

# MATLAB EXPO 2017

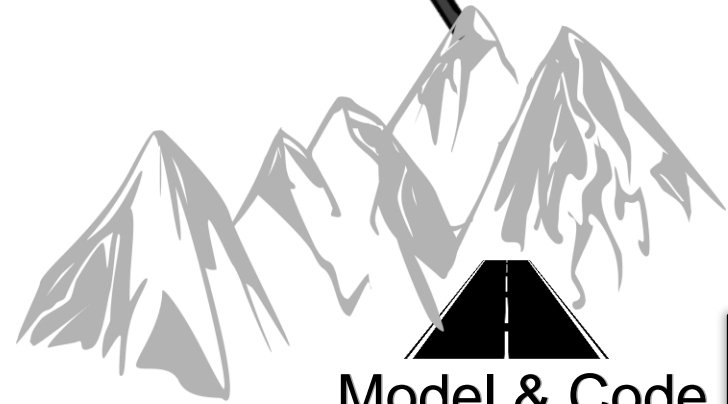
## 基于模型设计中的验证，确认和测试

Wu Jing  
Application Engineer  
MathWorks China

# 连续的 测试 & 验证

连续的

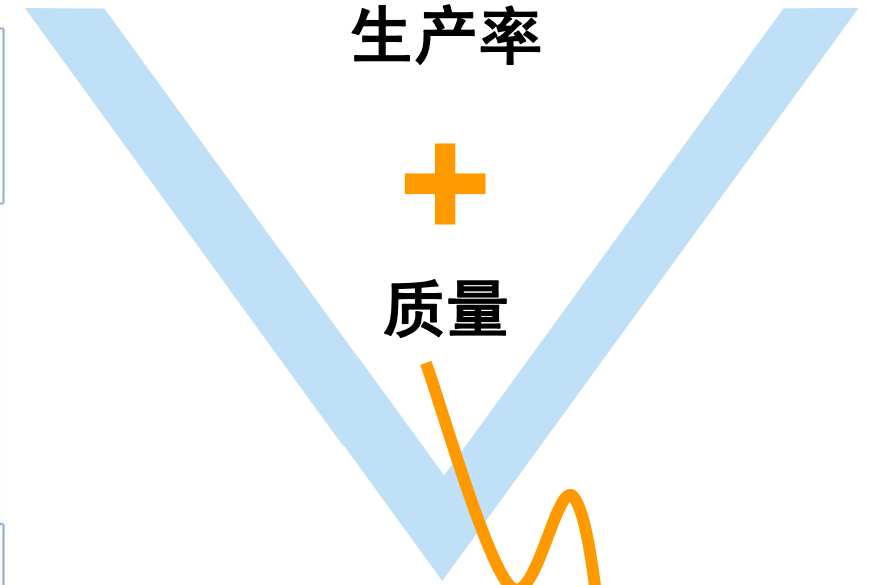
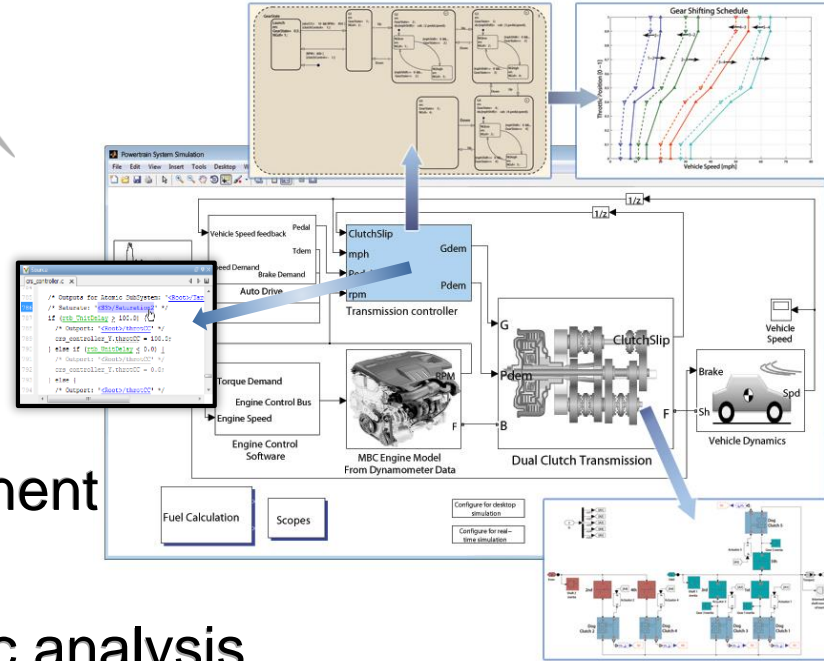
测试 & 验证



Model & Code

System & Component

Dynamic testing & Static analysis



生产率

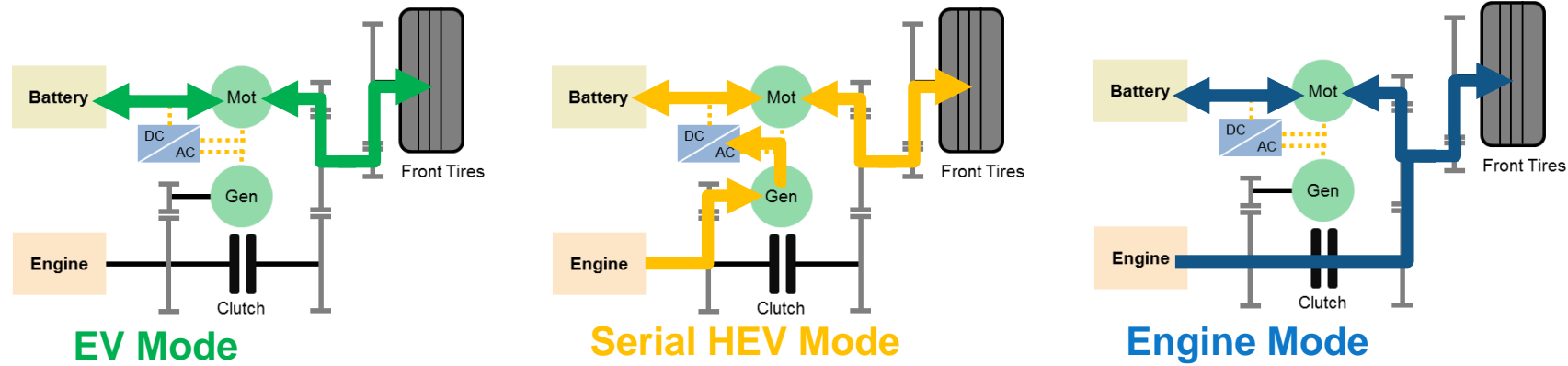
+

质量

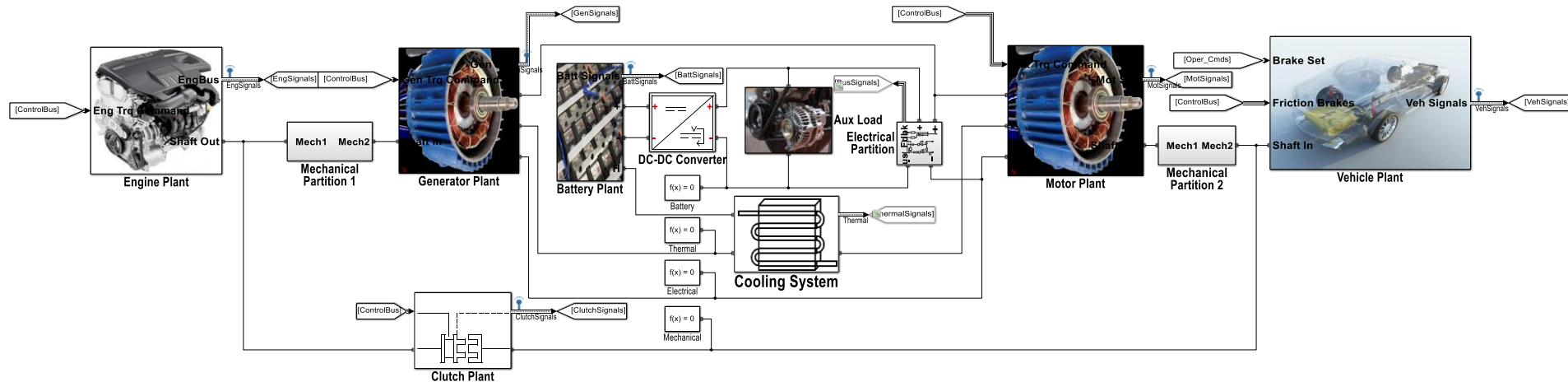
需要验证!

连续的

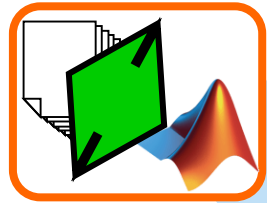
# 基于模型设计中的多模式混动车设计



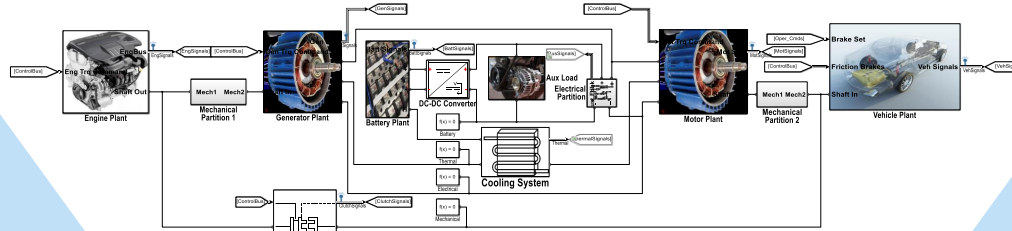
Higuchi, N., Sunaga, Y., Tanaka, M., Shimada, H.: Development of a New Two-Motor Plug-In Hybrid System, SAE 2013-01-1476 (2013)



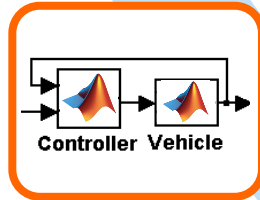
# 多模式混动车



Define Requirements



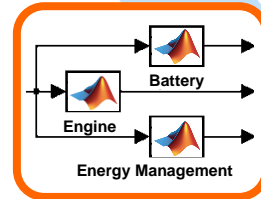
Complete Integration & Test



System-Level Specification



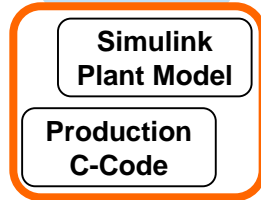
System-Level Integration & Test



Subsystem Design



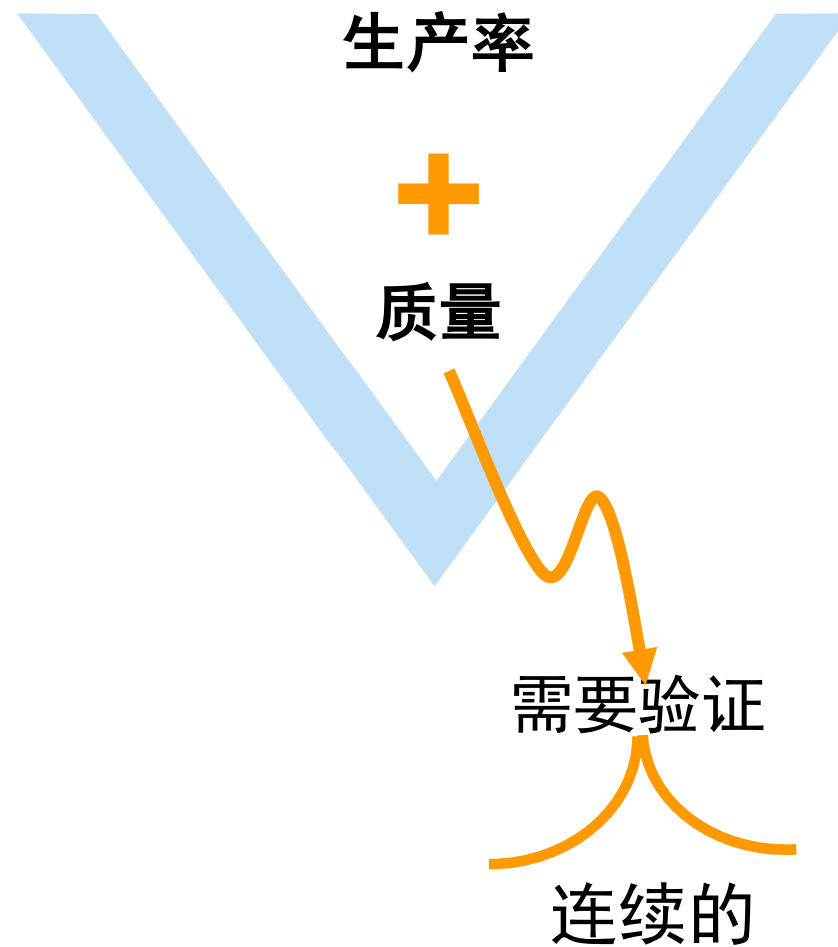
Subsystem Integration & Test



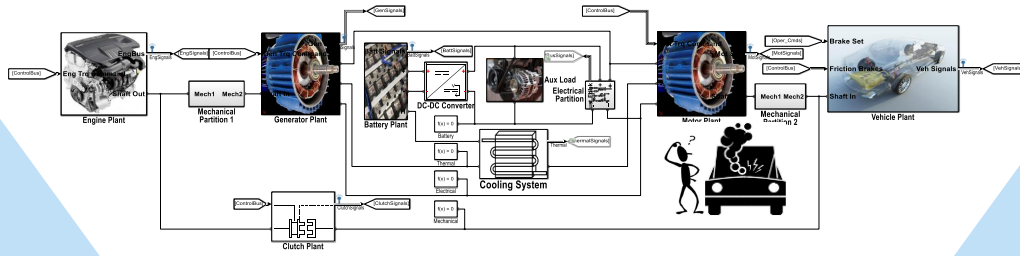
Subsystem Implementation



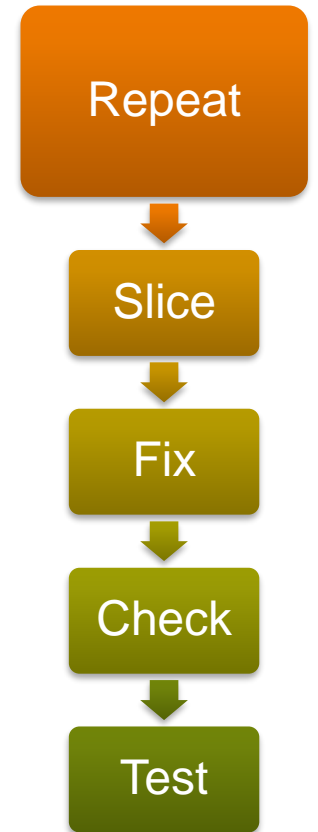
# 连续的测试和验证框架



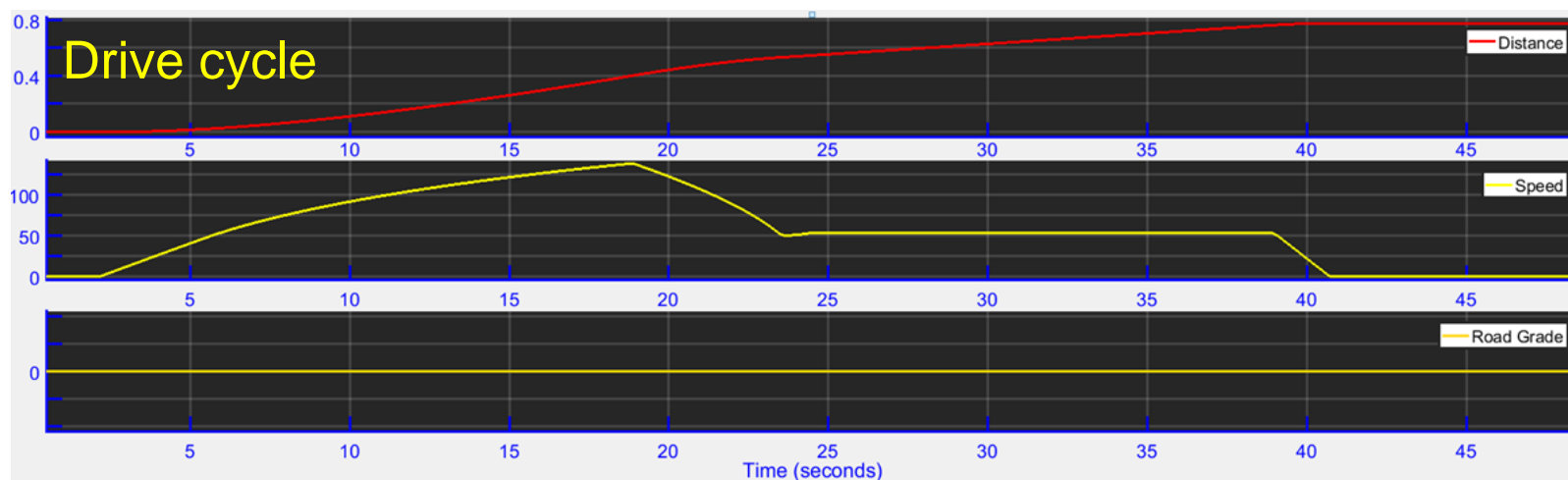
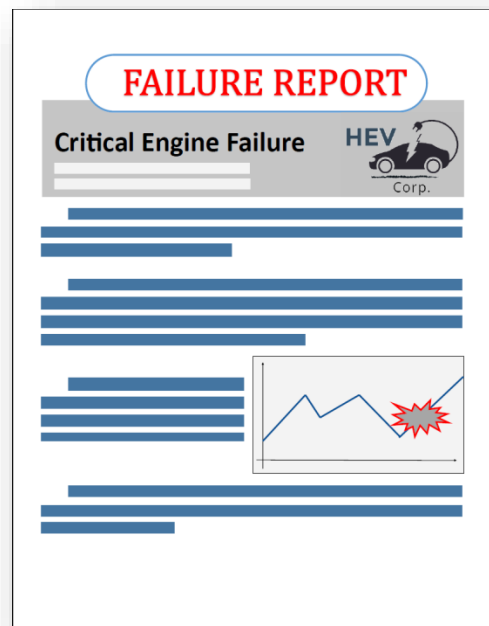
# 在仿真层面复现失效



