Home Appliance Controls Development using Model Based Design

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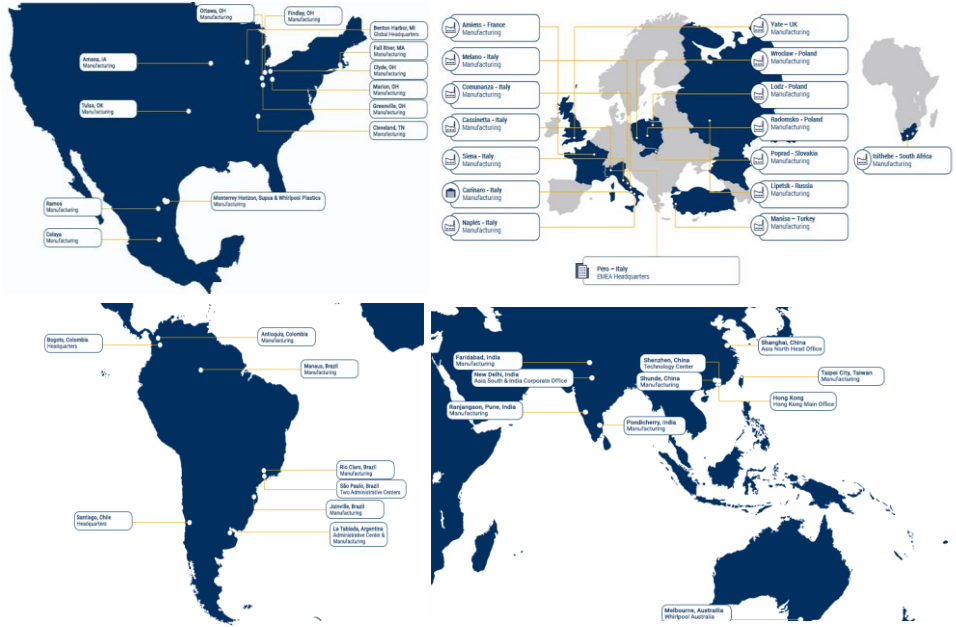
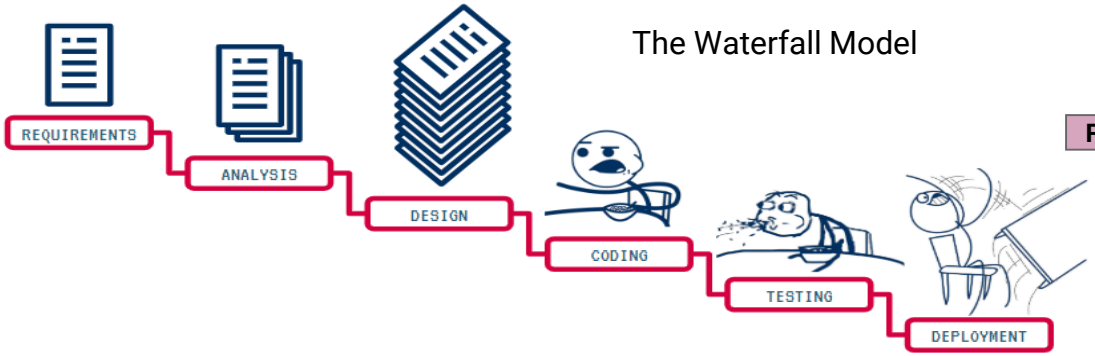
- About Whirlpool
- Model Based Development Process in Whirlpool
- Case Study : Universal Motor Controls Development
- Organisational Benefits through MBD

About Whirlpool

- World's leading major Home Appliance company
- Founded over 100 years ago
- ~$21 billion in revenue in 2018
- 92,000 employees and 70 manufacturing and technology research centers
- 1 in 3 employees volunteer for taking care of our neighborhoods and the planet

