

# Scaling up Model-Based Design: Moving from First Success to Optimized Deployment

## 提升基于模型的设计：从第一次成功到优化部署

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**MathWorks**

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*“When I step into a new car  
these days, I don’t smell  
leather anymore,  
**I smell software”**”*

*“这些天当我走进一辆新车的时候，我  
不再闻到真皮座椅的味道，**而是闻到了  
软件的气息。”**”*



MATLAB Automotive Conference, Stuttgart, 2015



*John Lauckner, CTO at General Motors*

# Recalls in the automotive industry

## 汽车行业的召回

### Breaking News - Business

#### Chrysler recalls 630,000 SUVs over defects

(06-06 21:03)

Just two days after refusing a US government request to recall 2.7 million older-model Jeeps, Chrysler has decided to do two other recalls totaling 630,000 vehicles worldwide.

The automaker will recall more than 409,000 Jeep Patriot and Compass small sport utility vehicles across world capitals from the 2010 and 2012 model years to fix air bags and seat-belt problems. It's also recalling 221,000 Jeep Wranglers worldwide from 2012 and 2013 to fix transmission fluid leaks, according to documents posted today on the National Highway Traffic Safety Administration website. AP reports.

#### Daimler to Recall Freightliner Cascadia Trucks for Light Issue

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Daimler Trucks North America will recall about 46,000 Freightliner Cascadia trucks due to a software glitch that may cause the daytime running lights to turn off, the company said in a report released by the federal government Wednesday.

The problem affects all model-year 2013 and 2014 Cascadias produced from May 7, 2012, to March 2, 2013, totaling 42,823 in the United States and 3,223 in Canada, DTNA estimated in its March 15 report to the National Highway Traffic Safety Administration.

#### Lexus Recalls 2013 GS 350 F Sport for Potential Steering Hazard

By CHRISTOPHER JENSEN

Toyota is recalling about 660 of its [redesigned Lexus GS 350 sedans](#) because of a steering problem that may occur when leaving a parking space, the automaker told the [National Highway Traffic Safety Administration](#).

The models affected have rear-wheel drive and are equipped with the F Sport

- Increasing news of recalls
- 不断增加的召回新闻
- Often due to ECU software bug
- 原因通常是ECU的软件缺陷
- SW complexity worsens situation
- 软件复杂程度使形势更加严峻
- Expensive, damaging to OEMs
- 给整车厂商带来昂贵的破坏性后果

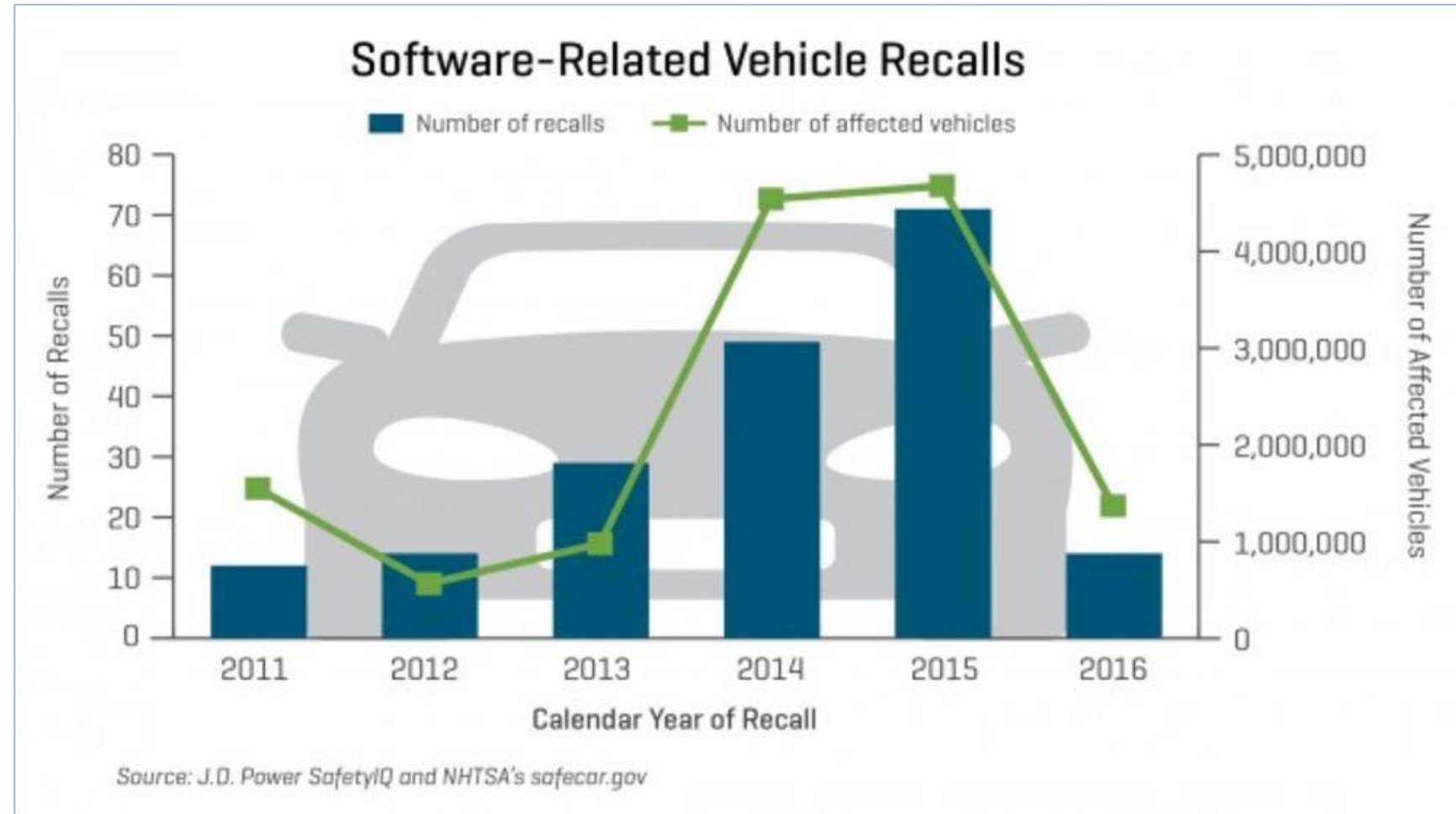
# Recalls in the automotive industry

## 汽车行业的召回

### SOFTWARE NOW TO BLAME FOR 15 PERCENT OF CAR RECALLS

YOU CAN'T JUST HOLD THE HOME AND LOCK BUTTONS TO SOLVE THIS ONE

Bengt Halvorson / The Car Connection Posted June 2, 2016



## Altran study: Study participants reported that quality improvement was a strong reason to move to Model-Based Design

Altran研究表明：质量改进是转向采用基于模型设计的重要原因

	No critical reason	Strong reason	Very strong reason
1 A new function with high complexity is being developed	1,5%	28,8%	69,7%
2 Increase of the product quality	1,6%	28,1%	70,3%
3 Shorter development times and earlier Time-to-Market-Time	4,9%	31,1%	63,9%
4 Cost savings in the software development	6,1%	43,9%	50%
5 Reuse of the function in other car lines is planned	6,5%	30,6%	62,9%

MathWorks Automotive Virtual Conference, June 2013

Dr. Jens Zimmermann, Altran

# MAB 1998

## 3 Organizations

1998年，MathWorks咨询委员会（MAB）  
起始于三个组织



**Alex Ohata**  
Toyota



**Armin Muller**  
Daimler-Benz



**Ken Butts**  
Ford

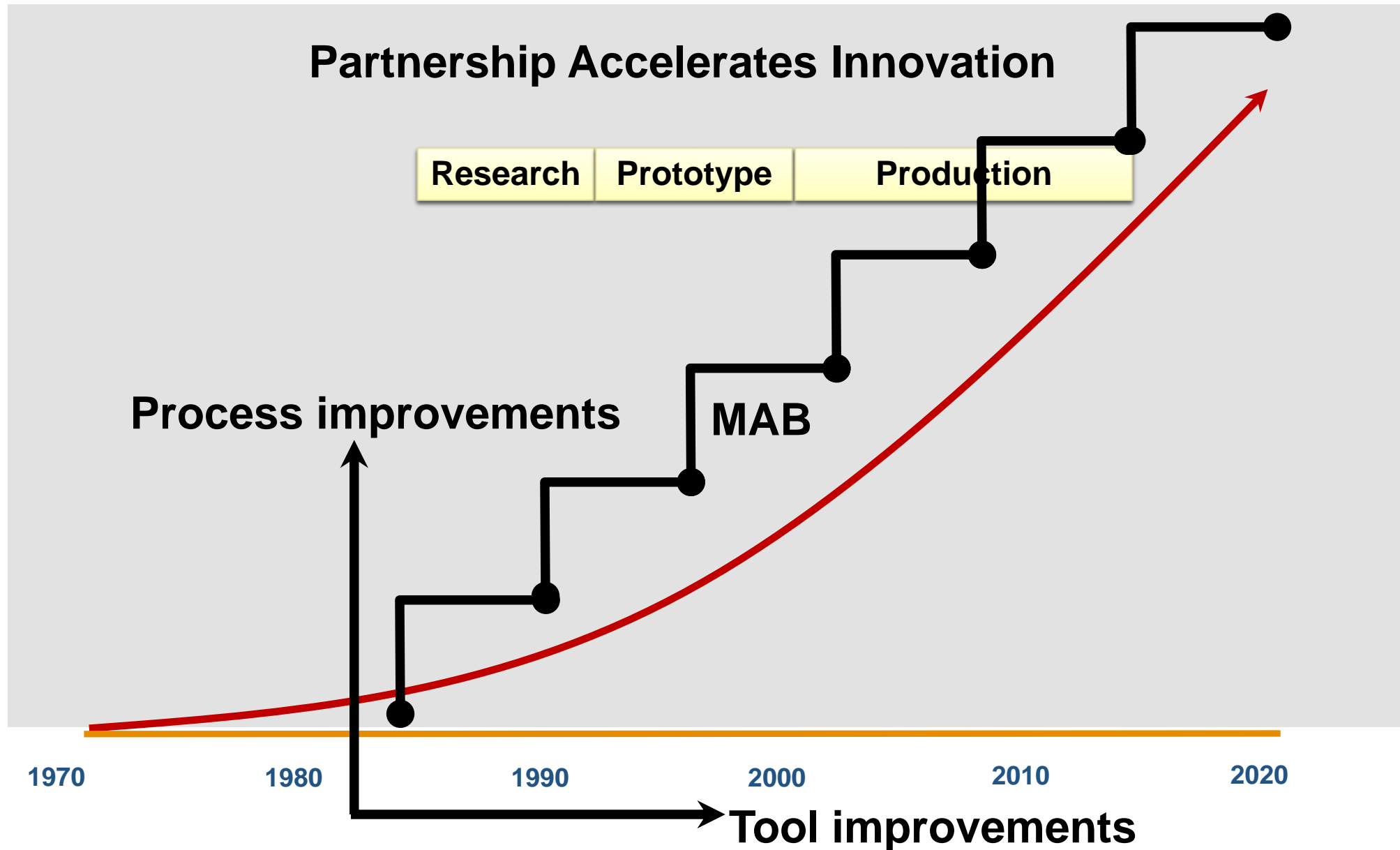


## MAB 2015

Boston: 107 Organizations  
Europe, China, Japan, Korea,  
India ...

