ATOZ

Dymola & DBM介绍

安托系统工程团队

安心托付，智造未来

Since 1978

PLATINUM PARTNER

DASSAULT SYSTEMES

目录

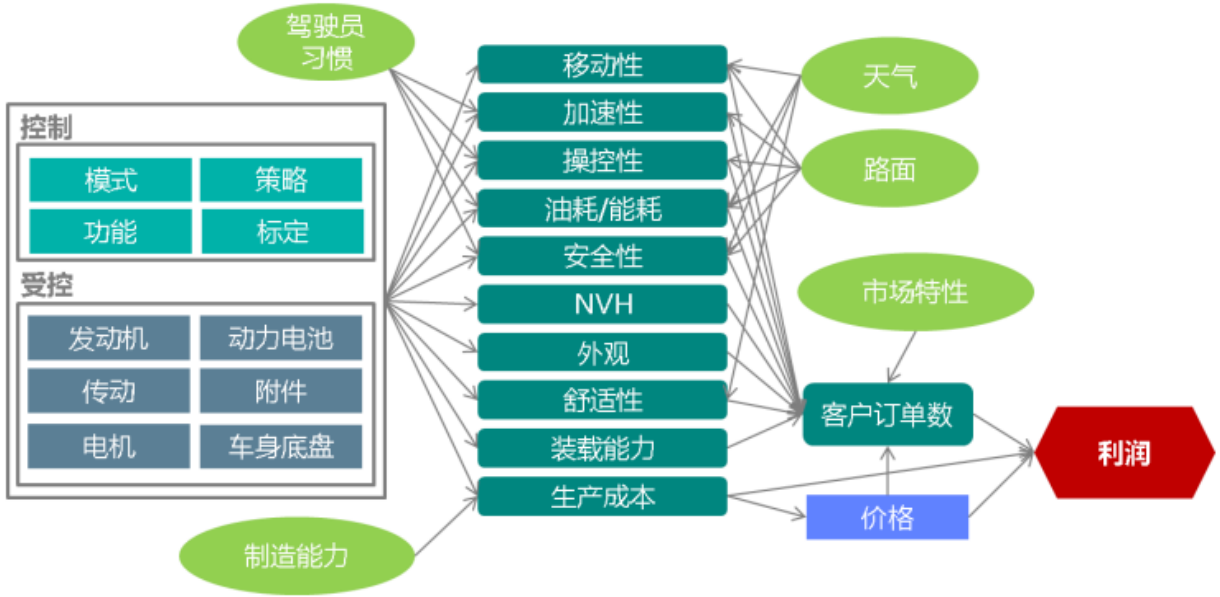
什么是系统？为什么仿真

ISO/IEC15288:2008: "A combination of interacting elements organized to achieve one or more **stated purposes**."

INCOSE: A construct or collection of different elements that **together** produce results not obtainable by the elements alone.

研究系统的目的

- ❖确认需求
- ❖理解互动
- ❖指导设计
- ❖提高质量



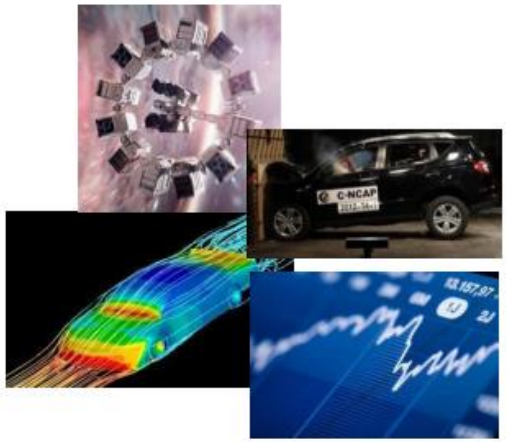
什么是系统？为什么仿真

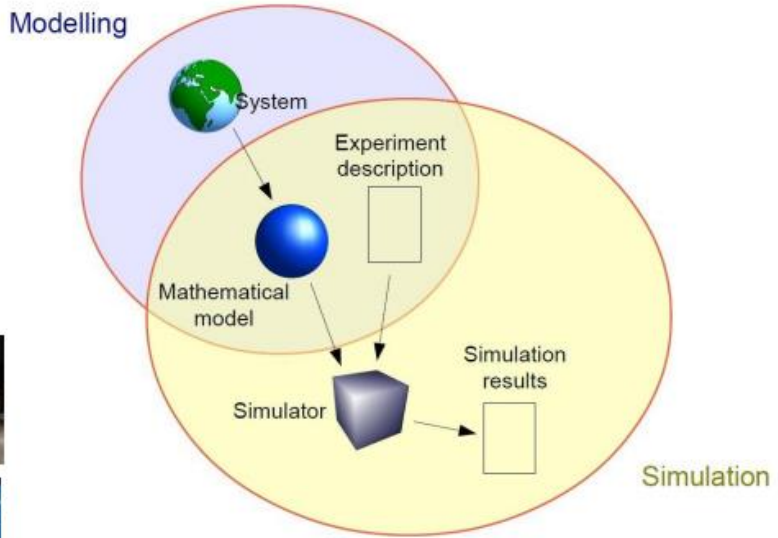
如何研究系统

- 在真实系统上直接进行实验
- 将真实系统抽象成模型然后仿真

为什么要仿真

- 无法进行真实实验
  - 真实系统仍未存在
  - 实验风险太大
  - 实验成本太高
- 无法进行分析求解
  - 不确定性
  - 动态性太强
  - 过于复杂





仿真模型的形式

仿真模型的形式

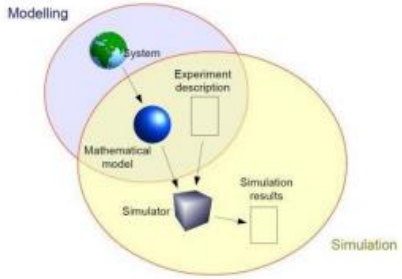
Analog(木条+绳索)

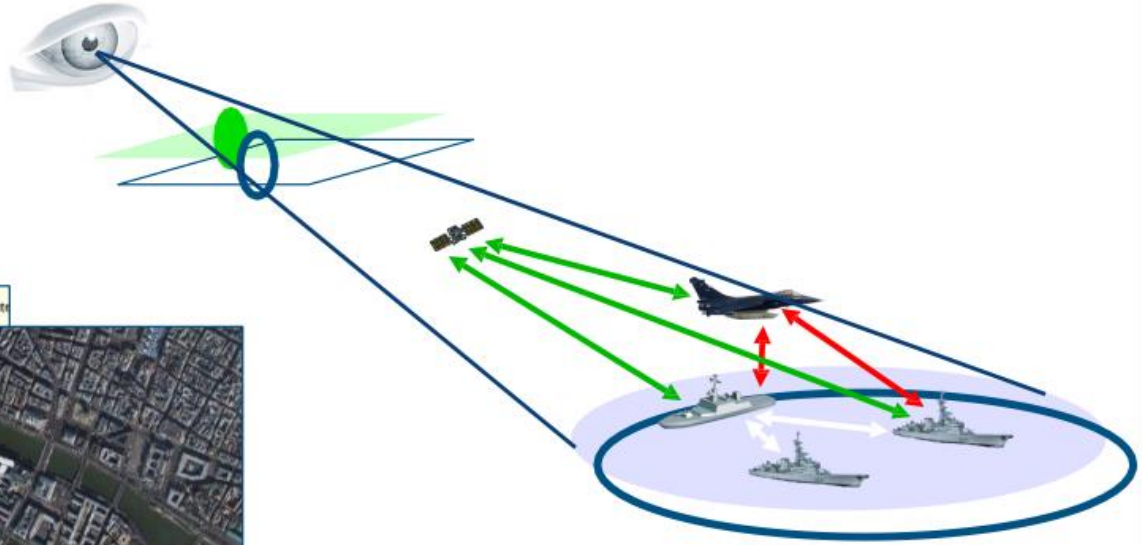
Antoinette Trainer ~1910

Digital(Dymola+Mechatronics)

