Model-Based Testing: Automated Generation of Test Cases, Test Data, and Test Procedures from SysML Models

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Motivation

- **Model-driven system and software development** has become an established best practice – at least in certain application fields
- **Model-based testing**, however, is an active research area, but many enterprises are hesitant to adopt it as an integrated part of their V&V processes

Motivation

- In this presentation, it is explained why
  - Model-based testing is fit for industrial application
  - The return of investment into test model development is significant, leading to
    - reduced V&V costs
    - increased test strength
    - simpler accumulation of certification evidence

Overview

- Workflow – overview
- Test model development
- Model-based requirements tracing
- Test procedure generation and execution
- Conclusions

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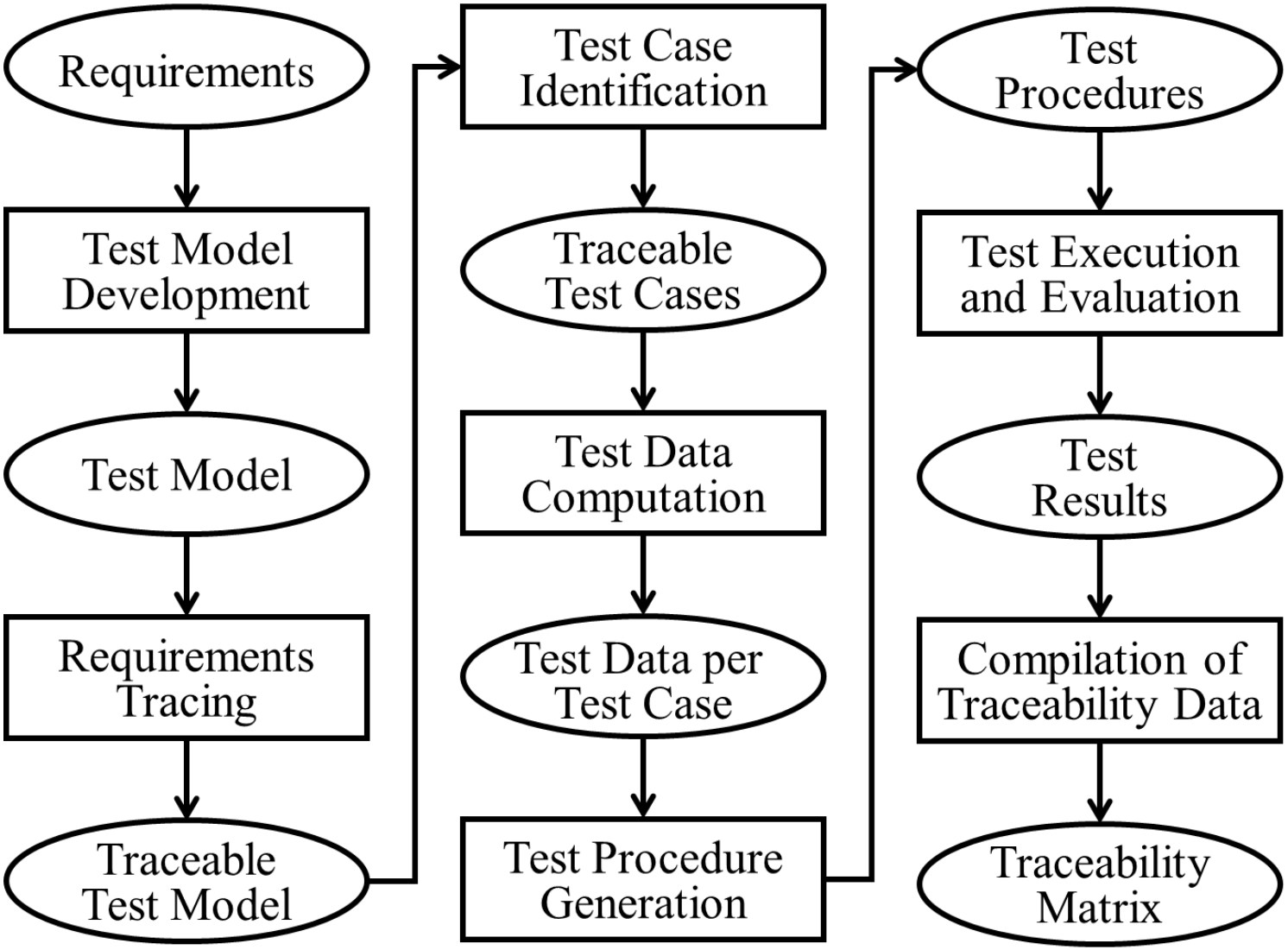
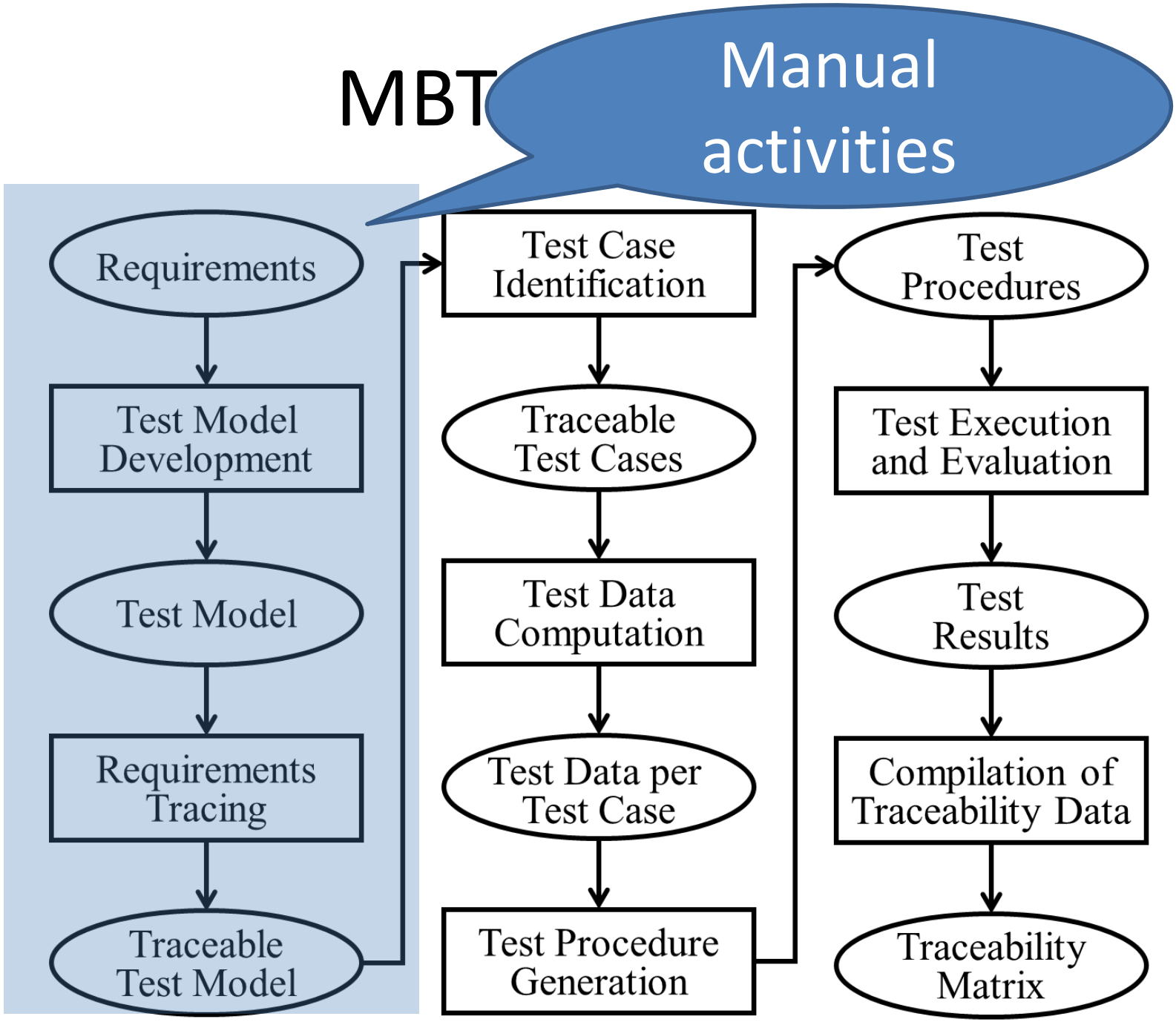
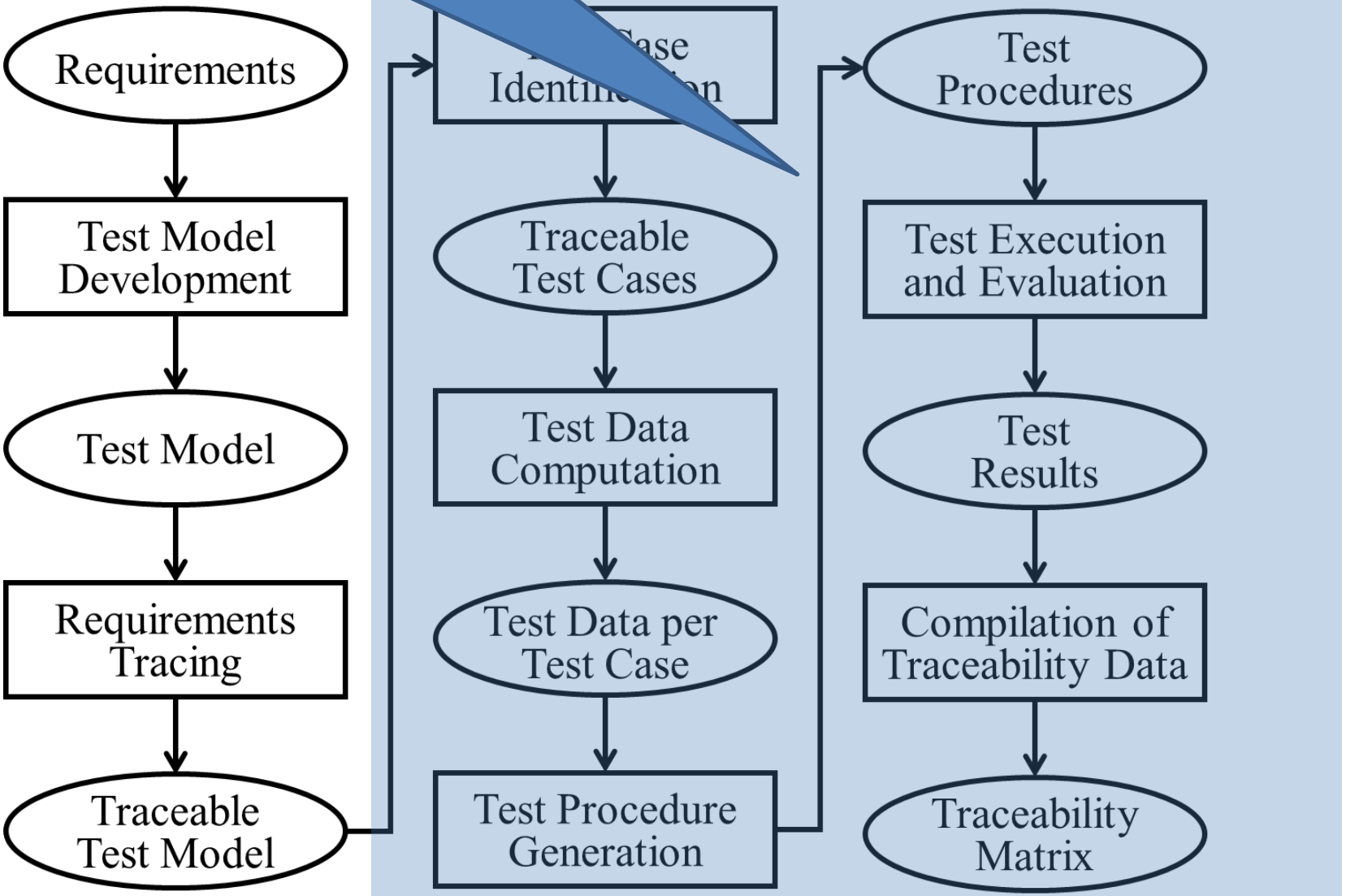
MBT Workflow



