DRYING CONTROL LOGIC DEVELOPMENT USING MODEL BASED DESIGN

Whirlpool CORPORATION

GTEC

Problem Definition

"To generate and deploy automatic code for Drying Control Logics compatible with new SW architecture in 6 months using MBD, a novel approach "

Key Challenges

- Drying Control logic is combination of four different modules having different Software routines.
- Generate AutoCode compatible with new Software Architecture
- Unclear requirements for Fault, Power and Safety Management

Need for Drying Control Logic

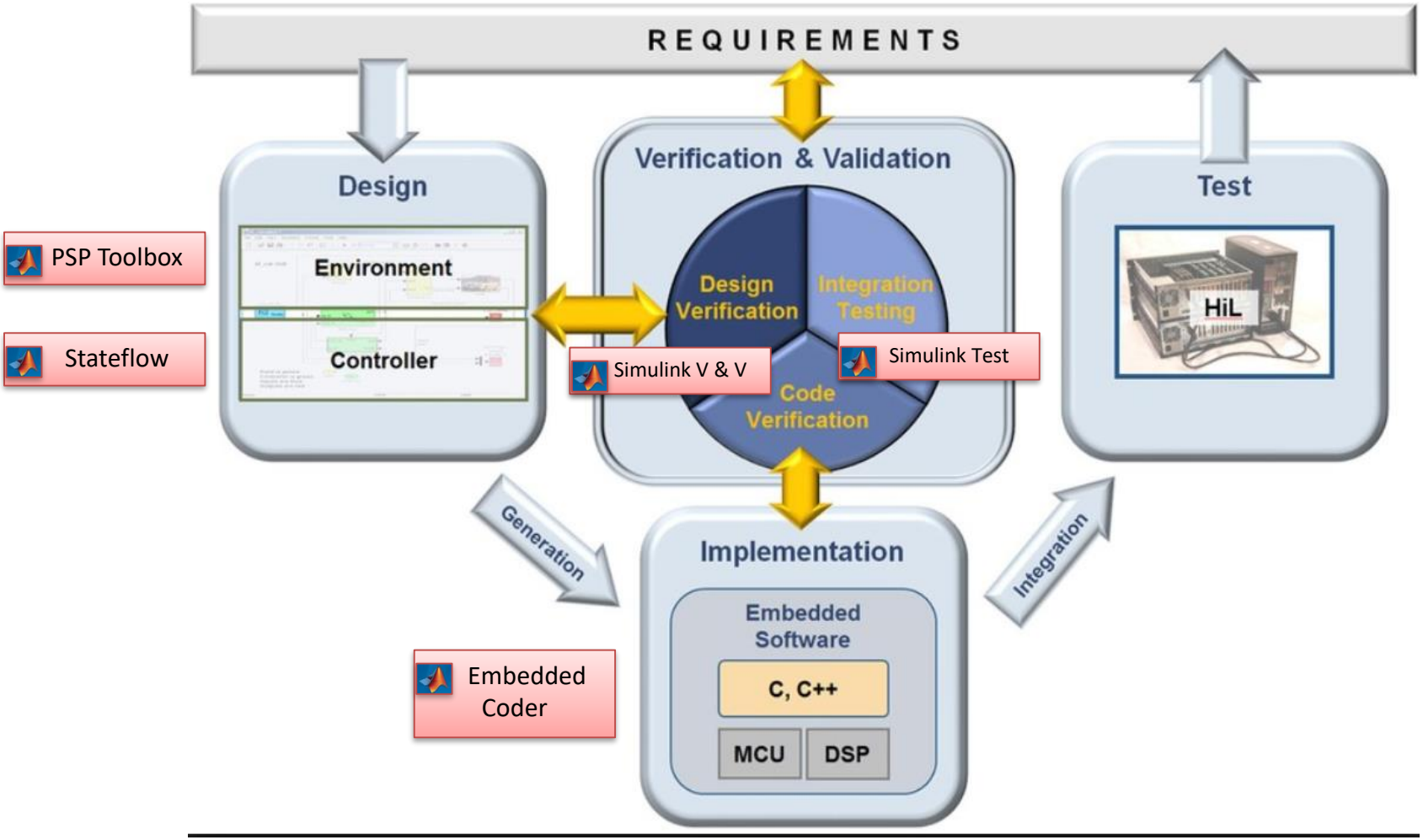
Washing machine with Drying Control

To have optimized Drying cycle for different load types and size

To avoid over drying and damage to laundry

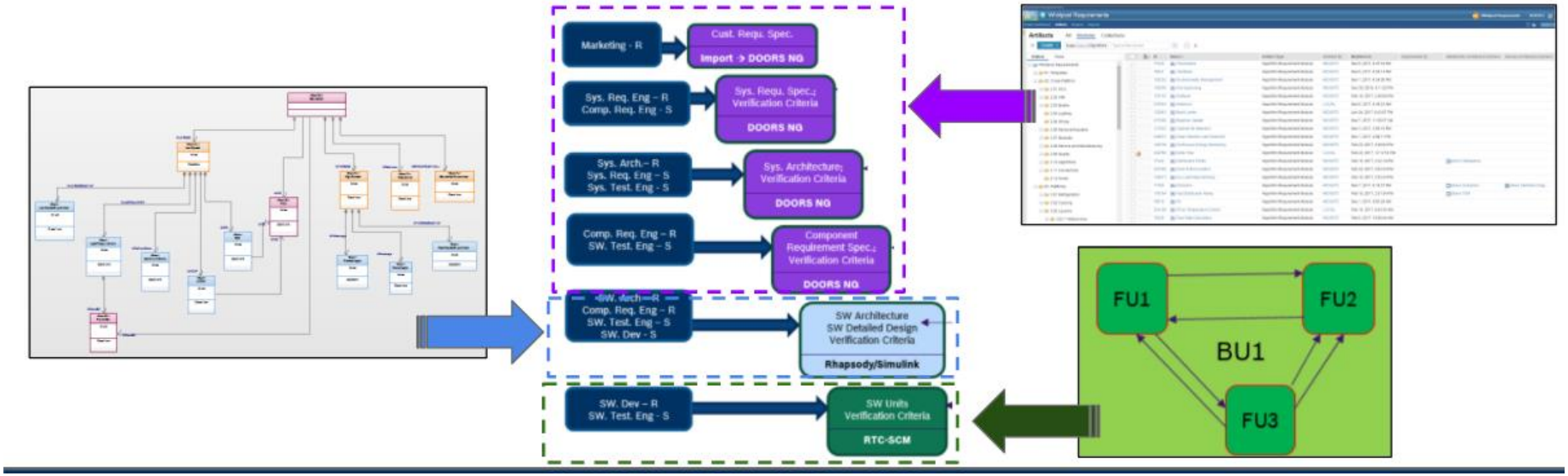
Ease of use for customer

Approach


REQUIREMENTS
Design
Environment
Controller
Verification & Validation
Design Verification
Integration Testing
Code Verification
Test
HiL
PSP Toolbox
Stateflow
Simulink V & V
Simulink Test
Generation
Integration
Implementation
