

A practical approach to reducing development risk and time through Model-driven Development

3T

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EVENT**



Het ontwerpen van
innovatieve elektronica

Woensdag 19 april 2023
1931 Congrescentrum 's-Hertogenbosch

Introduction: Who am I

- Jasper Keuning; Lead Electronics Engineer @ 3T since 2012
- Modeling and Simulation
 - Mathworks tooling (Matlab, Simulink, Simscape)
 - Signal & Power Integrity (Ansys)
 - Thermal Analysis (Ansys)
- High speed digital boards
- Medical devices
- Standards and Regulations

The logo for 3T, consisting of the numbers '3' and 'T' in a bold, red, sans-serif font.

Agenda

- What is Model-driven Development (MDD)
- MDD in the design process
- Project: Skytron Freedom

A large, bold, red logo consisting of the characters '3' and 'T' in a stylized, blocky font.

What is Model-driven development (MDD)

- Using models and simulation to:
 - Create
 - Evaluate
 - Optimize
- It is not a goal, just a means to enhance the design process
- Applicable for many phases of the development cycle

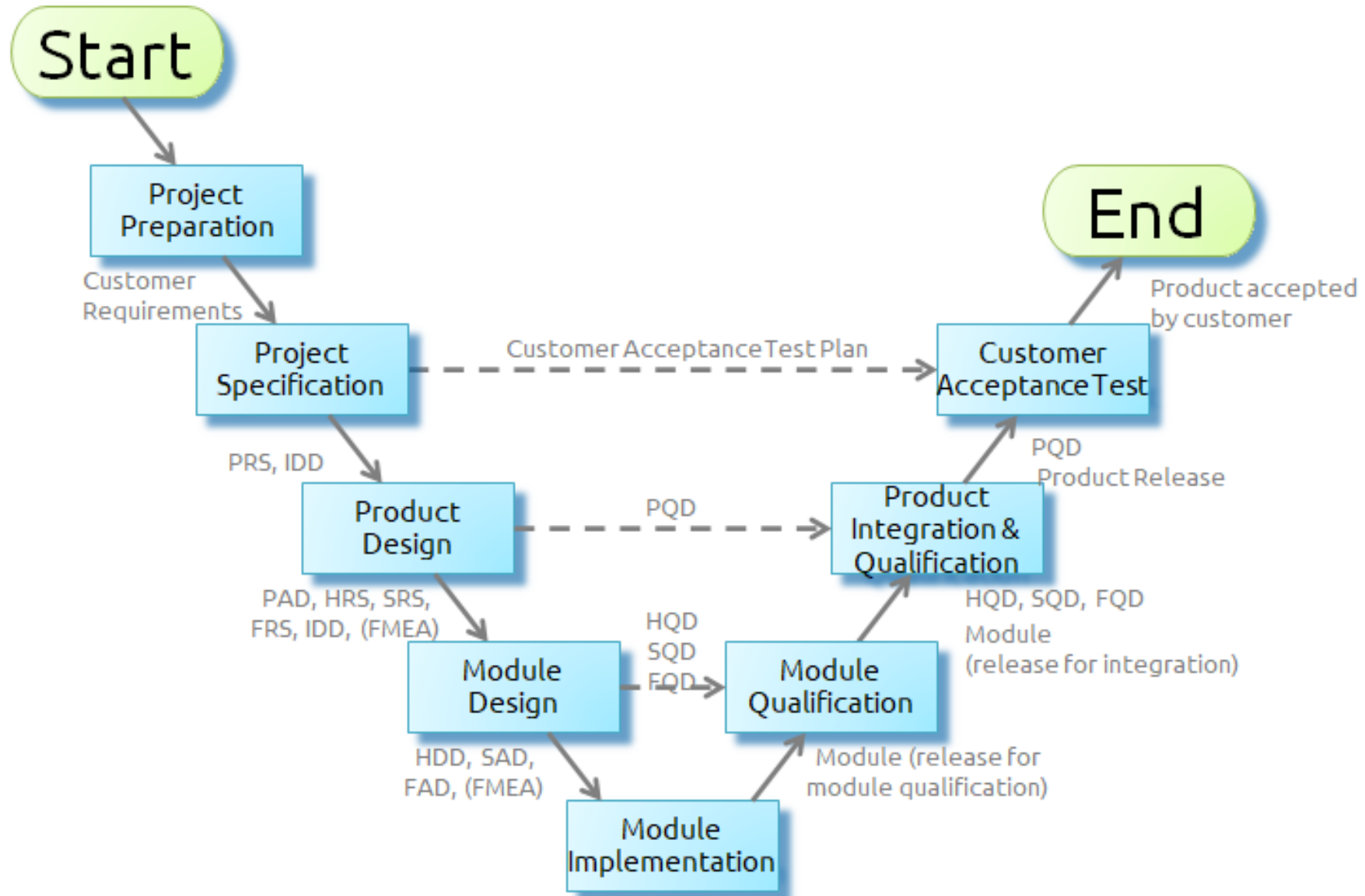
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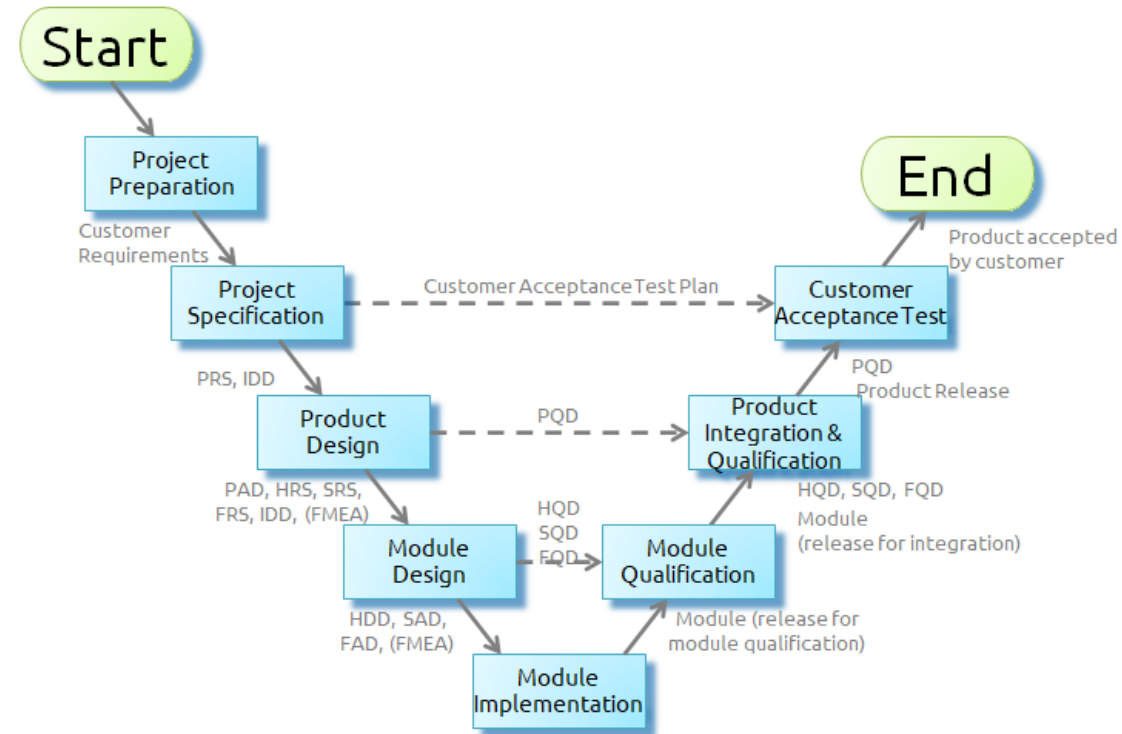
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MDD in the design process