**Confirm the problem  
In the Lab/Desktop  
Simulation**

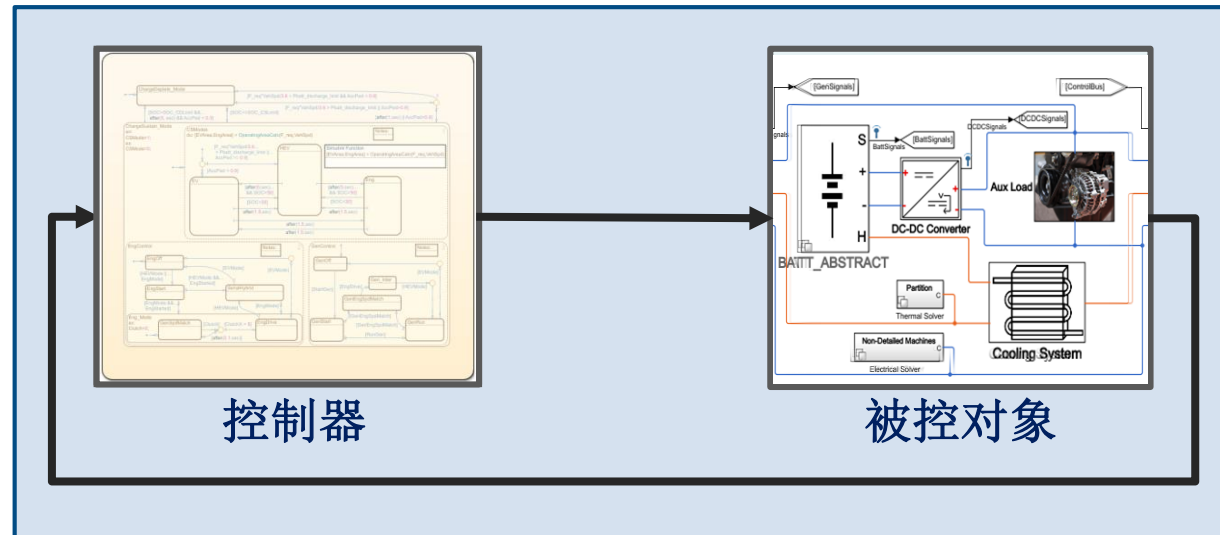


# 失效报告



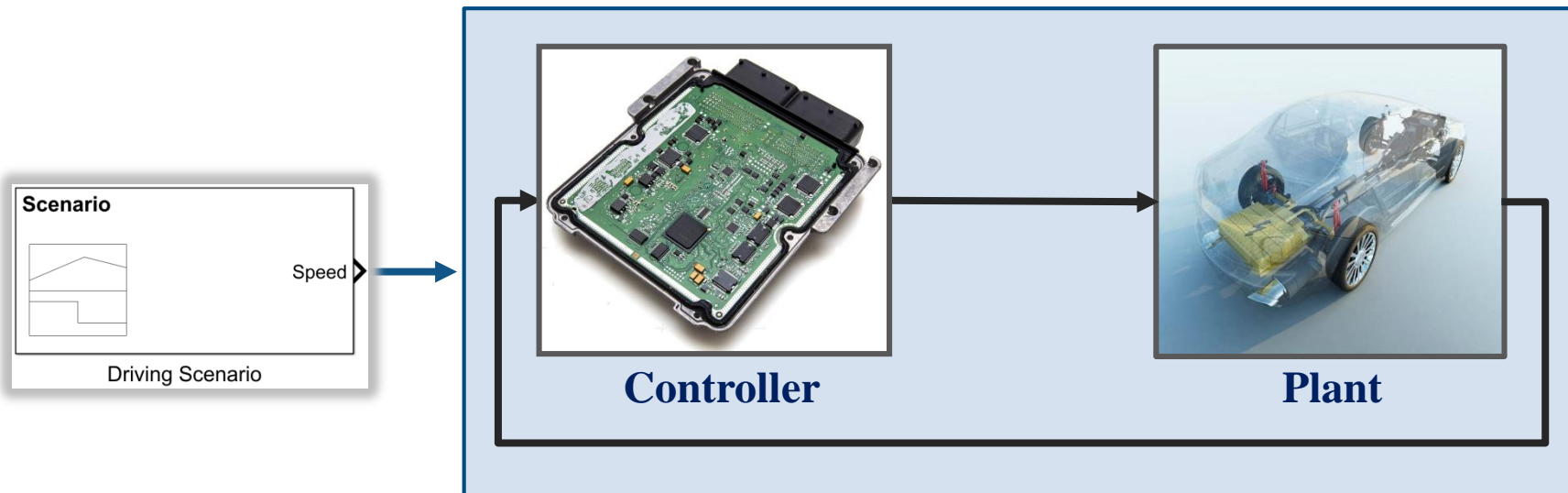
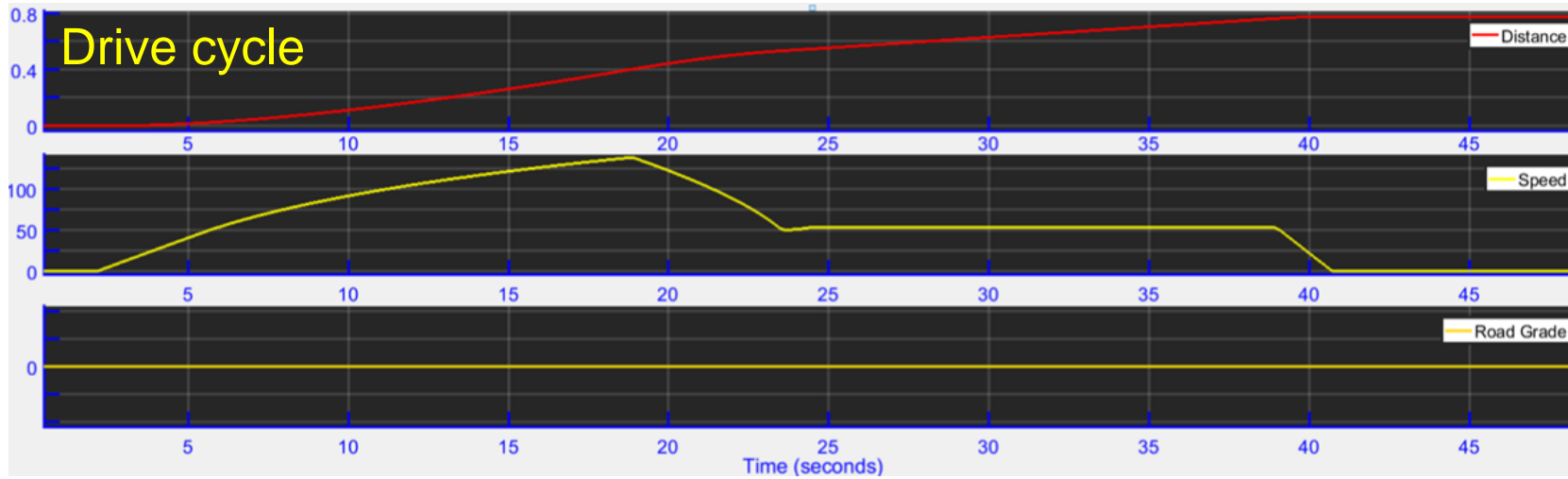
复现失效

# 仿真环境





# 测试建模



# 测试建模



## Safety Property

**Engine RPM must remain within operating bounds limits**



### Symbols

#### Input

1.  EngSignals
2.  BattSignals
3.  GenSignals
4.  VehSignals
5.  ClutchSignals
6.  MotSignals

### Step

Assessment

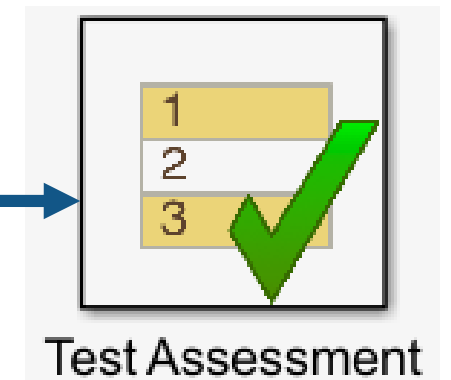
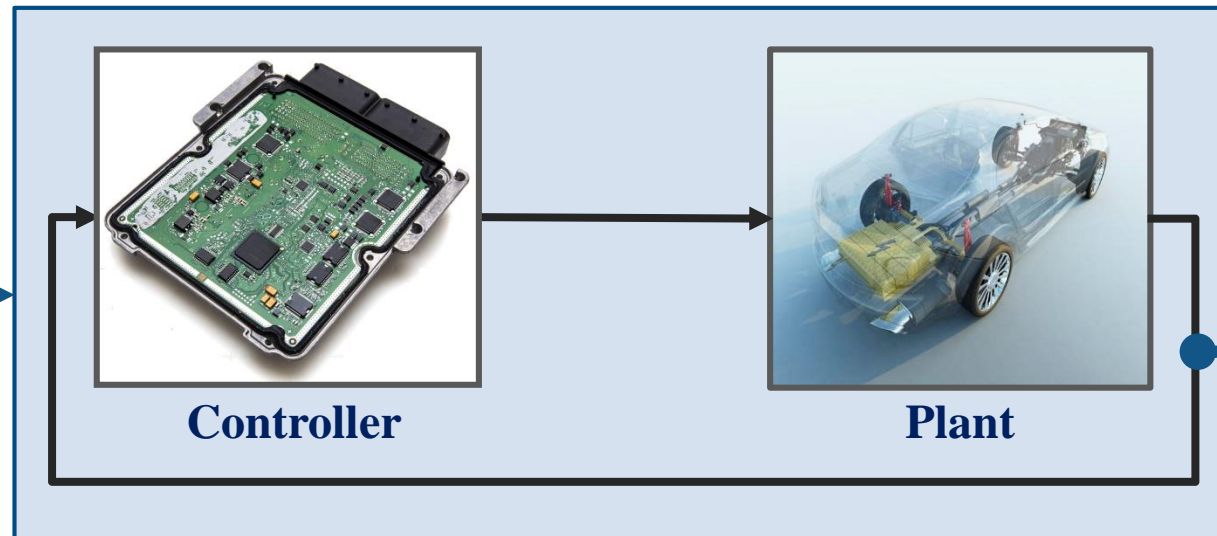
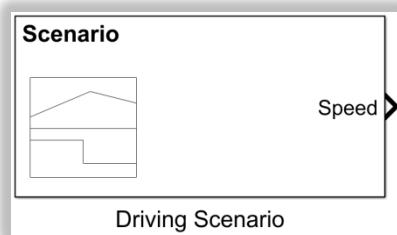
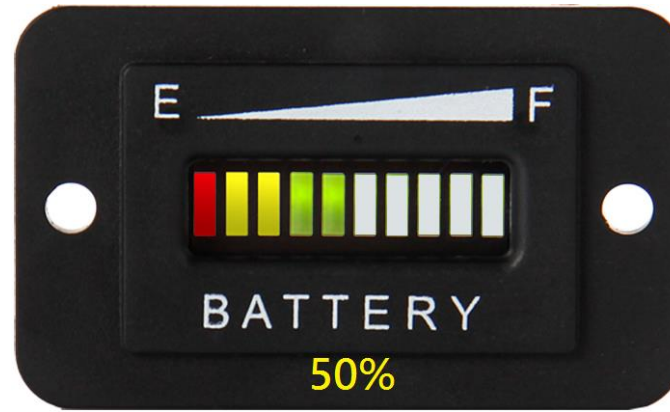


Test Assessment

# 电池的充电状态

Initial state of charge?

Sweep from 100% to 50%



## TESTS



## Test Browser Results and Artifacts

## New Test Suite 1 x

Filter tests by name or tags, e.g. \*

- HEVM\_Test\*
  - New Test Suite 1

## New Test Suite 1

 Enabled

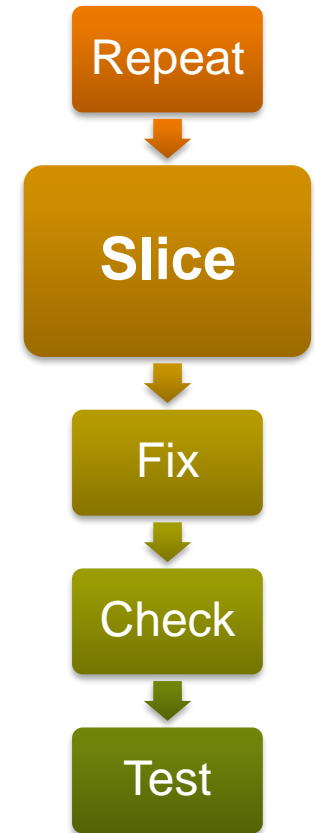
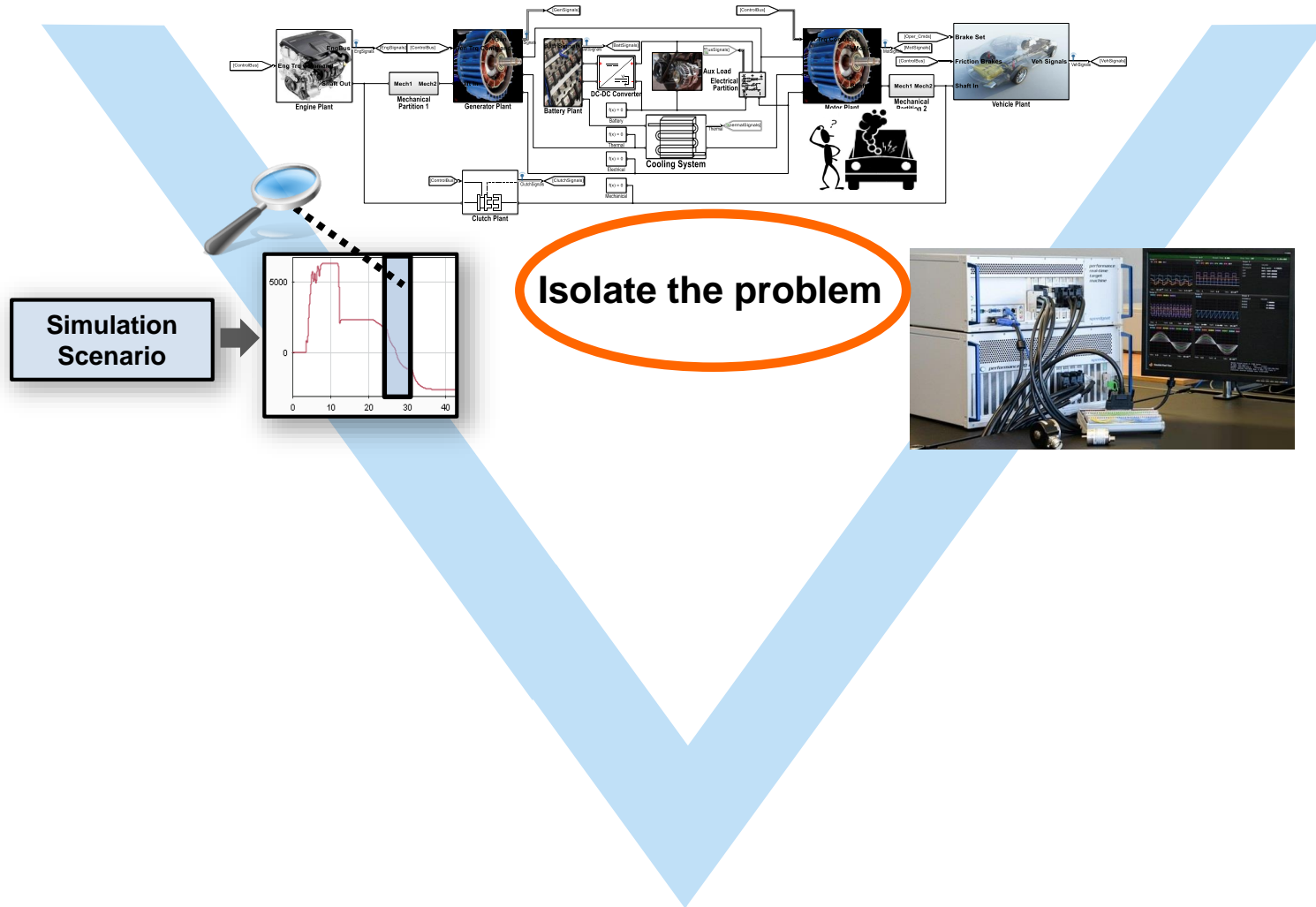
HEVM\_Test » New Test Suite 1

Test Suite

- ▶ TAGS
- ▶ DESCRIPTION
- ▶ REQUIREMENTS
- ▶ CALLBACKS ?
- ▶ COVERAGE SETTINGS ?

