MATLAB EXPO 2018

Automating Best Practices to Improve Design Quality

임베디드 SW 개발에서의 품질 확보 방안

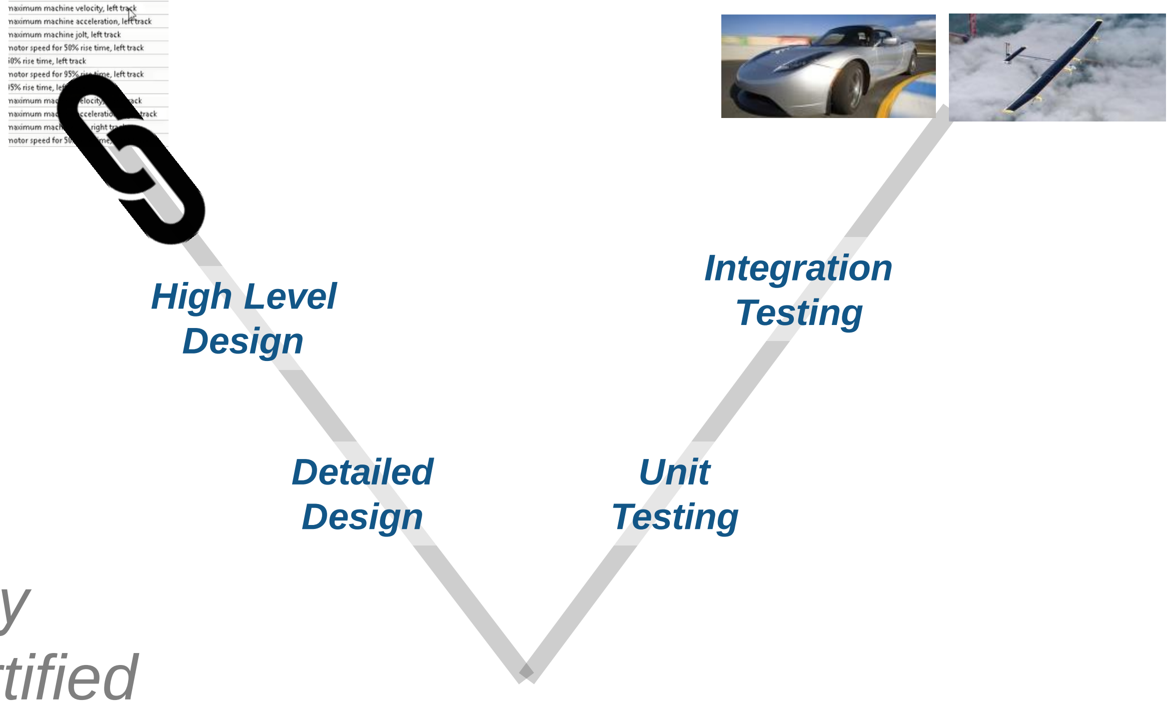
이제훈 차장

Key Takeaways

- Author, manage requirements in Simulink
- Early verification to find defects sooner
- Automate manual verification tasks
- Workflow that conforms to safety standards

System Requirements

Verified & Validated System



naximum machine velocity, left track
naximum machine acceleration, left track
naximum machine jolt, left track
notor speed for 50% rise time, left track
i0% rise time, left track
notor speed for 95% rise time, left track
95% rise time, lef
naximum mac elocity, ack
naximum mac cceleratio track
naximum mach right tra
notor speed for 50 ime,

High Level Design

Integration Testing

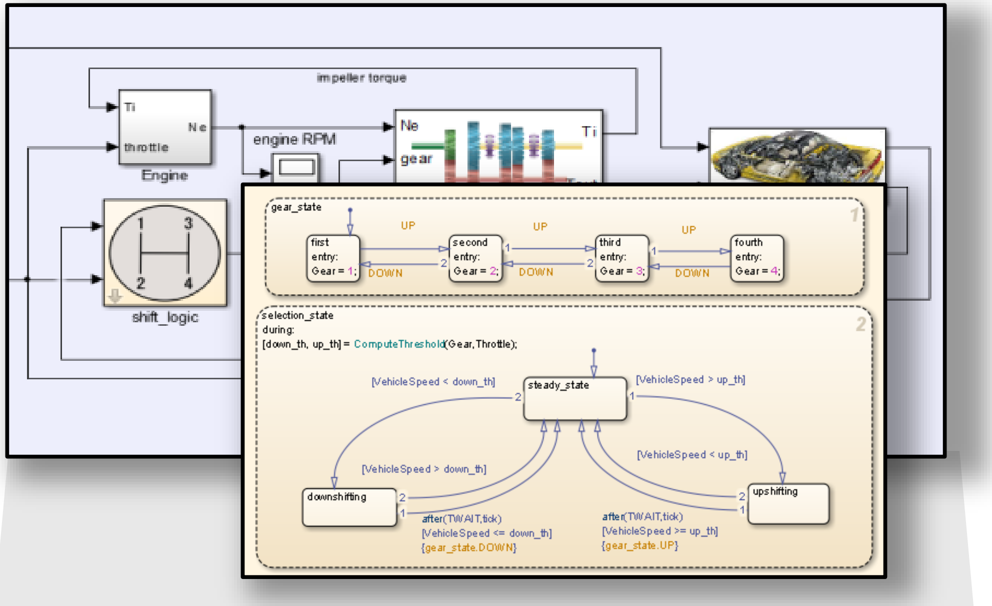
Detailed Design

Unit Testing

Coding

“Reduce costs and project risk through early verification, shorten time to market on a certified system, and deliver high-quality production code that was first-time right”   Michael Schwarz, ITK Engineering

Model Based Design Workflow



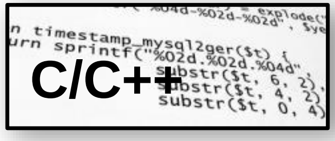
Requirements

Simulink Models

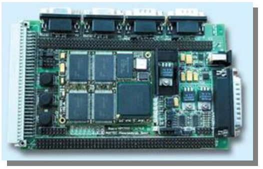
Executable Specification

Model used for production code generation

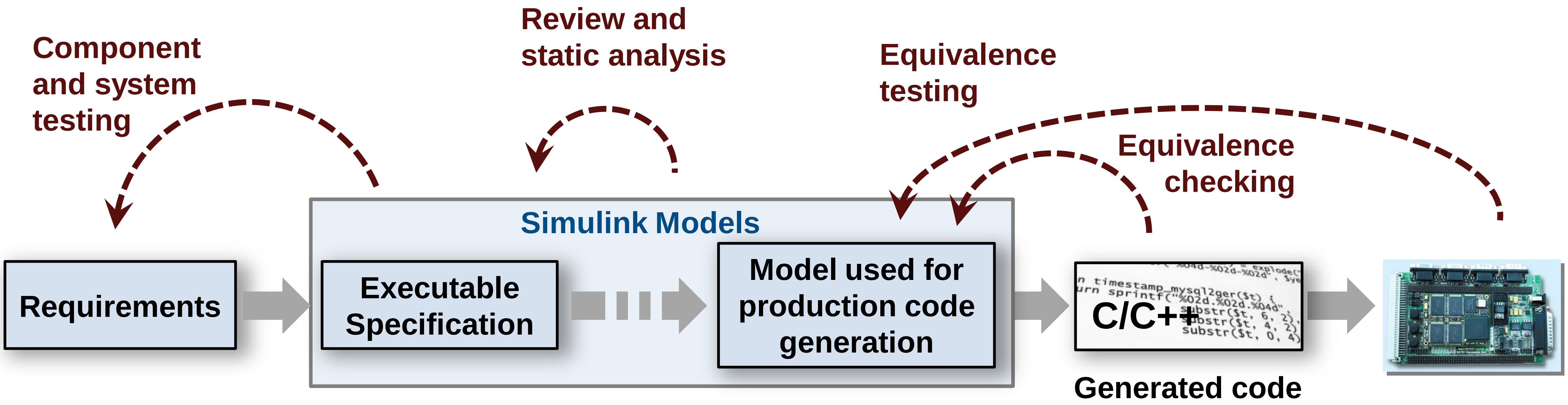
Code Generation



Generated code



Model Based Design Verification Workflow

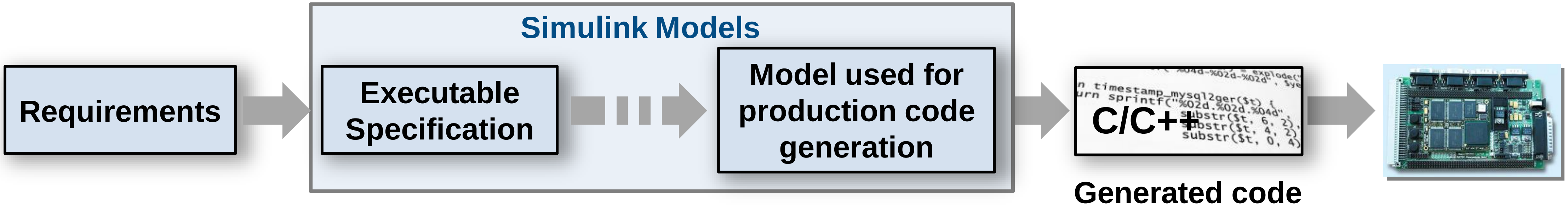


Challenges with Requirements

Where are requirements implemented?

Is design and requirements consistent?

How are they tested?



Requirements

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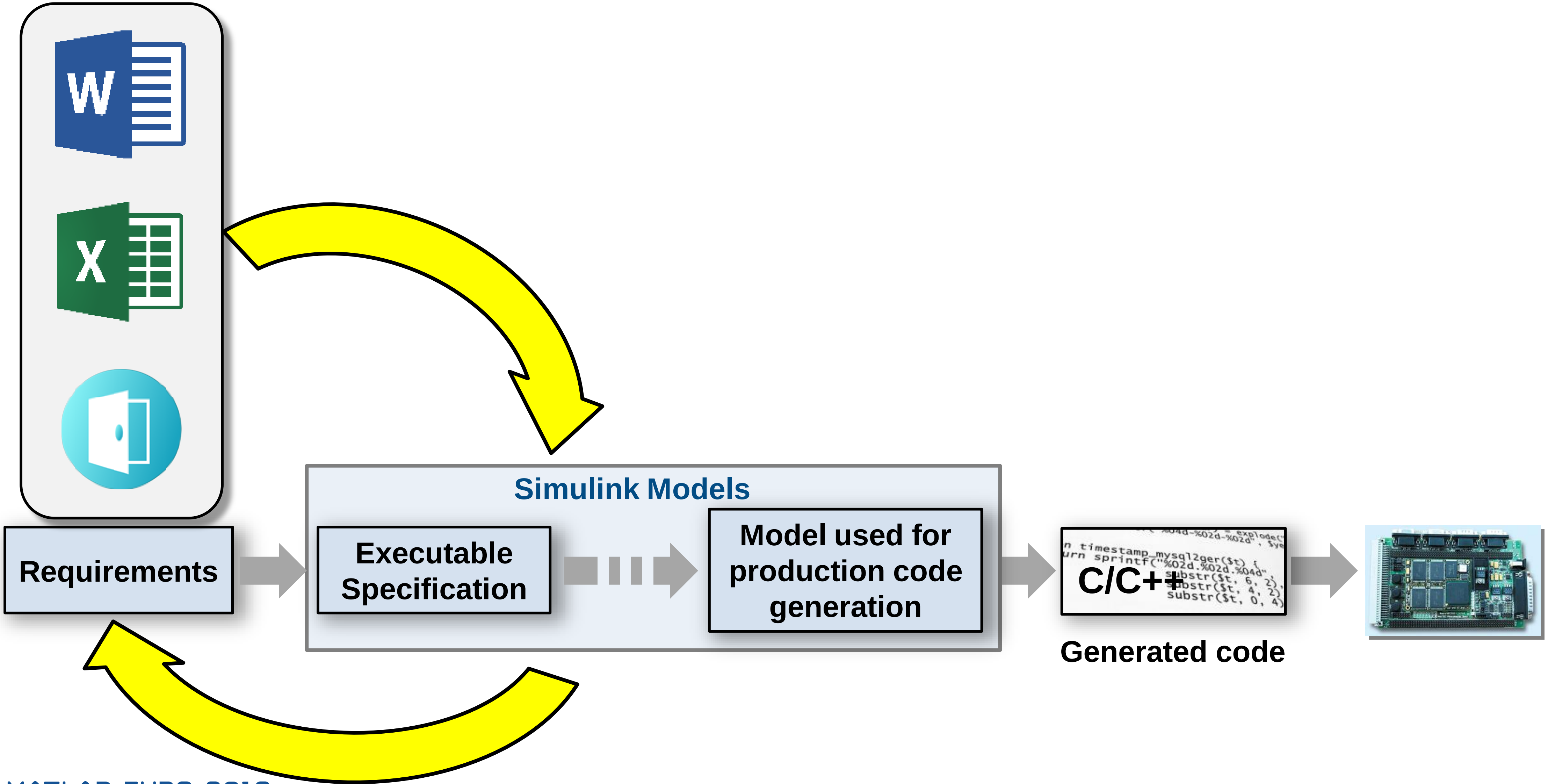
Executable Specification

Model used for production code generation

C/C++

Generated code

Gap Between Requirements and Design



Requirements

Simulink Models

Executable Specification

Model used for production code generation

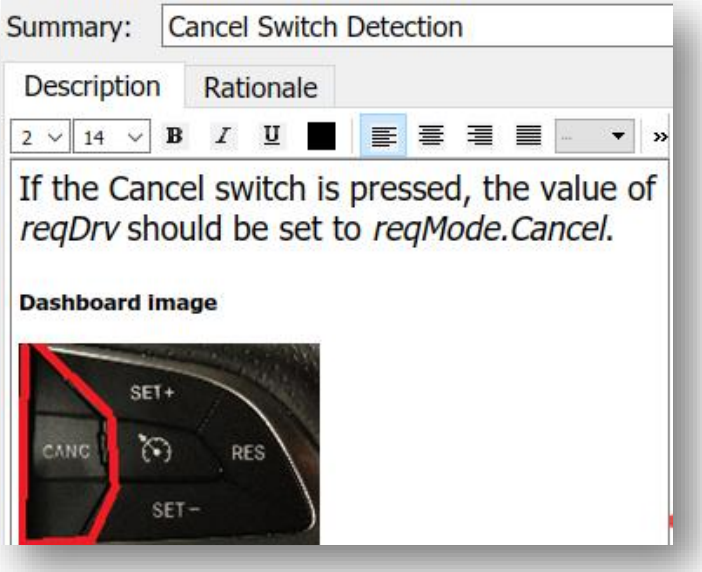
C/C++

Generated code

Simulink Requirements

R2017b

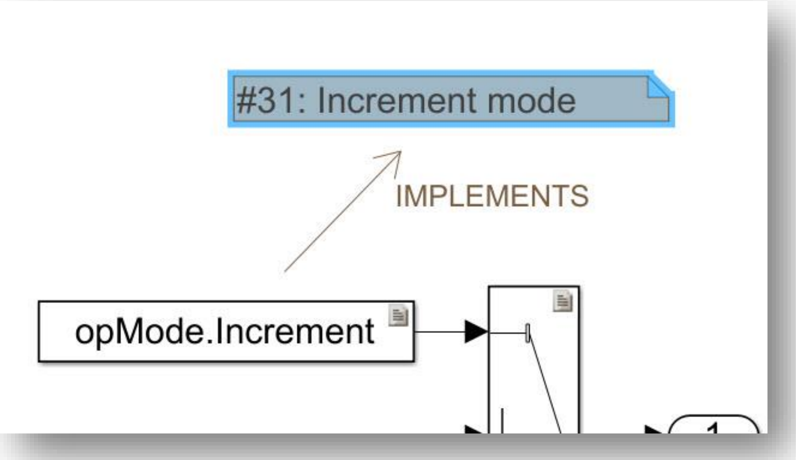
Author



Summary: Cancel Switch Detection

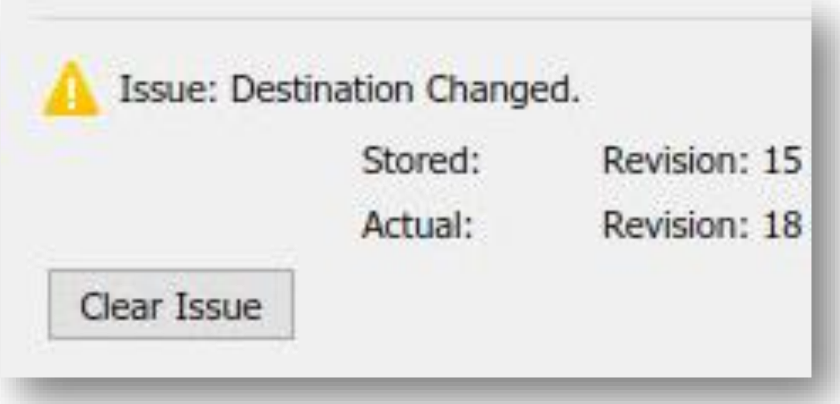
If the Cancel switch is pressed, the value of *reqDrv* should be set to *reqMode.Cancel*.

