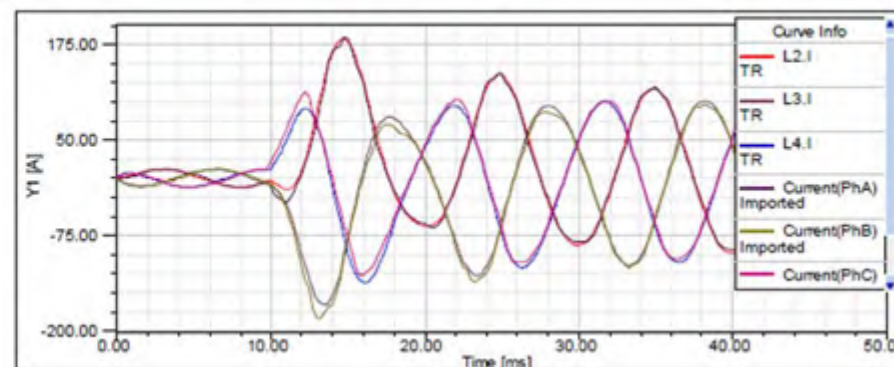
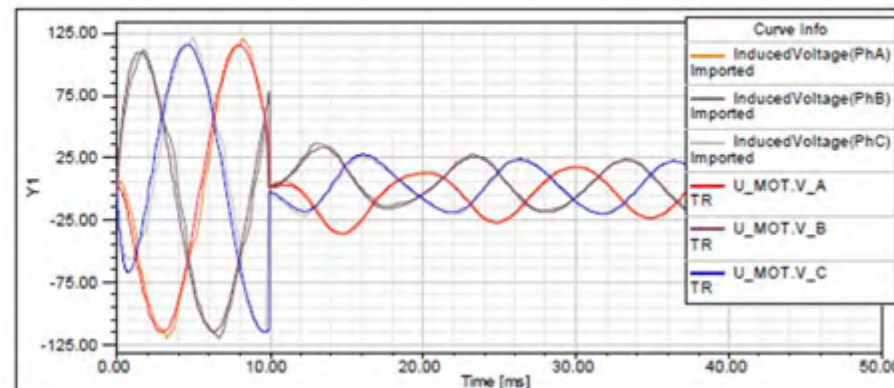
案例

电机 ECE ROM 提取



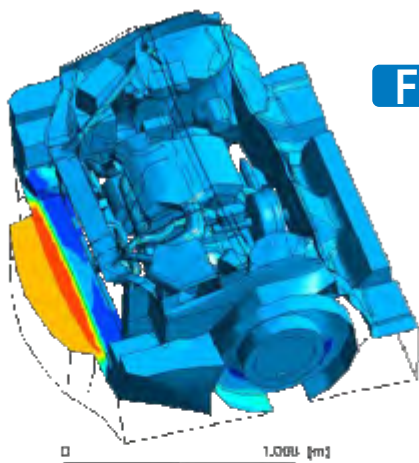
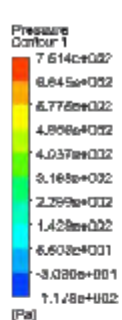
ECE ROM 瞬态特性
与有限元模型精度对比

求解时间：几秒vs.几小时



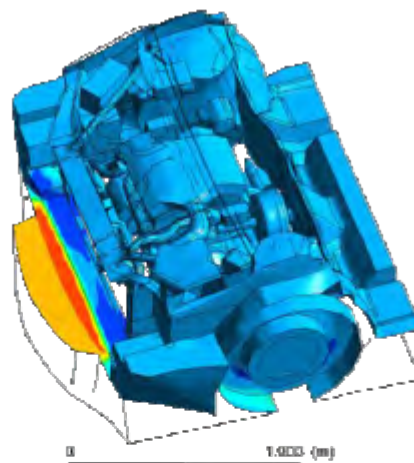
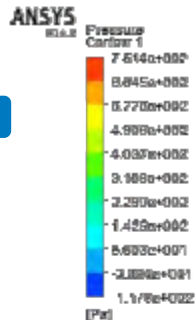
案例