2005年，MathWorks咨询委员会（MAB）  
波士顿：拥有107个组织参加  
另外还有欧洲/中国/日本/韩国/印度等等

# Model-Based Design Adoption 采用基于模型的设计





# Automatic Code Generation has been an Important Motivation for Deploying Model-Based Design

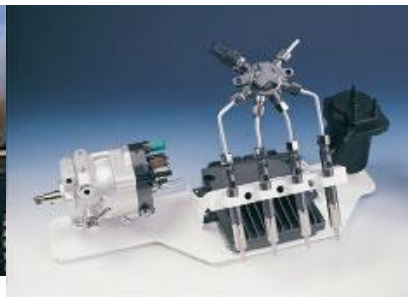
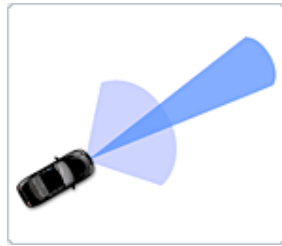
自动代码生成已经成为采用基于模型设计的重要驱动力

**Daimler: Vehicle Controller**  
**Delphi: Radar Module**  
**Caterpillar: Machine Control**

**GM: Hybrid Powertrain**  
**Continental: Active Suspension**  
**Delphi: Common Rail Diesel**

**Toyota: Hybrid Control Unit**  
**Lear: Body Control Module**  
**Cummins: Diesel EMS**

**CNH: Combine Control Unit**  
**GM: HVAC Module**  
**Vodafone: Telematics**



# MATLAB and Simulink Help Engineers Put ADAS and Autonomous Driving on the Road

## MATLAB 和 Simulink 帮助工程师将ADAS与自动驾驶在真实路面上得以实现

### Sensor fusion

#### Two sensors -> One "truth"

Sensors have different advantages

- Radar
  - + Range (longitudinal)
  - + Relative velocity
  - + Solid object reflection
  - No shapes
  - Lateral position
- Camera
  - + Object type
  - + Object width
  - + Lateral position
  - Range
  - Optical illusions

Redundance required for stationary objects

2015-09-24 Jonny Andersson

### Model Based Design for fusion

#### Easy to get nice and readable architecture

#### For-each systems and Matlab Function blocks, suitable for loops and similar calculations.

#### MATLAB is a suitable platform for debugging and visualization.

#### Easy debugging in Matlab Function Block

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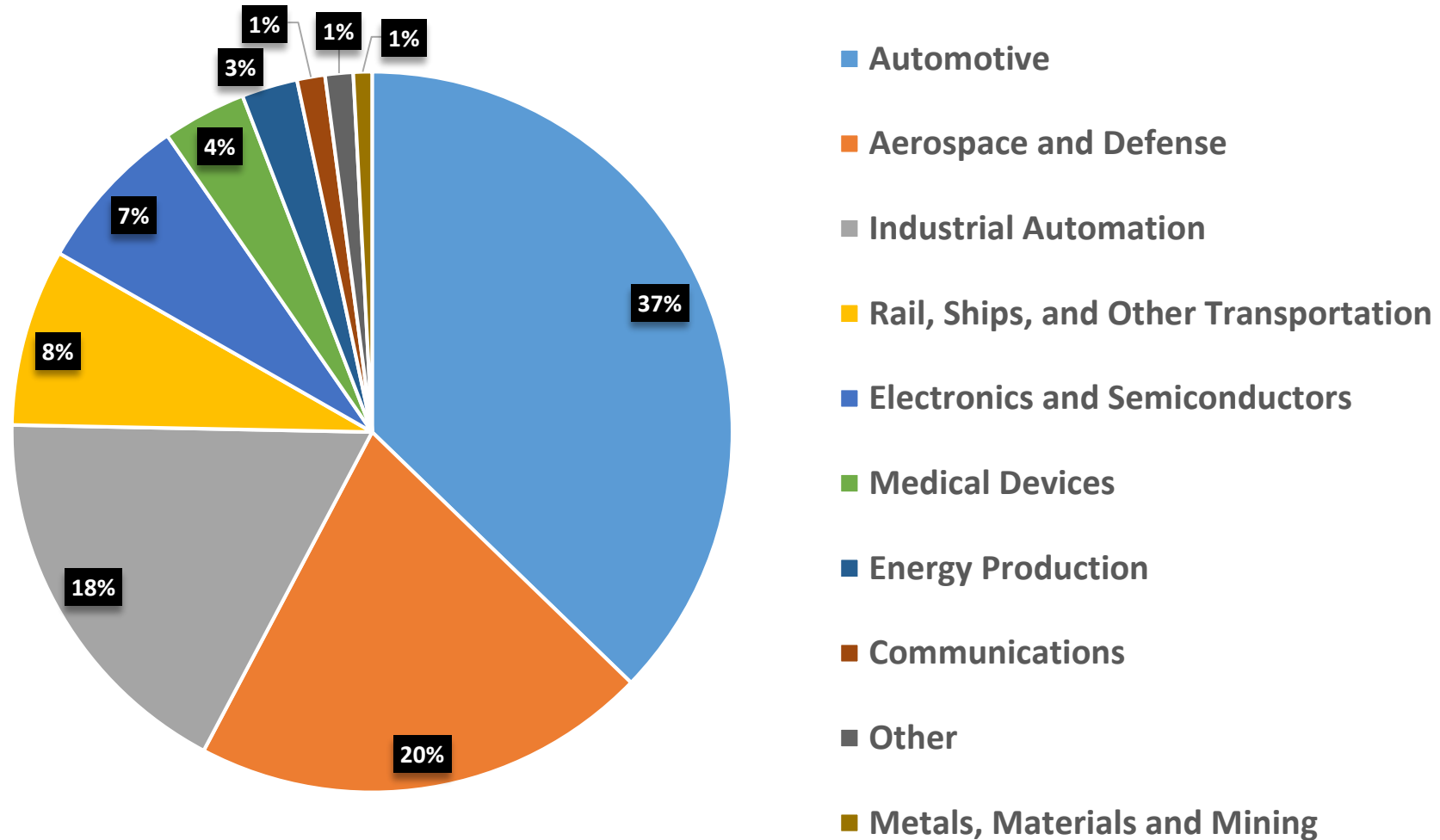
2015-09-24 Jonny Andersson

**50 km/h - sudden brake**

**Model-Based Design and Code Generation  
for AEB Sensor Fusion**

# Surveys from 3 continents, 176 companies representing 30,000+ users

以下调查来自于：三个大陆，176家公司，代表了30000多名用户



Source: 2015 MathWorks Model-Based Design Survey

# Perceived Current Benefit Versus Traditional Methods

## 与传统方法相比，可以看出当前MBD的优势

MBD Component	Benefit
Desktop simulation	4.17
Graphical authoring of algorithms	4.14
Real-Time Prototyping	4.05
Production code deployment	4.04
Plant modeling	4.04
On target prototyping	3.93
Hardware-in-the-Loop	3.91
Model verification	3.72
Textual authoring of algorithms	3.66
Code verification	3.62

**5 = very high**  
**4 = high**  
**3 = medium**  
**2 = low**  
**1 = very low**

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趋势表明：如果你刚接触MBD，可以考虑从以下方面作为开展MBD的突破口。

1. 桌面仿真
2. 可执行的需求描述
3. 快速原型与产品代码生成

# Cummins in 2007 康明斯，2007年

采用代码生成：

功能设计与快速原型

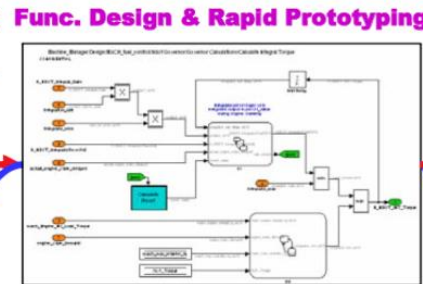
目标码生成

在真实硬件中进行测试

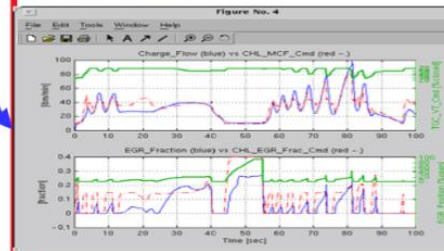
## Cummins' Vision for Embedded Controls Development



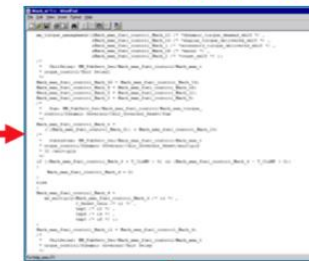
Cummins generates models of the controller . . .



& test these models in simulation . . .



Target Code Generation



to produce automatic C-code straight from the controller model . . .

that is tested on actual hardware which is >95% bug free.



