

Home Appliance Controls Development using Model Based Design

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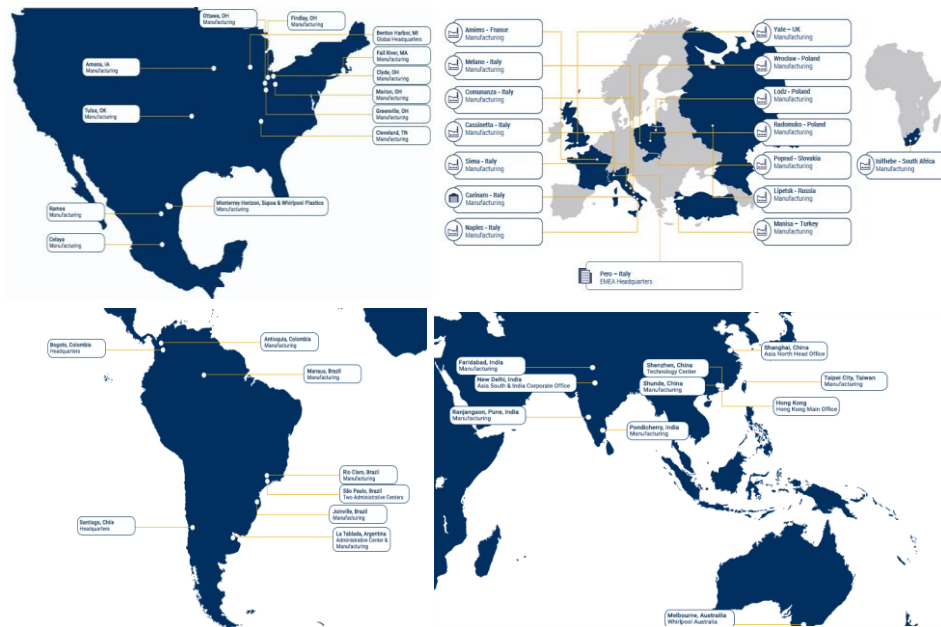
MATLAB EXPO 2019
PUNE

The logo for MATLAB EXPO 2019 PUNE is a dark blue arrow pointing to the right. The text "MATLAB EXPO 2019" and "PUNE" is written in white, bold, sans-serif font. The arrow's tail is decorated with a pattern of small, colorful squares in shades of blue, green, and white.

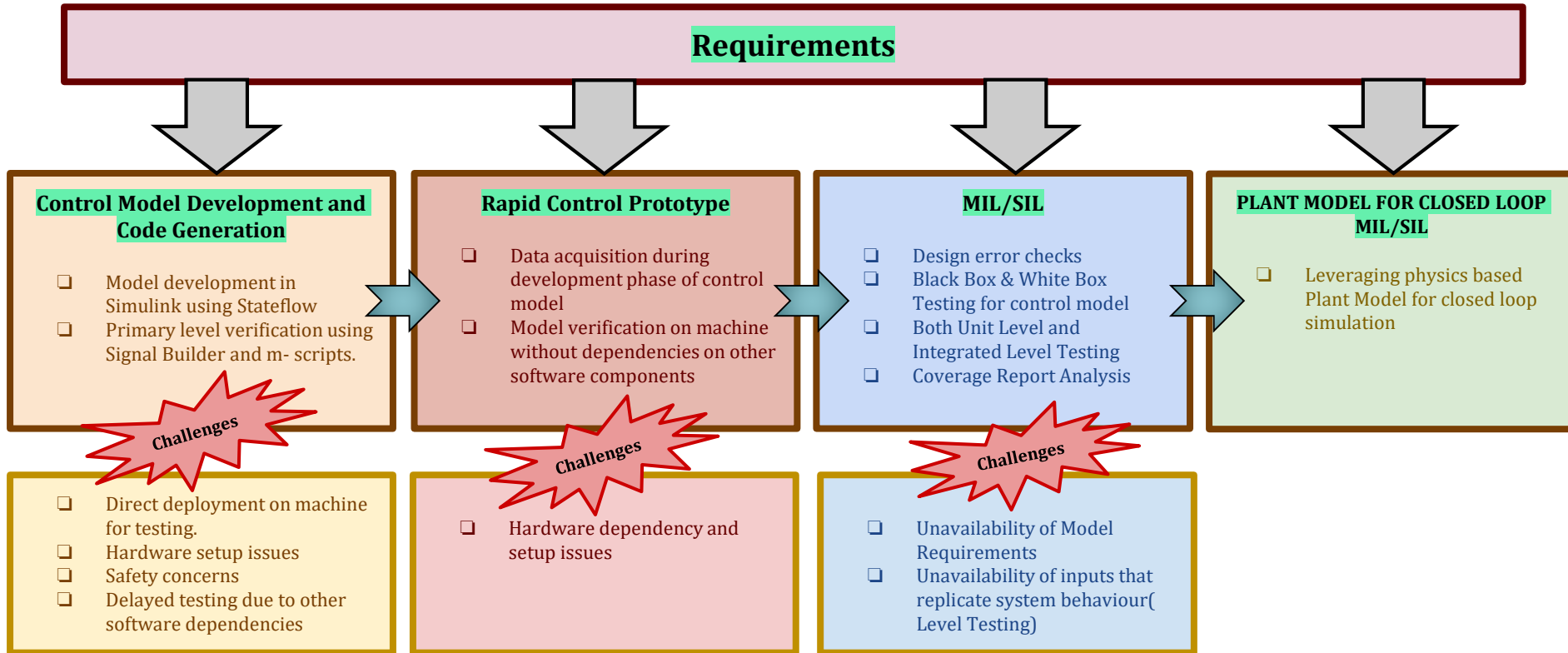
- **About Whirlpool**
- **Model Based Development Process in Whirlpool**
- **Case Study : Universal Motor Controls Development**
- **Organisational Benefits through MBD**

