A new approach to Model-Based Testing in Simulink®

ETAS

Presented by:
Sean Wyatt

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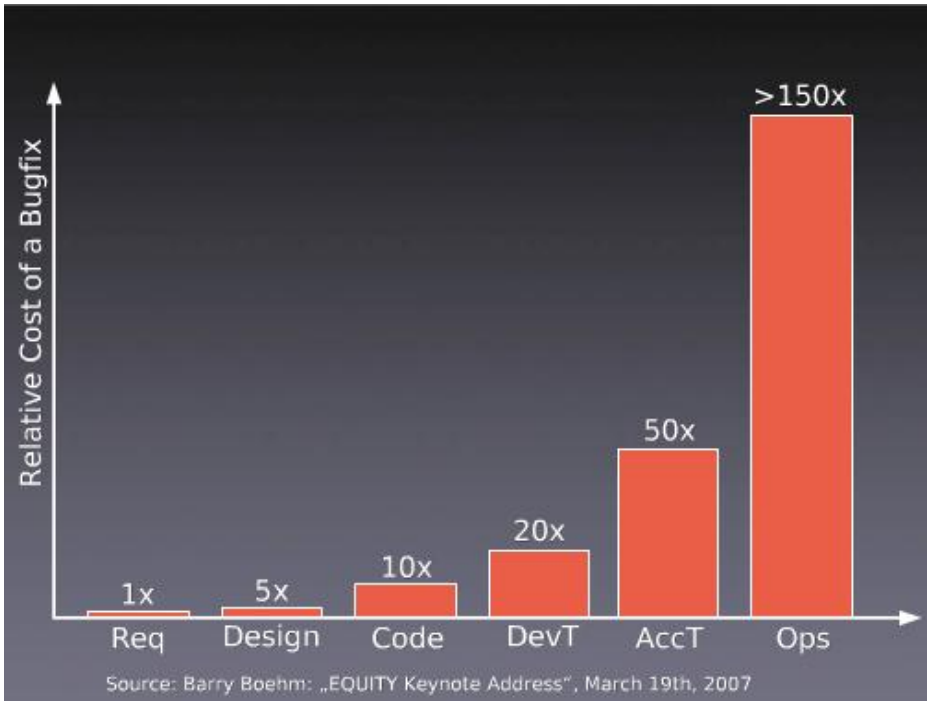
The Need

- Software defects originate from all stages of the development process
  - (Model-based) function development
  - Software code generation
  - Software build and integration
  - Hardware development
  - …
- Errors are often found far too late
  - High pressure and risk at the end of the engineering cycle

….. resulting in high cost of fixing errors



Barry Boehm, Software Engineering Economics

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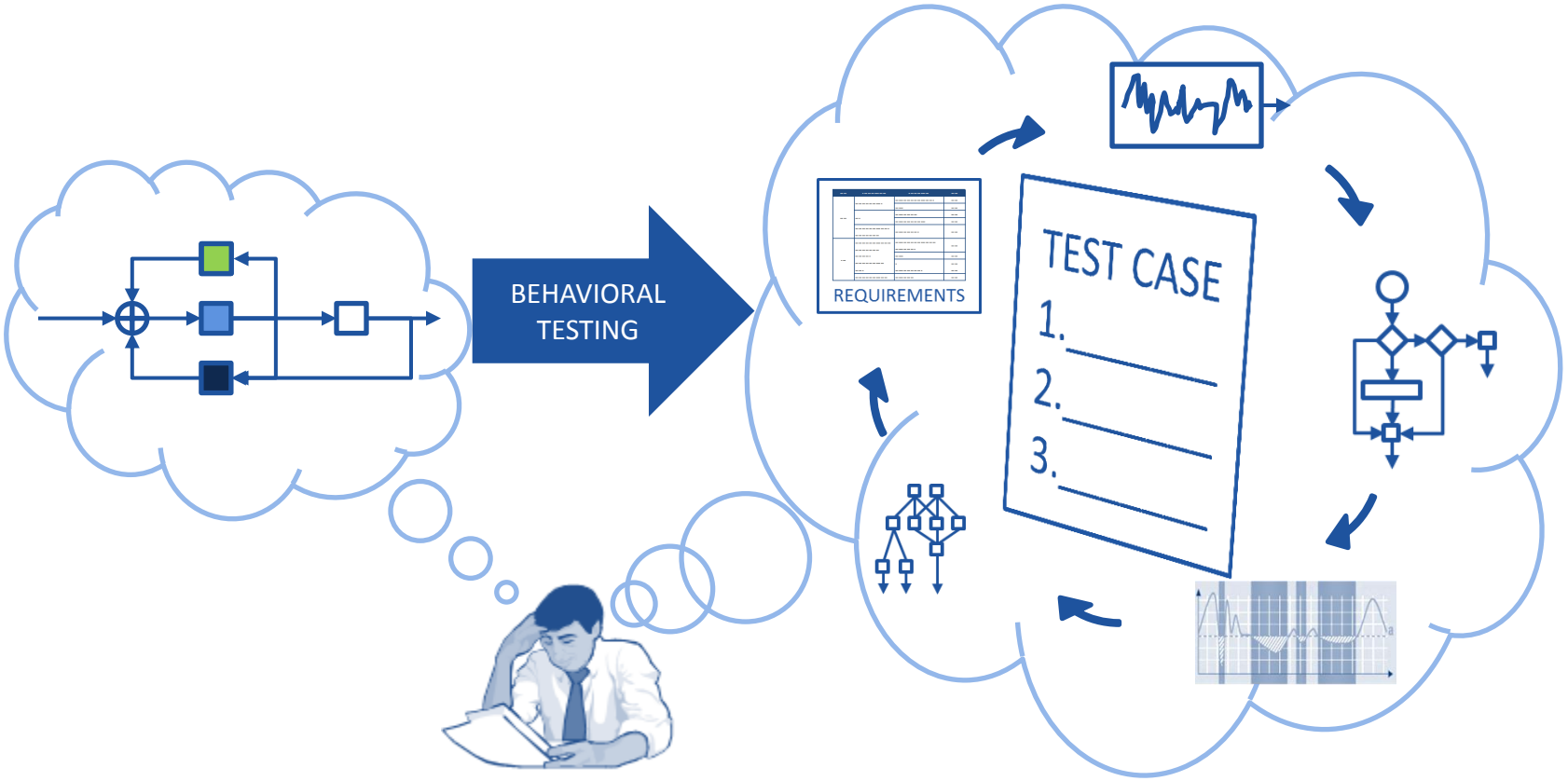
The Challenges for Function Developers