MBT


Manual activities
Requirements
Test Model Development
Test Model
Requirements Tracing
Traceable Test Model
Test Case Identification
Traceable Test Cases
Test Data Computation
Test Data per Test Case
Test Procedure Generation
Test Procedures
Test Execution and Evaluation
Test Results
Compilation of Traceability Data
Traceability Matrix

Fully automated activities



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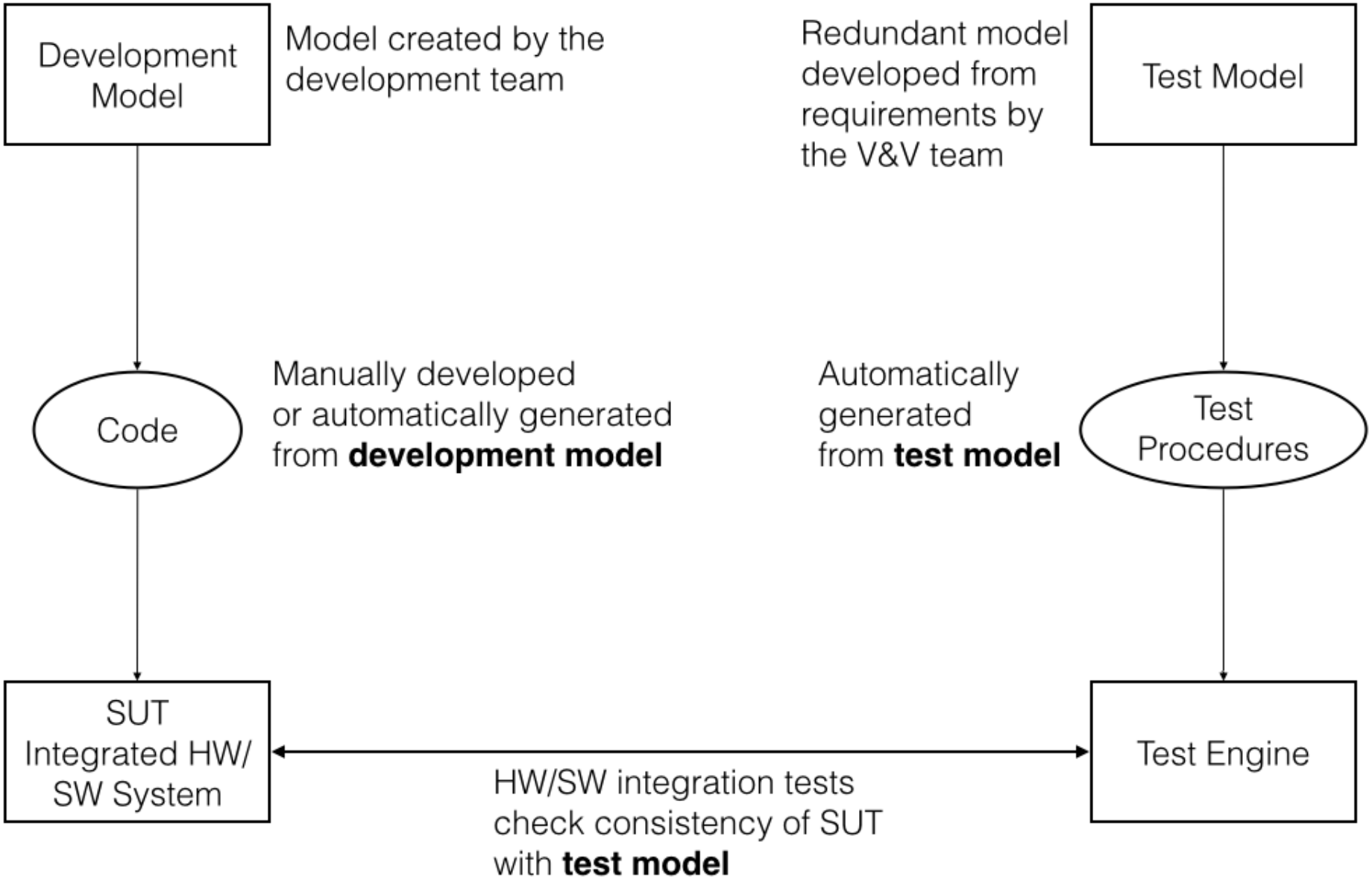