Dashboard image



Track

Manage

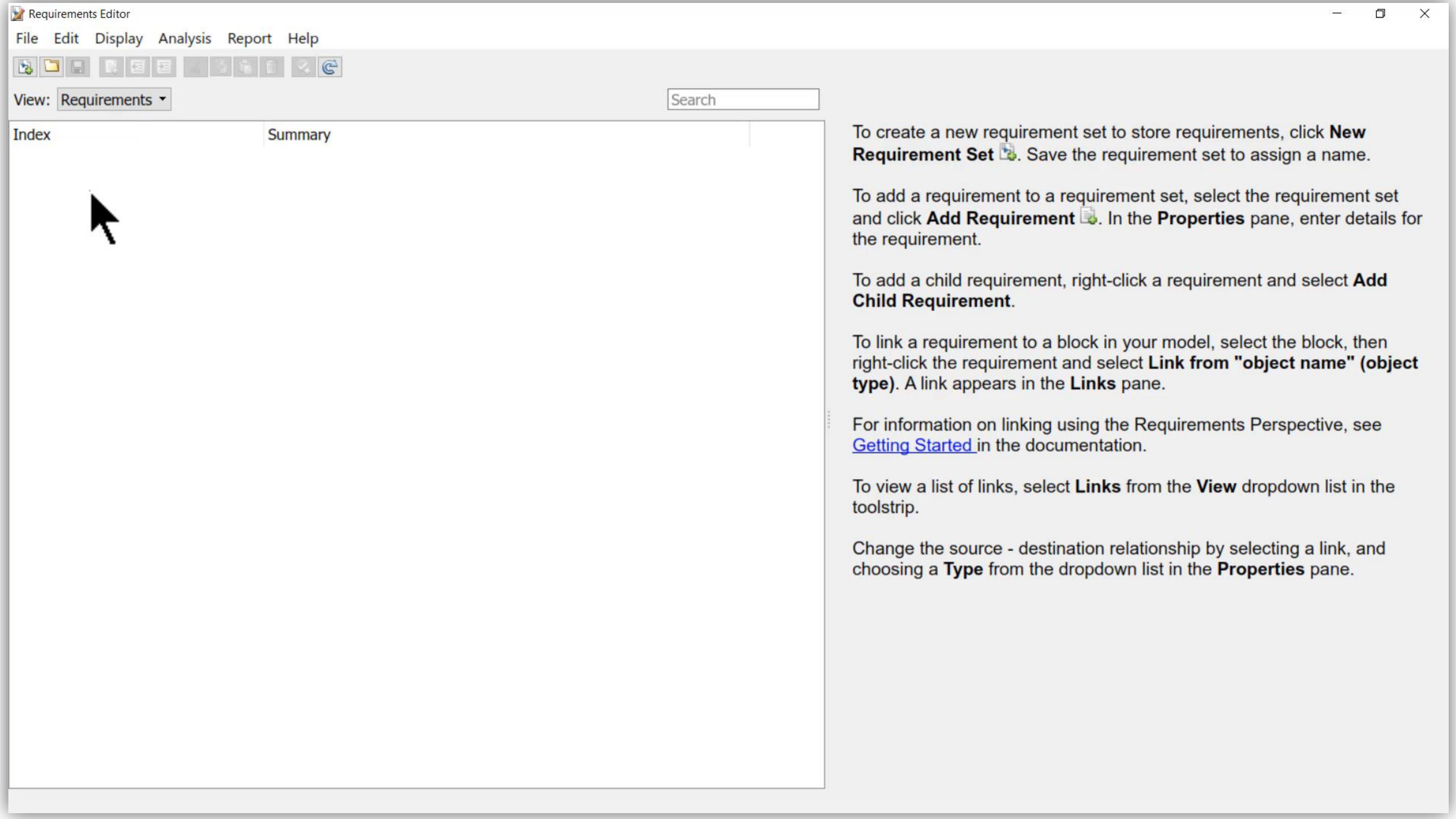


Issue: Destination Changed.

Stored: Revision: 15

Actual: Revision: 18

Requirements Editor



To create a new requirement set to store requirements, click **New Requirement Set**. Save the requirement set to assign a name.

To add a requirement to a requirement set, select the requirement set and click **Add Requirement**. In the **Properties** pane, enter details for the requirement.

To add a child requirement, right-click a requirement and select **Add Child Requirement**.

To link a requirement to a block in your model, select the block, then right-click the requirement and select **Link from "object name" (object type)**. A link appears in the **Links** pane.

For information on linking using the Requirements Perspective, see Getting Started in the documentation.

To view a list of links, select **Links** from the **View** dropdown list in the toolstrip.

Change the source - destination relationship by selecting a link, and choosing a **Type** from the dropdown list in the **Properties** pane.

Import Requirements from External Sources

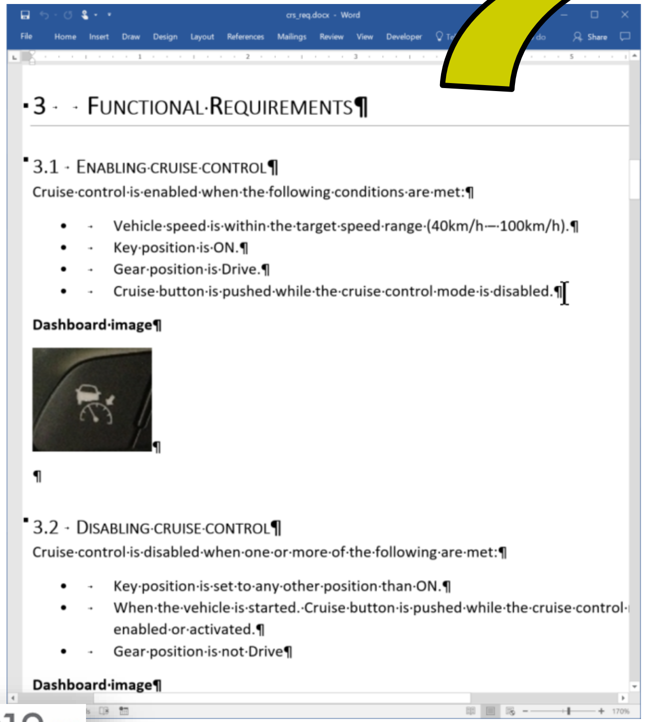
Import

IBM Rational DOORS

R2018a

ReqIF Requirements Interchange Format

Microsoft Word



3 · FUNCTIONAL REQUIREMENTS¶

3.1 · ENABLING CRUISE CONTROL¶

Cruise control is enabled when the following conditions are met:¶

- Vehicle speed is within the target speed range (40km/h — 100km/h).¶
- Key position is ON.¶
- Gear position is Drive.¶
- Cruise button is pushed while the cruise control mode is disabled.¶

Dashboard image¶

¶

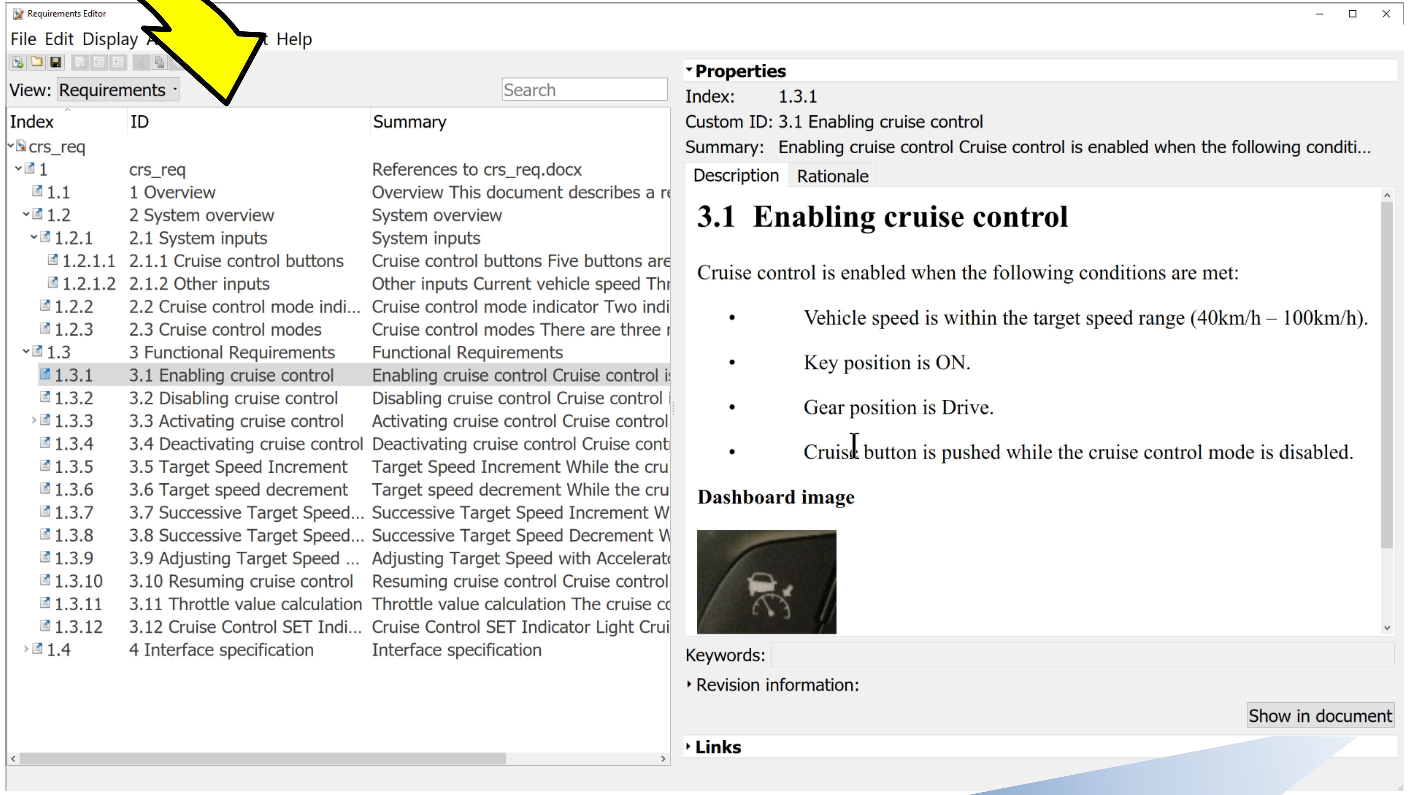
3.2 · DISABLING CRUISE CONTROL¶

Cruise control is disabled when one or more of the following are met:¶

- Key position is set to any other position than ON.¶
- When the vehicle is started. Cruise button is pushed while the cruise control enabled or activated.¶
- Gear position is not Drive¶

Dashboard image¶

Simulink Requirements Editor



View: Requirements

Index	ID	Summary
crs_req		
1	crs_req	References to crs_req.docx
1.1	1 Overview	Overview This document describes a re
1.2	2 System overview	System overview
1.2.1	2.1 System inputs	System inputs
1.2.1.1	2.1.1 Cruise control buttons	Cruise control buttons Five buttons are
1.2.1.2	2.1.2 Other inputs	Other inputs Current vehicle speed Thr
1.2.2	2.2 Cruise control mode indi...	Cruise control mode indicator Two indi
1.2.3	2.3 Cruise control modes	Cruise control modes There are three r
1.3	3 Functional Requirements	Functional Requirements
1.3.1	3.1 Enabling cruise control	Enabling cruise control Cruise control is
1.3.2	3.2 Disabling cruise control	Disabling cruise control Cruise control i
1.3.3	3.3 Activating cruise control	Activating cruise control Cruise control
1.3.4	3.4 Deactivating cruise control	Deactivating cruise control Cruise cont
1.3.5	3.5 Target Speed Increment	Target Speed Increment While the cru
1.3.6	3.6 Target speed decrement	Target speed decrement While the cru
1.3.7	3.7 Successive Target Speed...	Successive Target Speed Increment W
1.3.8	3.8 Successive Target Speed...	Successive Target Speed Decrement W
1.3.9	3.9 Adjusting Target Speed ...	Adjusting Target Speed with Accelerat
1.3.10	3.10 Resuming cruise control	Resuming cruise control Cruise control
1.3.11	3.11 Throttle value calculation	Throttle value calculation The cruise cc
1.3.12	3.12 Cruise Control SET Indi...	Cruise Control SET Indicator Light Crui
1.4	4 Interface specification	Interface specification

Index: 1.3.1
Custom ID: 3.1 Enabling cruise control
Summary: Enabling cruise control Cruise control is enabled when the following conditi...

3.1 Enabling cruise control

Cruise control is enabled when the following conditions are met:

- Vehicle speed is within the target speed range (40km/h – 100km/h).
- Key position is ON.
- Gear position is Drive.
- Cruise button is pushed while the cruise control mode is disabled.

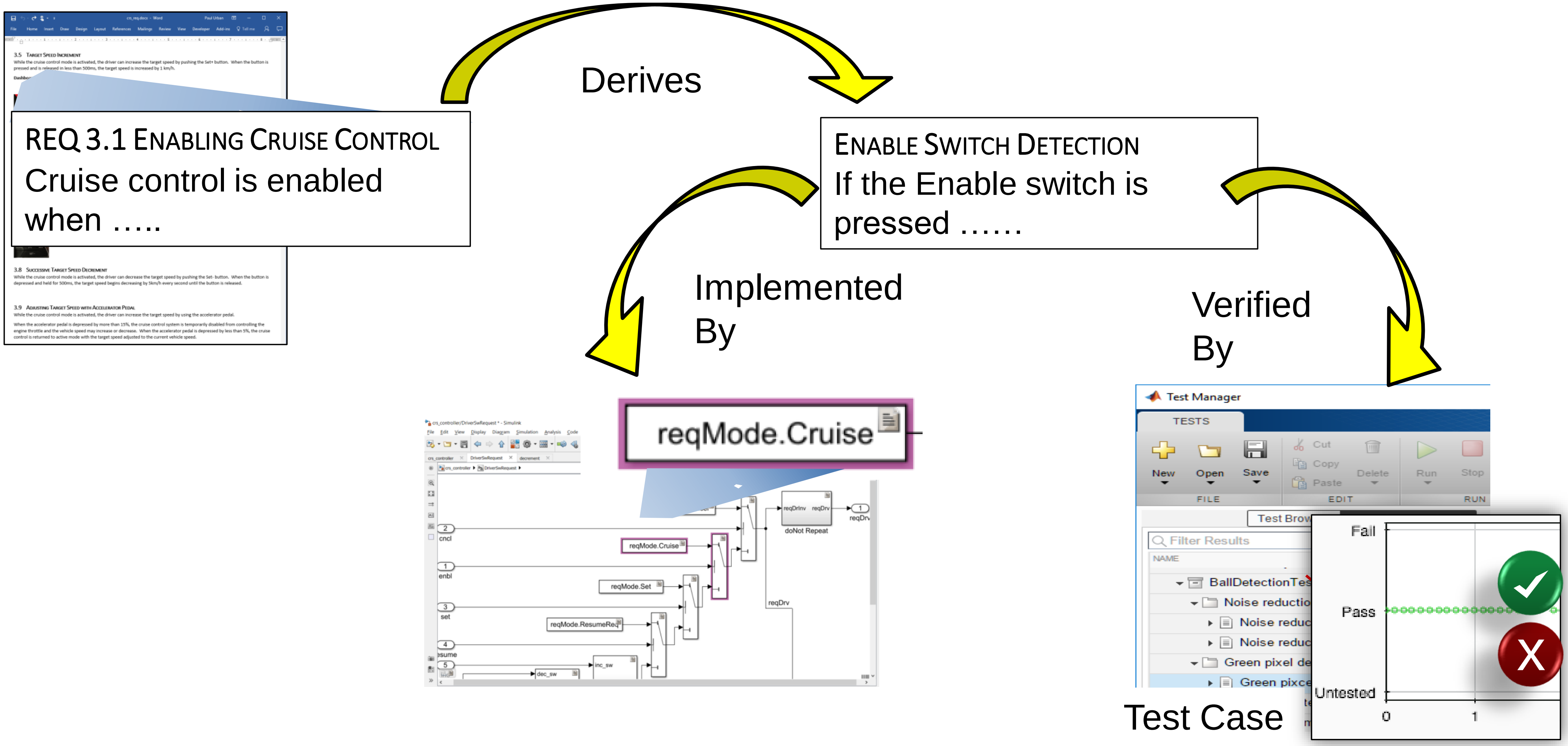
Dashboard image

Keywords:

Revision information:

Show in document

Link Requirements, Designs and Tests



crs_req.docx - Word

3.5 Target Speed Increment

While the cruise control mode is activated, the driver can increase the target speed by pushing the Set+ button. When the button is pressed and is released in less than 500ms, the target speed is increased by 1 km/h.