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Challenges Summarized

- Tracking requirements coverage and changes to their dispositions
- Deciding how to stimulate the function
- Creating test variants of the stimulations in a systematic and repeatable manner
- Assessing the results
- Creating reports with rich details that support ISO 26262:6 and 8

ETAS' solution is RT2

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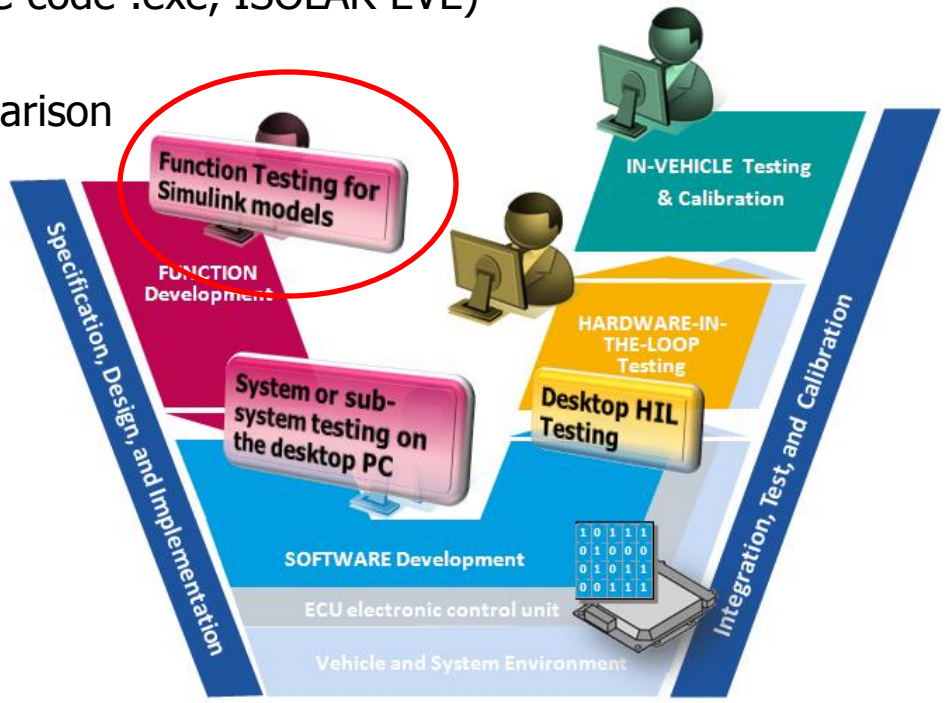
ETAS RT2 is a tool for **designing, executing and assessing systematic tests** for:

- **Functional models** (Simulink or ASCET)
- **Software-in-the-loop** platforms (e.g. C-code .exe, ISOLAR-EVE)
- **Back-to-back** testing: automated comparison of test results between model and software test



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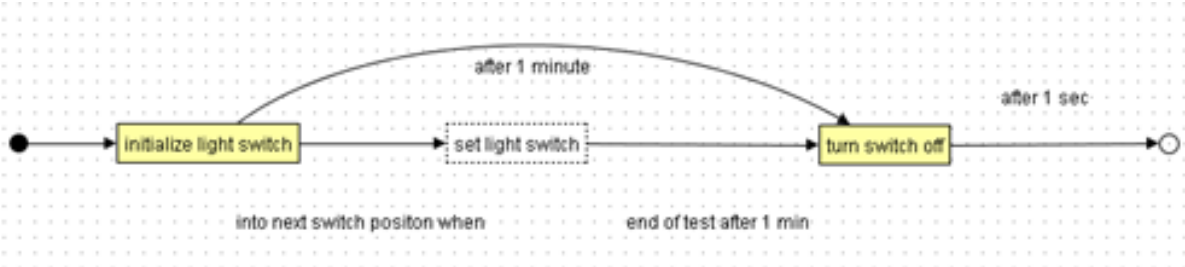
RT2 Testing Approach: Model-based Testing

- Normally, test case design is done using scripts

- What's the challenge of scripting?
  - Manage huge amounts of variants
  - Hard to overview the testing strategy and coverage
  - Programming skills required
  - High maintenance effort

- RT2 takes a different approach: test cases are described using **models**
  - Intuitive representation of complexity
  - Efficient management of variants
  - A "language" function developers understand



