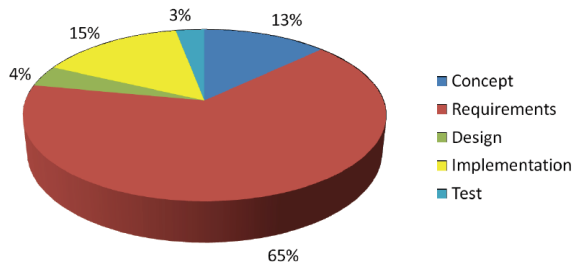


Requirement Modeling and Testing

John Lee and Jon Friedman
MathWorks, Inc.

Distribution of Severity 1&1N Issues: NASA Human-Rated Systems



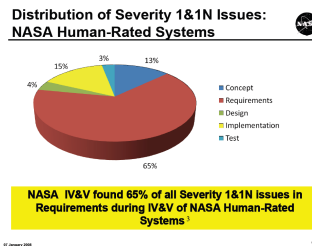
NASA IV&V found 65% of all Severity 1&1N issues in Requirements during IV&V of NASA Human-Rated Systems³

How Can We Reduce the Amount of Requirement Errors?

- Use of Requirements Model to systematically flush out requirement inconsistencies through modeling.
- Use of Requirements Model to improve the quality of the verification result through “pure” requirement based test vectors and coverage analysis.



What is Requirements Model?



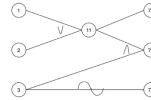
3

Agenda – Questions to be Answered

- What is Requirements Modeling?
- What are the benefits of Requirements Modeling?
- How is a Requirement Model different from a Design Model?
 - Example of a Requirements Model and Requirements-Based Tests.

4

Requirement Modeling and Test Generation using Cause-Effect Graphing



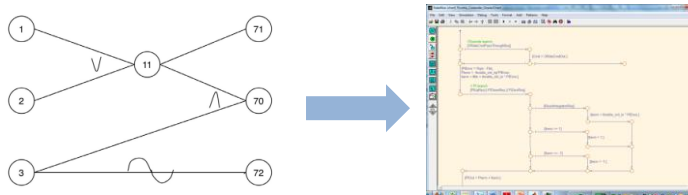
- **Process**
 - Build an independent model of the requirements
 - Create test based on requirements, not the implementation
 - Automatically generate requirement-based test cases from the requirement model

- **Benefits**
 - Identify requirements defect early
 - Increase coverage
 - Reduce time through requirements test cases generation

Myers, Glenford J. (1979). *The Art of Software Testing*. John Wiley & Sons. [ISBN 0-471-04328-1](#).

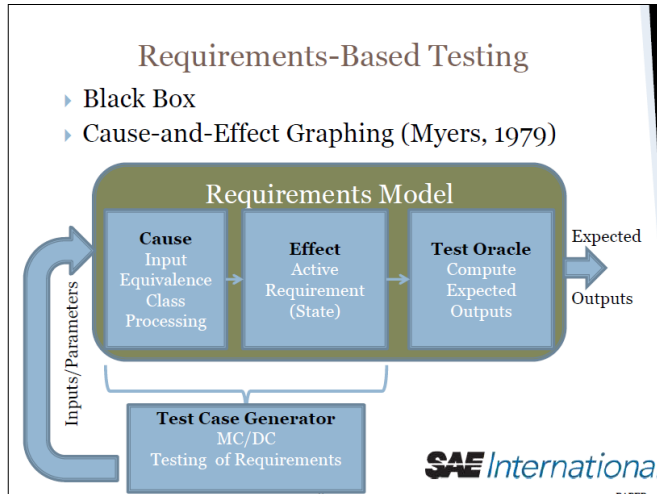
Cause-Effect Graphing

- A **cause-effect graph** maps a set of causes (inputs) to a set of effects (outputs).
- Creates a logical representation of the requirements
- Modeled with stateless-statechart or flow chart