# Difference between perceived current benefit and future benefit

## 当前获得的优势与未来可获得优势的区别

MBD Component	Delta in benefit*
Code verification	0.40
Plant modeling	0.39
Model verification	0.38
Hardware-in-the-Loop	0.34
Desktop simulation	0.32
Production code deployment	0.31
Textual authoring of algorithms	0.30
Graphical authoring of algorithms	0.29
On target prototyping	0.28
Real-Time Prototyping	0.26

调查结果建议如果你正在应用MBD，接下来请考虑关注以下两方面：

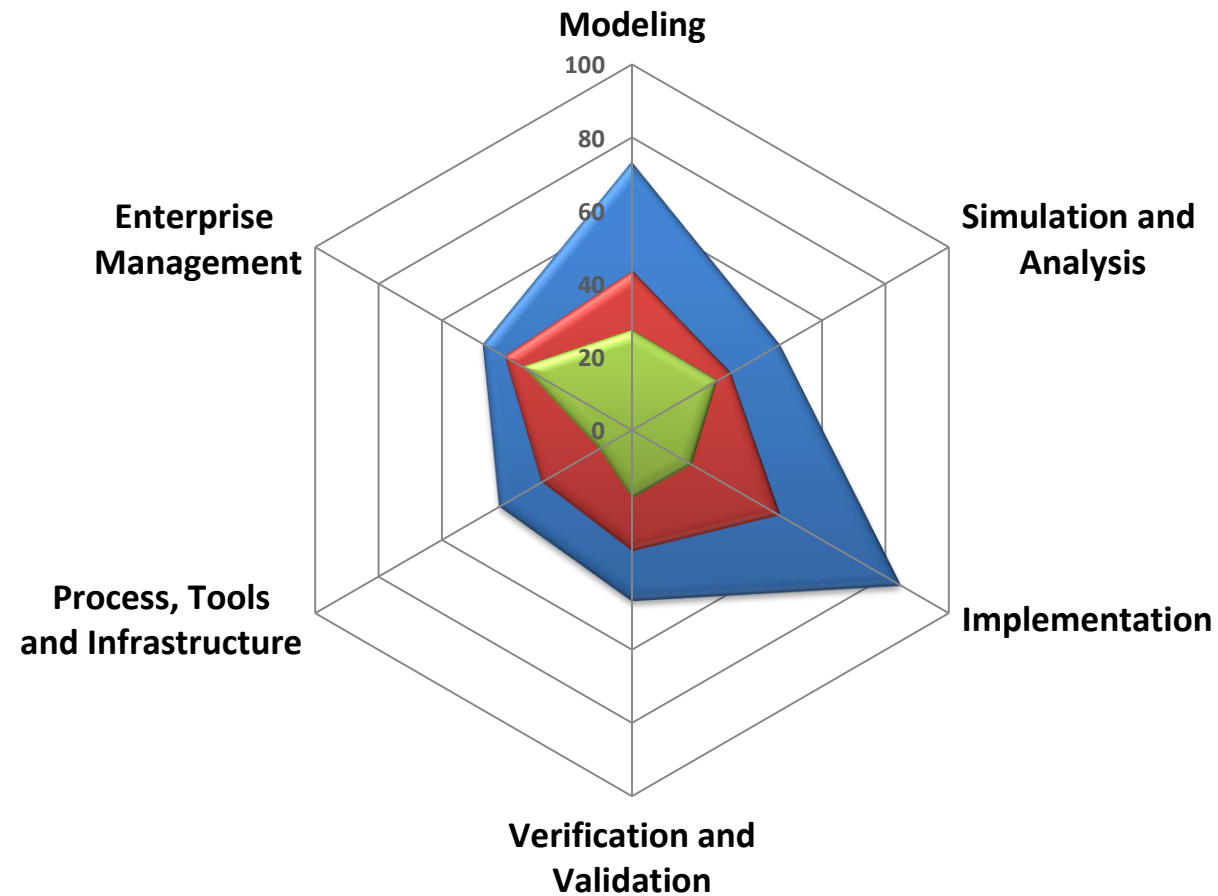
1. 验证与确认
2. 被控对象物理建模



# Model-Based Design Maturity Auto Industry Maturity:

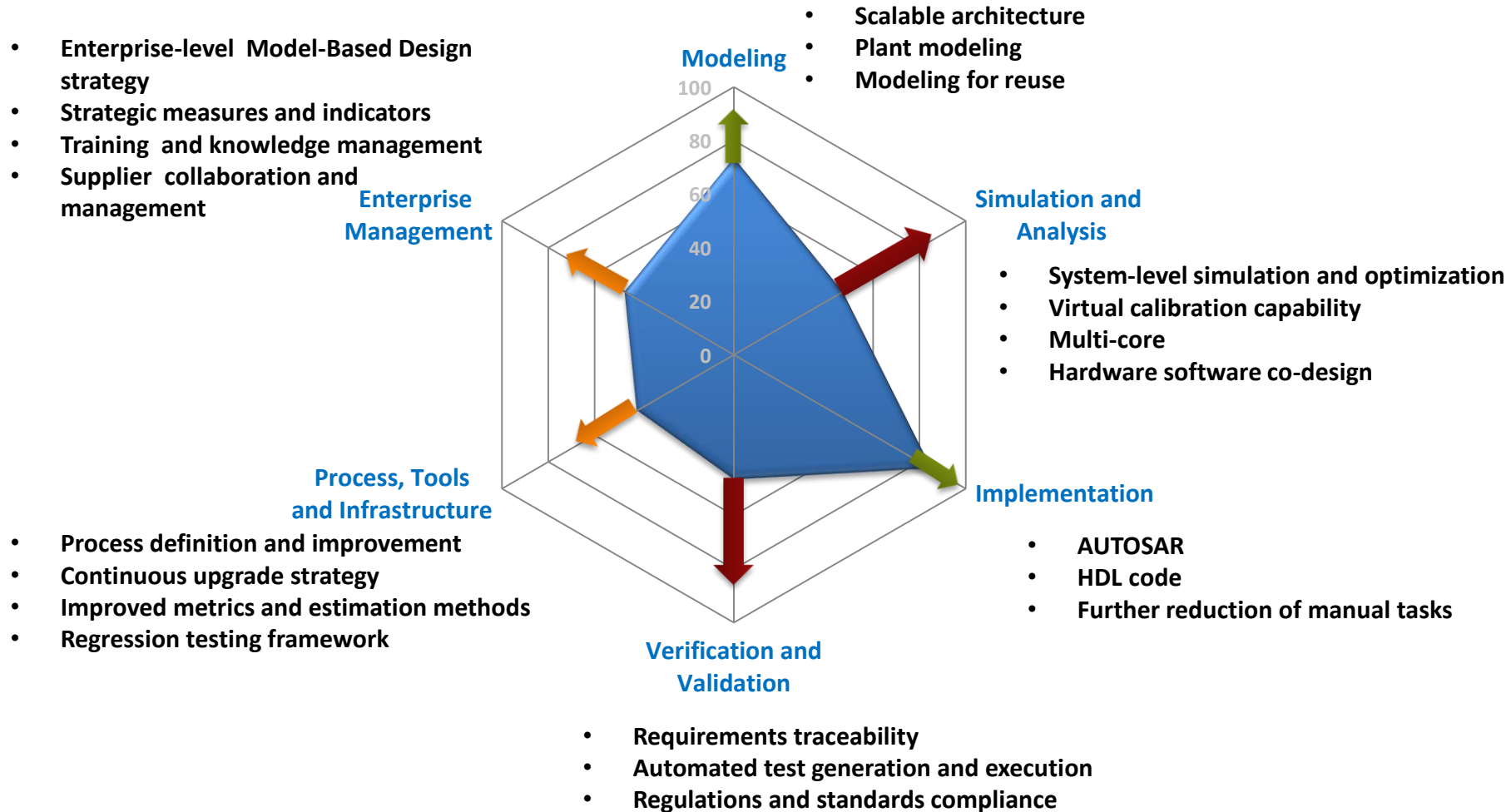
汽车行业基于模型设计的成熟度:

Top 20%, Average, Bottom 20%



# Model-Based Design Auto Industry Leaders: Trends and Focus Areas

## 汽车行业基于模型设计的领导者：趋势与关注领域

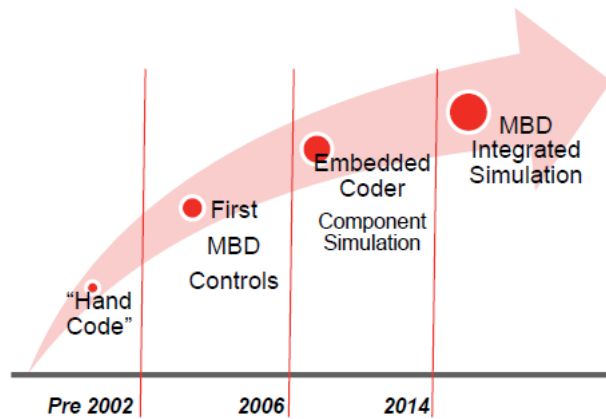


# Cummins: Model-Based Design Deployment History

## 康明斯: 基于模型设计的部署历史

### 基于模型设计为软件工程师带来的益处

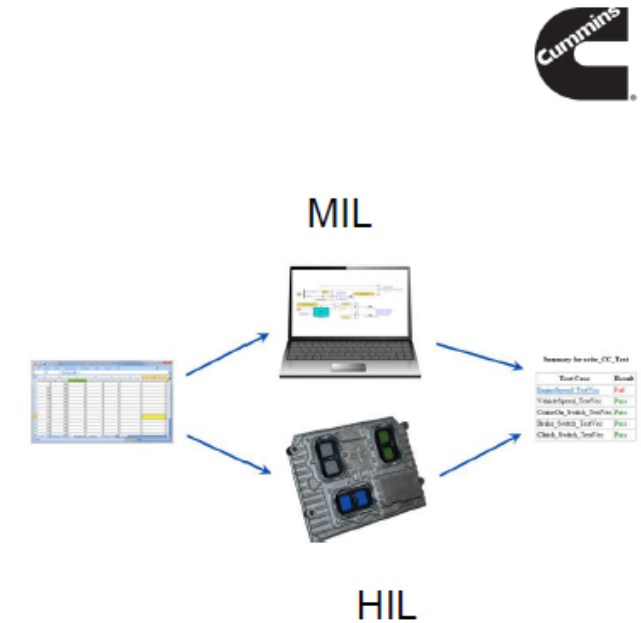
Cummins MBD (Controls) History



MBD capability growth takes continual process improvement investment

### Accelerating MBD, Reducing Development Cost

- Software workflow Improvements
  - Reduction in engineering SW builds by 80%
  - Integration of Control MIL with HIL, work flows (\$xM/yr)
    - But more importantly, improved test coverage
- Calibration Workflow
  - MIL Transient Engine Calibration
    - » **50% Test Cell Reduction**