About Whirlpool

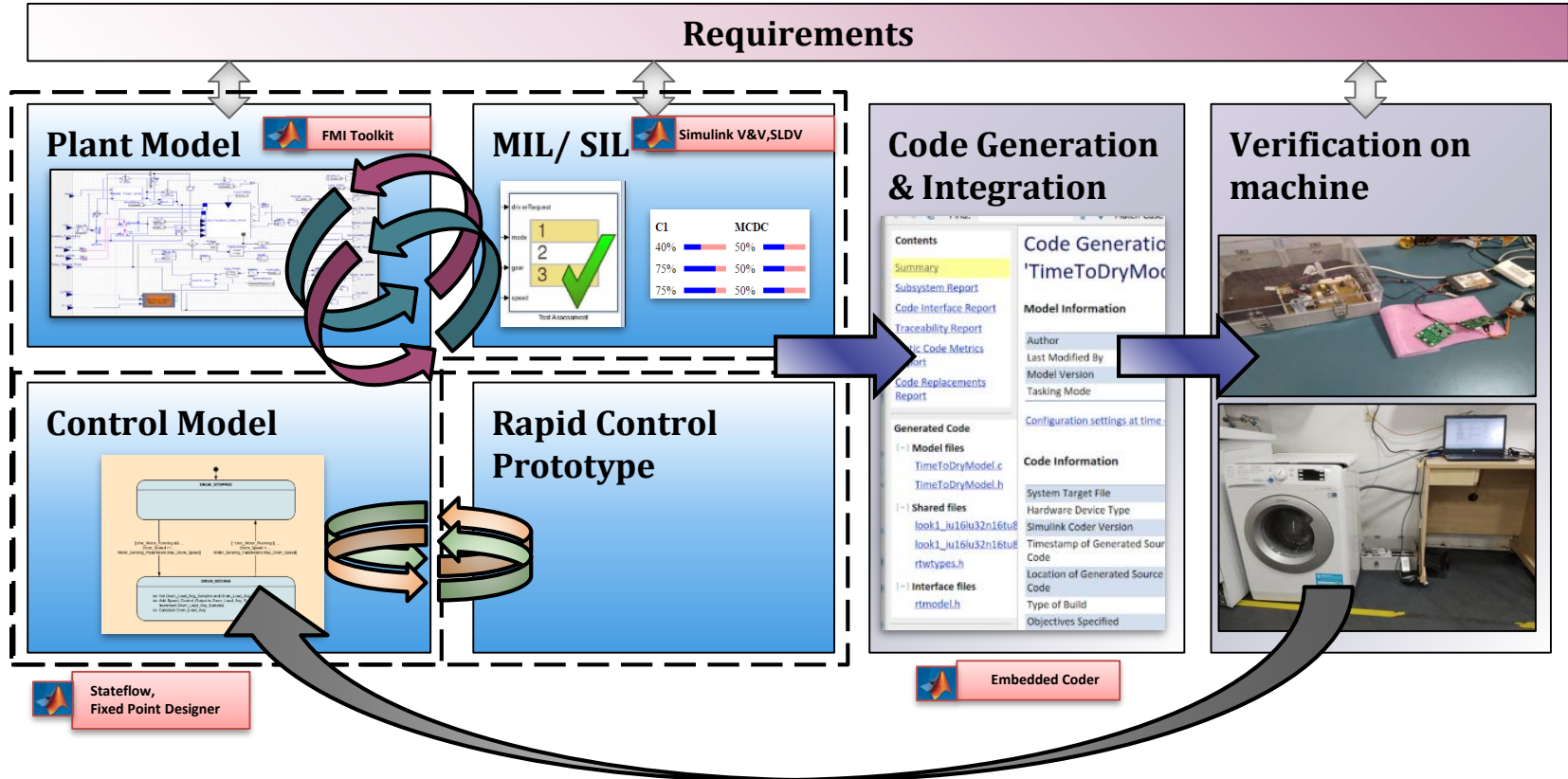
- World's leading major Home Appliance company
- Founded over 100 years ago
- ~\$21 billion in revenue in 2018
- 92,000 employees and 70 manufacturing and technology research centers
- 1 in 3 employees volunteer for taking care of our neighborhoods and the planet