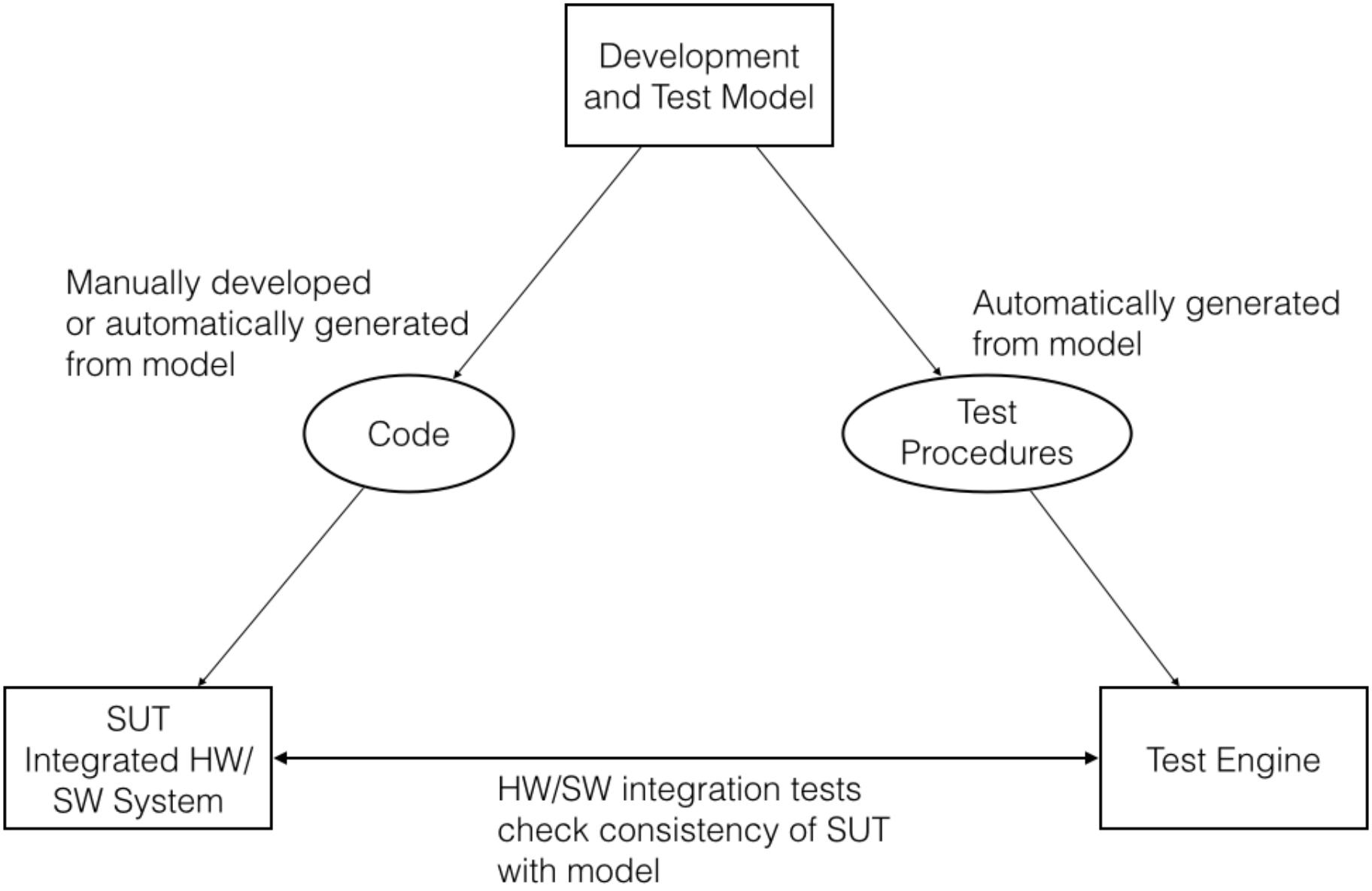
Test Model Development

- The test model specifies
  - **Interfaces** between SUT and environment are represented as readable or writable in the test campaign
  - **Structural aspects** – functional decomposition
  - **Behavioral aspects** – transformation of inputs into outputs, sequencing, synchronisation ...
- Two alternatives for test model creation and utilisation (see next slides)

