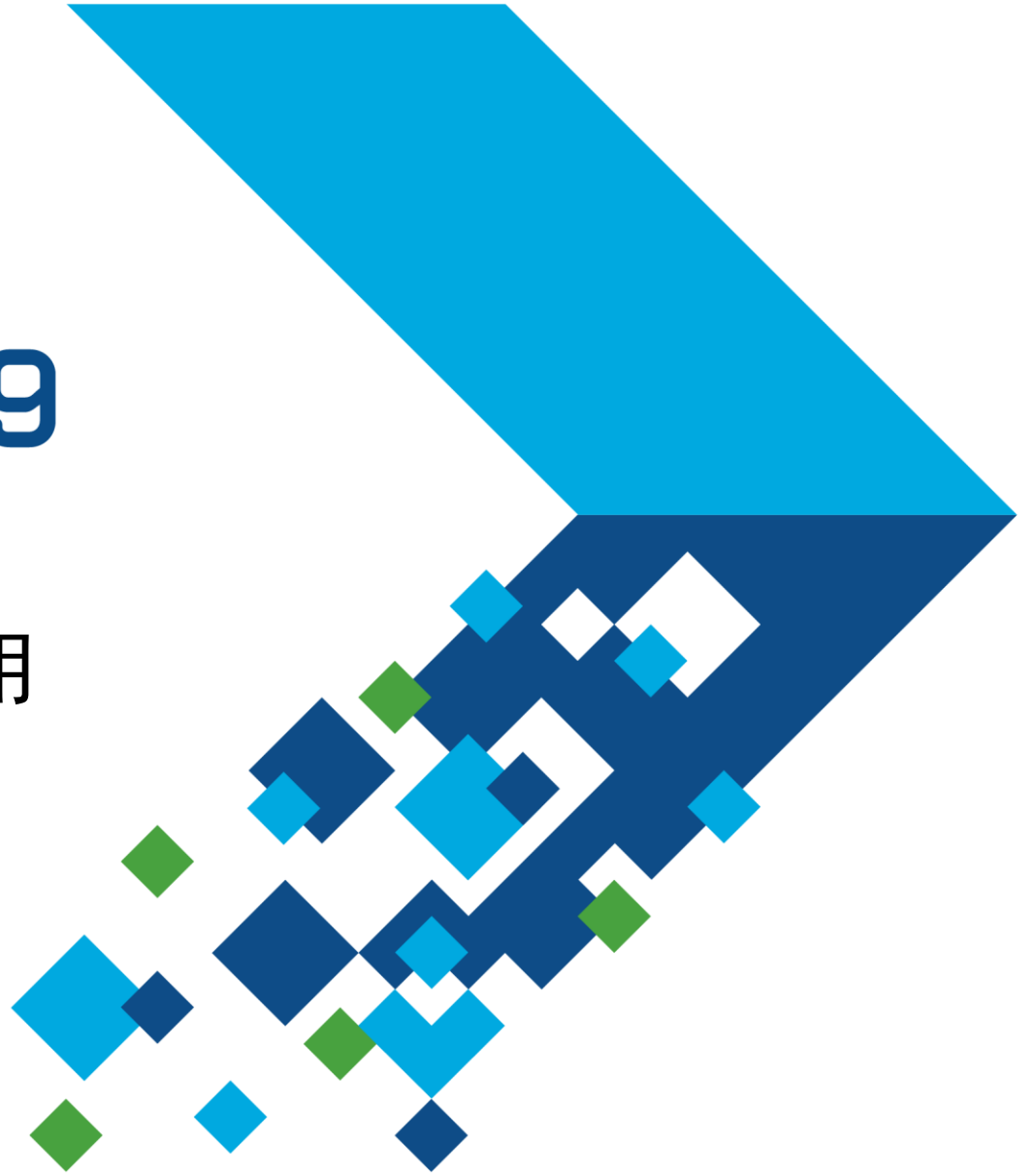


# MATLAB EXPO 2019

## Simulink作为企业仿真平台的应用

吴菁

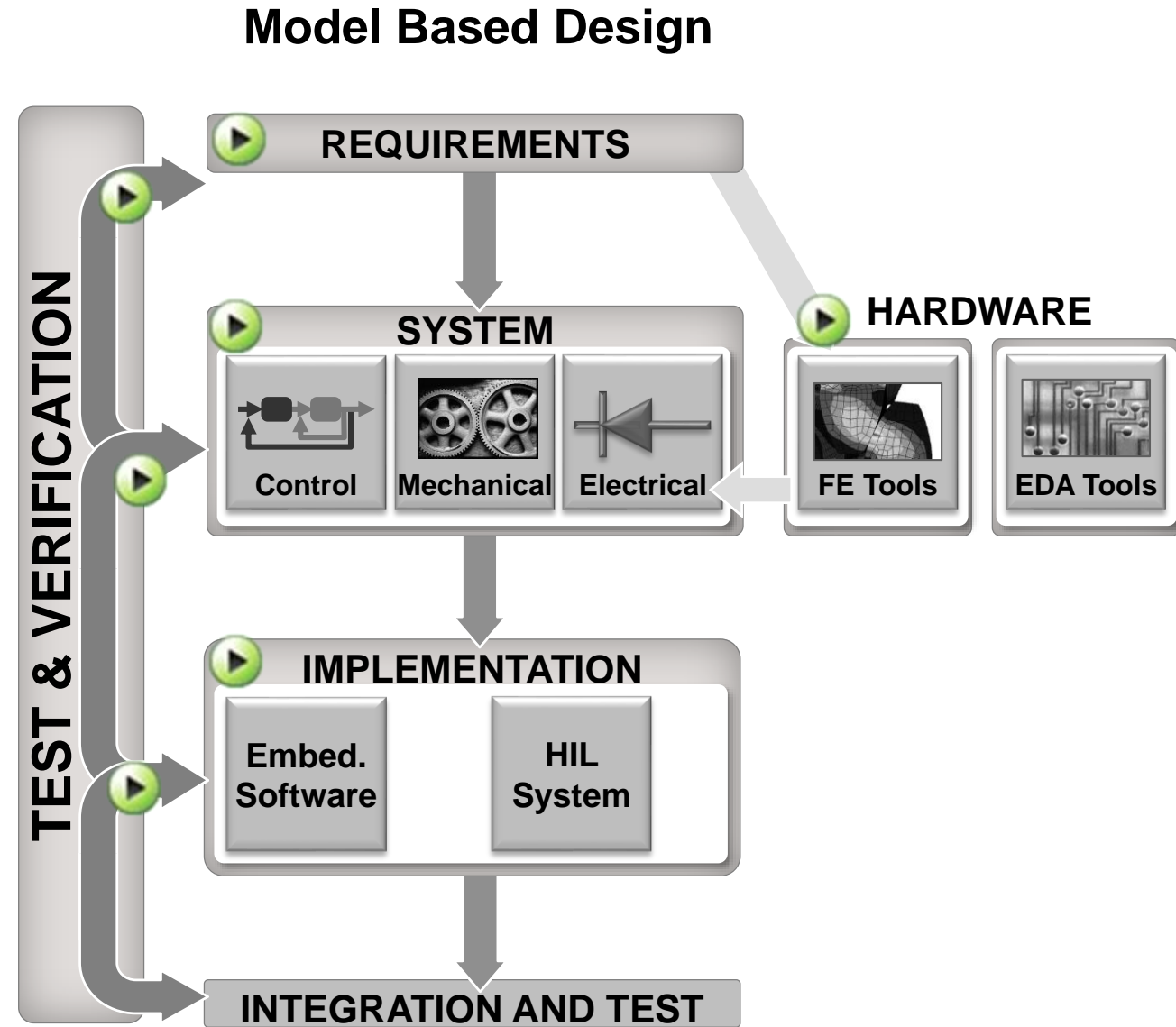
MathWorks China



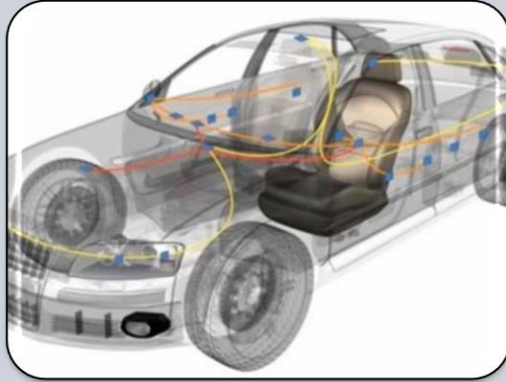
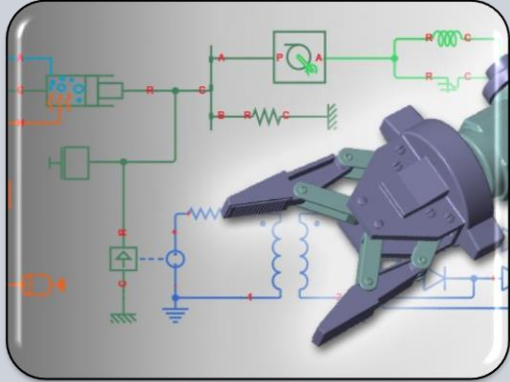
# 企业仿真平台