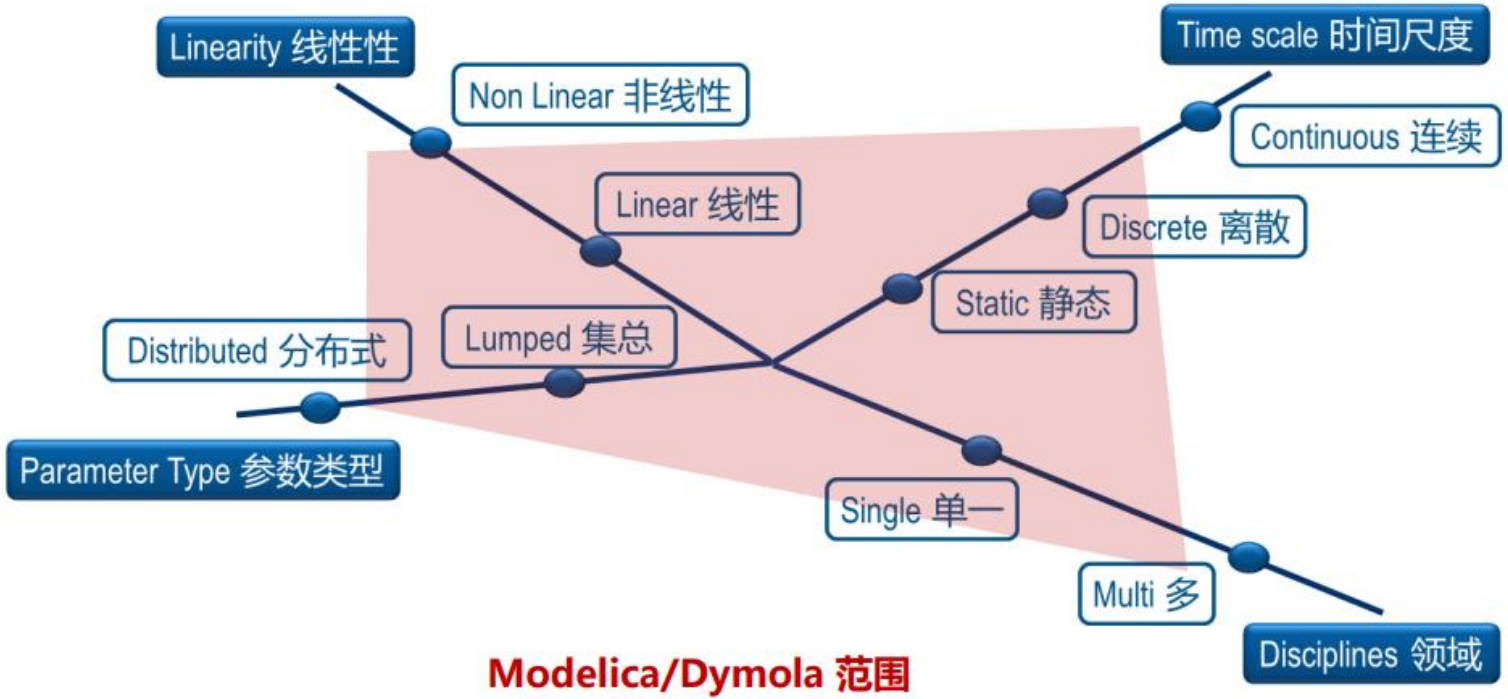
DLR 德宇航 2013

仿真模型的形式

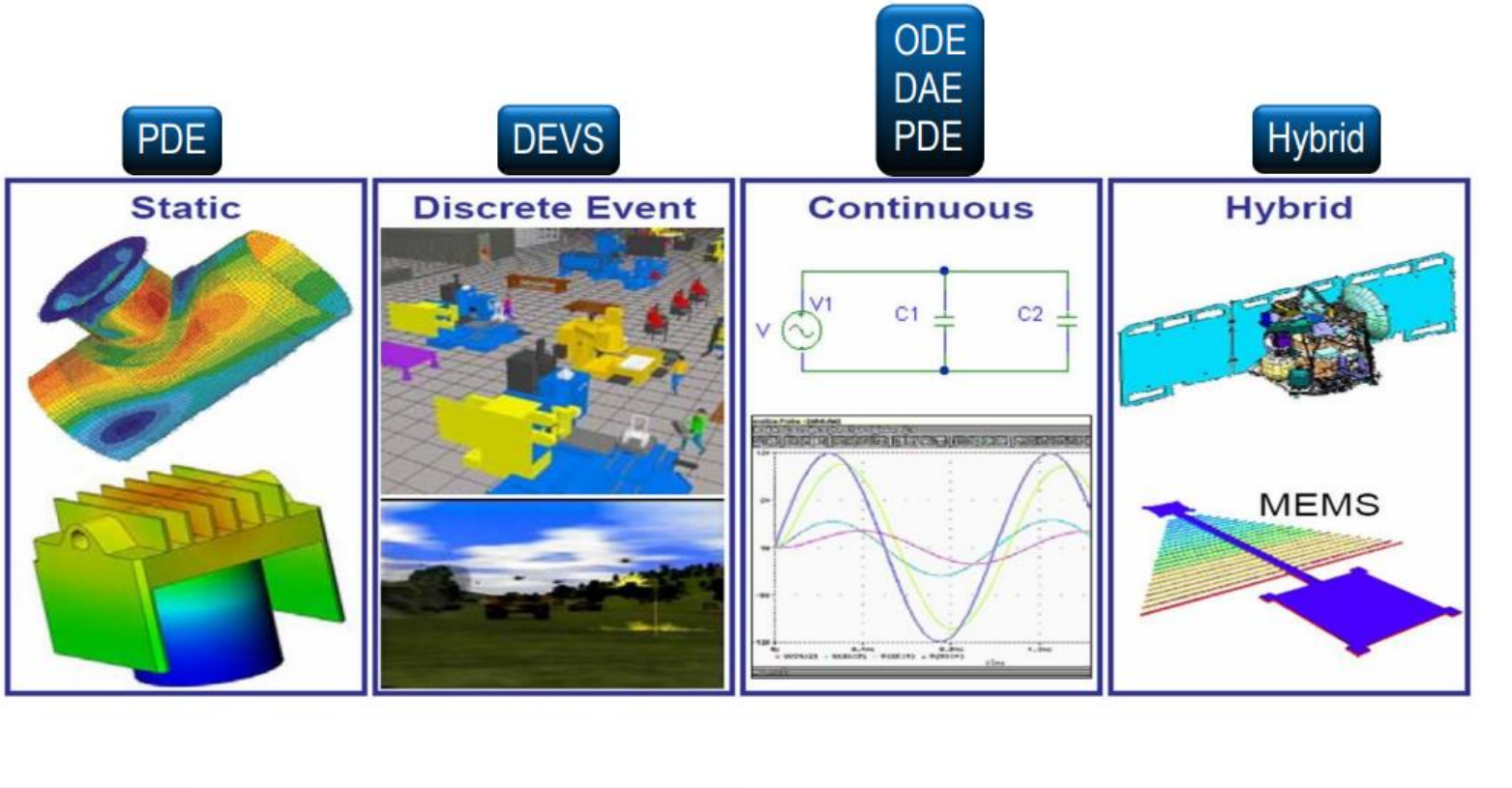




仿真模型的形式



仿真模型的形式



仿真模型的形式

DYMOLA应用范围

Algebraic Equations 代数方程

$$y + 9 = 15$$

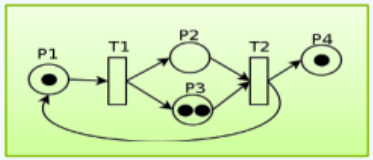
Ordinary Differential Equations (ODE) 常微分方程

$$\frac{d^2x}{dt} = -c\frac{dx}{dt} - x$$

Differential Algebraic Equations (DAE) 微分代数方程组

$$f\left(\frac{dx}{dt}, x, y, t\right) = 0$$

Discrete Event Systems Specification (DEVS) 离散系统规范

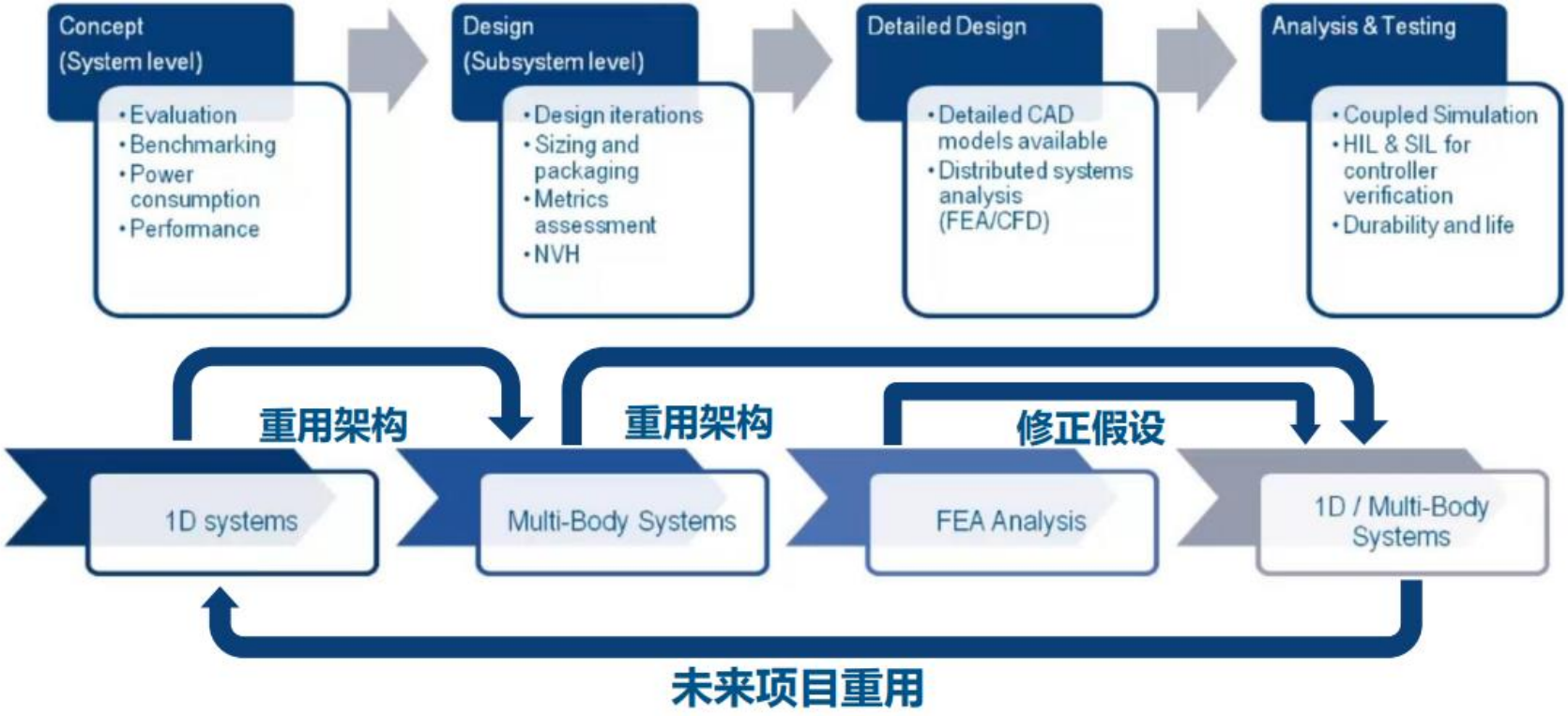