Validated Test Models – Variant 1



Validated Test Models – Variant 2



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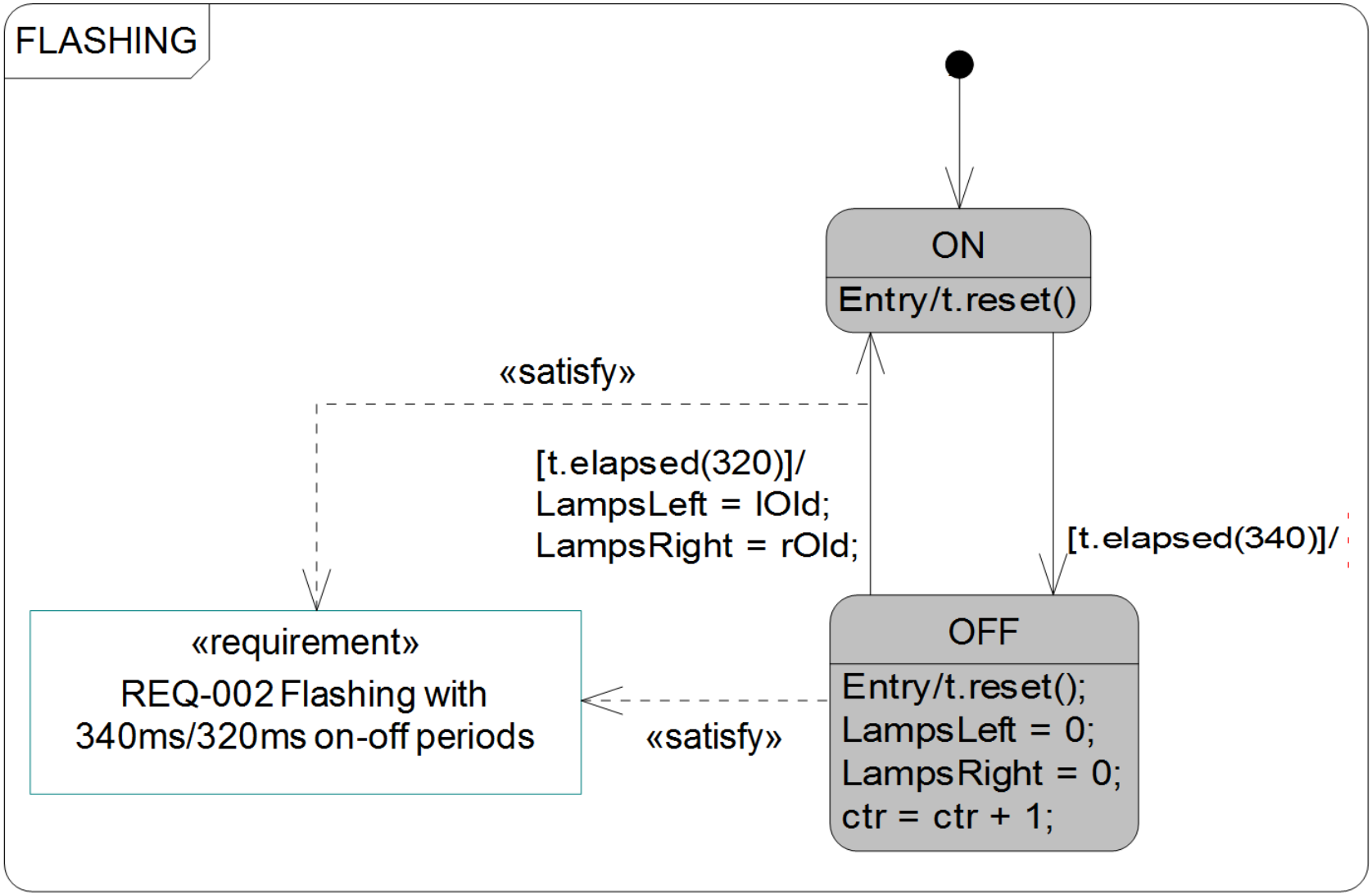
Model-Based Requirements Tracing

- Objective
  - **Link model elements to associated requirements** that are represented by these elements
  - This allows us to identify test cases suitable for verifying a given requirement in an automated way
- **SysML** is a system modeling language providing (graphical and textual) syntax for linking requirements to behavioral and structural model elements