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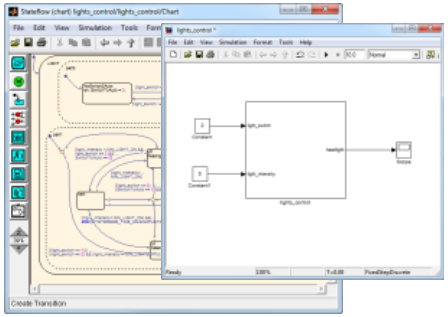
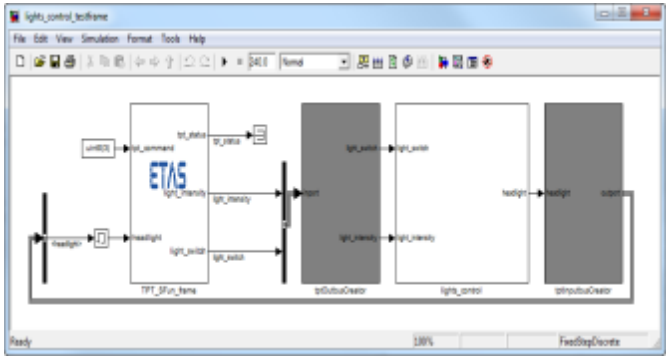
RT2 Testing Process

Simulink® Model



Instrumented Simulink® Model

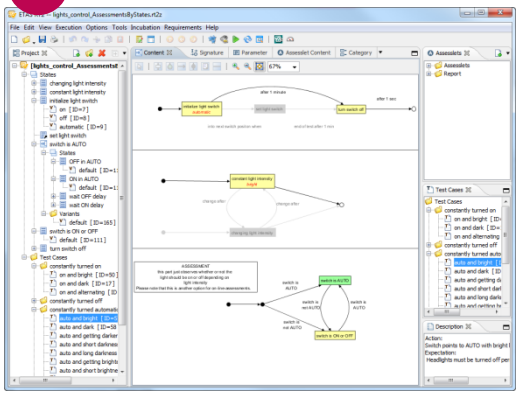


Interface

Parameters

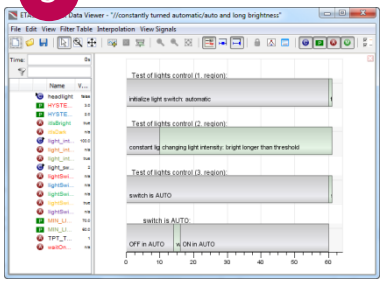
RT2

1 **Test Case Design Model**

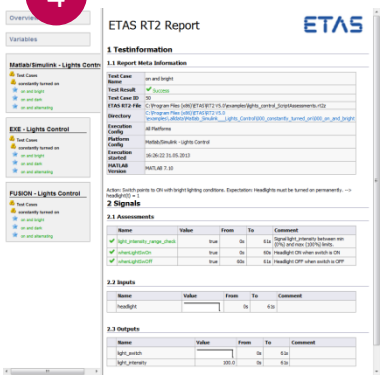


2 **Execution**

3 **Automated Test Assessment**



4 **Test Report**



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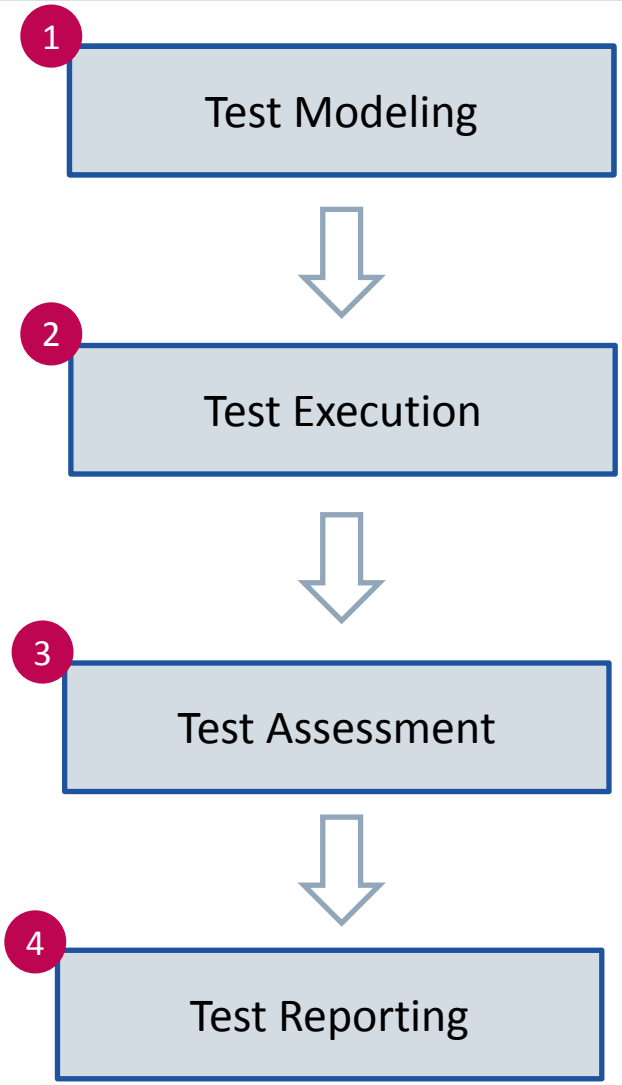