Hybrid Models 离散连续混合模型

Partial Differential Equations (PDE) 偏微分方程

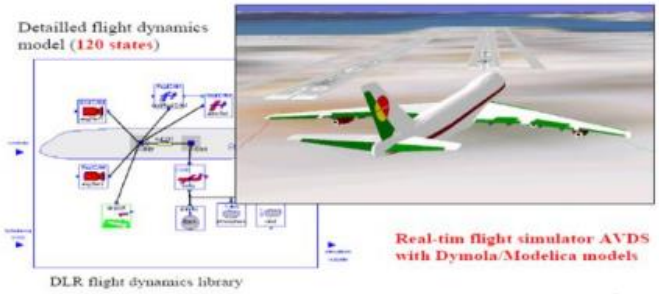
$$i\hbar\frac{\partial}{\partial t}\psi = -\frac{\hbar^2}{2m}\left(\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2}\right)$$

仿真模型的形式

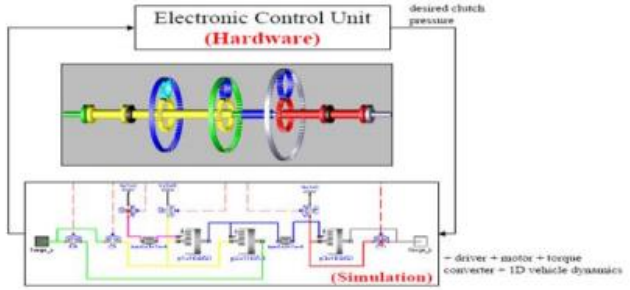


应用领域

Aircraft flight simulator AVDS with Modelica models (DLR)

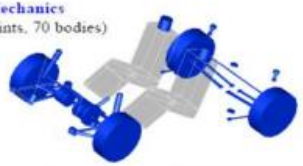


Hardware-in-the-loop simulation of automatic gearbox
(different car manufacturers)