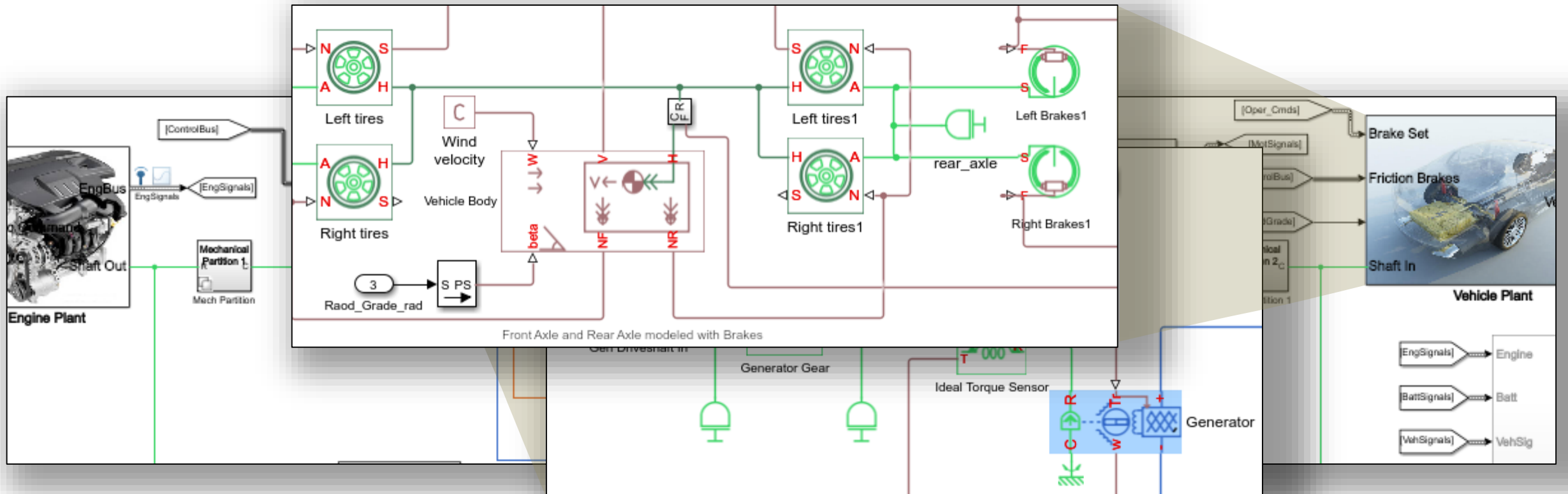
PROPERTY	VALUE
Name	📁 New Test S...
Location	C:\work\MabDe...
Hierarchy	HEVM_Test » N...
Enabled	<input checked="" type="checkbox"/>
Record Coverage	<input type="checkbox"/>
Tags	<i>type comma or spc</i>