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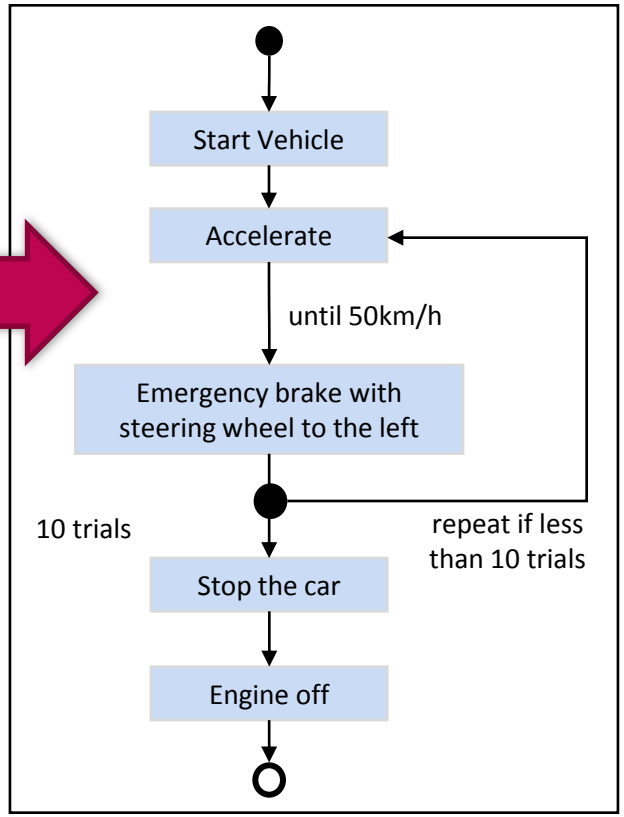
Test case scenarios often consist of sequences of logical phases.

1. Start Vehicle
2. Accelerate until 50 km/h
3. Emergency brake with steering wheel to the left
4. Repeat steps 2 and 3 a total of 10 times
5. Stop the car
6. Engine off

State machine with textual annotations are descriptive and easy to understand



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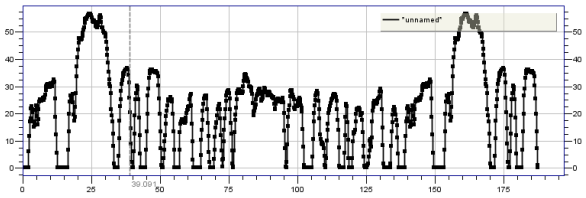
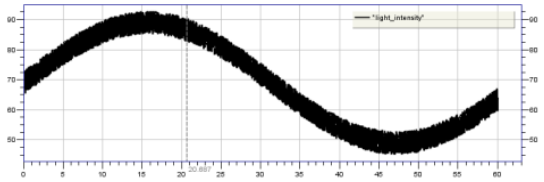
Test Modeling: Test State Definitions

– Direct definition

Imported Signals



Signal Editor



Formulas

```
MIN_LIGHT_OFF
+ 20 * sin(t/10)
+ 7.5 * random ()
```

– Test step list: definition of a step sequence supported by a graphical editor

1	Set channel	Brake	:= 80
2	Set channel	Klemme_15	:= 1
3	Wait	10ms	
4	Set channel	Klemme_50	:= 1
5	Wait for value	Engine_RPM	>= 700
6	Set channel	Klemme_50	:= 0
7	Set channel	PRNDL	:= DRIVE
8	Set channel	Brake	:= 0
9	Set channel	Acceleration_Pedal	:= 50
10	Wait for value	Speed	>= 50

– Time partitioned tests: definition through a hierarchical state machine

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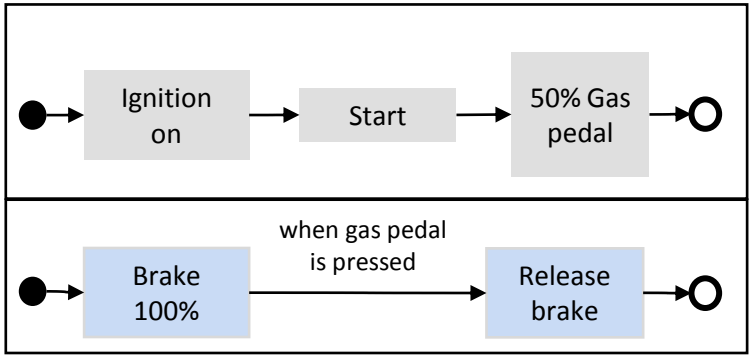
Test Modeling: State Arrangements and Variations

Hierarchical and parallel states



Variants of a state

with half throttle

with full throttle

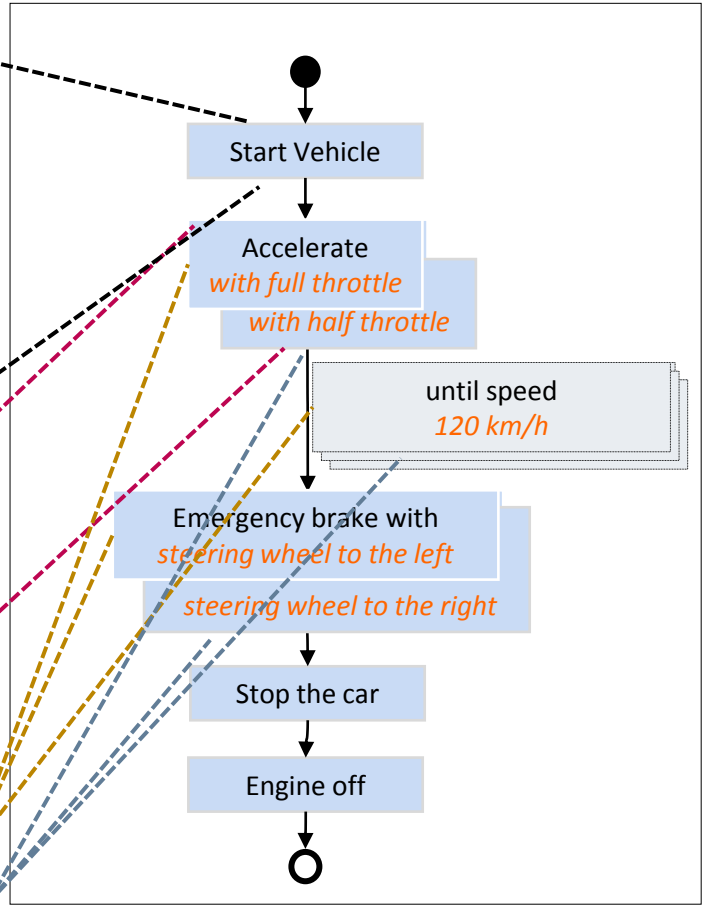
throttle(t) = 100.0
brake(t) = 0.0
handbrake(t) = 0.0