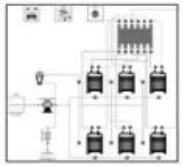
Large, detailled vehicle model (Ford Motors, Dynasim, DLR)

3D-Mechanics
(60 joints, 70 bodies)

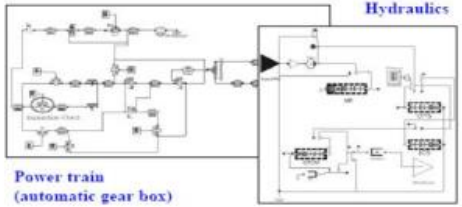


- 25000 nontrival **algebraic equations**
- 320 states

Motor (combustion)

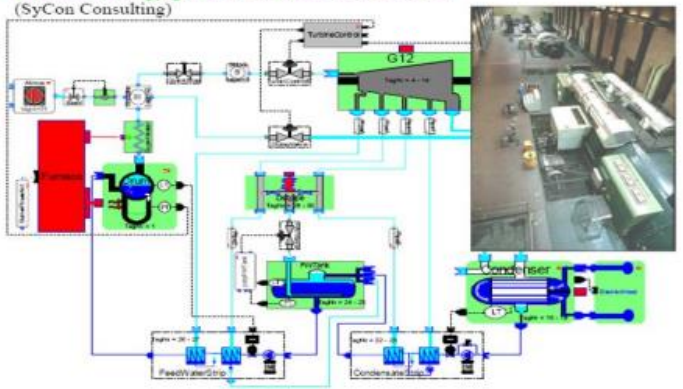


Hydraulics



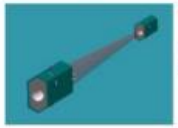
Power train
(automatic gear box)

Electric energy production and distribution
(SyCon Consulting)



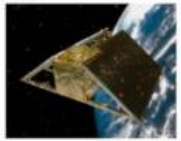
应用领域

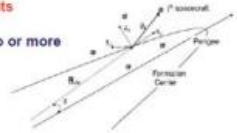
Modelica Spacecraft Dynamics Library



Formation flying on elliptical orbits

Control the relative motion of two or more spacecraft



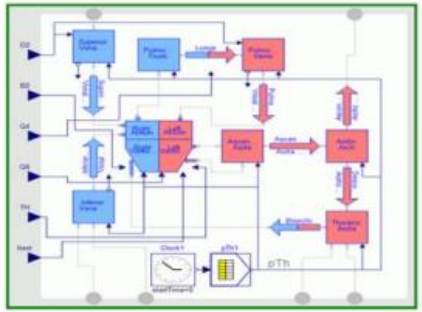


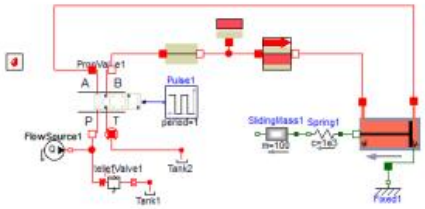
Attitude control for satellites using magnetic coils as actuators

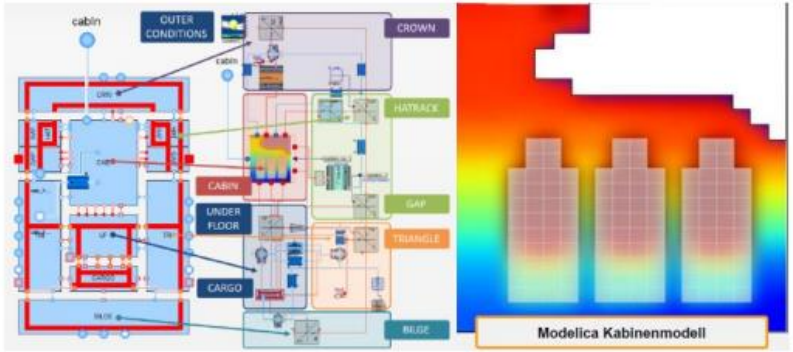
Torque generation mechanism: interaction between coils and geomagnetic field

Courtesy of Francesco Casella, Politecnico di Milano, Italy

Modelica in Biomechanics

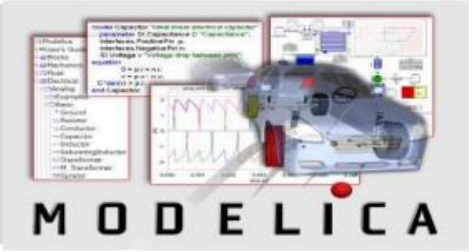






Modelica

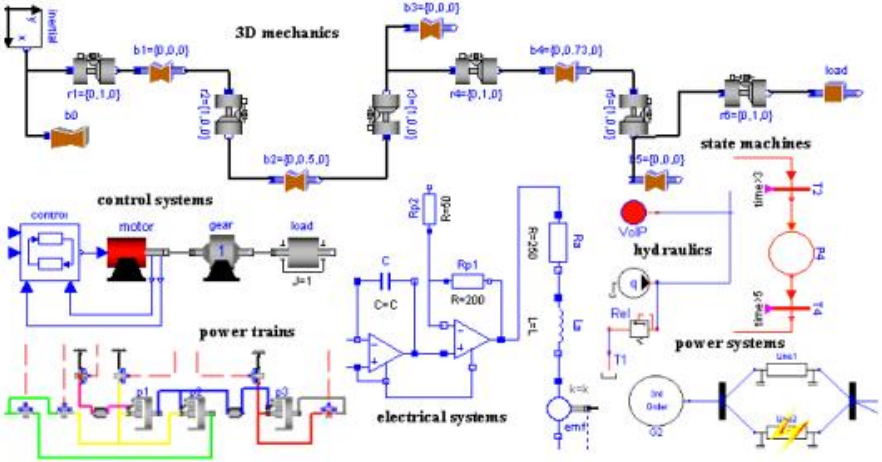
Modelica® 是一种开源，面向对象，基于方程的系统建模语言。
描述对象包括 机械，电气，电子，液压，热传导，控制，电力 驱动，工厂过程等等。



$$\begin{cases} \dot{x} &= f(x,u,t) \\ y &= h(x,u,t)) \end{cases}$$

$$\begin{cases} \dot{x} = A\,x + B\,u \\ y = C\,x + D\,u \end{cases}$$

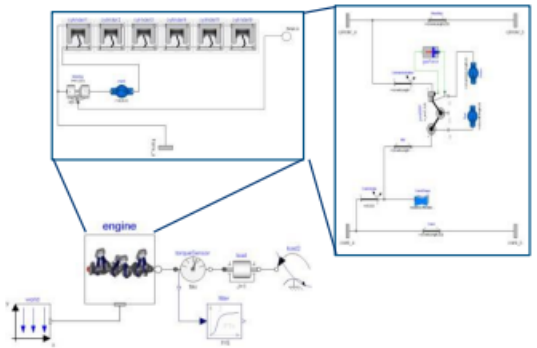
```
model SimplePendulum
  Real theta;
  Real omega(start=1);
  parameter Real g = 9.81;
  parameter Real L = 1;
equation
  der(omega) = -(g/L)*sin(theta);
  der(theta) = omega;
end SimplePendulum;
```



