ANSYS CONVERGENCE CONFERENCES

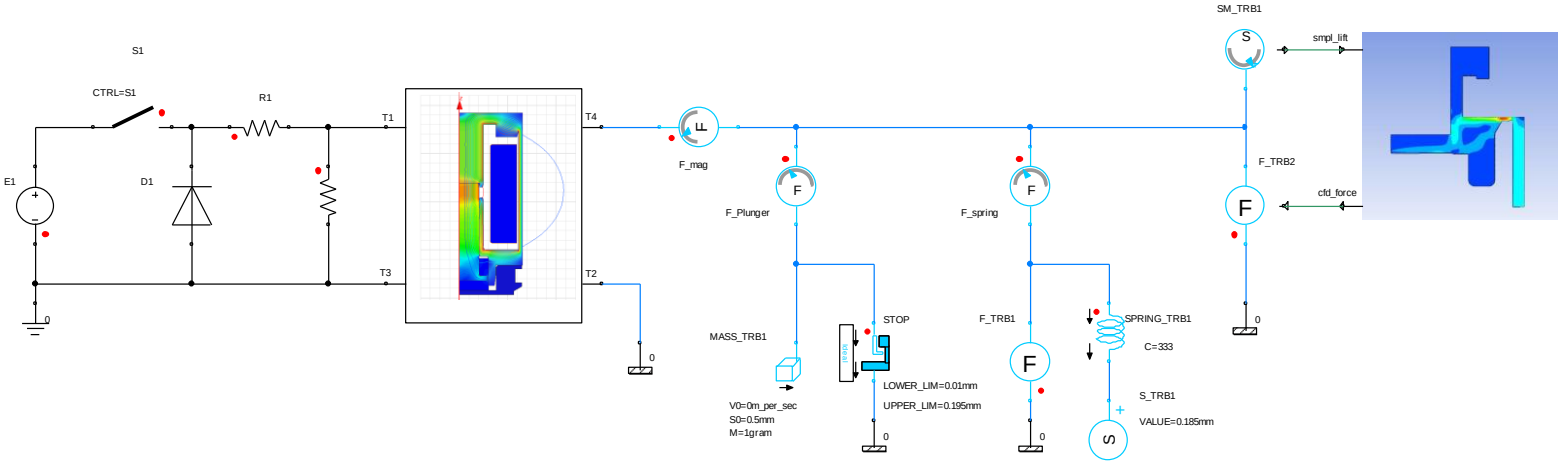
2018年7月11-13日 上海

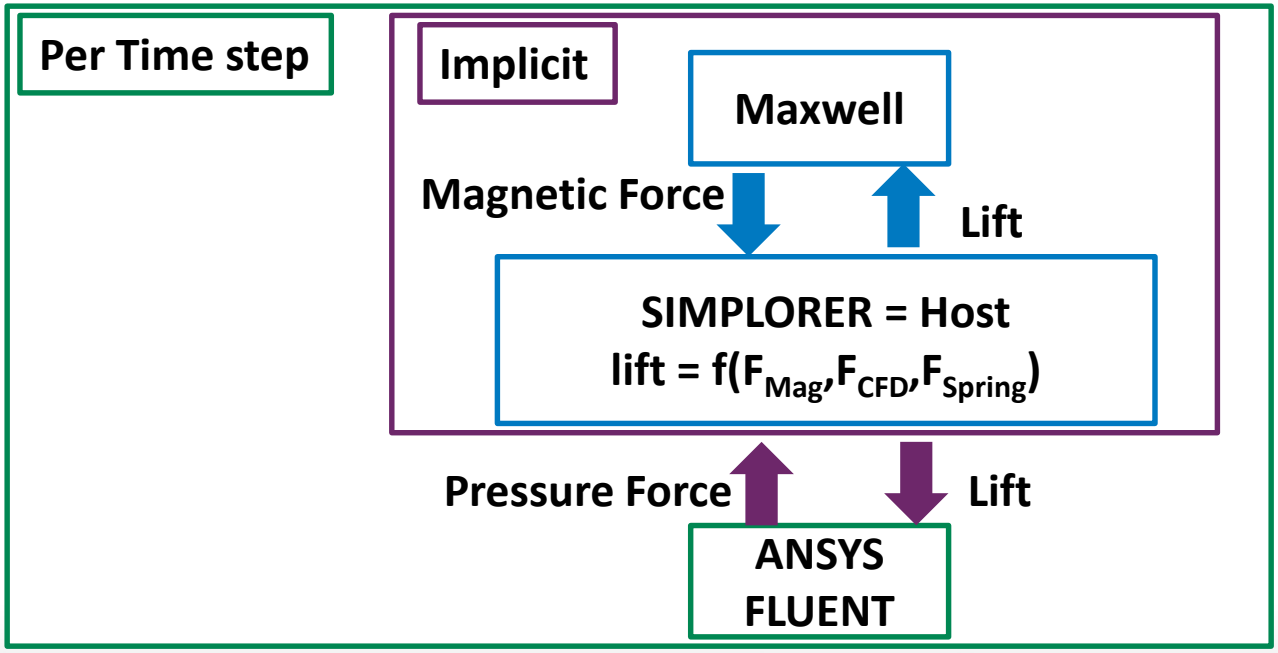
ANSYS数字孪生助力 产品创新

杨帆

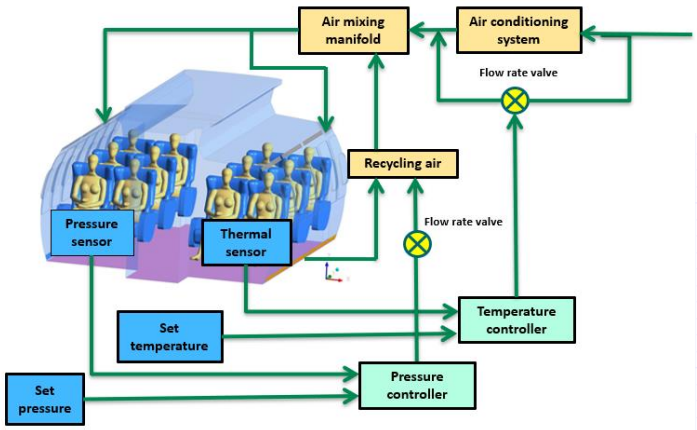
目录

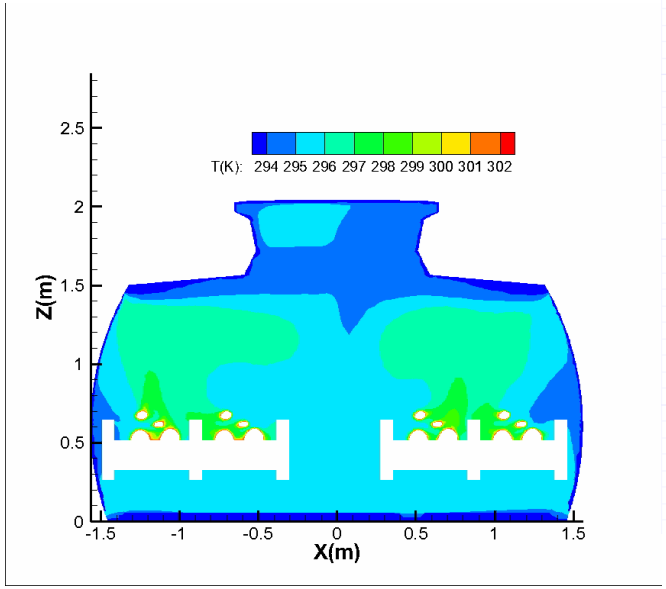
电磁阀——以3D为主

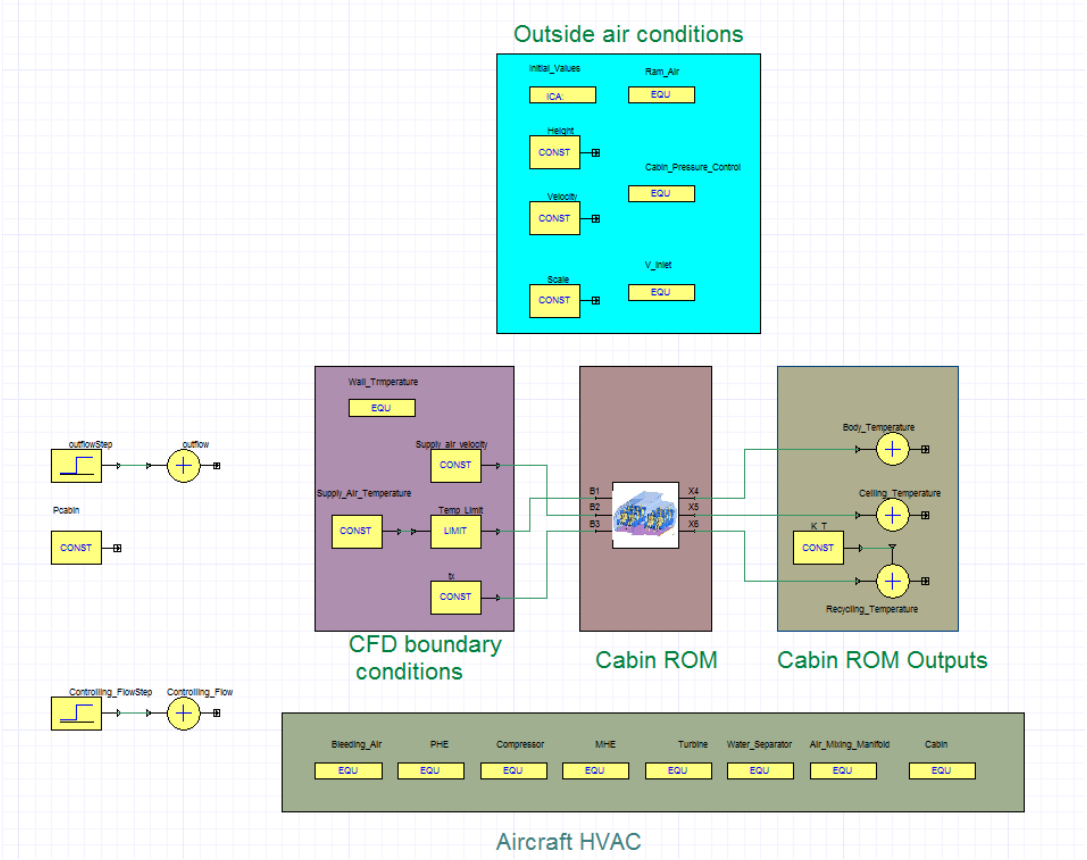




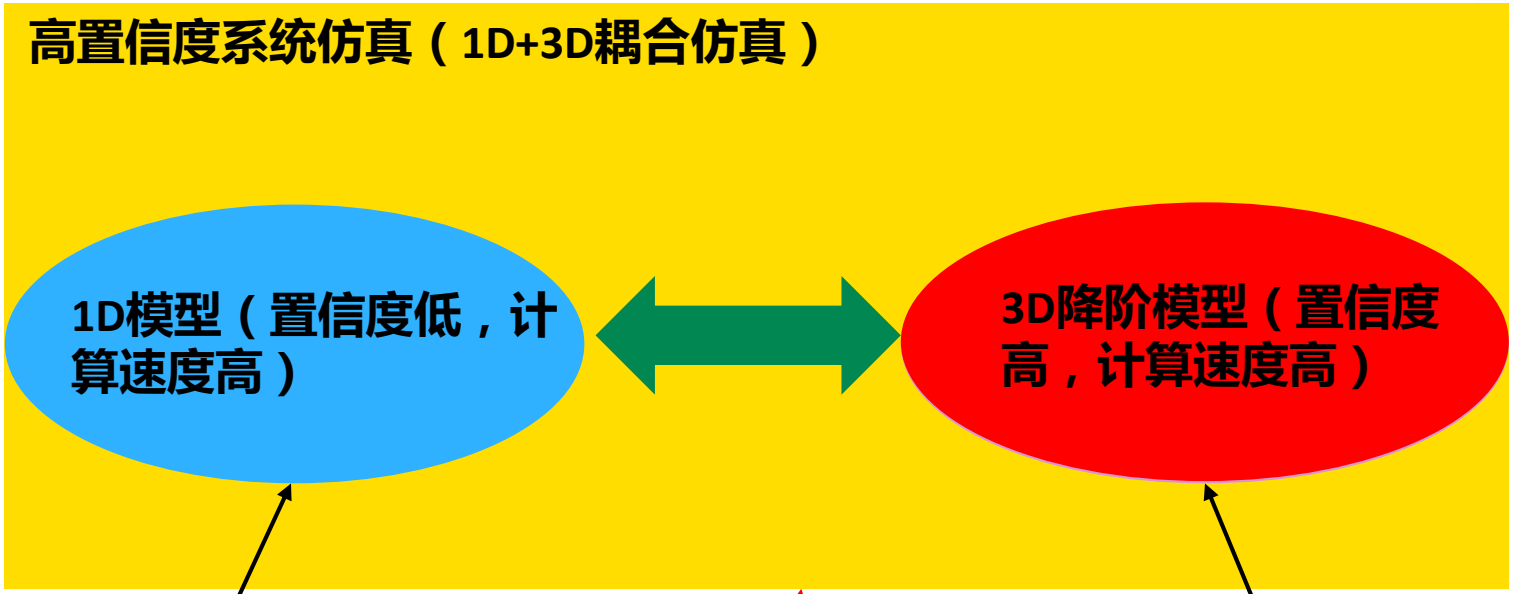
飞机环控系统——以系统为主







以系统为主的1D+3D耦合仿真的难点

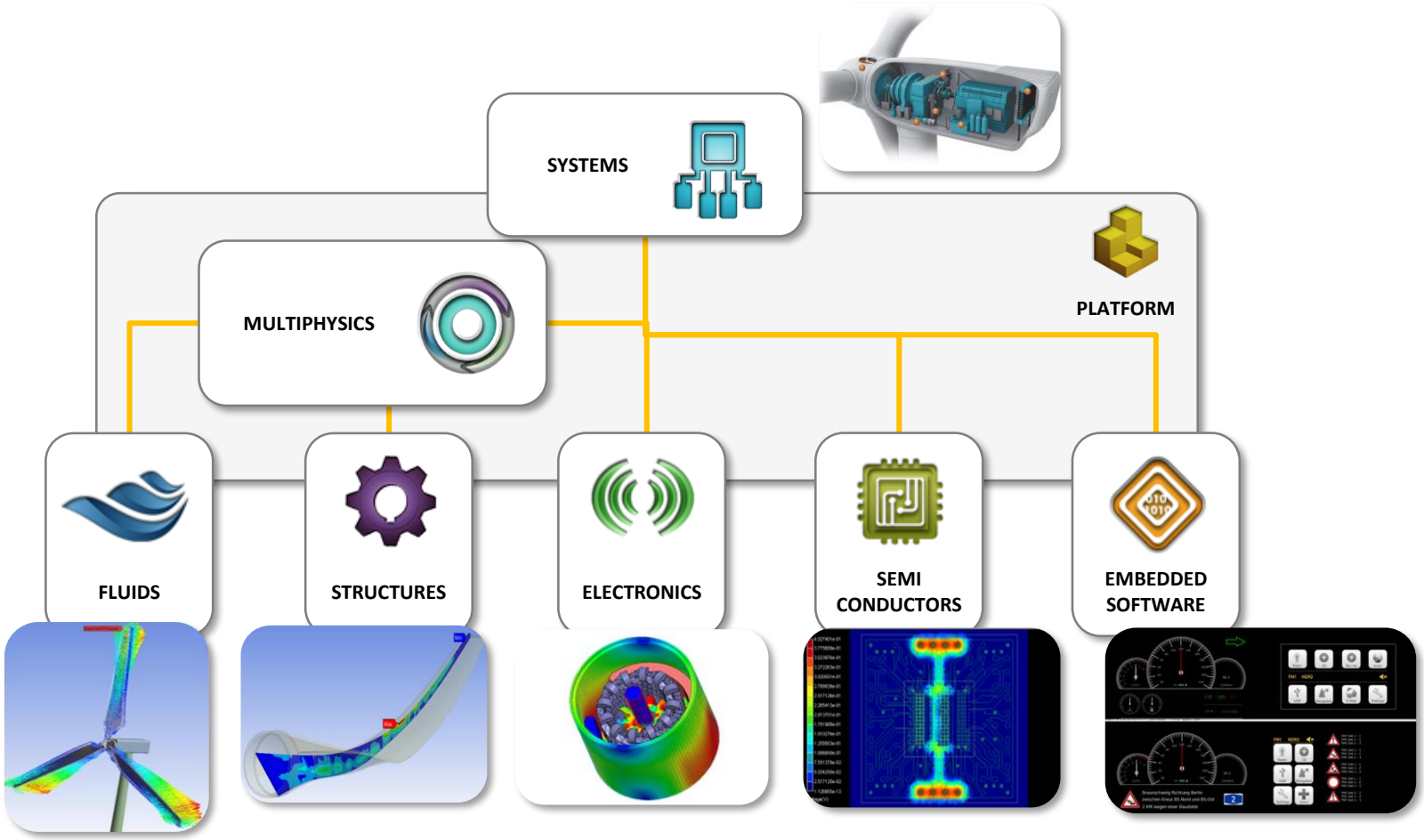


一个步长计算，毫秒级

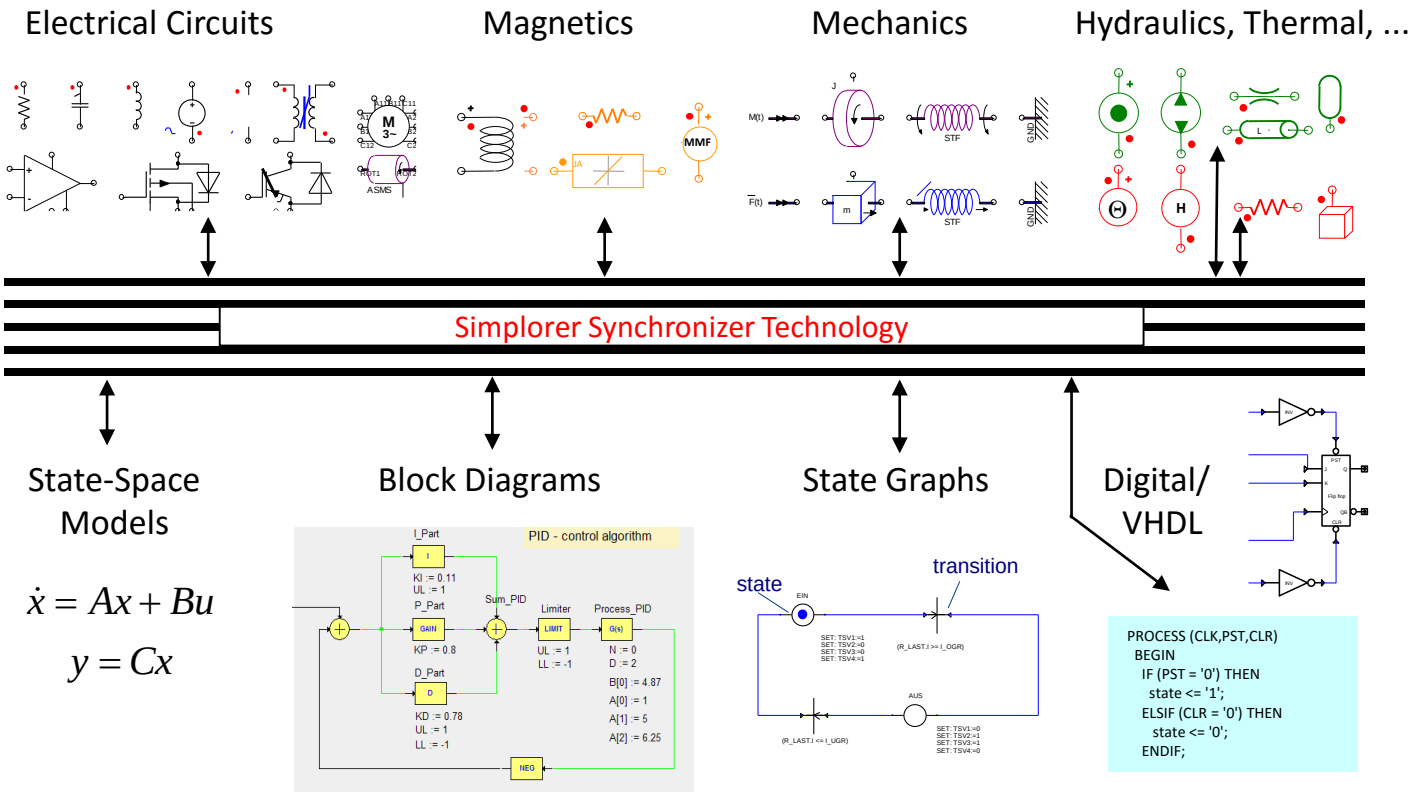
一个步长计算，毫秒-几百毫秒机

系统运行一秒的仿真时间，几秒-几分钟

ANSYS 仿真平台



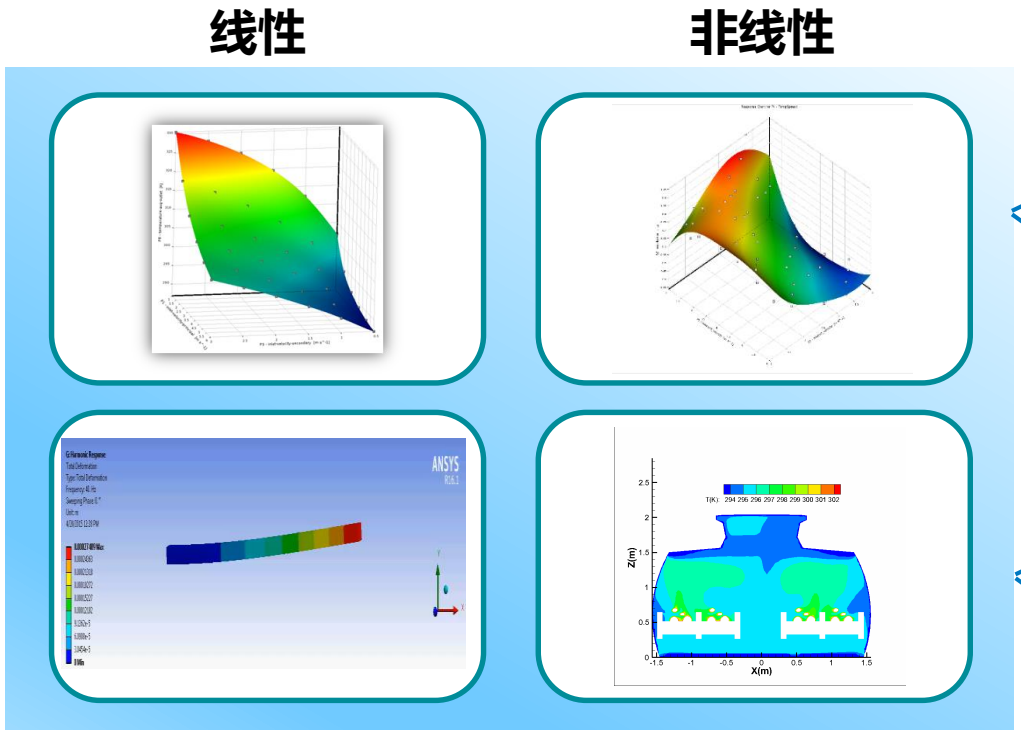
ANSYS Twin Builder – 多物理域仿真



目录

- ANSYS 系统仿真相关产品简介
- 降阶模型介绍
- 系统与三维耦合仿真应用案例
- ANSYS数字孪生介绍
- ANSYS数字孪生示例

ANSYS降阶模型的种类

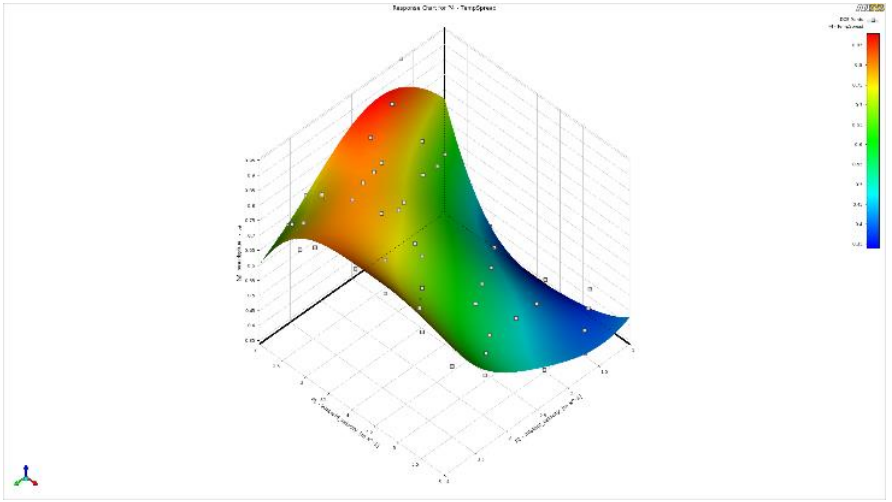


静态只输出接口数据——响应面降阶模型

Response Surface Modeling

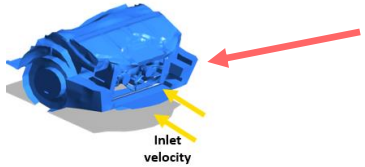
Table de Schéma B2: Plan d'expériences (Personnalisé + remplissage : Nombre total de points = 20)

	A	B	C	D	E	F	G	H	I	J
1	Nom	P1 - inlet -velocity -principal (m s^-1)	P2 - inlet -temperature -principal (C)	P3 - inlet -velocity -secondary (m s^-1)	P4 - inlet -tempera... -secondary (C)	P5 - pressure -drop -principal (Pa)	P6 - pressure -drop -secondary (Pa)	P7 - tempera... -max -outlet (K)	P8 - tempera... -avg-outlet (K)	P9 - temperature -point-outlet (K)
2	1	3,5	5	3,5	60	13024	12850	321,67	298,4	319,76
3	2	5,9006	9,6517	1,1516	79,393	8165,6	10938	330,88	290,47	330,48
4	3	5,7226	0,027105	1,0477	78,264	7313,6	9808,1	326,15	281,3	325,7