Variants of combinations of states

Test case ❶

Test case ❷

Accelerate: *with half throttle*
until speed: *120 km/h*
Emergency brake: *steering wheel to the right*



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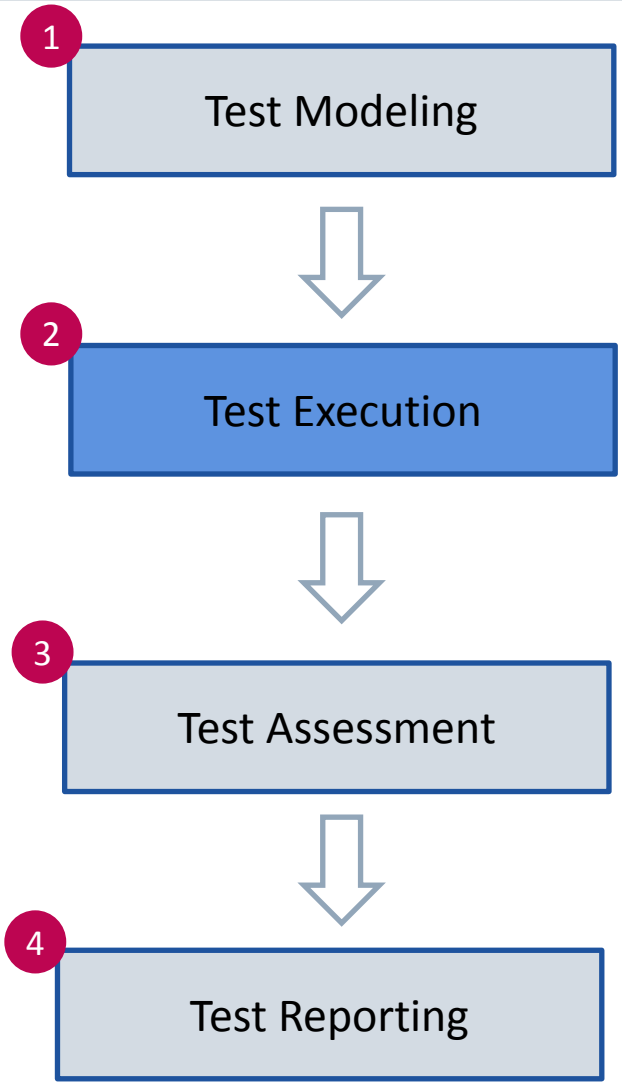

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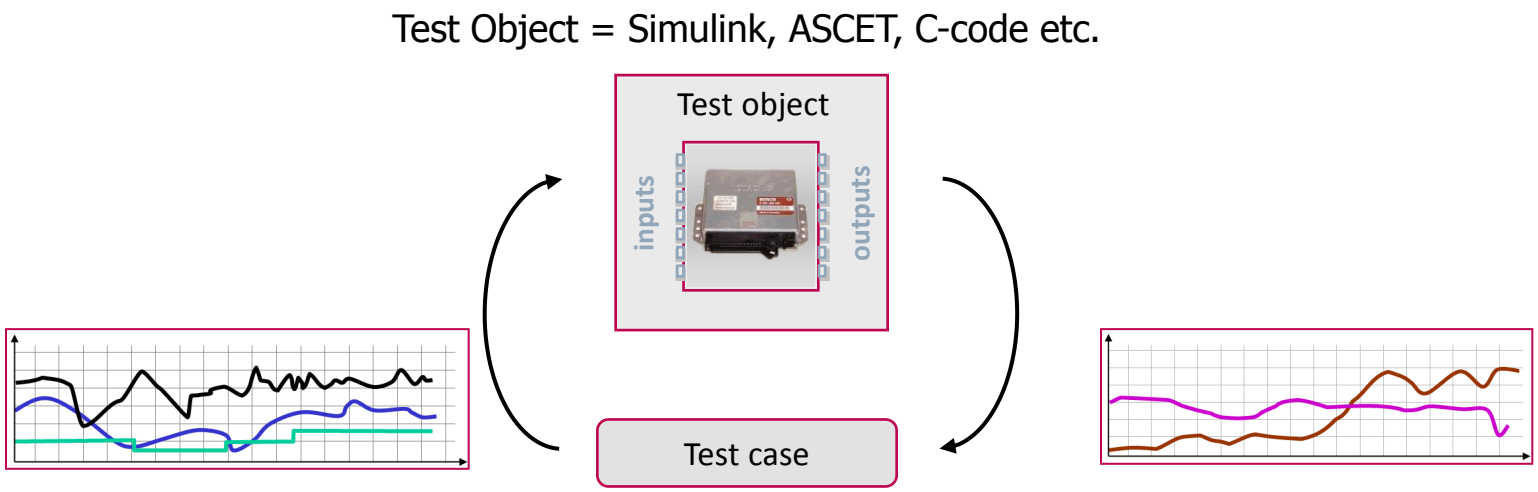
Test Execution (1/2)