# 模型裁剪: 隔离有问题的设计



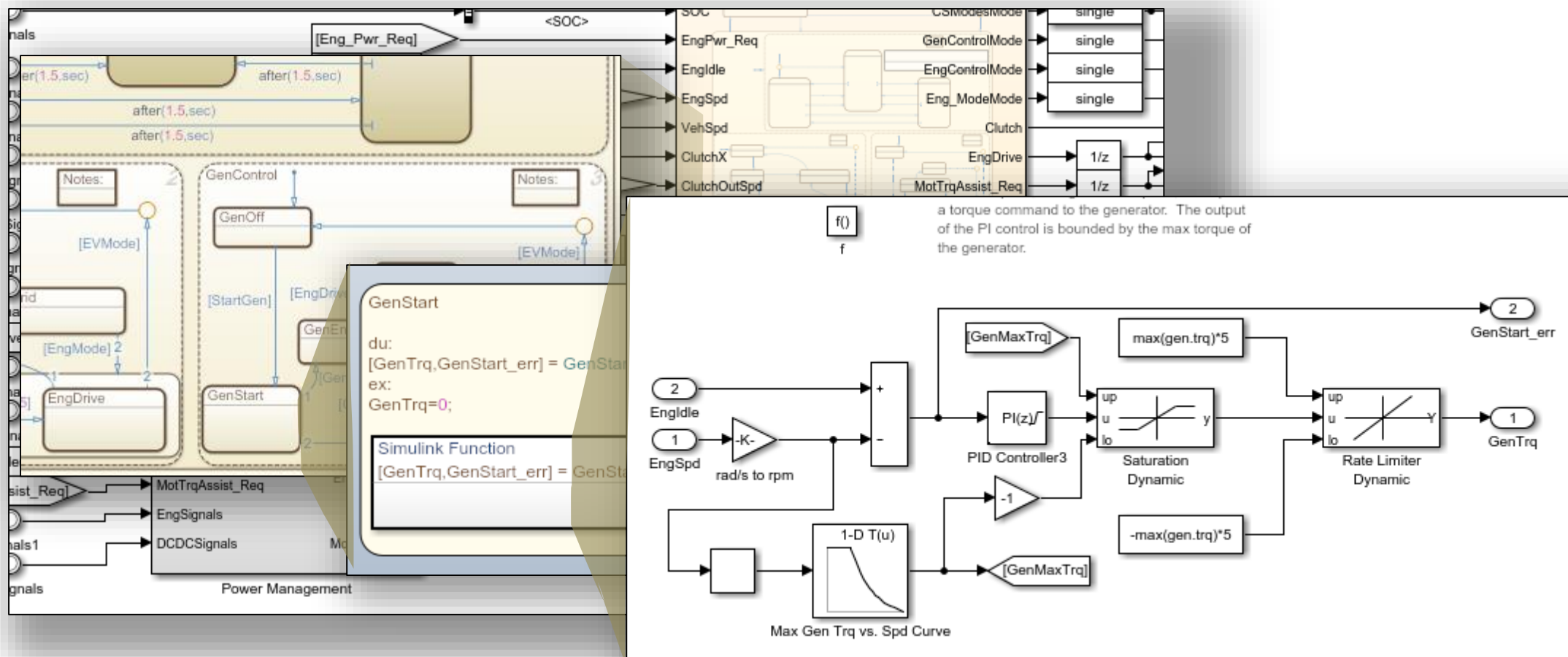
# 理解系统行为时遇到的挑战

- 复杂的被控对象



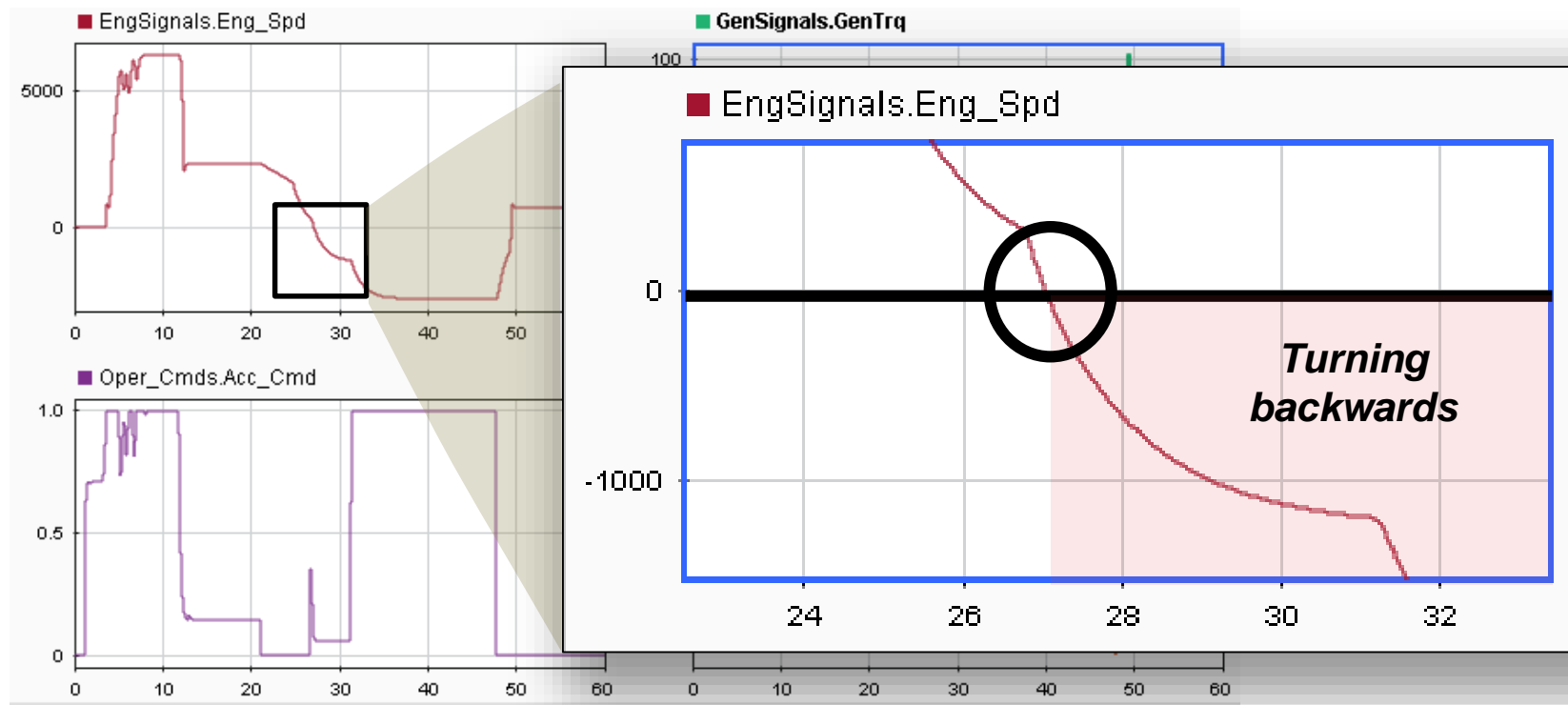
# 理解系统行为时遇到的挑战

- 复杂的被控对象
- 复杂的控制器



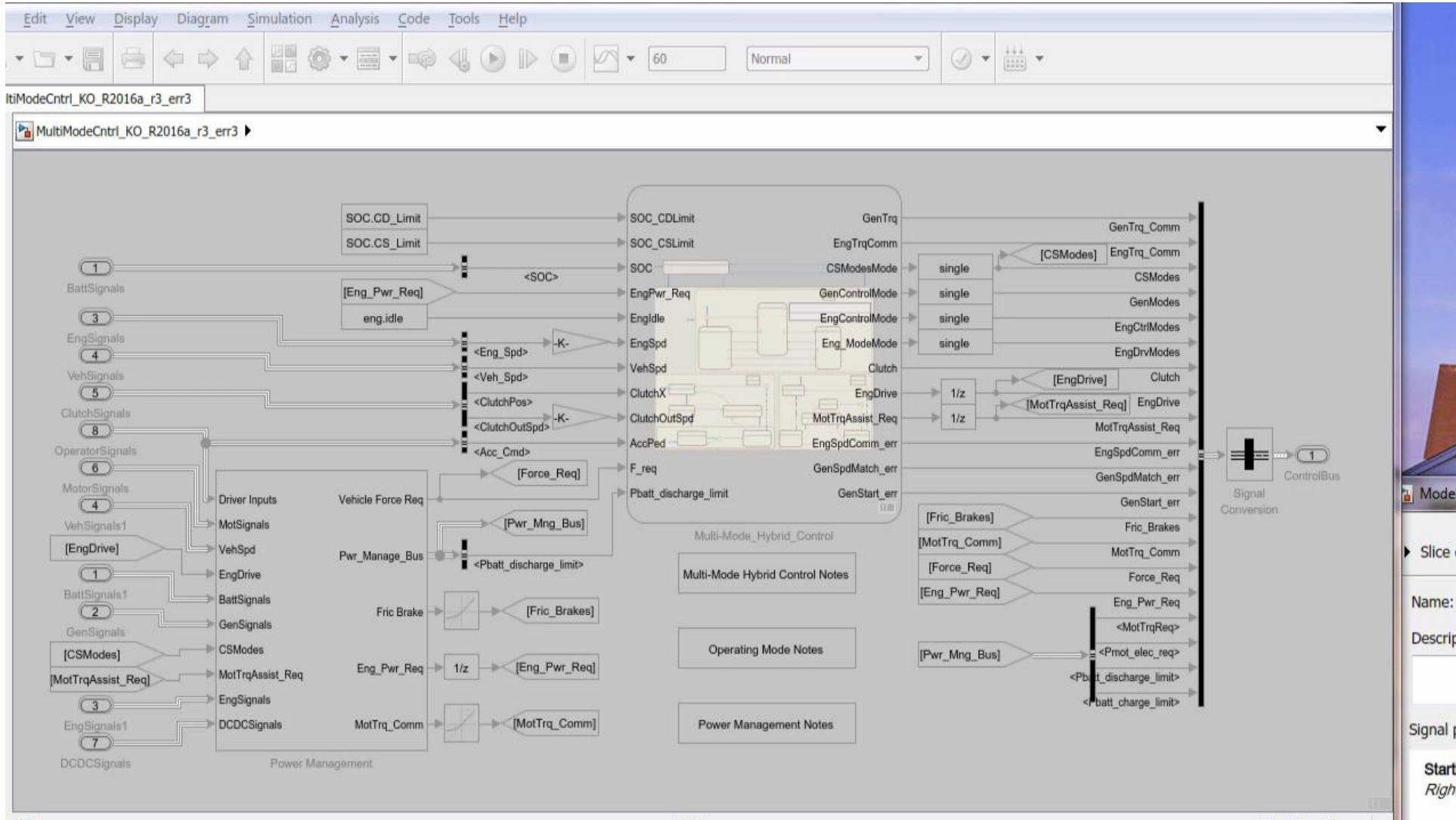
# 理解系统行为时遇到的挑战

- 复杂的被控对象
- 复杂的控制器
- 复杂的动态

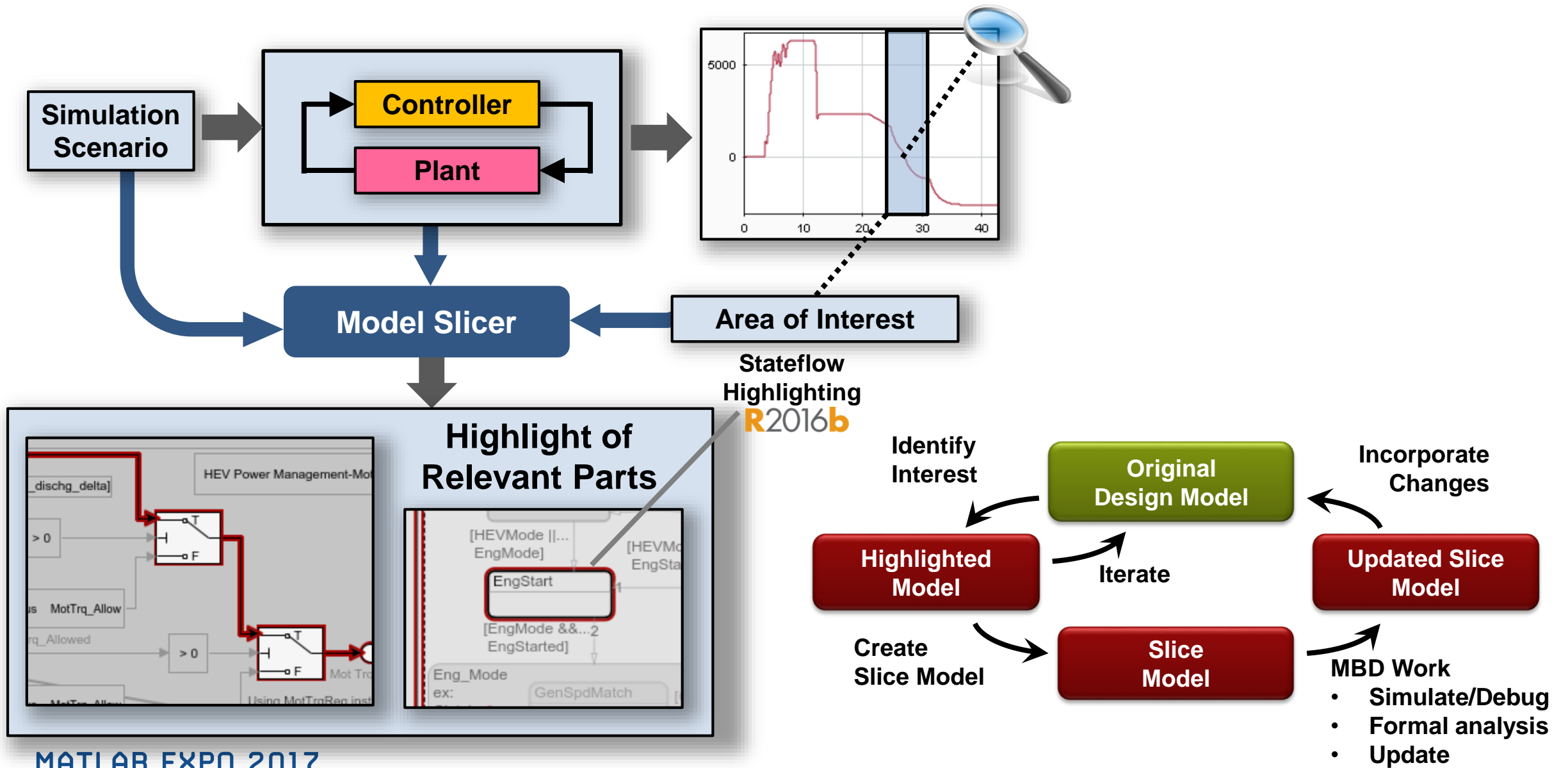




# 模型裁剪

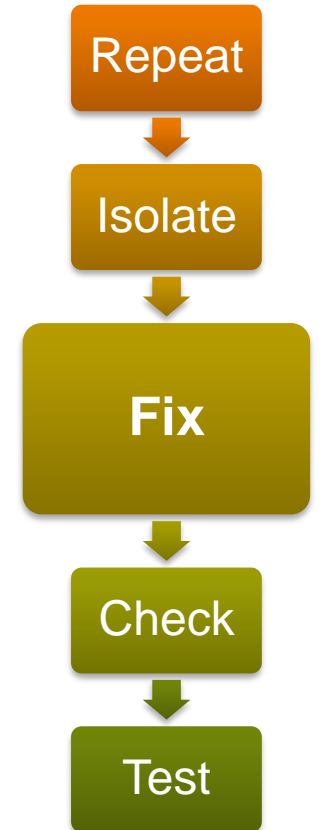
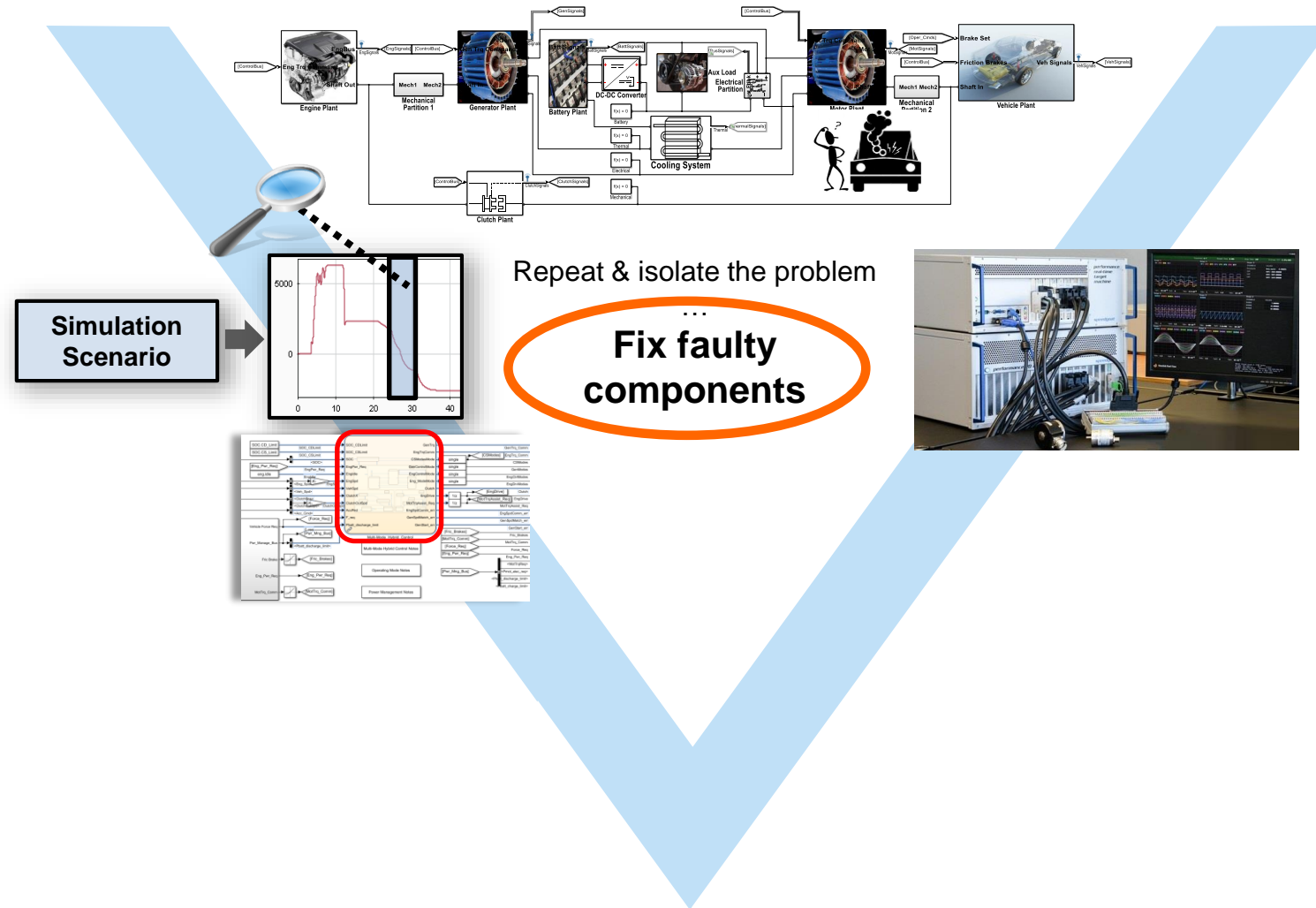