5	4	5,8995	0,32343	1,2792	40,448	8886,2	11851	301,85	278,32	301,63
6	5	1,2177	9,7172	5,7538	40,102	11945	5939,5	307,67	302,93	296,64
7	6	5,4229	9,9254	5,9732	79,814	34683	32514	338,08	310,26	335,27
8	7	5,9893	0,14884	5,8574	76,168	37042	36832	333,68	300,98	331,42
9	8	1,1292	9,4721	1,0421	77,542	1260,7	1282	335,86	306,4	332,91
10	9	5,9489	9,8079	5,7246	42,937	35913	35971	309,26	294,9	308,25
11	10	5,722	9,6062	1,1193	41,703	7700,1	10306	304,89	286,29	304,71
12	11	1,1901	8,7326	1,088	40,263	1384,9	1413,1	306,55	292,83	305,21
13	12	1,318	0,23442	5,564	40,576	11810	6114,3	305,1	299,39	292,52
14	13	1,5358	0,47407	5,7684	79,703	13473	7258,7	335,08	323,43	313,71
15	14	5,8859	0,42115	5,8085	40,941	36142	35419	305,42	288,36	303,79
16	15	1,2046	0,29695	1,0611	47,395	1365,3	1410,1	310,35	289,46	308,45
17	16	1,1244	9,576	5,693	79,866	11330	5515,4	341,18	329,82	313,97
18	17	1,8403	1,2284	1,1031	78,849	2155,8	2484	335,99	295,12	334,71
19	18	5,6622	5,1409	3,4435	79,261	20332	23548	337,52	298,35	336,7
20	19	5,9416	5,229	1,0888	60,731	7880,8	10579	315,97	284,15	315,65
21	20	3,4149	9,8548	3,2845	77,009	11885	11912	336,06	307,16	333,69
*	Nouveau point de conception									



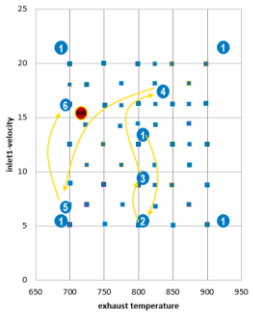
- The values of output parameters as a function of input parameters are obtained on the design points defined in the design of experiments
- Interpolation methods are essential to the model