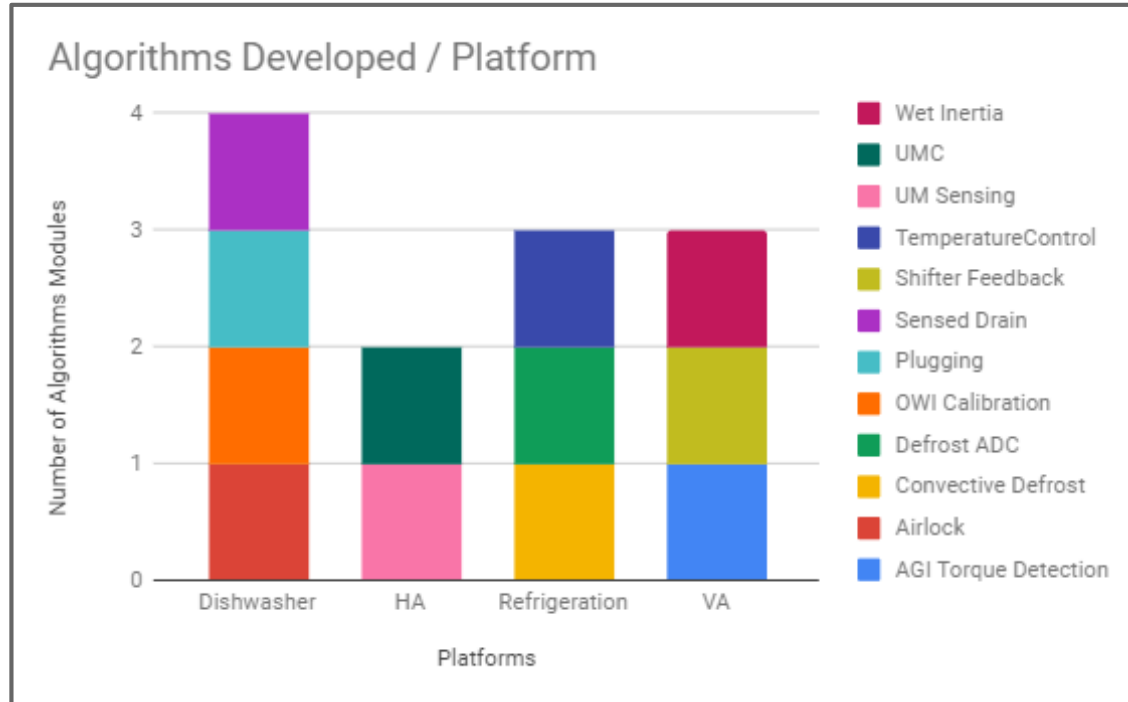
MBD process in Whirlpool...Few years Ago