- 企业 – 不同规模的业务或项目
- 仿真 – 通过计算评估系统行为
- 平台 – 协同设计工作流程

 Simulation



# 企业仿真平台的重要能力

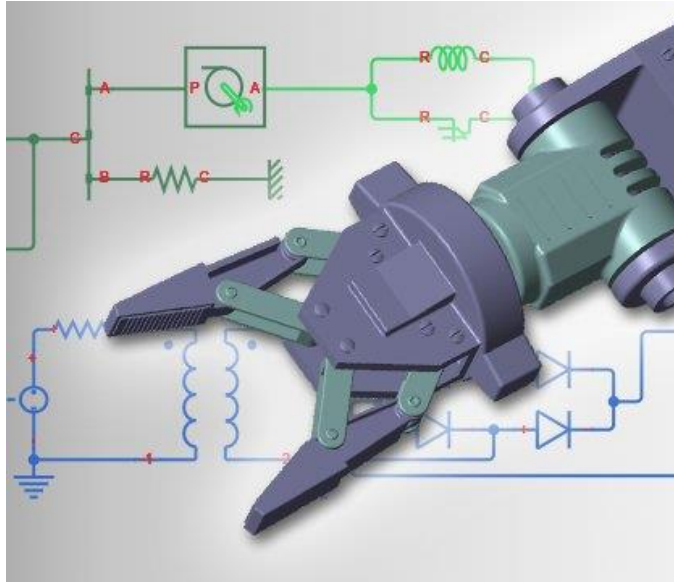


多域  
建模

仿真  
集成

协同  
设计

# 多域建模



# Simulink的多领域建模能力



动态系统



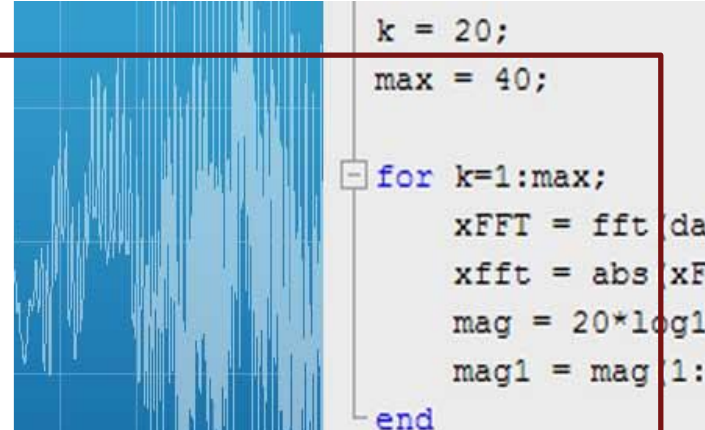
状态机



离散系统



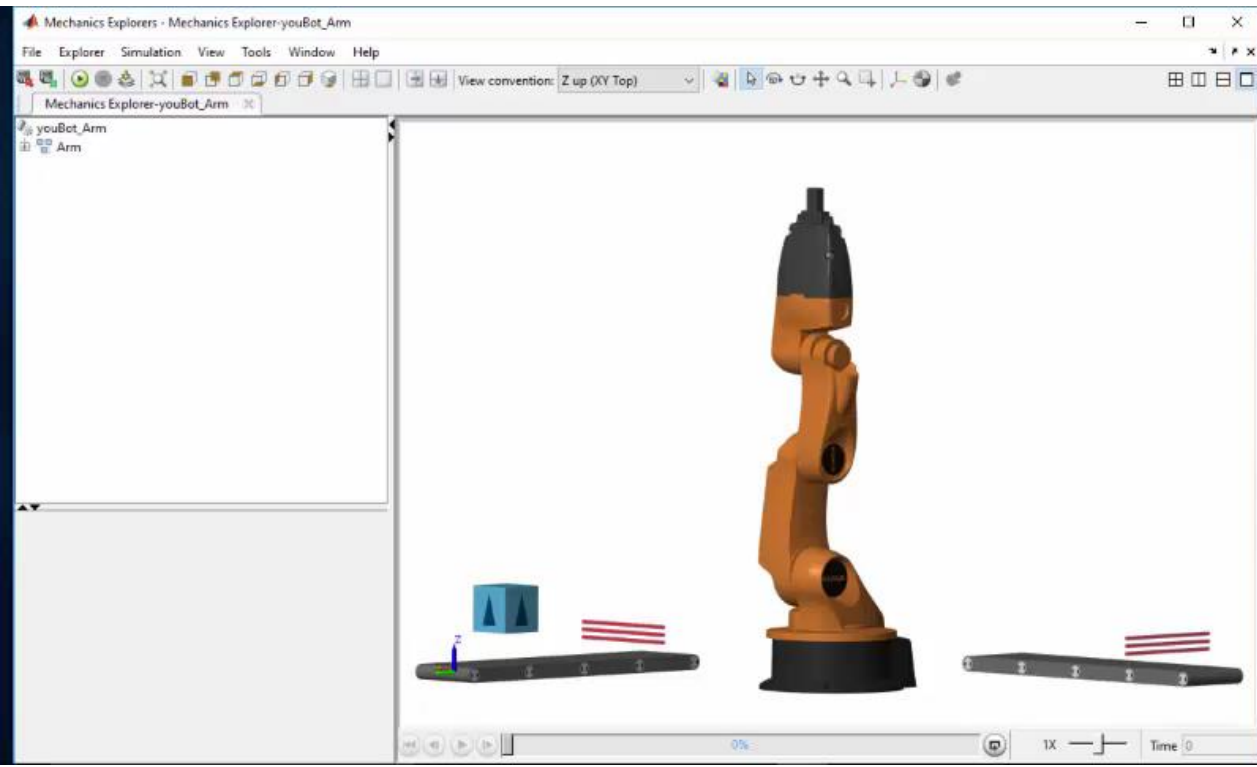
物理系统



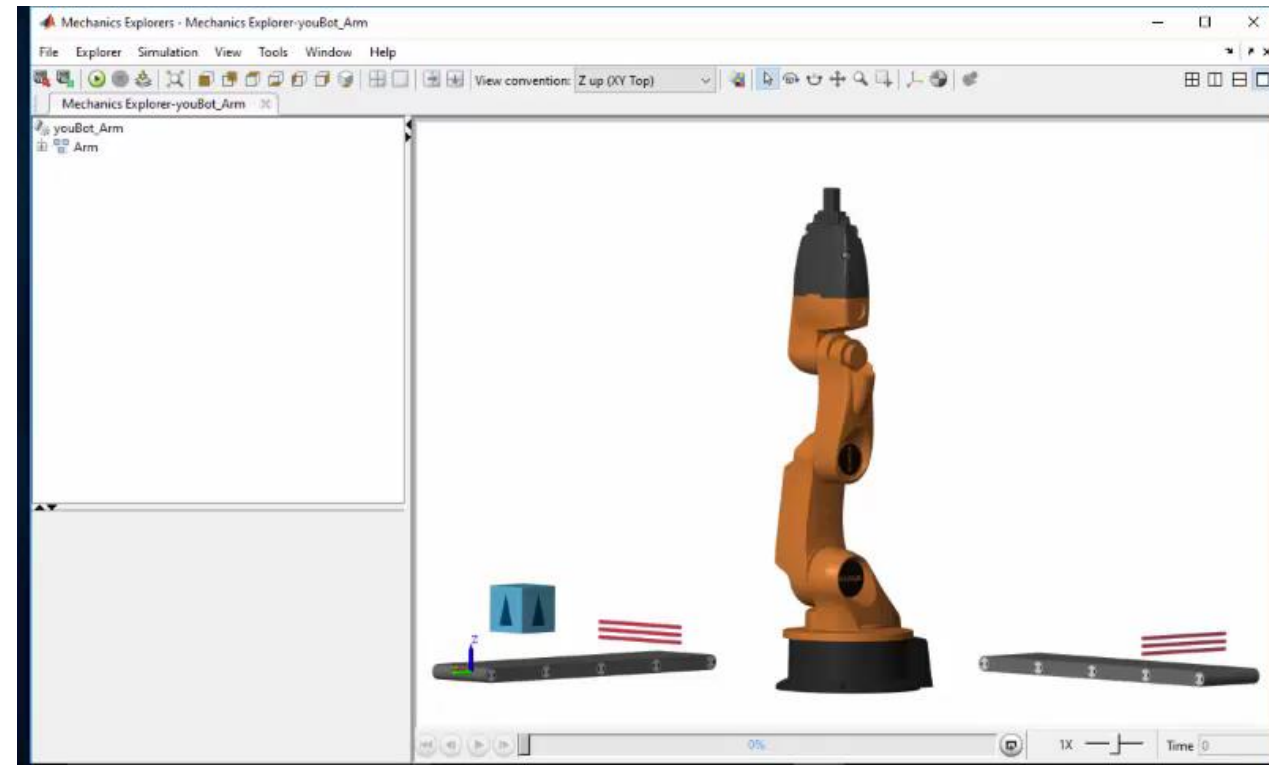
面向对象

# 机械臂的多领域仿真

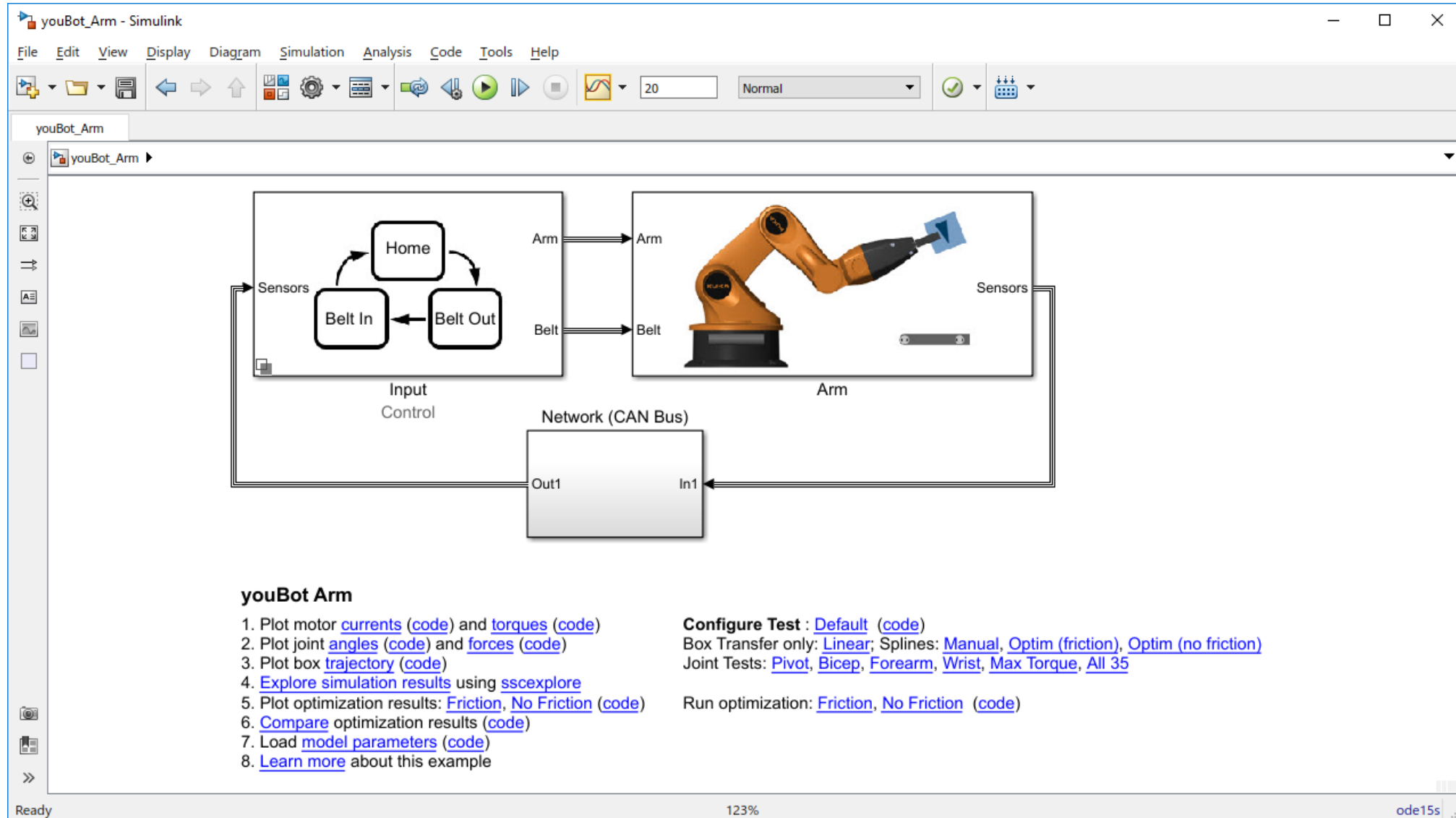
## 不带通讯网络的模型



## 带通讯网络的模型



# 机械臂的多域模型





# 状态图和系统动态建模

**youBot Arm**

1. Plot motor [currents \(code\)](#) and [torques \(code\)](#)
2. Plot joint [angles \(code\)](#) and [forces \(code\)](#)
3. Plot box [trajectory \(code\)](#)
4. [Explore simulation results](#) using [sscexplore](#)
5. Plot optimization results: [Friction, No Friction \(code\)](#)
6. [Compare](#) optimization results ([code](#))
7. Load [model parameters \(code\)](#)
8. [Learn more](#) about this example