Fluent静压力模型



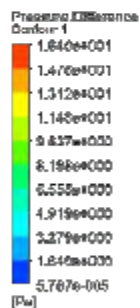
Fluent

2 hours on 16 cores cluster

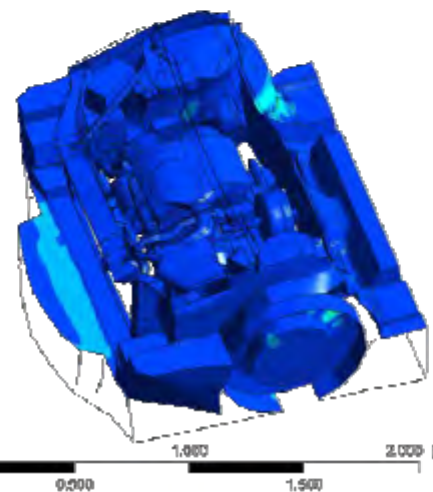


ROM

3 seconds on laptop

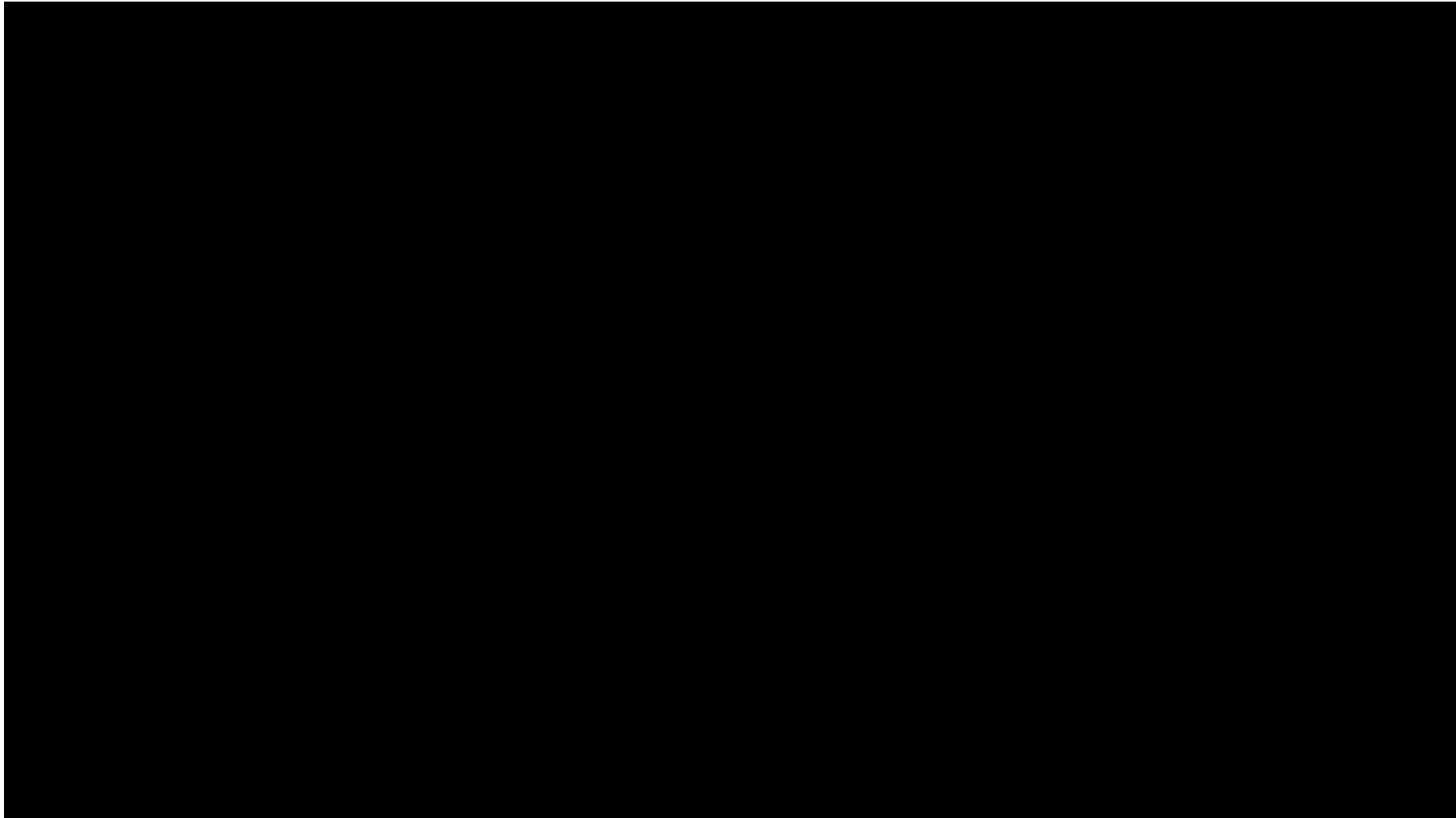


结果对比

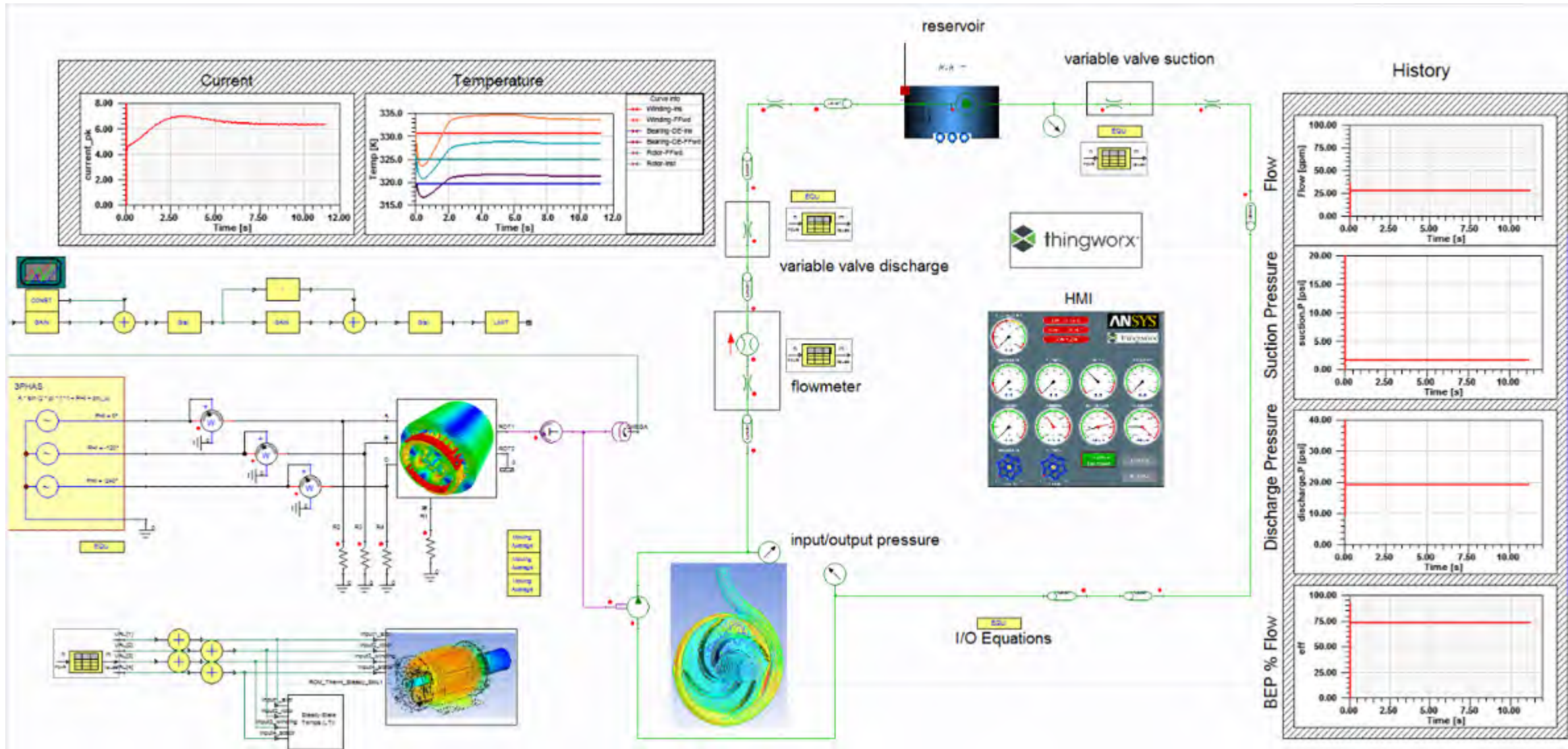