Model-Based Requirements Tracing



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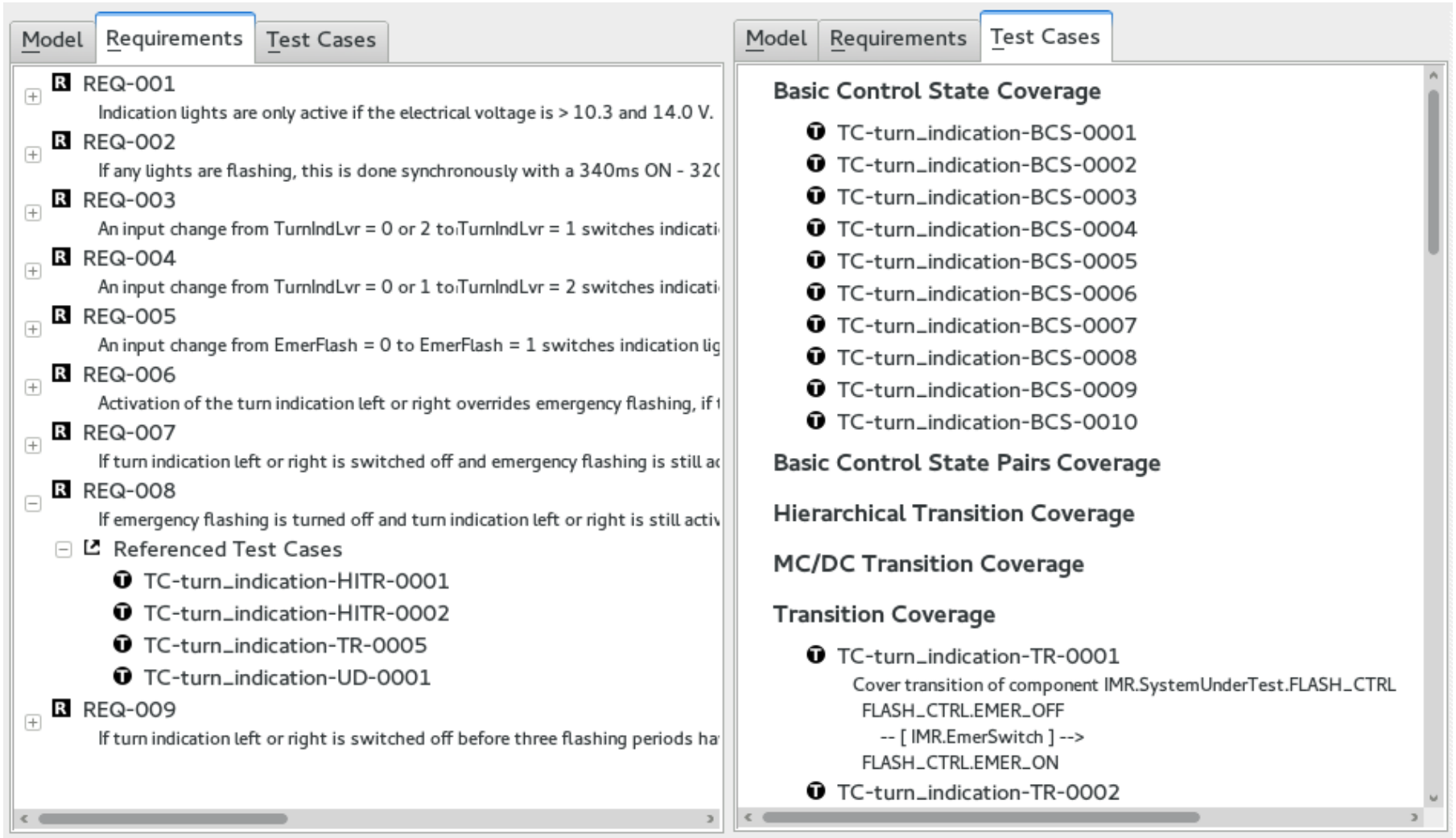
Test Procedure Generation and Execution

- Test cases can be identified by evaluating the links between model elements and requirements
- The behavior expressed by the model can be internally encoded by logical formulas
- The test case is internally represented by a logical formula as well
- → **Concrete test data can be automatically calculated using mathematical constraint solvers**