Embedded Software
C, C++
MCU
DSP
Embedded Coder

Requirements

- In Whirlpool, all requirements are defined, managed and reported through Rational Doors Next Generation.
- Stateflow and Simulink are used for gap analysis
- Multiple iterations of review and discussions were performed
- Referencing of interfacing inputs and feedbacks



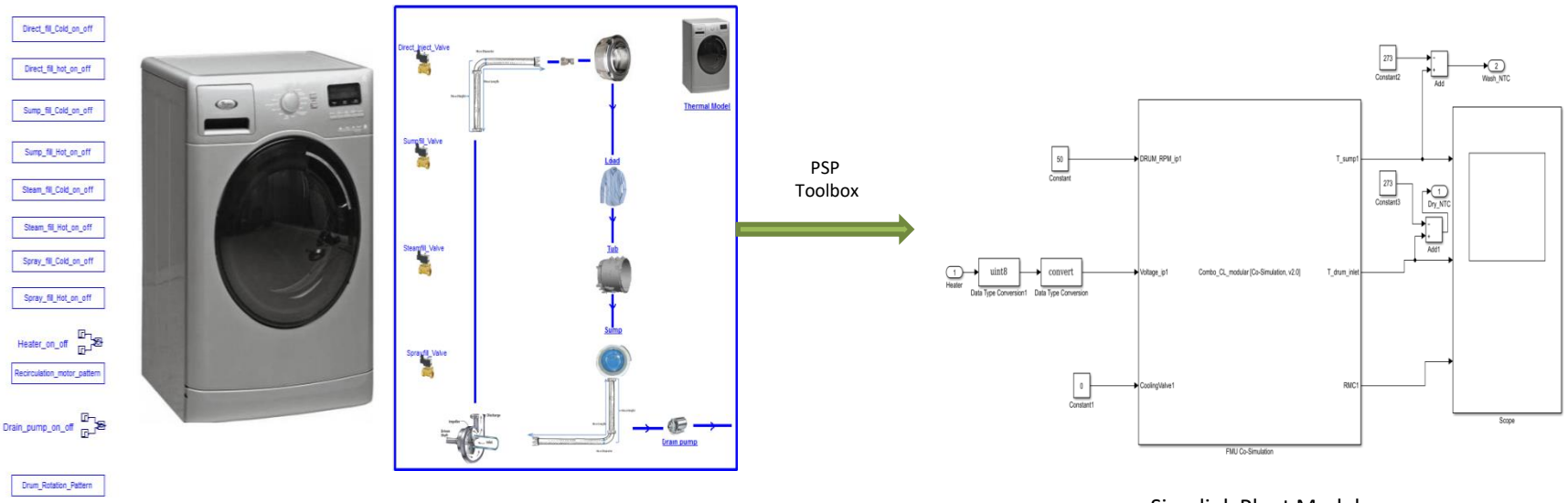
Requirements Reviews and Discussions

Modeling and Requirement Refinements:

- Added tuning parameters(timing, calibration parameter)
- While modeling missing parameters, relationships, interfaces were identified and corrected.
- Identified missing requirements required for Fault and Safety Management.
- Stateflow enabled to define transition, conditions and actions in the control logic

Plant Model Development

- Washer-Dryer plant model imported into Simulink from Dymola.
- System Models are developed by System modeling team.
- MBCD team will import these for Algorithm Validation in Simulink.
- Tools Used:- PSP Toolbox from Mathworks.