Max difference: 1.2%

Video: ROM & FMI 协同仿真



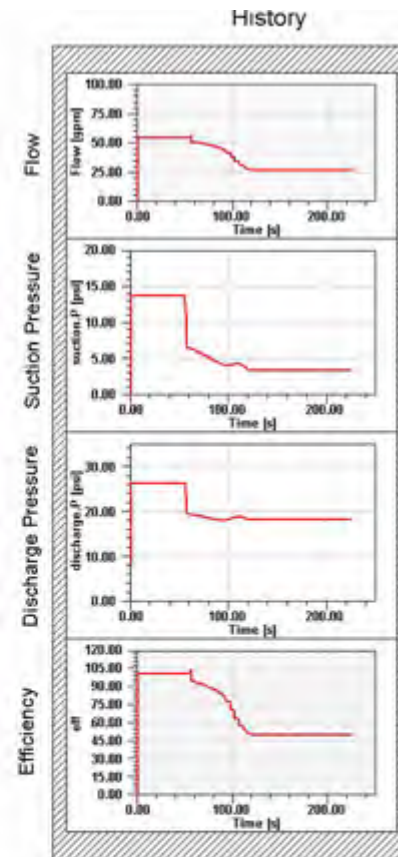
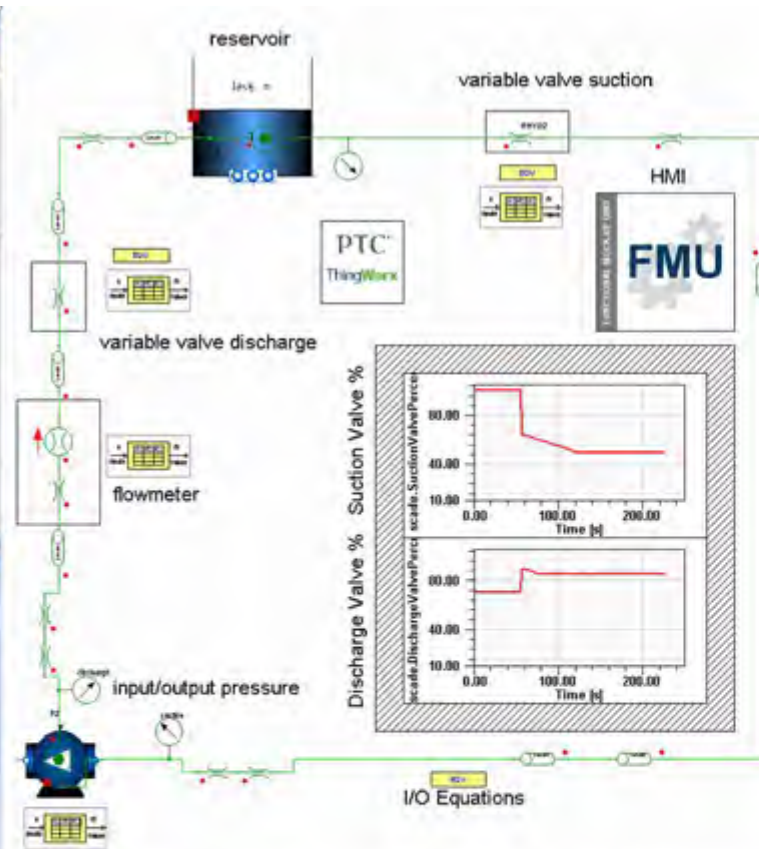
应用案例: 泵