Dashbo

3.8 Successive Target Speed Decrement

While the cruise control mode is activated, the driver can decrease the target speed by pushing the Set- button. When the button is depressed and held for 500ms, the target speed begins decreasing by 5km/h every second until the button is released.

3.9 Adjusting Target Speed with Accelerator Pedal

While the cruise control mode is activated, the driver can increase the target speed by using the accelerator pedal.

When the accelerator pedal is depressed by more than 15%, the cruise control system is temporarily disabled from controlling the engine throttle and the vehicle speed may increase or decrease. When the accelerator pedal is depressed by less than 5%, the cruise control is returned to active mode with the target speed adjusted to the current vehicle speed.

REQ 3.1 ENABLING CRUISE CONTROL
Cruise control is enabled when …..

Derives

ENABLE SWITCH DETECTION
If the Enable switch is pressed ……

Implemented By

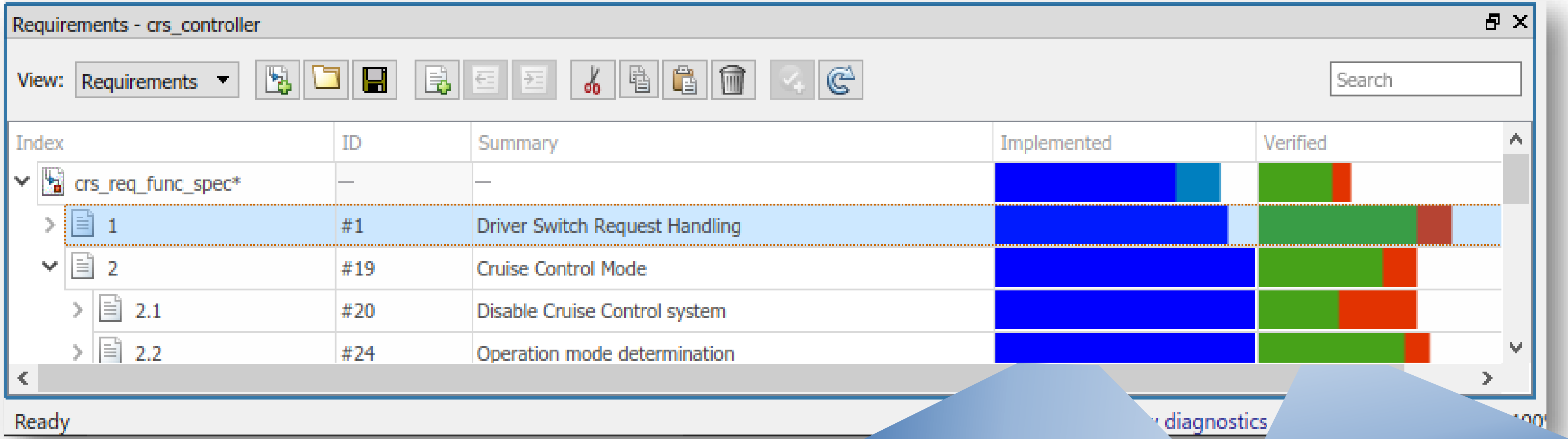
reqMode.Cruise

Verified By

Test Case

MATLAB EXPO 2018

Track Implementation and Verification



Requirements - crs_controller

Index	ID	Summary	Implemented	Verified
crs_req_func_spec*	—	—		
1	#1	Driver Switch Request Handling		
2	#19	Cruise Control Mode		
2.1	#20	Disable Cruise Control system		
2.2	#24	Operation mode determination		

Ready

Implementation Status

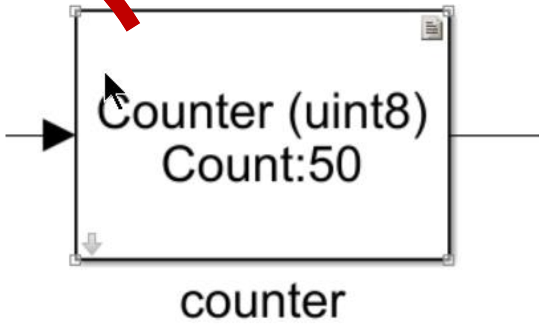
- 🟦 Implemented
- ▨ Justified
- □ Missing

Verification Status

- 🟩 Passed
- 🟥 Failed
- 🟧 No Result
- □ Missing

Respond to Change

Implements

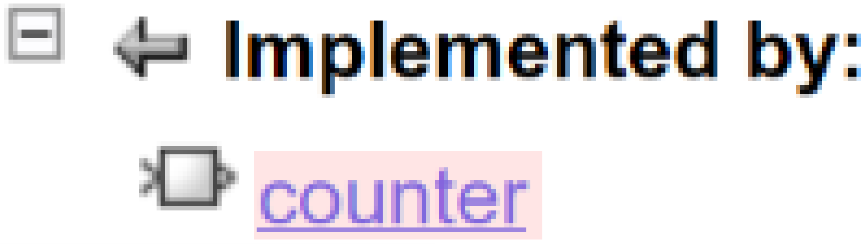


Original Requirement

If the switch is pressed and the counter reaches **50** then it shall be recognized as a long press of the tch.

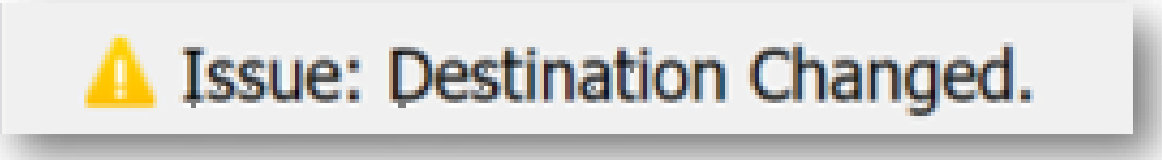
Updated Requirement

If the switch is pressed and the counter reaches **75** then it shall be recognized as a long press of the switch.



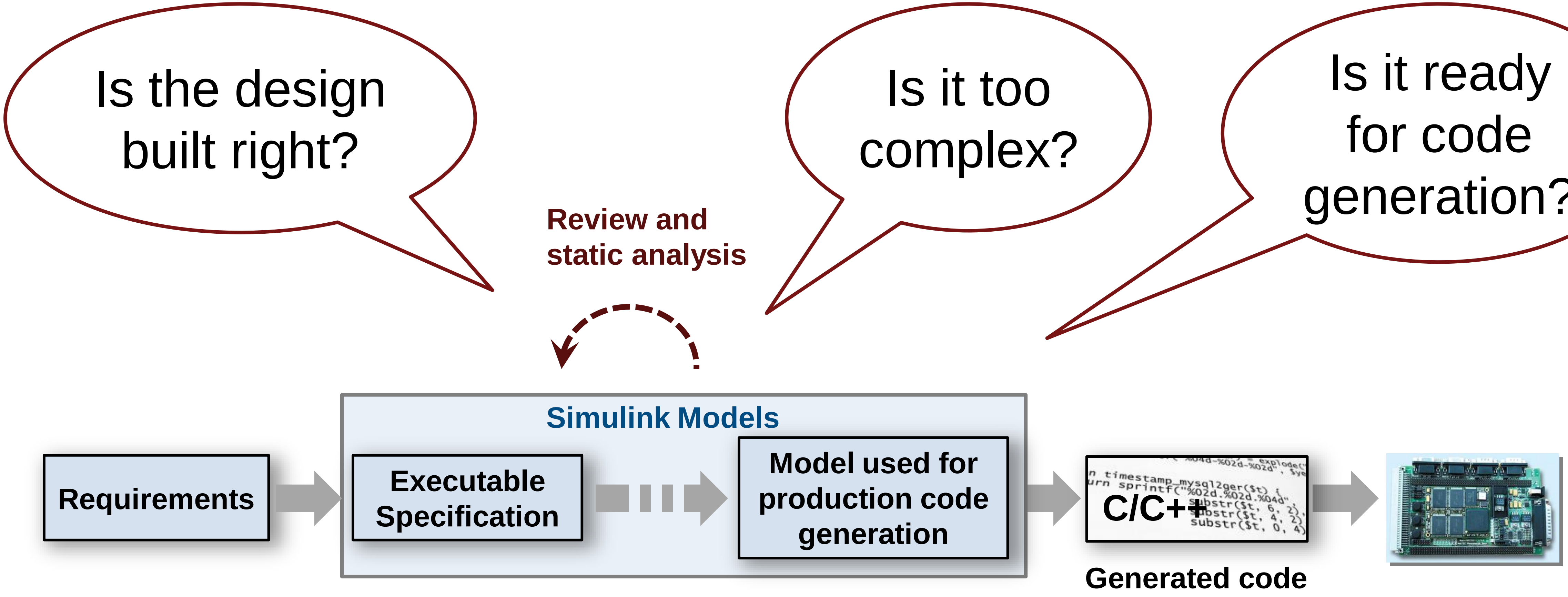
⊟ ⇐ **Implemented by:**

counter



⚠ Issue: Destination Changed.

Verify Design to Guidelines and Standards



Is the design built right?

Is it too complex?

Is it ready for code generation?

Review and static analysis

Simulink Models

Requirements

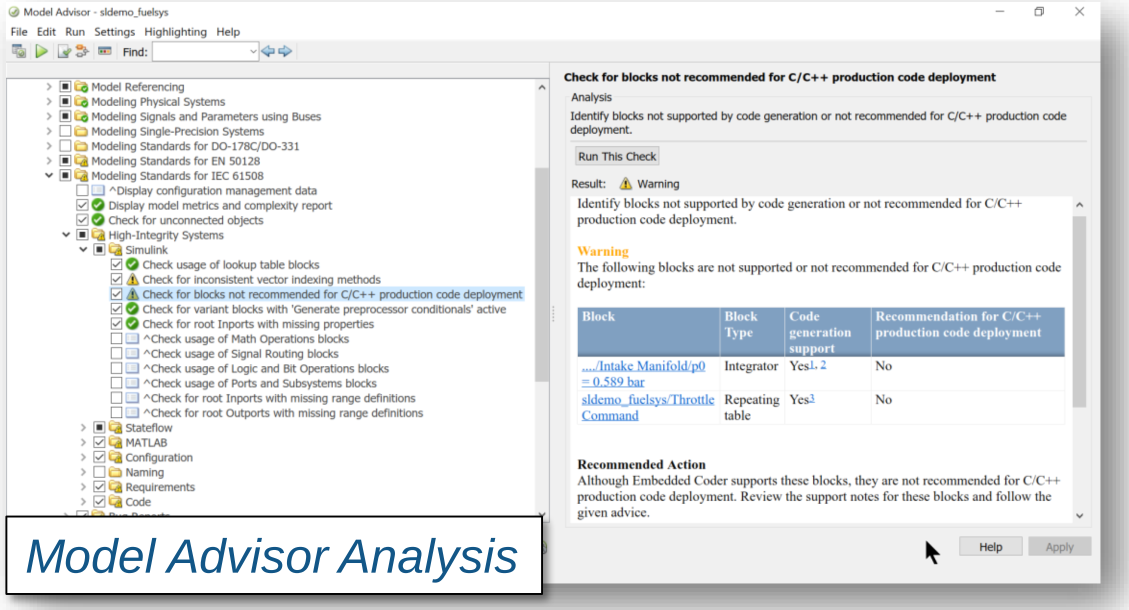
Executable Specification

Model used for production code generation

C/C++

Generated code

Automate verification with static analysis



Model Advisor - sldemo_fuelsys

- ■ Model Referencing
- ■ Modeling Physical Systems
- ■ Modeling Signals and Parameters using Buses
- □ Modeling Single-Precision Systems
- □ Modeling Standards for DO-178C/DO-331
- ■ Modeling Standards for EN 50128
- ■ Modeling Standards for IEC 61508
  - □ ^Display configuration management data
  - ☑ ✓ Display model metrics and complexity report
  - ☑ ✓ Check for unconnected objects
  - ■ High-Integrity Systems
    - ■ Simulink
      - ☑ ✓ Check usage of lookup table blocks
      - ☑ ⚠ Check for inconsistent vector indexing methods
      - ☑ ⚠ Check for blocks not recommended for C/C++ production code deployment
      - ☑ ✓ Check for variant blocks with 'Generate preprocessor conditionals' active
      - ☑ ✓ Check for root Inports with missing properties
      - □ ^Check usage of Math Operations blocks
      - □ ^Check usage of Signal Routing blocks
      - □ ^Check usage of Logic and Bit Operations blocks
      - □ ^Check usage of Ports and Subsystems blocks
      - □ ^Check for root Inports with missing range definitions
      - □ ^Check for root Outports with missing range definitions
    - ■ Stateflow
    - ☑ MATLAB
    - ☑ Configuration
    - □ Naming
    - ☑ Requirements
    - ☑ Code

Check for blocks not recommended for C/C++ production code deployment

Analysis

Identify blocks not supported by code generation or not recommended for C/C++ production code deployment.

Result: ⚠ Warning

Identify blocks not supported by code generation or not recommended for C/C++ production code deployment.

Warning

The following blocks are not supported or not recommended for C/C++ production code deployment:

Block	Block Type	Code generation support	Recommendation for C/C++ production code deployment
..../Intake Manifold/p0 = 0.589 bar	Integrator	Yes[1, 2]	No
sldemo_fuelsys/Throttle Command	Repeating table	Yes[3]	No

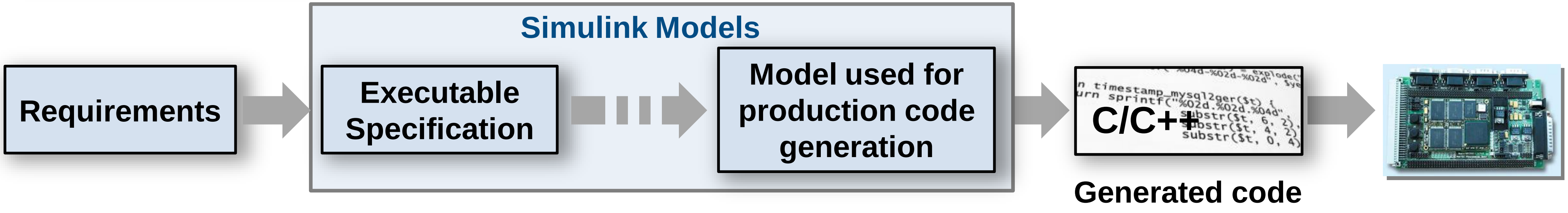
Recommended Action

Although Embedded Coder supports these blocks, they are not recommended for C/C++ production code deployment. Review the support notes for these blocks and follow the given advice.