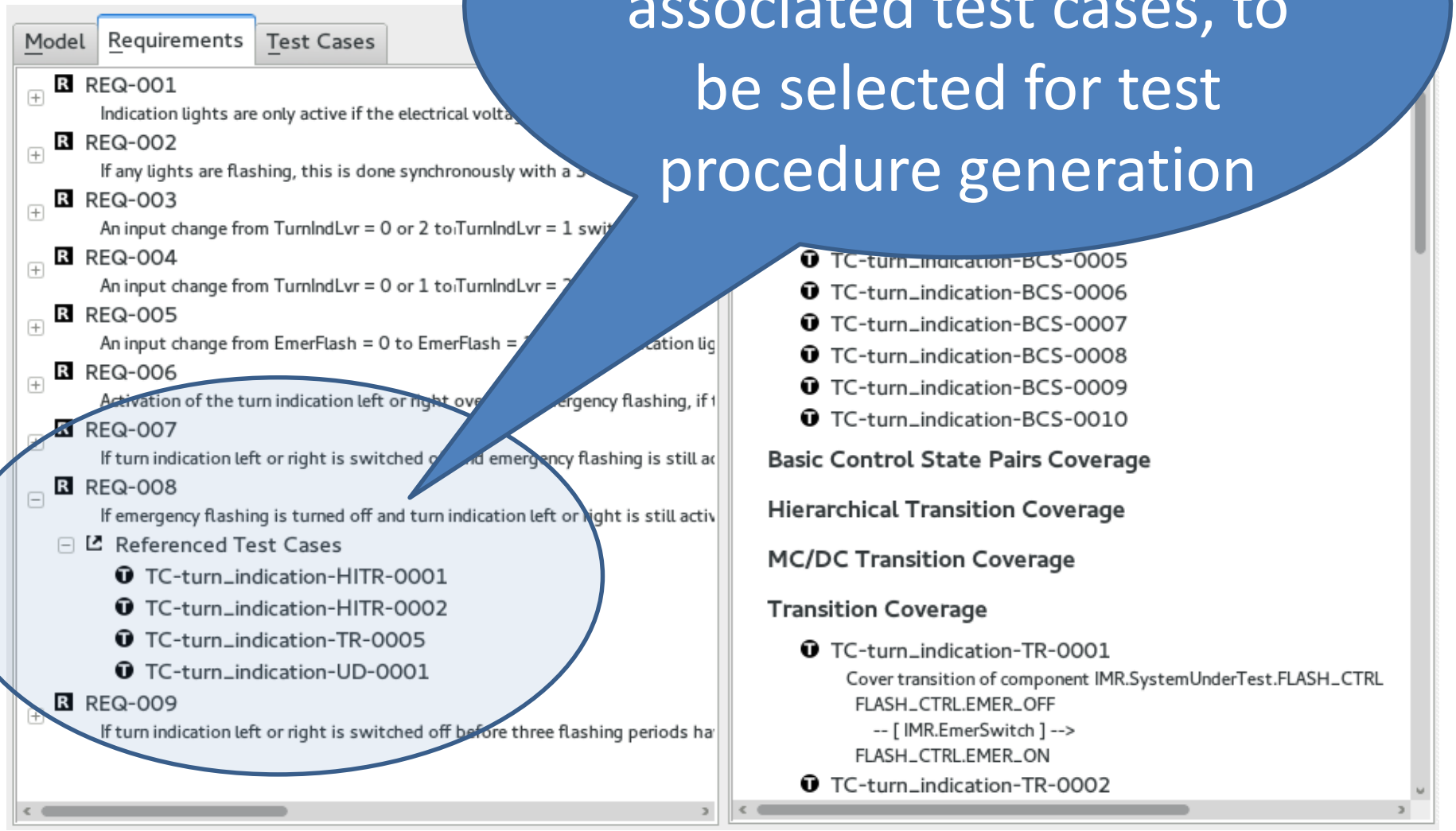
Test Procedure Generation and Execution

- For test procedure generation, users just configure which test cases should be covered by the procedure to be created
  - **Requirements-driven generation** is performed by identifying the requirement (or a subset of related test cases) to be tested by the procedure
  - **Model-driven generation** is performed by identifying the model portions to be covered by the test procedure

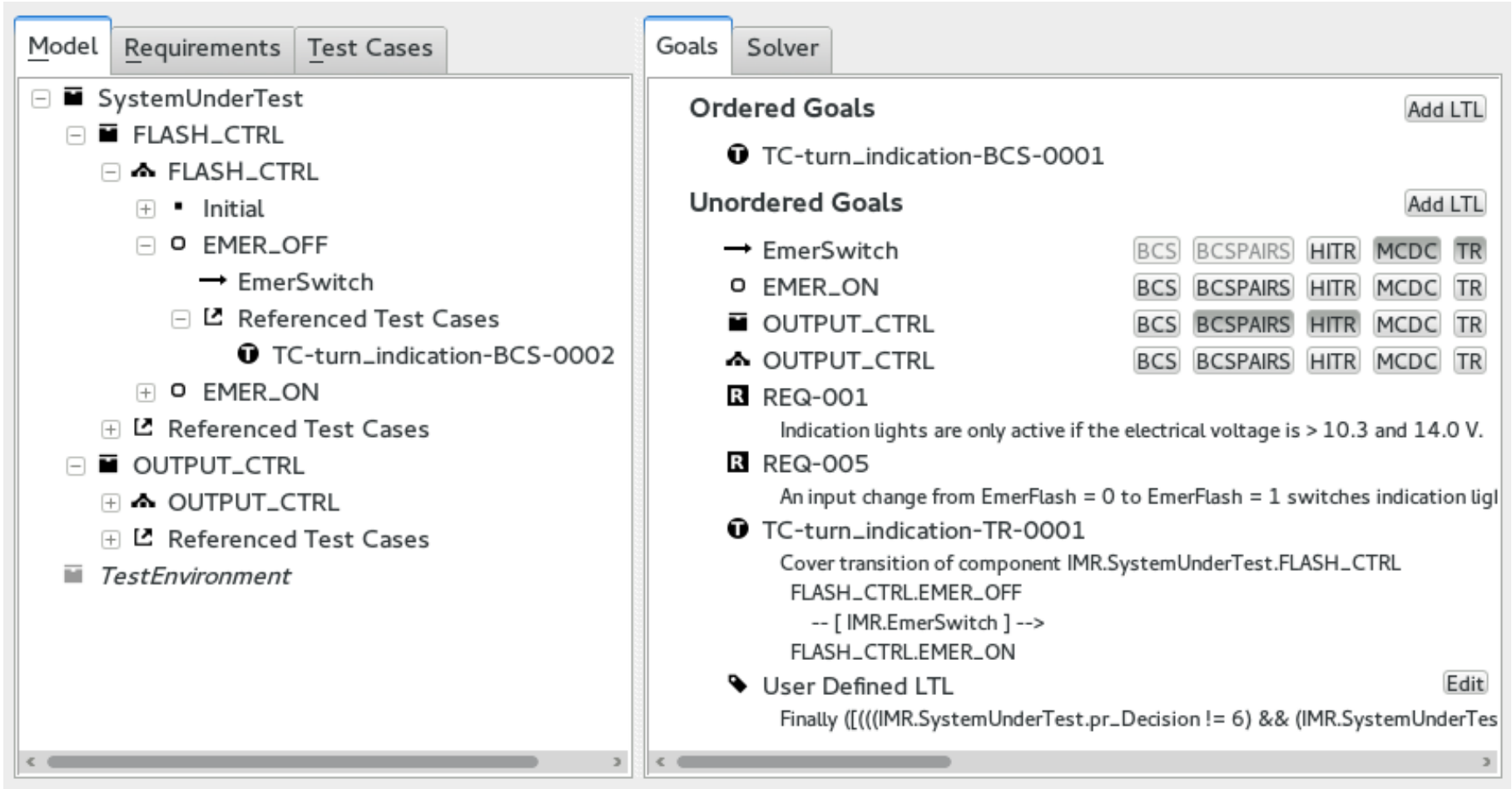
Requirements-Driven Test Procedure Generation