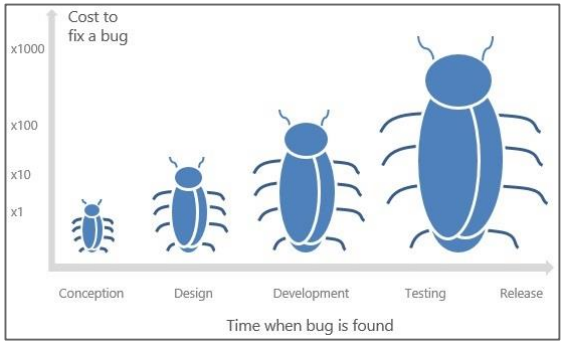


Limitations of Traditional Software Development Process

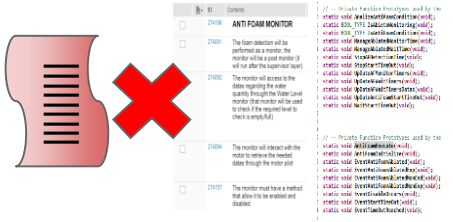


The Waterfall Model

RESULTS



Poor Requirements Management



- Missing linkage between requirement and software code.
- Unfreeze requirements

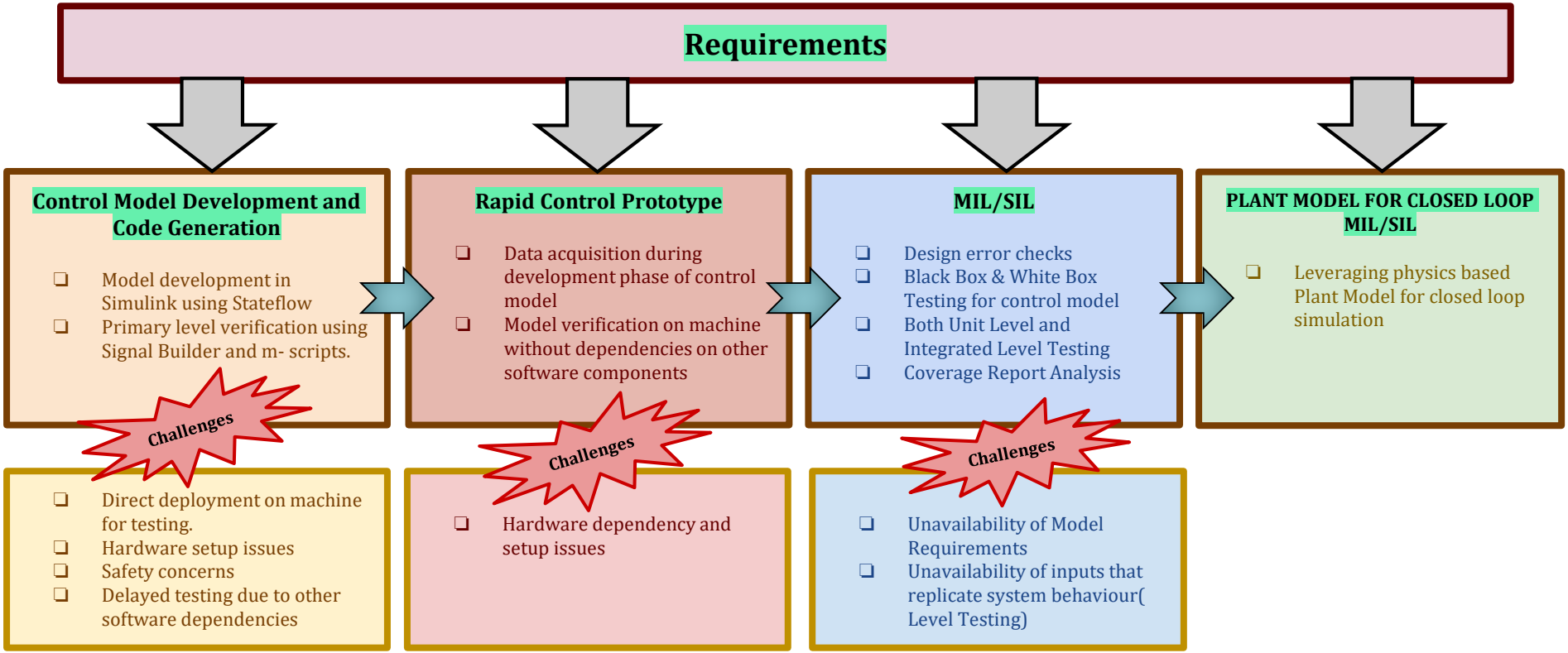
Manual Code Implementation

- Squeezed timelines.
- Software Integration with cross regional teams in workforce.
- Less readability , difficult debugging
- Variation in implementation method from developer to developer.