Data Classification: Public

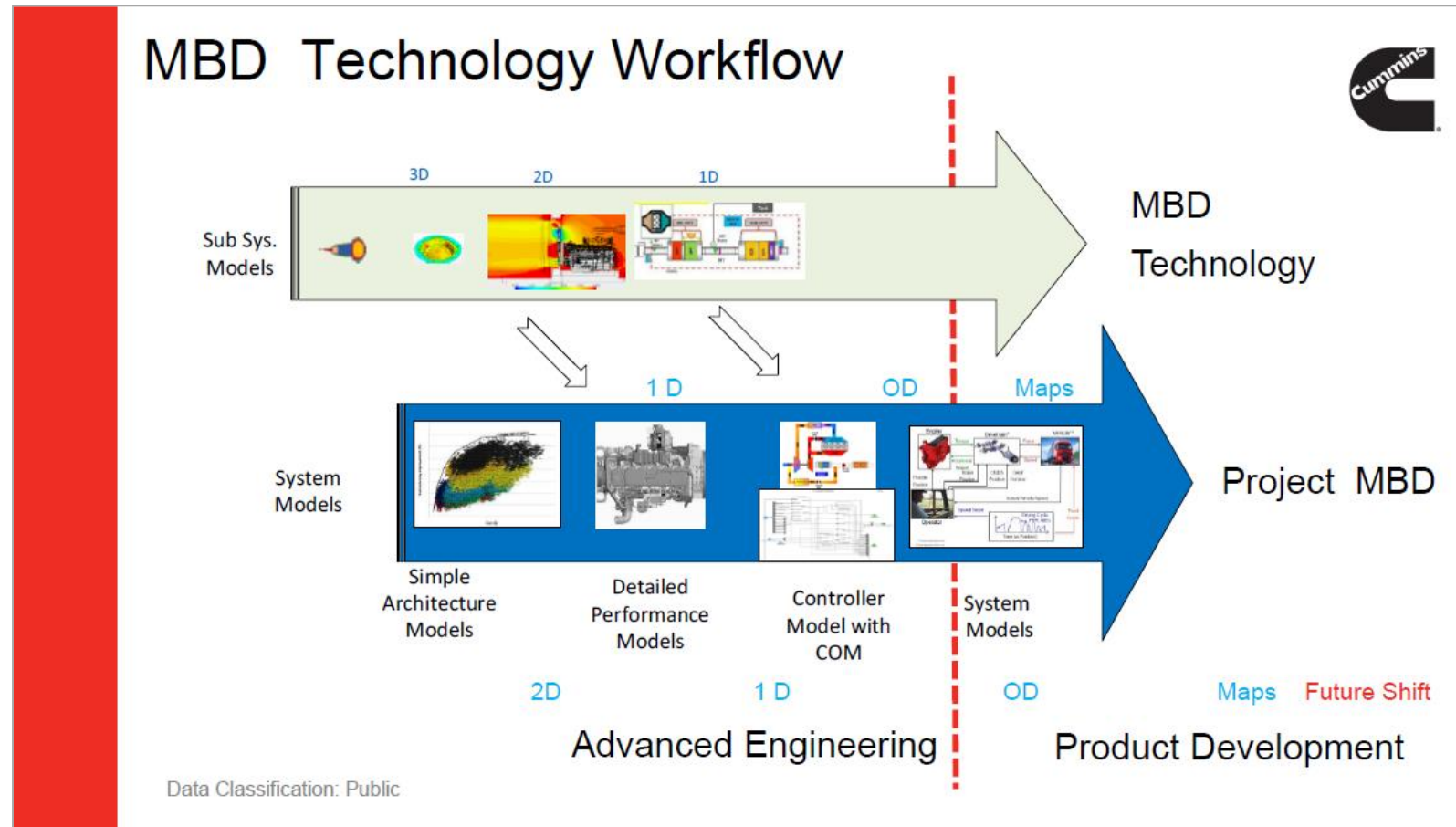
Data Classification: Public

Model Based Controls: Moving Beyond Software Domain, Ed Hodzen, Director, Advanced Engineering, Cummins, Inc., MathWorks Automotive Conference, May 2015, Plymouth, Michigan, USA

# Cummins: Moving Beyond Software Domain

## 康明斯: 超越软件范畴

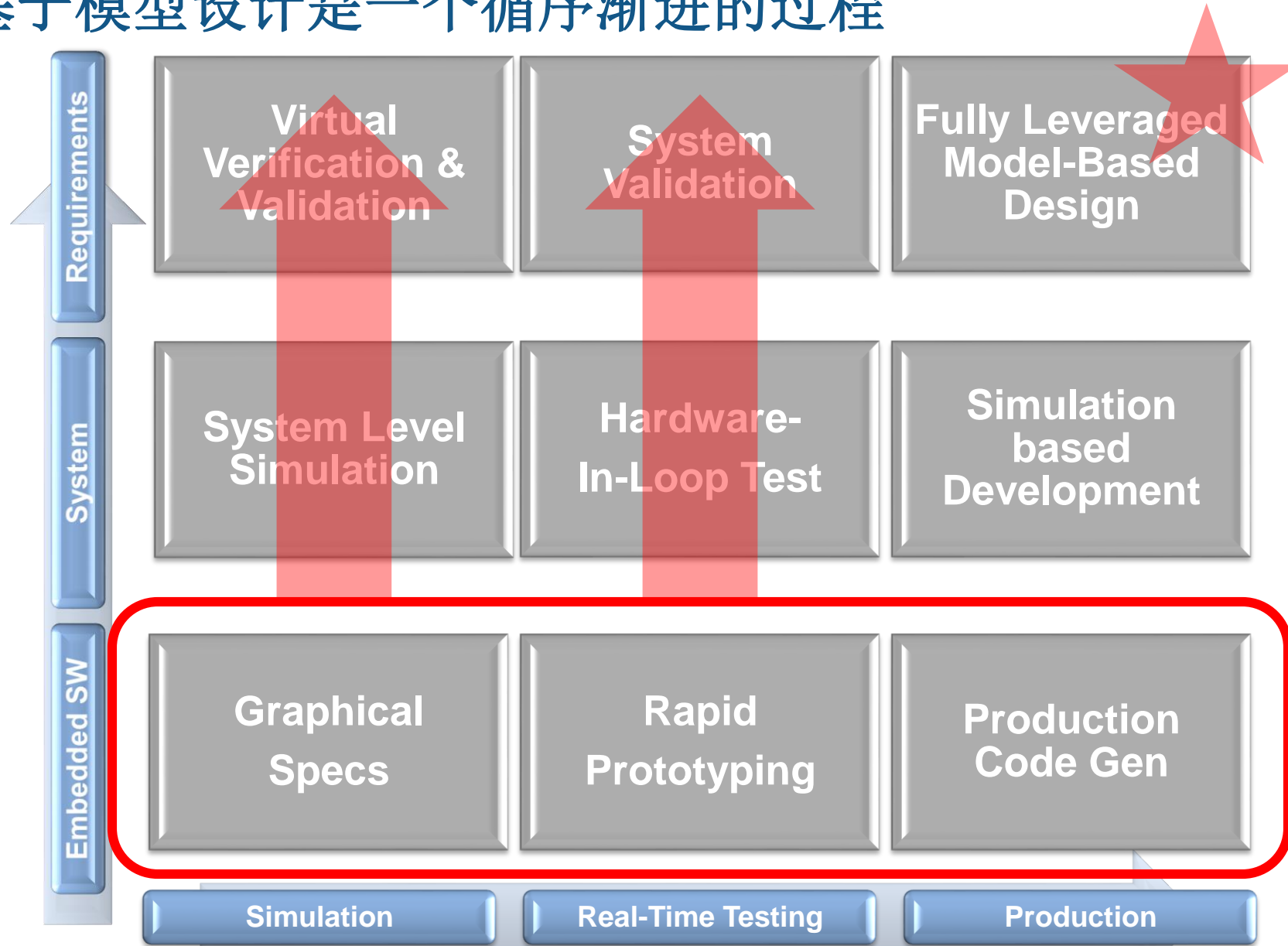
### 加速系统开发



Model Based Controls: Moving Beyond Software Domain, Ed Hodzen, Director, Advanced Engineering, Cummins, Inc., MathWorks Automotive Conference, May 2015, Plymouth, Michigan, USA

# Applying MBD is a Step-by-Step Process

采用基于模型设计是一个循序渐进的过程



# What Capabilities Can I Leverage?

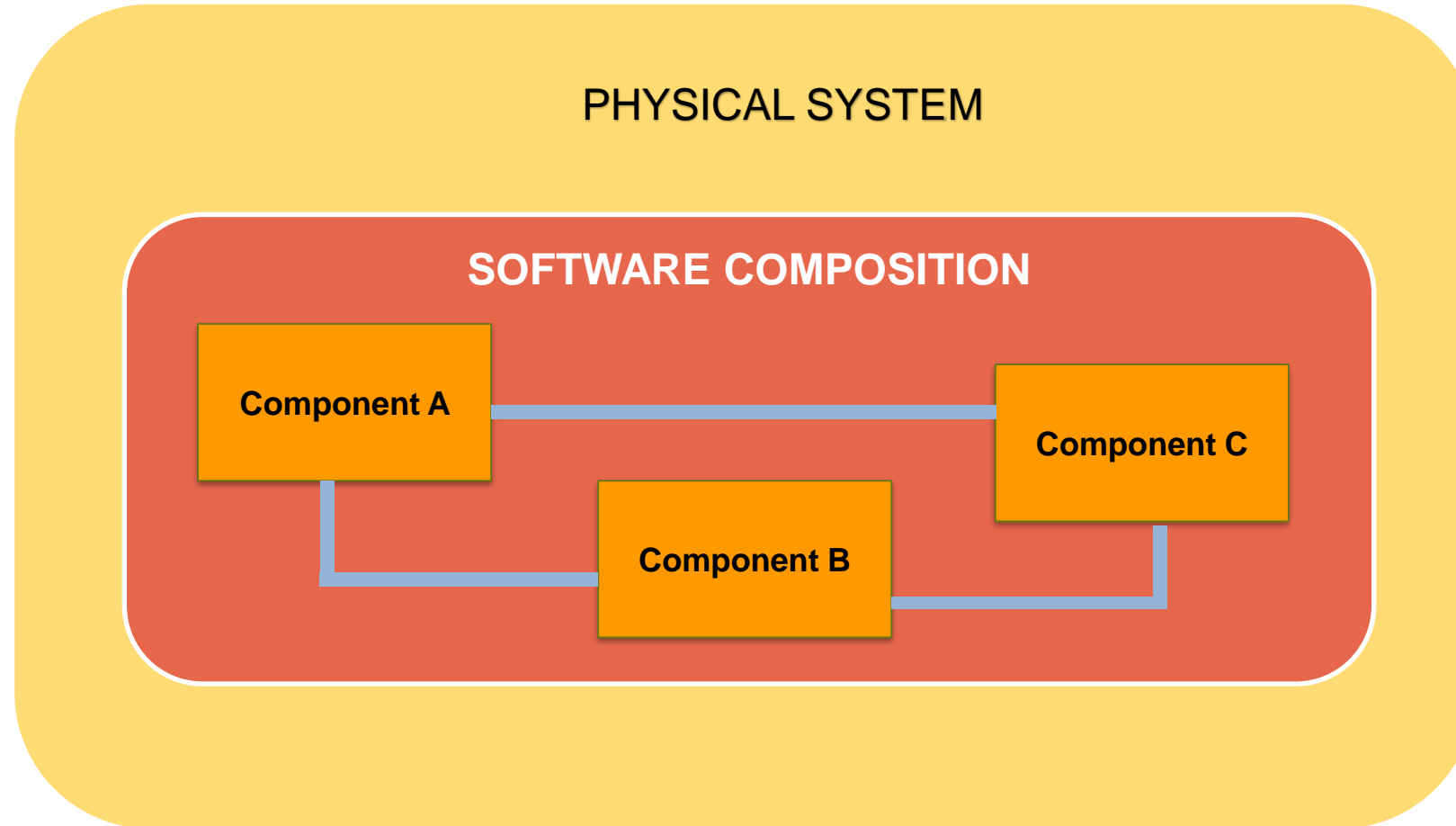
1. System modeling 系统建模
2. Verification and Validation 验证与确认

