



Model-Based Testing of Complex Hybrid Aerospace Systems

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EADS at a glance



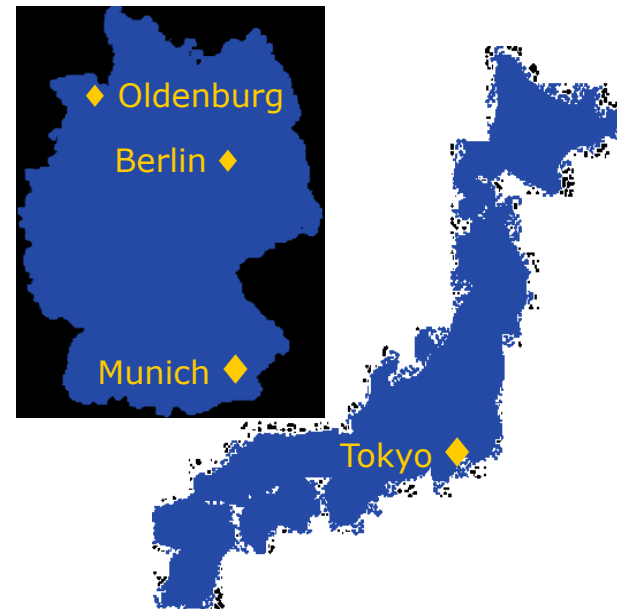
BTC Embedded Systems

Model-based Testing Company established in 1999

BTC-ES Headquarter in Oldenburg (D)

Subsidiaries in Munich and Berlin (D)

BTC Japan Co., Ltd.



Mission Statement:

Our mission is to enable customers to increase product quality in a shortened design phase by introducing automatic test and verification technology to the model-based systems & software development process.

Main Customer Domains:

Automotive, Aerospace

Agenda

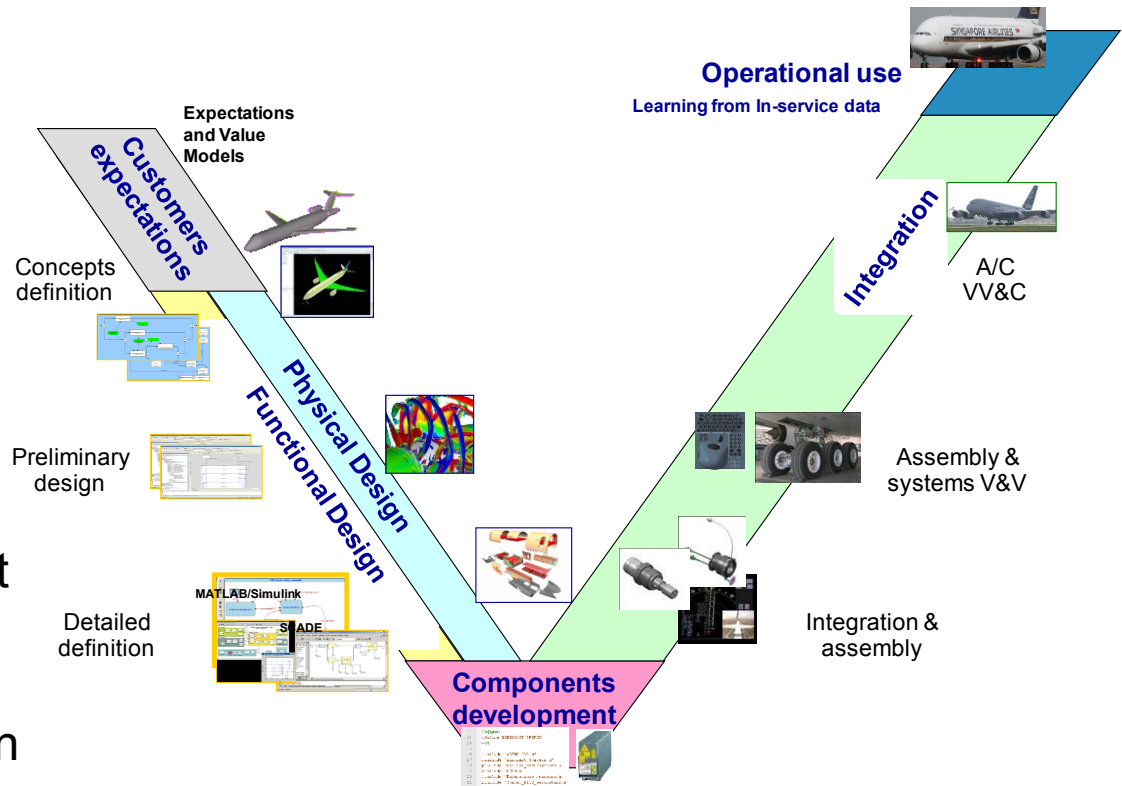
- EADS background and motivation
- Model-based Testing concept and artefacts
- Model-based Testing with Rational Rhapsody, Rhapsody ATG and Rhapsody TestConductor
- Example and Early Results
- Conclusion

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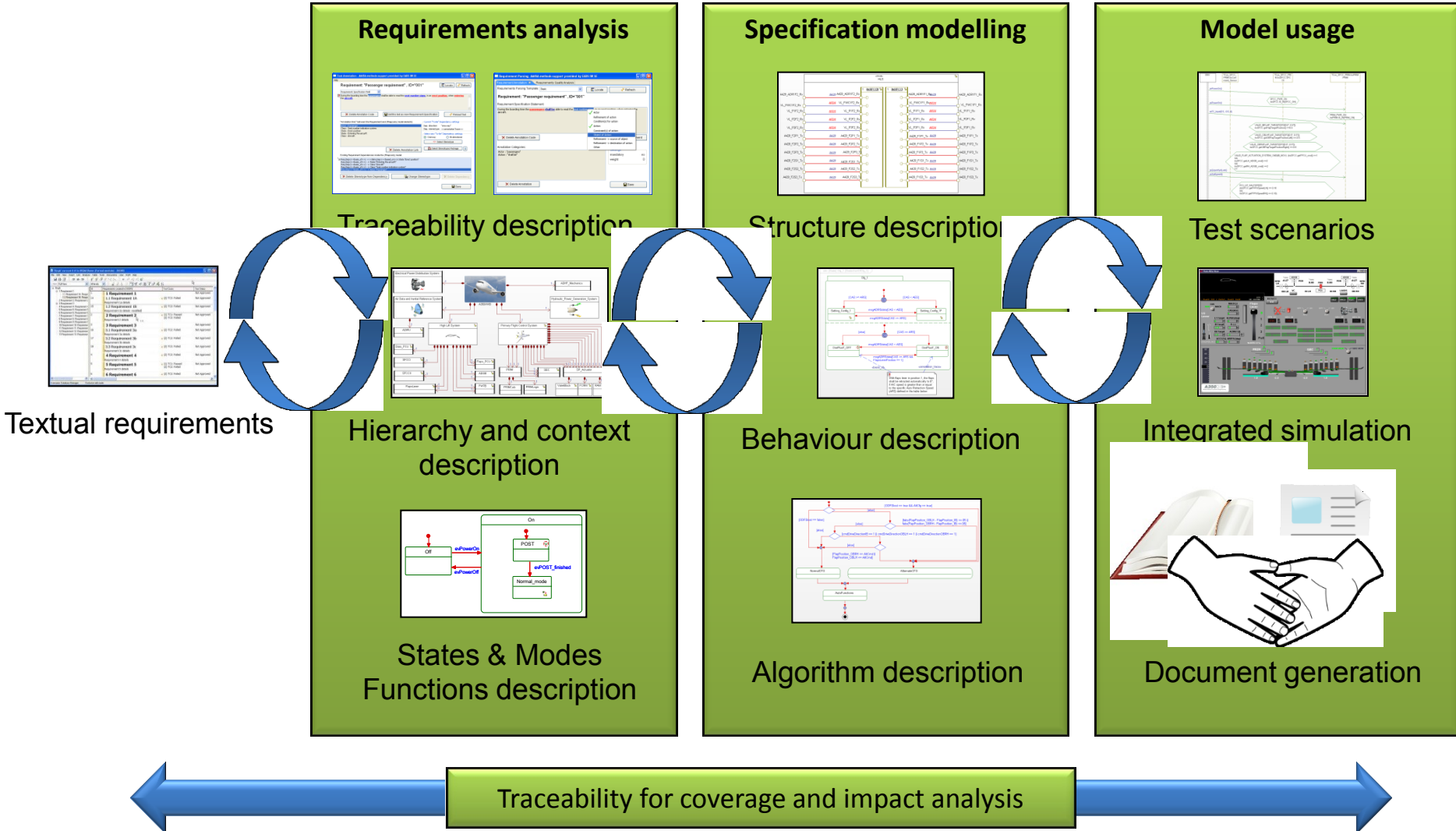
Systems Engineering at EADS