**Configure Test (code)**  
 Box Transfer only: [Manual, Or](#)  
 Joint Tests: [Pivot, Biceps, Wrist, Max](#)  
 Run optimization: [Friction, No Friction](#)



# 机械臂的多域模型

youBot\_Arm - Simulink

File Edit View Display Diagram Simulation Analysis Code Tools Help

youBot\_Arm

**youBot Arm**

1. Plot motor [currents \(code\)](#) and [torques \(code\)](#)
2. Plot joint [angles \(code\)](#) and [forces \(code\)](#)
3. Plot box [trajectory \(code\)](#)
4. [Explore simulation results](#) using [sscexplore](#)
5. Plot optimization results: [Friction](#), [No Friction \(code\)](#)
6. [Compare](#) optimization results ([code](#))
7. Load [model parameters \(code\)](#)
8. [Learn more](#) about this example

**Configure Test** : [Default \(code\)](#)  
 Box Transfer only: [Linear](#); Splines: [Manual](#), [Optim \(friction\)](#), [Optim \(no friction\)](#)  
 Joint Tests: [Pivot](#), [Bicep](#), [Forearm](#), [Wrist](#), [Max Torque](#), [All 35](#)  
 Run optimization: [Friction](#), [No Friction \(code\)](#)

Ready 123% ode15s



# 机械臂的多域模型

youBot\_Arm - Simulink

File Edit View Display Diagram Simulation Analysis Code Tools Help

youBot\_Arm

**youBot Arm**

1. Plot motor [currents \(code\)](#) and [torques \(code\)](#)
2. Plot joint [angles \(code\)](#) and [forces \(code\)](#)
3. Plot box [trajectory \(code\)](#)
4. [Explore simulation results](#) using [sscexplore](#)
5. Plot optimization results: [Friction](#), [No Friction \(code\)](#)
6. [Compare](#) optimization results ([code](#))
7. Load [model parameters \(code\)](#)
8. [Learn more](#) about this example

**Configure Test** : [Default \(code\)](#)  
 Box Transfer only: [Linear](#); Splines: [Manual](#), [Optim \(friction\)](#), [Optim \(no friction\)](#)  
 Joint Tests: [Pivot](#), [Bicep](#), [Forearm](#), [Wrist](#), [Max Torque](#), [All 35](#)

Run optimization: [Friction](#), [No Friction \(code\)](#)

Ready 123% ode15s

# 离散事件建模

The image displays two Simulink windows. The main window, titled 'youBot\_Arm - Simulink', shows a block diagram of a robotic arm system. It includes an 'Input Control' block with 'Home', 'Belt In', and 'Belt Out' states, a 'Network (CAN Bus)' block with 'Out1' and 'In1' ports, and an 'Arm' block represented by a 3D model of a robotic arm. A green arrow points from the 'In1' port of the network to the 'Arm' block.

The second window, titled 'youBot\_Arm/Network (CAN Bus)/CAN Node 1 - Simulink', provides a detailed view of the CAN bus node configuration. It is divided into two sections: 'Transmitter' and 'Receiver'. The transmitter section shows a 'Signal To CAN Message' block, a 'Drop Dated Message upon Buffer Overflow' block, a 'Transmission Buffer' block, a 'By ID' block, a 'Message Release Control' block, a 'Reception Control' block, a 'ReTx' block, a 'Re-Transmission Control' block, and a 'Send Message to Bus' block. The receiver section shows a 'Message from Bus' block, a 'FIFO From Bus' block, an 'Entity Replicator' block, a 'Received Message' block, a 'Sort' block, and 'Subscribed Message' and 'Unsubscribed Message' outputs.

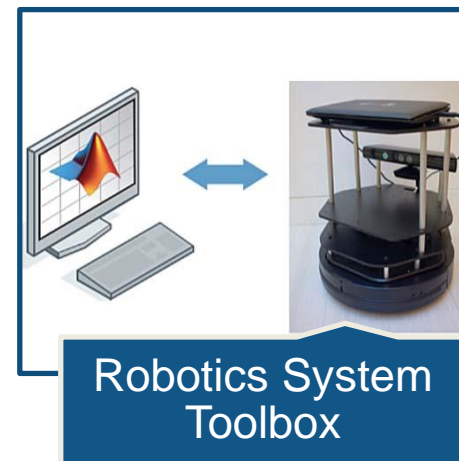
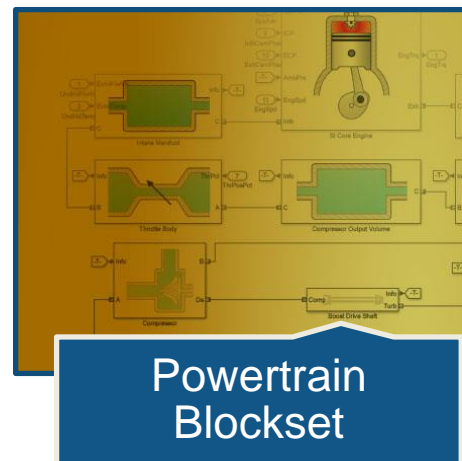
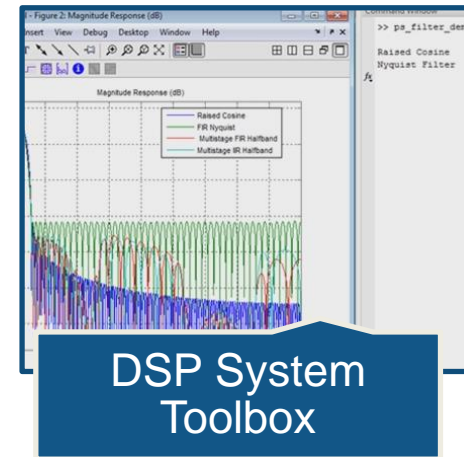
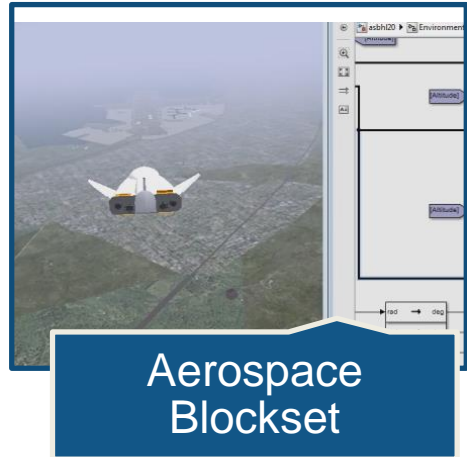
**youBot Arm**

1. Plot motor [currents \(code\)](#) and [torques \(code\)](#)
2. Plot joint [angles \(code\)](#) and [forces \(code\)](#)
3. Plot box [trajectory \(code\)](#)
4. [Explore simulation results](#) using [sscexplore](#)
5. Plot optimization results: [Friction](#), [No Friction \(code\)](#)
6. [Compare](#) optimization results ([code](#))
7. Load [model parameters \(code\)](#)
8. [Learn more](#) about this example

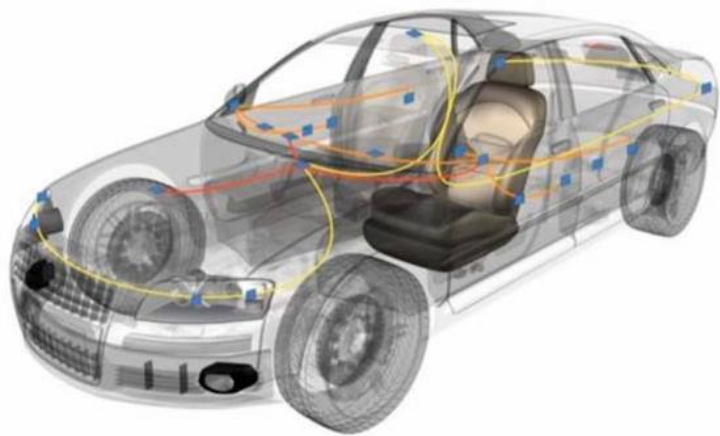
**Configure Test :** [Default \(code\)](#)  
 Box Transfer only: [Linear](#); [Splines](#);  
 Joint Tests: [Pivot](#), [Bicep](#), [Forearm](#),  
 Run optimization: [Friction](#), [No Friction](#)