# What Capabilities Can I Leverage?

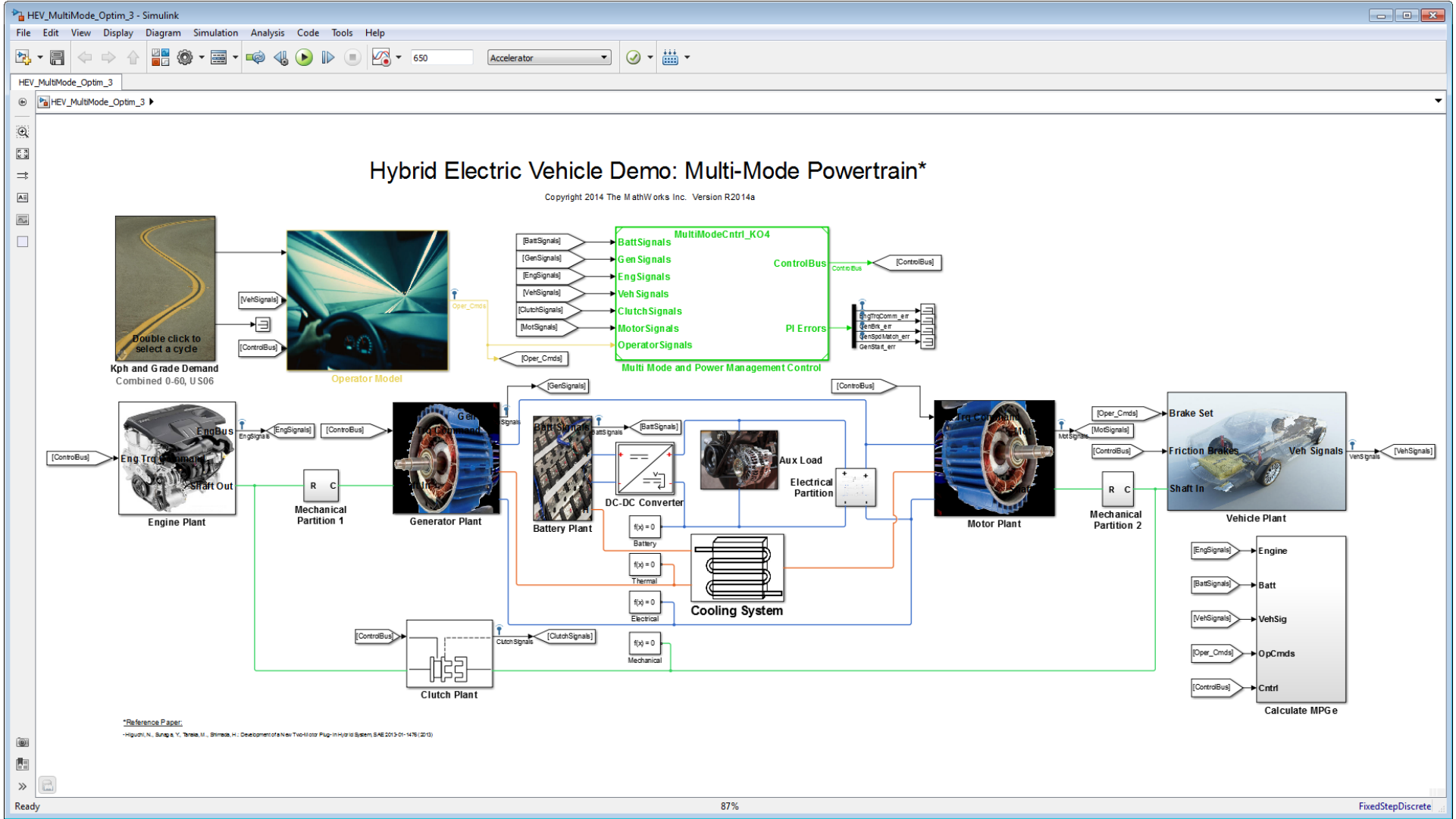
1. System modeling 系统建模

2. Verification and Validation 验证与确认

# Full system 完整系统

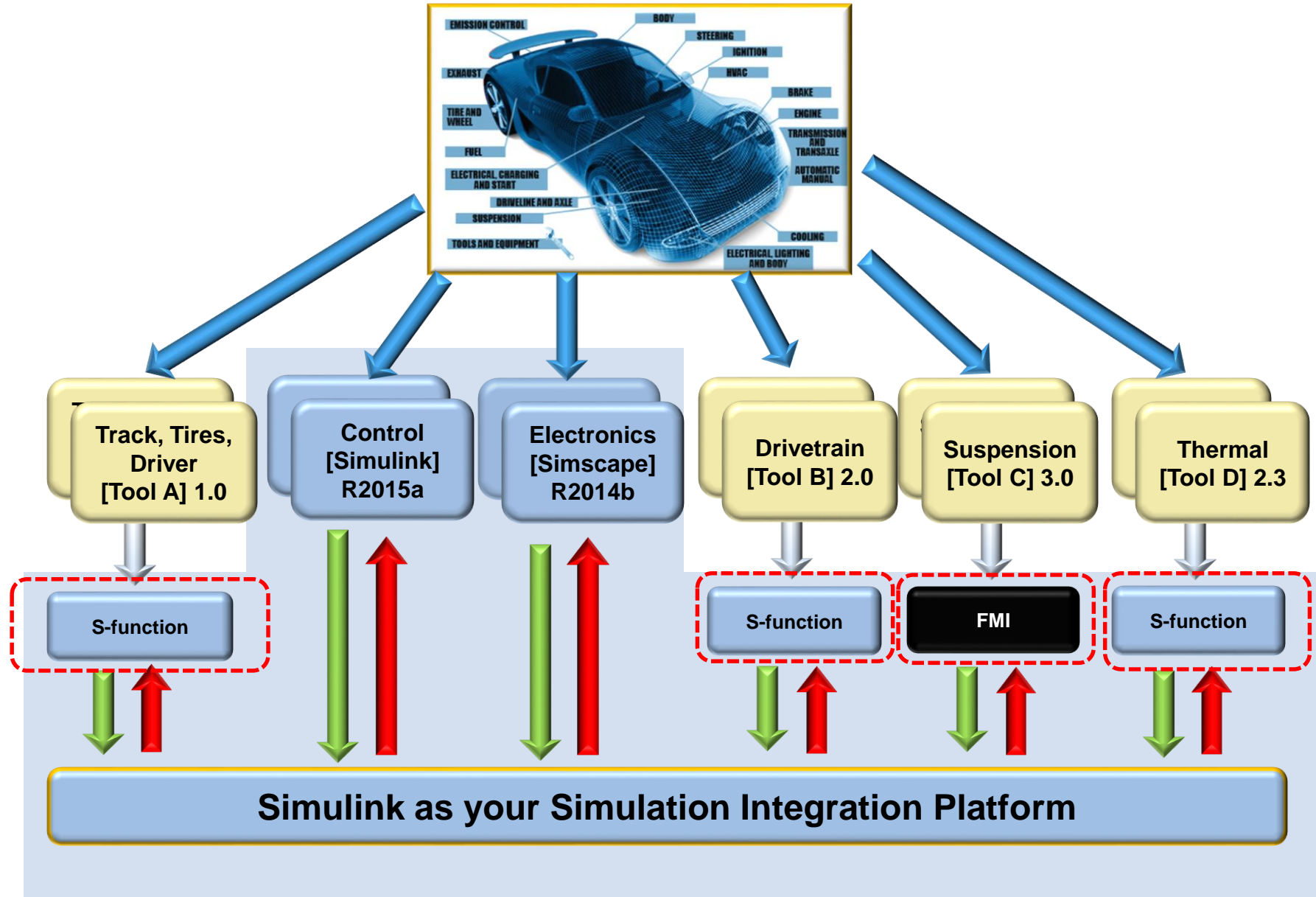






System model 系统模型

# Multi-Tool Simulation Integration 多工具仿真集成

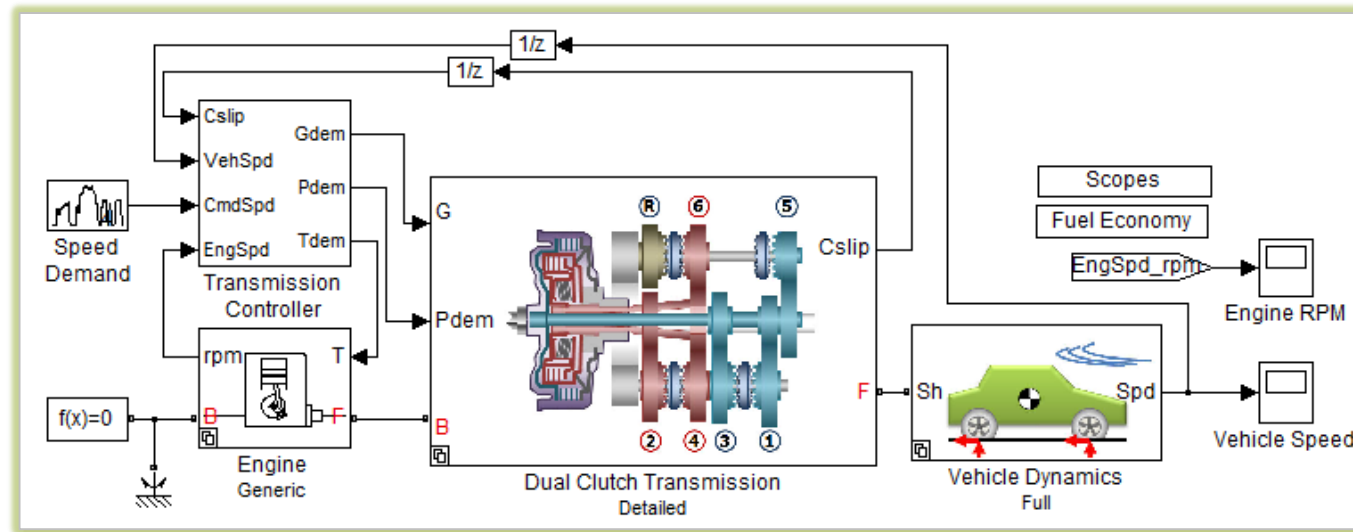


# Simulation Integration Platform Characteristics

## 仿真集成平台的特征

Authoring environment  
for component Models  
不同组件模型的构建环境

Mature and extensive API  
for 3<sup>rd</sup> party component integration  
成熟与广泛的第三方组件集成接口