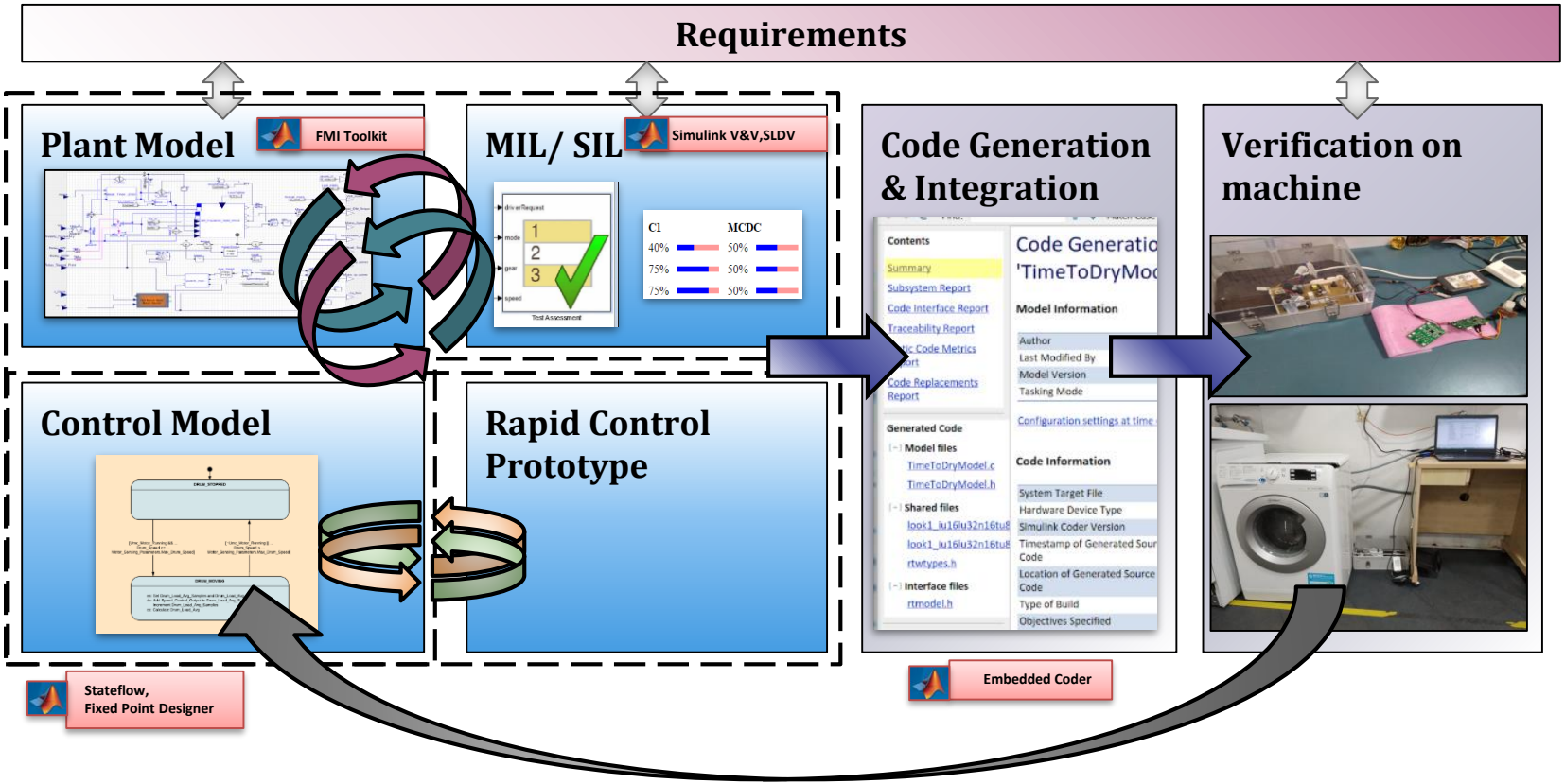
Hardware requirement for Verification

- Setup & Maintenance Cost Involved.
- Difficult setup replication.
- Hardware availability.
- Safety of Tester.