- EADS is typically doing systems specification and systems integration
- Duration and cost of system development efforts has experienced rapid exponential growth over time
- The system design of a product is a key driver for its lifecycle cost. Wrong / not optimal decisions in early phases are very costly to fix in later phases



Model-based Systems Engineering for early Virtual aircraft
Functional and Physical View

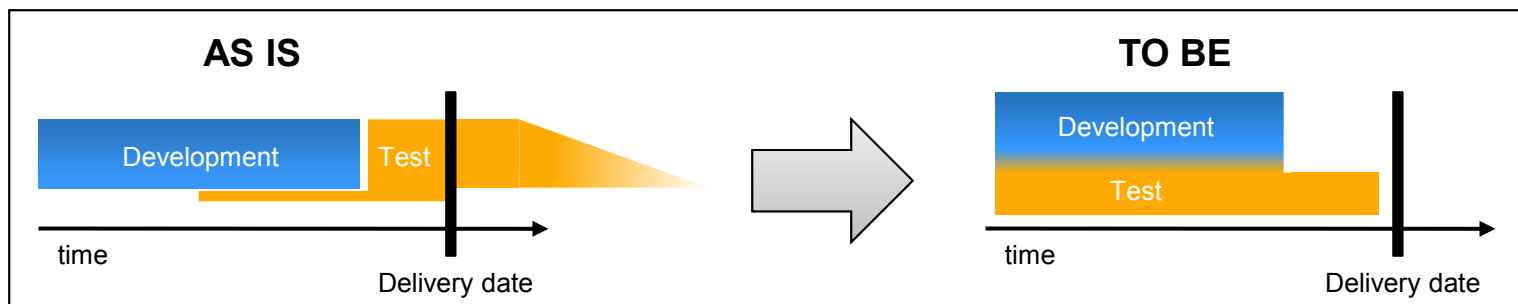
Model-based specification



Need for an integrated MBSE approach

- Development and testing are often enough separated in systems engineering resulting in an unnecessary high effort for testing while it is already seen as inseparable in software engineering
- An MBSE approach including model based testing allows **early validation of requirements and verification of the system design** by testing throughout the design phase and facilitates error tracing and impact assessment later on.
- The usage of the OMG UML Testing Profile in conjunction with SysML allows reusing the artefacts from the engineering stage at the testing stage of the development cycle and thereby enables **testing based on the system specification model**