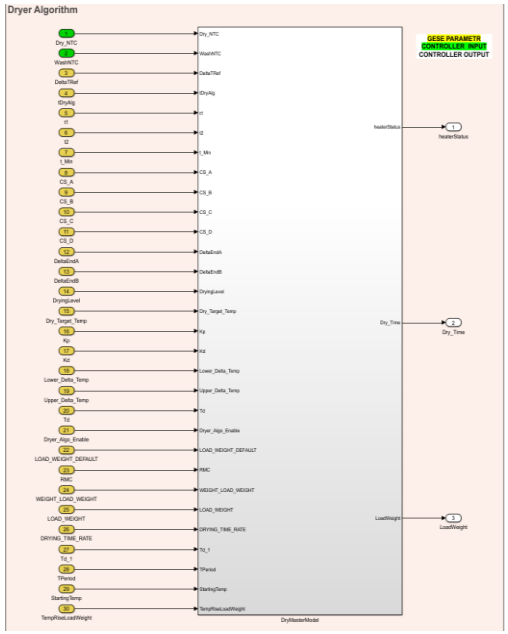


Plant Model in Dymola

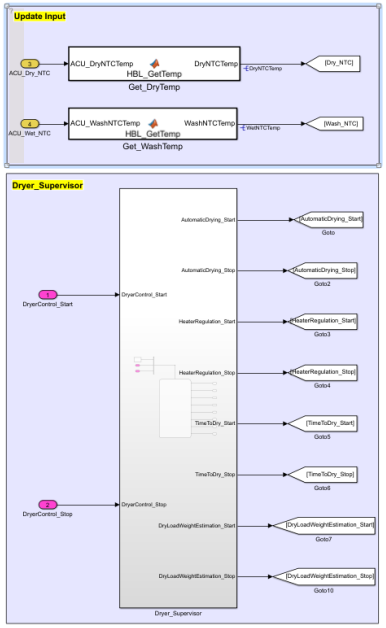
Simulink Plant Model

Mathworks PSP Toolbox

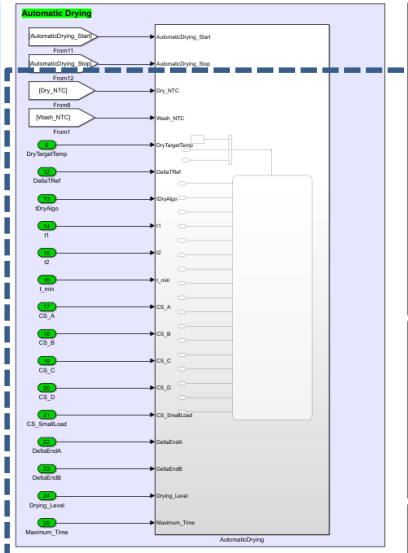
Control Logic Development

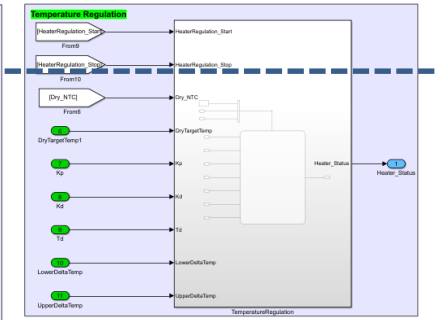


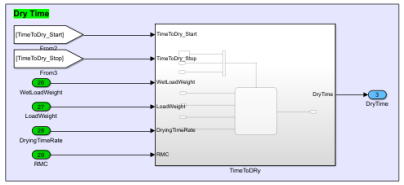
Model Overview:
Drying Logic Top Level

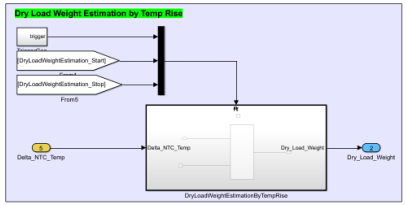


Drying Logic
Functional Unit







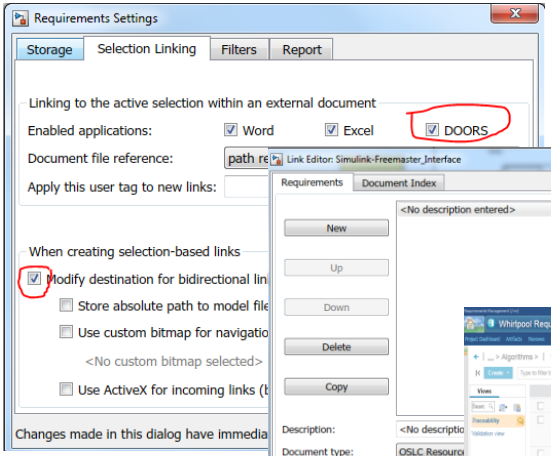


Drying Logic Modules

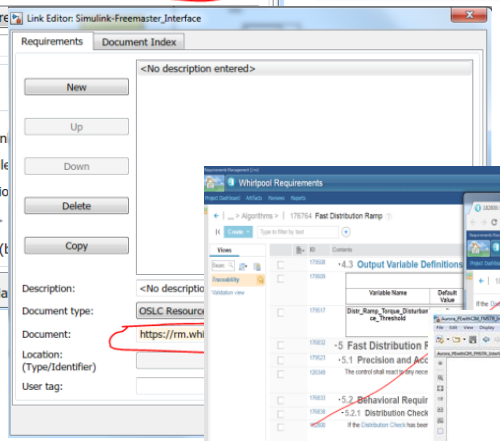
Simulink and Stateflow

Requirement linking from Simulink to DNG

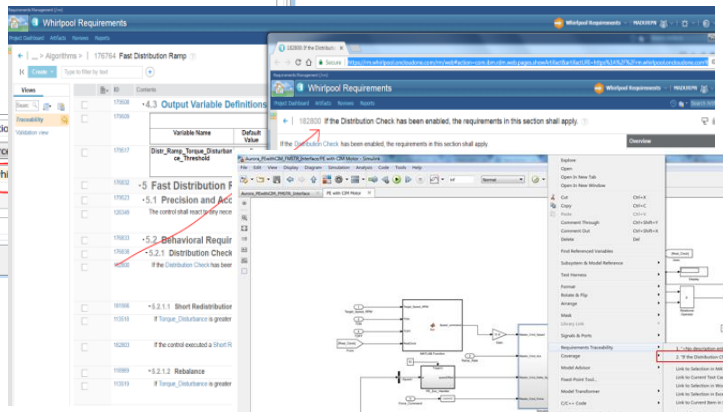
Configure Requirement Settings



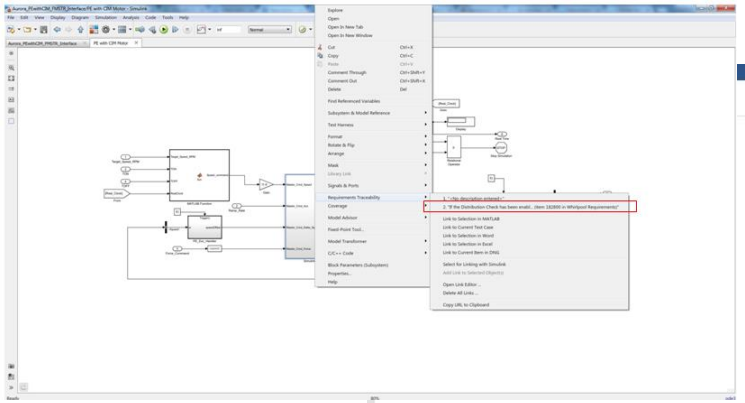