Current MBD Workflow in Whirlpool

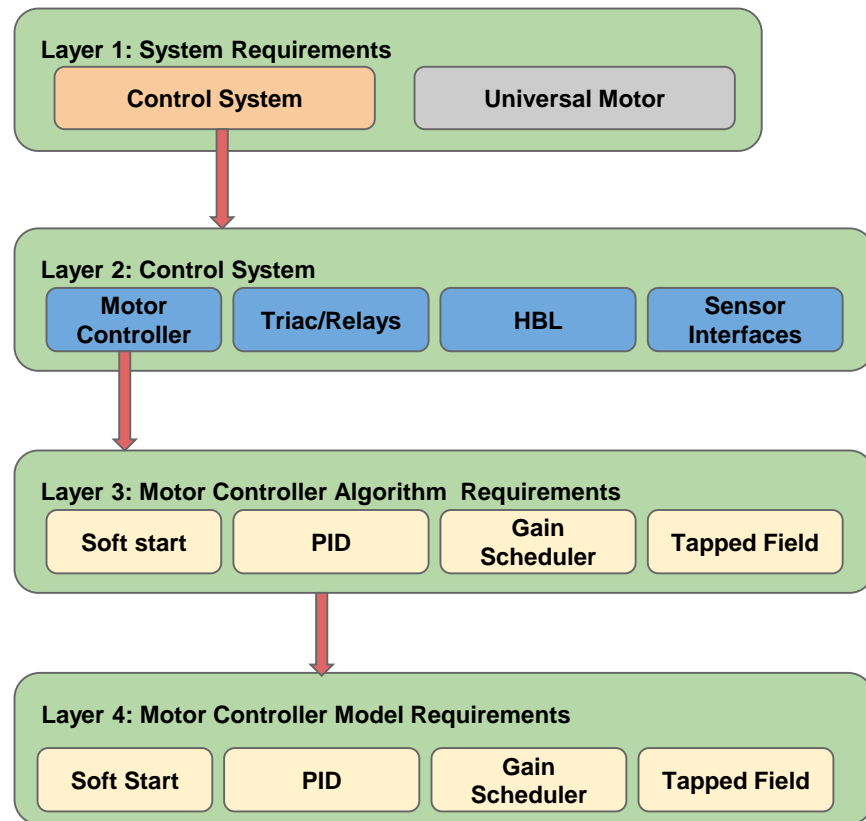


Summary of MBD algorithm in different whirlpool products



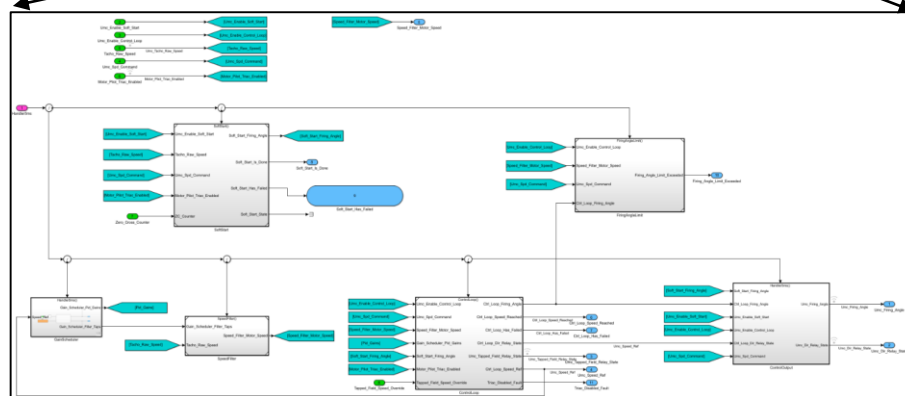
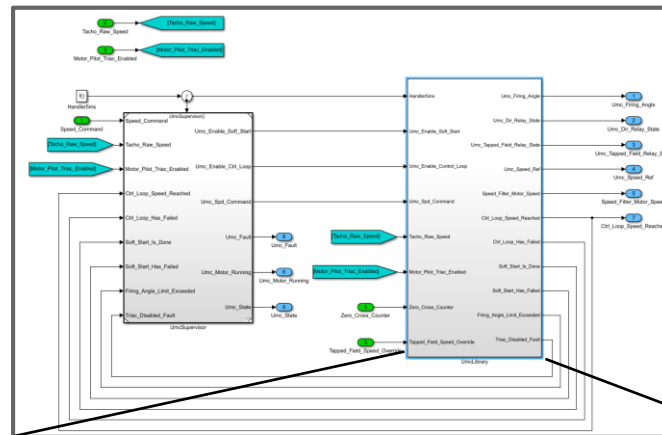
Universal Motor Controls Development