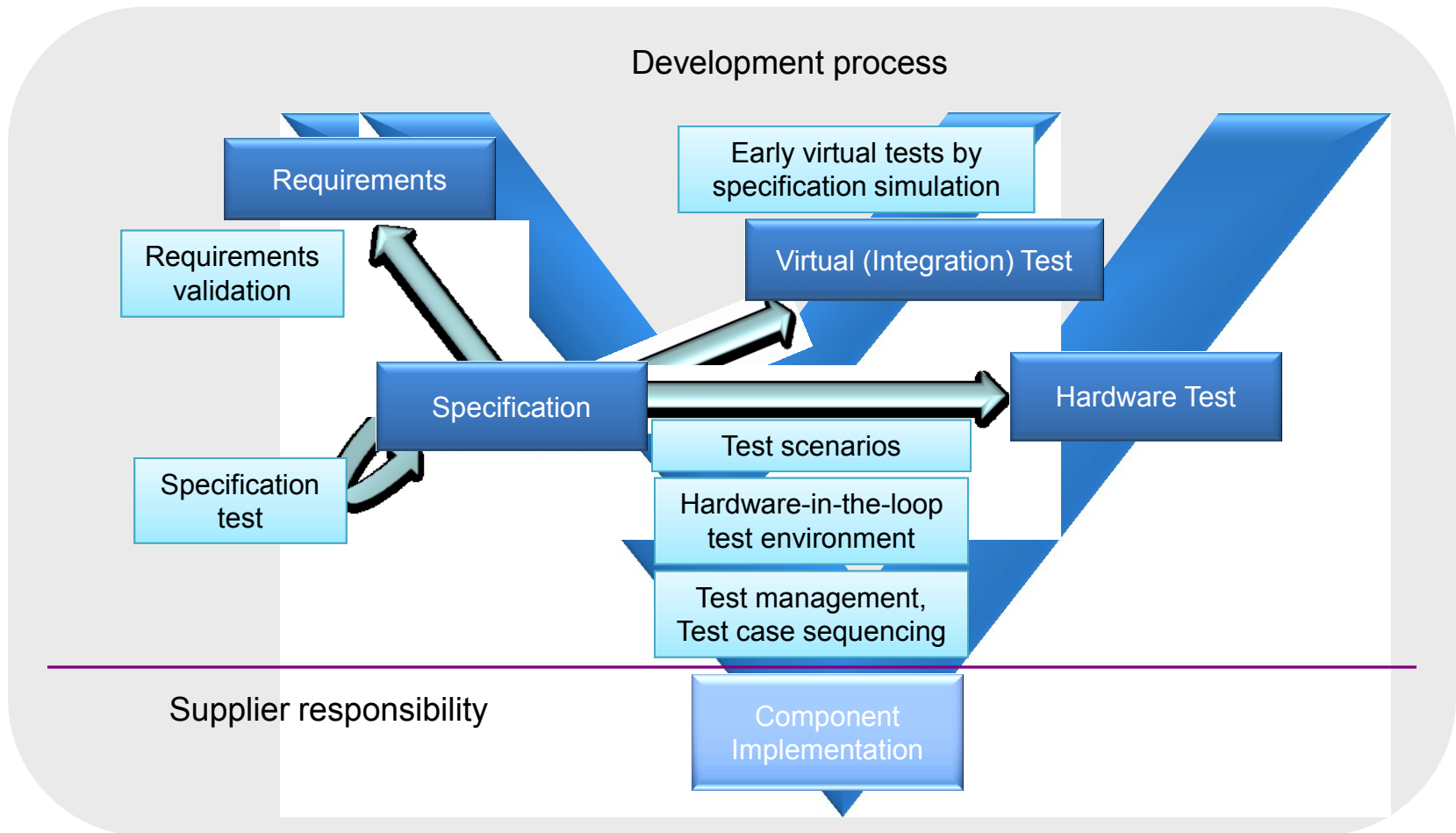
Model-based testing



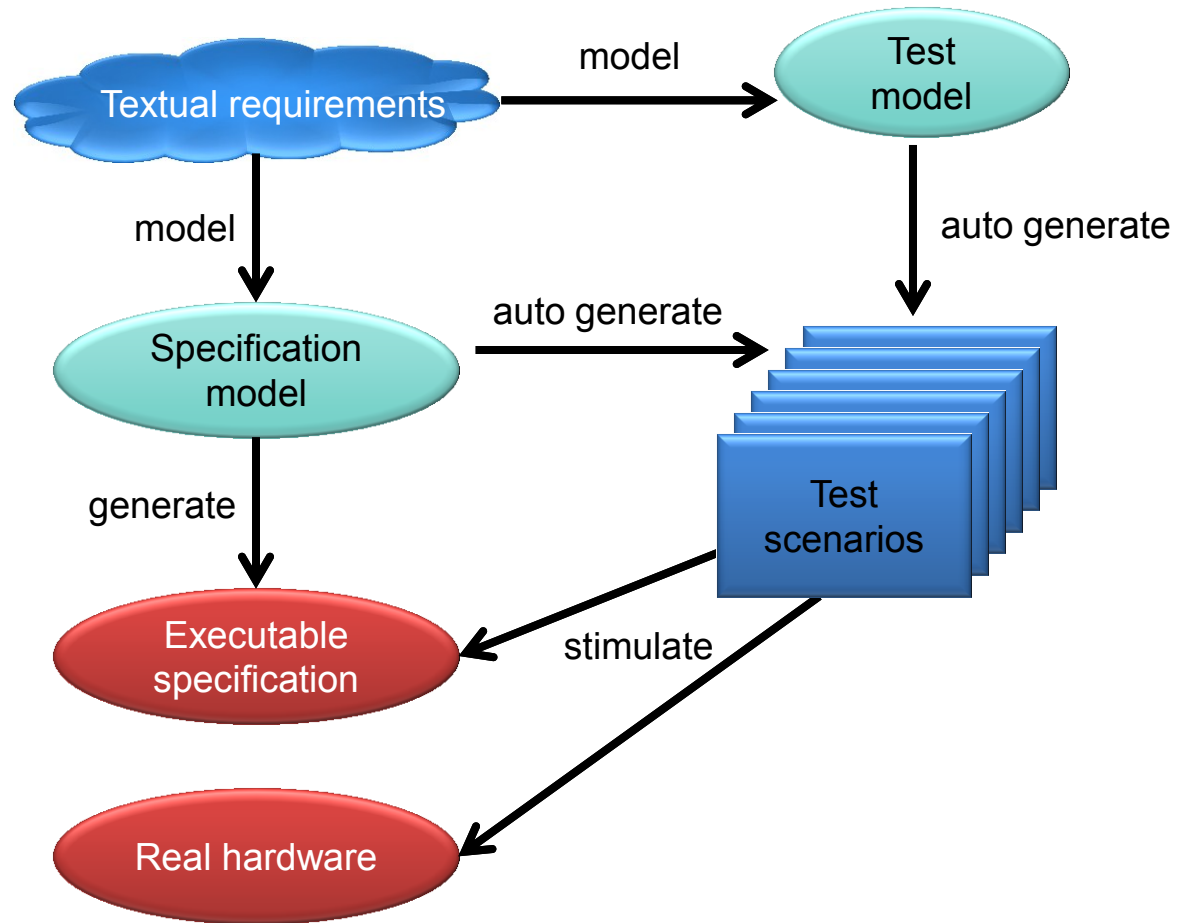
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- **Model-based Testing concept and artefacts**
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From model-based specification to model-based testing

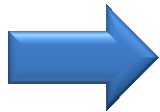


Artefacts and relations



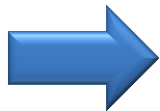
Benefits of model-based testing

- Seamless traceability from the initial requirements through the system and subsystem functions to test cases and test results



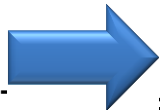
Better impact analysis

- Test scenarios can be automatically generated from the specification model based on an in-depth automatic white-box model analysis



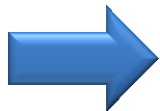
Higher test coverage

- Test plans are developed in the context of the SuT, the resources available and the coverage that can be delivered



Better test management

- Tests are created earlier in the development process, automatically executed, used for specification testing as well as system testing and reused when the design evolves

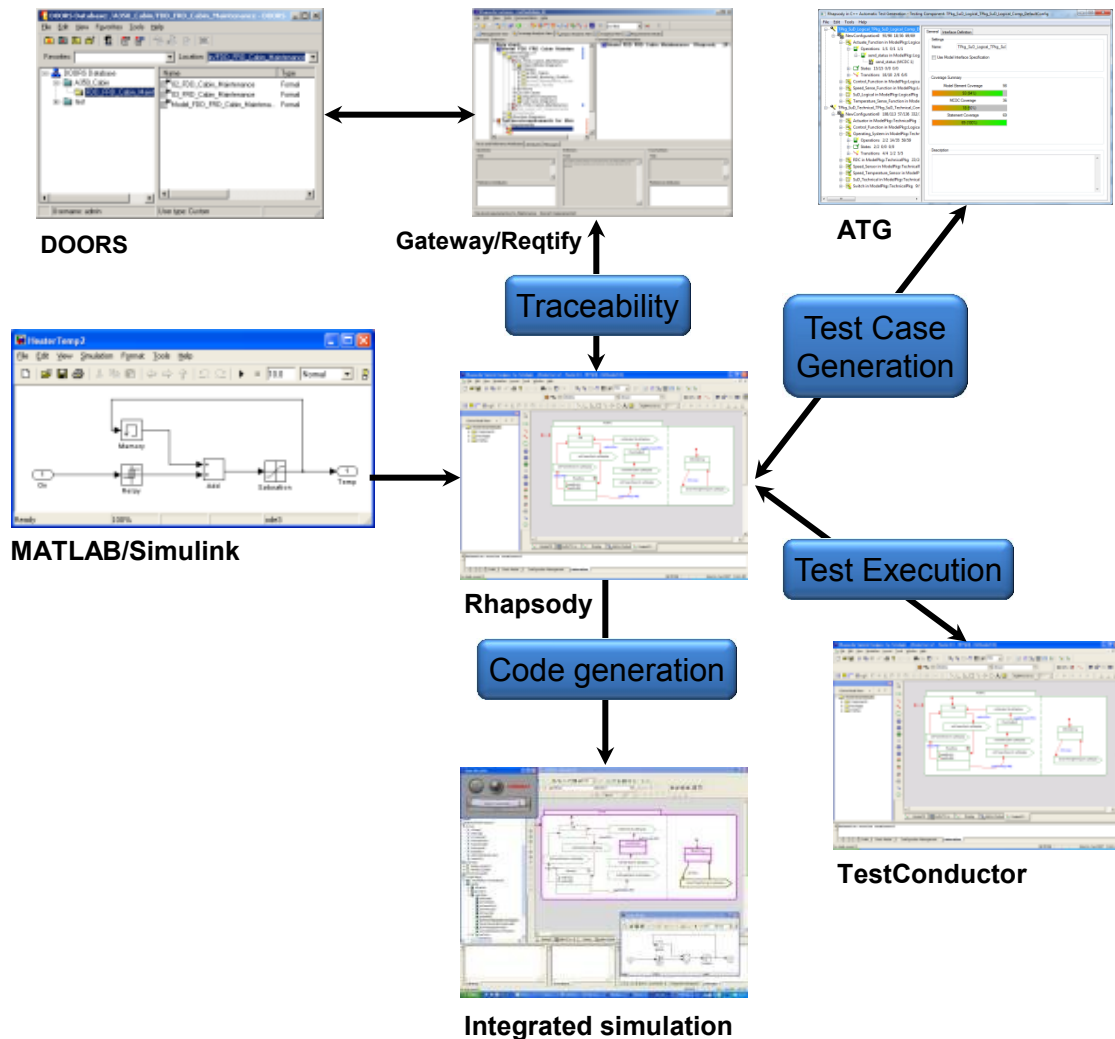


Overall test effort reduction

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EADS Model-based Tool chain

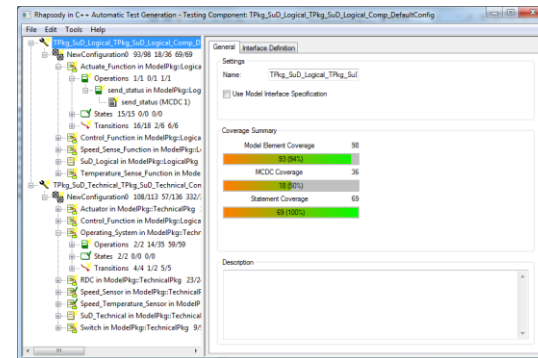


Tools:

- ▶ **DOORS (IBM)**
 - Requirements Management
- ▶ **Rhapsody Gateway (IBM/Geensoft)**
 - Requirements Traceability
- ▶ **Rhapsody (IBM)**
 - Specification modelling
 - Model Integration
 - Simulation Execution
- ▶ **ATG (IBM/BTC-ES)**
 - Automatic Test Case/Scenario generation
- ▶ **TestConductor (IBM/BTC-ES)**
 - Automatic test execution
 - Coverage report generation
- ▶ **MATLAB/Simulink (MathWorks)**
 - Physical Behaviour
 - Environment Simulation

Rhapsody ATG and Rhapsody TestConductor

- **IBM® Rational® Rhapsody® Automatic Test Generation (ATG) Add On:**
- Model-based test case generation using UML/SysML test models
- Model coverage, statement coverage, MC/DC
- Incremental creation of test suites

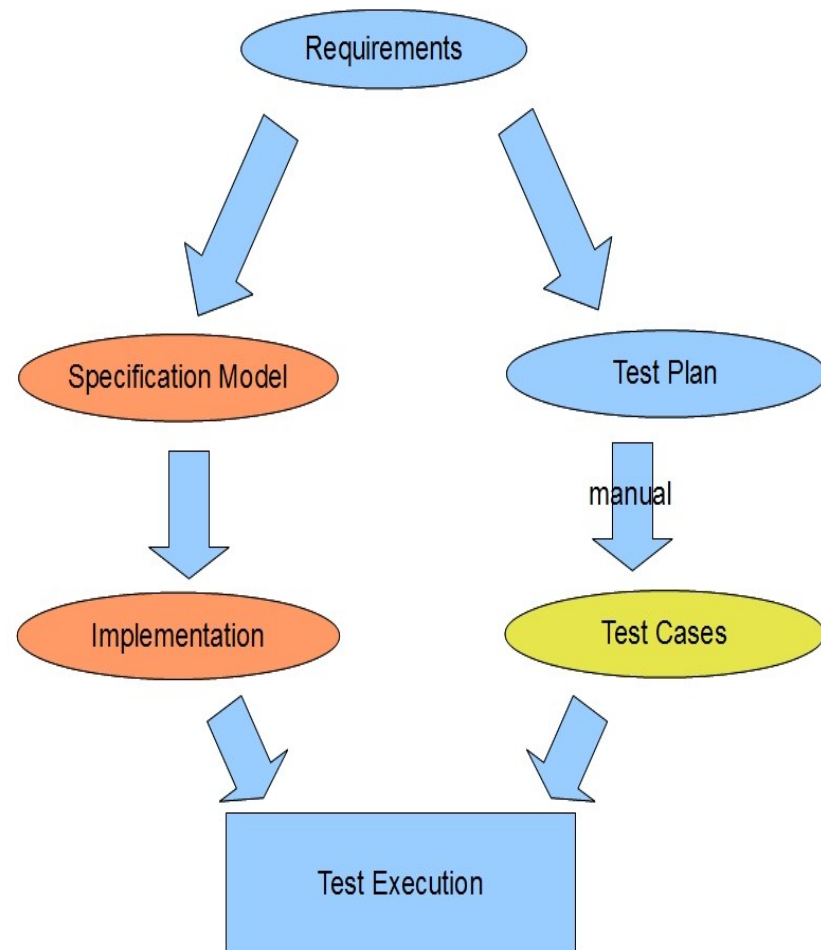


- **IBM® Rational® Rhapsody® TestConductor Add On:**
- Model-based test case specification and execution using the UML Testing Profile
- Test can be defined graphically using UML sequence diagrams, flowcharts, statecharts or code
- Error analysis using color coded sequence diagrams

Name	Status	File/Iteration
TCOn_SuD_Technical	EXECUTING	
atg_tc_002	PASSED	
ATG_TestCase.002	PASSED	1
atg_tc_003	EXECUTING	
atg_tc_004	NOT EXECUTED	
atg_tc_005	NOT EXECUTED	
atg_tc_006	NOT EXECUTED	
atg_tc_007	NOT EXECUTED	
atg_tc_008	NOT EXECUTED	
atg_tc_009	NOT EXECUTED	
atg_tc_011	NOT EXECUTED	
atg_tc_012	NOT EXECUTED	
atg_tc_013	NOT EXECUTED	
atg_tc_014	NOT EXECUTED	
atg_tc_015	NOT EXECUTED	
atg_tc_016	NOT EXECUTED	
atg_tc_017	NOT EXECUTED	
atg_tc_018	NOT EXECUTED	
atg_tc_019	NOT EXECUTED	
atg_tc_020	NOT EXECUTED	
atg_tc_021	NOT EXECUTED	
atg_tc_022	NOT EXECUTED	
atg_tc_023	NOT EXECUTED	

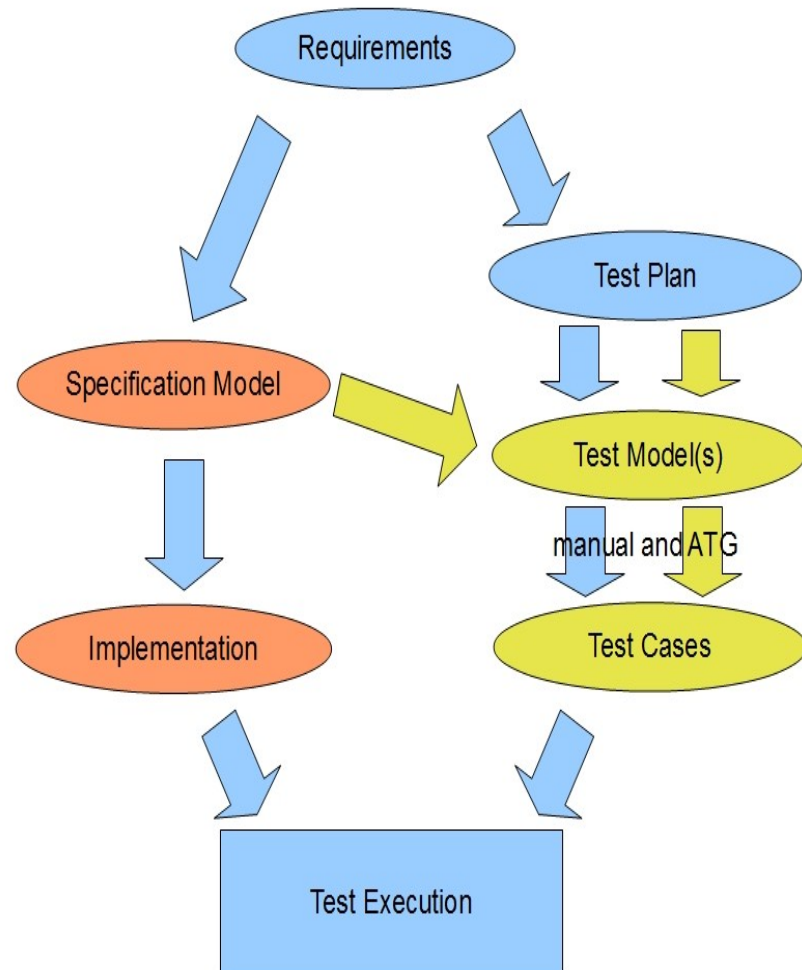
Test Models and Automatic Test Generation (ATG)

- Model based development using a specification model (left branch)
- creating tests directly from a mostly textual test plan (right branch)
- Development benefits from modelling but tests are mostly manually developed and maintained outside of models