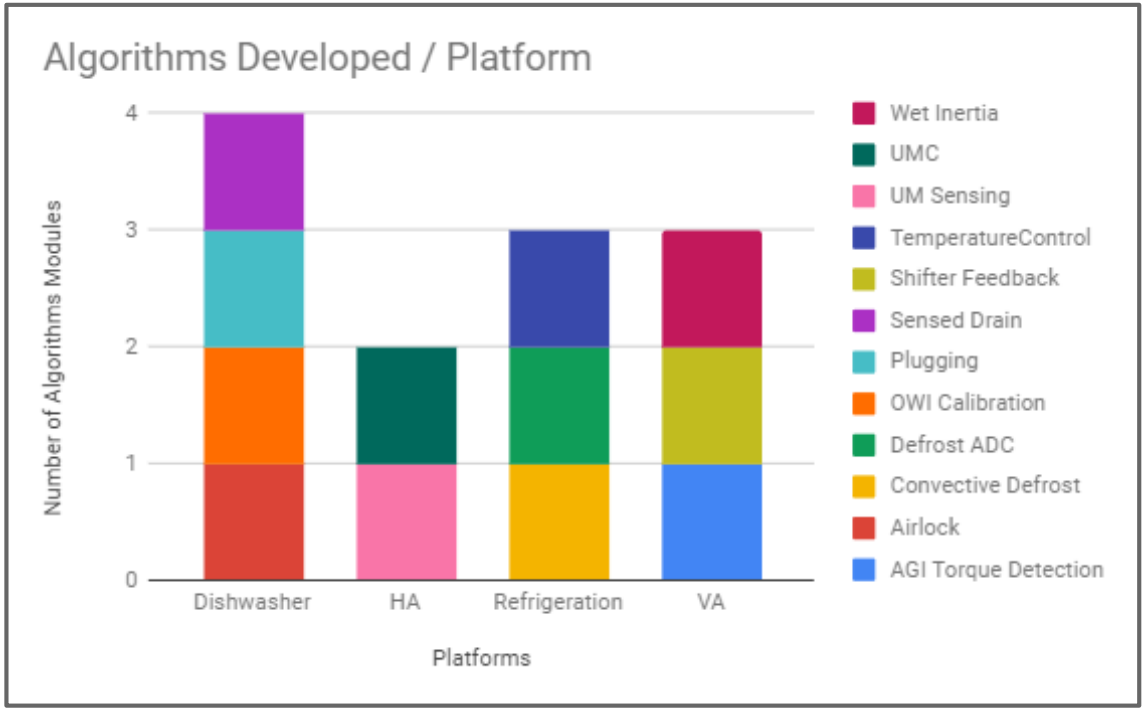
MBD process in Whirlpool….Few years Ago



Current MBD Workflow in Whirlpool

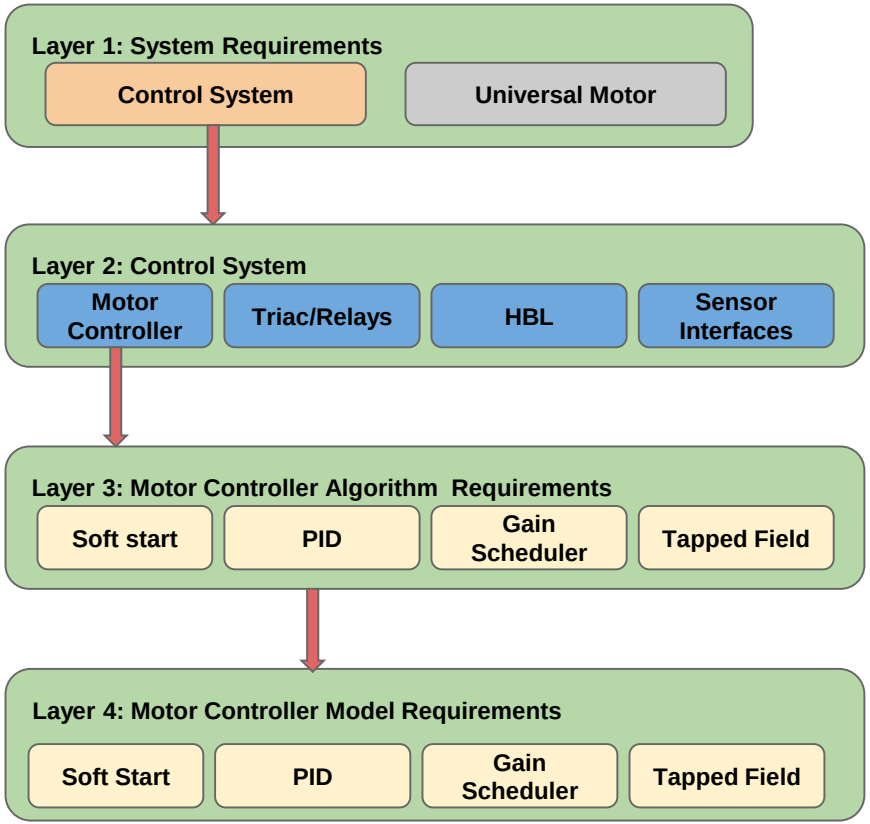


Summary of MBD algorithm in different whirlpool products



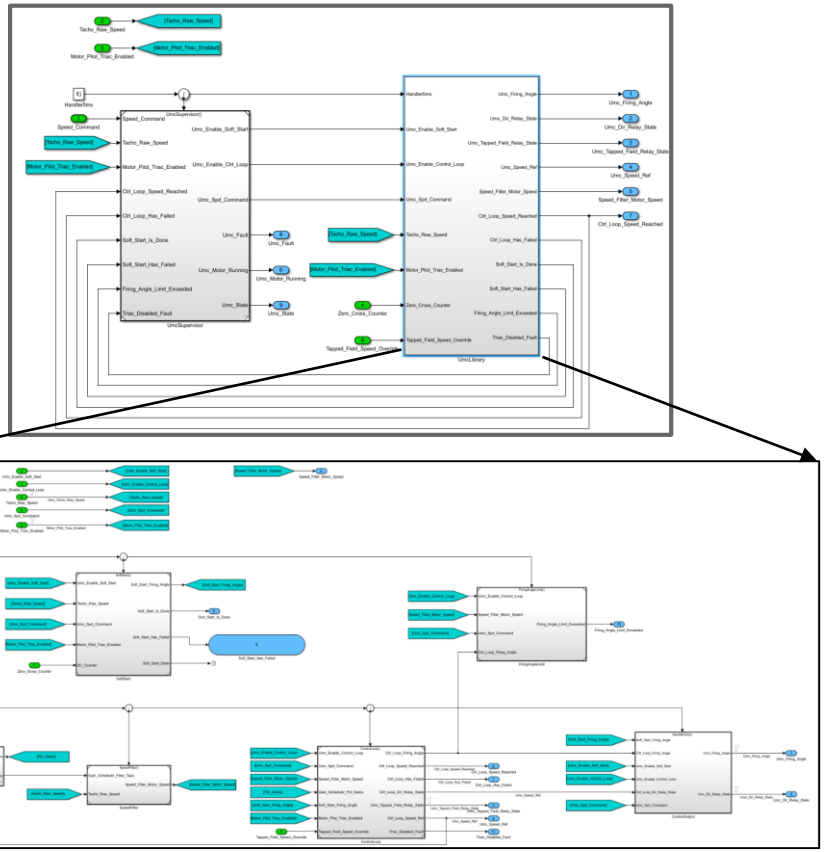
Universal Motor Controls Development

- Requirements breakdown
- Class Diagrams for Controller using SysML
- System Engineering Support for development of Universal Motor Plant Model
- Verification at Module level as well as integrated level.



Algorithm Modeling Using Stateflow & Simulink

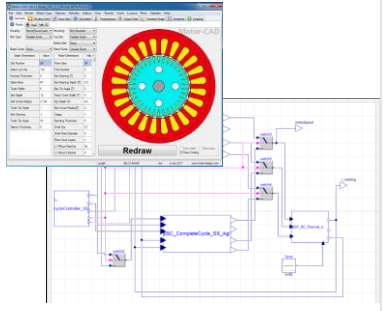
- Algorithm requirements have been implemented as a Simulink® model
  - Floating/Fixed point, Fixed step size
  - Use most convenient tools (Simulink, Stateflow, MATLAB code blocks)
  - Use referenced model
  - Use of Data Dictionaries
  - Capturing Model Metrics
  - Traceability



Stateflow, Matlab Functions, Simulink Blocks, Fixed Point Designer

Universal Motor and Washer Dynamics Plant Model

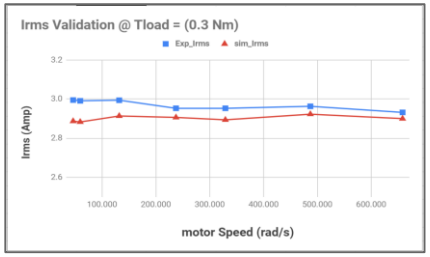
Plant Model Development