静态输出变量场数据——静态ROM生成模块

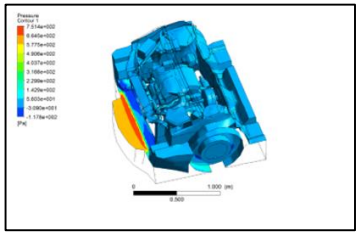


汽车发动机外部冷却空气流场仿真案例。两个冷却空气进口的流速作为输入变量。

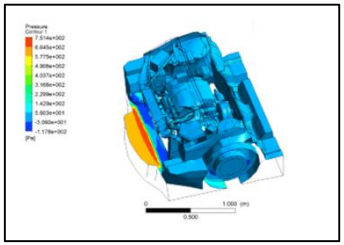
降阶模型生成方法



CFD 仿真结果



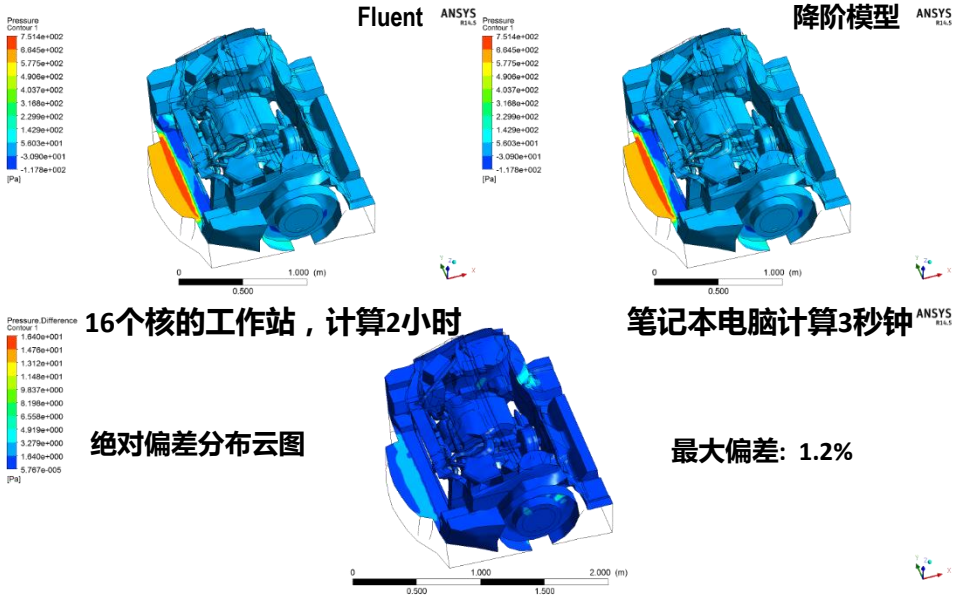
降阶模型仿真结果



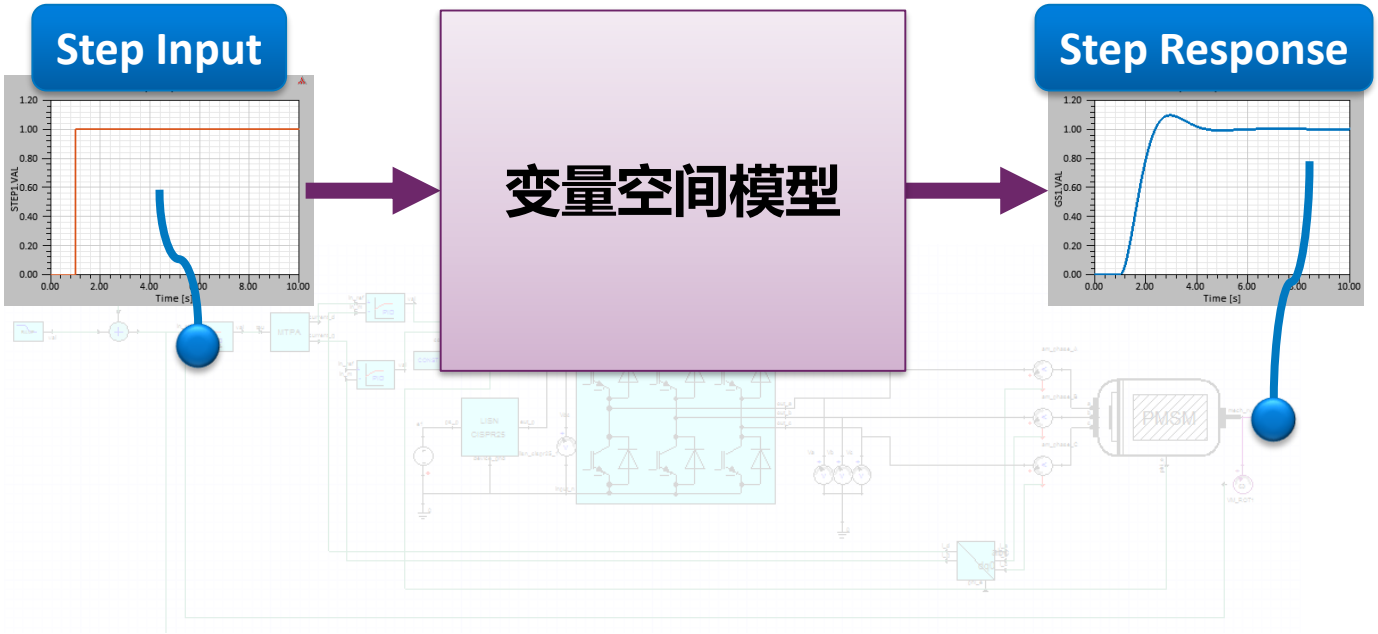
利用深度学习算法进行10次CFD仿真，获得整个工作范围内的流场分布降阶模型

CFD与降阶模型计算对比

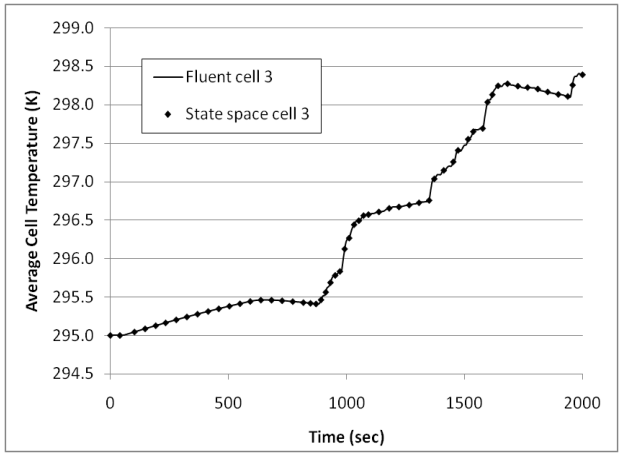
当生成降阶模型后，我们在工作范围内随机选取一个工况，分别采用Fluent和降阶模型进行计算，对比结果如下：