Multidomain simulation  
environment  
多域仿真环境

Scalable  
environment  
可扩展的环境

Analysis and Debug  
capabilities  
分析与调试能力

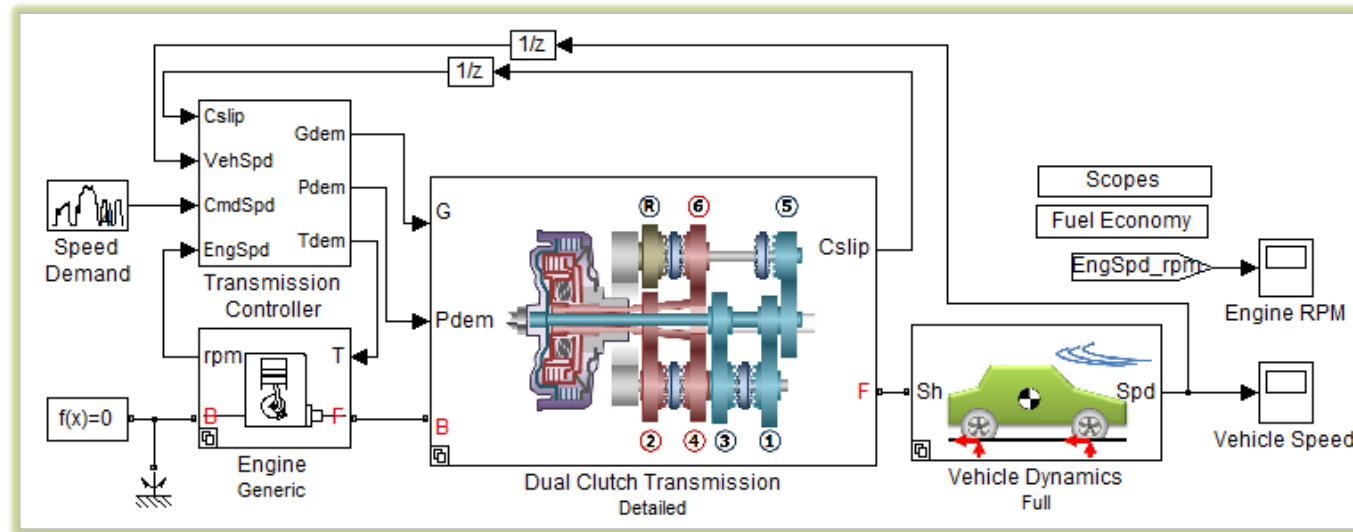
# Simulation Integration Platform Characteristics

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# Simulation Integration Platform Characteristics

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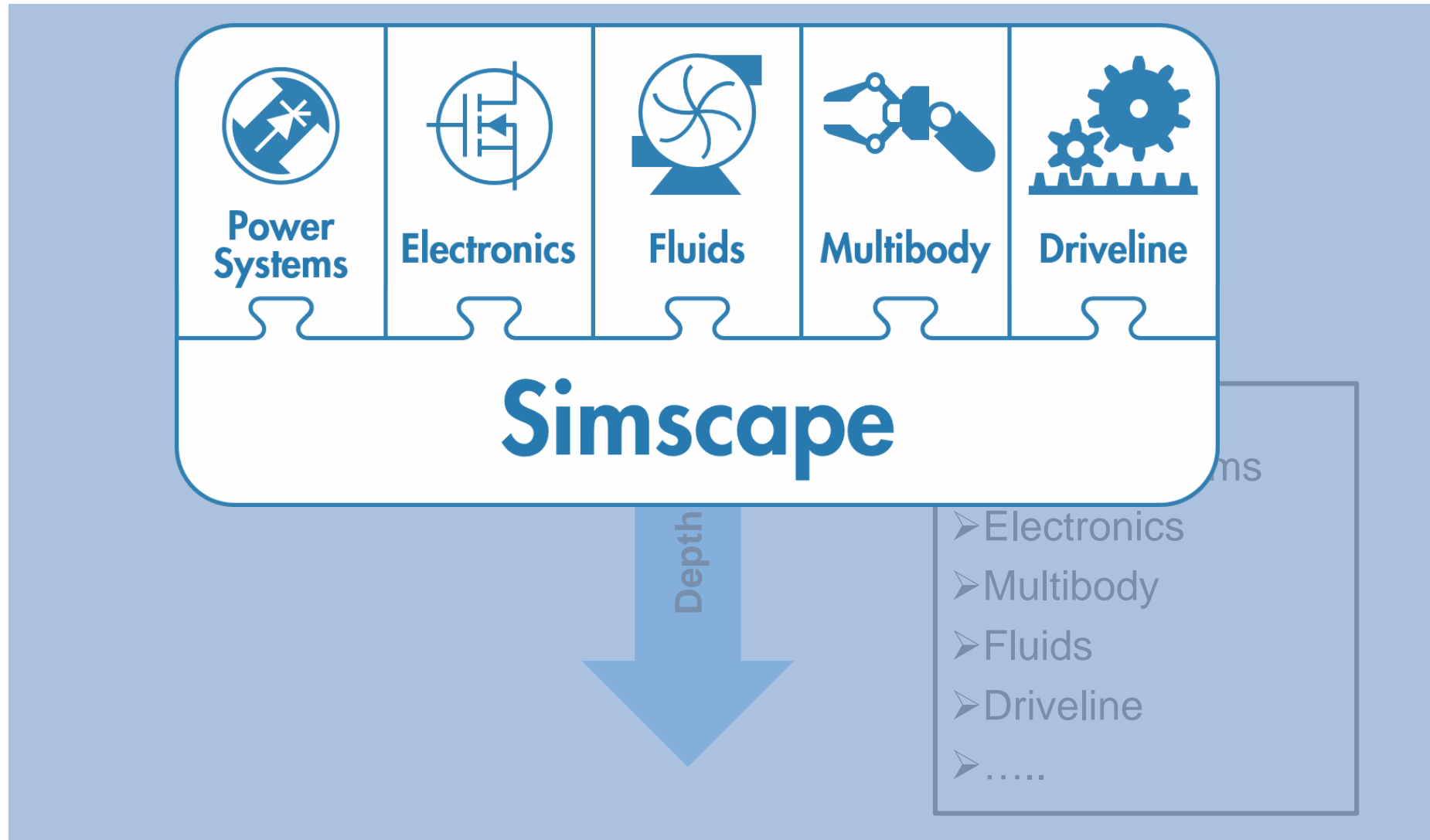
## 组件模型的构建环境

The image displays a collection of MATLAB/Simulink simulation tool windows, illustrating the integration platform's capabilities in modeling a vehicle transmission system. The windows include:

- Simulation Environment:** A main Simulink model window showing a block diagram of a transmission system with components like 'Transmission Controller', 'Engine Generic', and 'Vehicle Dynamics Full'. It includes various input signals like 'Speed Demand' and 'EngSpd'.
- Code Editor:** A window showing C code for a filter, including comments and mathematical operations like  $FLT\_filtOut = b0 * (*signal) + a1 * prevsignal;$ .
- Condition Table:** A table defining failure conditions for hydraulic systems and actuators.
 

#	Description	Condition	D1	D2	D3	D4	D5	D6	D7
1	Hydraulic system 1 Low_low_press(1) pressure (Left Outer line)	T   T   F   F   -   -   -							
2	Left Outer actuator position failed	-   -   -   T   T   -   -   -							
3	Hydraulic system 2 Low_low_press(2) pressure (Inner line)	F   -   F   -   T   -   -   -							
4	Left Inner actuator position failed	F   -   T   -   -   T   -   -							
- Stateflow Chart:** A Stateflow chart showing the logic for gear shifting, including states like 'SteadyState', 'preUpShifting', and 'UpShifting' with associated transitions and actions.
- Scopes and Data Inspector:** Windows for monitoring simulation data, such as 'Scopes' for 'Fuel Economy' and 'EngSpd\_rpm', and a 'Data Inspector' for 'Vehicle Dynamics Full'.
- Block Diagrams:** Detailed views of sub-models like 'Transmission Controller' and 'Vehicle Dynamics Full', showing internal gear and clutch logic.

# Physical modeling 物理建模



# Simscape Runtime Parameters (Simscape运行时参数)

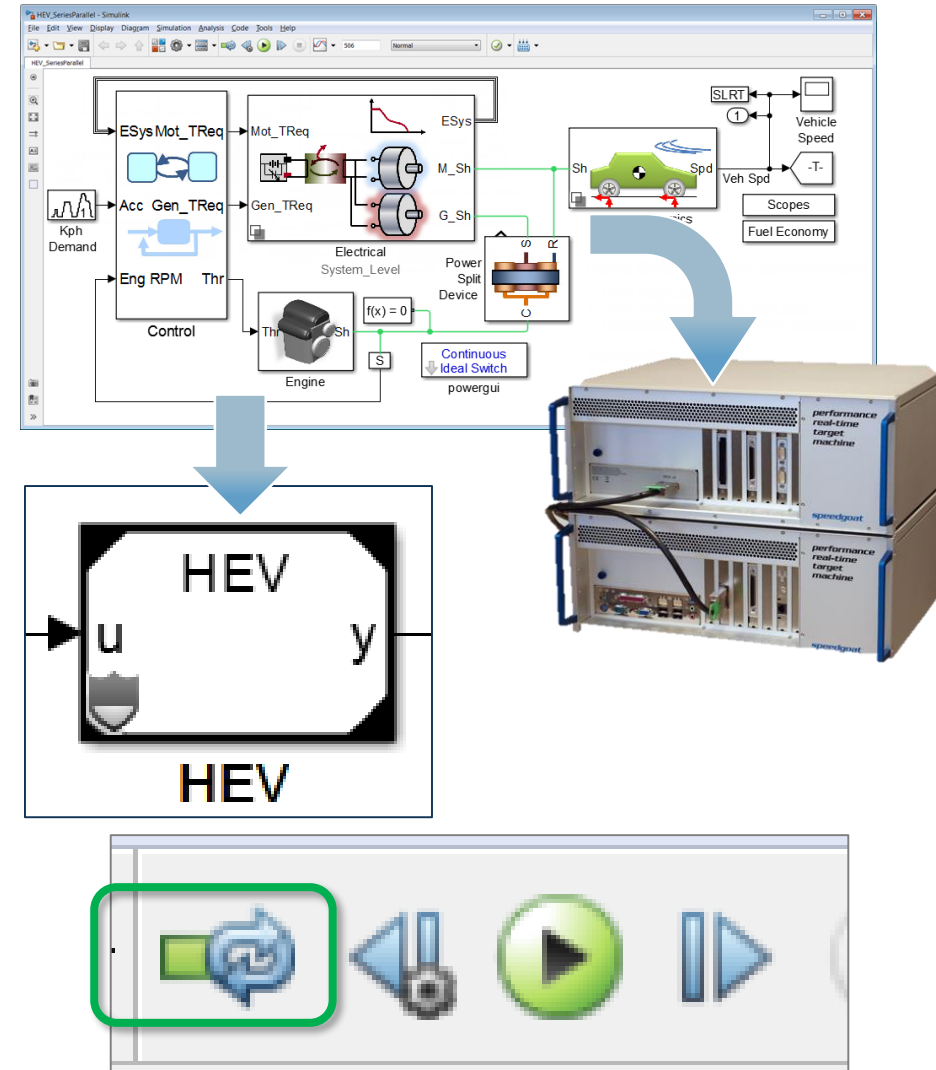
R2016a

Vehicle Mass: 