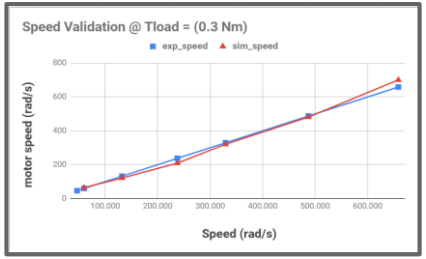



```
parameter Real m_t = 12.176;//tub mass12.176
  parameter Real m_d = 15.79; //drum mass 9.52
  parameter Real m_u = 0;//unbalance mass
  parameter Real m_b1 = 0;//mass of water ring1
  parameter Real m_b2 = 0;//mass of water ring2
  parameter Real e = 0.25349;//unbalance radius
  parameter Real d = 0.295;//balance ring radius
  parameter Real I_zt = 0.54;//tub inertia
  parameter Real I_zd = 0.95;//drum inertia 0.69826
  parameter Real K=2600;//spring Co-efficient(N/m)3300
  parameter Real Cd=200;//Damping Coefficient28
  parameter Real T_f=0.6;//friction torque1
  parameter Real C_b1=0.1;//viscous drag co-efficient of water ring1
  parameter Real C_b2=0.1;//viscous drag co-efficient of water ring2
  parameter Real D_r=0.016;//viscous drag co-efficient of machine shaft0.001
```

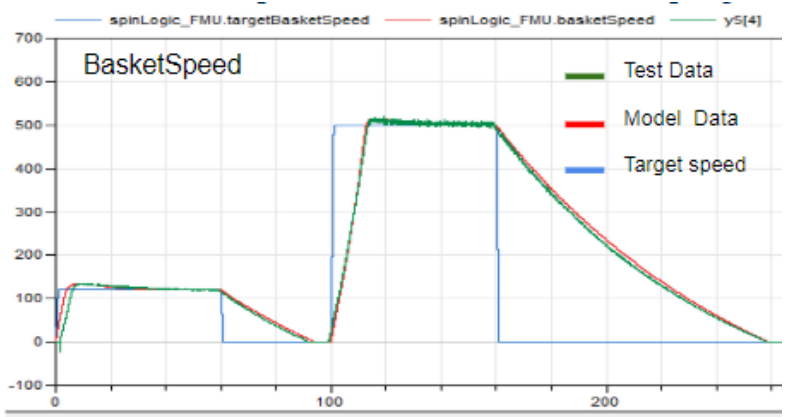
- Model Based System Engineering team support for Plant Model Development
- Use of Dymola/Modelica environment
- Calibration of Plant Parameters with Real Time Test Data