# 专业领域建模

Simulink提供了丰富的各专业领域建模工具

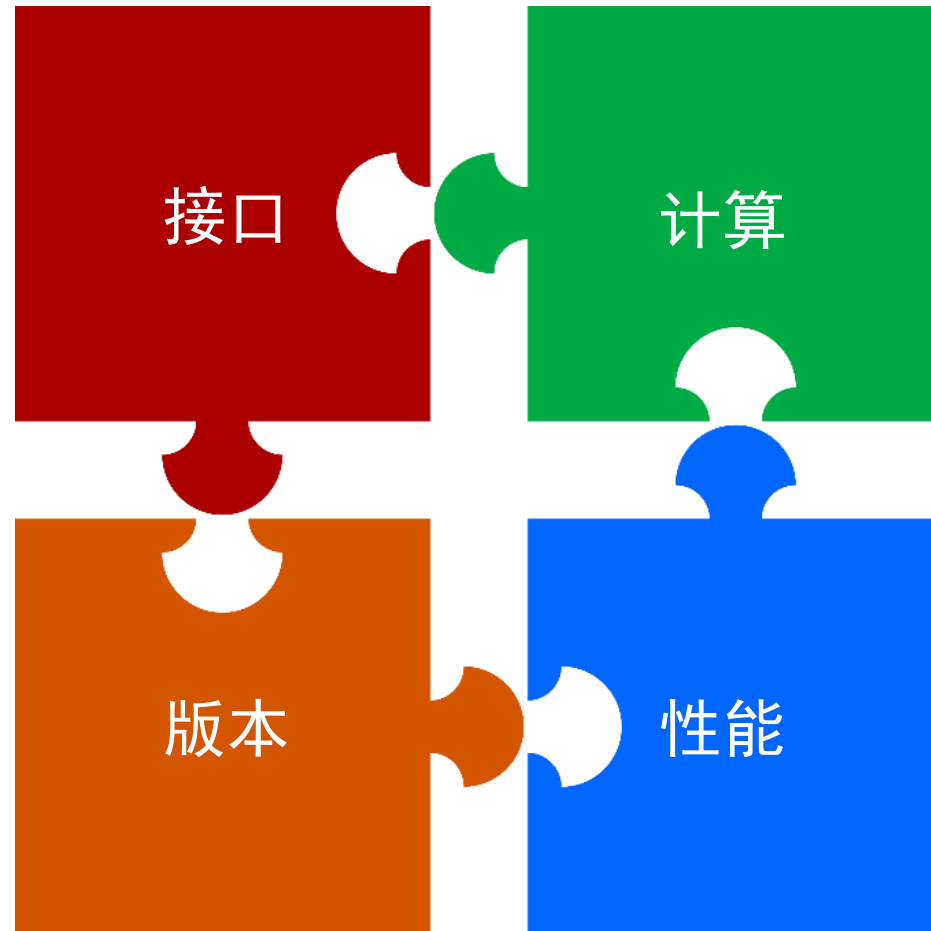


# 仿真集成





# 充分利用企业的模型资产

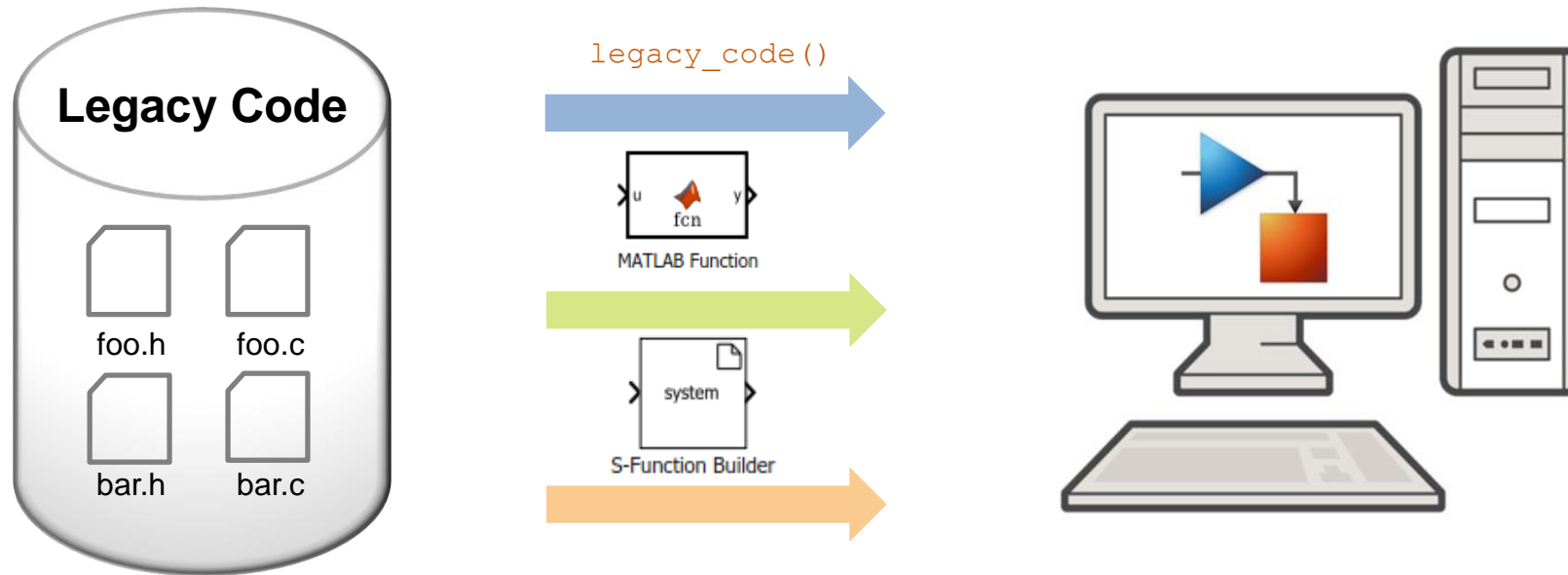


# 基于S-function的集成

- 被行业多次证明可行的解决方案
  - 二十余年的支持
  - 提供了丰富的 API
  - 良好的向下版本兼容性
- 许多工具支持导出S-function功能
- 提供C代码集成工具
  - Legacy Code Tool
  - S-function Builder

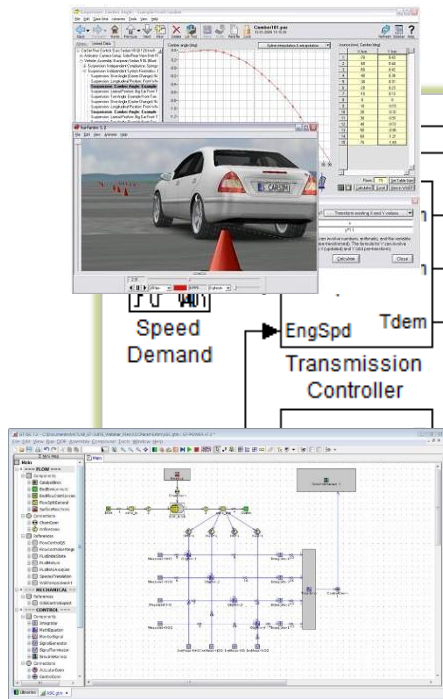
# 应用 – 代码集成

多种方式重用已有代码



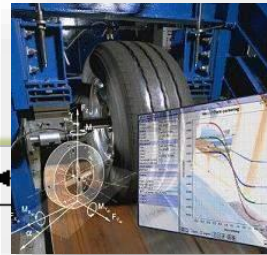
# 应用 – 第三方工具集成

车辆动力学建模

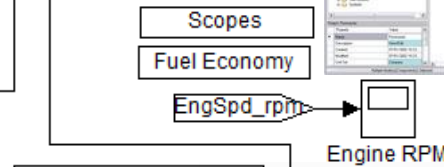
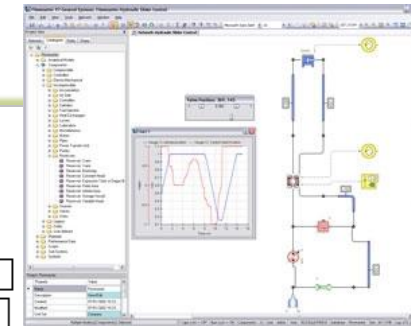


1D / 3D 发动机/排放仿真

轮胎行为评估



热液系统仿真



虚拟驾驶测试

# 基于S-function集成的优势

## 成熟而丰富的合作伙伴生态系统

The screenshot displays the MathWorks website's 'Third-Party Products & Services' section. The page is organized into several columns, each listing a different product or service. On the left side, there are filters for 'Refine by Product Type', 'Refine by Task', and 'Refine by Industry'. The products listed include:

- CarSim, TruckSim, BikeSim**: Simulation of the vehicle dynamics for SIL, HIL, and Driving Simulators. (Mechanical Simulation Corporation)
- CISC RFID ASD Kit+Library**: RFID system and appl... (CISC Semiconductor)
- FIPER (Federated Intelligent Product EnviRonment)**: A tool to streamline the design of highly engineered products. (Dassault Systèmes Simulia Corporation)
- Cockpit®**: Design for Six Sigma... (TASS International)
- Flowmaster®**: Fluid system modeling, sim... (Flowmaster)
- MADYMO**: Software for analyzing and optimizing occupant safety designs. (TASS International)
- Cosimate**: Mechanics co-simu... (Synopsys, Inc)
- FMI Blockset for Simulink**: Enables FMI compliant mo... (Synopsys, Inc)
- MagNet**: Low-frequency electromagn... (Synopsys, Inc)
- Saber®**: Design and analysis of mixed-technology and mixed-signal systems. (Synopsys, Inc)
- D-Six**: Real-time software for... (Synopsys, Inc)
- MUXlab Architect**: CAN and LIN architecture si... (Synopsys, Inc)
- SIDLAB**: Simulation of sound generation and propagation inside ducts. (Synopsys, Inc)
- DELFT-TYRE**: Tire behavior assessm... (Synopsys, Inc)
- No-Hooks/OnTarget F...**: A tool for bypass rapid prot... (Synopsys, Inc)
- SIMPACK**: Complete multibody simulation in combination with MATLAB. (Synopsys, Inc)
- Automotive D...**: A global data dic... (Synopsys, Inc)
- SimulationX**: High-end modeling tool for simulati... (Presagis)
- VAPS XT**: Custom Human-Machine Interface (HMI) prototyping, simulation, and development using commercial tools. (Presagis)
- Autonomie**: Plug-and-play co... (Synopsys, Inc)
- DSHplus**: Fluid power simulation... (Synopsys, Inc)
- GL Studio®**: Transition high-end graphic... (Synopsys, Inc)
- NX Motion Control Sir...**: Mechanism simulation allow... (Synopsys, Inc)
- SimWise 4D**: Simulation and validation of function... (Synopsys, Inc)
- veDYNA**: A professional software tool for the efficient simulation of vehicle dynamics in real time. (TESIS DYNAware GmbH)
- AVL InMotion**: Real-life simulati... (Synopsys, Inc)
- Dymola**: Dynamic Modeling Lat... (Synopsys, Inc)
- gPROMS Block Objec...**: Process modeling, simulati... (Synopsys, Inc)
- optiSLang**: Software for CAE-based ser... robust design optimization. (Synopsys, Inc)
- Structural Dynamics Toolbox**: Finite element modeling and modal... (Synopsys, Inc)
- Vehicle Dynamics for use with MATLAB/Simulink**: Time-based dynamic simulations of steering, ride, and handling. (Milliken Research Associates, Inc.)
- axisuite**: Software for the... (Synopsys, Inc)
- DYNA4**: Open simulation frame... (Synopsys, Inc)
- GT-SUITE**: Engine, powertrain, and vel... (Synopsys, Inc)
- ORION**: Calibration automation tool... (Synopsys, Inc)
- SystemVision**: Mechanics system modeling and... (Synopsys, Inc)
- Virtual Lab Motion**: Multibody dynamics modeling interface and solver. (LMS Headquarters)
- Biomechanic...**: Biomechanical a... (Synopsys, Inc)
- EDEM**: Discrete element meth... material handling and... (Synopsys, Inc)
- HLA Blockset**: Simulink interface to HLA fr... (Synopsys, Inc)
- ParaMagic, Melody, P...**: SysML parametric solvers th... execution across multiple to... (Synopsys, Inc)
- Thermolib**: Toolbox for thermodynamic calculati... Simulink®. (Synopsys, Inc)
- BOOST**: Thermodynamic... (Synopsys, Inc)
- enDYNA®**: A software tool for real... (Synopsys, Inc)
- HYDSIM**: SIMULINK transient behavior... (Synopsys, Inc)
- PreScan**: Simulation of ADAS and act... (Synopsys, Inc)
- Thermosys**: An air conditioning and heat exchang... (Synopsys, Inc)
- WAVE**: Engine and powertrain simulation software. (Ricardo)
- CADNexus/C...**: Interoperability b... (Synopsys, Inc)
- iSIGHT**: Software for process integr... (Synopsys, Inc)
- Realtime BrakeHydra...**: Real-time simulation of hydr... (Synopsys, Inc)
- Wind River Simics**: Full-system simulator and virtual platform for software and systems development. (Wind River)
- CANoe**: Tool for design a... (Synopsys, Inc)
- JMAG**: Simulation software for elec... (Synopsys, Inc)
- RecurDyn**: Cosimulate a high fidelity m... (Synopsys, Inc)
- Working Model 2D**: Software for motion simulation and analysis of mechanical systems on desktop computers. (Design Simulation Technologies)
- CarMaker for...**: Open integration... (Synopsys, Inc)
- UniPhi**: Data dictionary and model management tool. (SimuQuest, Inc.)