Modelica

Modelica 语言特性:

- Modelica是一种描述性的**建模语言**而不是指令性的编程语言
- 所以允许**非因果性**建模
- 建模利用的是与物理定律（而不是算法）一致的**声明性方程**
  - 1/4*(der(x)+3)=x^2-a; 完全等价于der(x)=4*(x^2-a)-3;
- Modelica模型可以是微分方程，代数方程和离散方程
  - der(x)=exp(x)*x;　　x+a=b;　　u=1+pre(u);
- **基于对象**建模语言特性（class 类，instance 实例，inheritance 继承）
  - Resistor.PositivePin.Voltage
- **层级化**建模
- 由国际Modelica协会发展和维护的**开源语言**

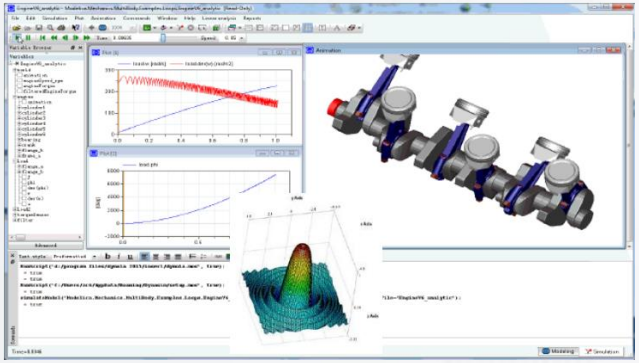


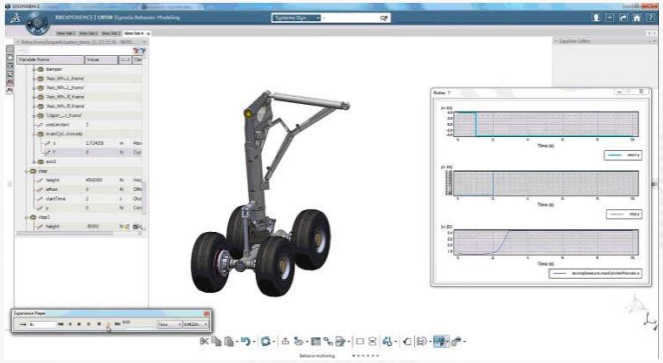
目录

Dymola (Dynamic Modeling Lab 动态建模实验室)，是基于公开Modelica系统建模语言的集成建模和仿真环境。

MODELICA

Functional Mock-up Interface



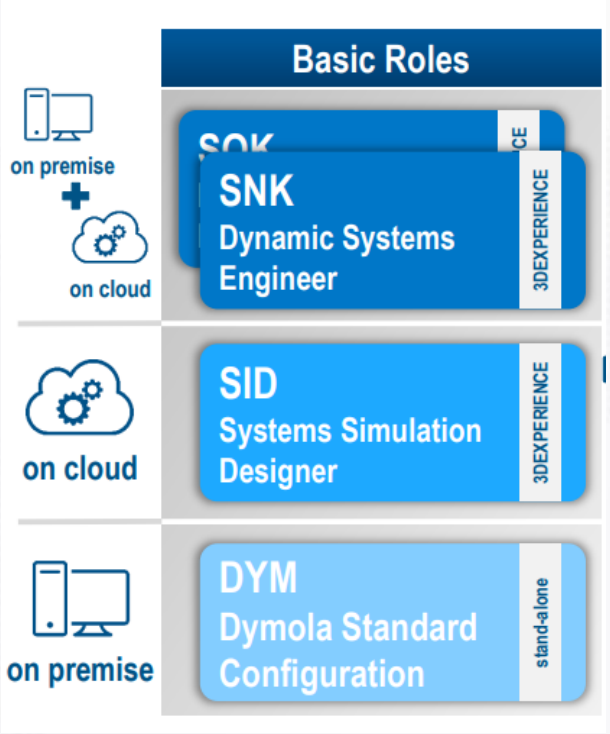


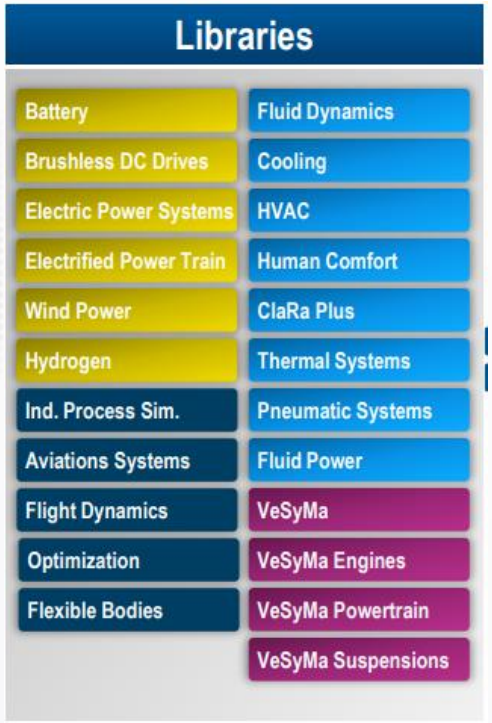
- 具有丰富多领域模型库或可利用简单易懂的Modelica语言开发专属部件；
- 图形化界面对模型进行参数配置或与PLM参数对象关联；
- 通过连接部件快速建立多层级复杂系统模型；
- 强大的仿真引擎以及开箱即用的后处理，可视化和3维展示；
- 独有的方程符号处理器及数字求解器并可输出高质量代码用于基于模型预测控制设计；

Dymola&DBM

平台集成
DBM（Dymola Behavior Modeling）

单机客户端
Dymola

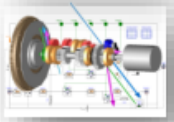




商业库

VeSyMA
Vehicle Systems Modelling and Analysis

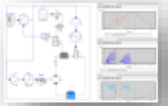
VeSyMA – Powertrain
Vehicle powertrain



VeSyMA – Suspensions
Suspension systems

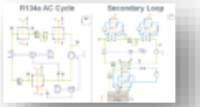
VeSyMA – Engines

Fluid Power
Hydraulic systems behavior

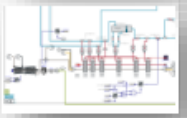


Flight Dynamics
Flight dynamic characteristics of flight vehicles

Thermal Systems
Large and complex thermal systems

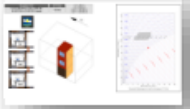


ClaRa Plus
Thermodynamic cycle processes for electricity power generation using



Human Comfort
Thermal comfort of building and vehicle occupants

HVAC
Heat, Ventilation and Air Conditioning Systems



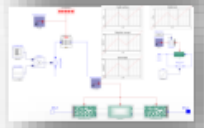
Wind Power
Wind Turbines at system-level for optimized performances

Design Optimization
Optimize and tune systems parameters

Electrical Power System
DC and high-frequency AC electrical network

Hydrogen
Fuel cells systems

Battery
Battery simulation



Electrified Power Train
Electric drives

Brushless DC Drives
Brushless DC motors and control

Systems Cooling
Cooling systems for batteries, electric drives and electronic thermal management

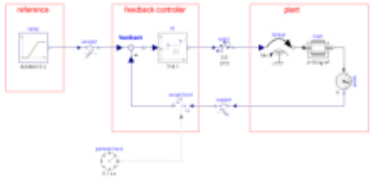
Flexible Bodies
Large motions of flexible parts

Powertrain
Vehicle powertrain systems

Modelica库

Modelica Synchronous

Free library to precisely define and synchronize sampled data systems with different sampling rates.