Open Loop Validation

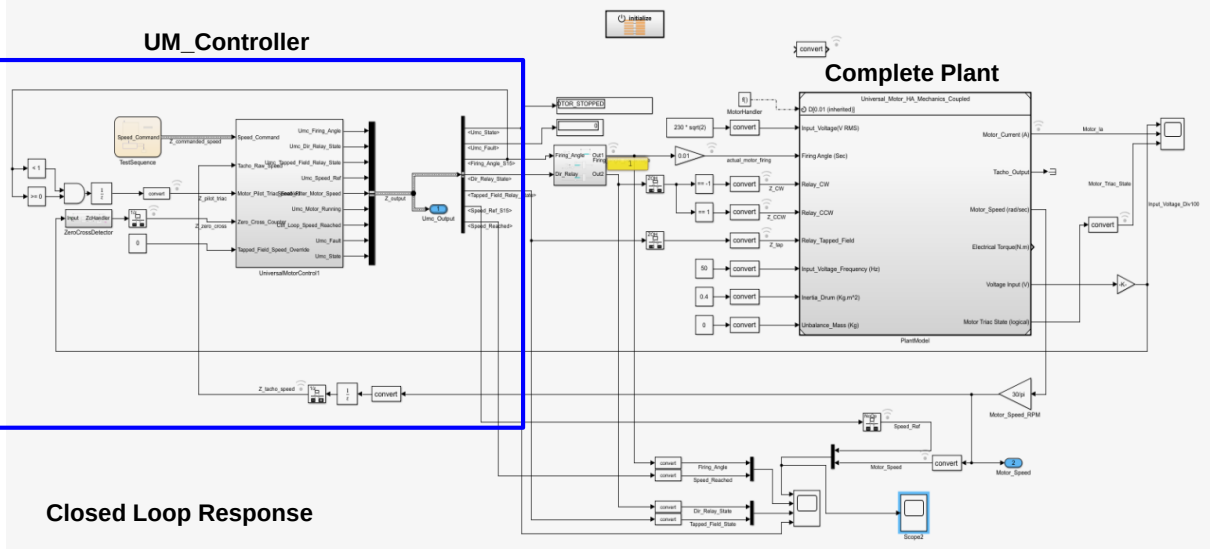




Closed Loop Validation with Basic Control



Integration of Control Model and Plant Model

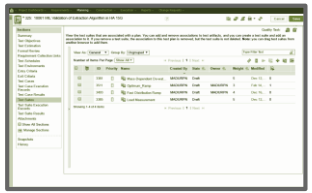


- Use of Functional MockUp units for leveraging Dymola Plant Models in Simulink
- Provides Capability to find robustness of the logic at system level.
- Allows to perform System Level verification

Simulink PSP Toolbox till 2016
Inbuilt Simulink FMI kit feature 2017 onwards

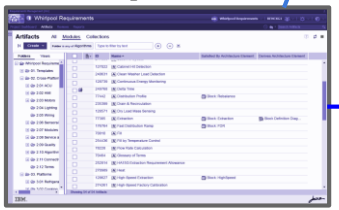
Verification and Validation

Test Case Generation in RQM

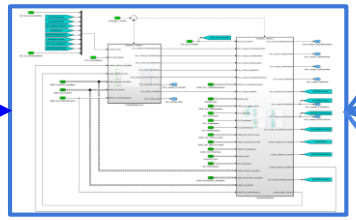


Prepare Test Cases for Simulink models linked with DNG Requirement

Model Requirements in DNG

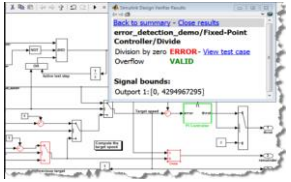


Simulink Model



Automatic Design Error Check

Simulink Design Verifier

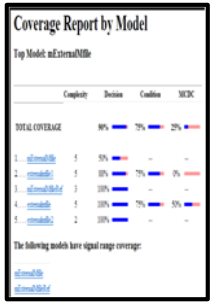


Simulink V&V

Test Harness

Harness model allows testing the component in simulation

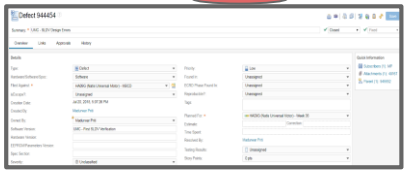
Coverage Analysis

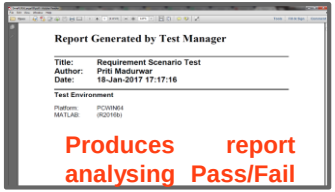


Decision coverage, condition coverage, MC/DC coverage

Test Report From Simulink Test

Raising defects in RTC and updating results in RQM





Produces report analysing Pass/Fail conditions.