Shaft Compliance: 

Final Drive Ratio: 

- During HIL tests
- In protected models
- During iterative simulation workflows
- For power systems and other modeling domains



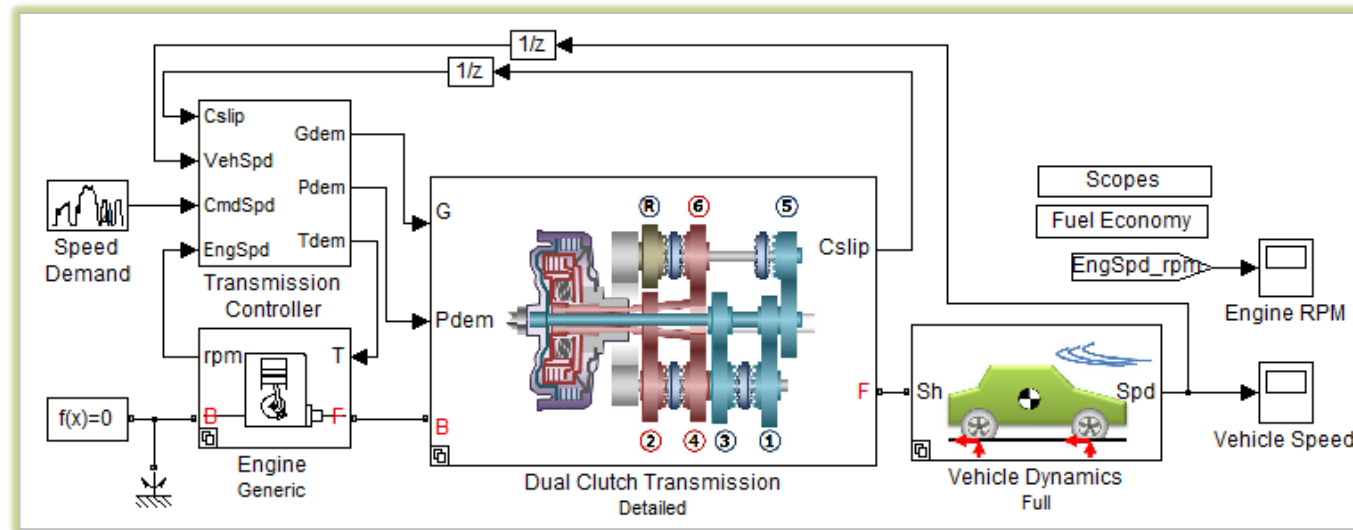
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Multidomain simulation  
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Analysis and Debug  
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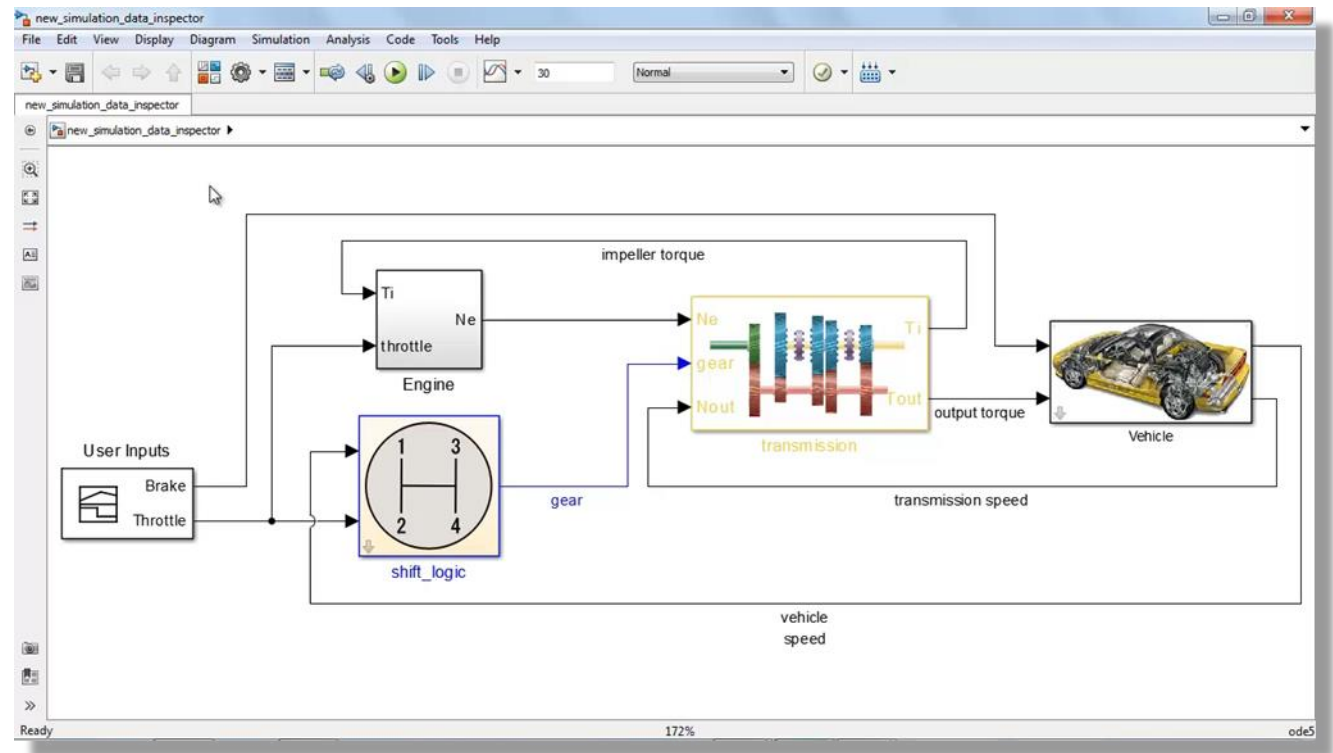
# Simulation Integration Platform Characteristics

## 仿真集成平台的特征

## 分析与调试能力

仿真集成平台必须具备以下能力：

- 分析仿真结果
  - 仿真过程中选择并监测信号
  - 比较仿真值
- 诊断未预计到的行为
  - 向前和后退调试
  - 设置时间和条件断点
  - 提供诊断信息



# What Capabilities Can I Leverage?

1. System modeling 系统建模
2. Verification and Validate 验证与确认

# Verification and validation 验证与确认: Automate testing and find design errors 自动化测试并发现设计缺陷

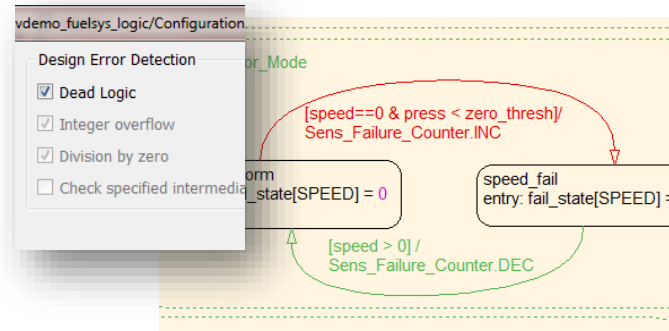
```
typedef int int32_t;

int32_t test1(void)
{
    char *data;
    data = (char *)malloc(100*sizeof(char));
    memset(data, 'A', 100-1);

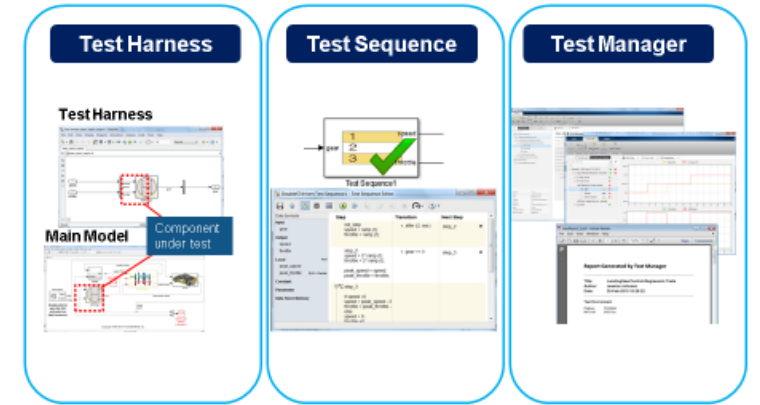
    return(0);
}

int32_t test2(void)
```