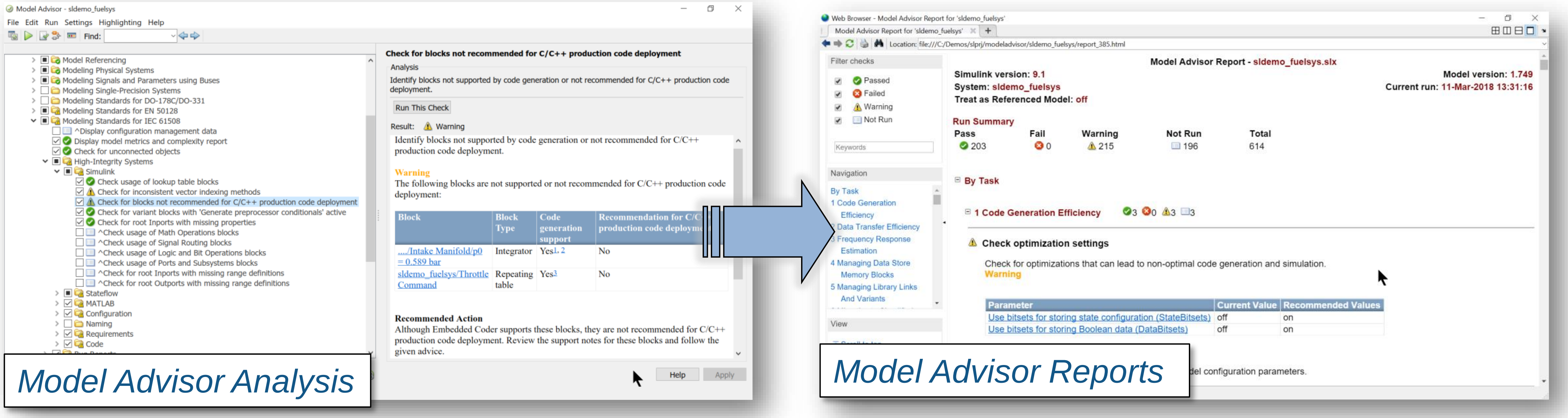
Model Advisor Analysis

Check for:

- Readability and Semantics
- Performance and Efficiency
- Clones
- And more……



Generate reports for reviews and documentation



Model Advisor - sldemo_fuelsys

- ■ Model Referencing
- ■ Modeling Physical Systems
- ■ Modeling Signals and Parameters using Buses
- □ Modeling Single-Precision Systems
- □ Modeling Standards for DO-178C/DO-331
- ■ Modeling Standards for EN 50128
- ■ Modeling Standards for IEC 61508
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      - □ ^Check for root Outports with missing range definitions
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    - ☑ MATLAB
    - ☑ Configuration
    - □ Naming
    - ☑ Requirements
    - ☑ Code

Check for blocks not recommended for C/C++ production code deployment

Analysis

Identify blocks not supported by code generation or not recommended for C/C++ production code deployment.

Result: ⚠ Warning

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..../Intake Manifold/p0 = 0.589 bar	Integrator	Yes[1, 2]	No
sldemo_fuelsys/Throttle Command	Repeating table	Yes[3]	No

Recommended Action

Although Embedded Coder supports these blocks, they are not recommended for C/C++ production code deployment. Review the support notes for these blocks and follow the given advice.

Model Advisor Analysis

Web Browser - Model Advisor Report for 'sldemo_fuelsys'

Location: file:///C:/Demos/slprj/modeladvisor/sldemo_fuelsys/report_385.html

Filter checks
☑ Passed
☑ Failed
☑ Warning
☑ Not Run
Keywords
Navigation
By Task
1 Code Generation Efficiency
2 Data Transfer Efficiency
3 Frequency Response Estimation
4 Managing Data Store Memory Blocks
5 Managing Library Links And Variants
View

Model Advisor Report - sldemo_fuelsys.slx

Simulink version: 9.1
System: sldemo_fuelsys
Treat as Referenced Model: off

Model version: 1.749
Current run: 11-Mar-2018 13:31:16

Run Summary

Pass	Fail	Warning	Not Run	Total
✓ 203	✗ 0	⚠ 215	□ 196	614

⊟ By Task

⊟ 1 Code Generation Efficiency ✓3 ✗0 ⚠3 □3

⚠ **Check optimization settings**

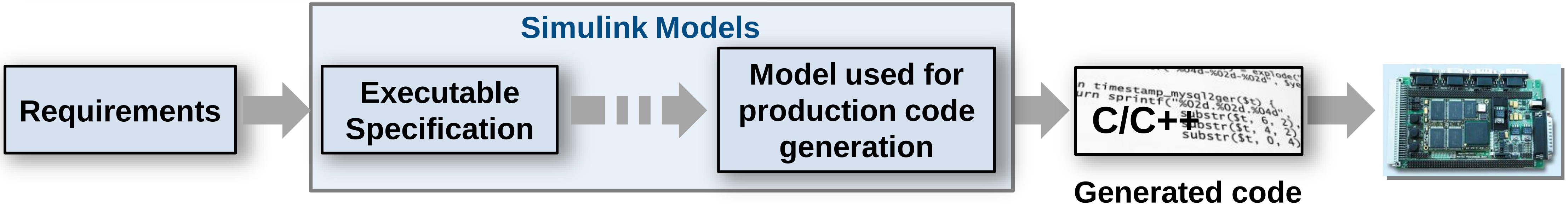
Check for optimizations that can lead to non-optimal code generation and simulation.

Warning

Parameter	Current Value	Recommended Values
Use bitsets for storing state configuration (StateBitsets)	off	on
Use bitsets for storing Boolean data (DataBitsets)	off	on

del configuration parameters.

Model Advisor Reports



Simulink Models

Requirements

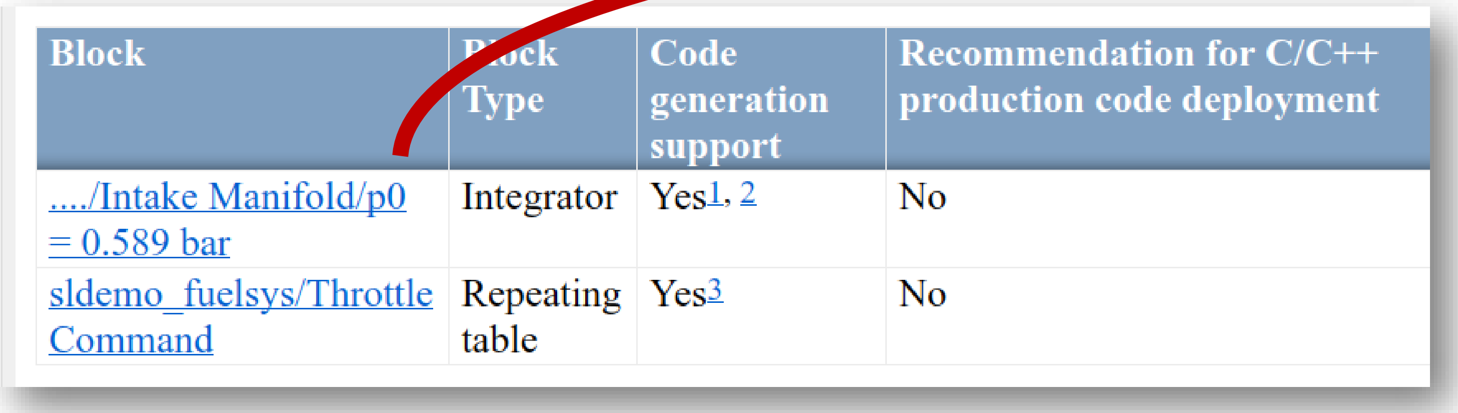
Executable Specification

Model used for production code generation

C/C++

Generated code

Navigate to Problematic Blocks



Block	Block Type	Code generation support	Recommendation for C/C++ production code deployment
..../Intake Manifold/p0 = 0.589 bar	Integrator	Yes[1], [2]	No
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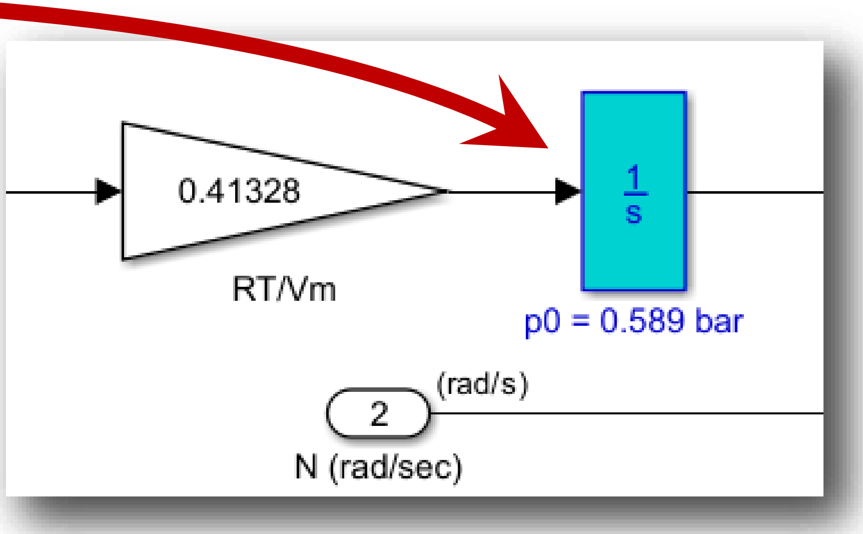
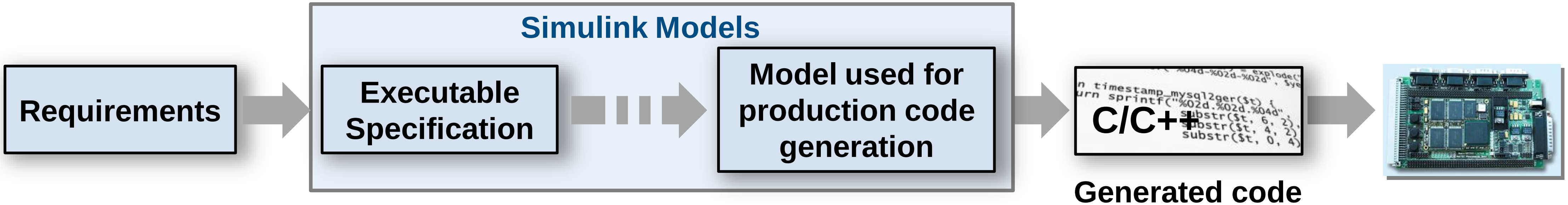




Requirements

Simulink Models

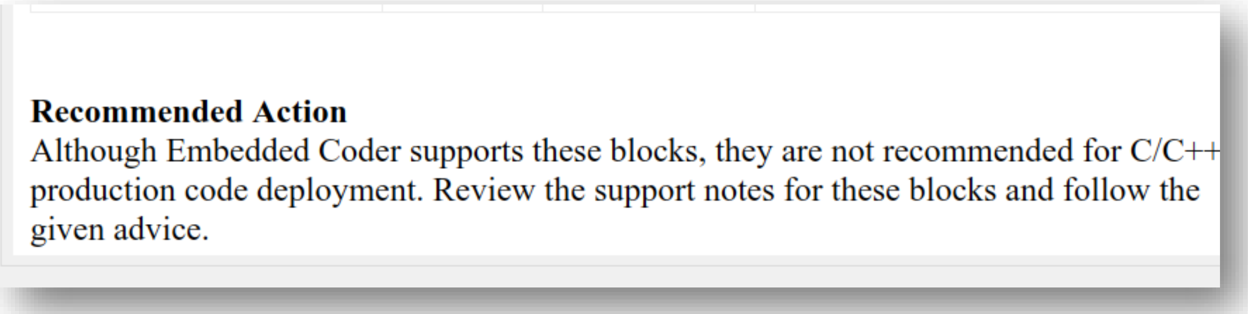
Executable Specification

Model used for production code generation

C/C++

Generated code

Guidance Provided to Address Issues or Automatically Correct



Recommended Action
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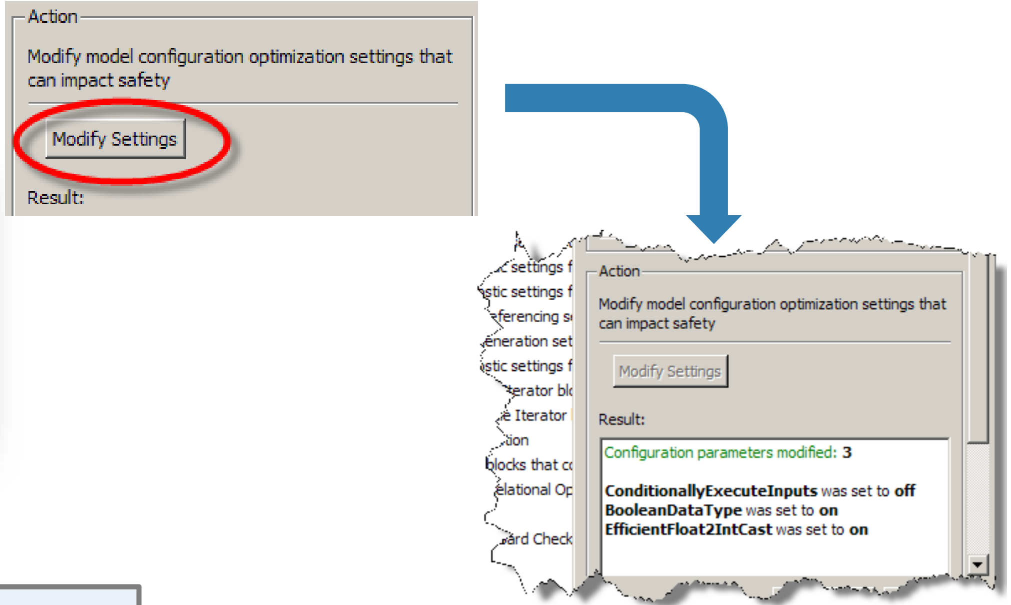


Action

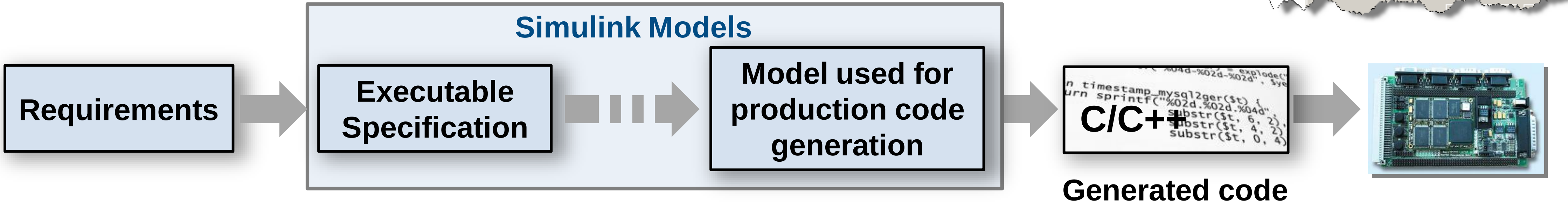
Modify model configuration optimization settings that can impact safety

Action

Modify model configuration optimization settings that can impact safety

Configuration parameters modified: 3

ConditionallyExecuteInputs was set to **off**
BooleanDataType was set to **on**
EfficientFloat2IntCast was set to **on**