Select Project Area from DNG



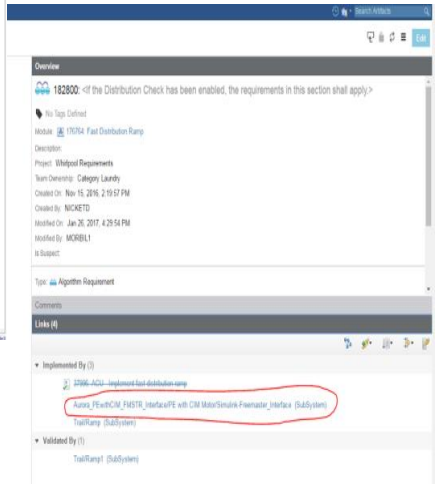
Selecting Requirement from DNG



DNG Link of requirement in Simulink



Simulink Implemented link in DNG



Simulink Verification & Validation

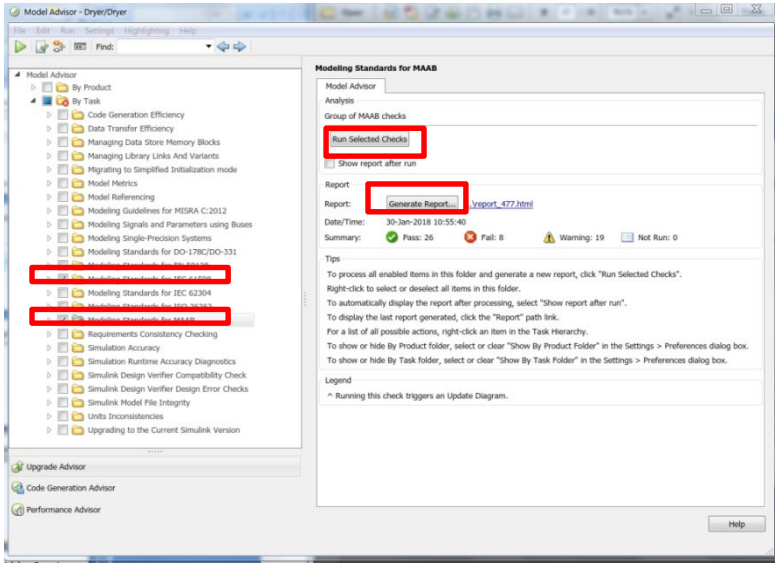
Model Analysis

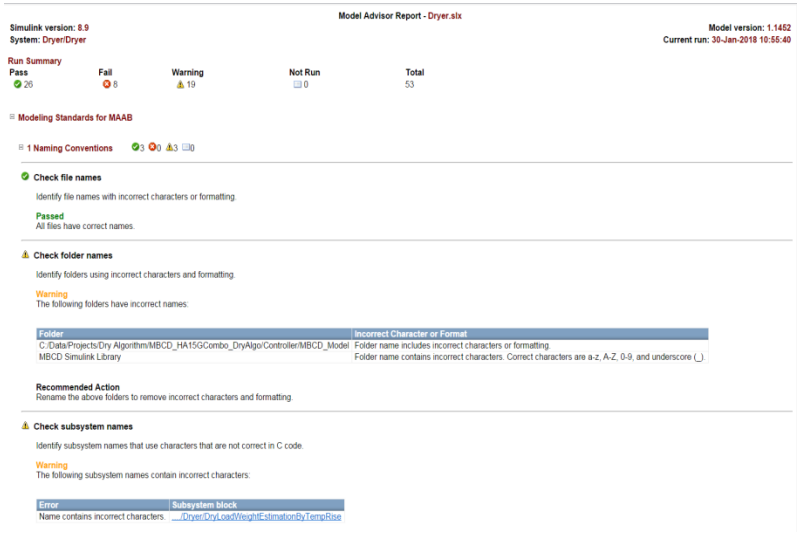
Following standard guideline checks were performed:

- **MATHWORKS Automotive Advisor Board**
- **IEC 61508**

Warnings and Failures are corrected after analyzing reports (e,g)

- Identify signal labels and block labels that are not correct for C variable names.
- Check usage of exclusive and default states in state machines
- Identify mismatches between names of Stateflow ports and the associated signals.