* Courtesy of Flowserve and Regal Beloit



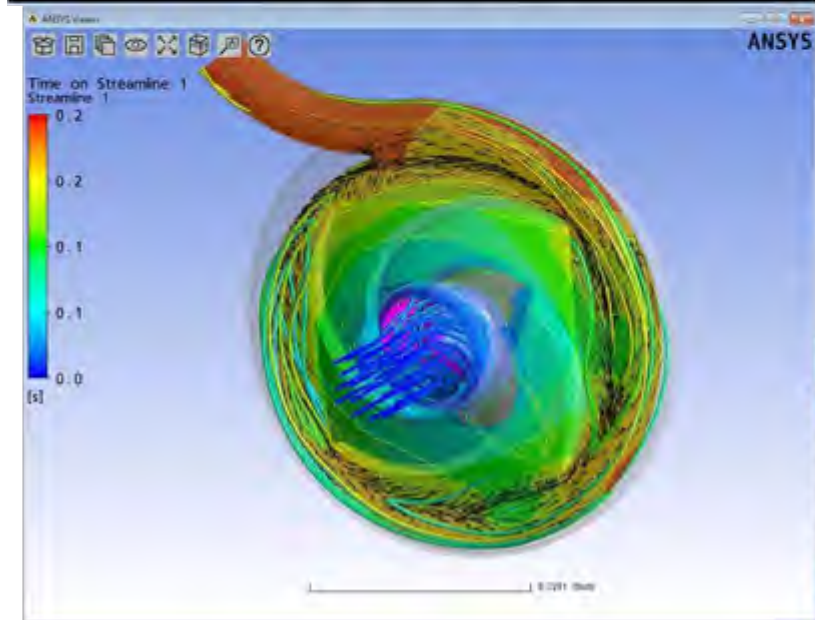
泵系统与3D物理场仿真耦合



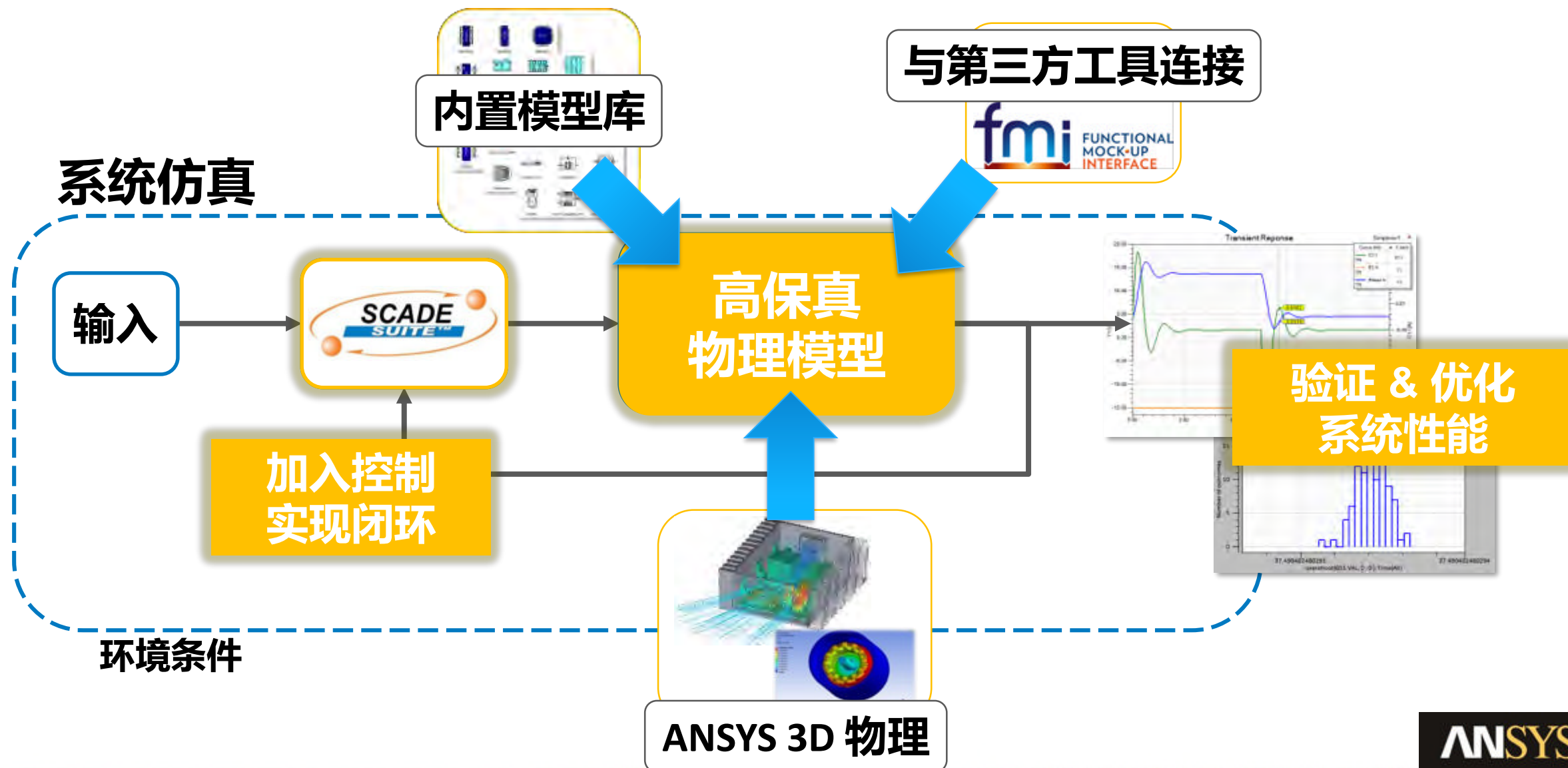
```

C:\WINDOWS\system32\cmd.exe - CFDAAnalysisAgent\RunAgent.bat

[//org/slf4j/impl/StaticLoggerFinder.class]
SLF4J: See http://www.slf4j.org/codes.html#multiple_bindings for an explanation.
SLF4J: Actual binding is of type [ch.qos.logback.classic.util.ContextSelectorStaticBinder]
11:16:49.083 [main] INFO c.p.a.client.impl.AnalysisSOKClient - AnalysisSOKClient initialized
11:16:49.114 [main] INFO c.ptc.analysis.client.impl.SOKClient - *****SOKClient afterBinding vvoidyall
*****
11:17:31.623 [ClientProcessor-3] DEBUG c.ptc.analysis.client.impl.SOKClient - Entered submitJob
11:17:31.628 [ClientProcessor-3] DEBUG c.ptc.analysis.client.impl.SOKClient - Done submitJob
11:17:31.628 [pool-1-thread-1] DEBUG c.p.a.c.impl.Analysis3DAnalysisService - Started Job on Thread
** CFD Pump Simulation **
** Inlet pressure = 3.4313, Mass flow rate = 26.91
    
```