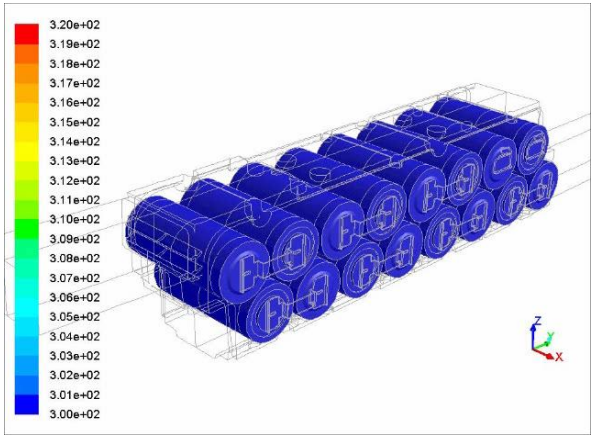
动态线性只输出接口数据——LTI技术



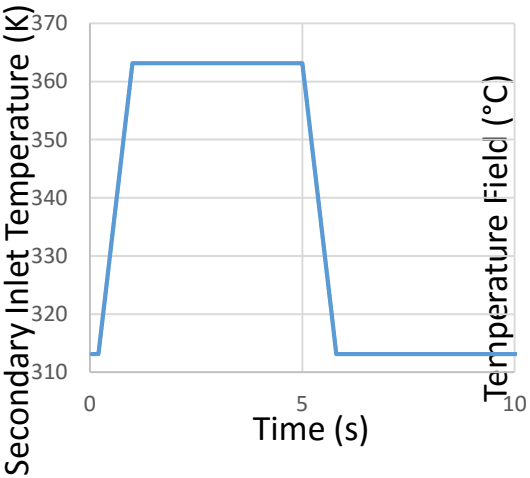
动态线性输出变量场数据——SVD技术

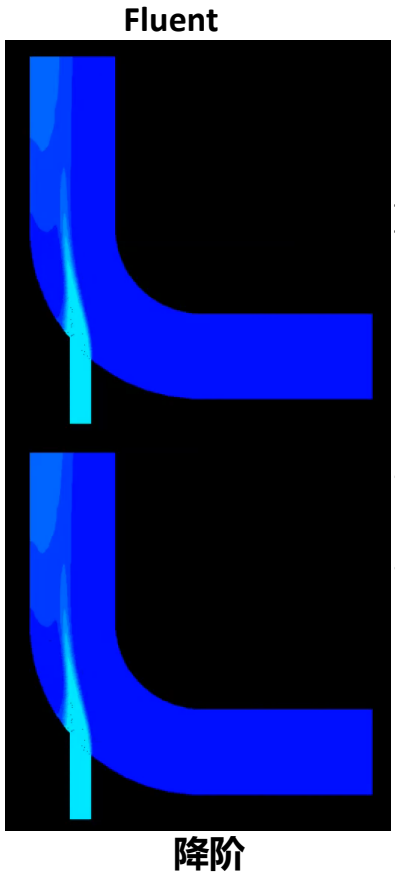


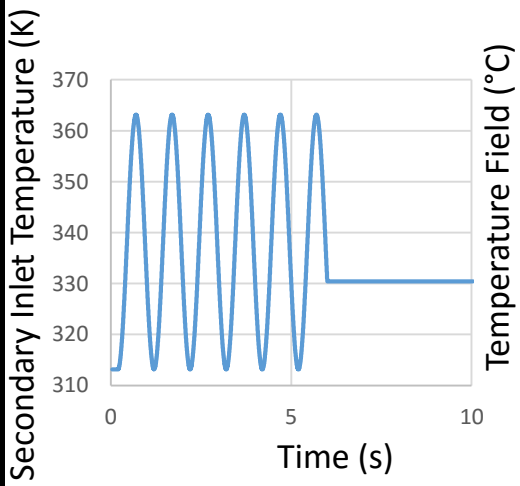
VS

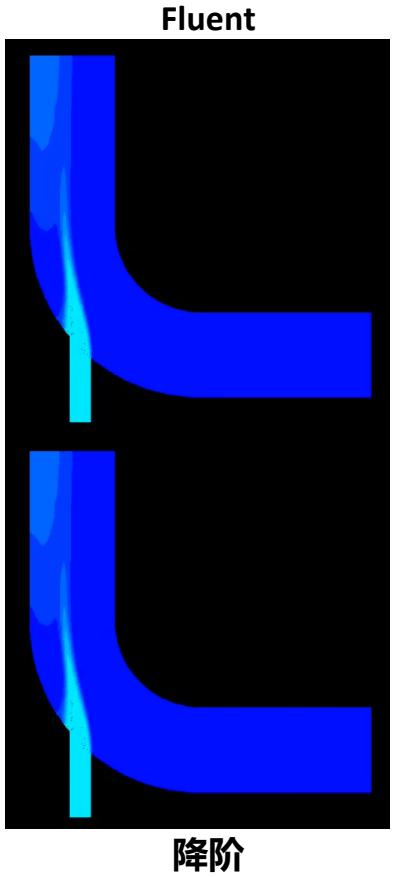


动态非线性输出变量场数据









SVD+机器学习（深度学习）+递归神经网络

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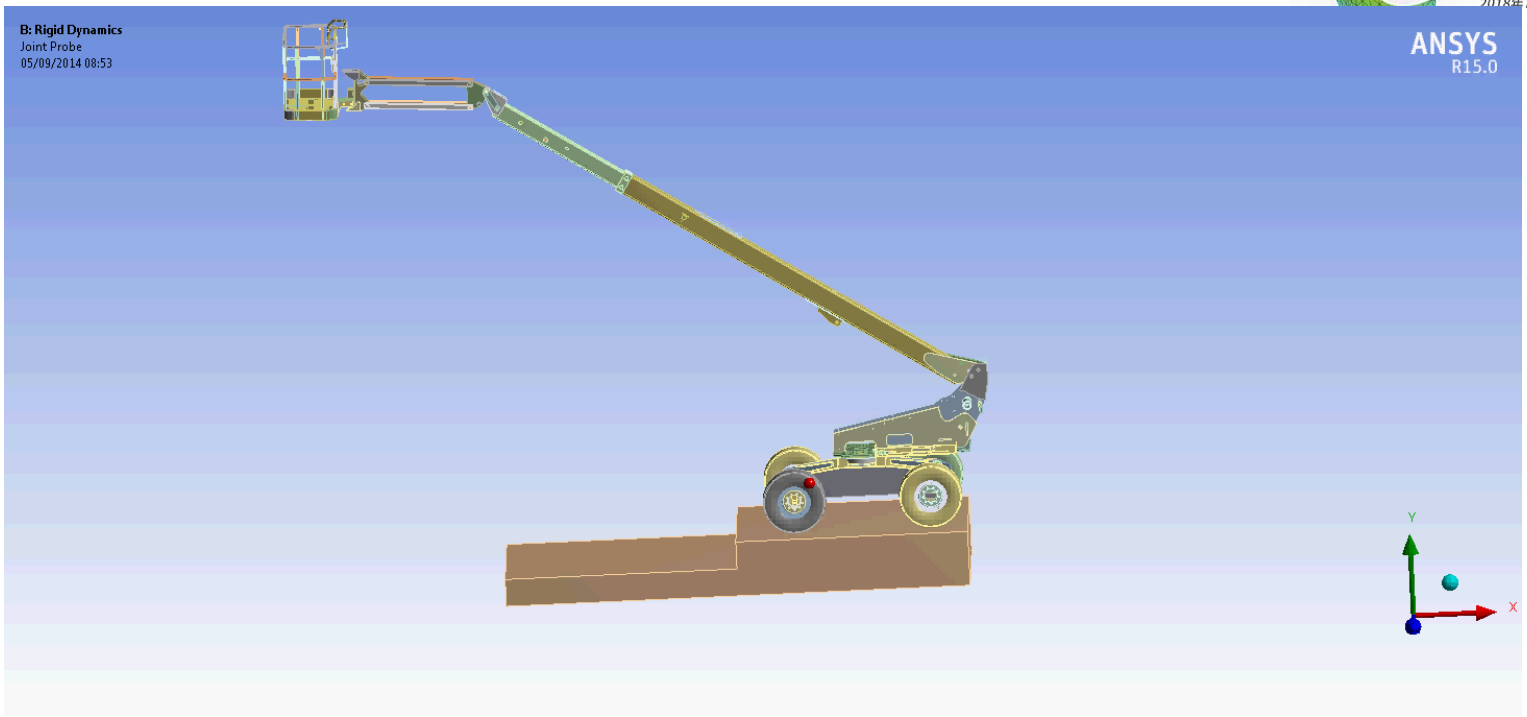
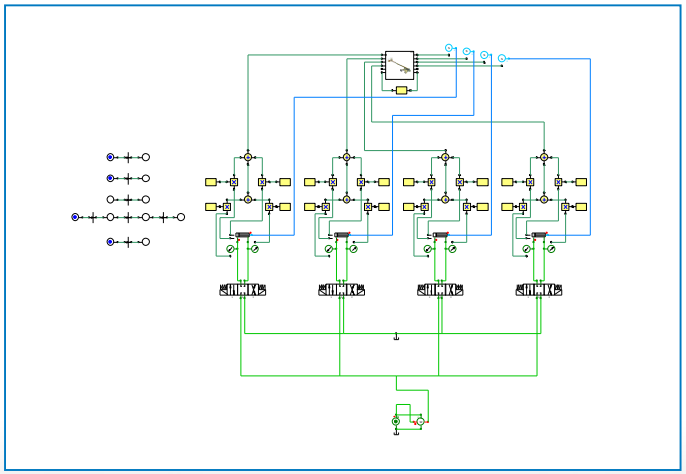
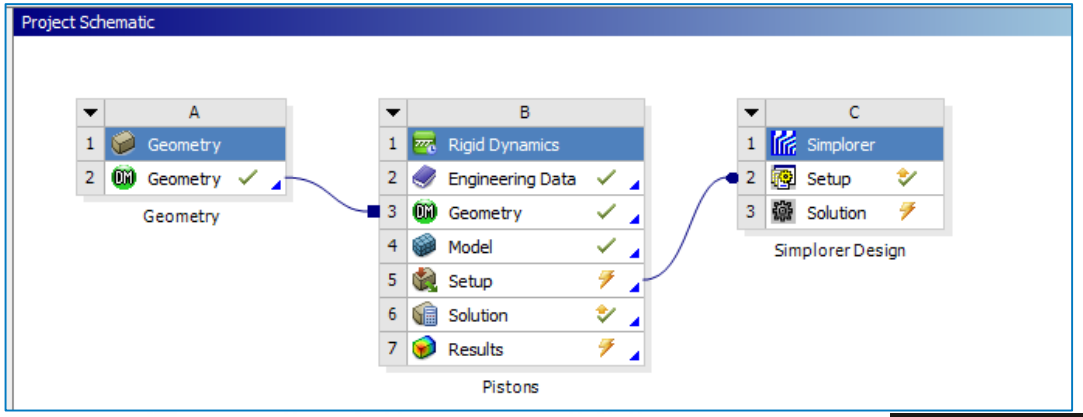
- ANSYS数字孪生示例

云梯分析案例


B: Rigid Dynamics
Joint Probe
05/09/2014 08:53
ANSYS
R15.0
Y
X




Project Schematic
A
1 Geometry
2 Geometry
Geometry
B
1 Rigid Dynamics
2 Engineering Data
3 Geometry
4 Model
5 Setup
6 Solution
7 Results
Pistons
C
1 Simplorer
2 Setup
3 Solution
Simplorer Design

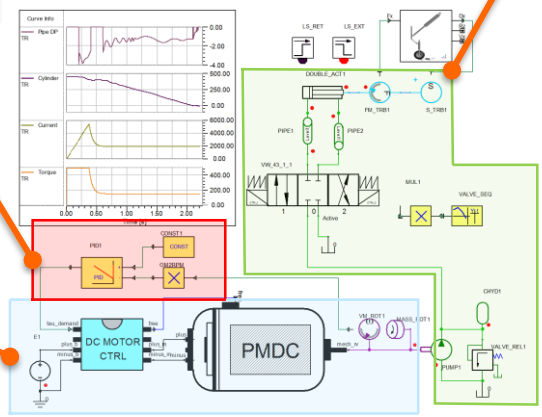
起落架分析案例

Mechanical RBD
Retraction cylinder controlled by Simplorer

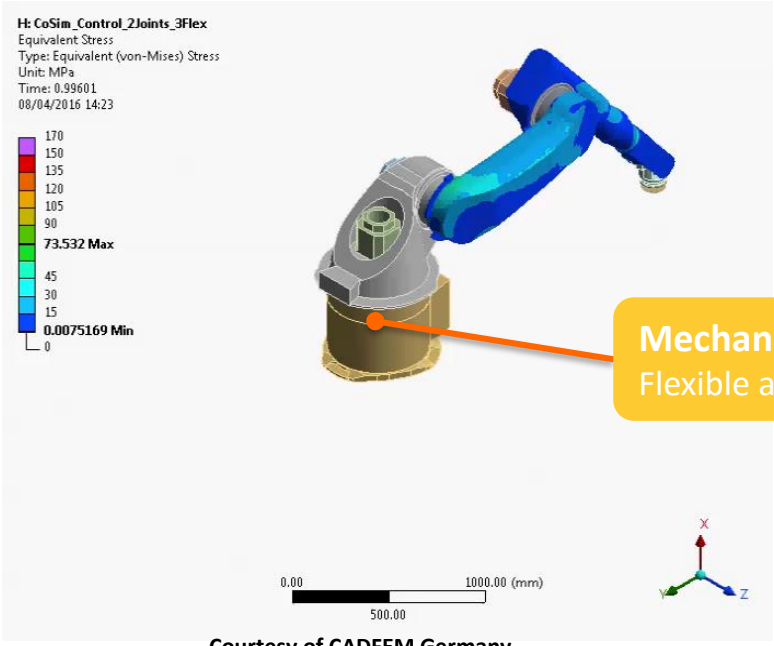
Hydraulics in Simplorer
Pump, 3-way valve, pipes, cylinder

Control in Simplorer
PID control for pump speed

Electronics in Simplorer
Motor and control electronics



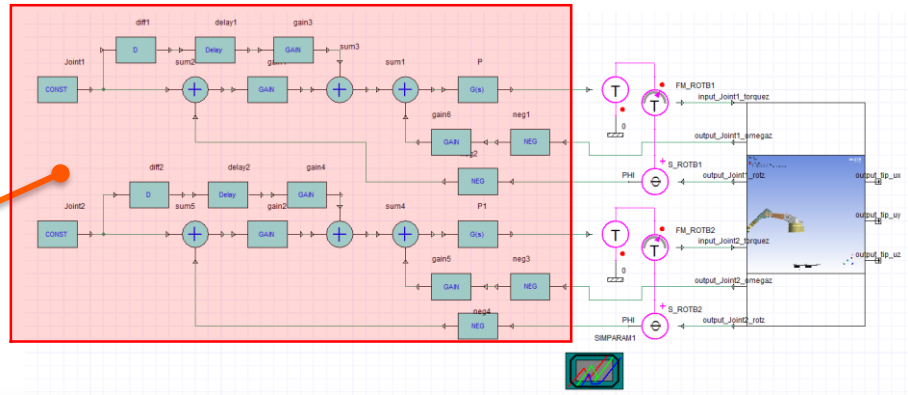
机械臂分析案例



Mechanical RBD
Flexible arm, stress results

Courtesy of CADFEM Germany

Control in Simplorer
Two-axis control



XX飞行器案例

系统仿真模型

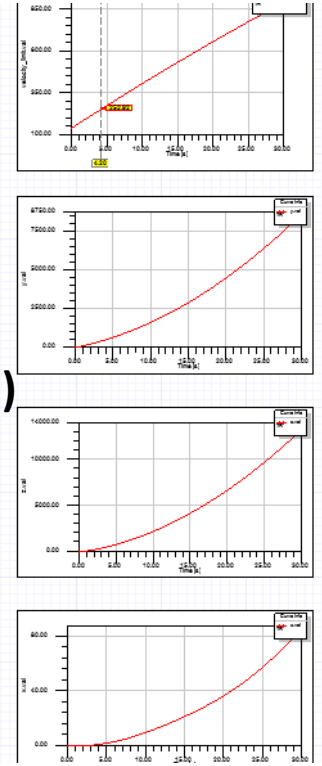
基于Modelica语言的系统模型

燃料量(输入)

舵偏(输入)

弹的坐标(输出)