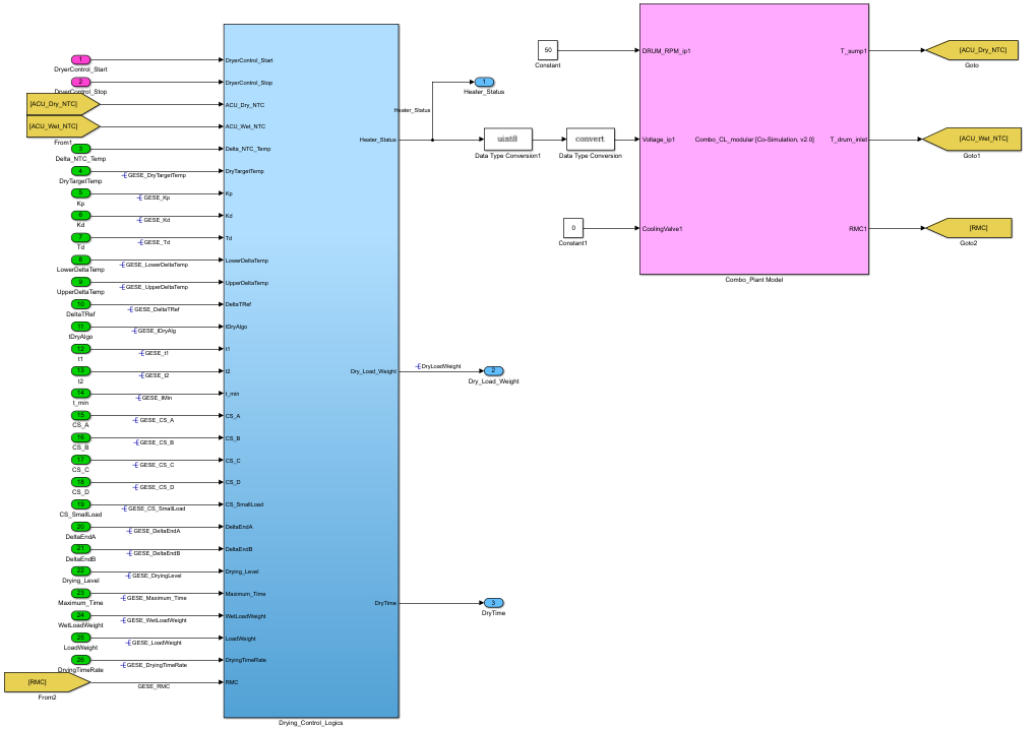


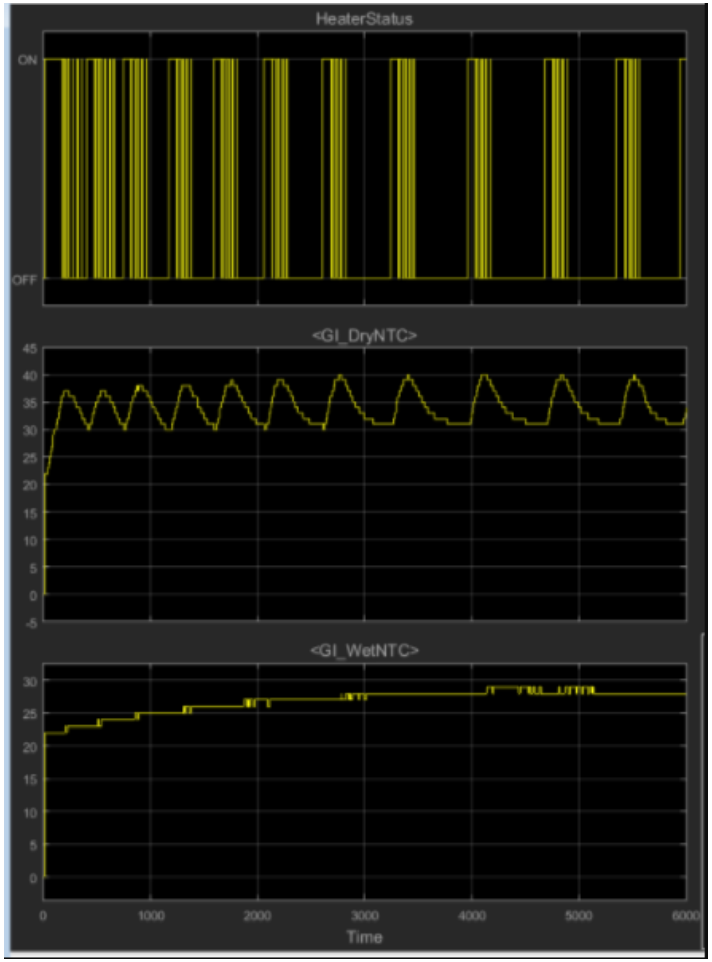


Simulink Verification & Validation

Simulink Model Advisor

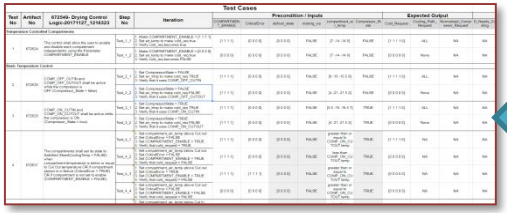
Control Logic Validation with Plant Model