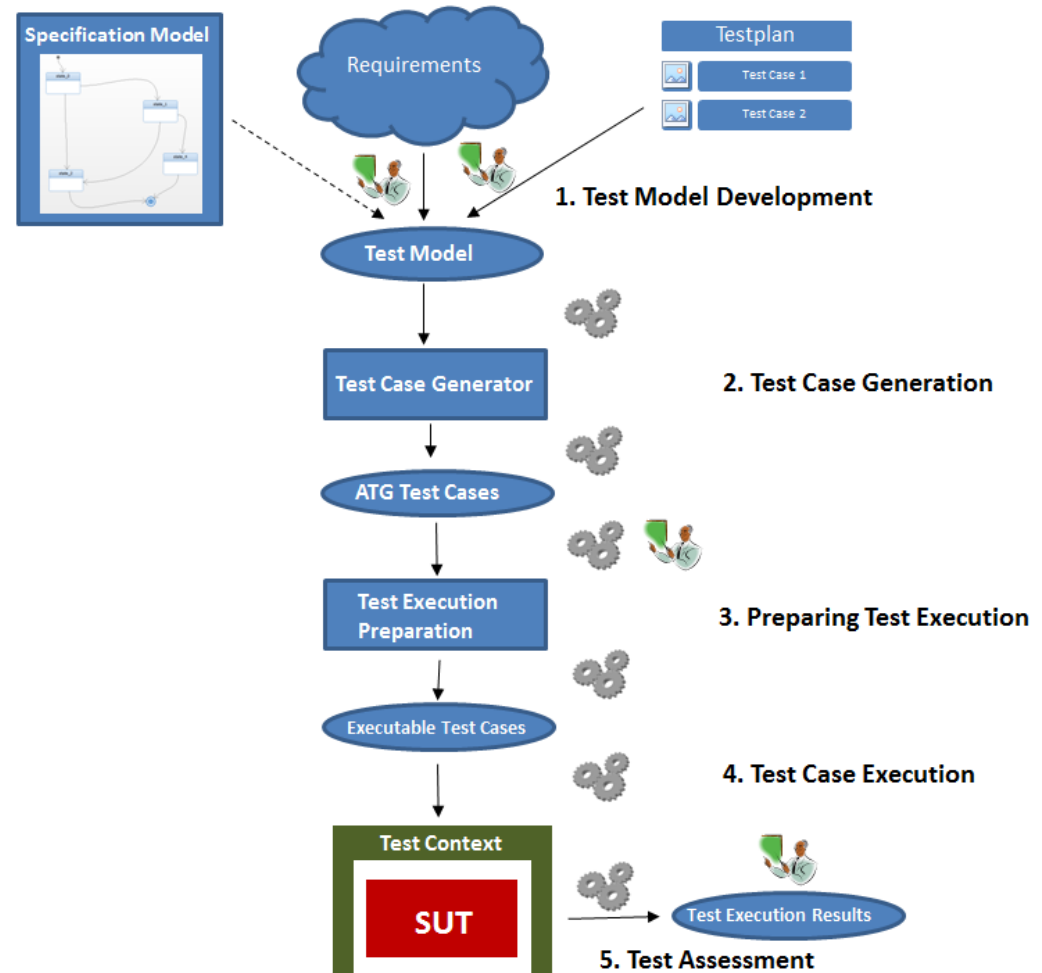
Test Models and Automatic Test Generation (ATG)

- Model based development **and** model based testing
- Automatically generate tests from test model using ATG
- Test maintenance means maintaining test models



Test Models and Automatic Test Generation (ATG)

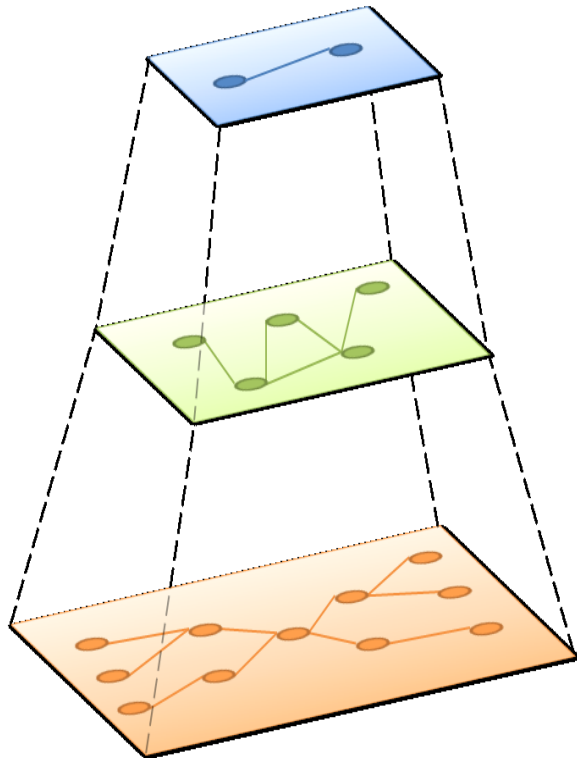
- Test models capture test objectives and test strategies
- ATG generates test cases
- ATG test cases are tailored to the concrete test environment, e.g. TestConductor
- Tests are executed and results are analyzed



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Generic example model and application results



Functional model

Descriptive
5 functions
4 functional links

Logical model

Executable
4 logical block classes
9 logical block instances
14 logical links

Technical model

Executable
6 technical block classes
18 technical block instances
36 technical links