# 通过Model Slicer隔离有问题的设计



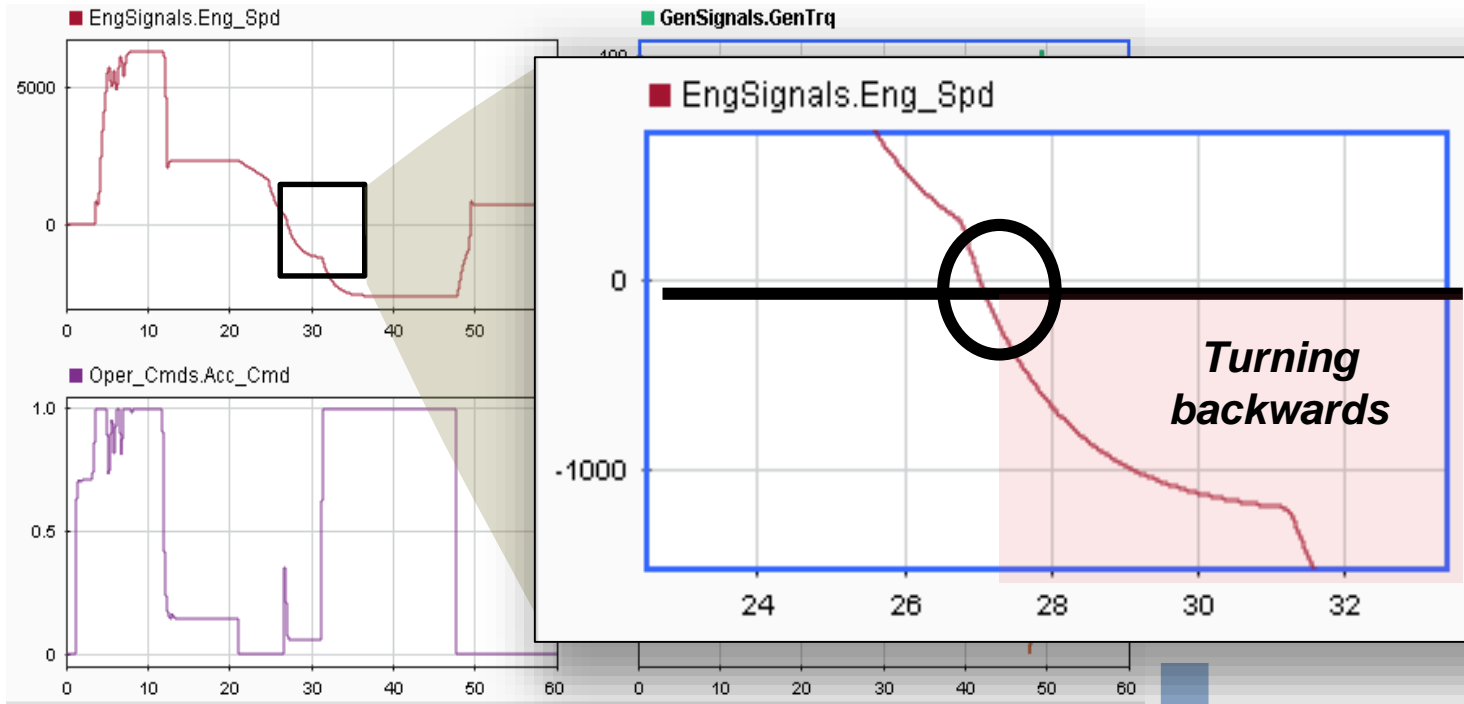
MATLAB EXPO 2017

# 修复错误与单元测试

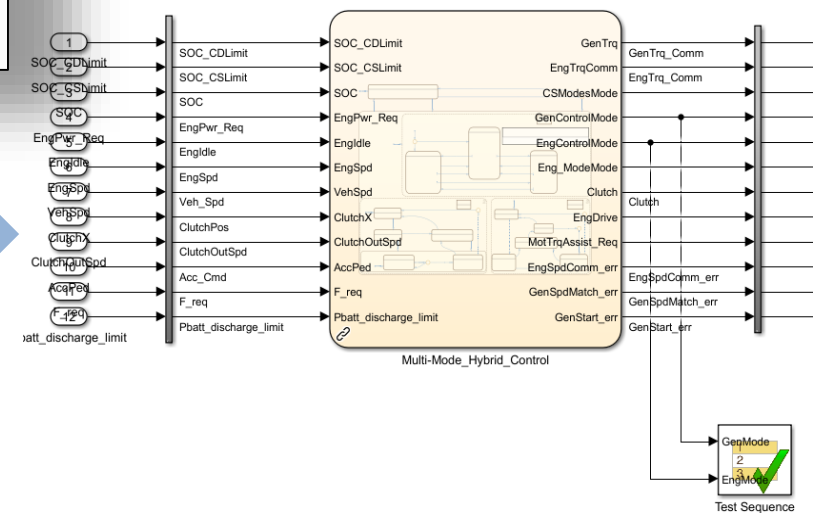


# 状态同步错误

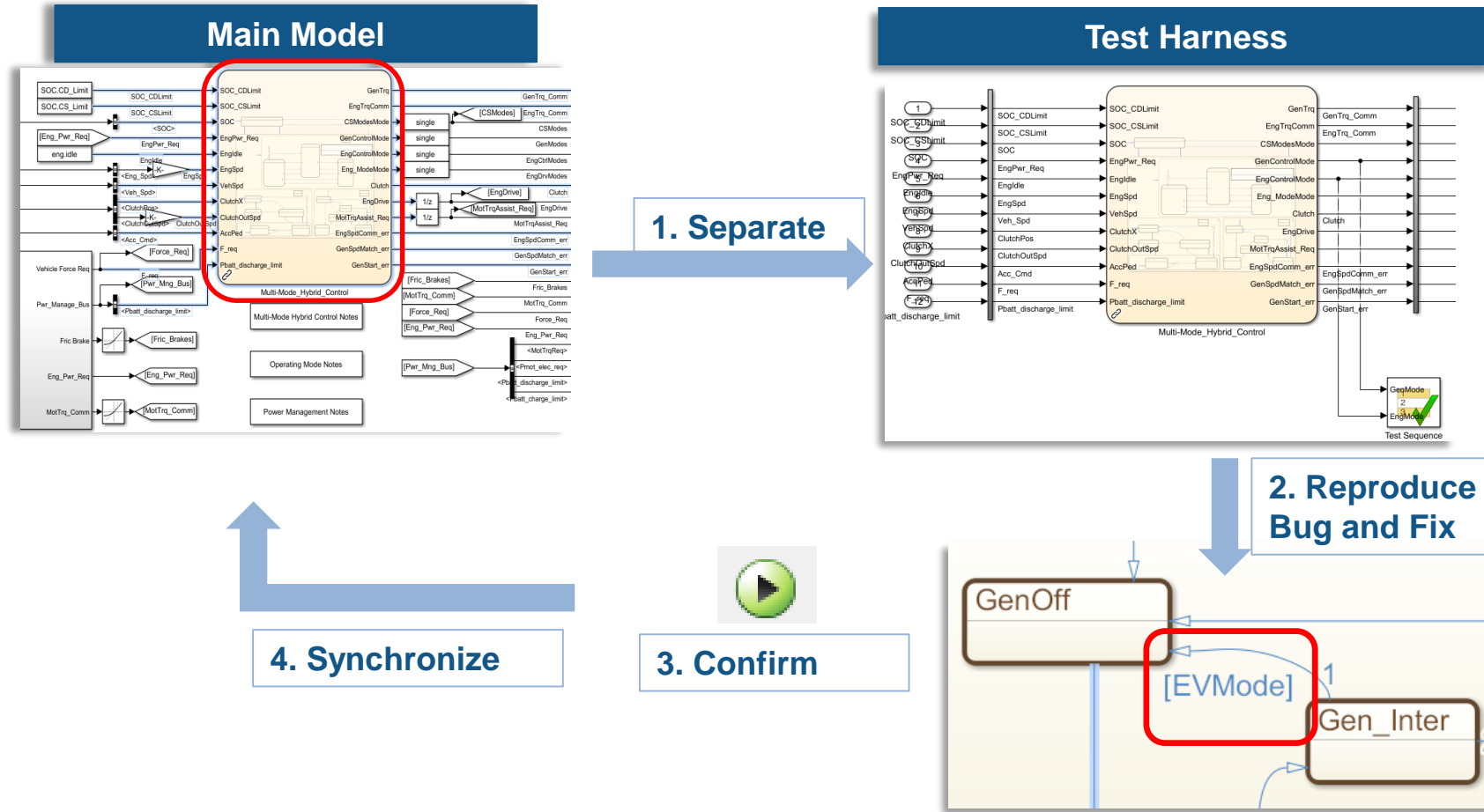
## Engine Turning Backwards

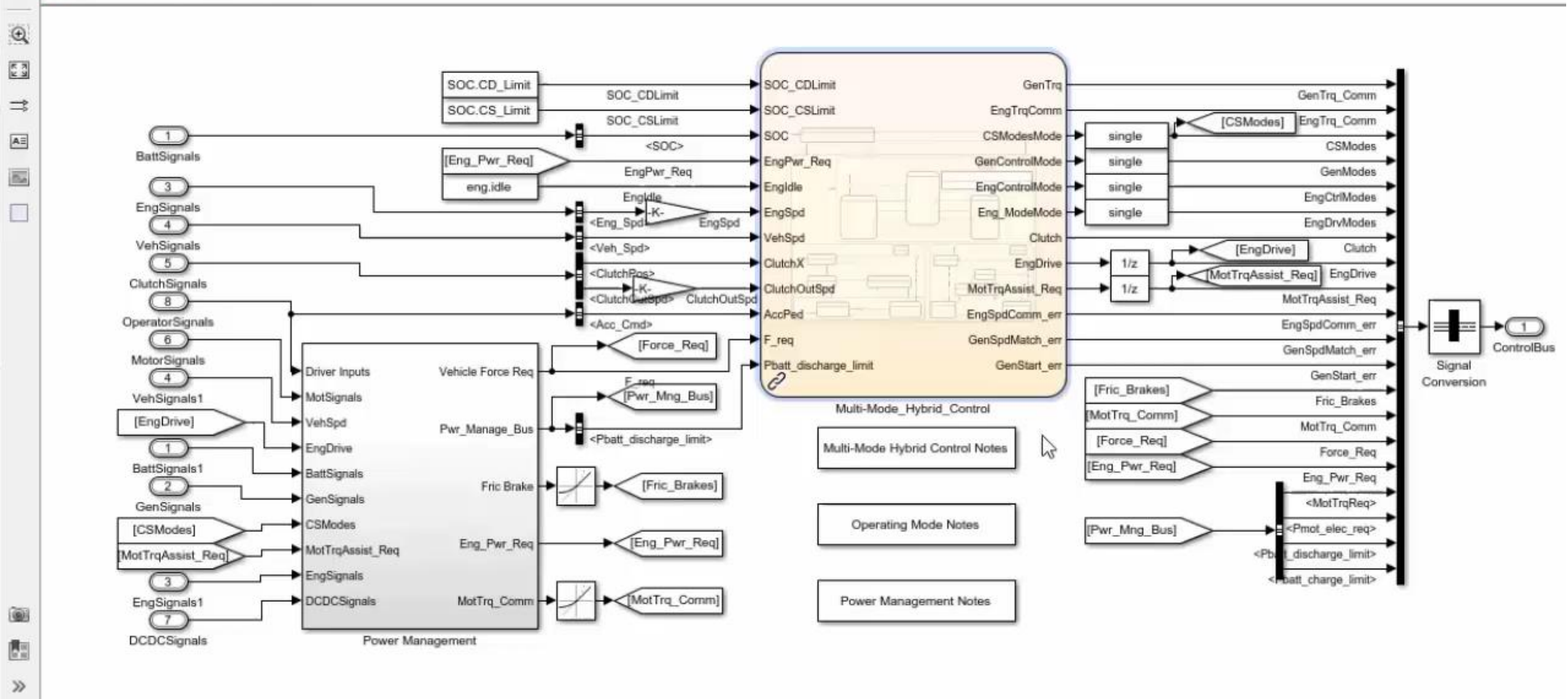


## Isolate and Fix



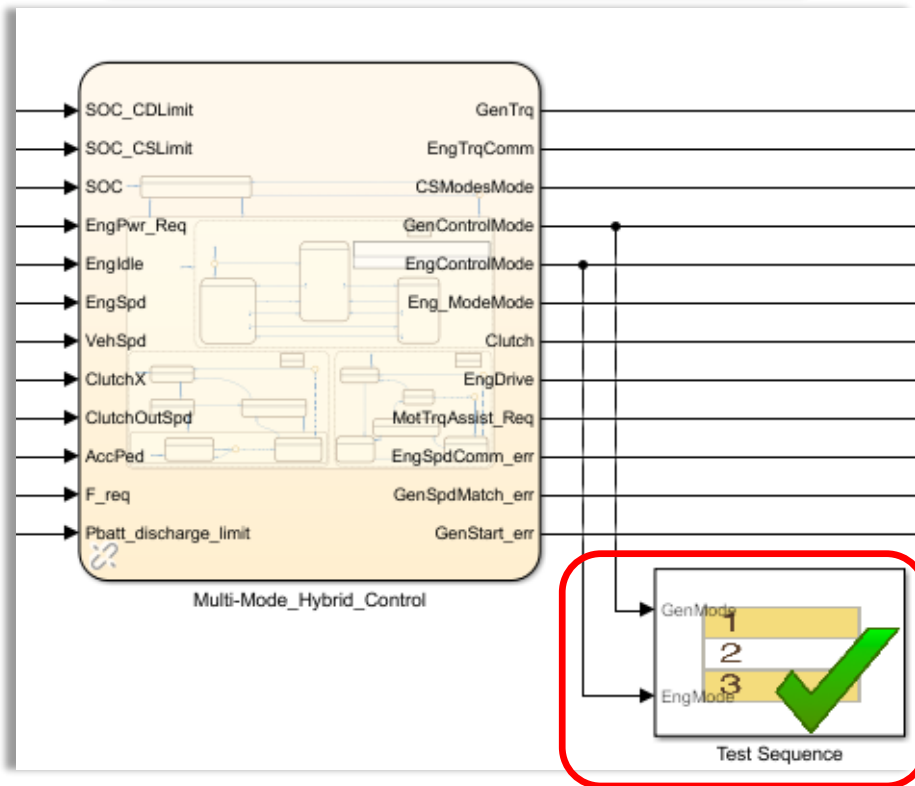
# 单元测试流程





# In-model 验证

## Isolate Component in Test Harness



## Verification Result streamed to Data Inspector

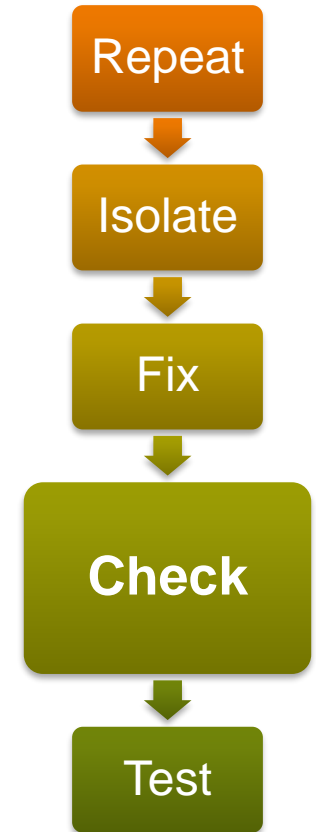
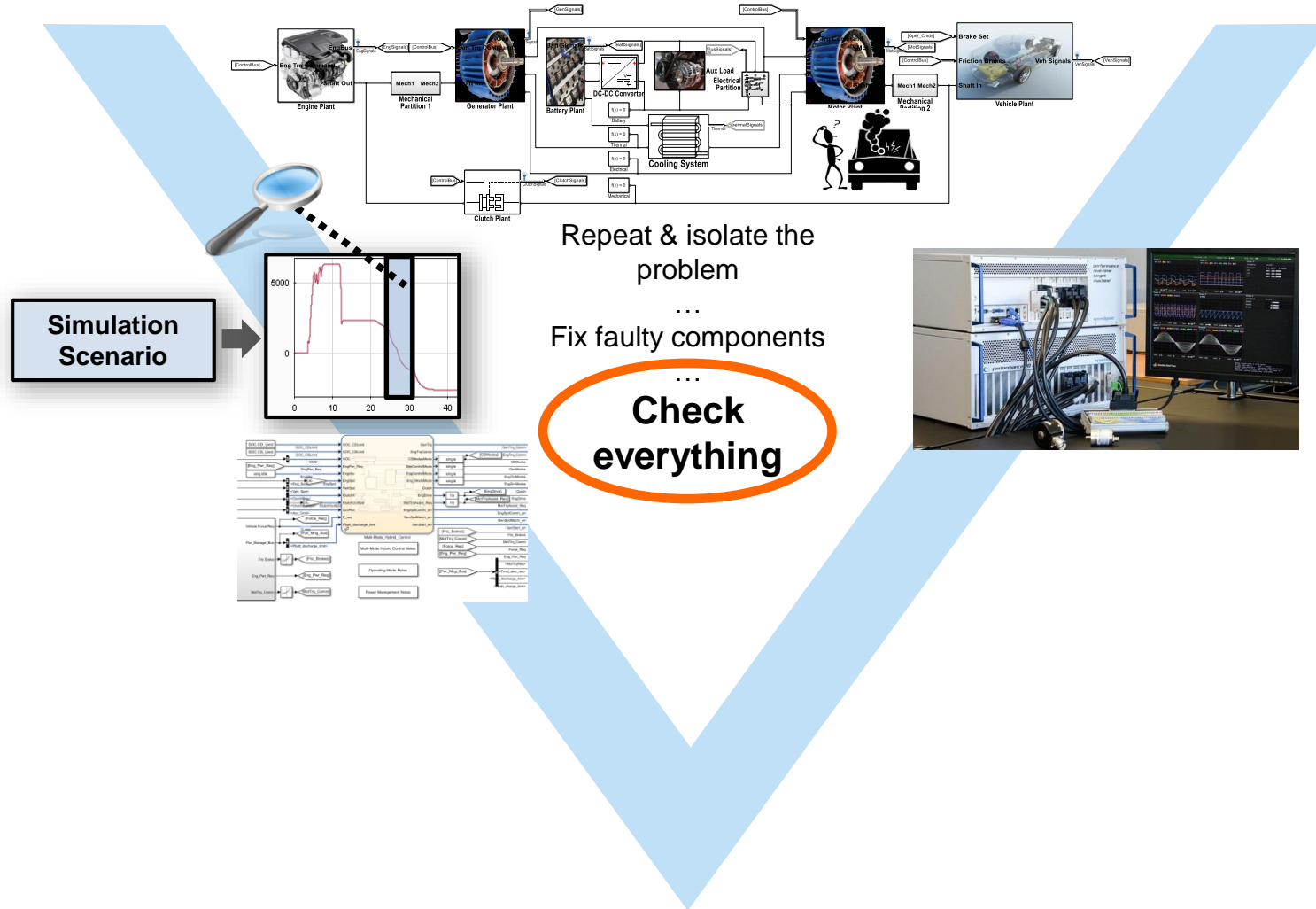


## In-model Verification with *verify* keyword

CheckOperatingModes

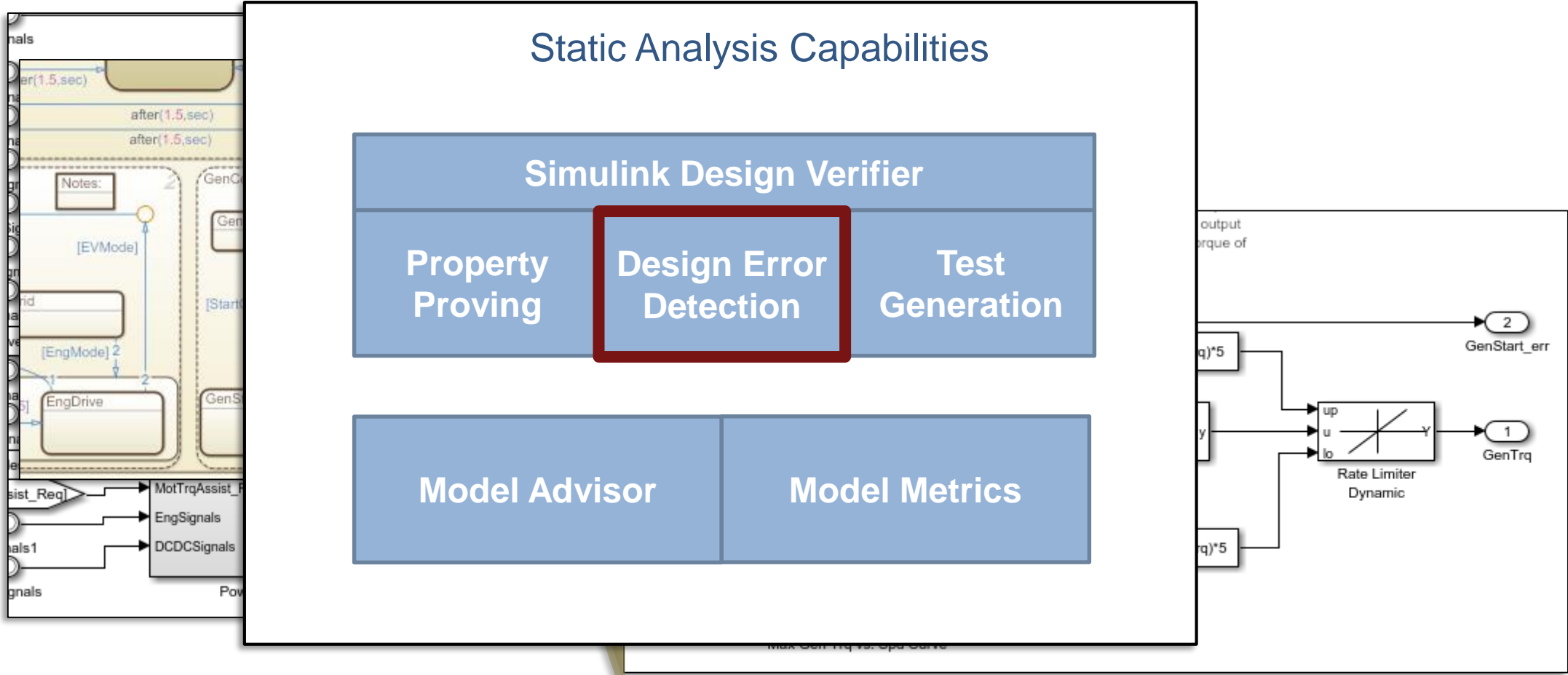
```
if EngMode == Start
    verify(GenMode ~= Run);
end
```

# 进一步检查设计错误

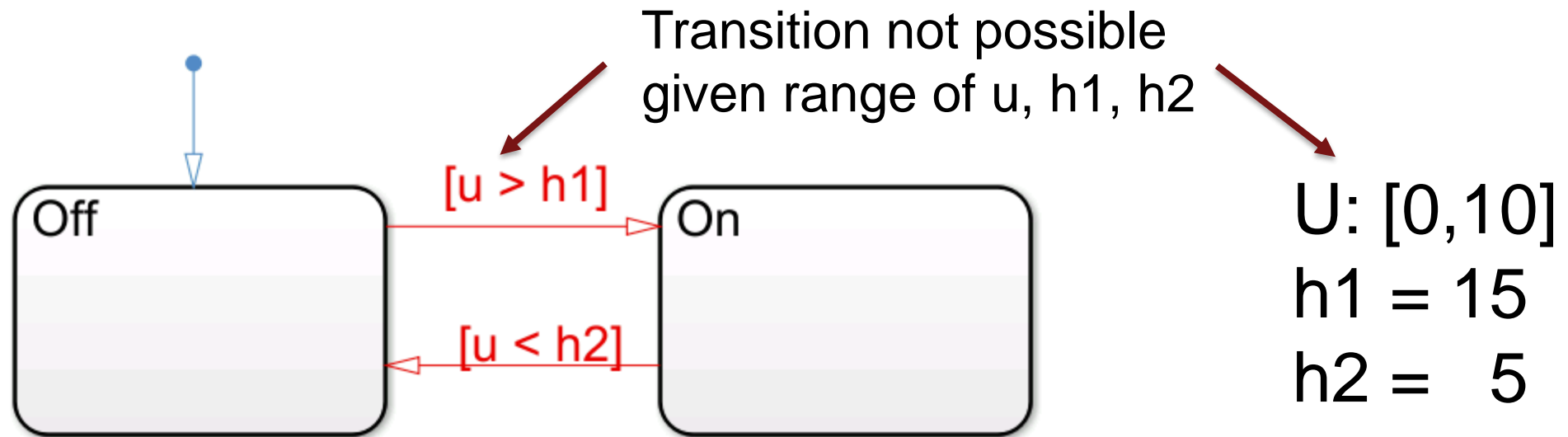
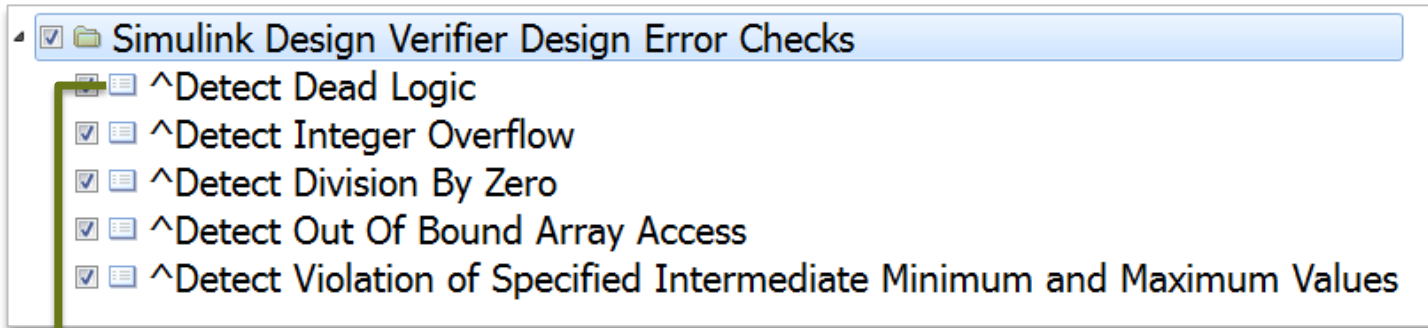