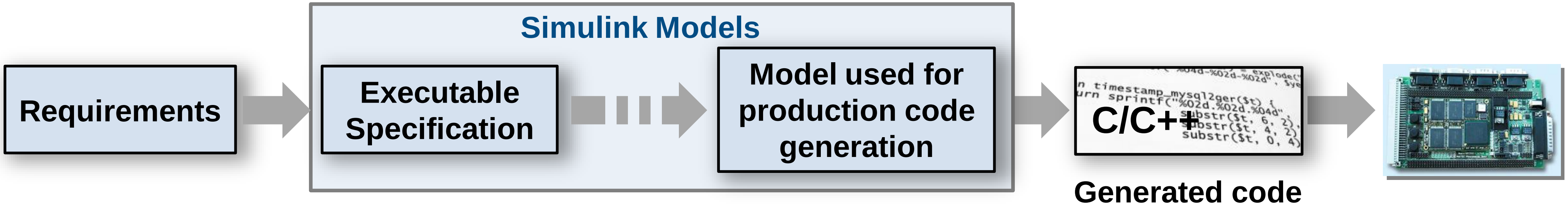


Generated code

Built in checks for industry standards and guidelines

- DO-178/DO-331
- ISO 26262
- IEC 61508
- IEC 62304
- EN 50128

- MISRA C:2012
- CERT C, CWE, ISO/IEC TS 17961
- MAAB (MathWorks Automotive Advisory Board)
- JMAAB (Japan MATLAB Automotive Advisory Board)



Requirements

Simulink Models

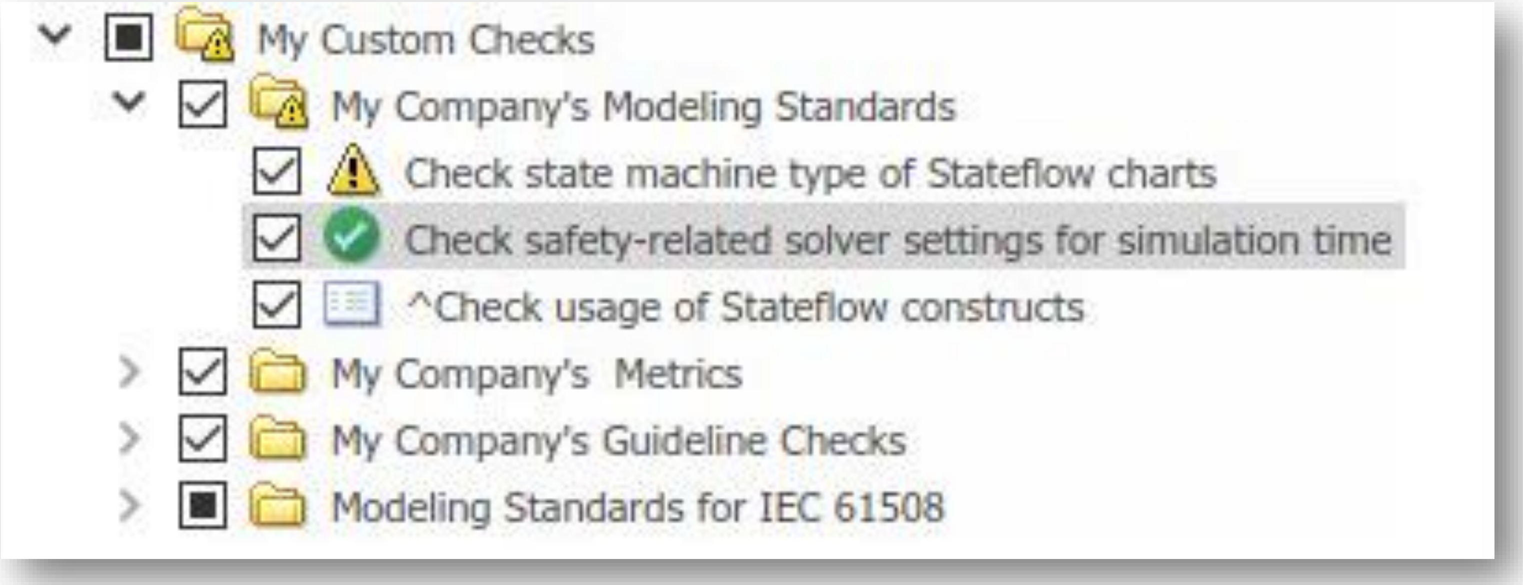
Executable Specification

Model used for production code generation

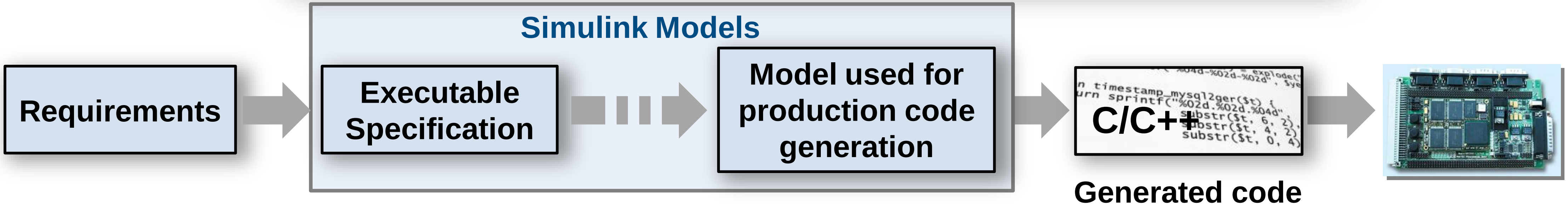
C/C++

Generated code

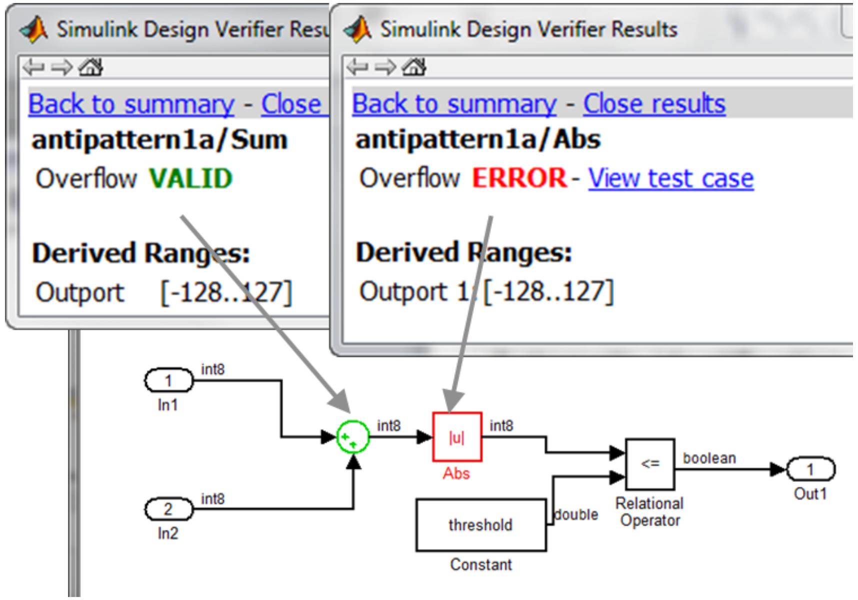
Configure and customize analysis



- ■ My Custom Checks
  - ☑ My Company's Modeling Standards
    - ☑ ⚠ Check state machine type of Stateflow charts
    - ☑ ✓ Check safety-related solver settings for simulation time
    - ☑ ^Check usage of Stateflow constructs
  - ☑ My Company's Metrics
  - ☑ My Company's Guideline Checks
  - ■ Modeling Standards for IEC 61508



Detect Design Errors with Formal Methods



Simulink Design Verifier Resu

Back to summary - Close

antipattern1a/Sum

Overflow VALID

Derived Ranges:

Outport [-128..127]

Simulink Design Verifier Results

Back to summary - Close results

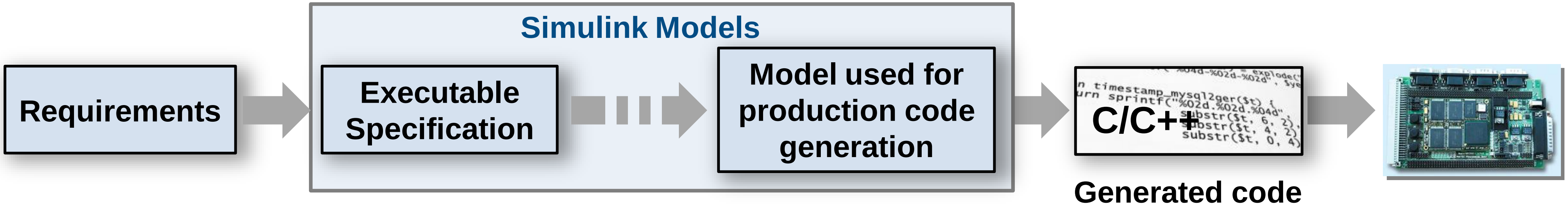
antipattern1a/Abs

Overflow ERROR - View test case

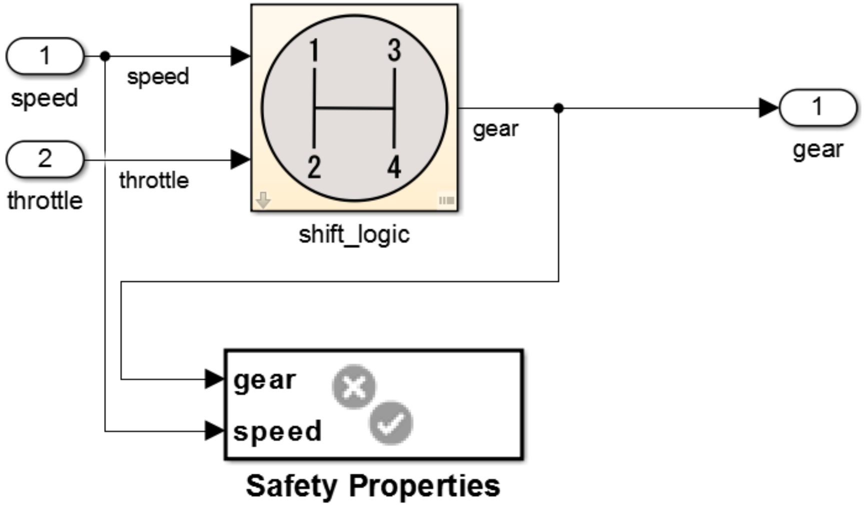
Derived Ranges:

Outport 1 [-128..127]

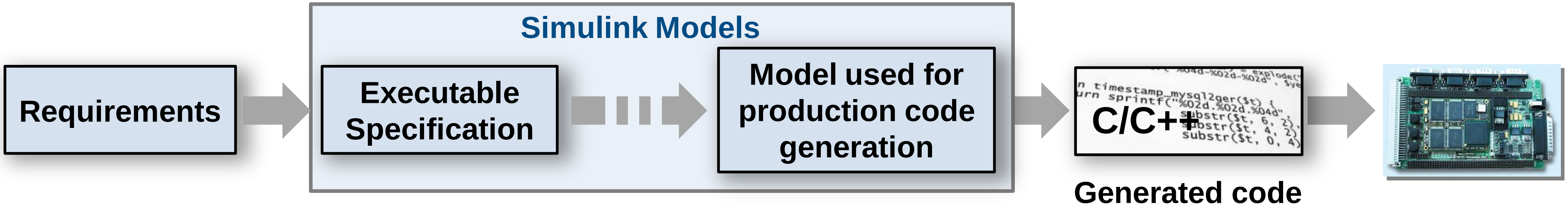
- Find run-time design errors:
  - Integer overflow
  - Dead Logic
  - Division by zero
  - Array out-of-bounds
  - Range violations



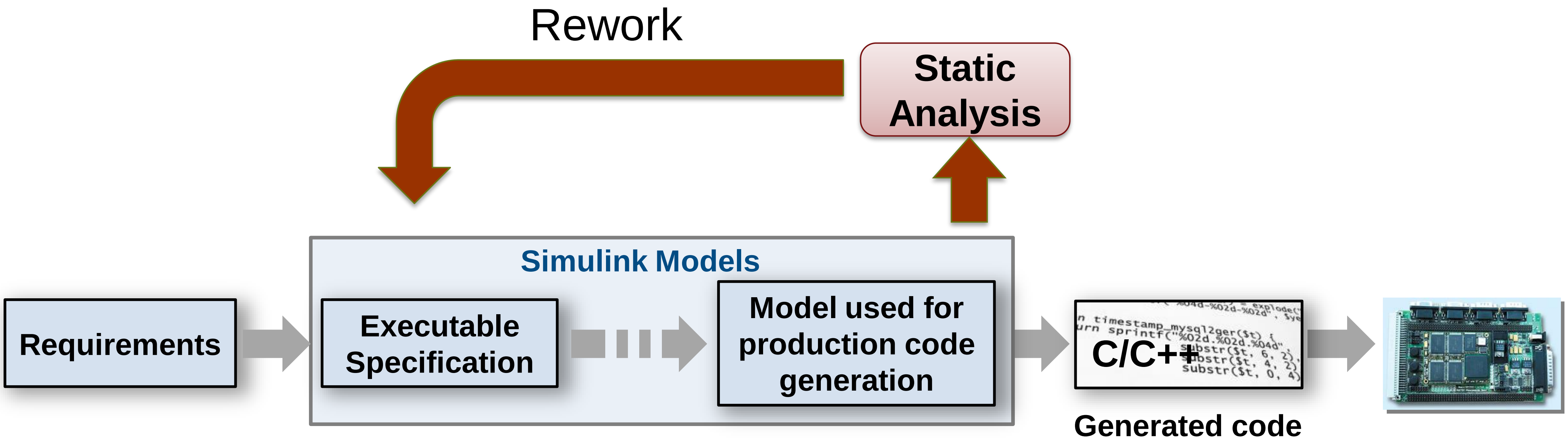
Prove That Design Meets Requirements



- Prove design properties
- Model functional and safety requirements
- Generates counter example