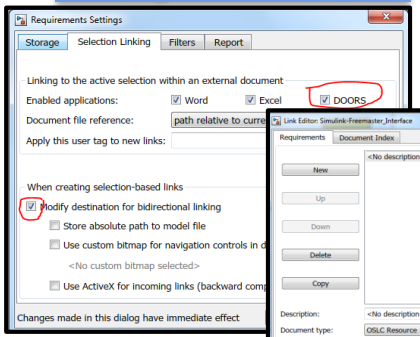
Simulink V&V

Simulink Design Verifier

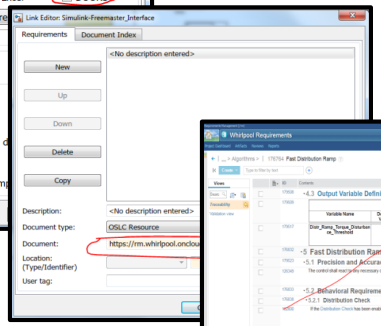
Simulink Coverage & Test

Requirement Linking from Simulink to DNG

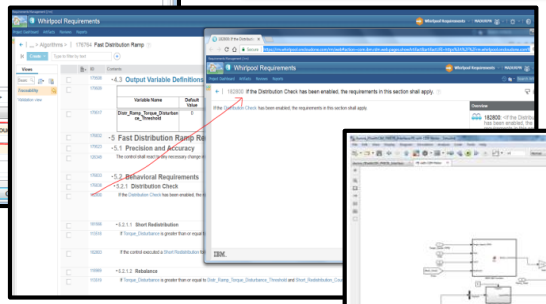
Configure Requirement Settings



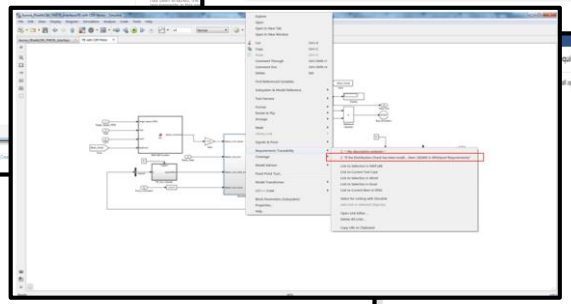
Select Project Area from DNG



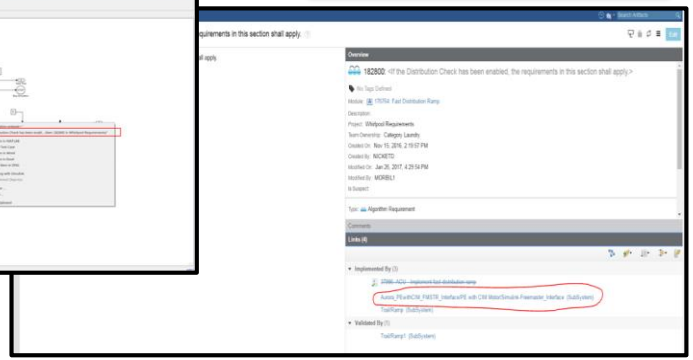
Selecting Requirement from DNG



DNG Link of requirement in Simulink



Simulink Implemented link in DNG

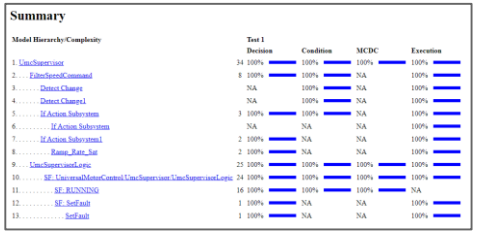


Simulink Requirement Toolbox

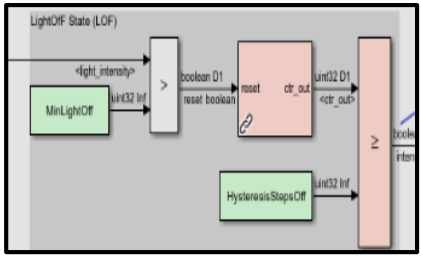
Application of Simulink V&V & Design Verifier