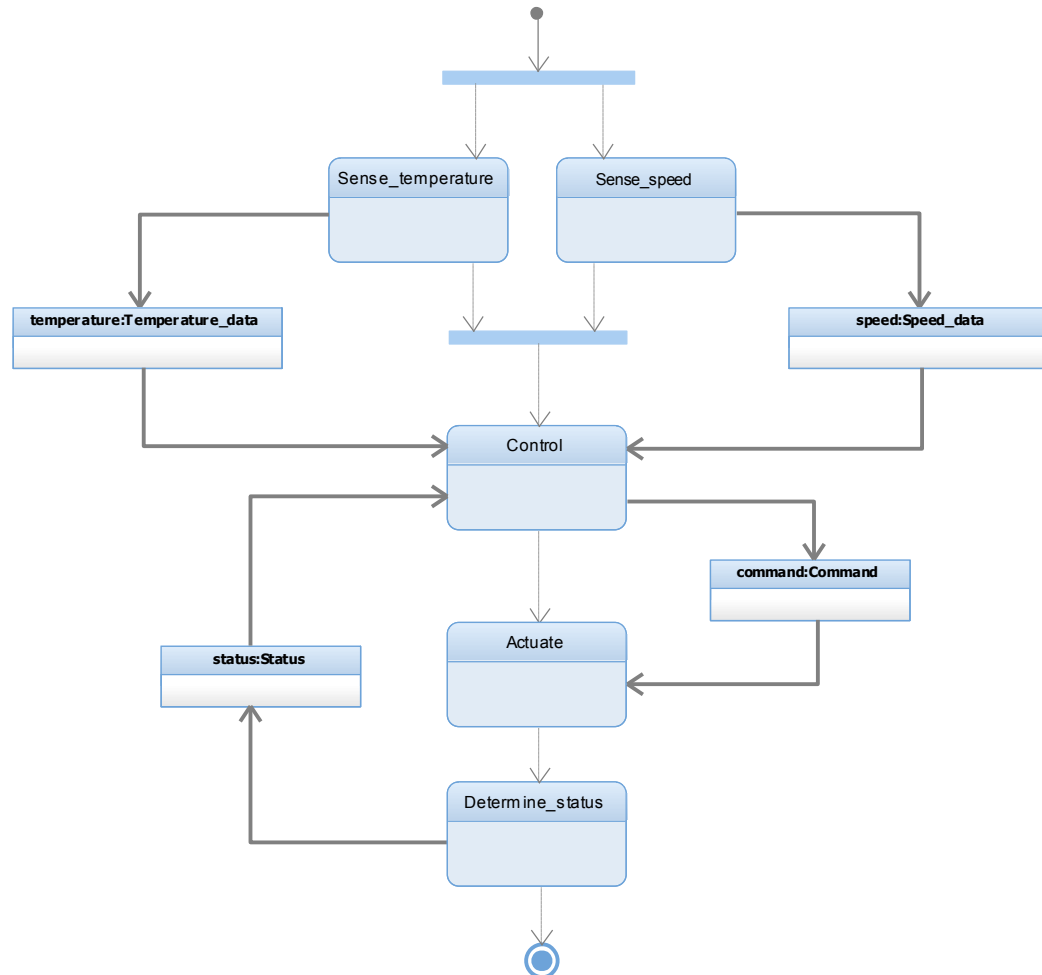
ATG

17 Test cases
94% model element coverage (93/98)
50% MC/DC coverage (18/36)
100% statement coverage (69/69)

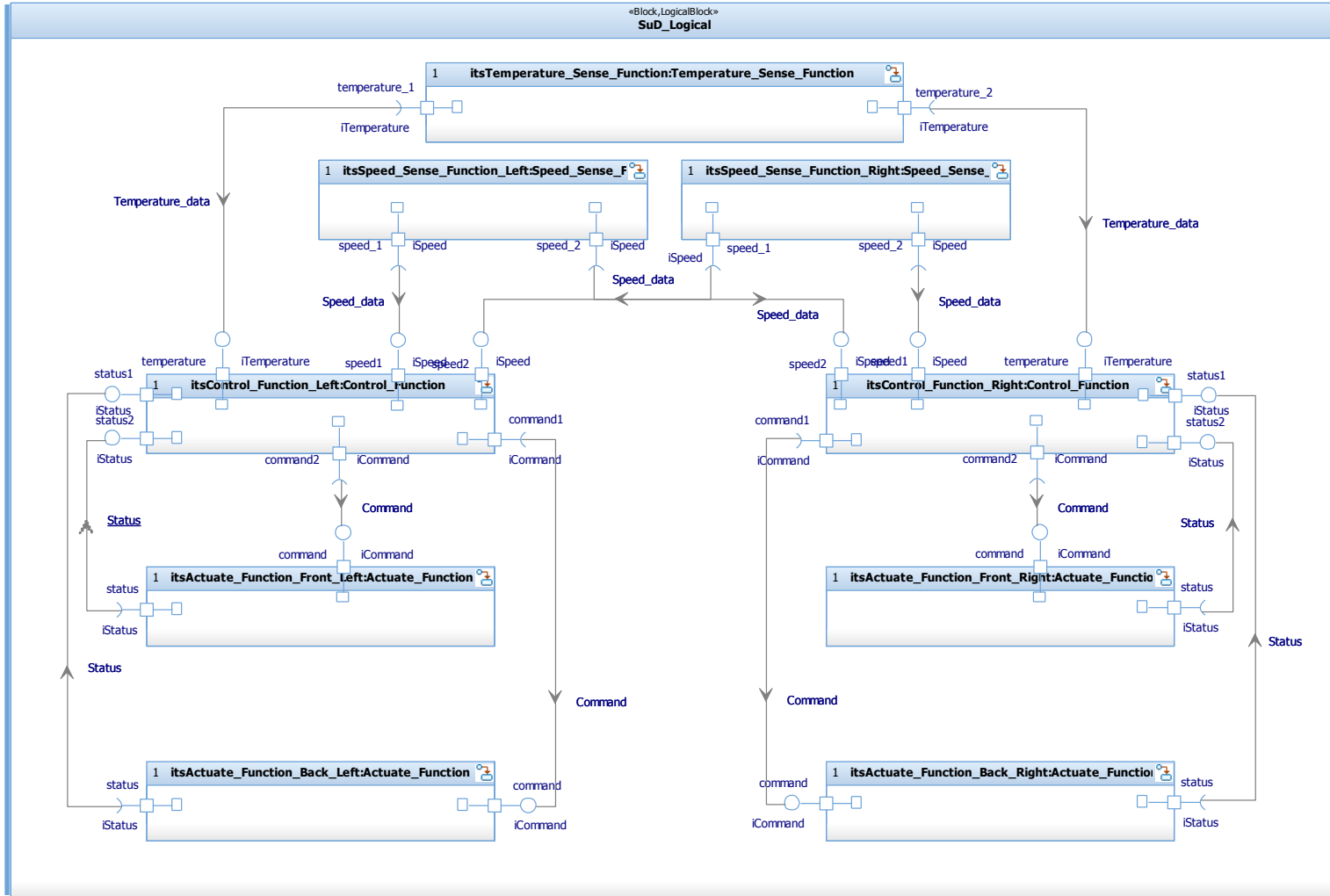
ATG

30 Test cases
95% model element coverage (108/113)
41% MC/DC coverage (57/136)
99% statement coverage (332/335)

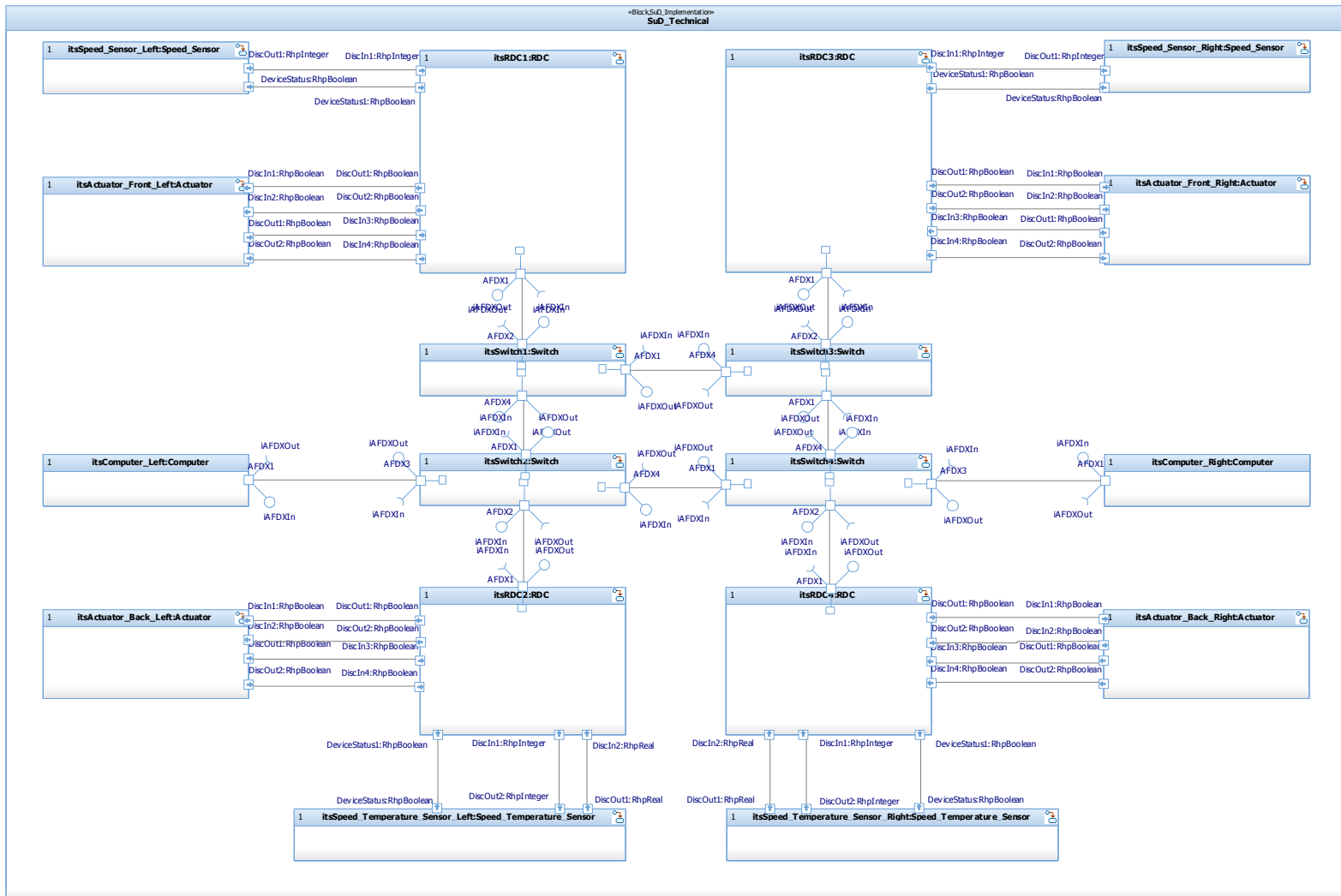
Functional model



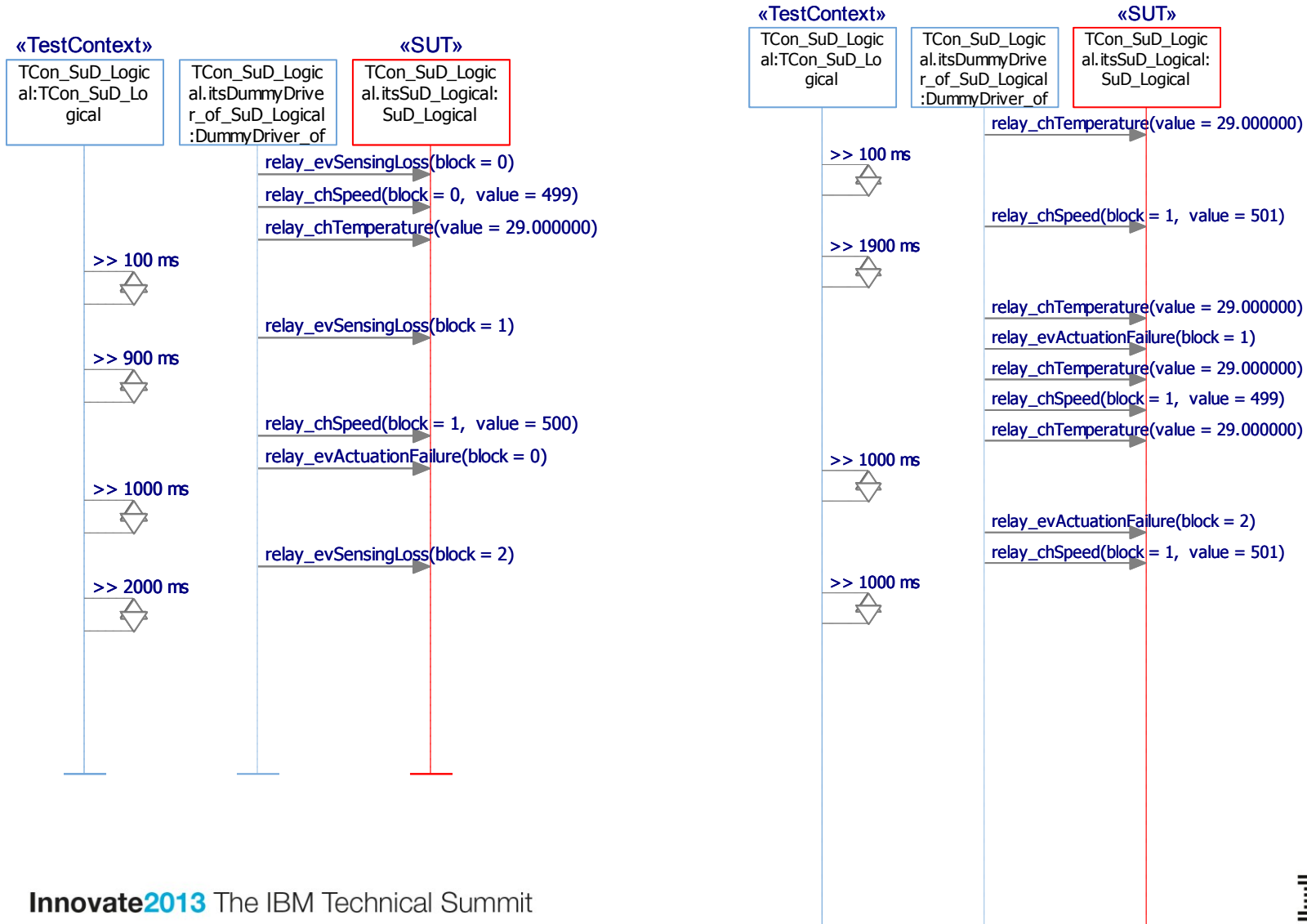
Logical model



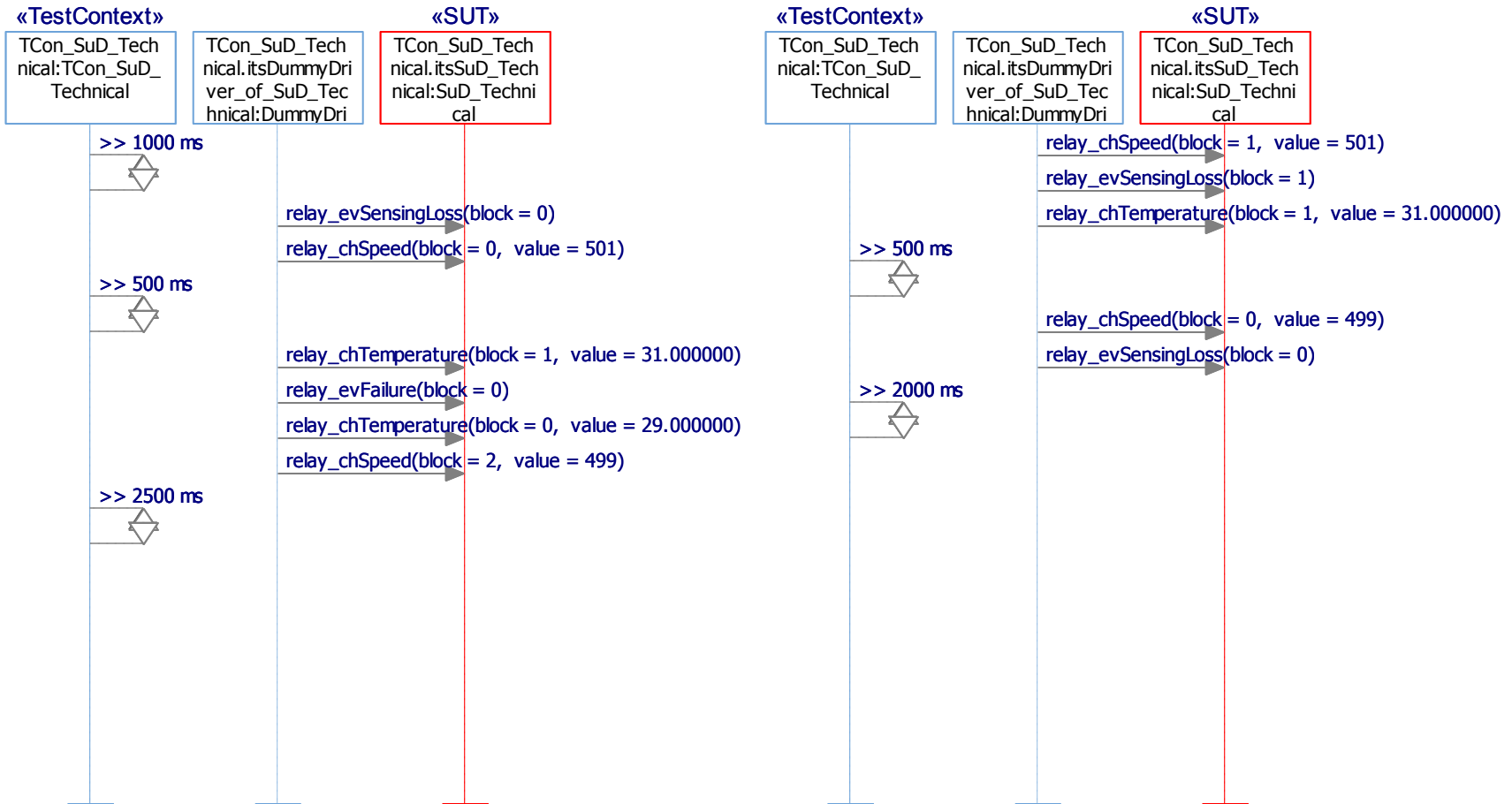
Technical model



ATG Test scenario examples – logical model



ATG Test scenario examples – technical model



ATG screenshot - coverage

The screenshot displays the Rhapsody in C++ Automatic Test Generation interface. The left pane shows a tree view of test configurations and model elements. The right pane shows the 'Coverage Definition' settings and a coverage summary.

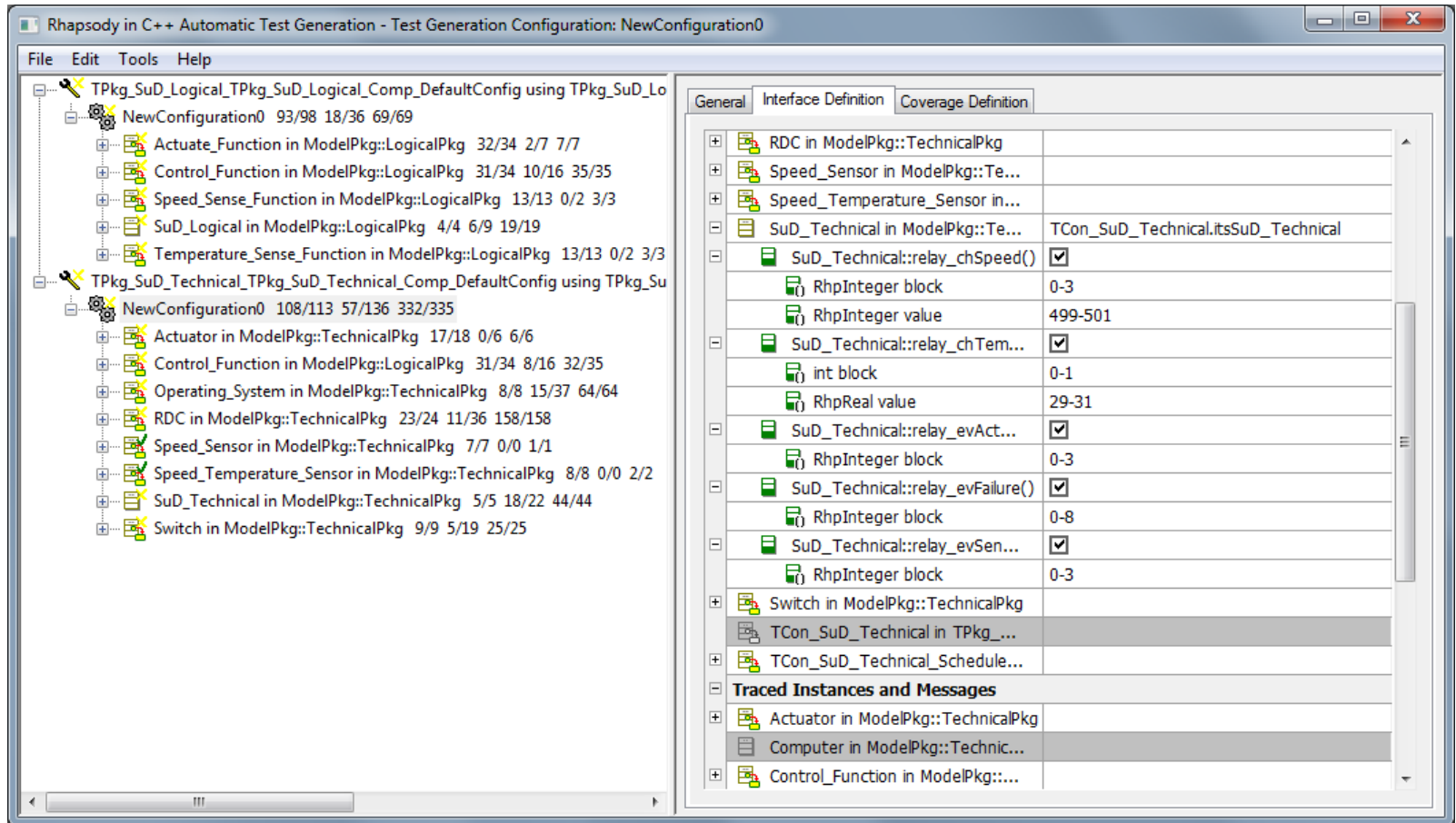
Test Generation Configuration: NewConfiguration0

- TPkg_SuD_Logical_TPkg_SuD_Logical_Comp_DefaultConfig using TPkg_SuD_Lo
 - NewConfiguration0 93/98 18/36 69/69
 - Actuate_Function in ModelPkg::LogicalPkg 32/34 2/7 7/7