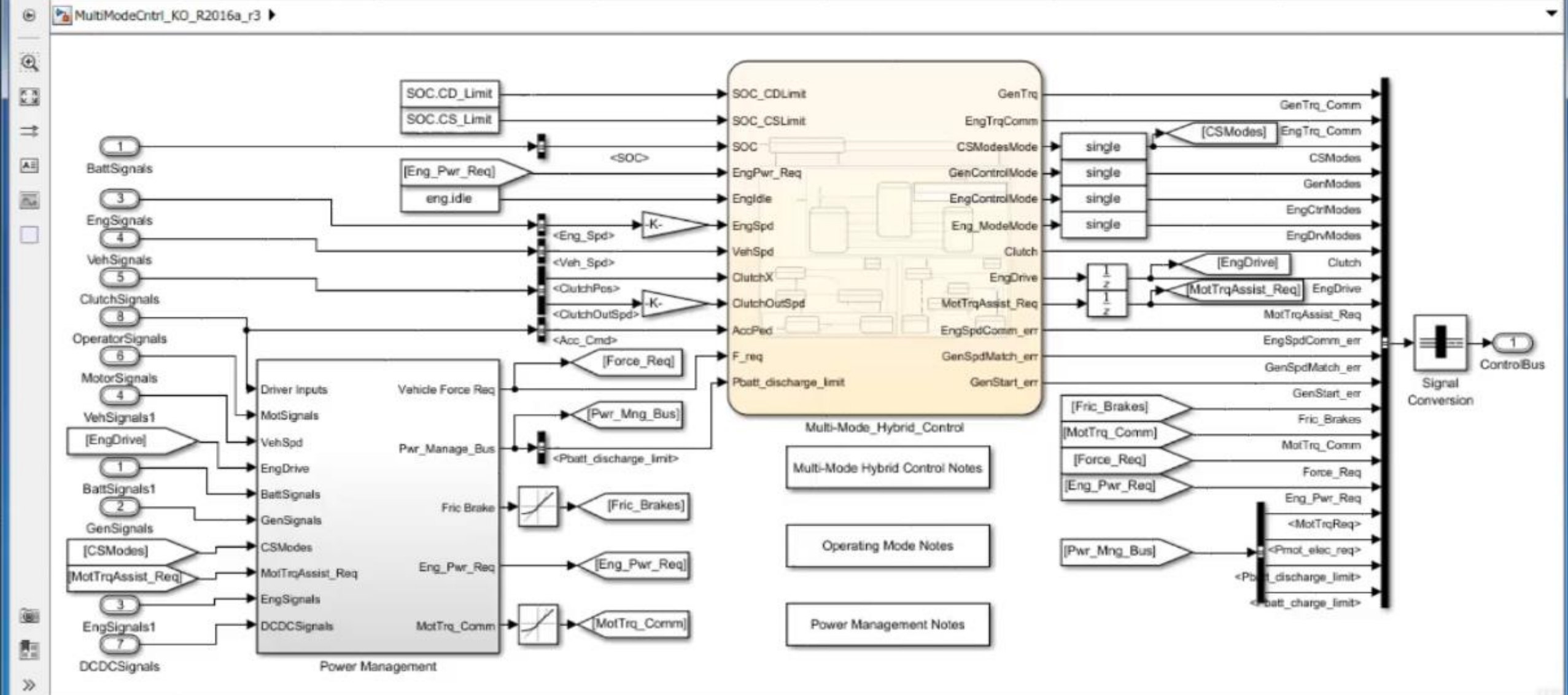


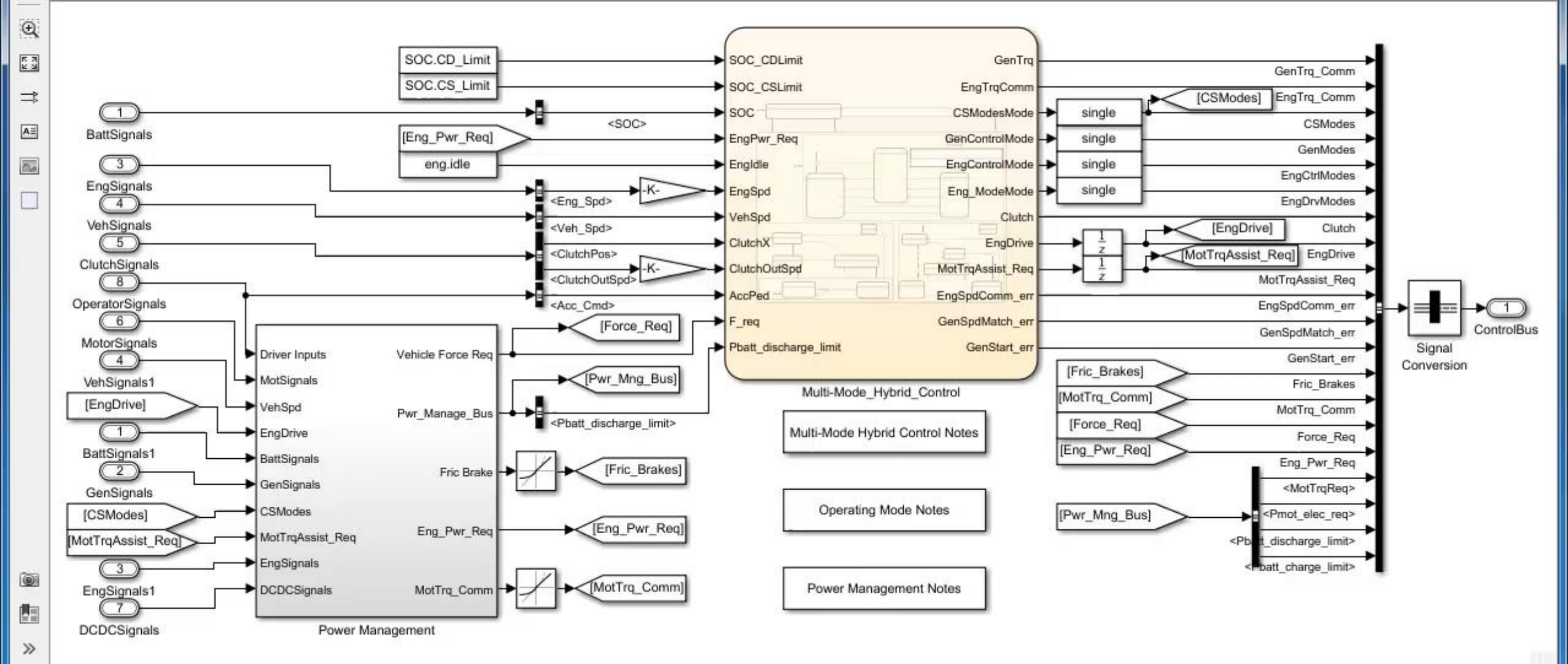
# 利用Static Checking进行鲁棒设计

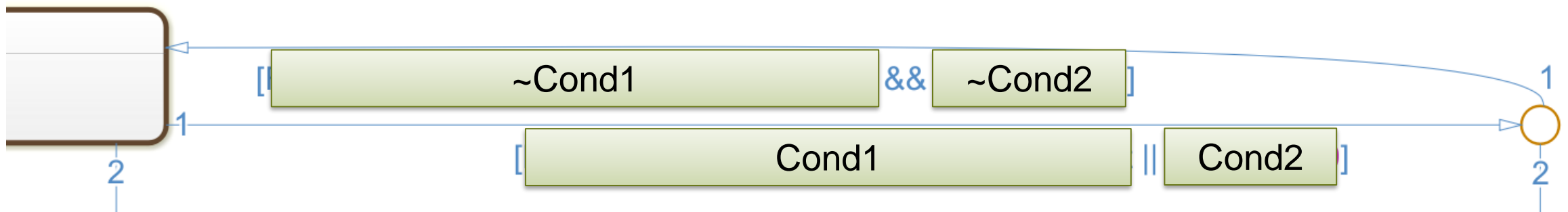


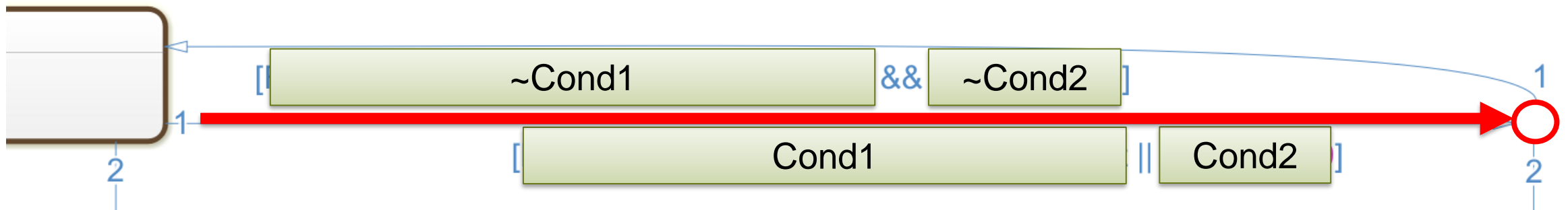
# 利用Design Error Detection发现隐藏问题

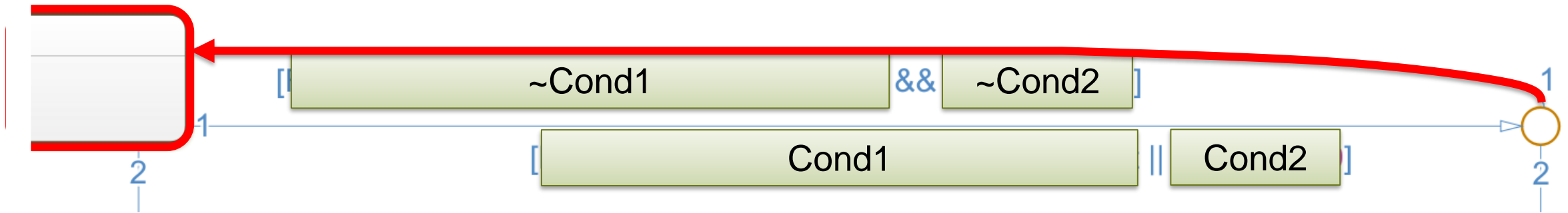


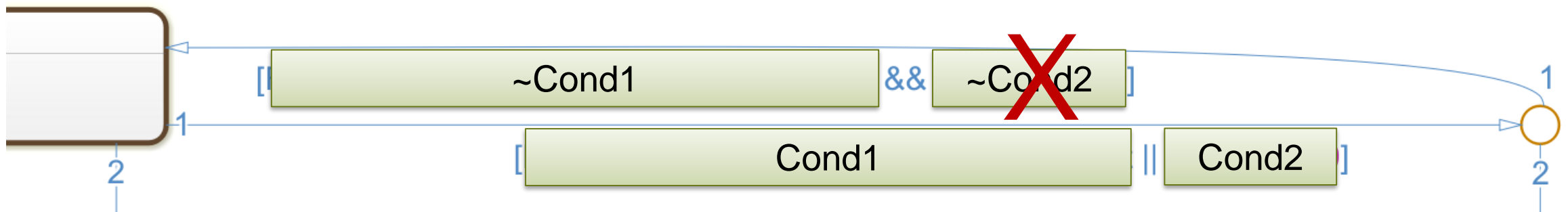














Close results

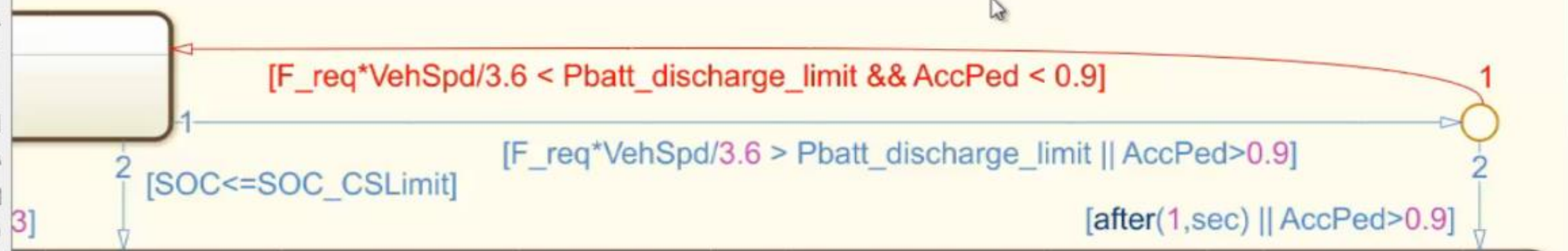
**Design error detection completed normally.**  
30/473 objectives are dead logic.

**Results:**

- Detailed analysis report: [\(HTML\)](#) [\(PDF\)](#)

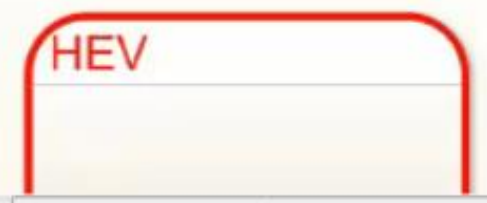
Tools Help

inf Normal



$[EVArea, EngArea] = OperatingAreaCalc(F\_req, VehSpd)$

Notes:



**Simulink Function**

$[EVArea, EngArea] = OperatingAreaCalc(F\_req, VehSpd)$

$[F\_req * VehSpd / 3.6 > Pbatt\_discharge\_limit \ \parallel \ AccPed \geq 0.9]$

Simulink Design Verifier Results Inspector

Close results

**Design error detection completed normally.**  
30/473 objectives are dead logic.

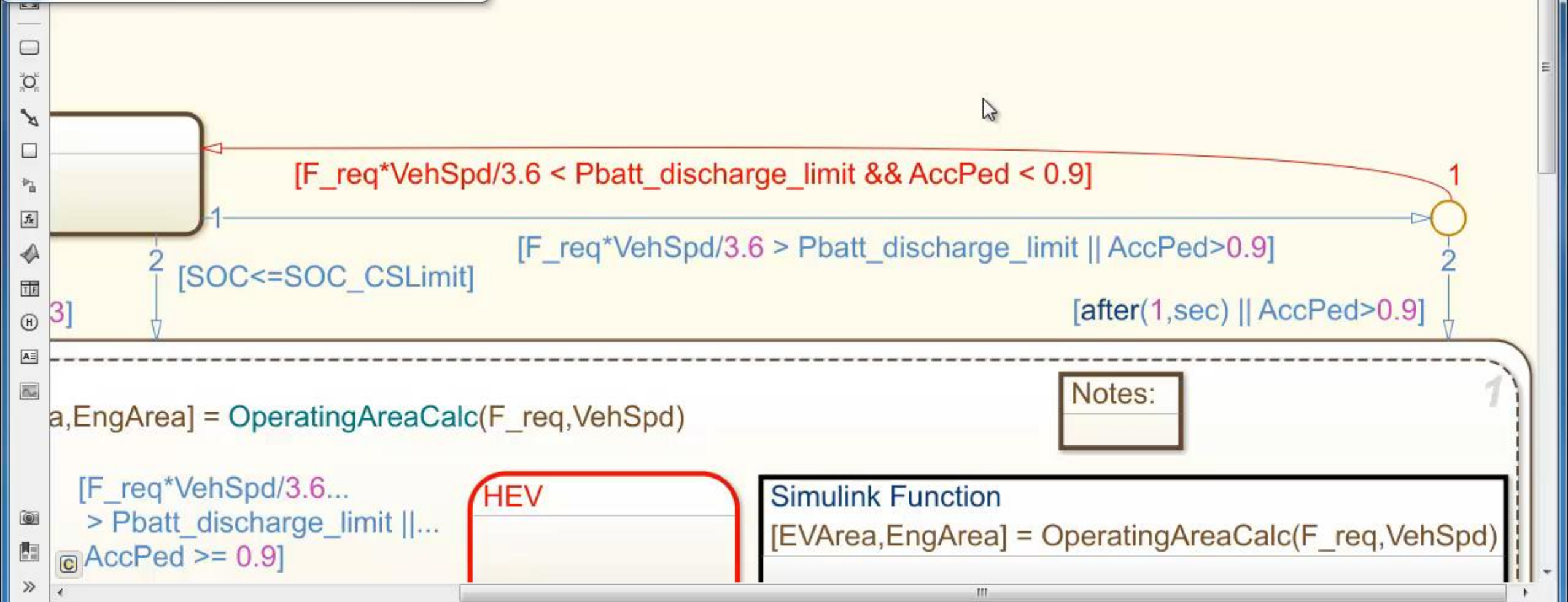
**Results:**

- Detailed analysis report: [\(HTML\)](#) [\(PDF\)](#)