- 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

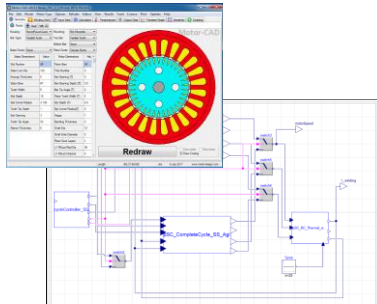


*Stateflow, Matlab Functions,
Simulink Blocks, Fixed Point Designer*



Universal Motor and Washer Dynamics Plant Model

Plant Model Development

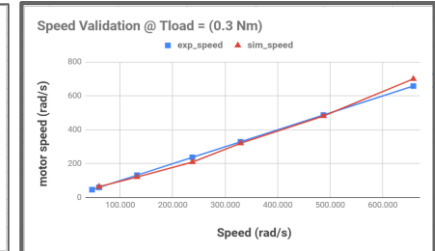
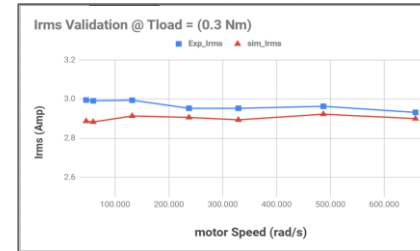


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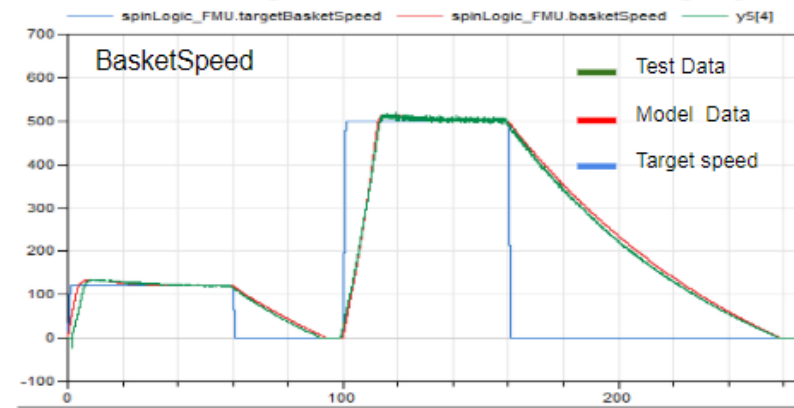
parameter Real m_t = 12.176; //tub mass12.176
parameter Real m_d = 15.79; //drum mass 9.52
parameter Real m_u = 0; //unbalance mass
parameter Real m_b1 = 0; //mass of water ring1
parameter Real m_b2 = 0; //mass of water ring2
parameter Real e = 0.25349; //unbalance radius
parameter Real d = 0.295; //balance 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