## 基于FMI的仿真集成



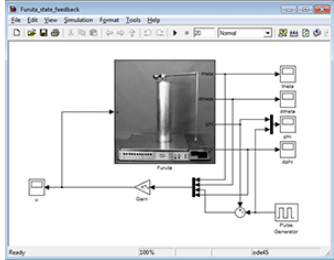

- 2010年发布了1.0版, 2014年发布了2.0版
- Simulink自R2017b版起内嵌支持FMU导入功能
- Simulink自R2019a版起支持FMU导出功能



Solver	Import/Master Simulation Integration Platform	Export/Slave Component Authoring
Variable Step	✓ R2017b	
Fixed Step	✓ R2017b	

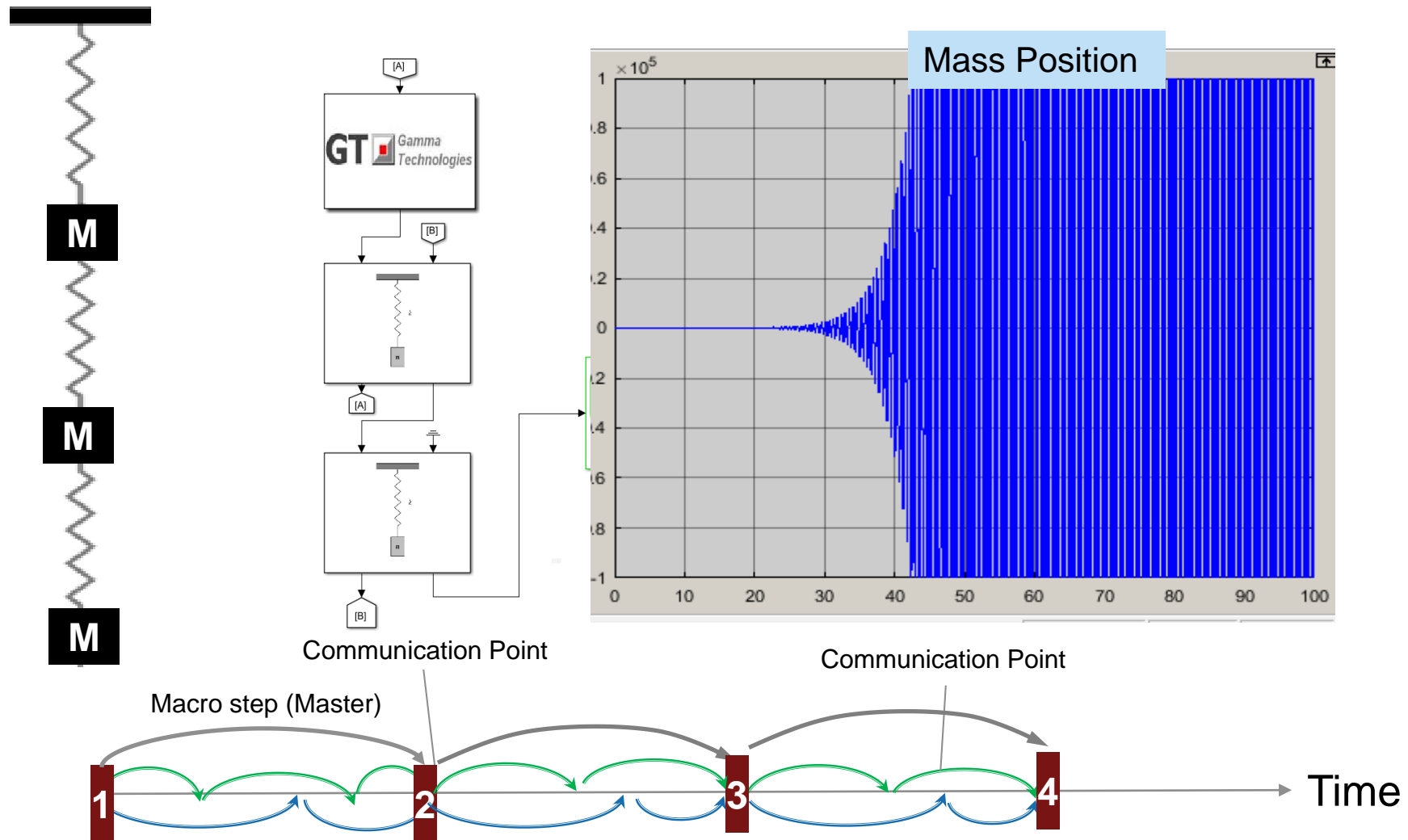


# 第三方的FMI解决方案

Third-Party Products & Services	Third-Party Products & Services	Third-Party Products & Services
<p><b>FMI Target for Simulink Coder</b> Add-on for exporting models from MATLAB and Simulink as functional mock-up units (FMUs) for cosimulation and use across a variety of platforms. This allows a continuous workflow in a complete toolchain throughout the product lifecycle.</p> <p><b>Highlights</b></p> <ul style="list-style-type: none"> <li>Serves as a cross-platform solution</li> <li>Exports models from MATLAB and Simulink as functional mock-up units (FMUs)</li> <li>Exports FMUs that include the MATLAB and Simulink solvers</li> <li>Supports FMI 1.0</li> </ul> <p><b>Description</b></p> <p>The FMI Target for Simulink Coder™ enables you to export models from Simulink® as functional mock-up units (FMUs) for cosimulation and use across a variety of platforms. This allows a continuous workflow in a complete toolchain throughout the product lifecycle.</p> <p>With this add-on, you can export models from MATLAB® and Simulink as FMUs that are fully FMI 1.0 compliant and include models' functionality. Models can also include a Simulink solver that enables any tool supporting FMUs for cosimulation to run it.</p>	<p><b>FMI Blockset for Simulink</b> Enables FMI compliant models to be imported and run in Simulink.</p> <p><b>Highlights</b></p> <ul style="list-style-type: none"> <li>Supports the FMI open standard for cosimulation</li> <li>Import models from over 30 tools into Simulink</li> <li>Configure the models in Simulink with an intuitive interface</li> </ul> <p><b>Description</b></p> <p>The FMI Blockset for Simulink provides support for the FMI open standard for cosimulation. Users can import models that follow FMI open standard (Functional Mockup Units, or FMUs) into Simulink® for cosimulation.</p> <p>The FMI Blockset for Simulink contains blocks that handle the communication between Simulink and the FMI compliant model. Each version of FMI is supported by a separate block. There is graphical interface that allows the user to select and configure the FMU within the Simulink model. The interface supports the load and configuration of the model for cosimulation. It also provides access to the model parameters, and it includes support for converting units and linking parameters to the MATLAB® workspace.</p>	<p><b>FMI Toolbox</b> Command line interface and blockset for integrating FMI-compliant model units into MATLAB and Simulink</p> <p><b>Highlights</b></p> <ul style="list-style-type: none"> <li>Model exchange with more than 35 different software tools</li> <li>Import/export and simulation of FMUs in Simulink</li> <li>Import and simulation of FMUs in MATLAB scripts</li> <li>Support for co-simulation and model-exchange FMUs</li> <li>FMI open standard version 1.0 fully supported</li> <li>FMI standard version 2.0 supported for Simulink FMU import</li> </ul> <p><b>Description</b></p> <p>FMI Toolbox enables integration and exchange of models developed in a variety of modeling tools into the MATLAB® and Simulink® environments using the open standard functional mock-up interface (FMI) format.</p> <p>FMI Toolbox offers user functions to load and access FMUs from command line and scripts, as well as a blockset for using FMUs in Simulink, and the capability to export Simulink models as FMUs. FMI Toolbox enables the use of MATLAB and Simulink as integration platforms in heterogeneous engineering tool environments. The toolbox is used for batch simulation processing, design of experiments, control design, as well as validation and verification analysis. The FMI Toolbox offers an intuitive workflow to combine physical models on a system level in an efficient manner.</p>
 <p><i>Supporting your vision</i></p> <p><b>ITI GmbH</b> Schweriner Straße 1 01067 Dresden Tel: +49-351-26050-200 Fax: +49-351-26050-155 info@itsim.com www.itsim.com</p> <p><i>Related Connections Views: Modeling and Simulation Tools, C Modeling and Simulation, Automotive</i></p>	 <p><b>Claytex Services Ltd</b> Rugby Rd Leamington Spa CV32 6EL UNITED KINGDOM Tel: +44-1926-885900 Fax: +44-1926-885910 info@claytex.com www.claytex.com</p>	 <p><a href="#">Enlarge</a> Simulink model containing an FMU and a simple control system developed using Simulink blocks</p> <p>FMI was pioneered by OEMs in the automotive industry, and is now an established technology in all systems industries. The FMI technology is supported by a large number of open source and commercial software tools for systems engineering. See <a href="http://fmi-standard.org">fmi-standard.org</a> for more information.</p>  <p><b>Modelon AB</b> Ideon Science Park LUND, 223 70 SWEDEN Tel: +46-462-962204 Fax: +46-462-962201 info@modelon.com www.modelon.com</p>