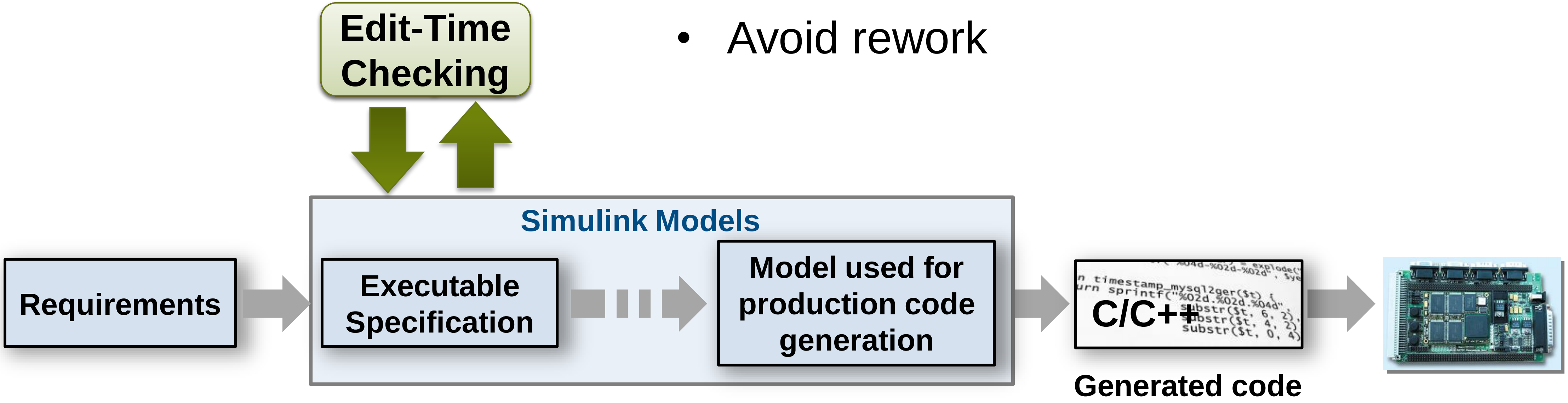


Checks for standards and guidelines are often performed late



Shift Verification Earlier With Edit-Time Checking

- Highlight violations as you edit
- Fix issues earlier
- Avoid rework



Edit-Time Checking

Simulink Models

Requirements

Executable Specification

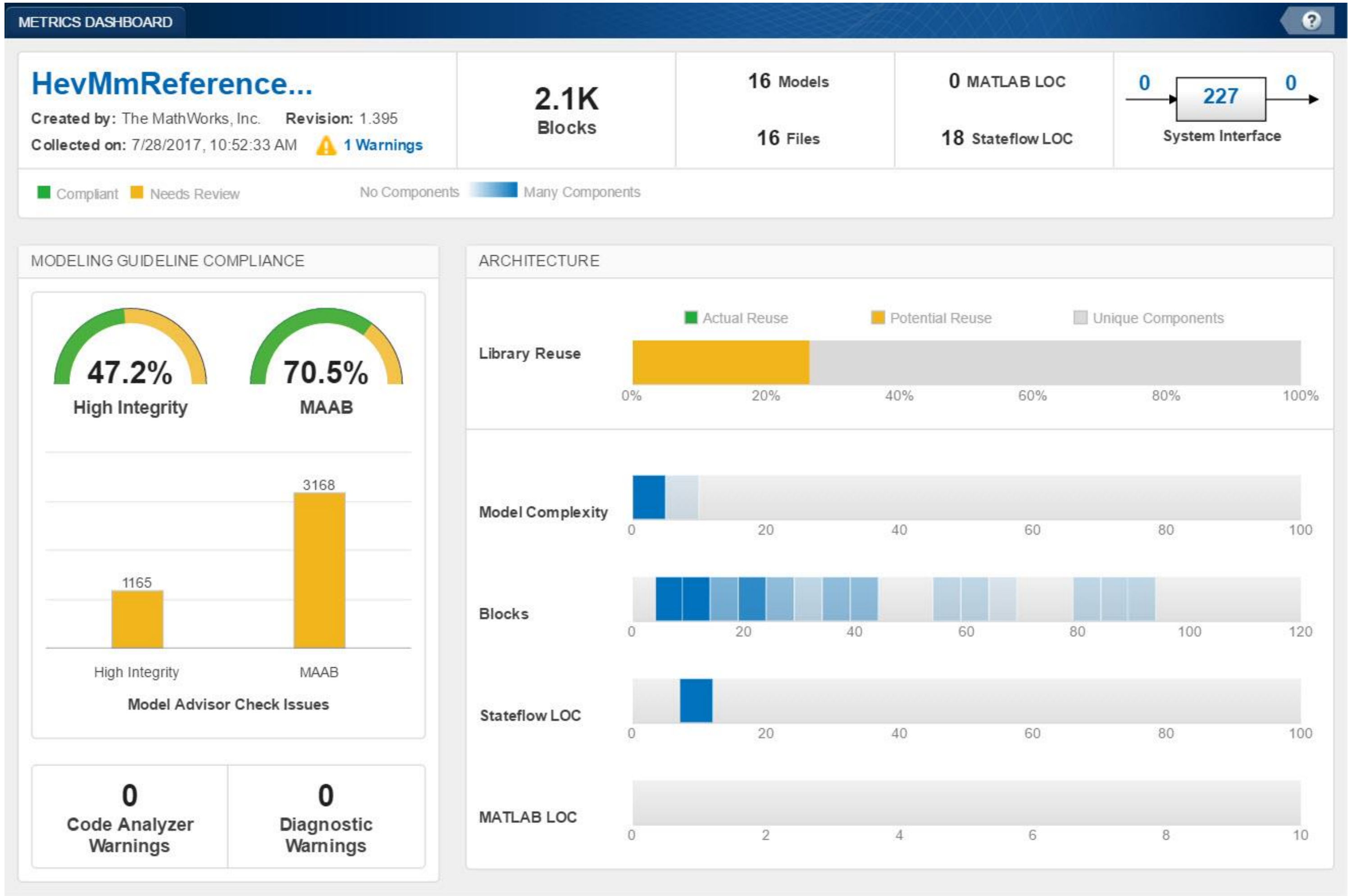
Model used for production code generation

C/C++

Generated code

Assess Quality with Metrics Dashboard

- Consolidated view of metrics
  - Size
  - Compliance
  - Complexity



METRICS DASHBOARD

HevMmReference...

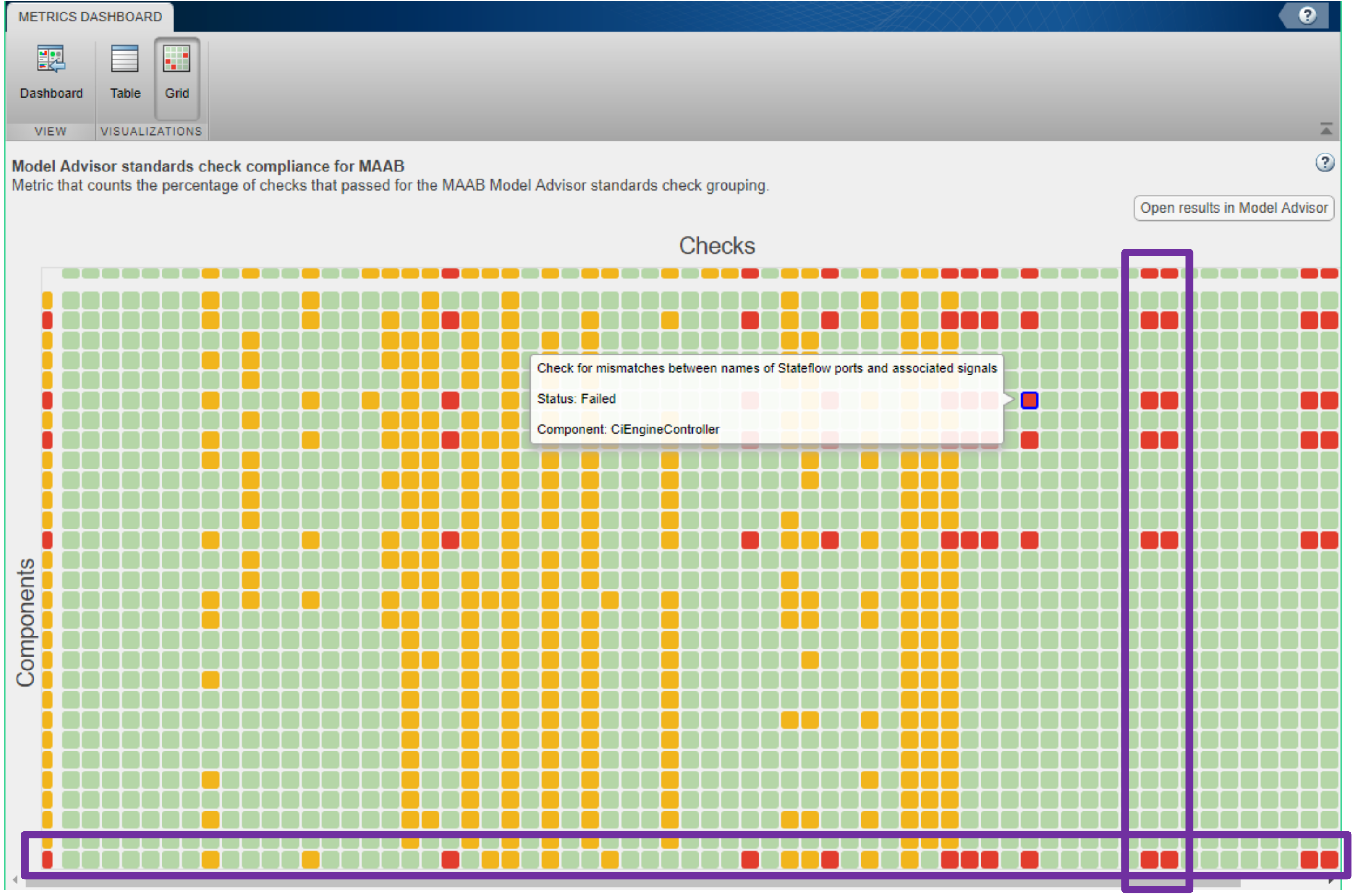
Created by: The MathWorks, Inc. Revision: 1.395

Collected on: 7/28/2017, 10:52:33 AM ⚠ 1 Warnings

Grid Visualization for Metrics

R2018a

- Visualize Standards Check Compliance
  - Find Issues
  - Identify patterns
  - See hot spots



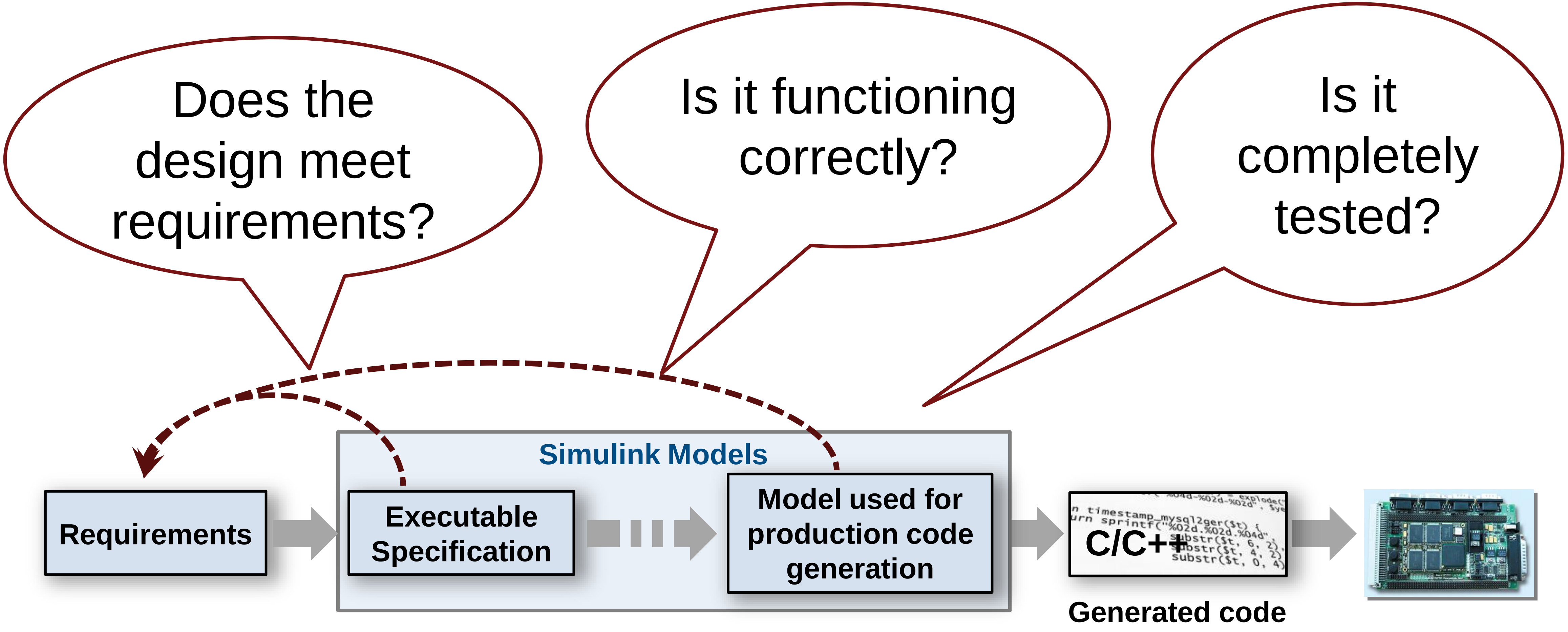
Model Advisor standards check compliance for MAAB
Metric that counts the percentage of checks that passed for the MAAB Model Advisor standards check grouping.

Check for mismatches between names of Stateflow ports and associated signals
Status: Failed
Component: CiEngineController

Legend:

🟥	Red:	Fail
🟧	Orange:	Warning
🟩	Green:	Pass
▨	Gray:	Not run

Functional Testing



Does the design meet requirements?

Is it functioning correctly?

Is it completely tested?

Requirements

Simulink Models

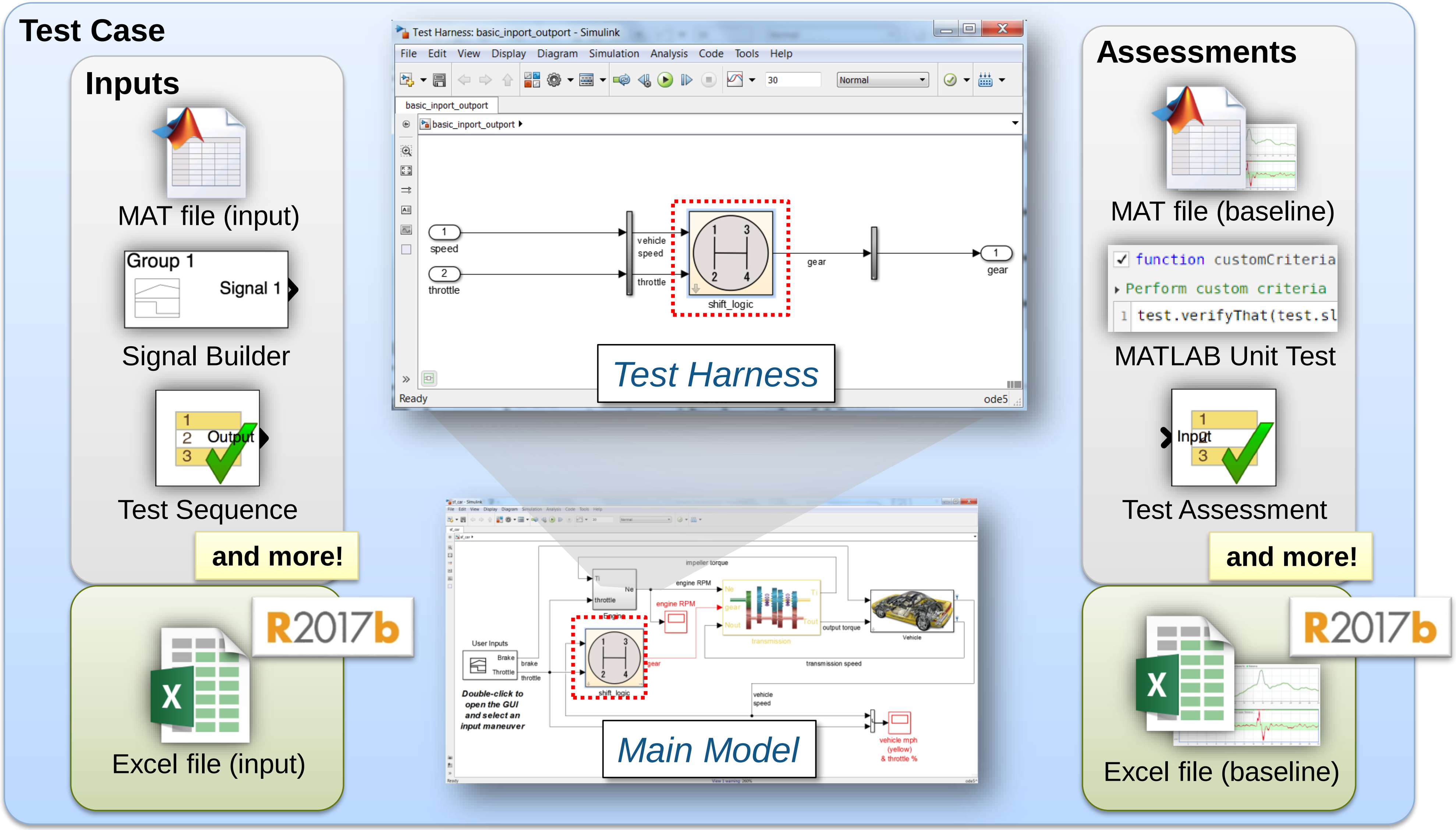
Executable Specification

Model used for production code generation

C/C++

Generated code

Systematic Functional Testing



Test Case

Inputs

MAT file (input)

Signal Builder

Test Sequence

and more!