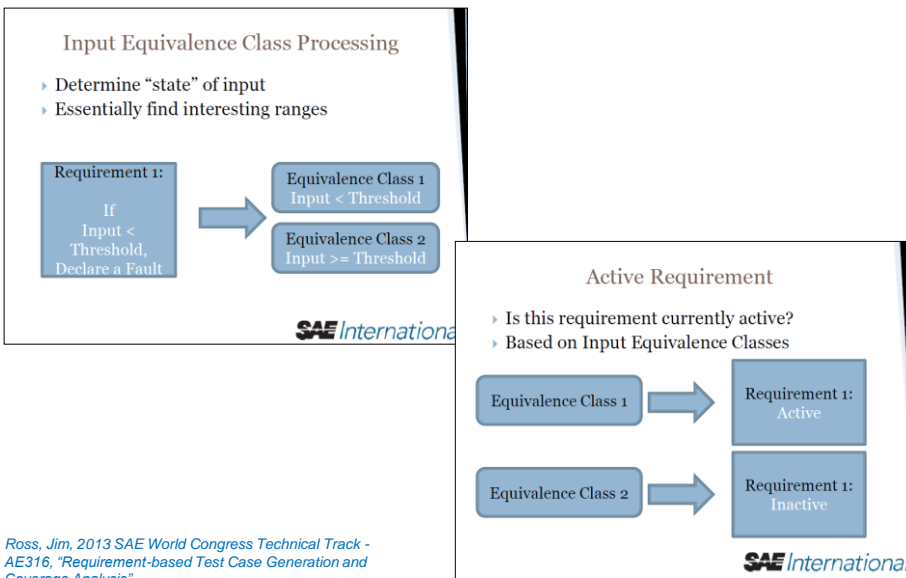
Note: Cause-Effect graph is one example of requirements model

Industry Example of Requirements-Based Testing (2013 SAE World Congress)



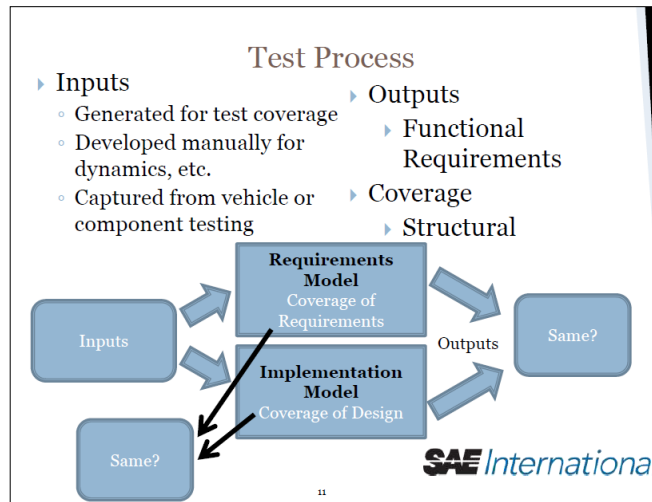
Ross, Jim, 2013 SAE World Congress Technical Track - AE316, "Requirement-based Test Case Generation and Coverage Analysis"

Equivalence Classes and Active Requirements



Ross, Jim, 2013 SAE World Congress Technical Track - AE316, "Requirement-based Test Case Generation and Coverage Analysis"

Compare Requirements and Implementation Model Results



Ross, Jim, 2013 SAE World Congress Technical Track - AE316, "Requirement-based Test Case Generation and Coverage Analysis"

Benefits of Requirements Modeling

- Modeling language supports development of complete and consistent requirements and expected outputs.
- Test Oracle (which generates the expected outputs) is developed independently of the input test vectors.
- Use of requirements model to generate test cases helps prevent creation of test vectors biased by the design.
- Coverage analysis reveals inconsistencies between requirements and design.

Building of
Requirements Model
(Cause, Effect, and
Test Oracle)

Test Generation using
Requirements Model

Auto Pilot Example

Textual Requirement

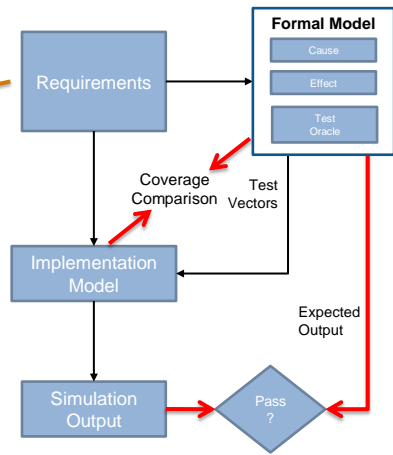
1. Roll Autopilot Requirements

1.1. Roll Autopilot Engage Control

Requirement	Roll Autopilot shall engage when the pilot selects the autopilot engage switch in the cockpit and disengage when the switch is deselected. When not engaged, the command to the roll actuator shall be zero.
Rationale	The autopilot should only be engaged when the pilot selects it.

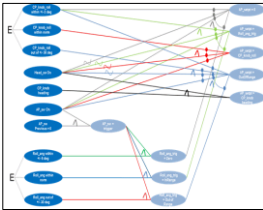
1.2. Roll Hold Mode

Requirement	Roll hold mode shall be the active mode whenever the autopilot is engaged and no other lateral mode is active.
Rationale	Roll hold mode is the default mode in the roll axis for the autopilot when no other mode is active.