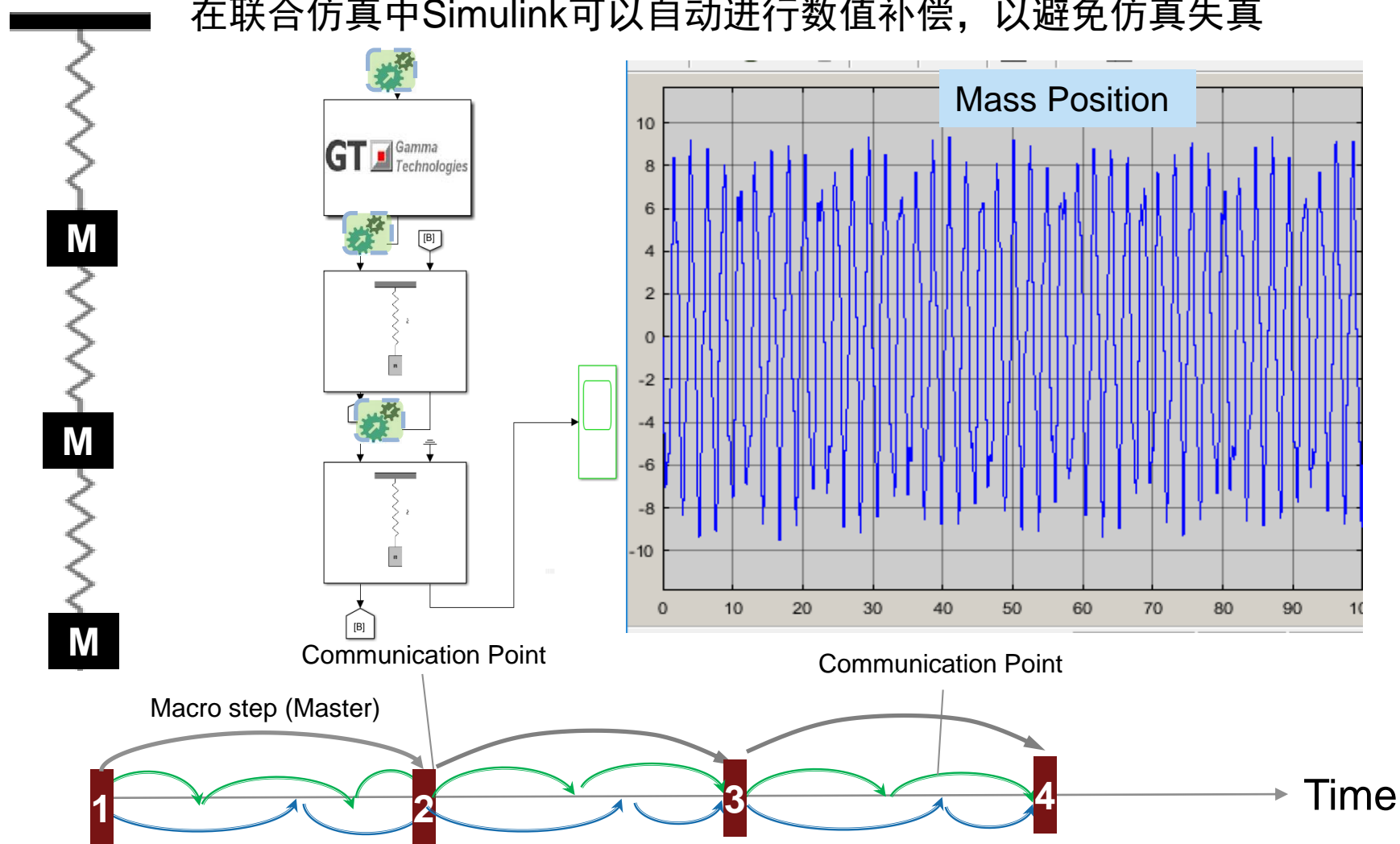
# 联合仿真的失真问题

零阶保持器在联合仿真边界的数据交换导致仿真失真

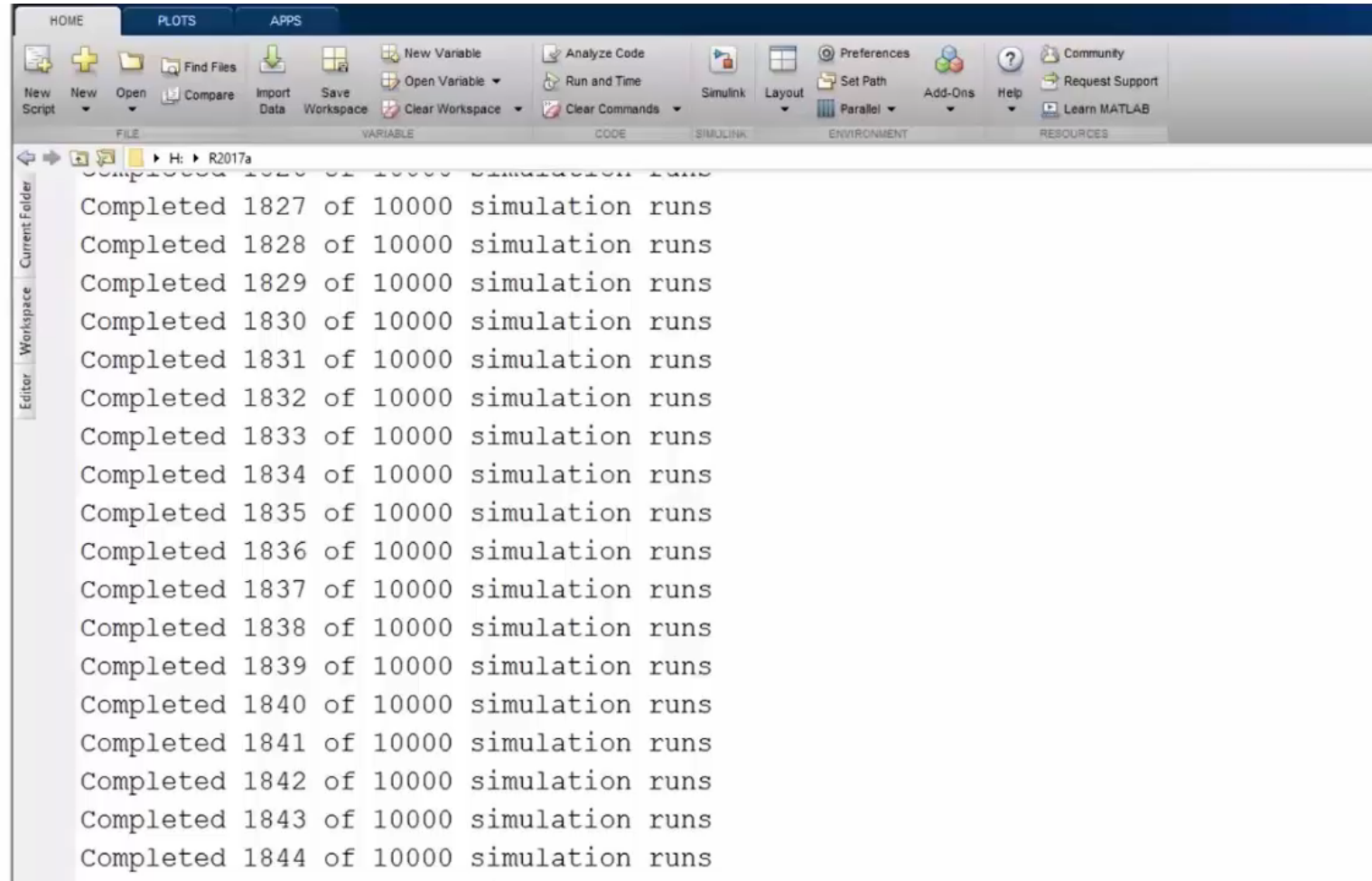


# 联合仿真的数值补偿功能

在联合仿真中Simulink可以自动进行数值补偿，以避免仿真失真



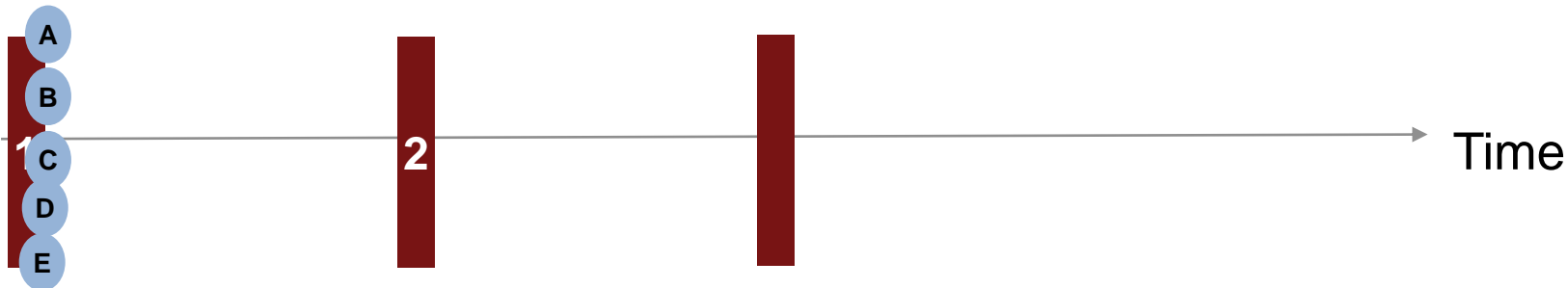
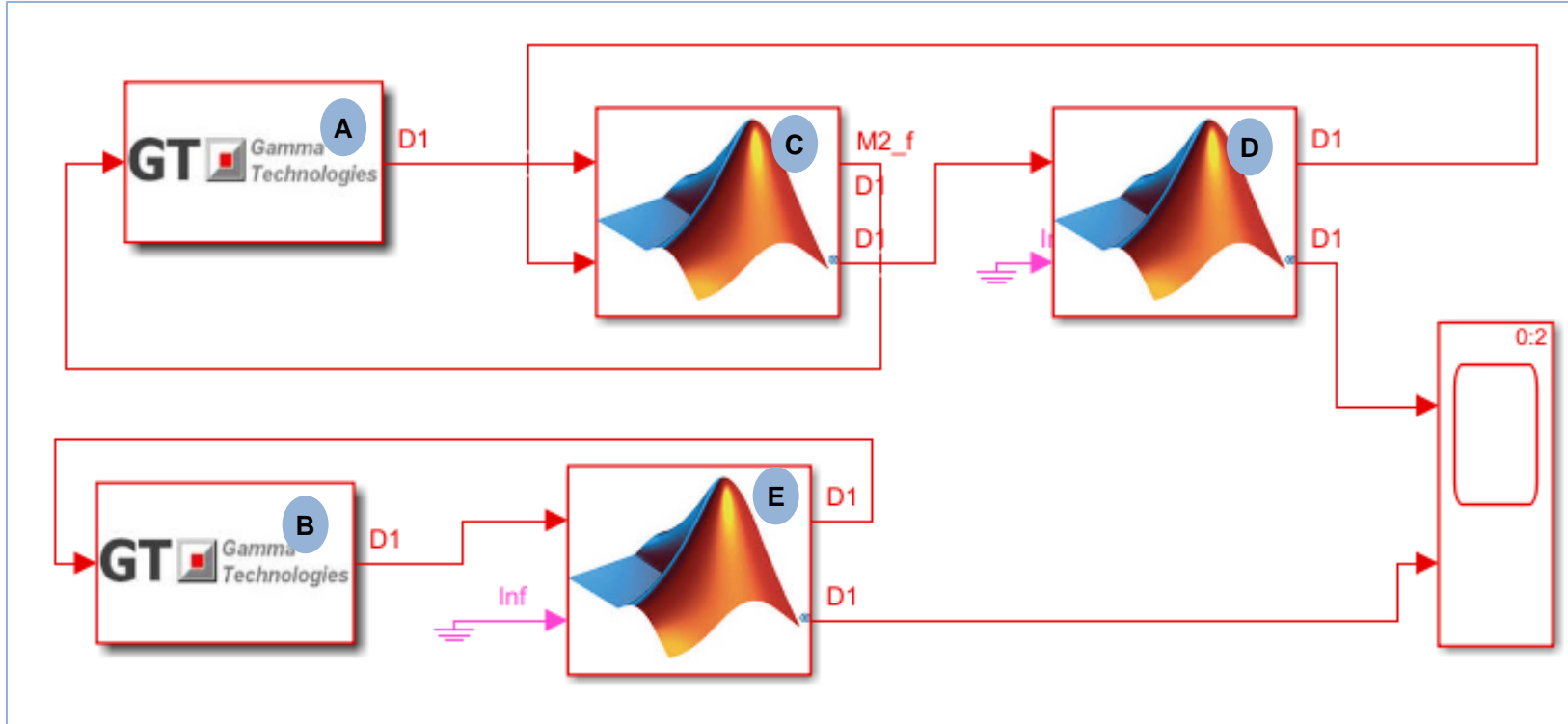
# 并行仿真