基于3D仿真建立的降阶模型



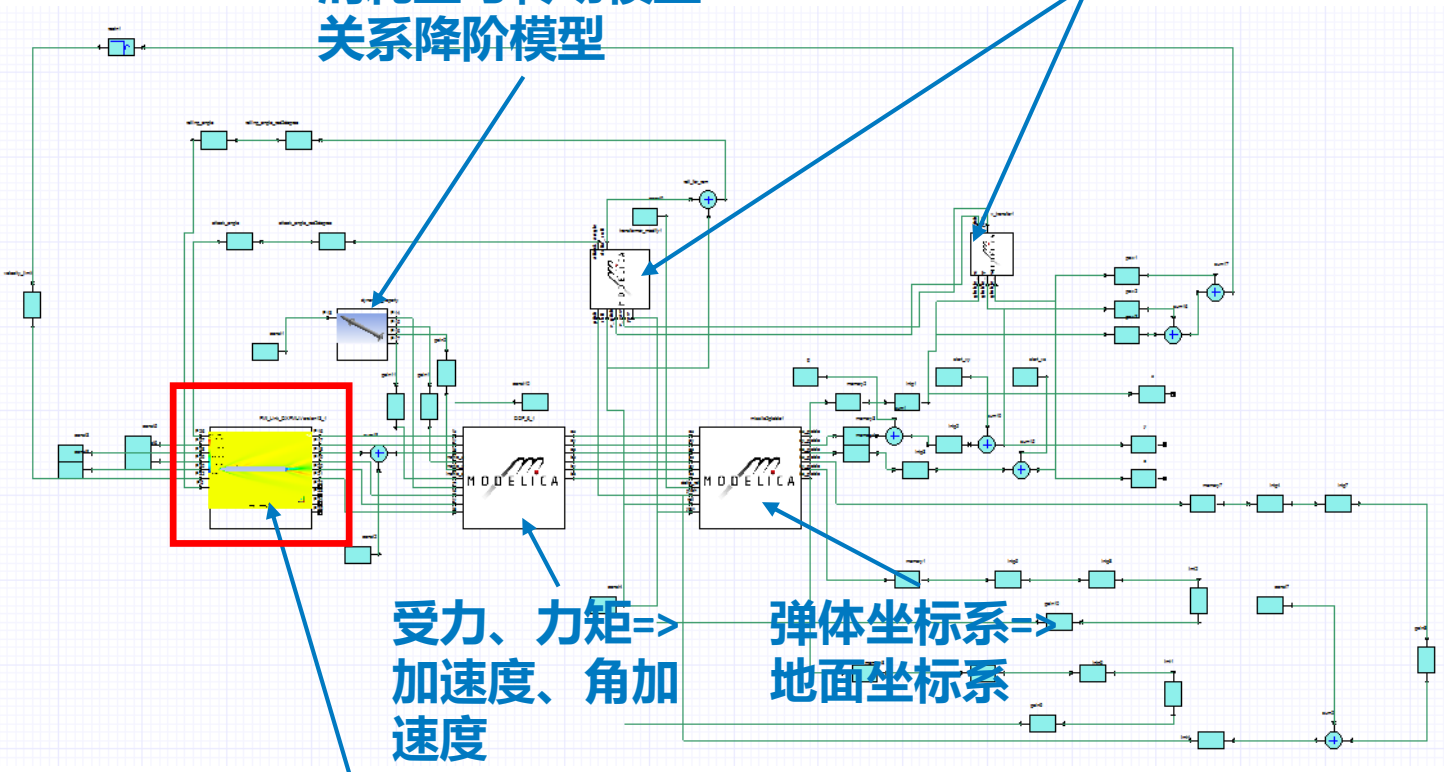
舵偏 → 动力学系统模型 → 飞行轨迹

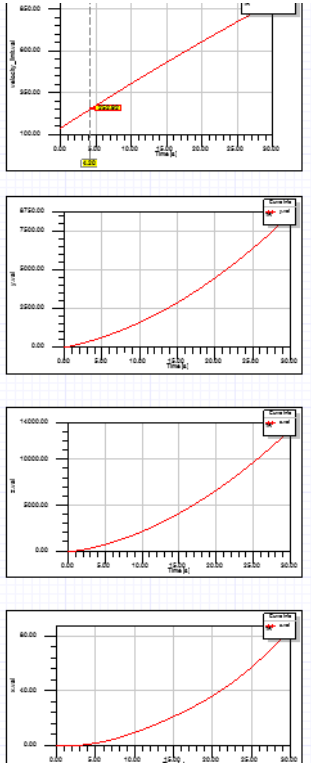
燃料量 → 动力学系统模型

系统模型各部分功能

基于3D计算的燃料消耗量与转动惯量关系降阶模型

地面坐标系速度与姿态=>折合攻角与滚转角





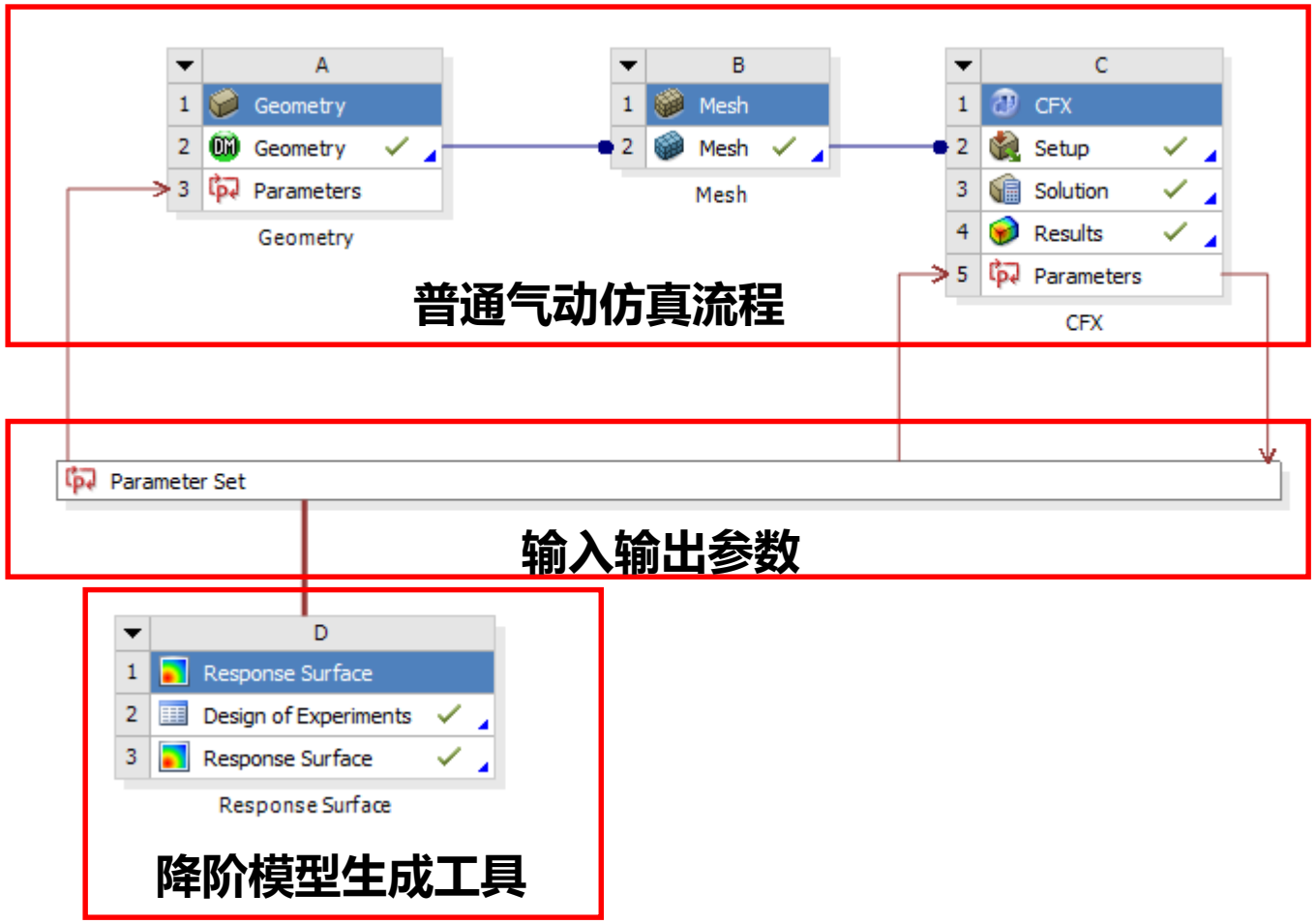
受力、力矩=>加速度、角加速度

弹体坐标系=>地面坐标系

基于3D气动计算的相应面降阶模型：

（气动力，气动力矩，舵扭矩）=f（舵偏，速度，攻角，滚转角）

气动降阶模型的生成



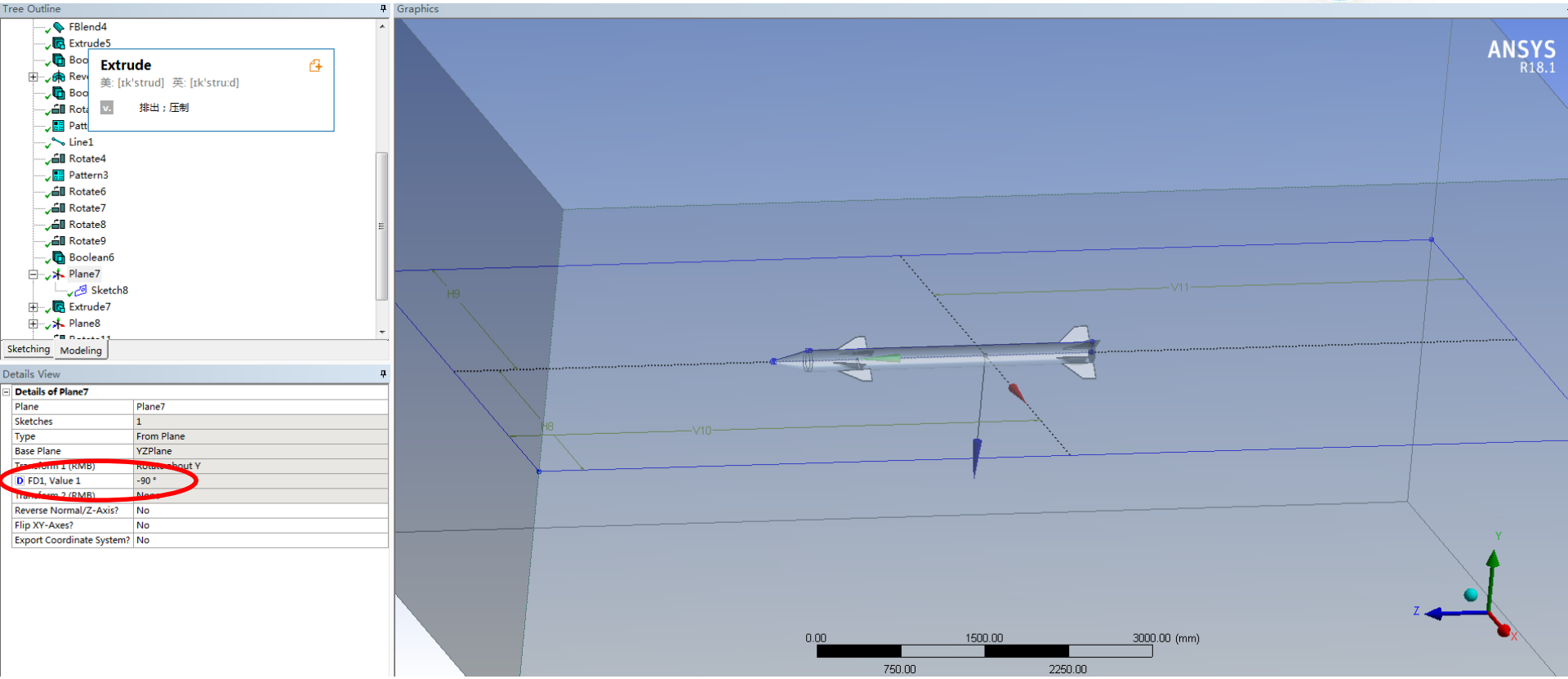
建立普通的气动仿真流程

把要用的输入、输出参数设置成降阶模型输入输出参数

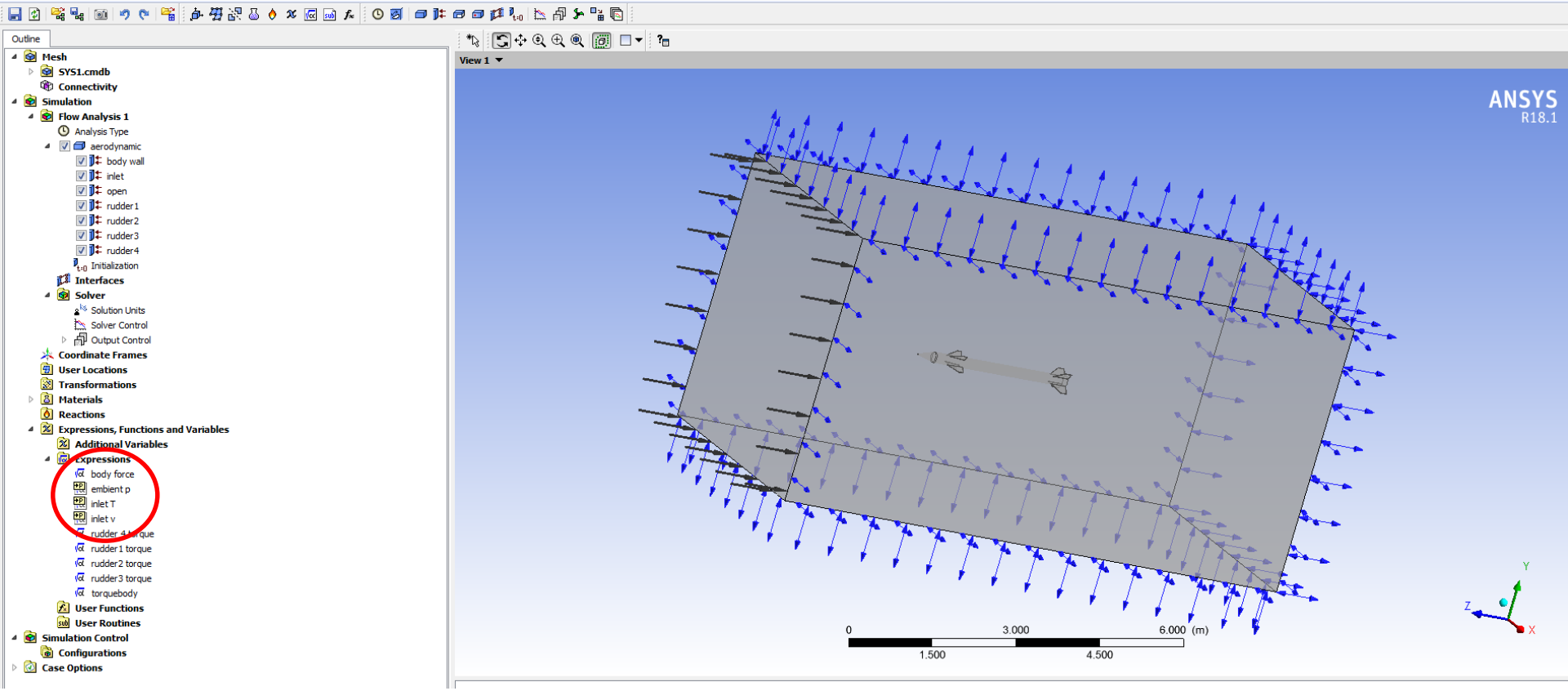
利用降阶模型生成工具重复运行仿真流程，计算所有采样点

根据采样点计算结果生成降阶模型

攻角、滚转角与舵偏的参数化



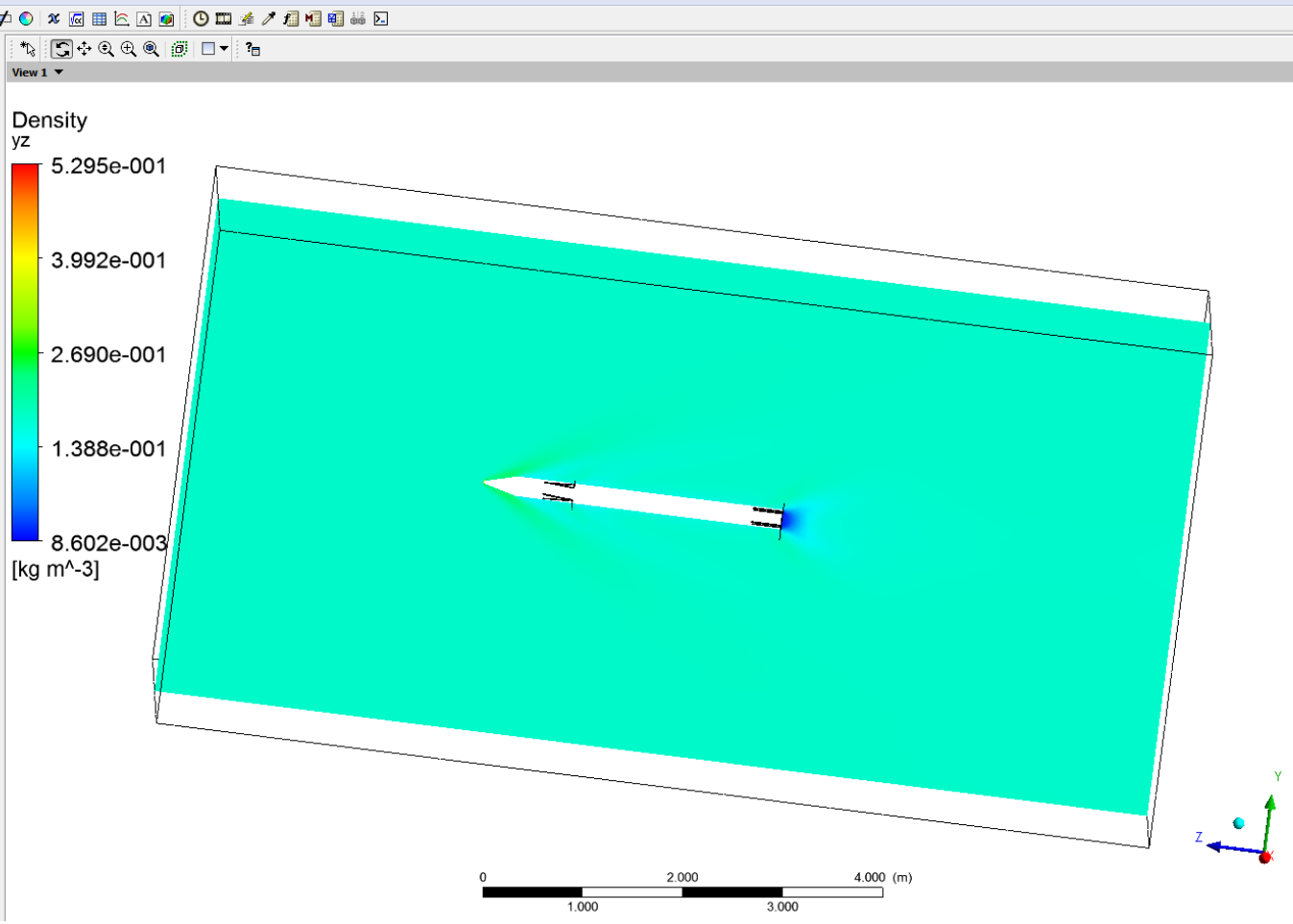
飞行速度参数化


Outline
Mesh
SYS1.cmdb
Connectivity
Simulation
Flow Analysis 1
Analysis Type
aerodynamic
body wall
inlet
open
rudder1
rudder2
rudder3
rudder4
Initialization
Interfaces
Solver
Solution Units
Solver Control
Output Control
Coordinate Frames
User Locations
Transformations
Materials
Reactions
Expressions, Functions and Variables
Additional Variables
Expressions
body force
embient p
inlet T
inlet v
rudder 4 torque
rudder1 torque
rudder2 torque
rudder3 torque
torquebody
User Functions
User Routines
Simulation Control
Configurations
Case Options
View 1
ANSYS
R18.1
0
3.000
6.000 (m)
1.500
4.500
Y
Z
X