Control Model Verification & Validation- MIL

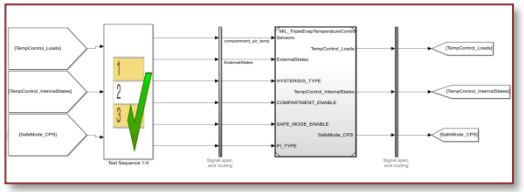
Whirlpool CORPORATION



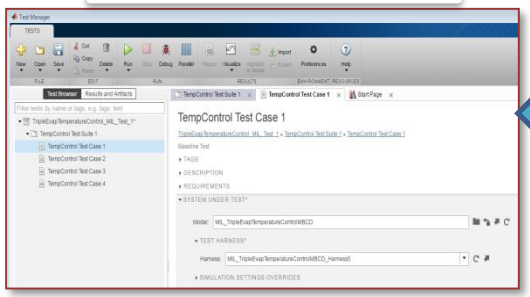
Test Case Preparation

Test Harness Creation

Simulink V & V

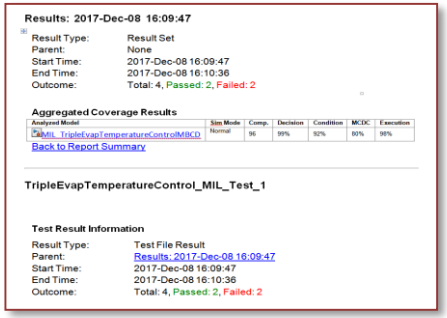


Simulink Test Manager

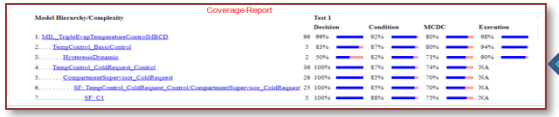


Running Test Cases

Generating Test Reports



Model Coverage Analysis

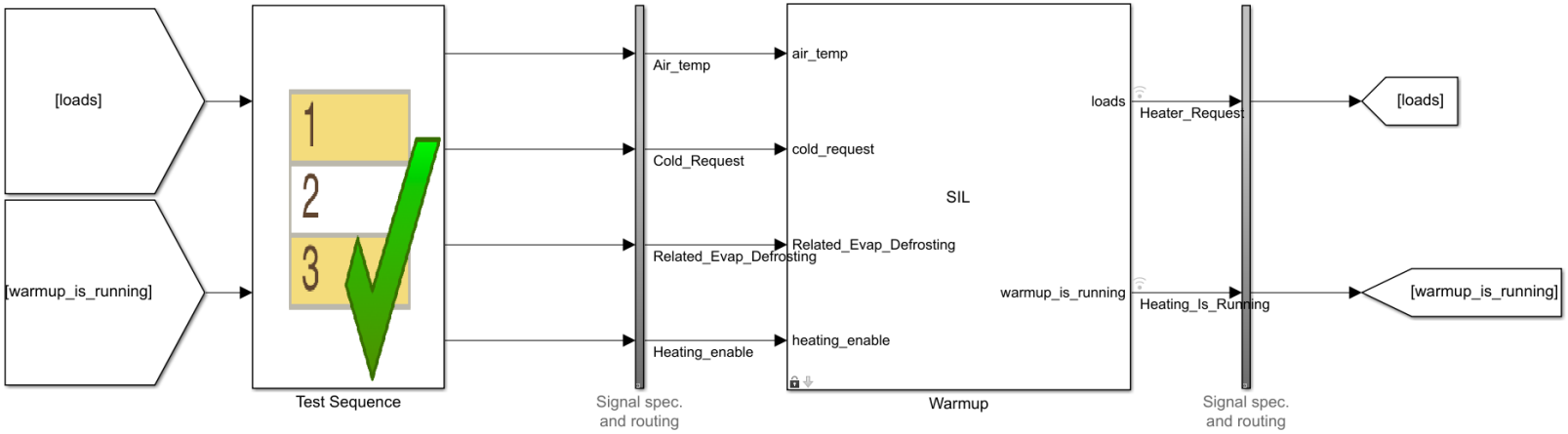


Simulink Verification & Validation

Simulink Test

Control Model Verification & Validation- SIL

- **Results of SIL are compared with Model test results**
- **Same test cases can be used**
- **Test source code on development computer**
- Report of SIL includes untraceable code or model part as well as gaps between model output and generated code output