The screenshot displays the MATLAB Parallel Computing Toolbox interface. The top menu bar includes tabs for HOME, PLOTS, and APPS. Below the menu bar, there are several toolbars with icons for file operations (New, Open, Find Files, Compare, Import Data, Save, Clear Workspace), code execution (Analyze Code, Run and Time, Clear Commands), and simulation management (Simulink, Layout, Parallel, Set Path, Add-Ons, Help, Community, Request Support, Learn MATLAB). The main workspace area shows a list of simulation runs, with the following text:

```
Completed 1827 of 10000 simulation runs  
Completed 1828 of 10000 simulation runs  
Completed 1829 of 10000 simulation runs  
Completed 1830 of 10000 simulation runs  
Completed 1831 of 10000 simulation runs  
Completed 1832 of 10000 simulation runs  
Completed 1833 of 10000 simulation runs  
Completed 1834 of 10000 simulation runs  
Completed 1835 of 10000 simulation runs  
Completed 1836 of 10000 simulation runs  
Completed 1837 of 10000 simulation runs  
Completed 1838 of 10000 simulation runs  
Completed 1839 of 10000 simulation runs  
Completed 1840 of 10000 simulation runs  
Completed 1841 of 10000 simulation runs  
Completed 1842 of 10000 simulation runs  
Completed 1843 of 10000 simulation runs  
Completed 1844 of 10000 simulation runs
```

# 多线程联合仿真

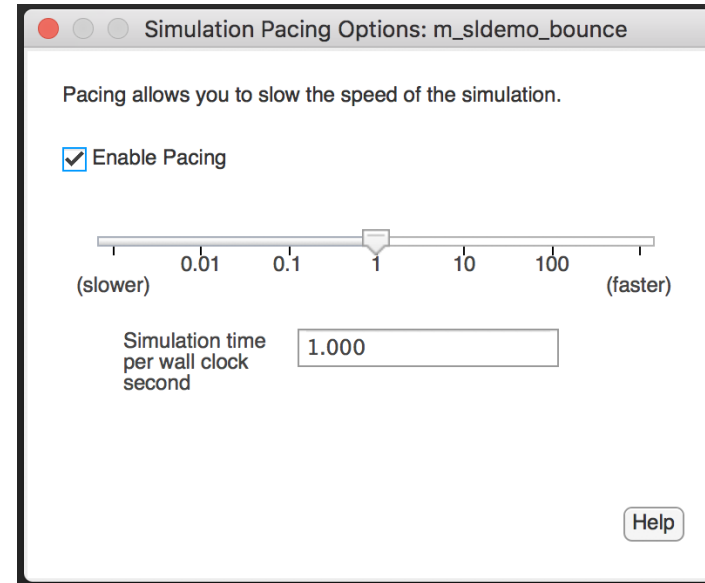
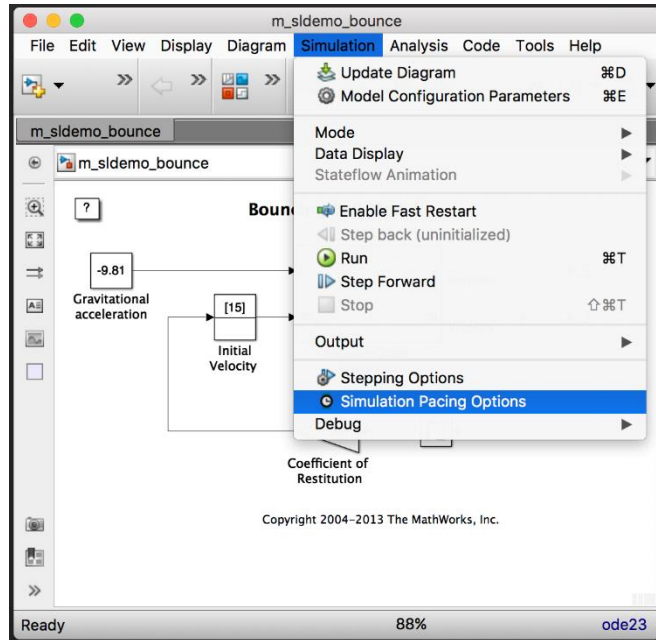


Parallel execution  
Simulation time: 73 sec



Simulink Today (Sequential)  
Simulation time: 123 sec

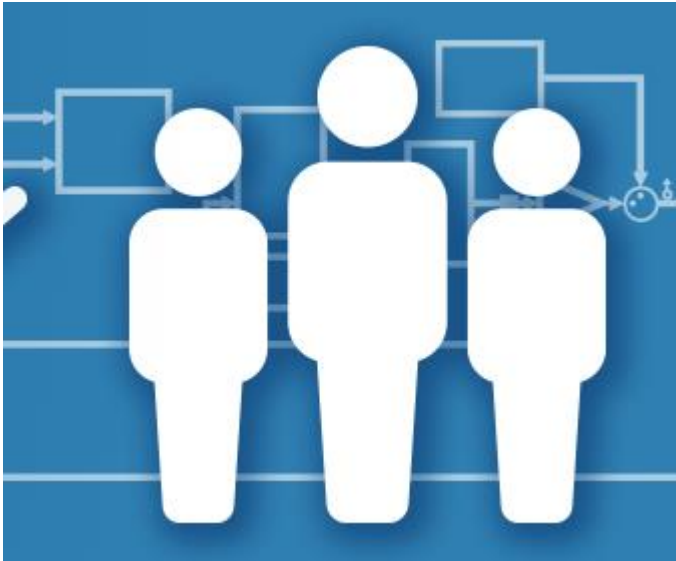
# 仿真调速



- Slow down a running simulation for easier:
  - Interaction with hardware
  - Demos
  - Control with HMI widgets

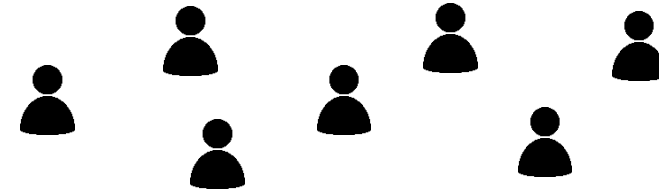


# 协同设计



# 组件式开发实现复杂系统协同设计

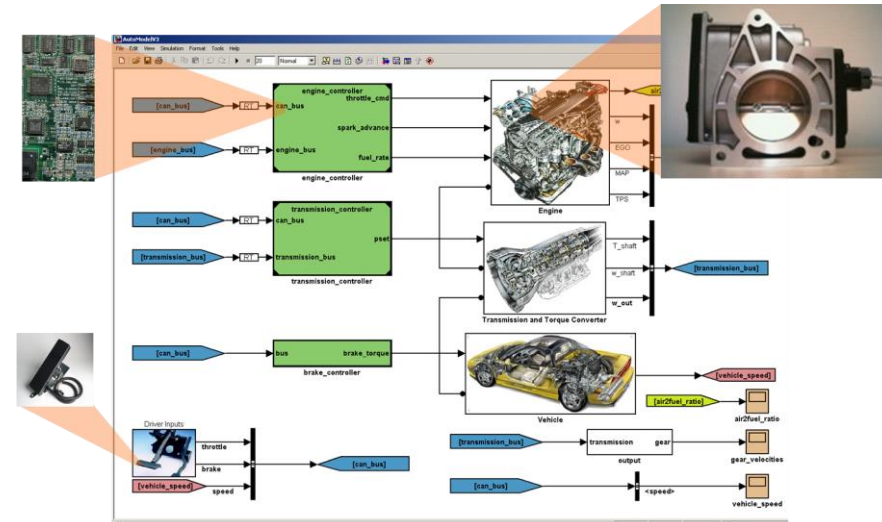
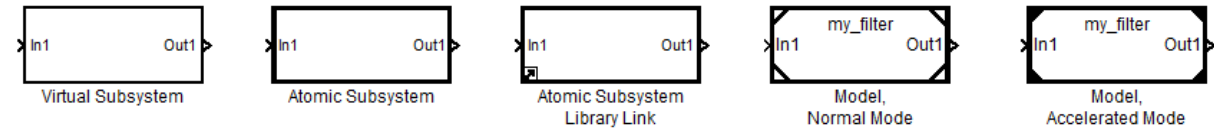
- Simulink支持组件式协同开发流程



- 更快的模块化开发

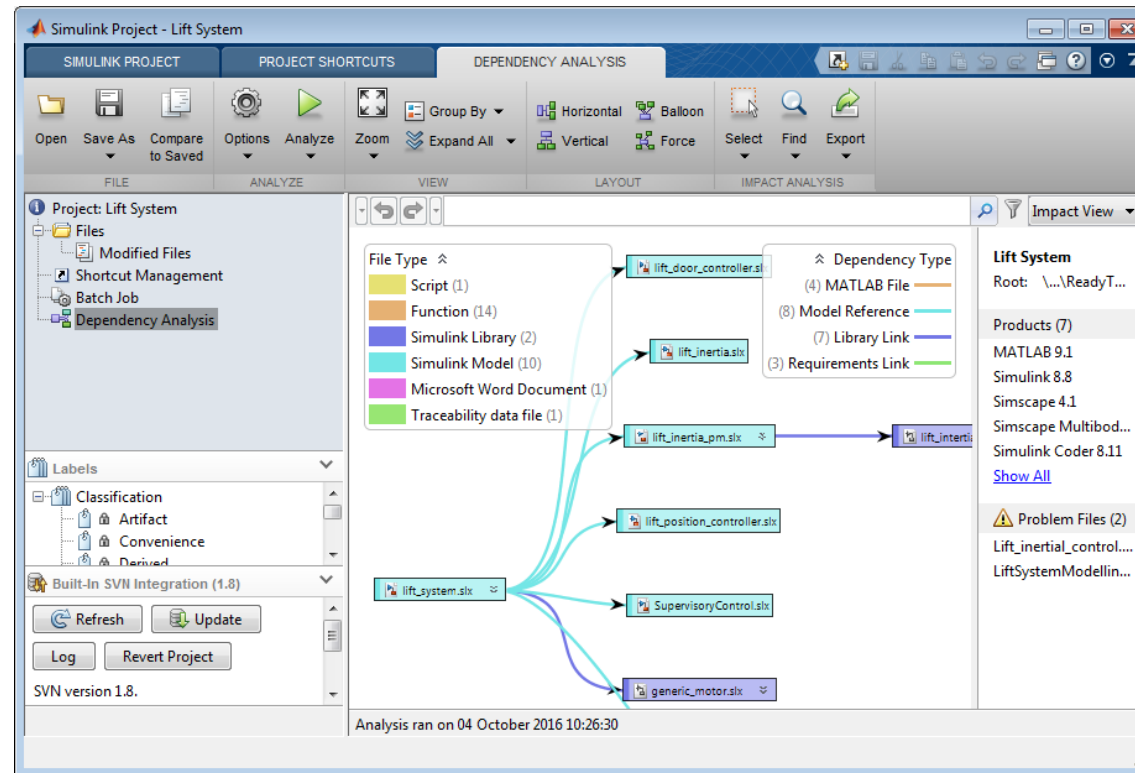
- 更有效的验证

- 提升重用性



# 基于团队的工作流程支持

- 版本控制
- 设计比较与合并
- 依赖性分析
- 任务自动化



# 支持多种版本控制工具集成

Microsoft Team Foundation Server (TFS) integration available now from MathWorks File Exchange



Products Solutions Academia Support **Community** Events

## File Exchange

### TFS Version Control Integration

by [Jasper Schneider](#)