Excel file (input)

R2017b

Test Harness

Main Model

Assessments

MAT file (baseline)

```
function customCriteria
Perform custom criteria
test.verifyThat(test.sl
```

MATLAB Unit Test

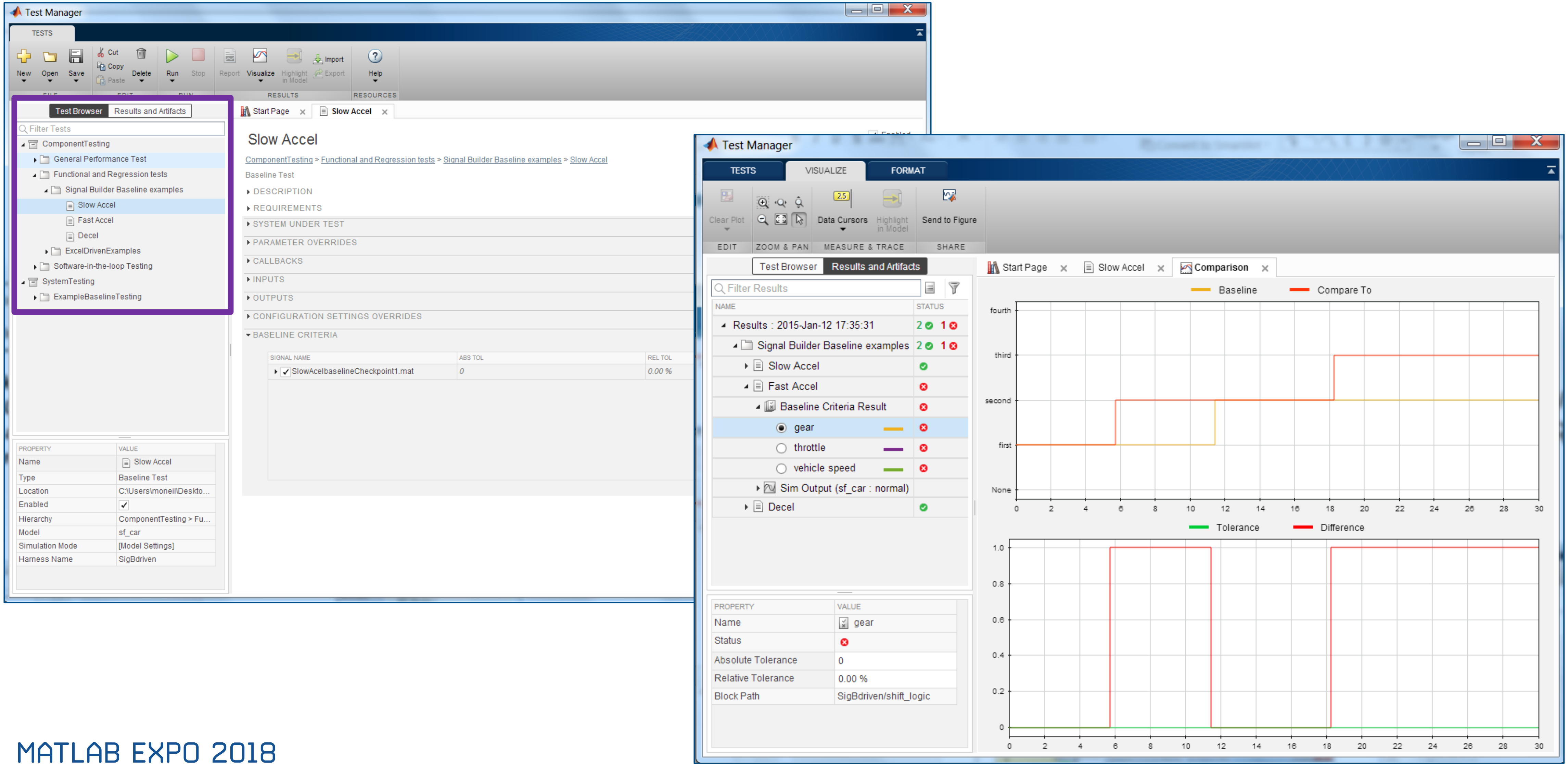
Test Assessment

and more!

Excel file (baseline)

R2017b

Manage Testing and Test Results



- ComponentTesting
  - General Performance Test
  - Functional and Regression tests
    - Signal Builder Baseline examples
      - Slow Accel
      - Fast Accel
      - Decel
    - ExcelDrivenExamples
  - Software-in-the-loop Testing
- SystemTesting
  - ExampleBaselineTesting

PROPERTY	VALUE
Name	Slow Accel
Type	Baseline Test
Location	C:\Users\moneil\Deskto...
Enabled	✓
Hierarchy	ComponentTesting > Fu...
Model	sf_car
Simulation Mode	[Model Settings]
Harness Name	SigBdriven

Slow Accel

ComponentTesting > Functional and Regression tests > Signal Builder Baseline examples > Slow Accel

Baseline Test

- DESCRIPTION
- REQUIREMENTS
- SYSTEM UNDER TEST
- PARAMETER OVERRIDES
- CALLBACKS
- INPUTS
- OUTPUTS
- CONFIGURATION SETTINGS OVERRIDES
- BASELINE CRITERIA

SIGNAL NAME	ABS TOL	REL TOL
✓ SlowAccelbaselineCheckpoint1.mat	0	0.00 %

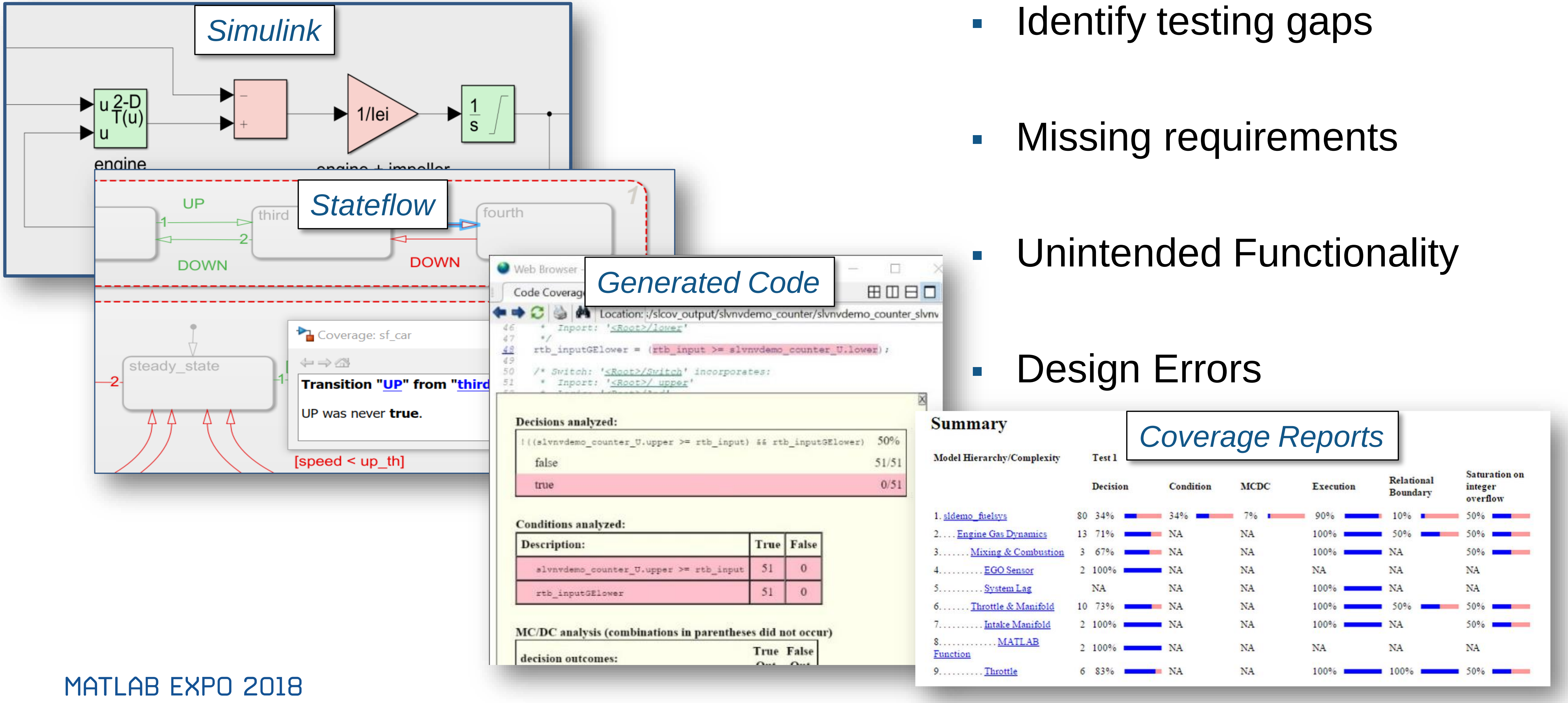
NAME	STATUS
Results : 2015-Jan-12 17:35:31	2 ✓ 1 ✗
Signal Builder Baseline examples	2 ✓ 1 ✗
Slow Accel	✓
Fast Accel	✗
Baseline Criteria Result	✗
● gear	✗
○ throttle	✗
○ vehicle speed	✗
Sim Output (sf_car : normal)	
Decel	✓

PROPERTY	VALUE
Name	gear
Status	✗
Absolute Tolerance	0
Relative Tolerance	0.00 %
Block Path	SigBdriven/shift_logic

MATLAB EXPO 2018

Coverage Analysis to Measure Testing

- Identify testing gaps
- Missing requirements
- Unintended Functionality
- Design Errors



Transition "UP" from "third

UP was never **true**.

Location: :/slcov_output/slvnvdemo_counter/slvnvdemo_counter_slvnv

```
 *  Inport: '<Root>/lower'
 */
rtb_inputGElower = (rtb_input >= slvnvdemo_counter_U.lower);

/* Switch: '<Root>/Switch' incorporates:
 *  Inport: '<Root>/ upper'
```

Decisions analyzed:

!((slvnvdemo_counter_U.upper >= rtb_input) && rtb_inputGElower)	50%
false	51/51
true	0/51

Conditions analyzed:

Description:	True	False
slvnvdemo_counter_U.upper >= rtb_input	51	0
rtb_inputGElower	51	0

MC/DC analysis (combinations in parentheses did not occur)

decision outcomes: True Out False Out

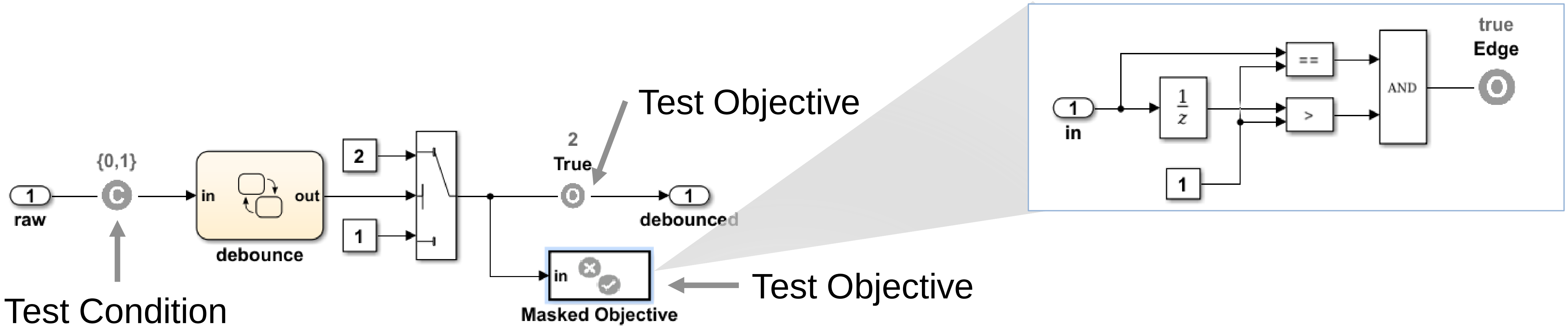
Summary

Model Hierarchy/Complexity	Test 1						
		Decision	Condition	MCDC	Execution	Relational Boundary	Saturation on integer overflow
1. sldemo_fuelsys	80	34%	34%	7%	90%	10%	50%
2.... Engine Gas Dynamics	13	71%	NA	NA	100%	50%	50%
3....... Mixing & Combustion	3	67%	NA	NA	100%	NA	50%
4.......... EGO Sensor	2	100%	NA	NA	NA	NA	NA
5.......... System Lag		NA	NA	NA	100%	NA	NA
6....... Throttle & Manifold	10	73%	NA	NA	100%	50%	50%
7.......... Intake Manifold	2	100%	NA	NA	100%	NA	50%
8............. MATLAB Function	2	100%	NA	NA	NA	NA	NA
9.......... Throttle	6	83%	NA	NA	100%	100%	50%

Test Case Generation for Functional Testing

- Specify functional test objectives
  - Define custom objectives that signals must satisfy in test cases

- Specify functional test conditions
  - Define constraints on signal values to constrain test generator

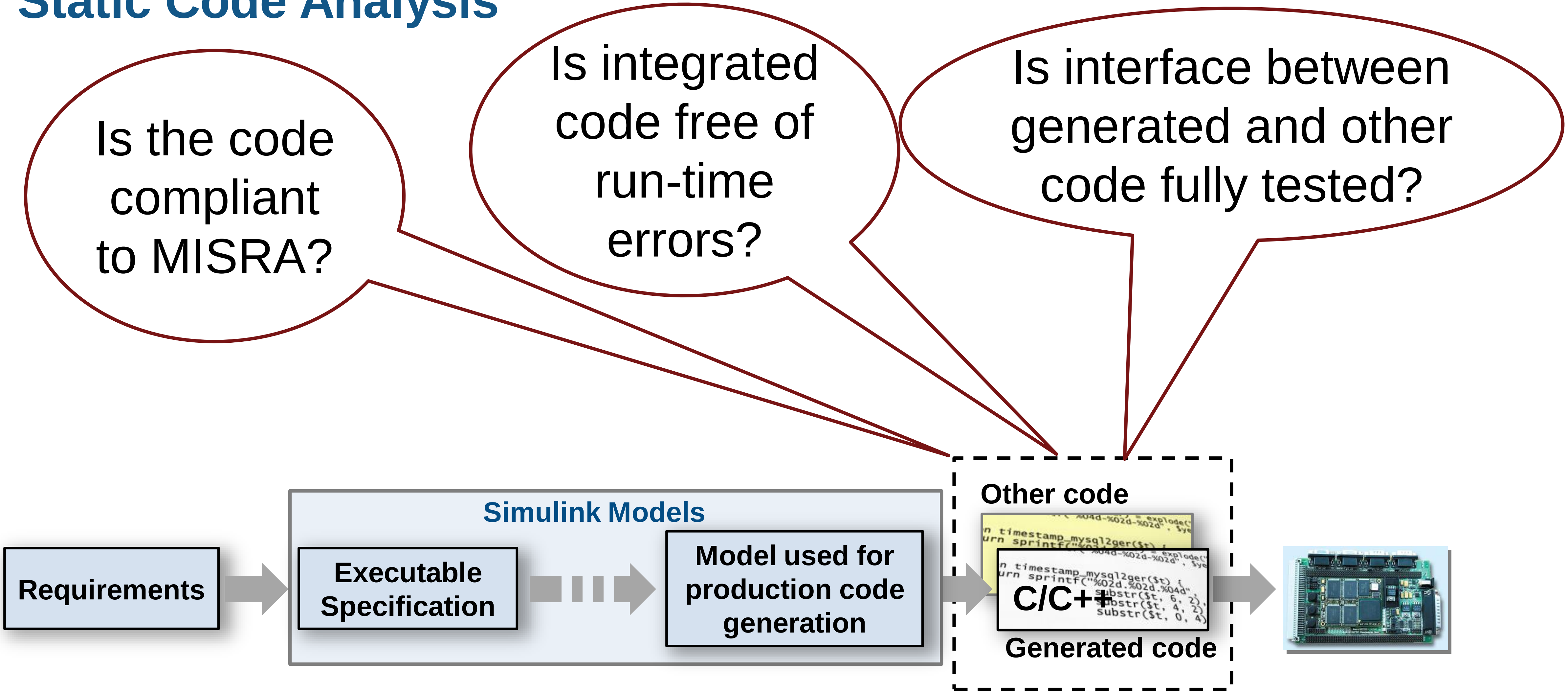


Test Objective

Test Objective

Test Condition

Static Code Analysis



Is the code compliant to MISRA?