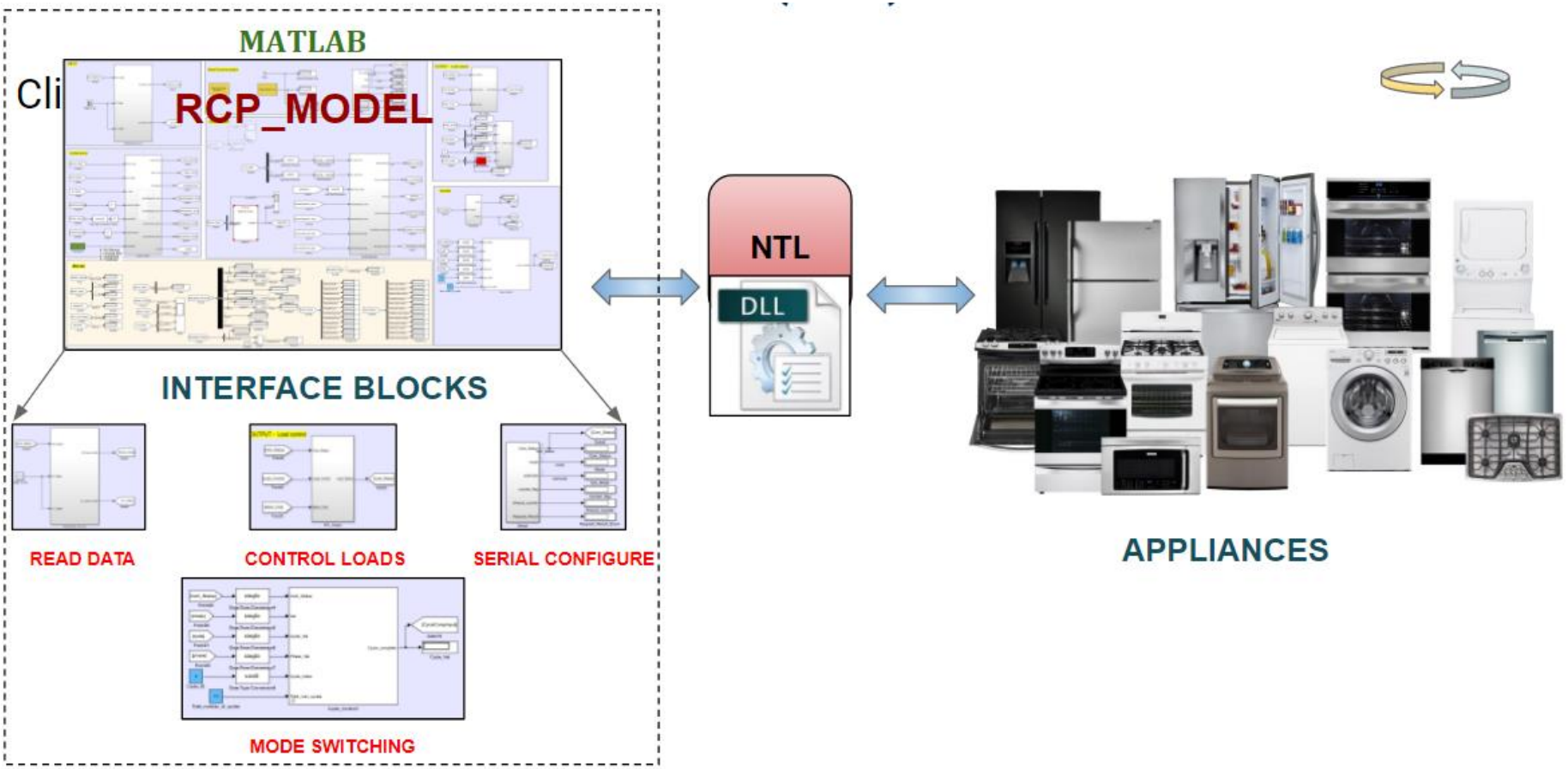


Simulink V&V

Simulink Test

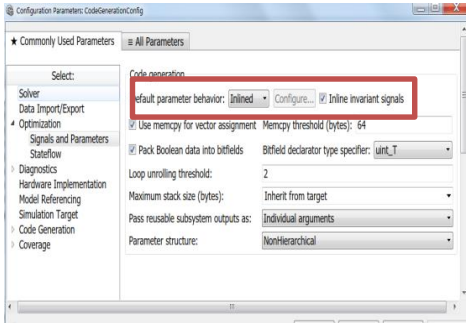
Simulink Embedded Coder

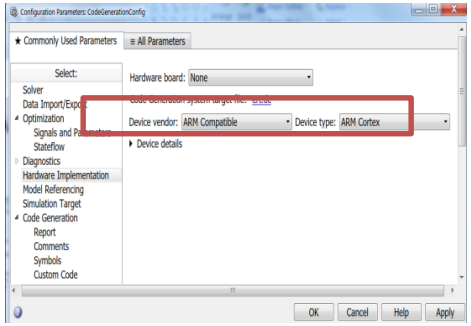
Rapid Control Prototyping

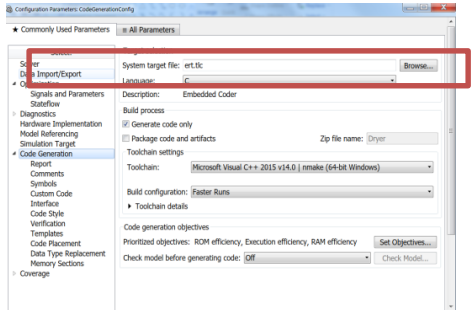


Autocode Generation and Integration

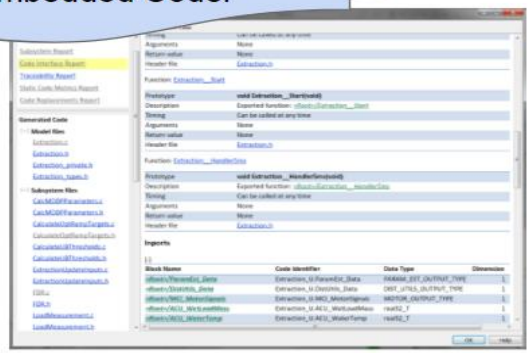
Configuration Settings



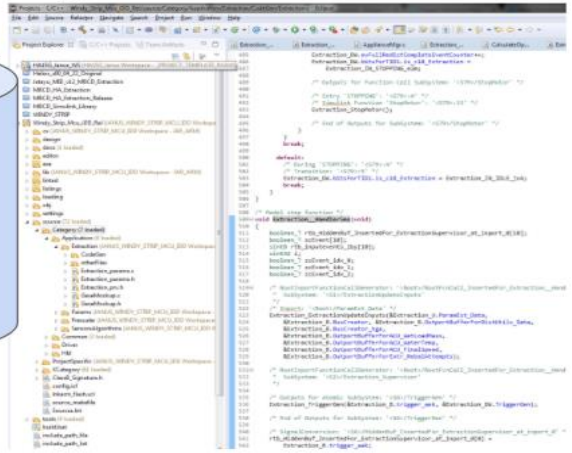




C code is generated using Simulink Embedded Coder



Code is then integrated to the RTC stream and tested in the appliance



Simulink Embedded Coder

Advantages of MBD Approach

- Direct Import of Dymola Plant Models into Simulink.
- Detecting errors in early stages
- Powerful and Formal Analysis
- Reusable Components
- Automatic Code Generation
- Highly Scalable, Ease of maintenance
- Reusability of Test Cases
- Good Test Management