- Test cases stimulate the test object by continuously affecting system quantities (inputs)
- Test cases can react to system behavior by observing system quantities (outputs)



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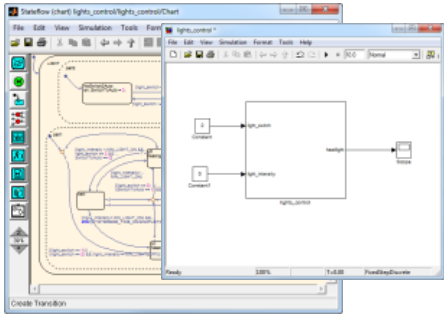
2 Test Execution (2/2)

Simulink® Model



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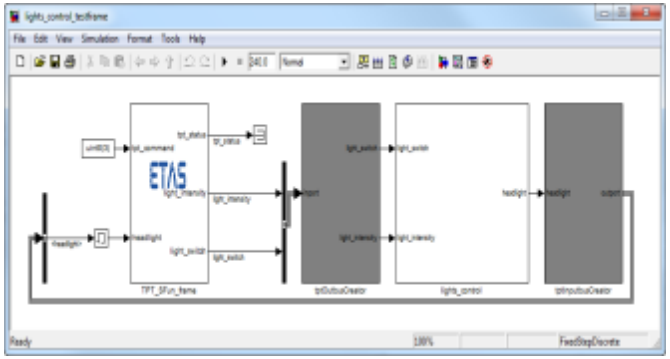

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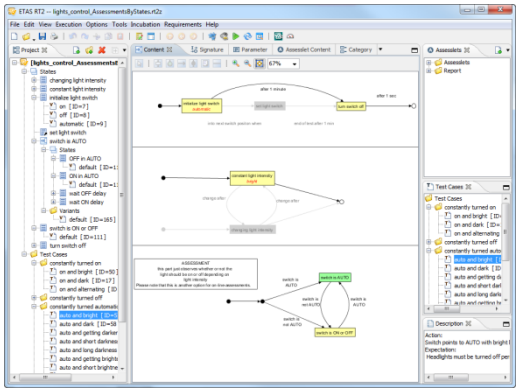
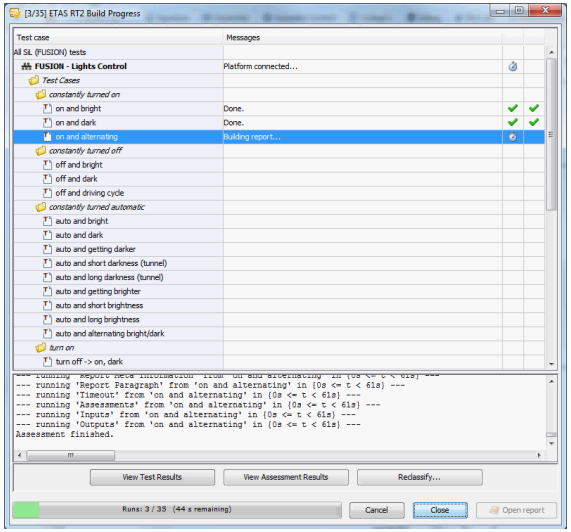
Test Case Design Model



Execution



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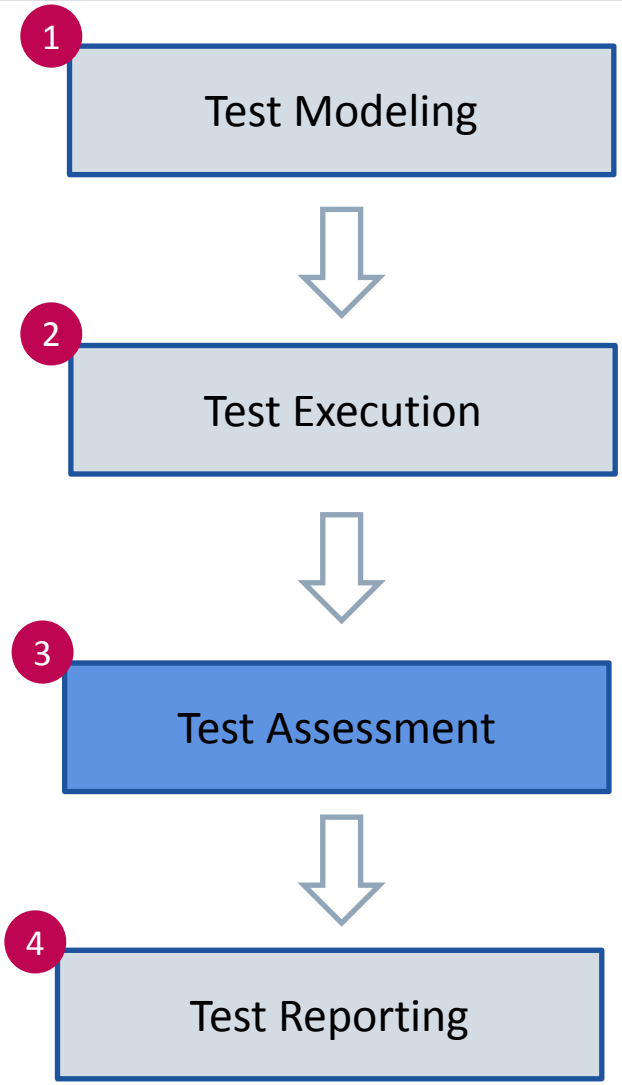