Model Management

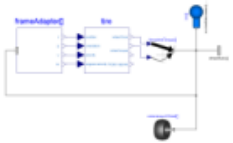
The ModelManagement package contains features for library checking, model comparison and model structure API.

Modelica Linear System2

Library Modelica_LinearSystems2 is a Modelica package providing different representations of linear, time invariant differential and difference equation systems, as well as typical operations on these system descriptions.

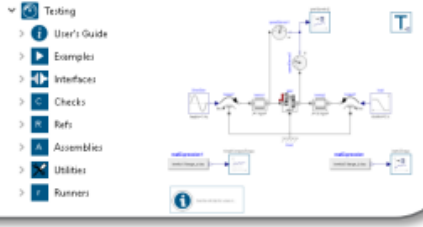
FTire Interface

The FTire library is intended to enable the use of the high end tire model within vehicle dynamics simulations (like VeSyMa library form Claytex) in Dymola.



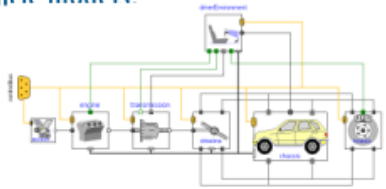
Testing

The idea of the Testing library is that every component is tested in one or more test models.



Vehicle Interface

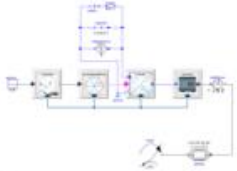
This library provides standard interface definitions for automotive subsystems and vehicle models.



Modelica库

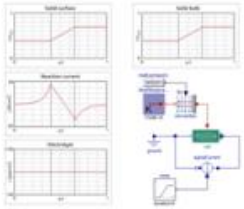
Electrified Powertrain

Assists design steps during the entire process of developing electric machine and power electonics



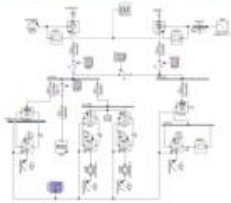
Battery

Bring battery simulation to the system level



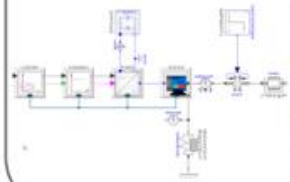
Electric Power Systems

Multi-level modelling of DC and high frequency AC electrical network



Brushless DC Drives

Allows the integration of Brushless DC motors and control into systems

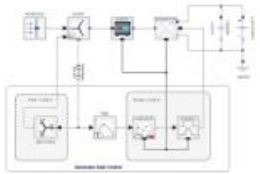


Hydrogen

Design and validate performances of fuel cells systems

Wind Power

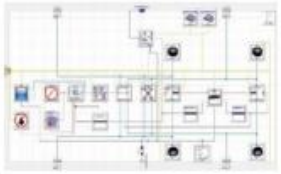
Rapidly model and simulate Wind Turbines at system-level for optimized performances

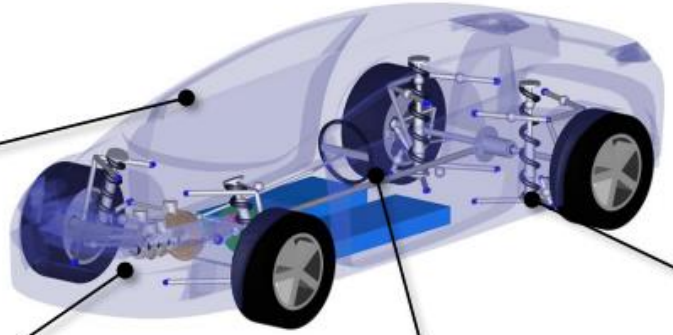


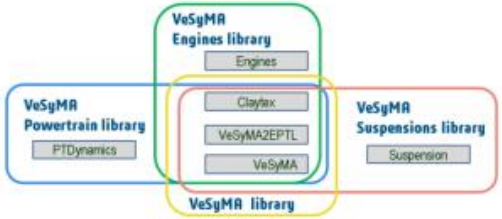
Modelica库

VeSyMA

Provides necessary assets and interfaces for Vehicle Systems Modelling and Analysis





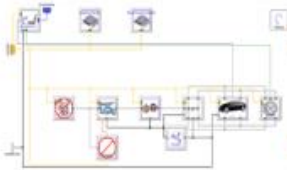


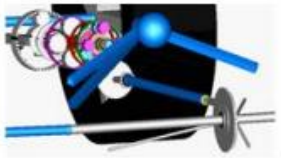
VeSyMA Engines

Model spark ignition and compression ignition engines, intake and exhaust flows, emissions and torque assessment

VeSyMA Powertrain

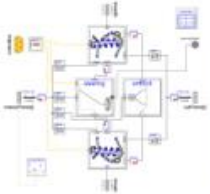
Model and validate the performances of the full motion of the vehicle powertrain





VeSyMA Suspensions

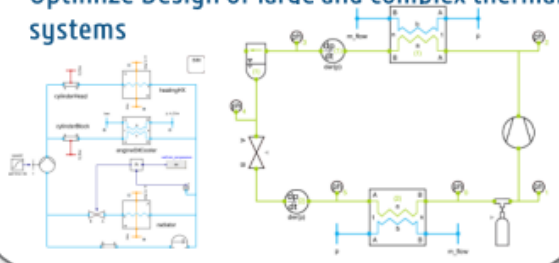
Develop suspension systems for vehicle handling, driver and stability control models



Modelica库

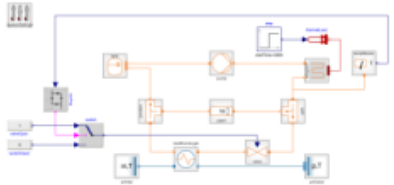
ThermalSystems

Optimize Design of large and complex thermal systems



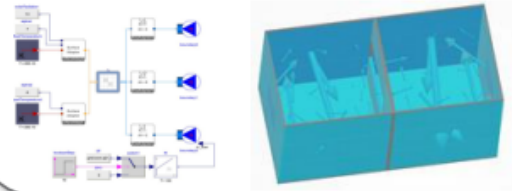
Systems Cooling

Develop cooling systems and dimension components, for batteries, electric drives and electronic thermal management



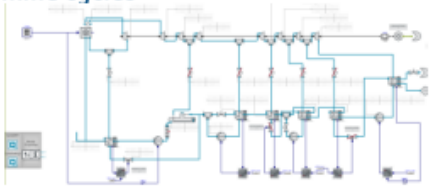
FluidDynamics Library

The FluidDynamics library carries out CFD-Simulations using Modelica language and provides standard interfaces to 1D-Modelica-models.