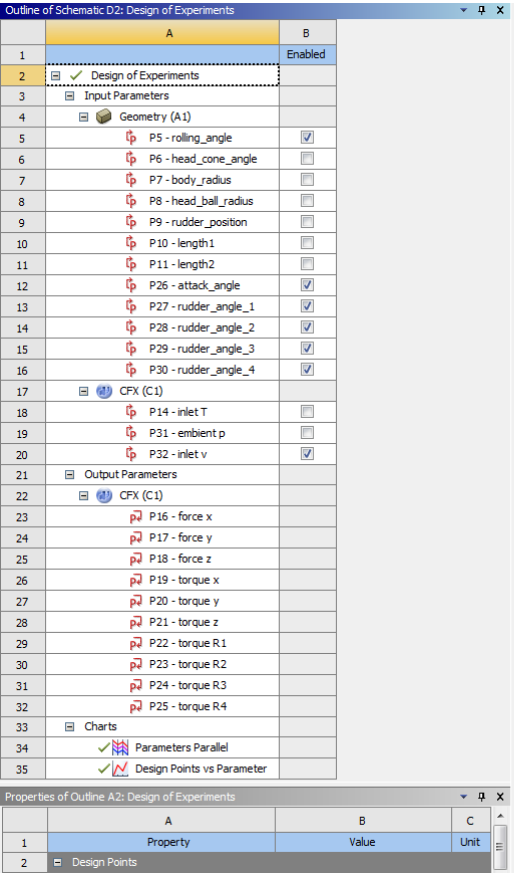
气动力等输出参数设置

Outline | Variables | Expressions | Calculators | Turbo

Time	0 [s]
atstep	Accumulated Time Step
body force	force()@body wall
ctstep	Current Time Step
ambient p	10132.5 [Pa]
force x	force_x()@body wall +force_x()@rudder1 +force_x()@rudder
force y	force_y()@body wall +force_y()@rudder1 +force_y()@rudder
force z	force_z()@body wall +force_z()@rudder1 +force_z()@rudder
inlet T	200 [K]
inlet v	600 [m s^-1]
rudder 4 torque	torque()@rudder4
rudder1 torque	torque()@rudder1
rudder2 torque	torque()@rudder2
rudder3 torque	torque()@rudder3
sstep	Sequence Step
t	Time
torque R1	(torque_x()@rudder1 ^2+torque_y()@rudder1 ^2)^0.5
torque R2	(torque_x()@rudder2 ^2+torque_y()@rudder2 ^2)^0.5
torque R3	(torque_x()@rudder3 ^2+torque_y()@rudder3 ^2)^0.5
torque R4	(torque_x()@rudder4 ^2+torque_y()@rudder4 ^2)^0.5
torque x	torque_x()@body wall +torque_x()@rudder1 +torque_x()@ru
torque y	torque_y()@body wall +torque_y()@rudder1 +torque_y()@ru
torque z	torque_z()@body wall +torque_z()@rudder1 +torque_z()@ruc
torquebody	torque()@body wall



输入与输出参数列表



Outline of Schematic D2: Design of Experiments

	A	B
1		Enabled
2	Design of Experiments	
3	Input Parameters	
4	Geometry (A1)	
5	P5 - rolling_angle	☑
6	P6 - head_cone_angle	☐
7	P7 - body_radius	☐
8	P8 - head_ball_radius	☐
9	P9 - rudder_position	☐
10	P10 - length1	☐
11	P11 - length2	☐
12	P26 - attack_angle	☑
13	P27 - rudder_angle_1	☑
14	P28 - rudder_angle_2	☑
15	P29 - rudder_angle_3	☑
16	P30 - rudder_angle_4	☑
17	CFX (C1)	
18	P14 - inlet T	☐
19	P31 - embient p	☐
20	P32 - inlet v	☑
21	Output Parameters	
22	CFX (C1)	
23	P16 - force x	
24	P17 - force y	
25	P18 - force z	
26	P19 - torque x	
27	P20 - torque y	
28	P21 - torque z	
29	P22 - torque R1	
30	P23 - torque R2	
31	P24 - torque R3	
32	P25 - torque R4	
33	Charts	
34	Parameters Parallel	
35	Design Points vs Parameter	

Properties of Outline A2: Design of Experiments

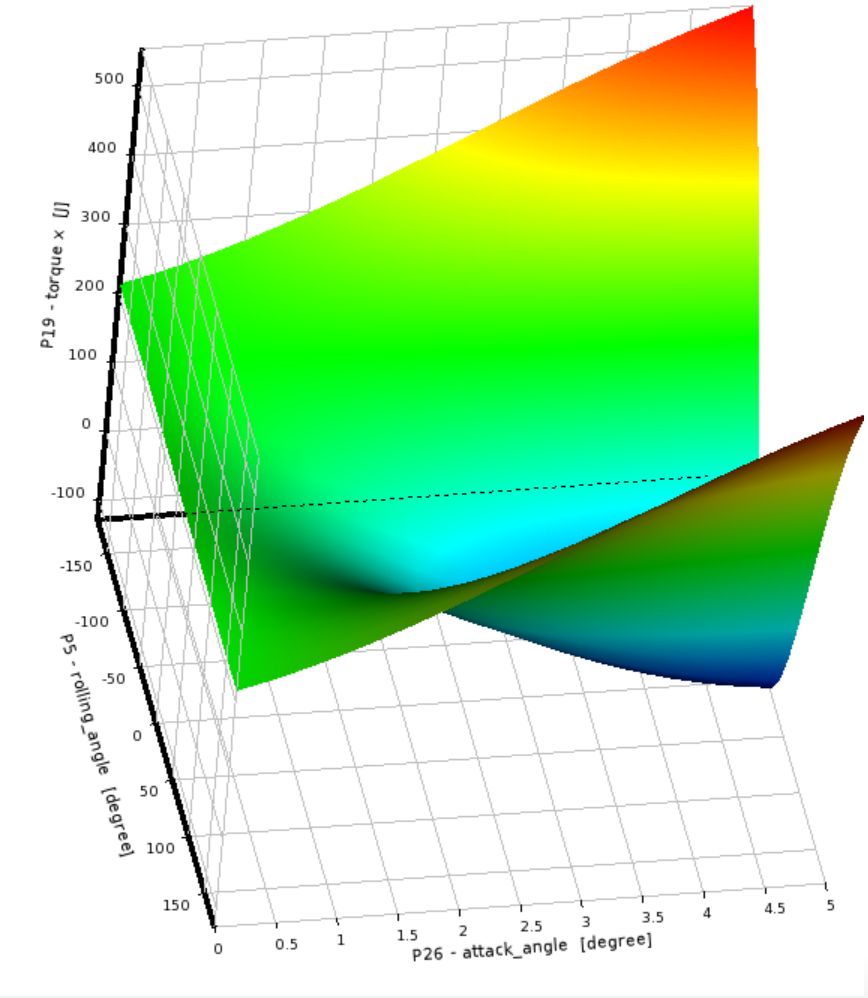
	A	B	C
1	Property	Value	Unit
2	Design Points		

Table of Outline A2: Design Points of Design of Experiments

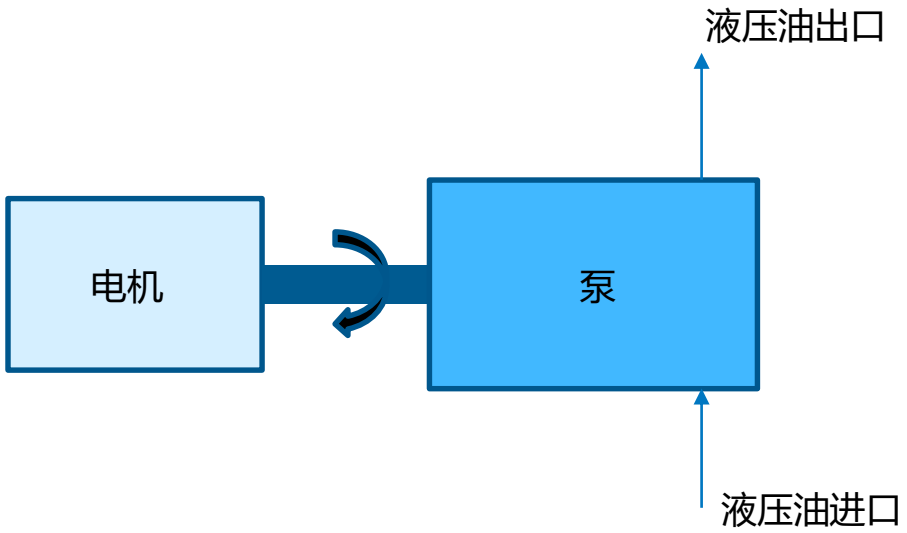
	A	B	C	D	E	F	G	H	
1	Name	Update Order	P5 - rolling_angle (degree)	P26 - attack_angle (degree)	P27 - rudder_angle_1 (degree)	P28 - rudder_angle_2 (degree)	P29 - rudder_angle_3 (degree)	P30 - rudder_angle_4 (degree)	P32
2	1	1	-180	0	5	5	-5	-5	1
3	2	2	-180	5	5	5	-5	-5	1
4	3	3	-180	0	5	5	-5	-5	200
5	4	4	-180	5	5	5	-5	-5	200
6	5	5	-180	0	5	5	-5	-5	400
7	6	6	-180	5	5	5	-5	-5	400
8	7	7	-180	0	5	5	-5	-5	600
9	8	8	-180	5	5	5	-5	-5	600
10	9	9	-180	0	5	5	-5	-5	800
11	10	10	-180	5	5	5	-5	-5	800
12	11	11	-180	0	5	5	-5	-5	100
13	12	12	-180	5	5	5	-5	-5	100
14	13	13	-90	0	5	5	-5	-5	1
15	14	14	-90	5	5	5	-5	-5	1
16	15	15	-90	0	5	5	-5	-5	200
17	16	16	-90	5	5	5	-5	-5	200
18	17	17	-90	0	5	5	-5	-5	400
19	18	18	-90	5	5	5	-5	-5	400
20	19	19	-90	0	5	5	-5	-5	600
21	20	20	-90	5	5	5	-5	-5	600
22	21	21	-90	0	5	5	-5	-5	800
23	22	22	-90	5	5	5	-5	-5	800
24	23	23	-90	0	5	5	-5	-5	100
25	24	24	-90	5	5	5	-5	-5	100
26	25	25	0	0	5	5	-5	-5	1
27	26	26	0	5	5	5	-5	-5	1
28	27	27	0	0	5	5	-5	-5	200
29	28	28	0	5	5	5	-5	-5	200
30	29	29	0	0	5	5	-5	-5	400
31	30	30	0	5	5	5	-5	-5	400
32	31	31	0	0	5	5	-5	-5	600
33	32	32	0	5	5	5	-5	-5	600
34	33	33	0	0	5	5	-5	-5	800
35	34	34	0	5	5	5	-5	-5	800
36	35	35	0	0	5	5	-5	-5	100
37	36 DP 19	36	0	5	5	5	-5	-5	100
38	37	37	90	0	5	5	-5	-5	1
39	38	38	90	5	5	5	-5	-5	1
40	39	39	90	0	5	5	-5	-5	200