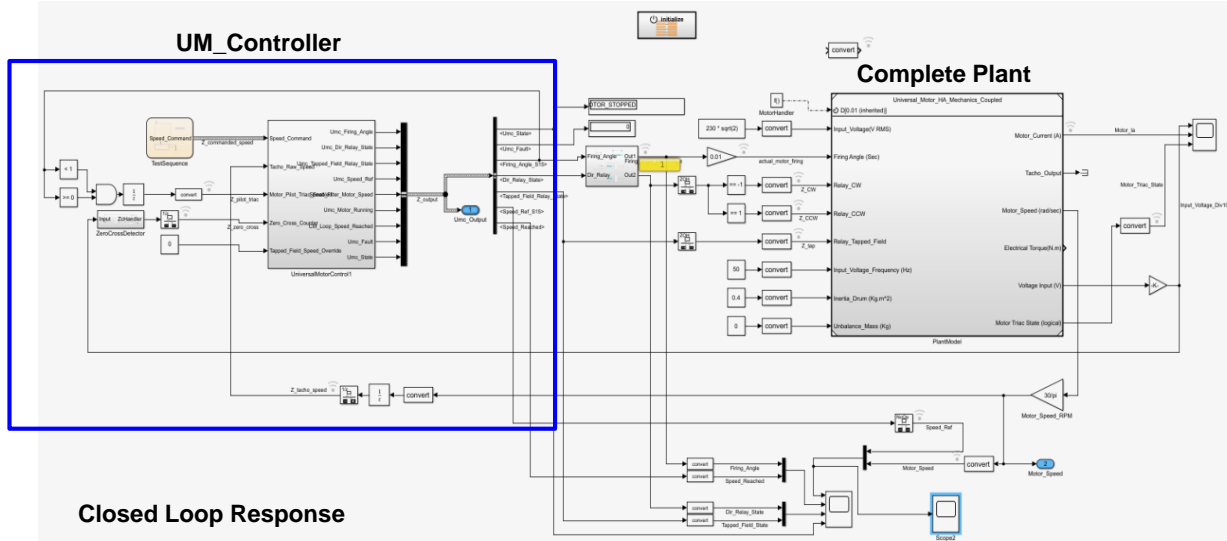
Open Loop Validation



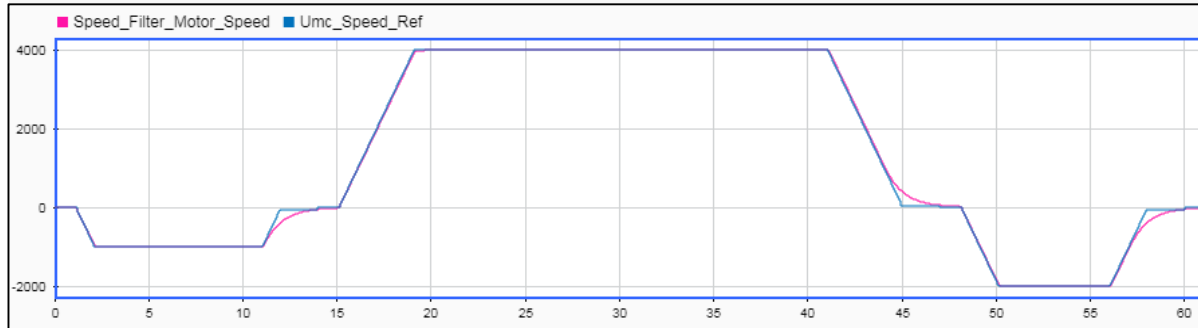
Closed Loop Validation with Basic Control