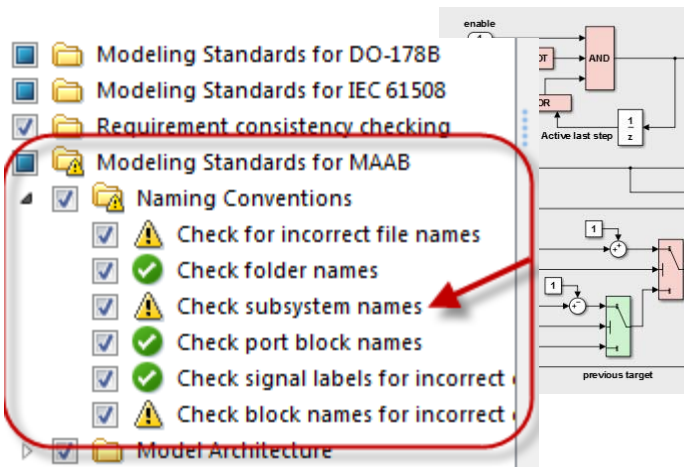
Polyspace



Simulink Design Verifier



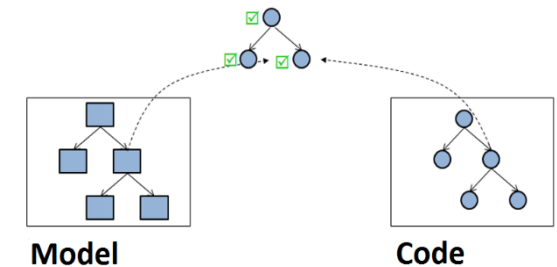
Simulink Test



Simulink Verification & Validation



HDL Verifier

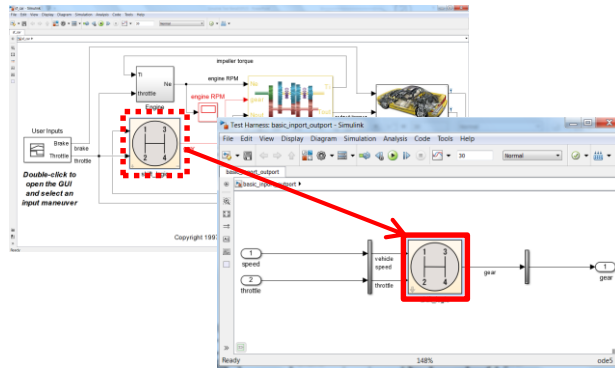


Simulink Code Inspector

# Simulink Test New Features in R2016a

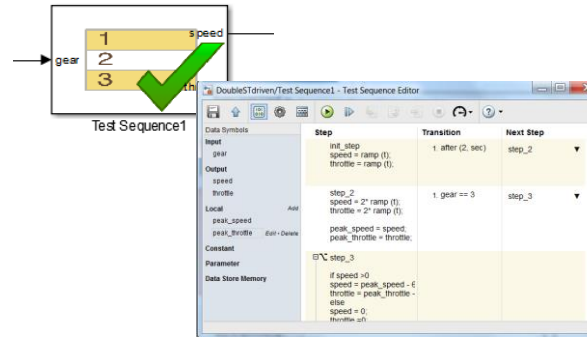
## Simulink Test 在2016a版本中的新功能

### Test Harnesses



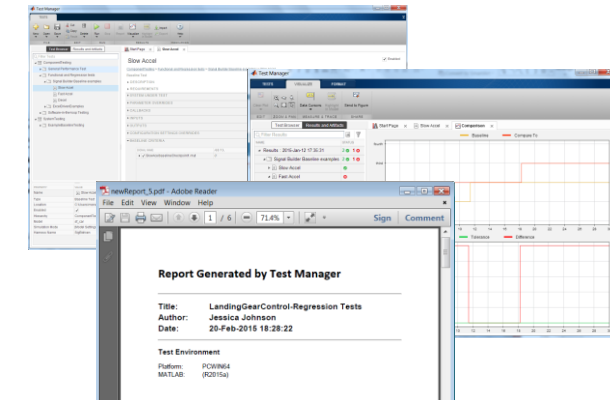
- Harness list dialog
- Library harnesses
- Simulink functions/export function models support (AutoSAR)
- Externally-saved harnesses
- Requirements linking

### Test Sequence Block



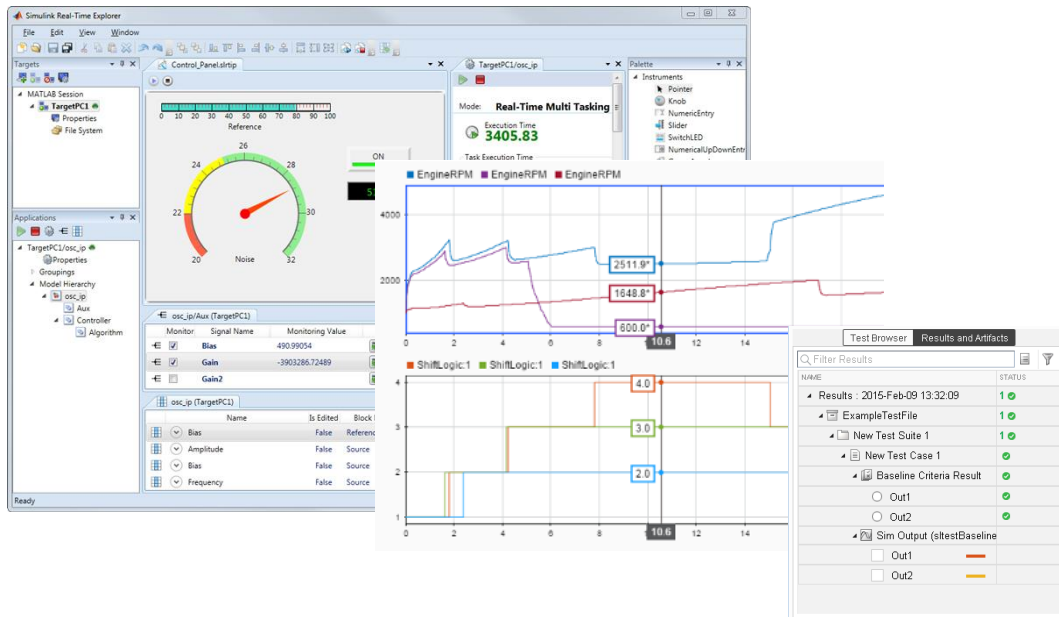
- Syntax highlighting
- Tab completion
- Enhanced symbol sidebar
- Message I/O, function call
- Description column
- "verify" statement
- API
- Requirements linking

### Test Manager



- Coverage
- Parallel test execution
- Report customization
- Iterations
- Dependency/impact analysis
- Test for subsystems
- Real-time test cases (SLRT)

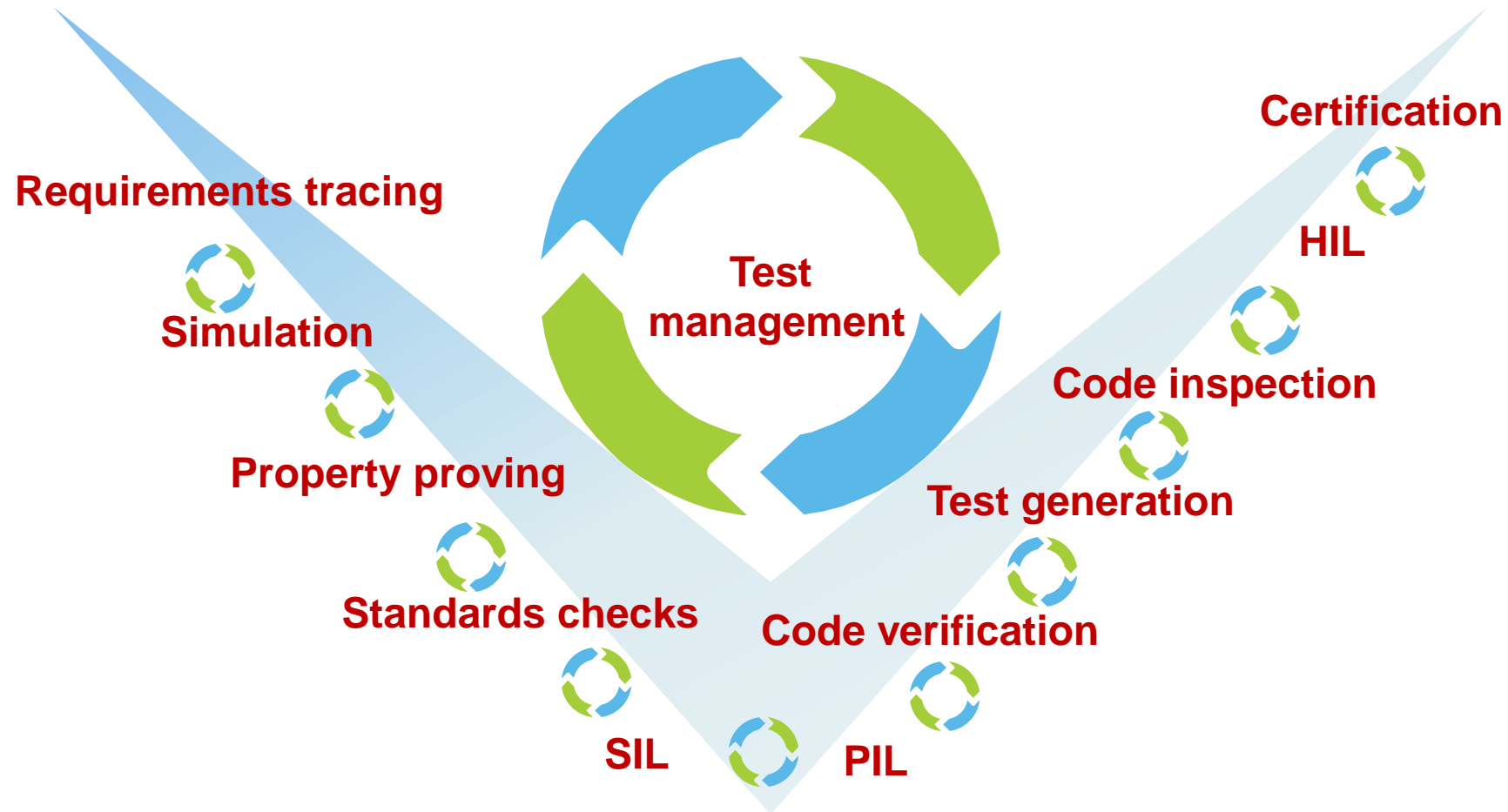
# Simulink Test R2016a: Author and execute real-time tests 构建并执行实时测试



- Run tests/assessments on Simulink Real-Time target
- Start simulation tests from model, application, connect to running target
- Test sequence assessments to verify behavior without stopping the test
- Bring back real-time test data for analysis in the test manager

# Verification 验证

## Fast and Small Iterations 快速与微小迭代



## Summary 总结

- Model-Based Design is in widespread use for new product development  
基于模型设计在新产品开发中得到广泛应用
- Automatic code generation provides significant benefit  
自动代码生成带来了显著优势
  - Often the first technology to adopt by automotive companies
  - Widespread usage including high performance and safety critical applications
- Beyond code generation 自动代码生成以外
  - Model verification and closed loop simulation are key to front loading
  - System modeling extends the scope and benefit of Model-Based Design
- MathWorks focus is to evolve the tooling for Model-Based Design  
迈斯沃克公司专注于基于模式设计相关工具的设计与发展