 - Control_Function in ModelPkg::LogicalPkg 31/34 10/16 35/35
 - Speed_Sense_Function in ModelPkg::LogicalPkg 13/13 0/2 3/3
 - SuD_Logical in ModelPkg::LogicalPkg 4/4 6/9 19/19
 - Temperature_Sense_Function in ModelPkg::LogicalPkg 13/13 0/2 3/3
- TPkg_SuD_Technical_TPkg_SuD_Technical_Comp_DefaultConfig using TPkg_Su
 - NewConfiguration0 108/113 57/136 332/335**
 - Actuator in ModelPkg::TechnicalPkg 17/18 0/6 6/6
 - Control_Function in ModelPkg::LogicalPkg 31/34 8/16 32/35
 - Operating_System in ModelPkg::TechnicalPkg 8/8 15/37 64/64
 - RDC in ModelPkg::TechnicalPkg 23/24 11/36 158/158
 - Speed_Sensor in ModelPkg::TechnicalPkg 7/7 0/0 1/1
 - Speed_Temperature_Sensor in ModelPkg::TechnicalPkg 8/8 0/0 2/2
 - SuD_Technical in ModelPkg::TechnicalPkg 5/5 18/22 44/44
 - Switch in ModelPkg::TechnicalPkg 9/9 5/19 25/25

Coverage Summary

Coverage Type	Count
Model Element Coverage	113
MCDC Coverage	136
Statement Coverage	335

ATG screenshot – interface definition



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Conclusion

- ATG...
 - works on a SysML specification model
 - achieves a high coverage even for complex models
 - does not have confining modelling restrictions as model checking based test case generators do
 - Helps improving testing performance
- Model-based Testing...
 - Supports in doing a better impact analysis
 - Leads to higher test coverage, resulting in higher product quality
 - Improves test management
 - Reduces overall test efforts

EADS and BTC-ES are partners in the European MBAT research project

MBAT - Combined Model-based static Analysis and dynamic Testing of Embedded Systems



MBAT will increase the competitiveness of European key players in transportation domain by *

- reducing V&V costs for embedded systems by at least **20 percent**
- shortening time-to-market by at least **20 percent**
- increasing the coverage of the embedded system under V&V by at least **30 percent**
- significantly increasing the probability to uncover errors
- enabling higher quality embedded systems

the ARTEMIS Joint Undertaking under grant agreement no 269335 (ARTEMIS project MBAT) and from the German BMBF.



Questions



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