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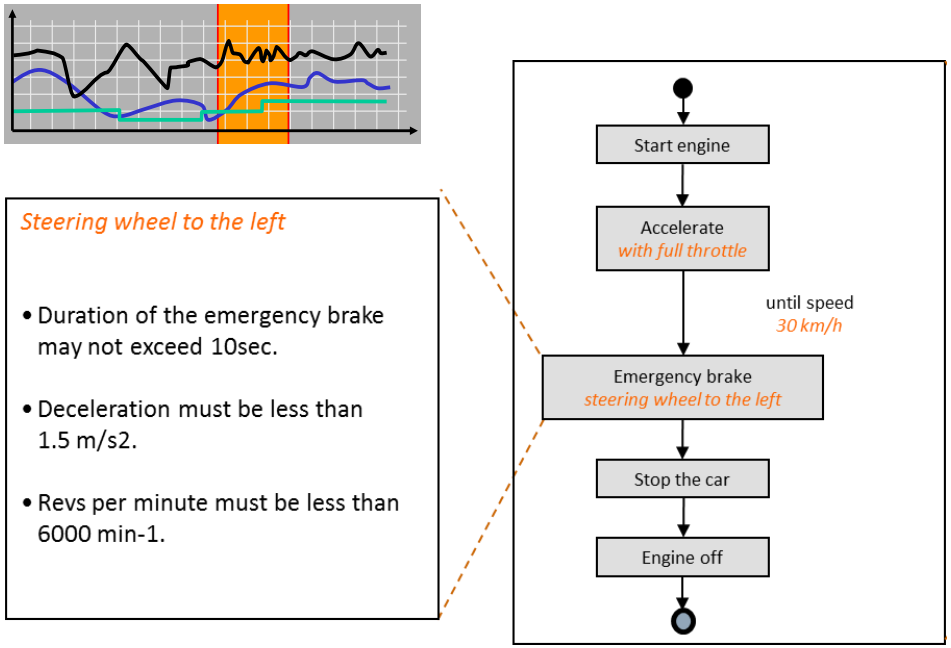
Test Assessment – Time Interval Analysis (1/2)

– Assessments conducted after test data is collected

– When specific state is active: Analyses focused on a time interval when a specific state is active



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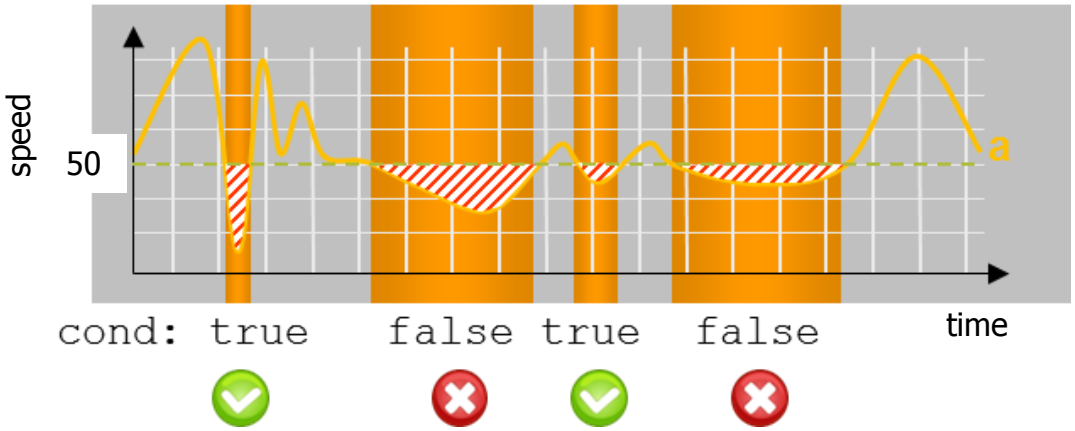
Test Assessment – Time Interval Analysis (1/2)

- Absolute time: A time interval specified by absolute time
  - **[t >= 50s]**

- Time patterns: Explicit time intervals specified
  - **[v_vehicle(t) >= 100 kph]** *time intervals with speed ≥ 100*
  - **[foo(t) == 1] [foo(t) == 2]** *time intervals with foo=1 followed by foo=2*

- Temporal regular expressions: Time patterns as special cases
  - Assessments can be analyzed in multiple time intervals:

    e.g. *time intervals where vehicle speed drops below 50kph for less than 10s*



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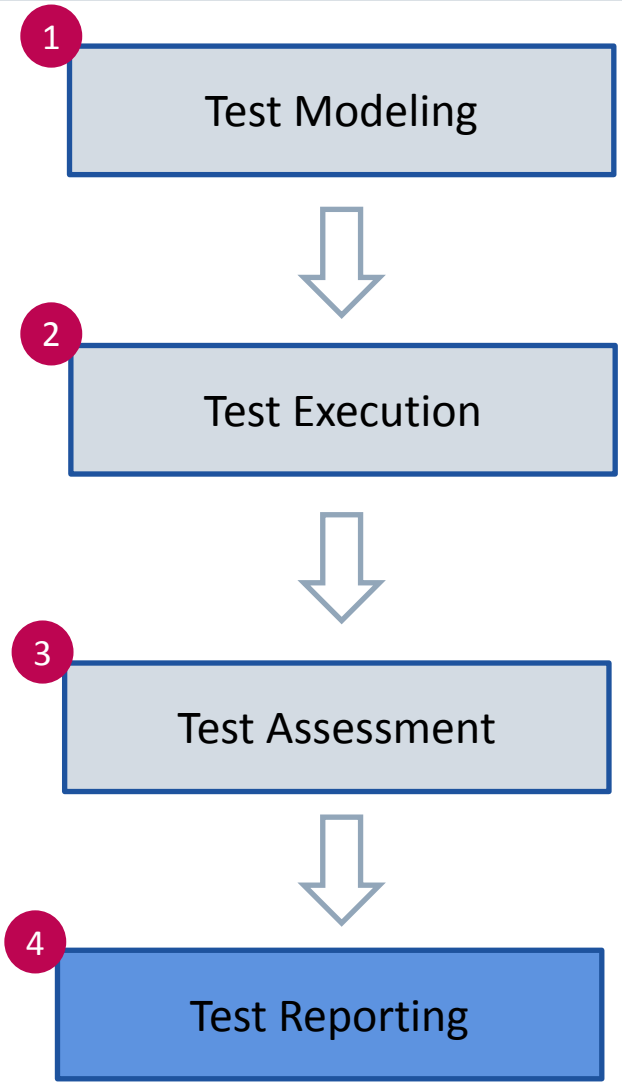

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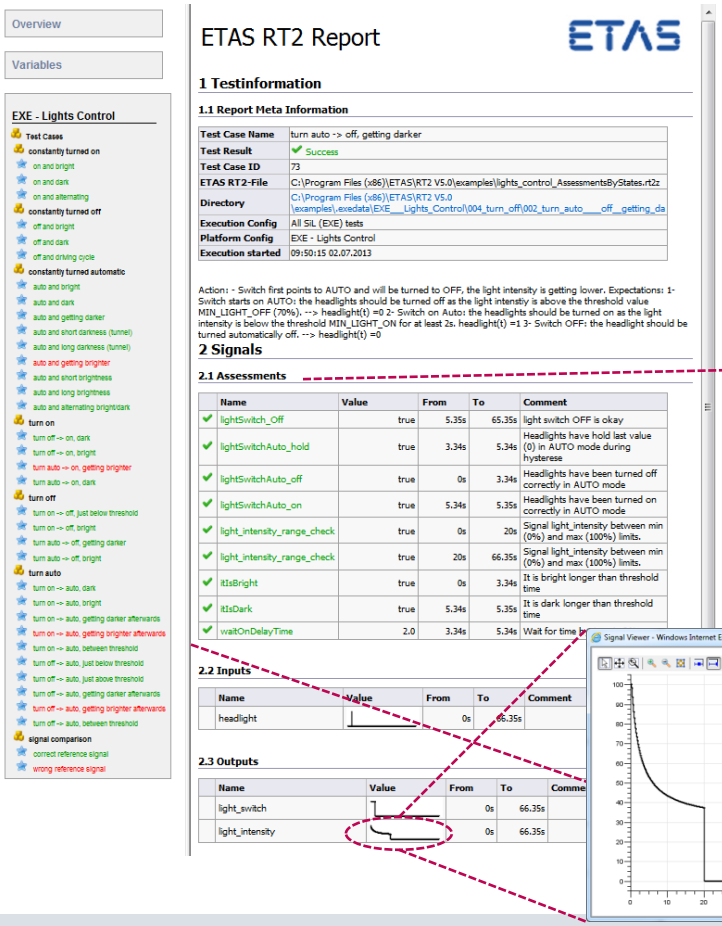
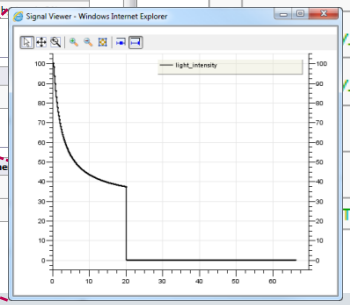
Test Summary and Requirements Tracking

Detail-rich reports





2.1 Assessments

	Name	Value	From	To	Comment
✔	lightSwitch_Off	true	5.35s	65.35s	light switch OFF is okay
✔	lightSwitchAuto_hold	true	3.34s	5.34s	Headlights have hold last value (0) in AUTO mode during hysterese
✔	lightSwitchAuto_off	true	0s	3.34s	Headlights have been turned off correctly in AUTO mode
✔	lightSwitchAuto_on	true	5.34s	5.35s	Headlights have been turned on correctly in AUTO mode
	_range_check	true	0s	20s	Signal light_intensity between min (0%) and max (100%) limits.
	_range_check	true	20s	66.35s	Signal light_intensity between min (0%) and max (100%) limits.
		true	0s	3.34s	It is bright longer than threshold time
		true	5.34s	5.35s	It is dark longer than threshold time
	Time	2.0	3.34s	5.34s	Wait for time hysteresis ON

Requirements Management

- Import/Synchronization of requirements
- Import/Export/Synchronization of test cases
- Import/Export/Synchronization of links
- Impact analysis when requirement changes
- DOORS ® Integration

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Comprehensive tools suite for test design, automation, assessment and documentation for Simulink® models

- Intuitive test case **creation** - Enables users to quickly develop test cases with a short learning curve
- Test **variant** management - Enables users to explore functional behavior in multi-faceted test cases, in large test campaigns
- Powerful **assessment** capabilities - Allows users to make decisions from test results without additional tools
- **Traceability** between requirements and models - Improves quality and ensures that deliverables meet the needs and expectations of stakeholders
- **Test reuse** across development phases (MiL/SiL)
- Supports **ISO26262** compliant development processes

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Thank you

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Vielen Dank

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