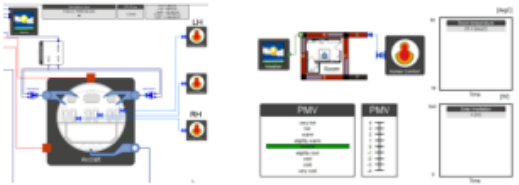
ClaRa +

Simulation thermodynamic cycle processes for electricity power generation using Clausius Rankine cycles



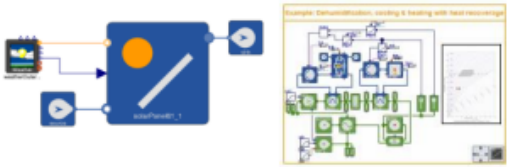
HumanComfort Library

Model and analyze the thermal comfort of building and vehicle occupants



HVAC Library

Optimize the design & performance of Heat, Ventilation and Air Conditioning Systems



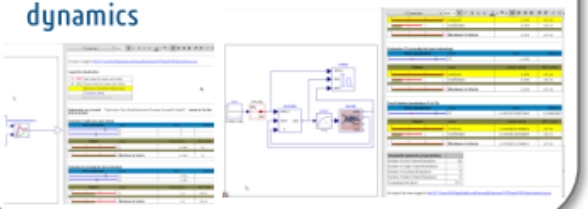
Modelica库

Fluid Power

The Fluid Power Library is a library for the modelling hydraulic systems such as those found in aircraft, cars, excavators and many other types of machine

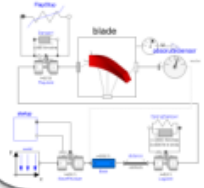
Design Optimization

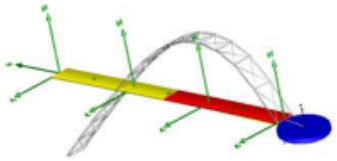
Optimize and tune systems parameters of a device or its controller to improve system dynamics



Flexible Body

Accelerate the analysis of large motions of flexible parts such as beams, annular plates and thermoelastic annular plates.



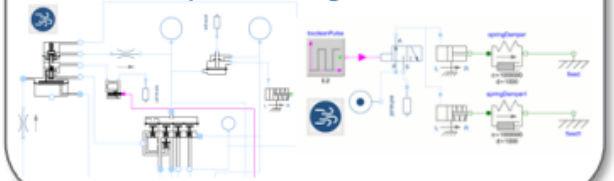


Flight Dynamics

The Flight Dynamics library is used to construct multi-disciplinary flight dynamics models of (rigid) flight vehicles, such as transport and military aircraft, UAVs, or airships.

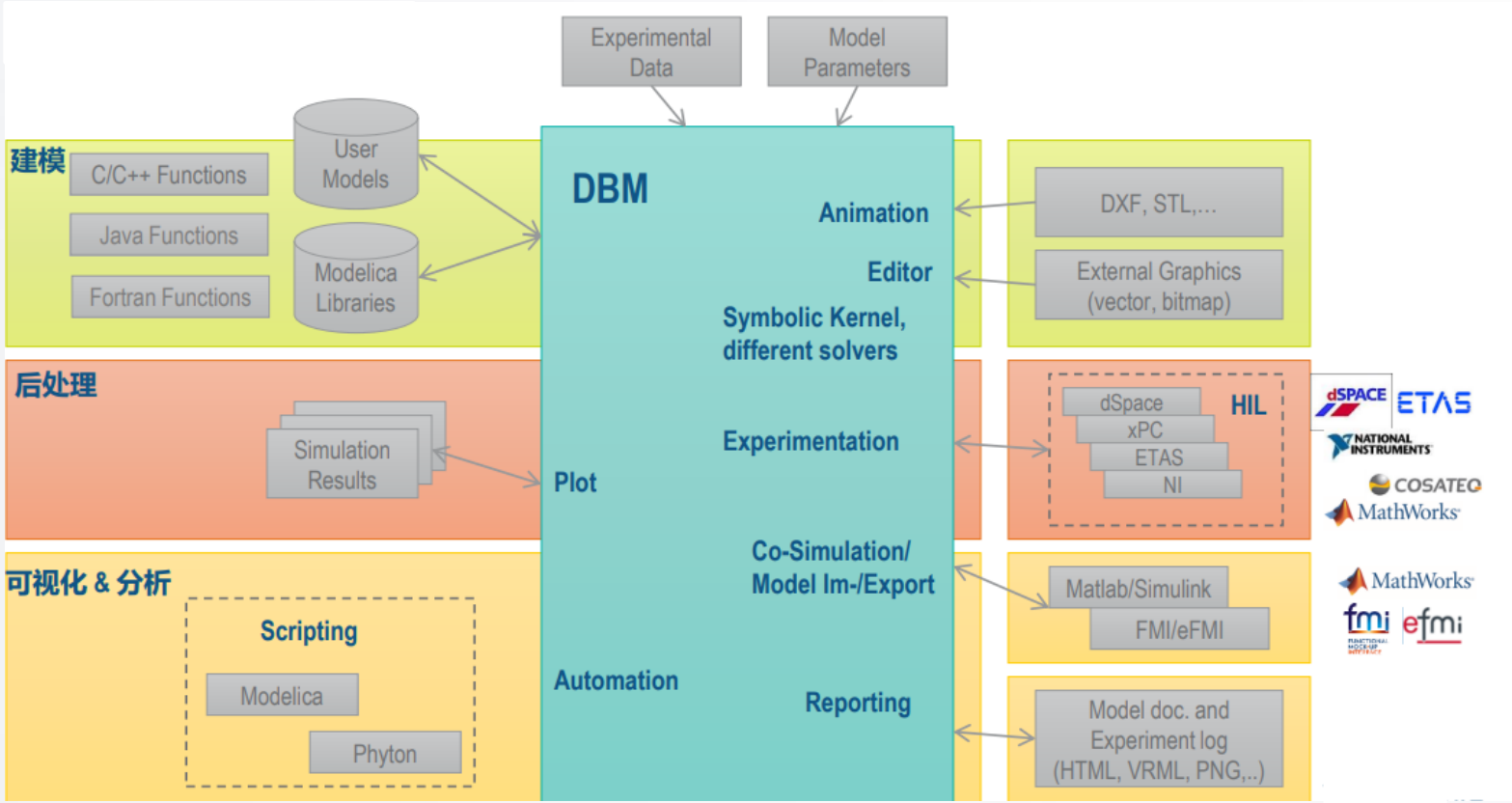
Pneumatic Systems

The PSL is a library enabling the architectural design, component sizing, modelling and simulation of pneumatic systems.