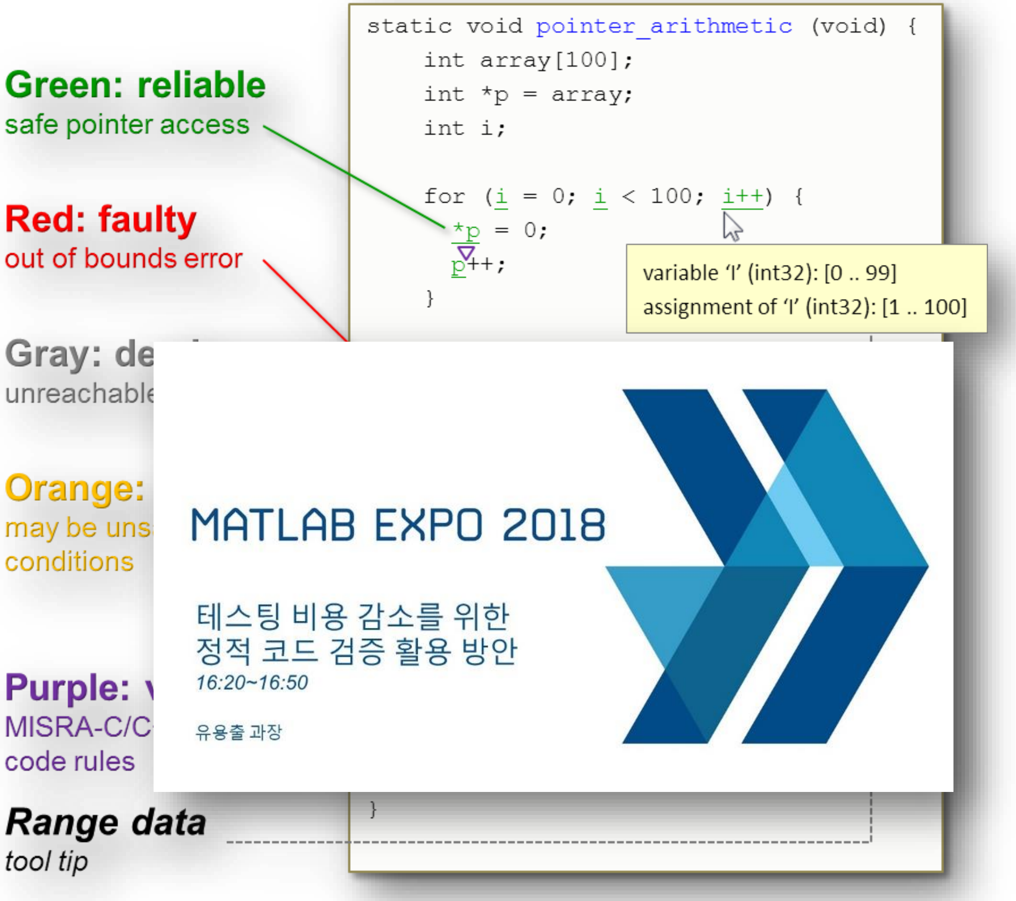
Is integrated code free of run-time errors?

Is interface between generated and other code fully tested?

The Generated Code is integrated with Other Code (Handwritten)

Static Code Analysis with Polyspace

- Code metrics and standards
  - Comment density, cyclomatic complexity,…
  - MISRA and Cybersecurity standards
  - Support for DO-178, ISO 26262, ….
- Bug finding and code proving
  - Check data and control flow of software
  - Detect bugs and security vulnerabilities
  - Prove absence of runtime errors



```
static void pointer_arithmetic (void) {
    int array[100];
    int *p = array;
    int i;

    for (i = 0; i < 100; i++) {
        *p = 0;
        p++;
    }
}
```

variable 'I' (int32): [0 .. 99]
assignment of 'I' (int32): [1 .. 100]

Green: reliable
safe pointer access

Red: faulty
out of bounds error

Gray: de
unreachable

Orange:
may be uns
conditions

Purple: v
MISRA-C/C
code rules

Range data
tool tip

MATLAB EXPO 2018

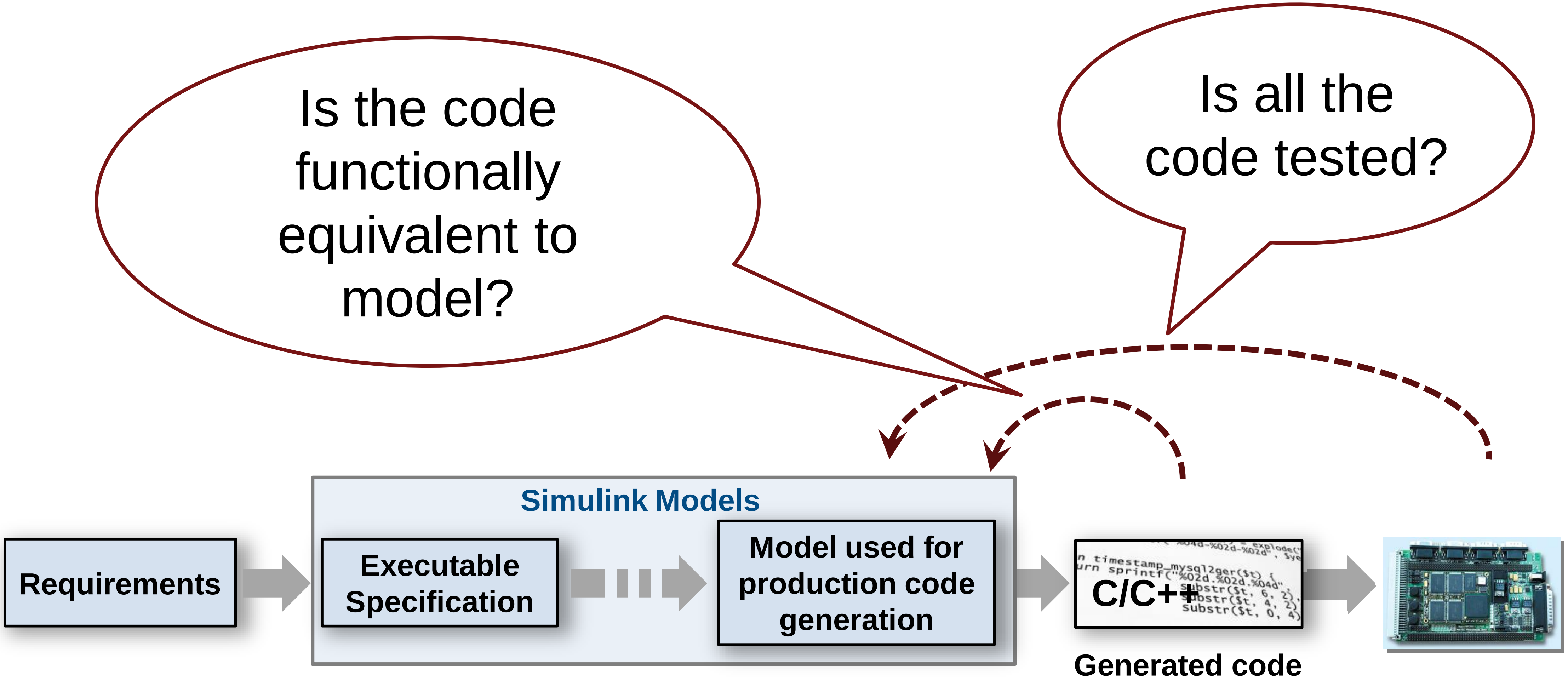
테스팅 비용 감소를 위한
정적 코드 검증 활용 방안

16:20~16:50

유용출 과장

Results from Polyspace Code Prover

Equivalence Testing

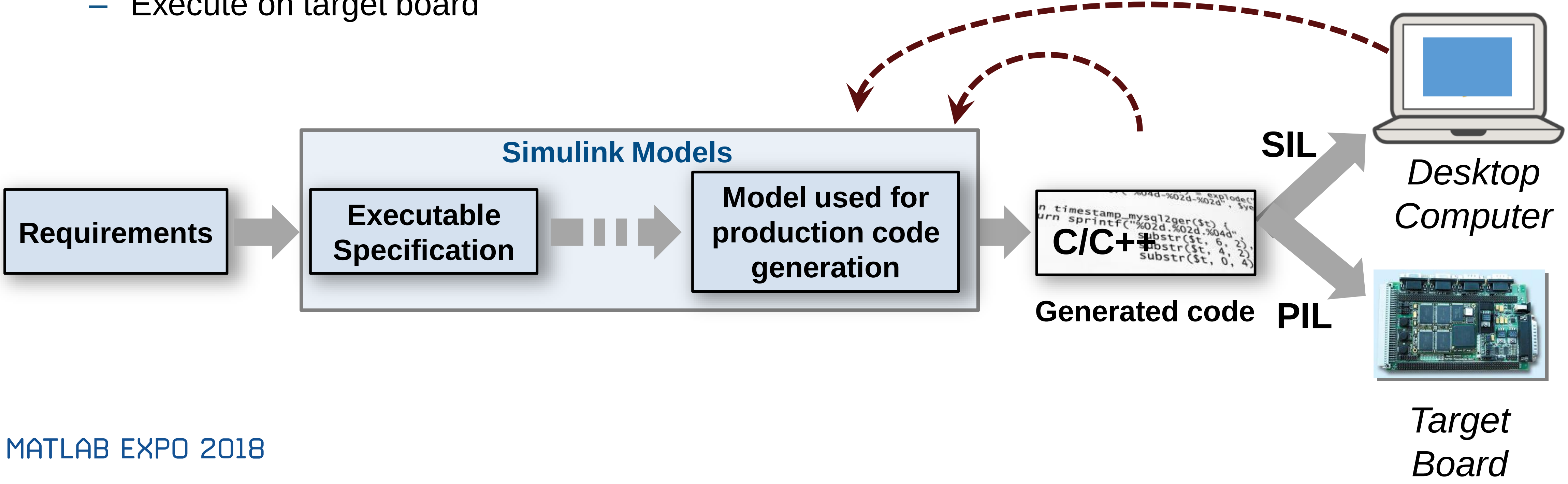


Is the code functionally equivalent to model?

Is all the code tested?

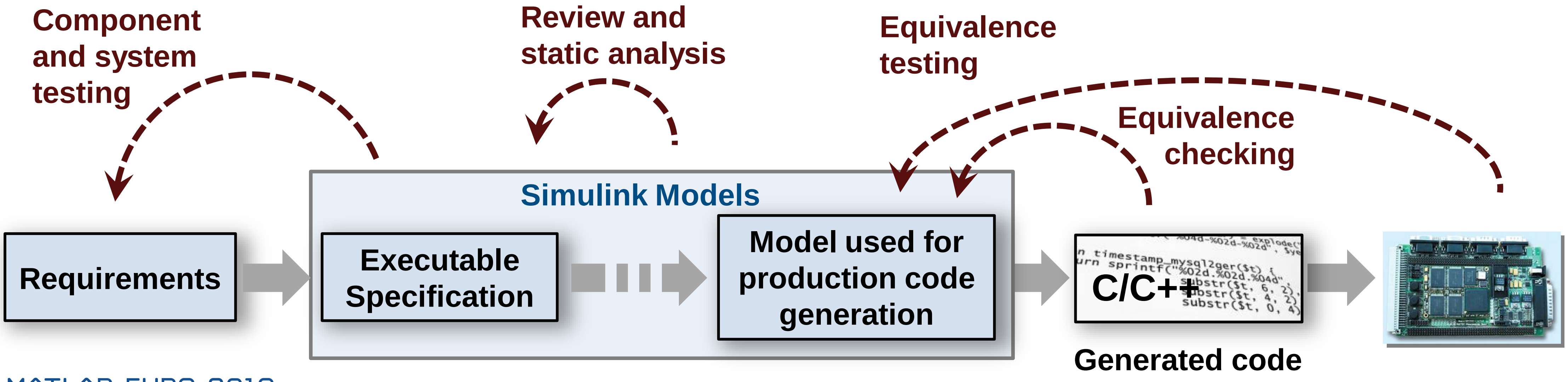
Equivalence Testing

- Software in the Loop (SIL)
  - Show functional equivalence, model to code
  - Execute on desktop / laptop computer
- Processor in the Loop (PIL)
  - Numerical equivalence, model to target code
  - Execute on target board
- Re-use tests developed for model to test code
- Collect code coverage



Summary

1. Author and manage requirements within Simulink
2. Find defects earlier
3. Automate manual verification tasks
4. Reference workflow that conforms to safety standards



Component and system testing

Review and static analysis

Equivalence testing

Equivalence checking

Simulink Models

Requirements

Executable Specification

Model used for production code generation

C/C++

Generated code

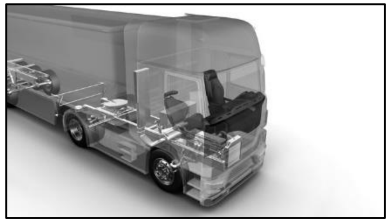
Customer References and Applications

Airbus Helicopters Accelerates Development of DO-178B Certified Software with Model-Based Design

Software testing time cut by two-thirds

LS Automotive Reduces Development Time for Automotive Component Software with Model-Based Design

Specification errors detected early



Continental Develops Electronically Controlled Air Suspension for Heavy-Duty Trucks

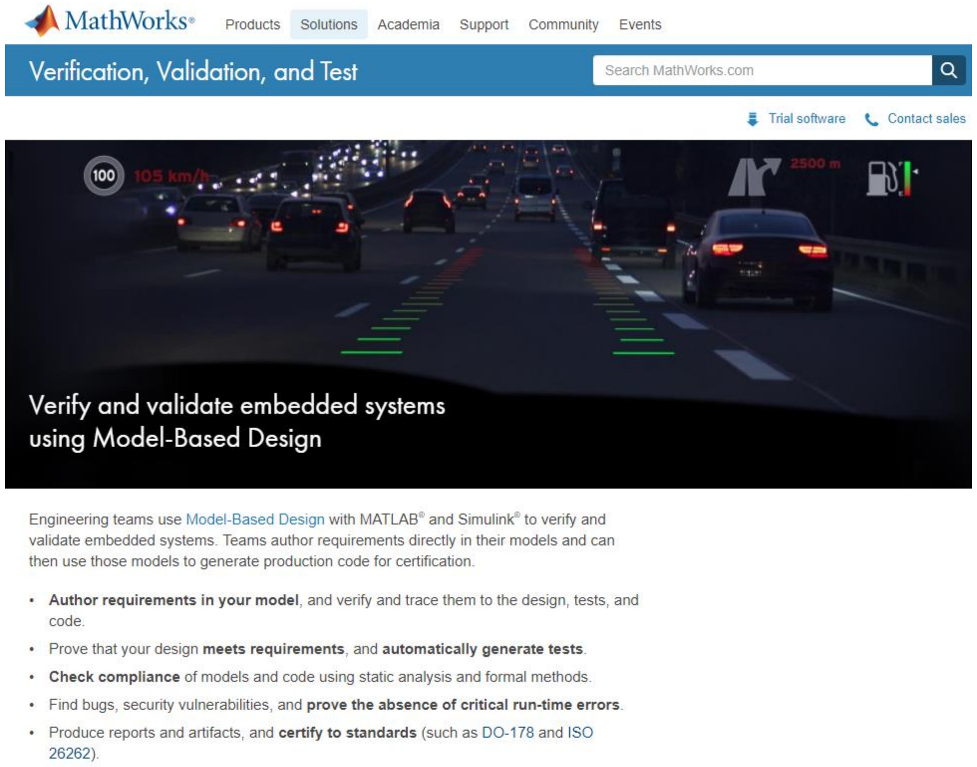
Verification time cut by up to 50 percent

More User Stories: www.mathworks.com/company/user_stories.html

Learn More

Visit MathWorks Verification, Validation and Test Solution Page:

https://kr.mathworks.com/solutions/verification-validation.html



Verification, Validation, and Test

Verify and validate embedded systems using Model-Based Design

Engineering teams use Model-Based Design with MATLAB® and Simulink® to verify and validate embedded systems. Teams author requirements directly in their models and can then use those models to generate production code for certification.

- **Author requirements in your model**, and verify and trace them to the design, tests, and code.
- Prove that your design **meets requirements**, and **automatically generate tests**.
- **Check compliance** of models and code using static analysis and formal methods.
- Find bugs, security vulnerabilities, and **prove the absence of critical run-time errors**.
- Produce reports and artifacts, and **certify to standards** (such as DO-178 and ISO 26262).

```
% Thank you
```