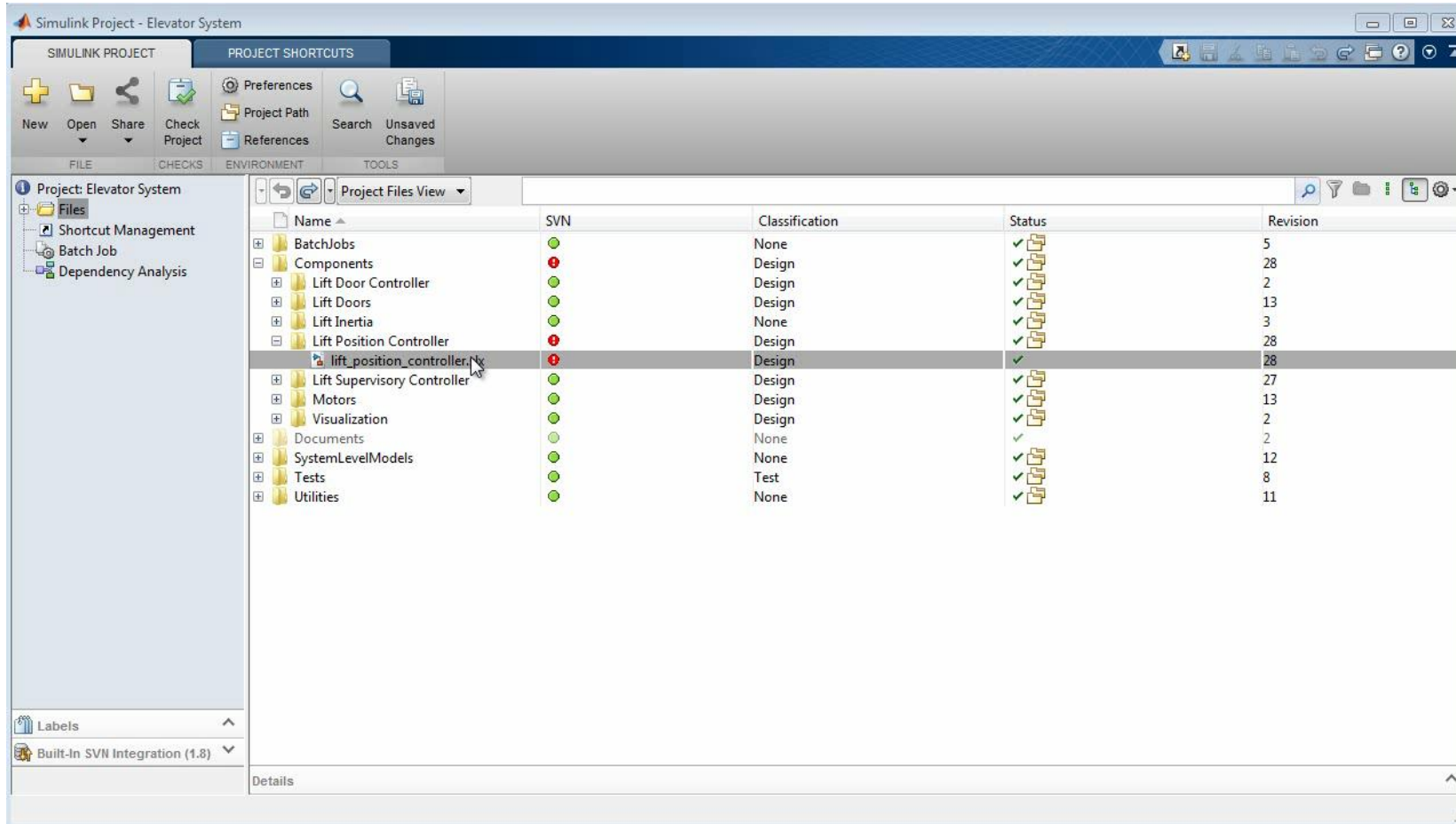
17 May 2016 (Updated 26 May 2016)

TFS Version Control integration in MATLAB and Simulink

[Watching this File](#)



# 设计合并



- 支持并行工程
- 可以专注于设计

# 依赖性分析

Simulink Project - Elevator System

SIMULINK PROJECT PROJECT SHORTCUTS

MANAGE DOCUMENTATION ENVIRONMENT TOP LEVEL MODELS UTILITIES

Project: Elevator System

Project Files View

Name	Path	Status	Classification
Lift	\$\Tests	✓	Test
Lift Door Controller	\$\Components	✓	Design
Lift Door Controller	\$\Tests	✓	Test
Lift Doors	\$\Components	✓	Design
Lift Doors	\$\Tests	✓	Test
Lift Inertia	\$\Components	✓	None
Lift Motor	\$\Tests	✓	Test
Lift Position Controller	\$\Components	✓	Design
Lift Position Controller	\$\Tests	✓	Test
Lift Supervisory Controller	\$\Components	✓	Design
Lift Supervisory Controller	\$\Tests	✓	Test
Motors	\$\Components	✓	Design
SystemLevelModels	\$\	✓	None
Tests	\$\	✓	Test
Utilities	\$\	✓	None
Visualization	\$\Components	✓	Design
Visualization	\$\Tests	✓	Test
basic_animation.slx	\$\Components\Visualization	✓	Design
ElevatorTemplate.slx	\$\Utilities	✓	Other
exportToR2016a.m	\$\BatchJobs	✓	Design
generateBillOfMaterials.m	\$\BatchJobs	✓	Design
generateICD.m	\$\Utilities	✓	Design
generic_motor.slx	\$\Components\Motors	✓	Design
history.m	\$\Utilities	✓	Design
lift_door.req	\$\Components\Lift Doors	✓	Design
lift_door.slx	\$\Components\Lift Doors	✓	Design
lift_door_controller.slx	\$\Components\Lift Door Controller	✓	Design

Labels

Details

# 依赖性分析

The screenshot displays the Simulink Dependency Analysis tool. The main window is titled 'DEPENDENCY ANALYSIS' and features a toolbar with options like 'Open', 'Save As', 'Compare to Saved', 'Options', 'Analyze', 'Zoom', 'Expand All', 'Horizontal', 'Vertical', 'Balloon', 'Force', 'Select', 'Find', and 'Export'. The left sidebar shows the project structure for 'lift\_system\_orig'. The central area contains a dependency graph with nodes such as 'lift\_system.slx', 'generic\_motor.slx', 'lift\_door\_controller.slx', 'lift\_inertia.slx', 'lift\_inertia\_pm.slx', 'lift\_inertia\_utils.slx', 'lift\_door.req', and 'lift\_system\_Harness1.slx'. The right-hand pane lists the required products: MATLAB 9.1, Simulink 8.8, Simscape 4.1, Simscape Multibody 4.9, and Simulink Coder 8.11. Below this, it indicates one problem file: 'LiftSystemModelling.docx'.

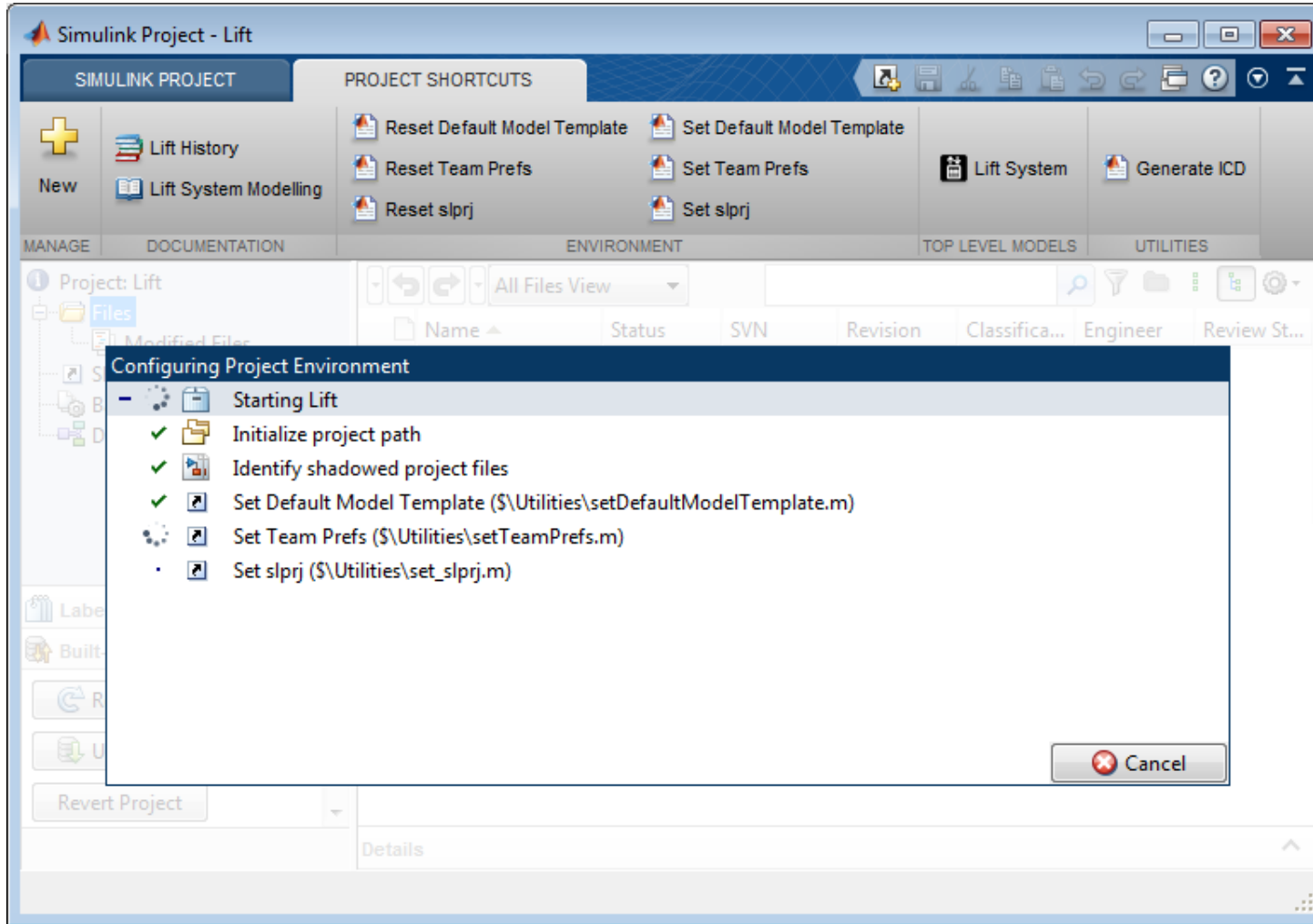
**Show model structure**

**List products required**

**Highlight issues**



# 任务自动化



- Robustly configure the team environment
- For everyone
- Automatically

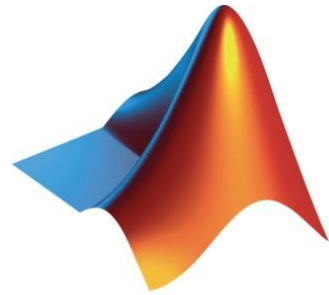


# 企业仿真平台总结

*“There is no such tool, which gives the simulation environment as well as the hardware verification and validation. In a single environment, I am getting these together. **That is why I use MATLAB and Simulink.**”*

Dr. Deepak Mishra,  
Indian Space Research Organization





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