目录

基础功能



从真实系统到虚拟仿真

Done by DBM/Dymola using existing Libraries

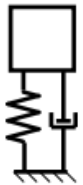
Real System → Physical Approximation → Mathematical Model → State-Space Form → Simulation Result

Done by DBM/Dymola solver

Simplification | Modelling | Sorting Equations/ Symbolic Preprocessing | Compilation Simulation/ Integration Visualisation

Suspension

$$F_g = m \cdot g$$
$$F_k = k \cdot x$$
$$F_b = b \cdot \dot{x}$$
$$F_a = m \cdot \ddot{x}$$
$$F_g - F_k - F_b - F_a = 0$$



Differential-Algebraic Equation System (DAE)

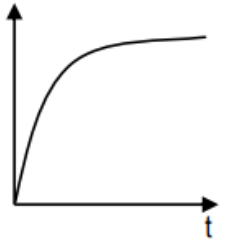
$$f(\dot{x}, x, u, t) = 0$$

Ordinary Differential Equation (ODE)

$$\dot{x} = f(x, u, t)$$

$$\begin{bmatrix} \dot{x} \\ \dot{z} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\frac{k}{m} & -\frac{b}{m} \end{bmatrix} \begin{bmatrix} x \\ z \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{m} \end{bmatrix} F + \begin{bmatrix} 0 \\ g \end{bmatrix}$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ z \end{bmatrix}$$



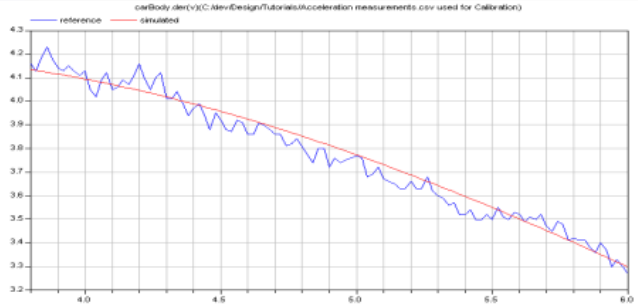
仿真分析

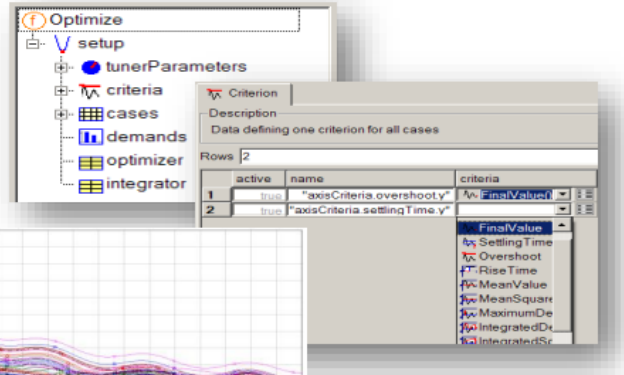
- 直流（DC）分析（执行点）
- 瞬态分析（Transient Analysis）
- 交流（AC）分析
- 稳态（Steady State）
- 蒙特卡洛分析（Monte-Carlo Analysis）
- 最坏情况分析（Worst-Case Analysis）
- 极点/零点分析（Pole/Zero Analysis）
- 特征值（Eigenvalue）

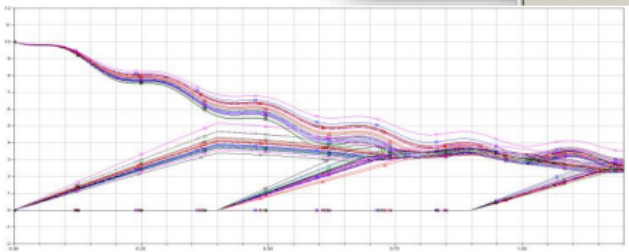
- Start from DC Operating Point
- 参数扫描
- FFT
- 参数识别/模型校准
- 优化

设计优化

- 设计优化
  - 调整设备或控制器的参数，以改善多种情况和多种标准下的系统动力学
- 模型校准
  - 根据瞬态测量确定未知模型参数
- 模型实验
  - 参数扫描
  - 蒙特卡洛实验
  - 最坏情况模拟
  - etc.

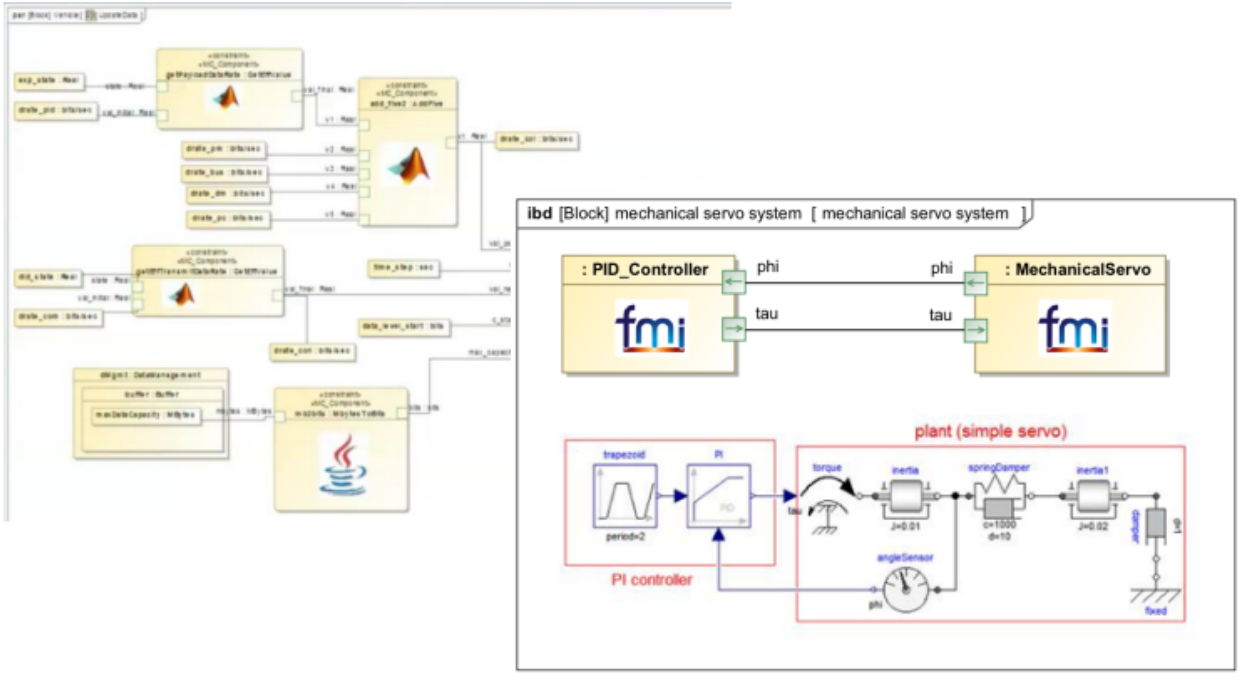


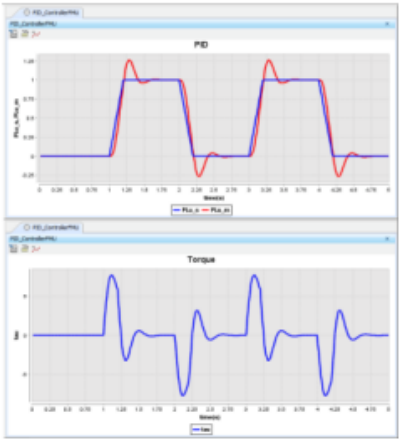




其他工具联合仿真（FMI）

- 通过FMUs的Cameo & DBM/Dymola联合仿真





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