Integration of Control Model and Plant Model



Closed Loop Response

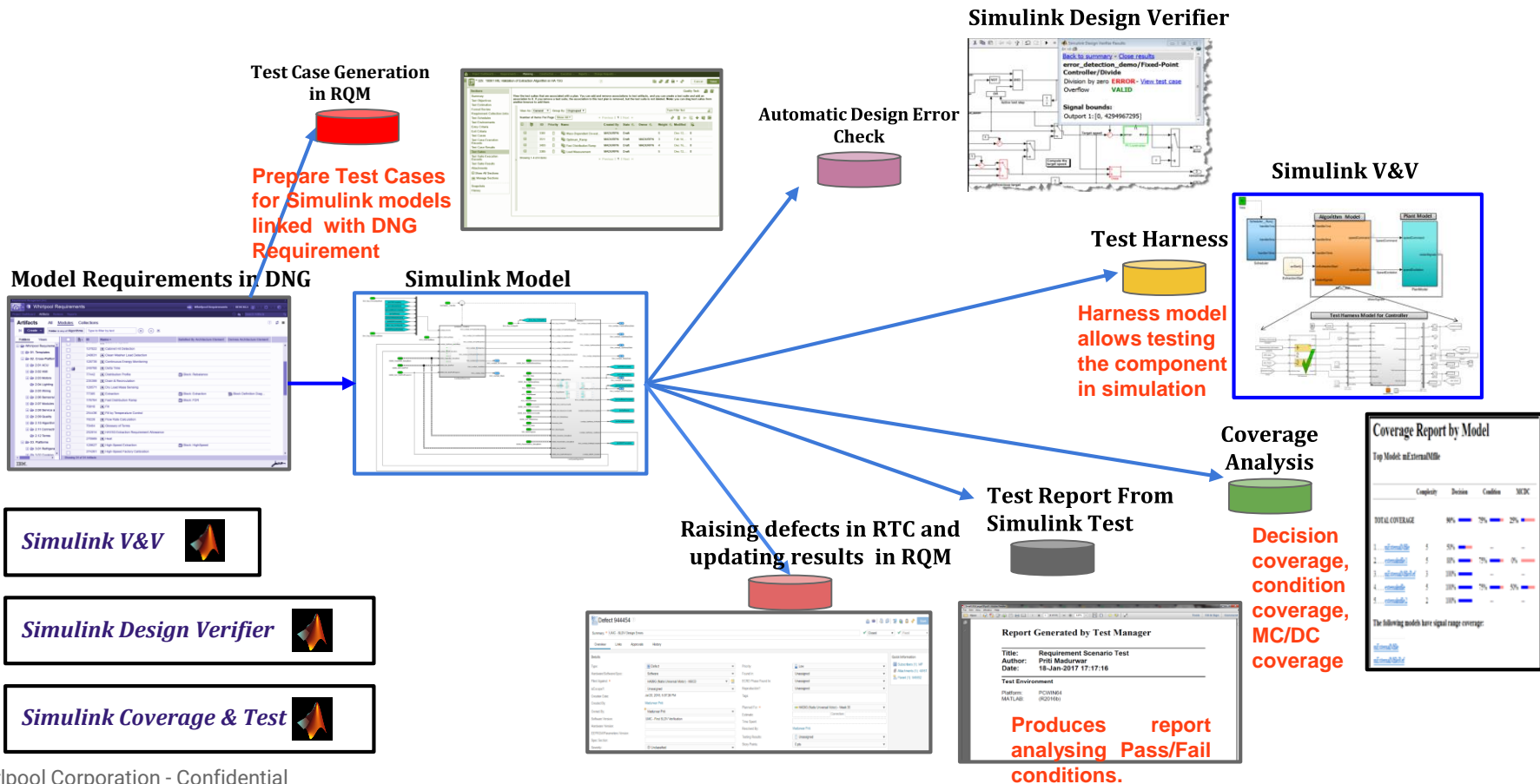


- Use of Functional MockUp units for leveraging Dymola Plant Models in Simulink
- Provides Capability to find robustness of the logic at system level.
- Allows to perform System Level verification

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



Verification and Validation



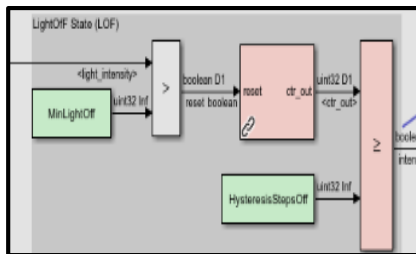
Application of Simulink V&V & Design Verifier

Simulink Validation & Verification

1. Cumulative coverage results on multiple tests

Summary					
Model Hierarchy Complexity					
	Test 1	Decision	Condition	MCDC	Execution
1. ...	24	100%	100%	100%	100%
2. ...	8	100%	100%	NA	100%
3. ...	NA	NA	100%	NA	100%
4. ...	NA	NA	100%	NA	100%
5. ...	3	100%	100%	NA	100%
6. ...	NA	NA	NA	NA	100%
7. ...	2	100%	NA	NA	100%
8. ...	2	100%	NA	NA	100%
9. ...	25	100%	100%	100%	100%
10. ...	24	100%	100%	100%	100%
11. ...	18	100%	100%	100%	NA
12. ...	1	100%	NA	NA	100%
13. ...	1	100%	NA	NA	100%