Control \* - Simulink prerelease use

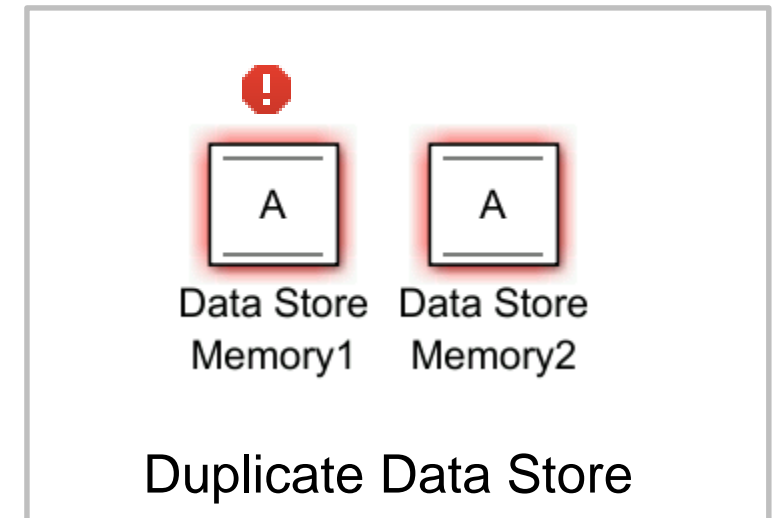
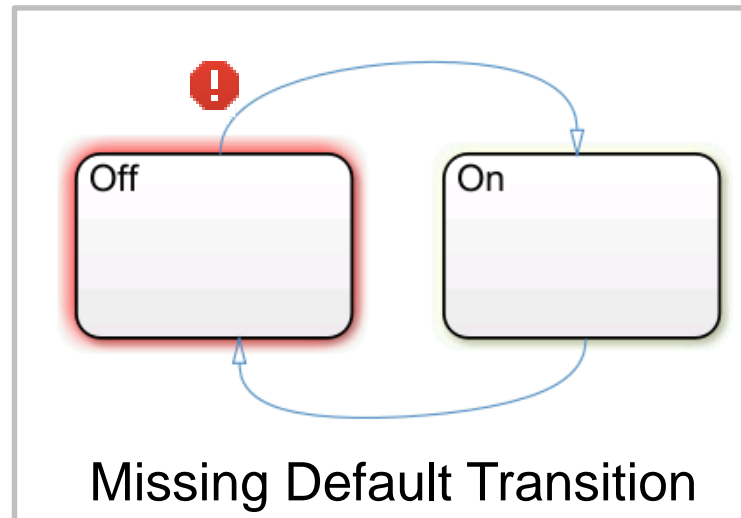
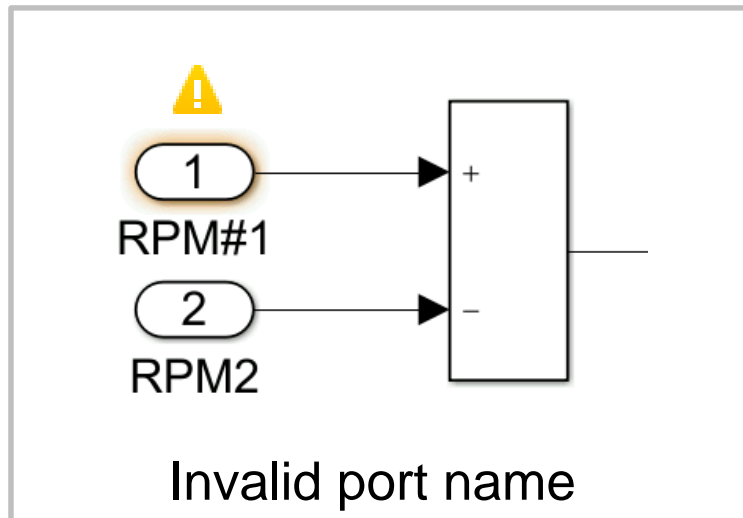
Tools Help

inf Normal

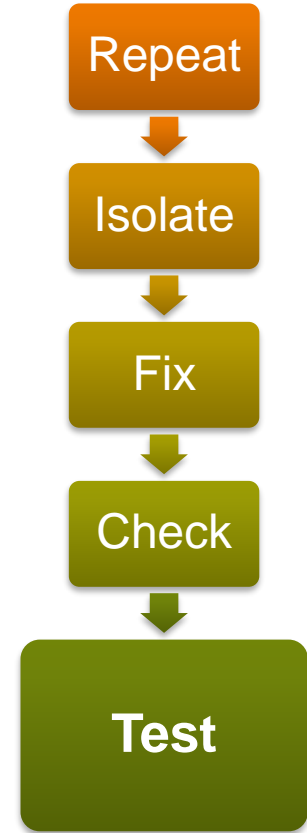
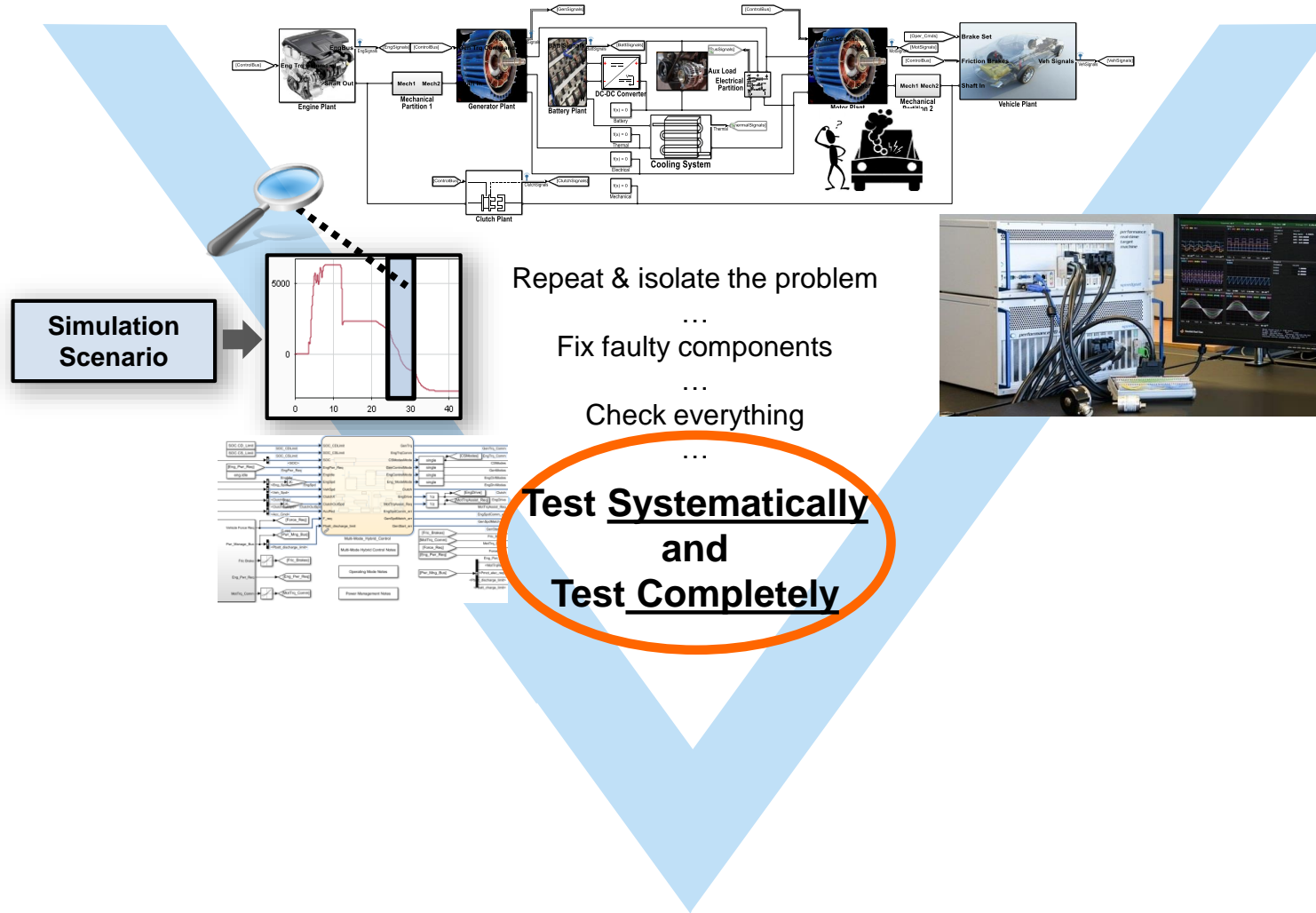


## 通过‘边做边改’（Fixing-as-you go）预防错误的发生

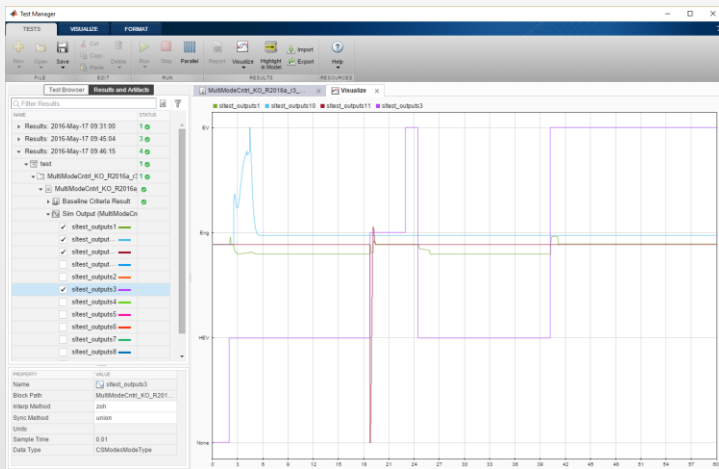
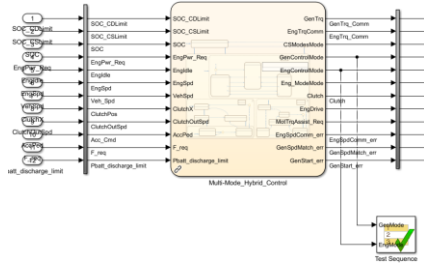
- Edit-time checking
  - Simulink
  - Stateflow
  - Modeling Standards
    - 阻止模块错误
    - 模块和端口名字违背
- 为本单位的标准定制规则



# 测试：系统化及完整性



# 使用Test Manager进行系统化测试



## Test Manager Platform

*Systematic authoring, management, execution, and reporting of test cases*

- Unites together a broad set of capabilities
- Simulink Test
- **R2015a**

TESTS

FILE      EDIT      RUN      RESULTS      RESOURCES

Test Browser      Results and Artifacts      Constant 70 Km/Hr

Filter tests by name or tags, e.g. tag: test

- HEV\_Control\_R...
- Scenarios
  - Constant
  - Constant
  - Highway

**R2016b**

CUSTOM CRITERIA

```

function customCriteria(test)
1
2 %% criteria 1: State of charge should not be below 30%
3 minSOC = min(test.SimOut.get('tmp_racel_logsout').get('BattSignal
4 test.verifyGreaterThan(minSOC, 30, 'SOC should be more than 30%');
5
6 %% criteria 2: Voltage should not be less than 250 V after starting
7 minVoltage = min(test.SimOut.get('tmp_racel_logsout').get('BattSi
8 test.verifyGreaterThan(minVoltage, 250, 'voltage should be more th
    
```

PROPERTY

Name	
Type	
Model	HEV_MultiMode_Optim_R...
Simulation Mode	[Model Settings]
Location	C:\work\mab2016\HEV_C...
Enabled	<input checked="" type="checkbox"/>
Record Coverage	<input checked="" type="checkbox"/>
Hierarchy	HEV_Control_Regression...
Tags	type comma or space separa

- ▶ OUTPUTS ?
- ▶ CONFIGURATION SETTINGS OVERRIDES ?
- ▶ BASELINE CRITERIA ?
- ▶ CUSTOM CRITERIA ?
- ▶ ITERATIONS ?
- ▶ COVERAGE SETTINGS ?

**MATLAB Script Criteria**

TESTS VISUALIZE FORMAT

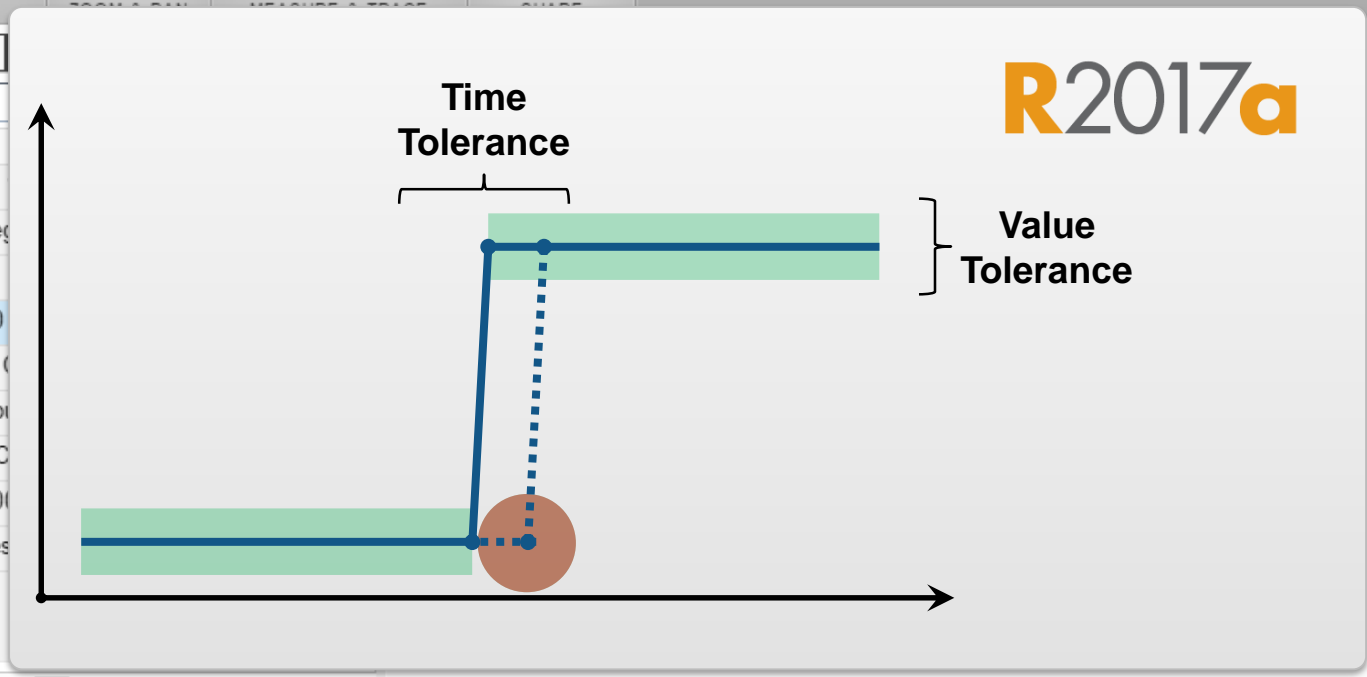
Subplots Clear Subplot Legend Data Cursors Highlight in Model Send to Figure

Test Browser

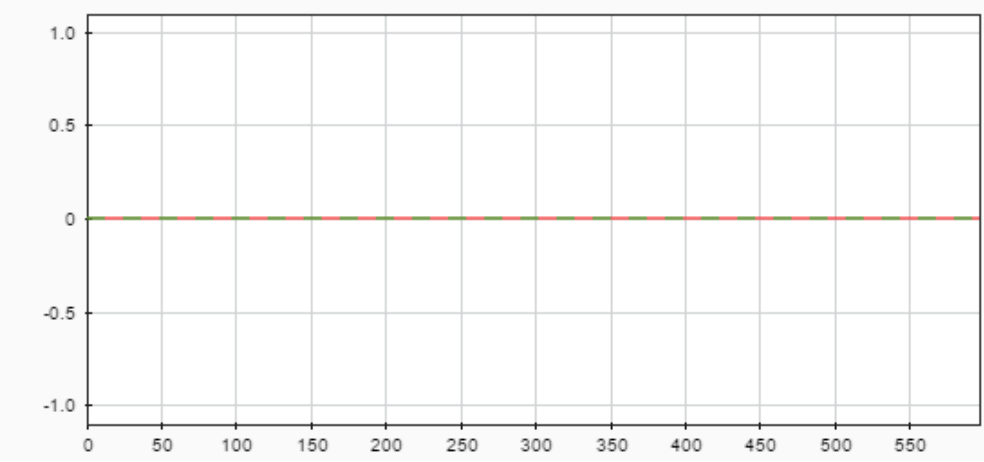
Filter Results

NAME

- Results: 2016-May-23
  - HEV\_Control\_Reg
    - Scenarios
      - Constant 70
        - Baseline
        - Sim Output
        - Custom C
        - Constant 100
        - Highway Test



PROPERTY	VALUE
Name	Constant 70 Km/Hr
Status	1
Start Time	05/23/2016 12:45:45
End Time	05/23/2016 12:48:36
Type	Baseline Test
Test File Location	C:\work\mab2016\HEV_Co...
Model	HEV_MultiMode_Optim_R...
Simulation Mode	accelerator
Test Case Definition	
Baseline File	C:\work\mab2016\baseline...
Time	



TESTS

VISUALIZE

FORMAT

Subplots Clear Subplot Legend 2.5 Data Cursors Highlight in Model Send to Figure

VIEWS    ZOOM & PAN    MEASURE & TRACE    SHARE

Test Browser

Results and Artifacts

Constant 70 Km/Hr

Comparison

## AGGREGATED COVERAGE RESULTS

ANALYZED MODEL	REPORT	COMP.	D1	C1	MCDC	EXECUTION
HEV_MultiMode_Optim_R2016a_r3		389	54%	81%	48%	100%
MultiModeCntnl_KO_R2016a_r3_err4		143	76%	62%		
Power_Management_v0		49	91%	97%		

## AGGREGATED COVERAGE RESULTS

ANALYZED MODEL	REPORT	COMP.	D1	C1
HEV_MultiMode_Optim_R2016a_r3		389	54%	81%
MultiModeCntnl_KO_R2016a_r3_err4		143	76%	62%
Power_Management_v0		49	94%	100%

**Report Generated by Test Manager**

**Title:** Test  
**Author:** David Boissy  
**Date:** 24-May-2016 13:05:13

**Test Environment**

Platform: PCWIN64  
 MATLAB: (R2017a Prerelease)

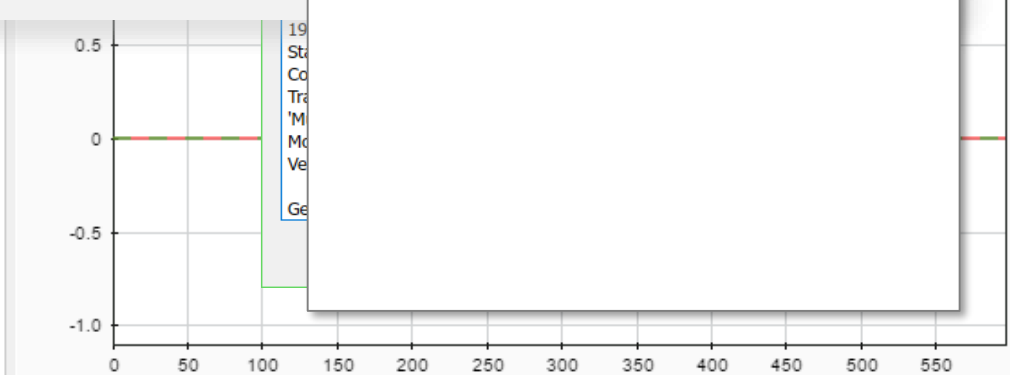
PROPERTIES

Name: [Empty]

Status: [Empty]

Start Time	05/23/2016 12:45:45
End Time	05/23/2016 12:48:36
Type	Baseline Test
Test File Location	C:\work\mab2016\HEV_Co...
Model	HEV_MultiMode_Optim_R...
Simulation Mode	accelerator
Test Case Definition	
Baseline File	C:\work\mab2016\baseline...