Requirements-D re

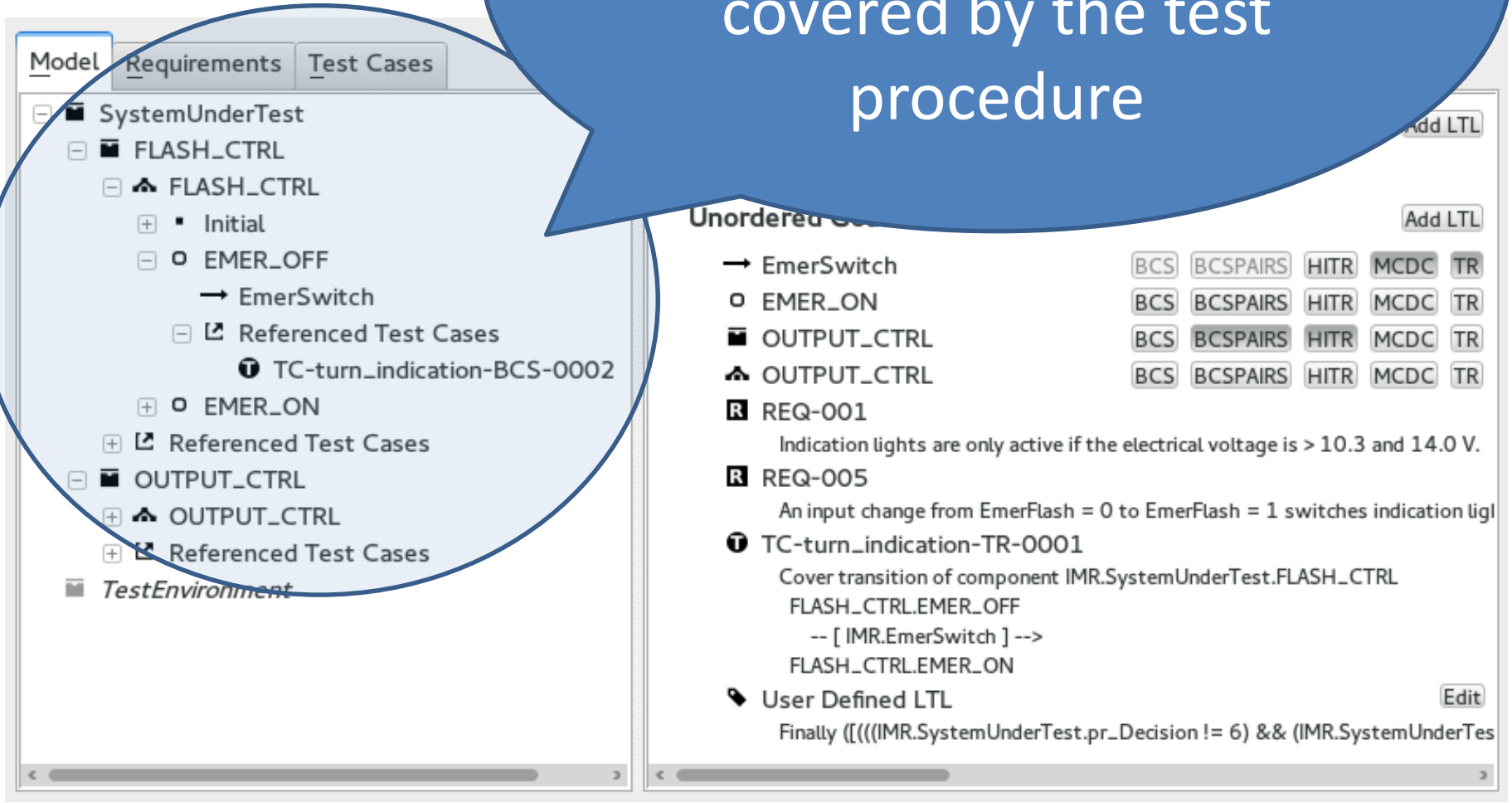


Model-Driven Test Procedure Generation



Model-Driv

Model browser allows to select elements to be covered by the test procedure



Test Procedure Generation and Execution

- 6 Different testing strategies are supported
  - **Simple:** Basic control state coverage, Transition coverage, Hierarchic transition coverage.
  - **Complex**:
    - **MC/DC coverage**. Complex guard conditions are exercised with different valuations of their atomic condition parts
    - **Basic control state pairs coverage**. Interacting state machine pairs are tested in every possible state combination
    - **Equivalence class testing strategy**. Inputs with large data types are automatically partitioned into equivalence classes

Test Procedure Generation and Execution

- Applicable **strategies can be automatically adapted to the criticality of SUT** component under consideration
  - For DAL-C components, transition coverage typically suffices
  - For DAL-A components, the more complex strategies have to be applied as well

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Conclusions

- Model-based testing is fit for large-scale application in industry
- Efficiency measurements performed by Verified Systems show that the following effort reductions in comparison to conventional testing approaches can be expected
  - 30% for a new project, where a new test model has to be created
  - 90% in the best case, where an optimised re-usable workflow has been set up for regular regression testing of a long-lived product