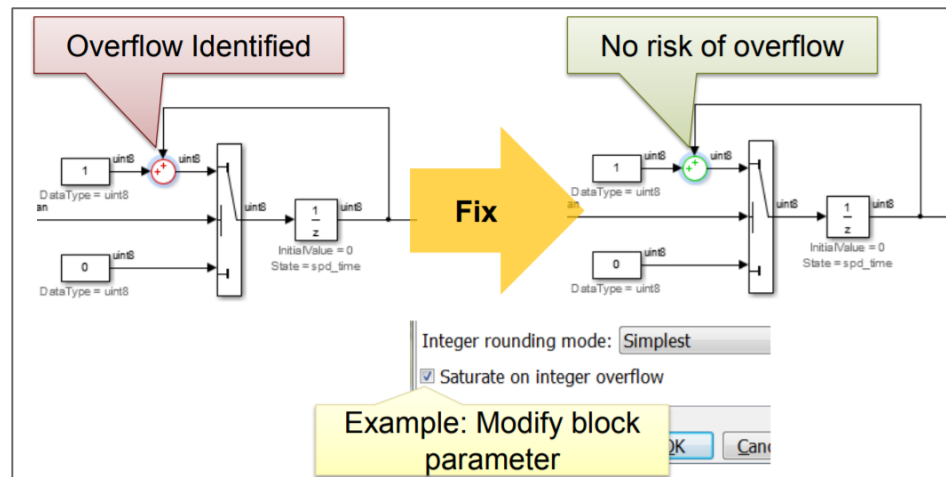
2. Identified missing coverage



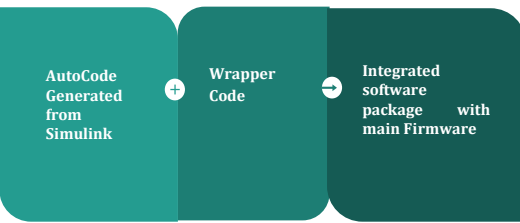
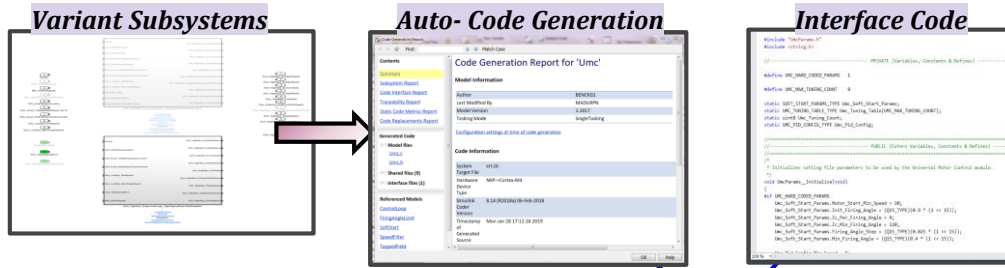
3. Traceability between DOORS requirements and Model

Simulink Design Verifier


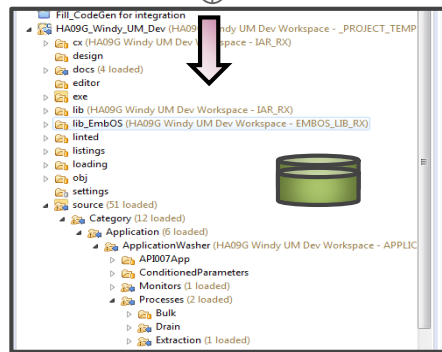
Check for risks of software design errors prior to implementation
 Integer overflow, division by zero, range violations, dead logic



Code Generation and Integration



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

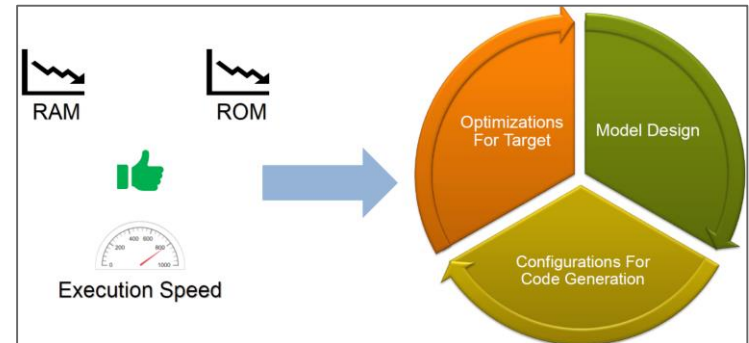
Delivery of complete package to the stream

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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