Simulink Validation & Verification

1. Cumulative coverage results on multiple tests



2. Identified missing coverage

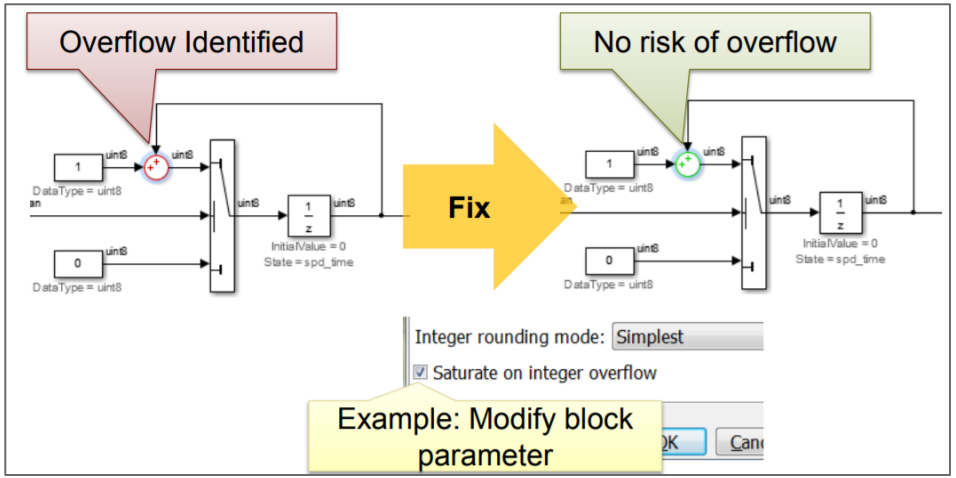


3. Traceability between DOORS requirements and Model

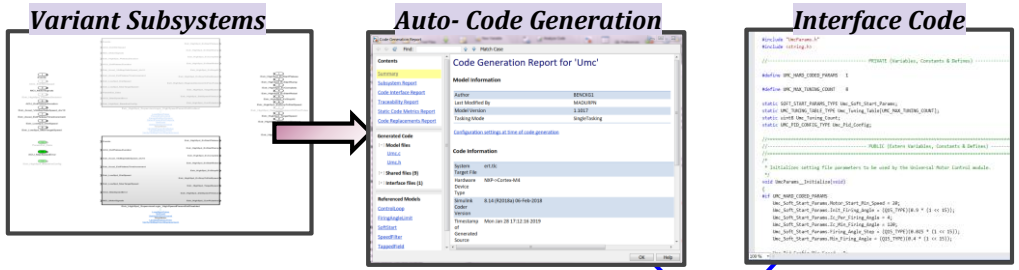
Simulink Design Verifier

Check for risks of software design errors prior to implementation

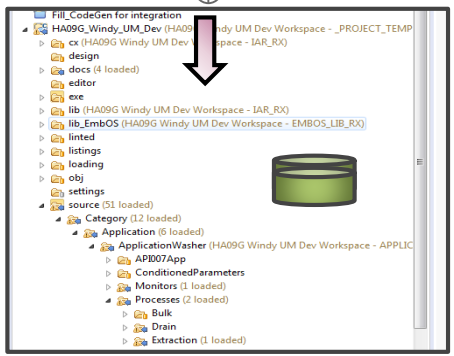
Integer overflow, division by zero, range violations, dead logic



Code Generation and Integration



AutoCode Generated from Simulink + Wrapper Code → Integrated software package with main Firmware

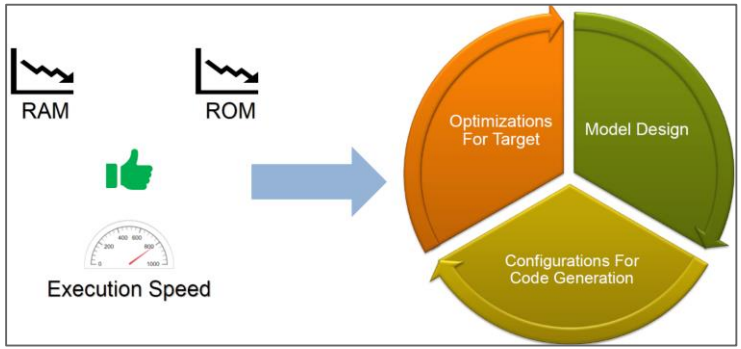


Delivery of complete package to the stream

Toolboxes Used:
Stateflow,
Embedded Coder,
Fixed Point Designer,
Matlab coder,
Simulink Coder

Achieving Optimized Code: (reference MATLAB EXPO 2018)

- Use of Model Advisor to apply and establish best Modeling practices
  - MAAB/MISRA C, ISO/IEC Standards etc
  - Simulink and Stateflow guidelines
- Model Advisor Guidelines
  - Modeling Standards for DO-178C/DO-331
  - Modeling Standards for EN 50128
  - Modeling Standards for IEC 61508
  - Modeling Standards for IEC 62304
  - Modeling Standards for ISO 26262
  - Modeling Standards for MAAB
  - Modeling Standards for JMAAB
  - Modeling Standards for MISRA C:2012



Advantages of Model Based Design

- ❏ Consistent design flow from conception to implementation using same language
- ❏ Detecting errors in early stages of Software Development
- ❏ Easy to deploy code in different projects by managing variant subsystems.
- ❏ Easy to handle change requests without impact on timelines.
- ❏ Very few defects in released softwares
- ❏ Early observation for unexpected emergent behavior.
- ❏ Good Test Management

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