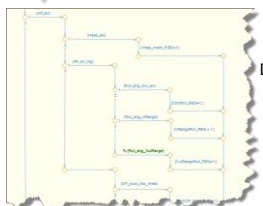


Auto Pilot Example

Cause-Effect Graph

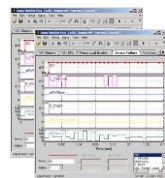


Translate Cause-Effect Graph to Stateflow Diagram

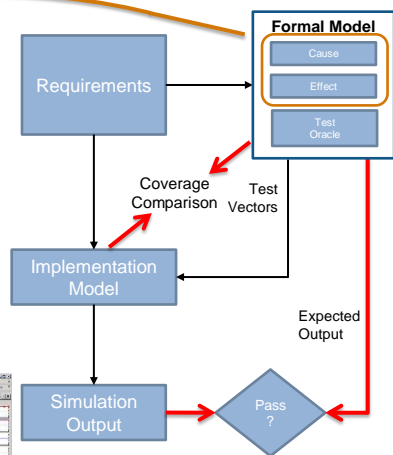


Stateflow Model

Simulink Design Verifier



Test Vectors



Auto Pilot Example

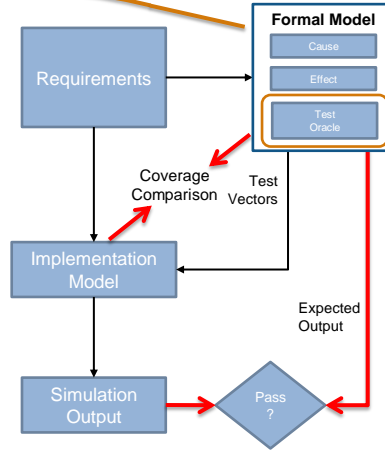
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Use to create Test Oracle (expected output)

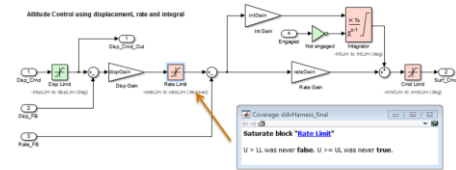


Stateflow Model of Test Oracle



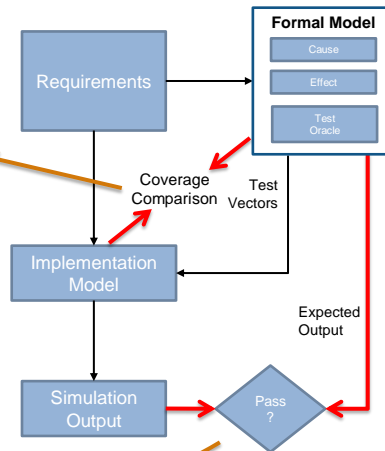
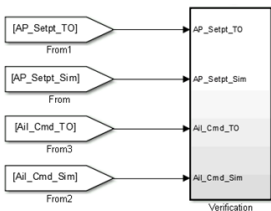
Auto Pilot Example

Analysis: Coverage comparison

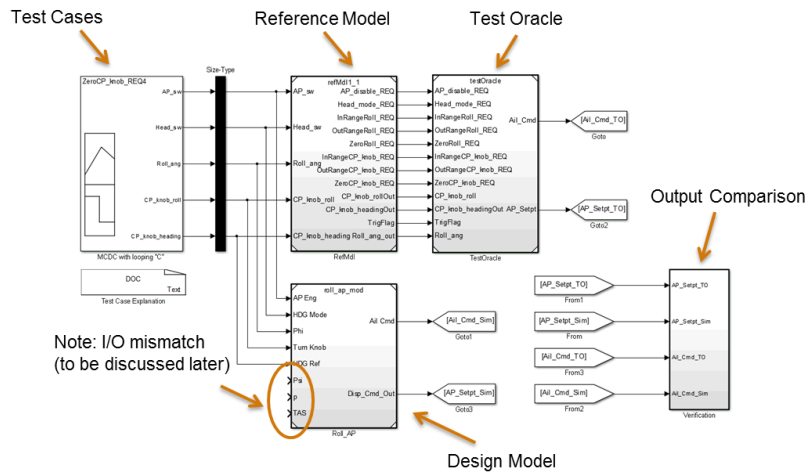


Note: blocks in red have missing coverage information

Analysis: Output comparison



Results – Identification of Undocumented Requirements or Design Assumptions



Autopilot Example

- Summary:
 - Cause-Effect graphing is one way to systematically analyze each requirement (including interactions with other requirements).
 - Results of test generation (unreachable objectives) can point to potential conflicting requirements.
 - Discrepancy between requirements model and design model can highlight inconsistency resulting from undocumented requirements and/or design elements needing additional requirements.
 - Building Cause-Effect graphs is a time investment. Return on Investment:
 - Avoiding potential rework (redesign and retest) later in the process due to requirements issues.
 - Test case generation from the requirements models.
 - Automation of the test result review via scripted comparison with the test oracle.