7个输入量，10个输出量，共500个点

最终获得的函数关系（响应面）

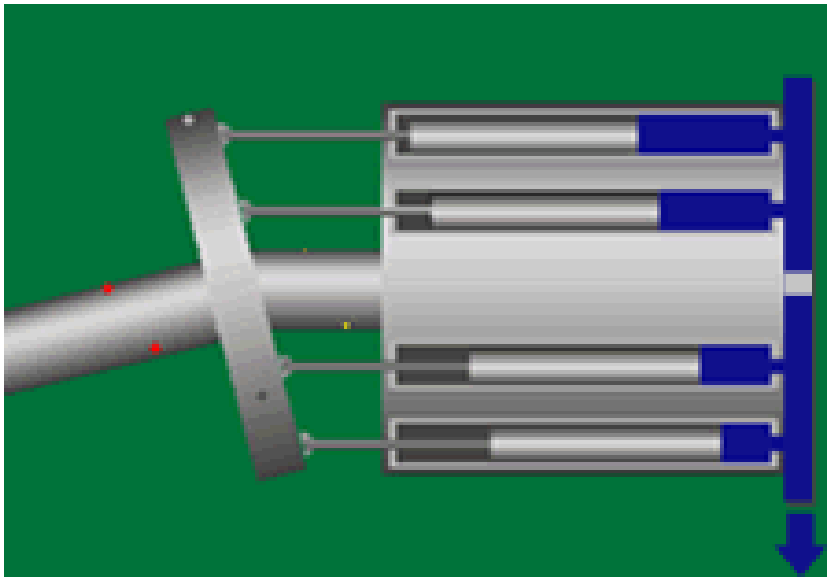


正在进行的项目

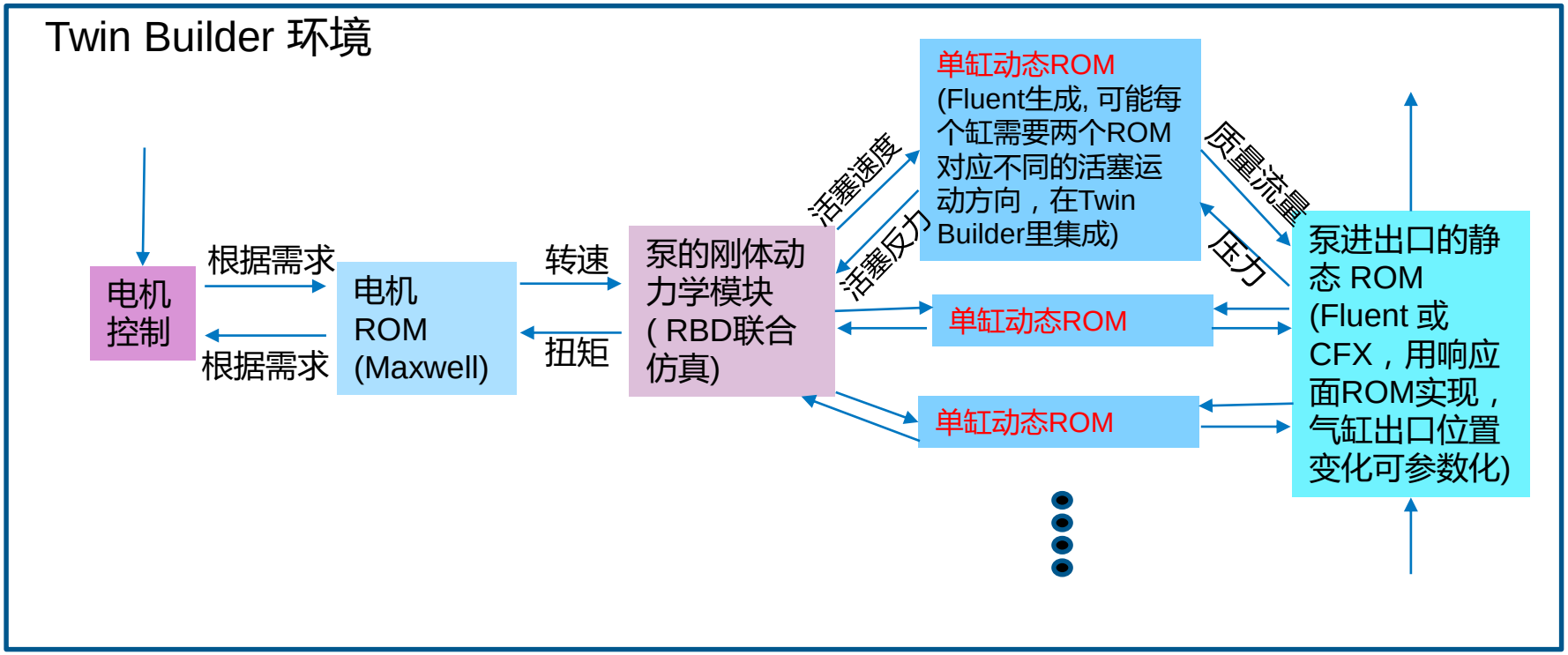


- 边界条件:
  - 电机电源
  - 泵的进出口压力
- 需要计算的:
  - 液压油流量

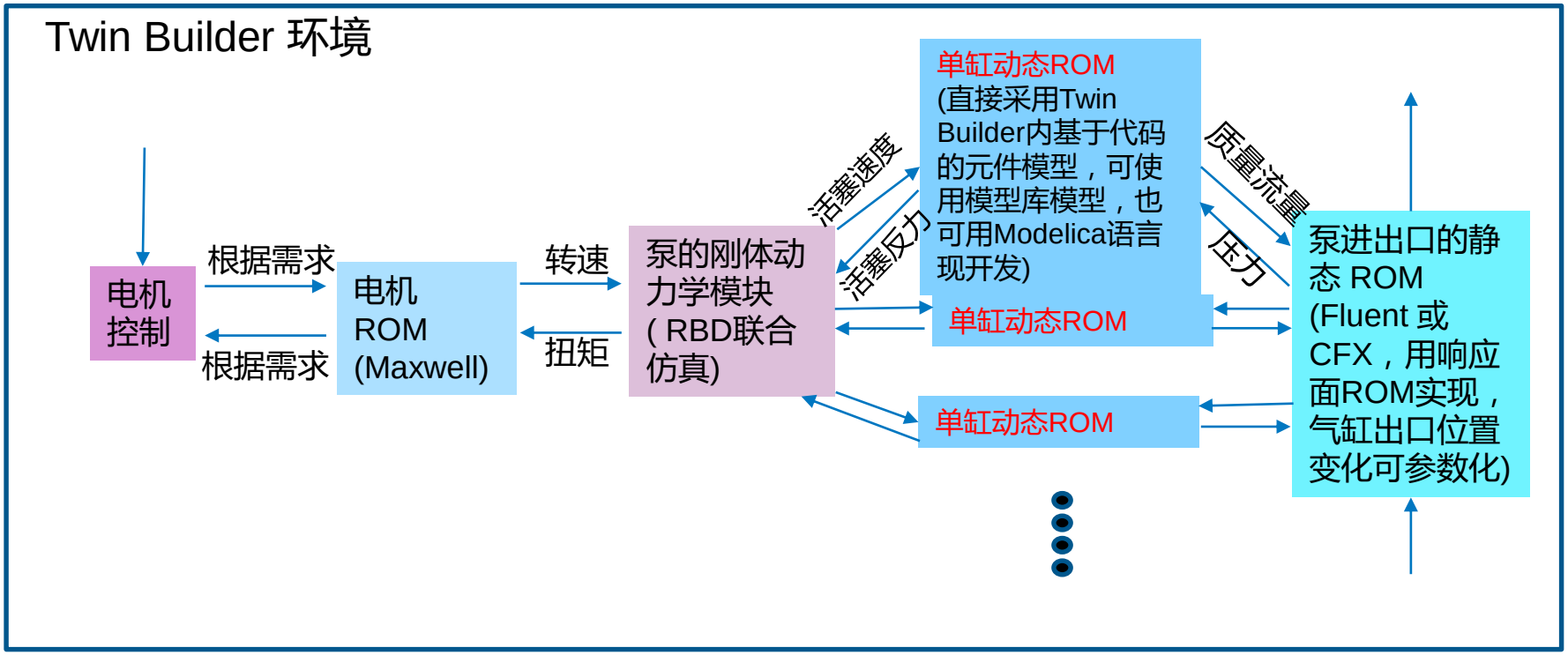
关键问题----柱塞泵的ROM模型



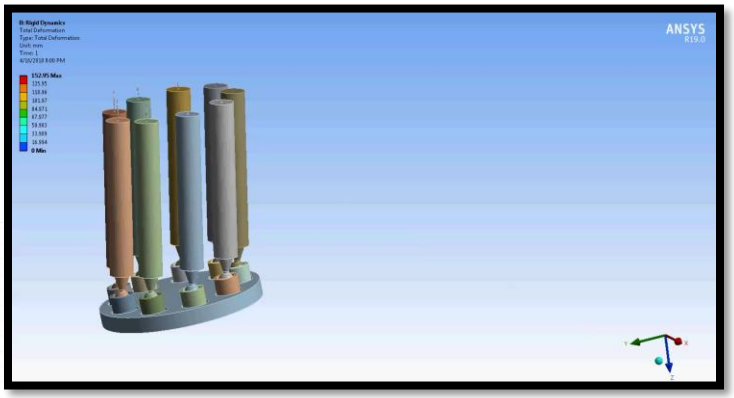
Plan A

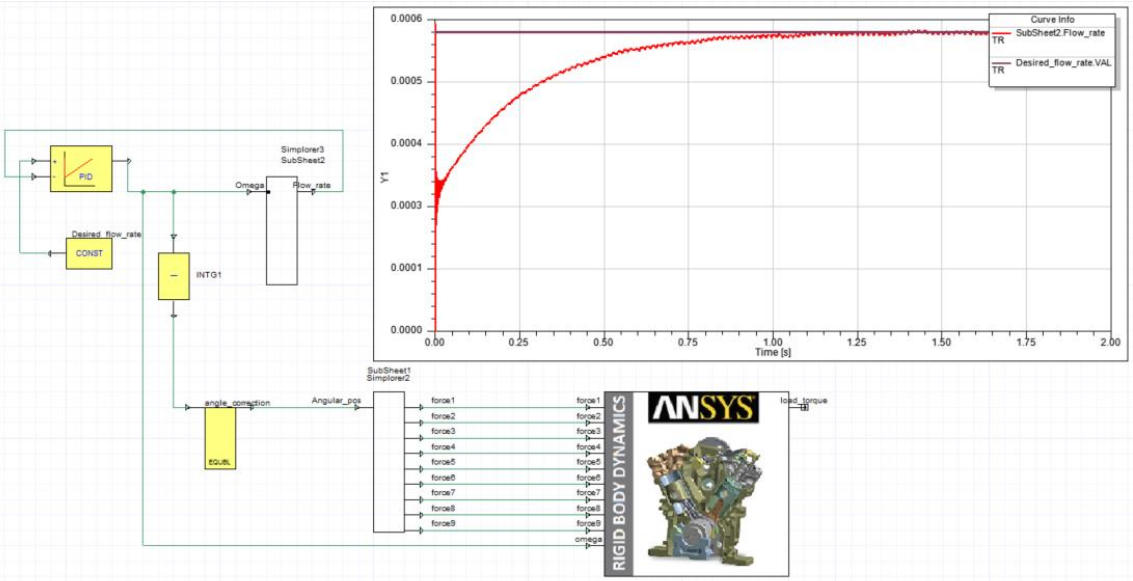


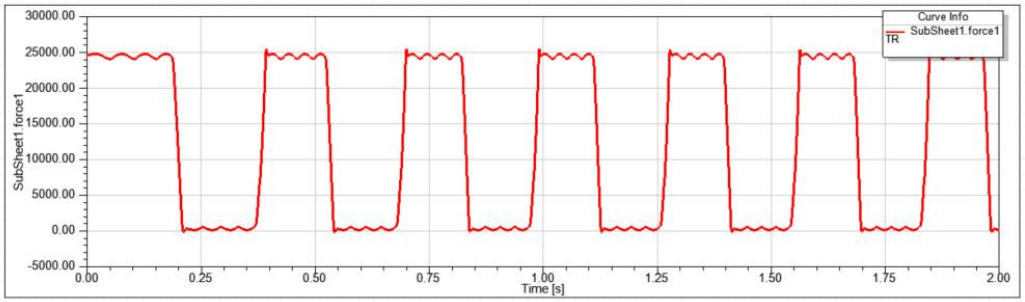
Plan B

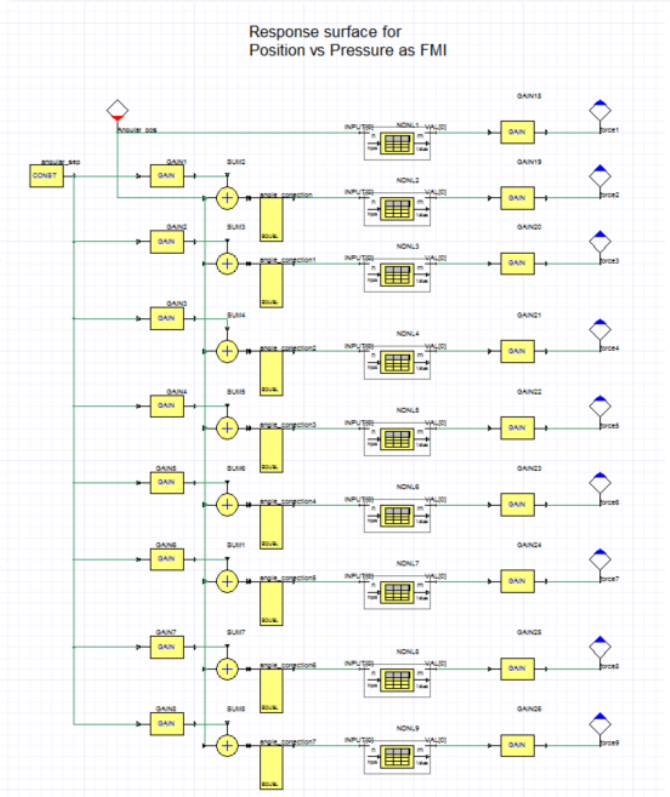


现在的进展









目录

- ANSYS 系统仿真产品简介
- 系统仿真在产品设计过程中的应用
- 系统与三维耦合仿真应用案例
- ANSYS数字孪生介绍
- ANSYS数字孪生在航空发动机上的应用

具备了高置信度仿真模型是否可模拟真实情况？

对真实的情况进行模拟

- 高置信度仿真模型——内部真实
- 真实的边界条件——外部真实

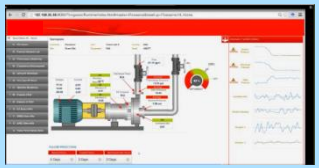
高置信度仿真模型 + 真实的边界条件 = 数字孪生

形象的描述

工作状态的电机-泵系统

数据

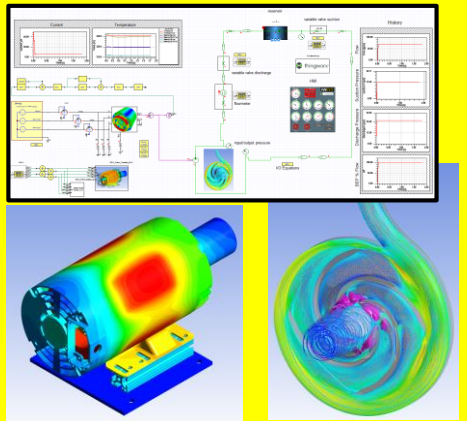
工业物联网平台
(PTC ThingWorx®)
大数据流
大数据分析
历史, 触发器
安全
连接