软件控制系统的闭环测试: Simplorer & SCADE



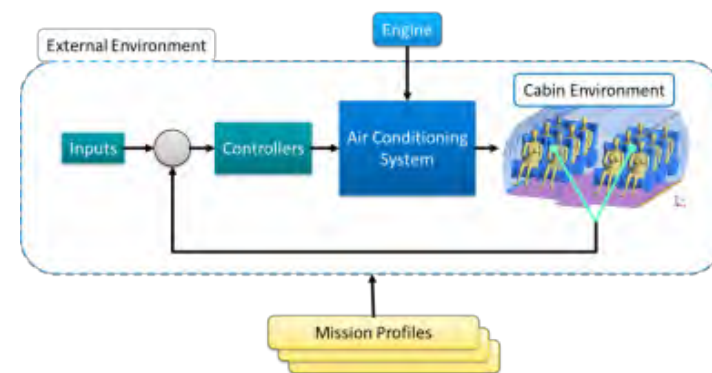
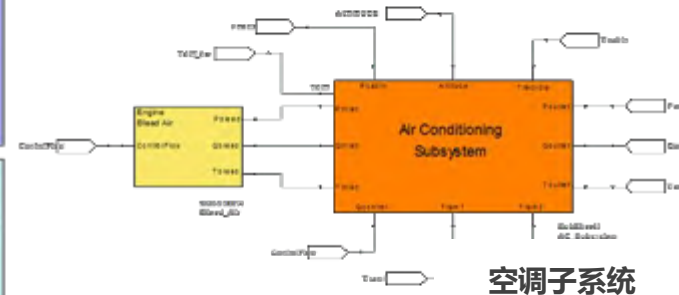
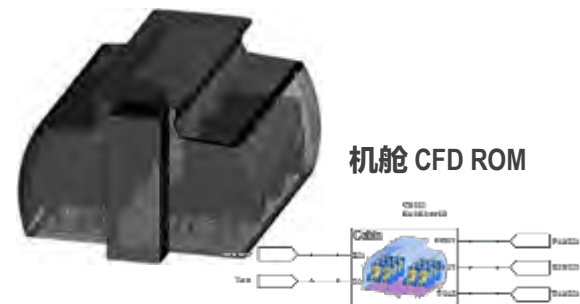
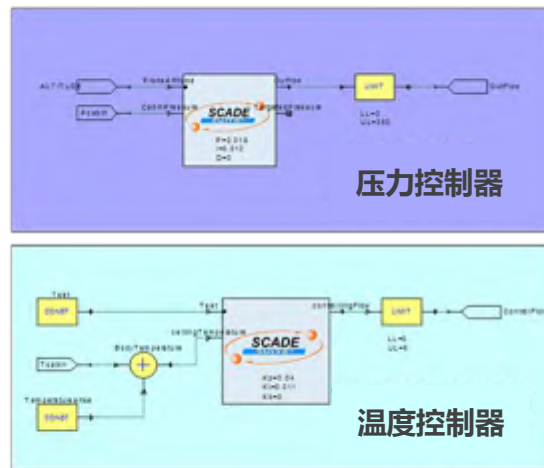
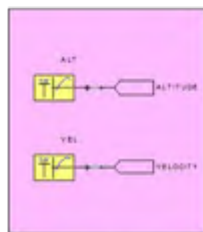
应用案例：飞机环控系统

系统仿真目标

- 优化组件选择、传感器布局和控制策略以降低排放
- 细调和优化控制器参数，以改善乘客在各种任务剖面 and 外部条件下的舒适度

关键系统级模型

- ANSYS Fluent: 详细的机舱气流模型
- ANSYS SCADE: 机舱压力/温度控制软件
- ANSYS Simplorer: 外部条件、任务剖面
- Modelica in Simplorer: 空调子系统组件 (作动器、传感器等)