Tags





# 完整地测试- Top-It-Off 流程

## R2017a

1

- Run Existing Tests
- Aggregate Coverage

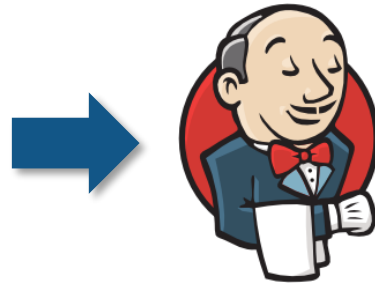
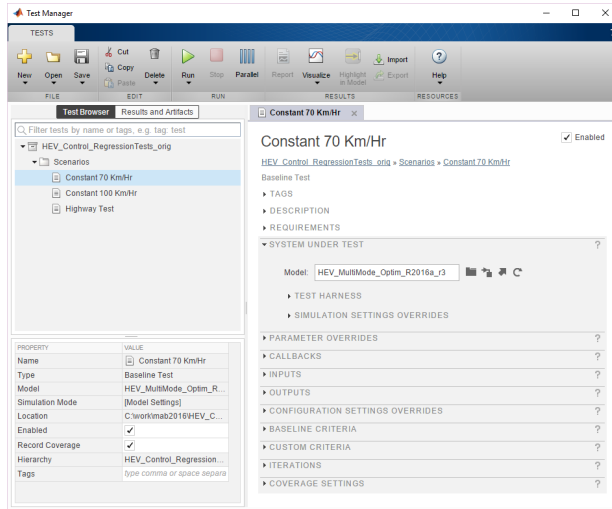
2

- Simulink Design Verifier
- Generate Test Cases

3

- Run New Tests
- Aggregate Coverage

# 与测试自动化服务器集成

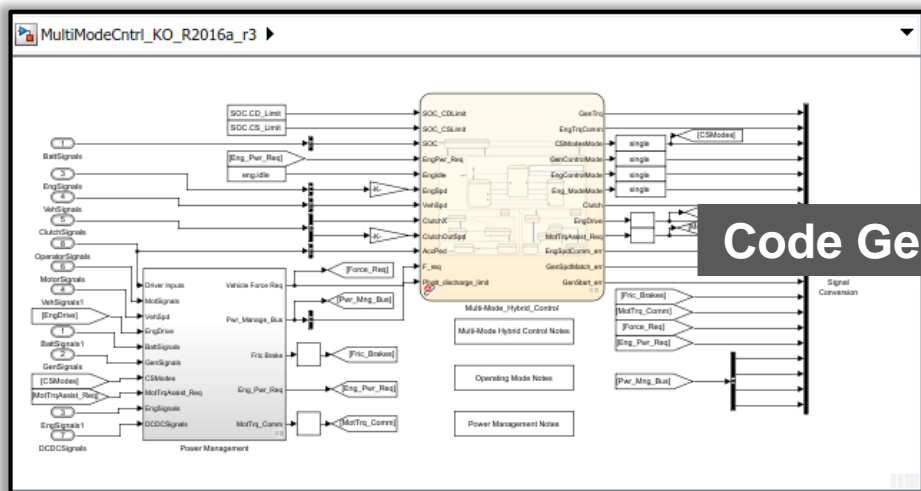


# Jenkins

Any continuous integration system that supports  
Test Anything Protocol (TAP)

R2016b

# 代码到模型的验证



```

/* Copyright 2007-2013 The MathWorks, Inc. */
#include "version.h"
#include "FRoots/FRoots_all_exports.hpp"
#include "mcas.h"

#include "cg_fr/base/Scope.hpp"
#include "cg_fr/builder/ScopeTypeBuilder.hpp"
#include "cg_fr/base/cg_string.hpp"
#include "cg_fr/factory/TypeFactory.hpp"
#include "cg_fr/utility/cg_pool.hpp"

void TypeFactory::pushPath(const char *str, int
    if (index != -1) {
        FPath->append(index+3);
        FPath->append(' ');
    }
    if (str != NULL) {
        FPath->append(str);
    }
}
    
```

**Code Generator**

**C**

**Test Manager**

**Test Manager**

MultiModeCtrl\_KO\_R2016a\_r3\_test

**Software-In-Loop (SIL)**

PROPERTY:  
Name: MultiModeCtrl\_KO\_R2016a\_r3  
Location: ...  
Enabled: [x]  
Record Coverage: [x]  
Tags:

Test Inputs:  
1. BattSignals  
2. EngSignals  
3. VehSignals  
4. ClutchSignals  
5. MotorSignals  
6. DCDCSignals  
7. OperatorSignals

Test Outputs:  
GenSignals  
EngSignals  
VehSignals  
ClutchSignals  
MotorSignals  
DCDCSignals  
OperatorSignals

**Polyspace**

**Polyspace Code Prover**

Results List

Check distribution

Code covered by verification

Category	Count
Green	98
Orange	7
Gray	2
Red	1

Code covered by verification: Procedure (100%), Code operation (96%)

Top 5 coding rule violations: D4.6, 2.5, 10.3, D4.9, 10.4

Top 5 orange sources: al\_values\_s32\_imp32, al\_values\_u16\_imp16

**Dynamic**

**Static**

# 等效性检查及代码覆盖度 (Software-In-Loop)

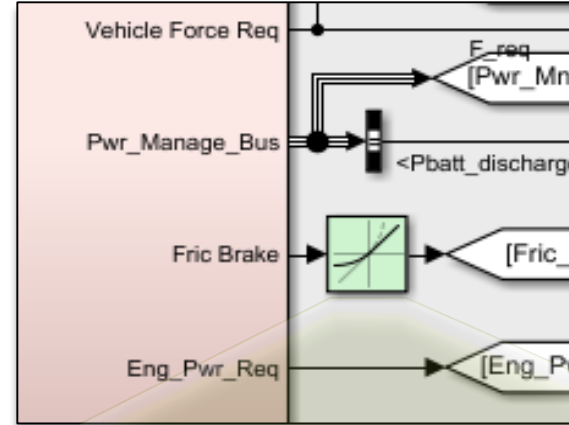
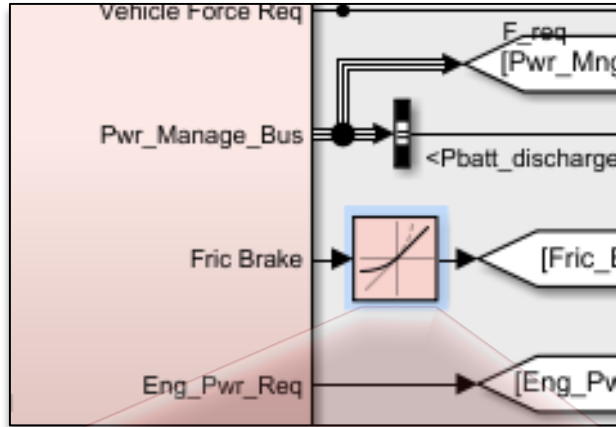
The screenshot displays the Test Manager application window. The interface is divided into several sections:

- Toolbar:** Contains icons for file operations (New, Open, Save), editing (Cut, Copy, Paste, Delete), execution (Run, Stop, Parallel), and reporting (Report, Visualize, Highlight in Model, Export, Import, Help).
- Test Browser:** A tree view on the left showing a hierarchy: ControllerRegressionTest > Test suite > Scenario 1.
- Property Table:** A table at the bottom left showing properties for the selected test.
 

PROPERTY	VALUE
Name	Scenario 1
Type	Equivalence Test
Simulation 1: Model	HEV_MultiMode_Optim_R2016a_r3
Simulation 1: Harness Name	HEV_MultiMode_Optim_R2016a_...
Simulation 1: Simulation Mode	Normal
Simulation 2: Model	HEV_MultiMode_Optim_R2016a_r3
Simulation 2: Harness Name	HEV_MultiMode_Optim_R2016a_...
Simulation 2: Simulation Mode	Software-in-the-Loop (SIL)
Location	I:\MARI\2016\AbhishekVer\HEVM
- Scenario 1 Configuration:** A detailed view on the right showing the test configuration.
  - Equivalence Test**
    - TAGS
    - DESCRIPTION
    - REQUIREMENTS
    - SIMULATION 1 ?
    - SIMULATION 2 [Copy settings from Simulation 1](#) ?
    - EQUIVALENCE CRITERIA ?
    - CUSTOM CRITERIA ?
    - ITERATIONS ?
    - COVERAGE SETTINGS ?
      - COVERAGE TO COLLECT
        - Record coverage for system under test
        - Record coverage for referenced models
      - COVERAGE METRICS
        - Decision
        - Condition
        - MCDC
        - Lookup Table
        - Signal Range
        - Signal Size

# Justification for Code Coverage

## R2016b



10.28. Decision `ClutchOutSpd > 250.0F` (line 2769)

**Justify or Exclude**

Function: [MultiModeCntrl\\_KO\\_R2016a\\_r3\\_err2\\_sil\\_step](#)  
 Model Object: [Rate Limiter3](#)  
 Uncovered Links:

Metric	Coverage
Decision (D1)	50% (1/2) decision outcomes

Decisions analyzed:

<code>ClutchOutSpd &gt; 250.0F</code>	50%
false	101/101
true	0/101

**Justify**

10.28. Decision `ClutchOutSpd > 250.0F` (line 2769)

**Justified**

[\(Remove this rule\)](#)

Function: [MultiModeCntrl\\_KO\\_R2016a\\_r3\\_err2\\_sil\\_step](#)  
 Model Object: [Rate Limiter3](#)

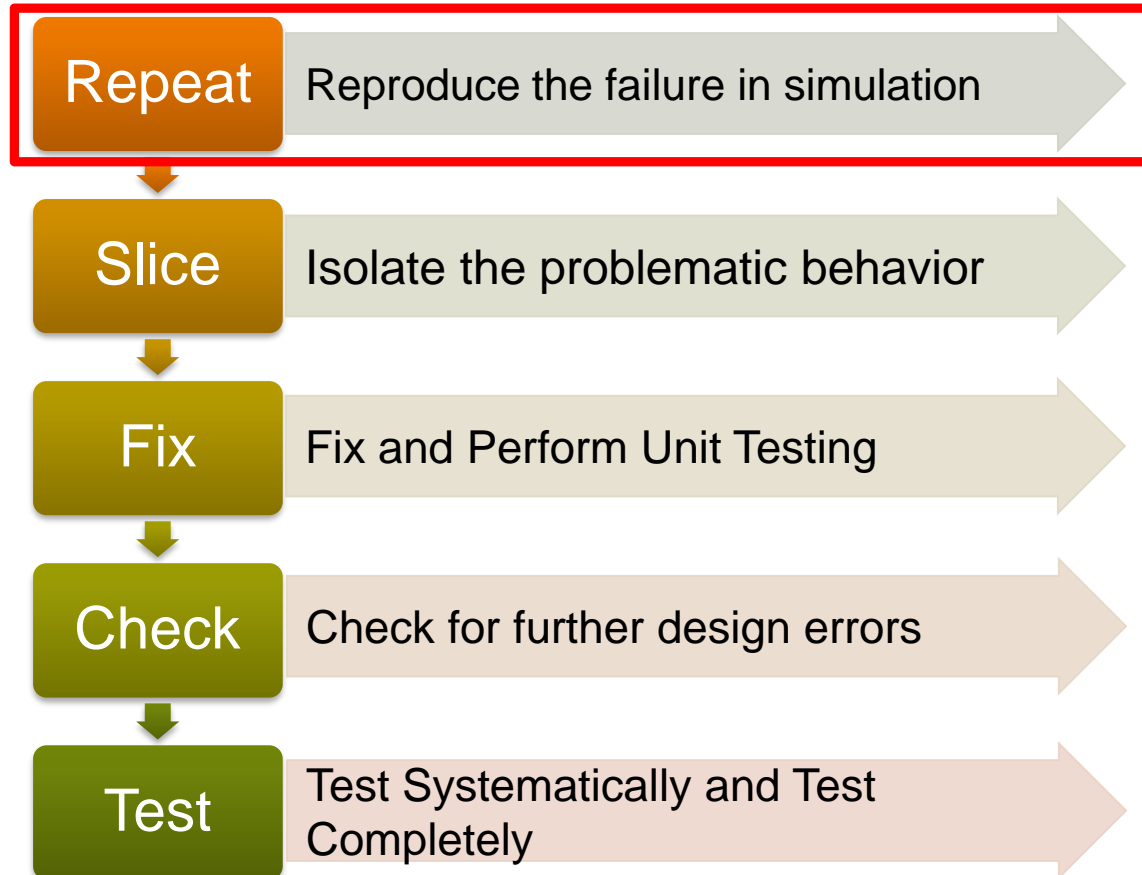
Metric	Coverage
Decision (D1)	100% ((1+1)/2) decision outcomes

Decisions analyzed:

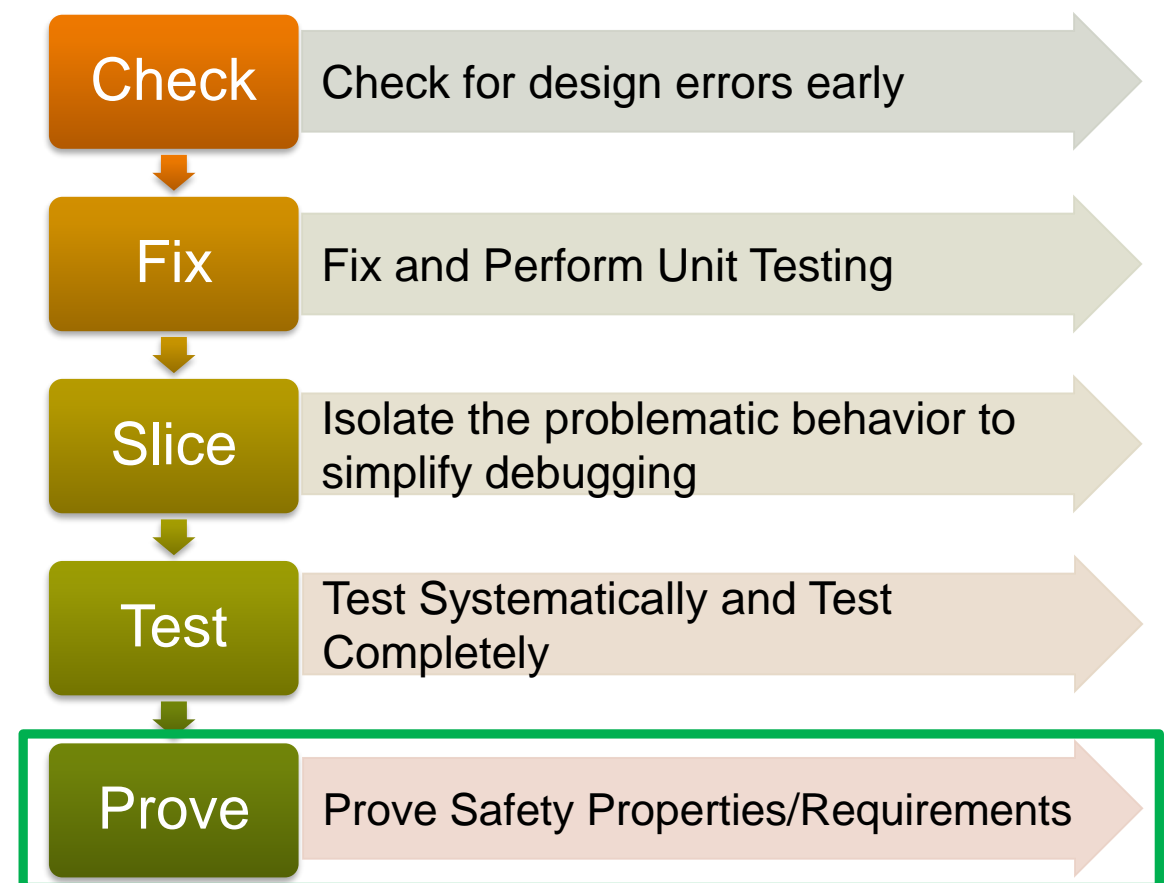
<code>ClutchOutSpd &gt; 250.0F</code>	50%
false	101/101
true	0/101

## 连续的测试和验证可以帮助...

*“Reactively” Reproduce the Field Issues  
in Simulation*



*“Proactively” Prove that Implementation  
satisfies Requirements*



# 基于模型的设计可以帮助...