输入

电机-泵系统数字孪生

ANSYS
仿真平台



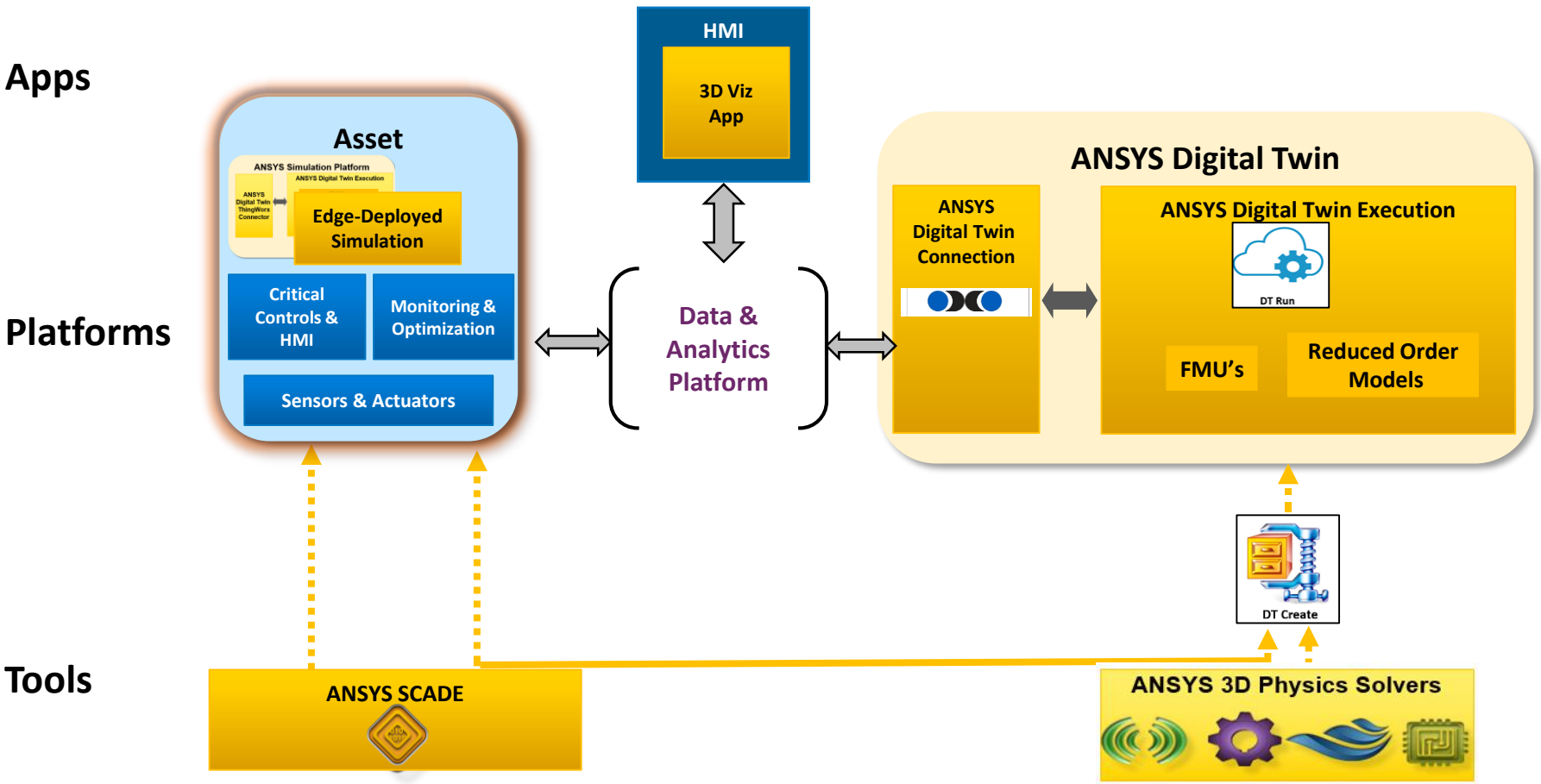
保护性维护
增值服务
工程反馈

仿真输出

Motor courtesy of Regal Beloit
Pump courtesy of Flowserve

将实物与它的数字孪生体在运行中连接

ANSYS 数字孪生解决方案架构



数字孪生实施举例

物理实物

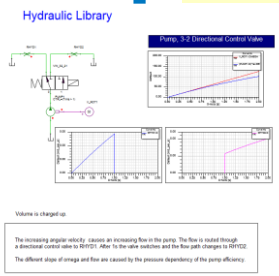
数采系统

用户环境

仿真流程管理平台

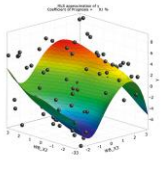
双向连接

数字孪生载体与数据分析平台

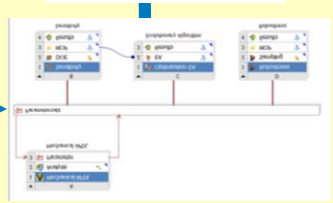


数字孪生模型与图表

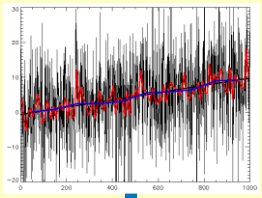
Updated response surface of output data

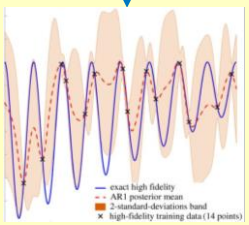


基于观察数据的新增仿真



Experimental data





ROM updated with data from operations

Updated model pushed to DT

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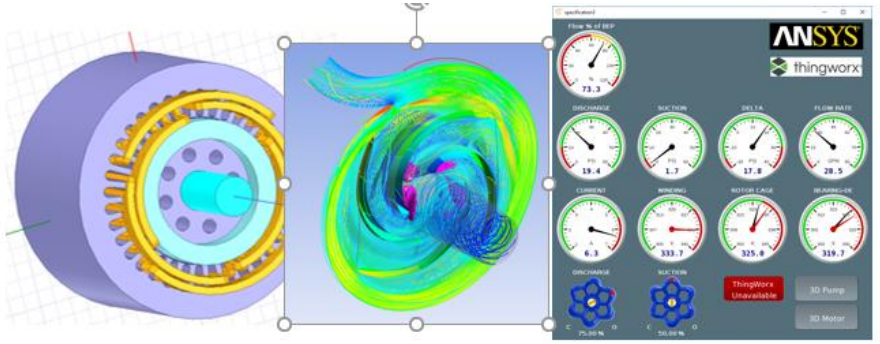
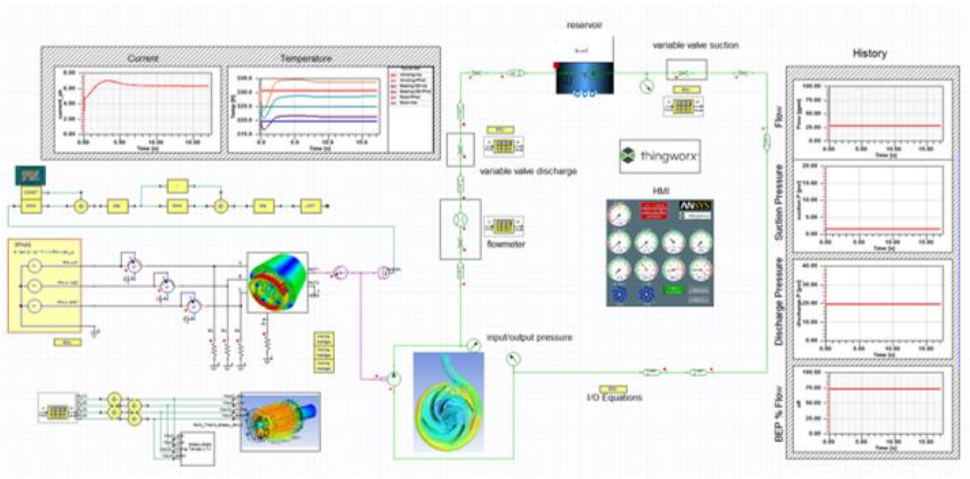
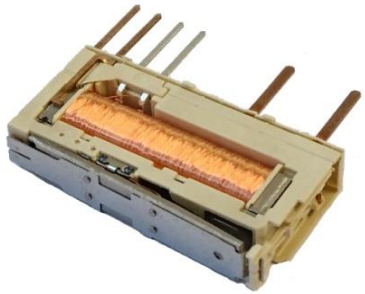
- ANSYS数字孪生示例


FLOWSERVE


ANSYS
thingworx
ThingWorx Unavailable
3D Pump
3D Motor


reservoir
variable valve suction
Current
Temperature
History
thingworx
variable valve discharge
HMI
flowmeter
input/output pressure
I/O Equations
Flow
Suction Pressure
Discharge Pressure
BEP % Flow

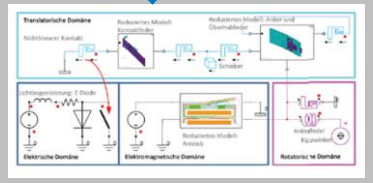
PHOENIX CONTACT Relay Digital Twin



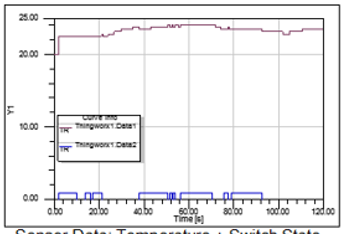
Relay

Controller

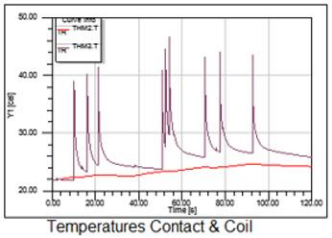
IoT



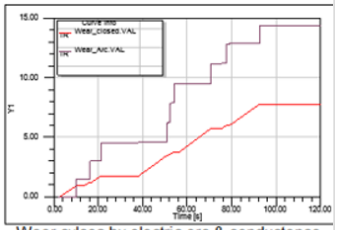
System Model



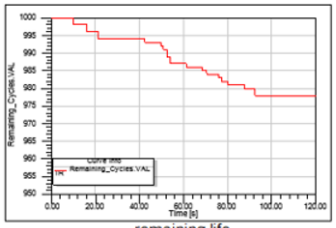
Sensor Data: Temperature + Switch State



Temperatures Contact & Coil



Wear cylces by electric arc & conductance

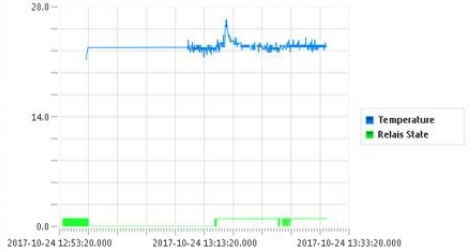


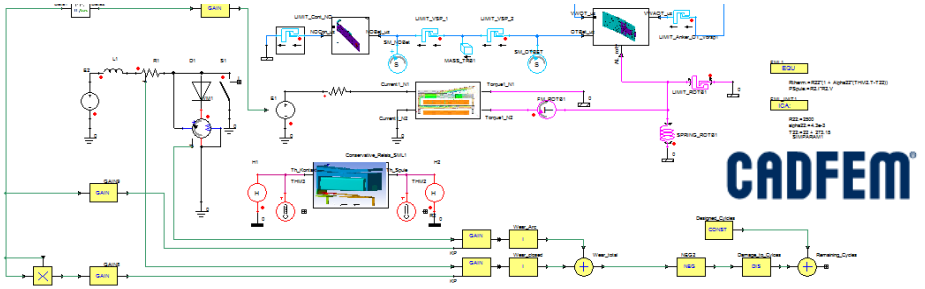
remaining life

CADFEM Management Console (Relais)

Things

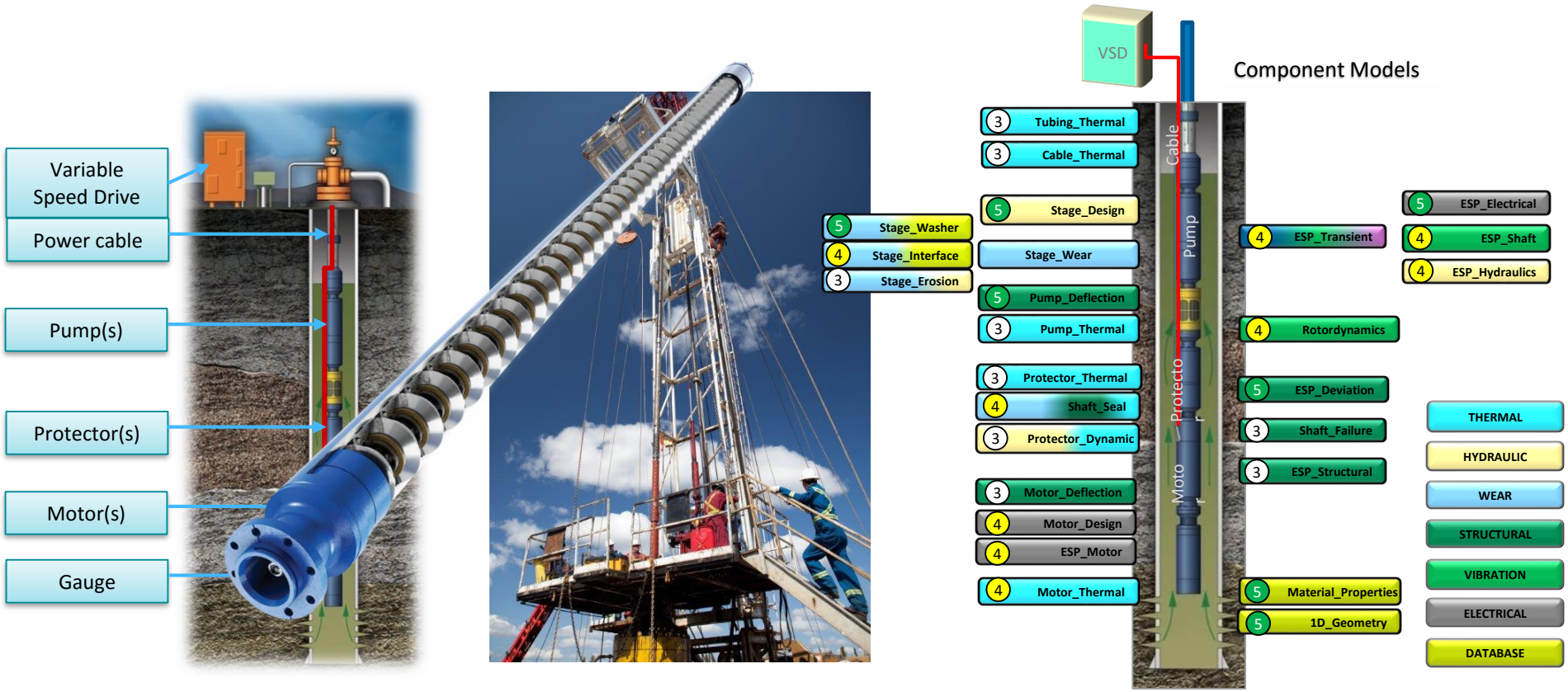
Dev-Name	Dev.Con	AnsysTwin	Twin	TwinState	Perm.	LastSync	Status	Interval	Simplorer	Active	Location	TwinRunning	TwinActive
Relais-01	✓					---	?				0.0000 : 0.0000		
Relais-02	✓					---	?				0.0000 : 0.0000		
Relais-03	✓					---	?				0.0000 : 0.0000		
Relais-04	✓					---	?				0.0000 : 0.0000		
Relais-05	✓					---	?				0.0000 : 0.0000		
Relais-06	✓					---	?				0.0000 : 0.0000		
Relais-07	✓					---	?				0.0000 : 0.0000		





ANSYS

潜油泵



https://www.sap.com/assetdetail/2018/06/3276ab9f-077d-0010-87a3-c30de2ffd8ff.html

The objective of this project is to develop a digital twin of an offshore Wind Turbine (Haliade 6MW) on Predix to monitor remotely and have a predictive maintenance solution.

感谢聆听！

ANSYS-China

ANSYS中国