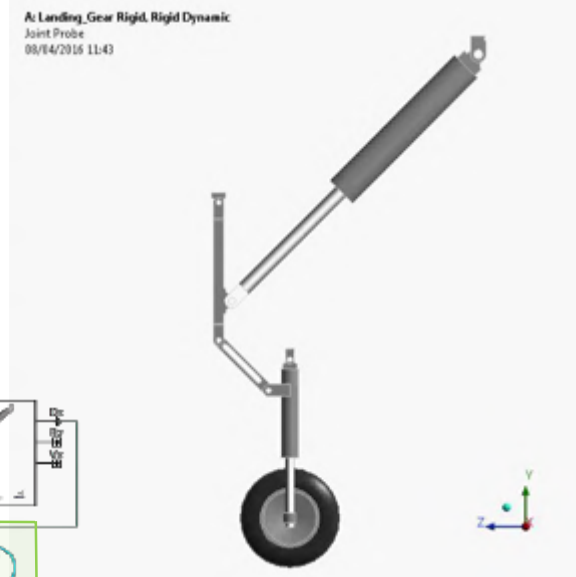
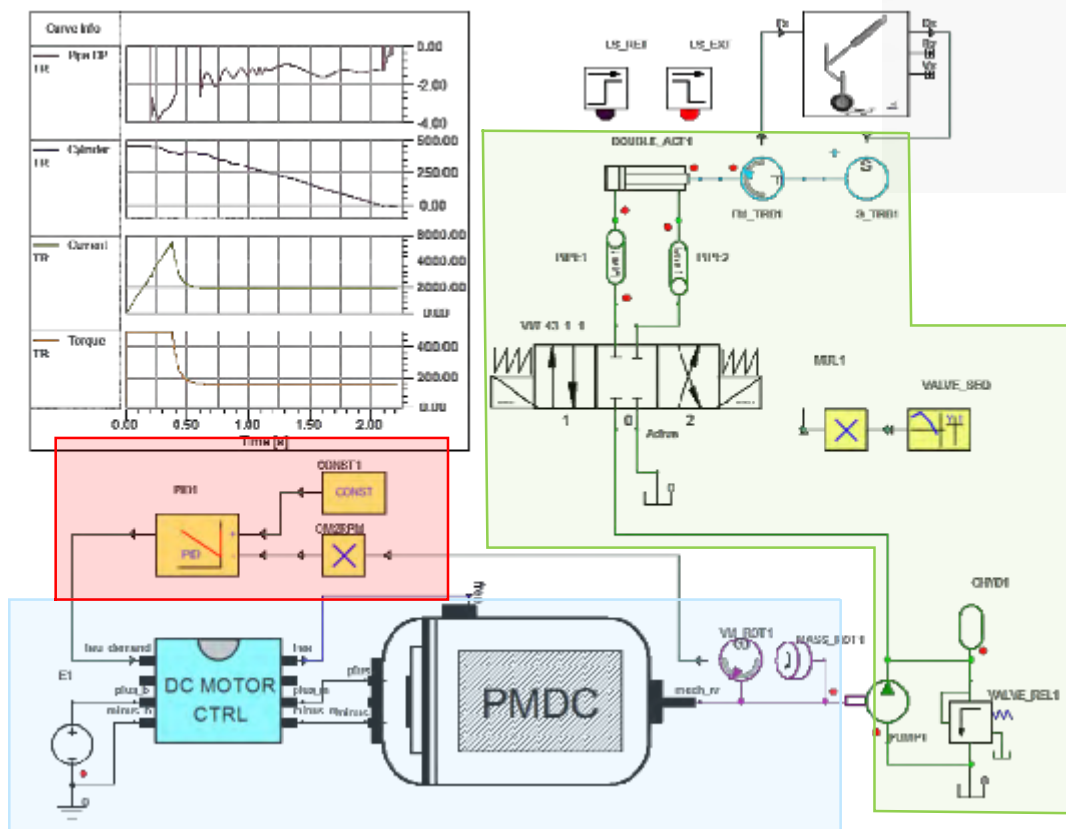
应用案例：起落架系统

系统仿真目标

- 起落架动态事件中的峰值载荷确定
- 验证控制策略并校准控制参数

关键系统级模型

- ANSYS Mechanical RBD:** 多体动力学模型
- ANSYS SCADE:** 认证代码的自动生成 (DO-178C)
- ANSYS Simplorer:** 外部条件、任务剖面、液压和电子子系统



用户案例分享：飞控系统



仿真
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感谢聆听