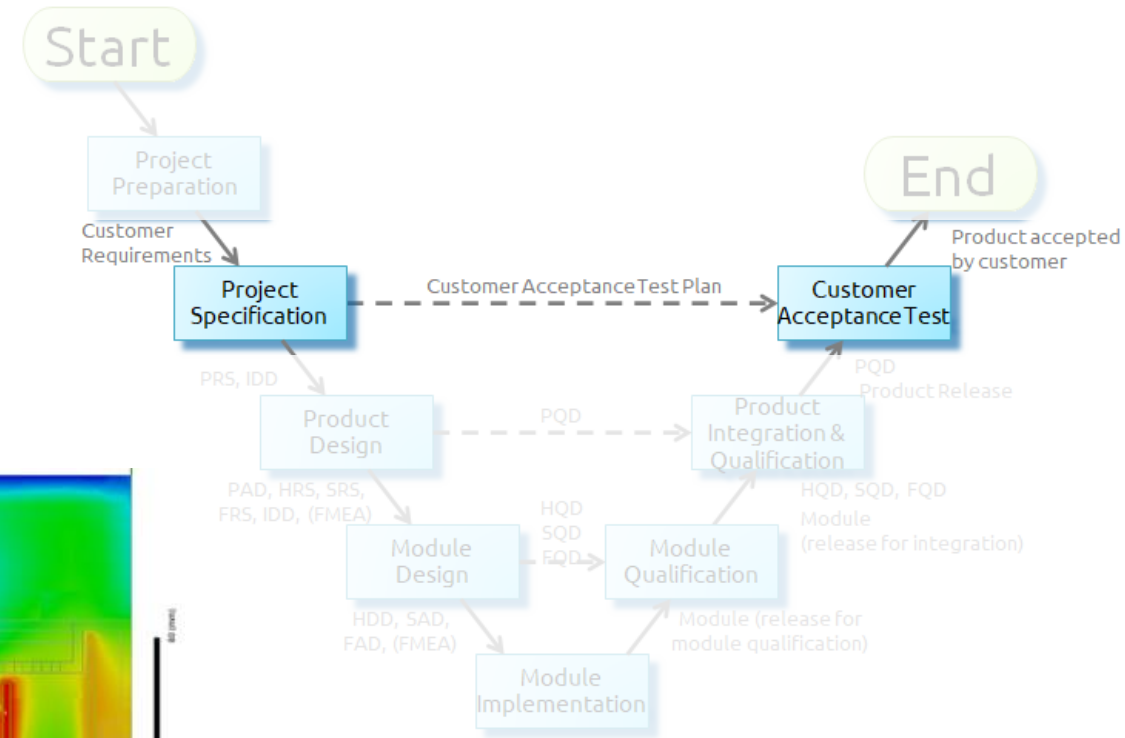
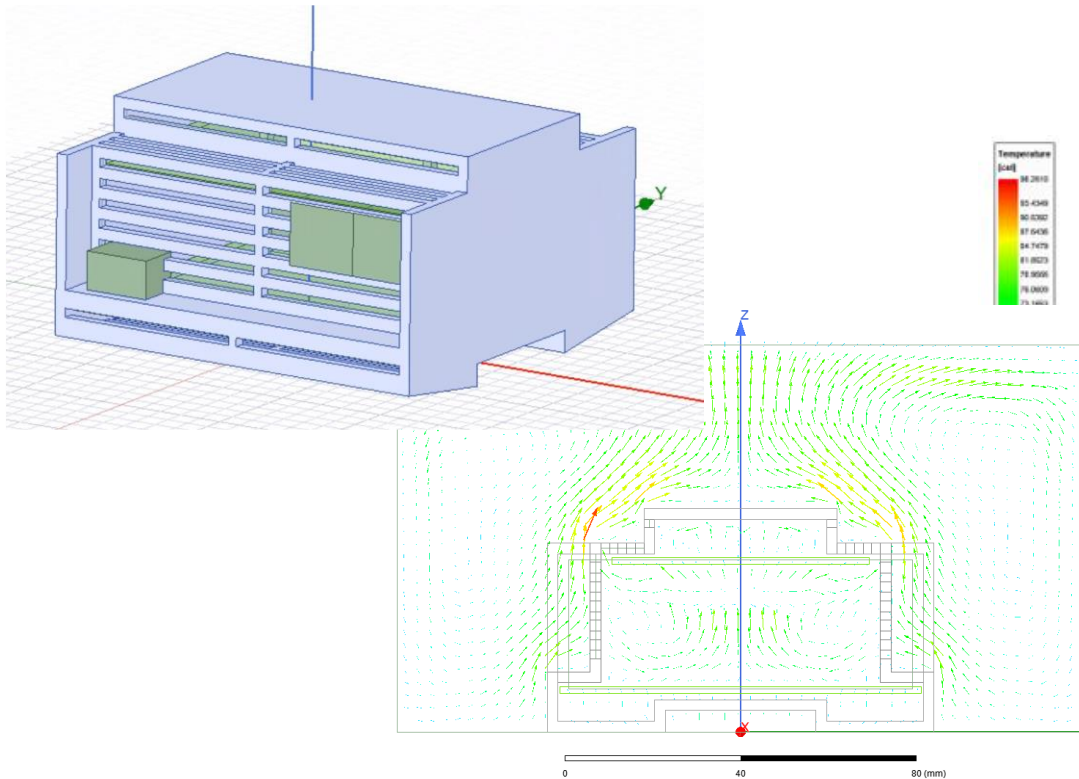


MDD in the design process



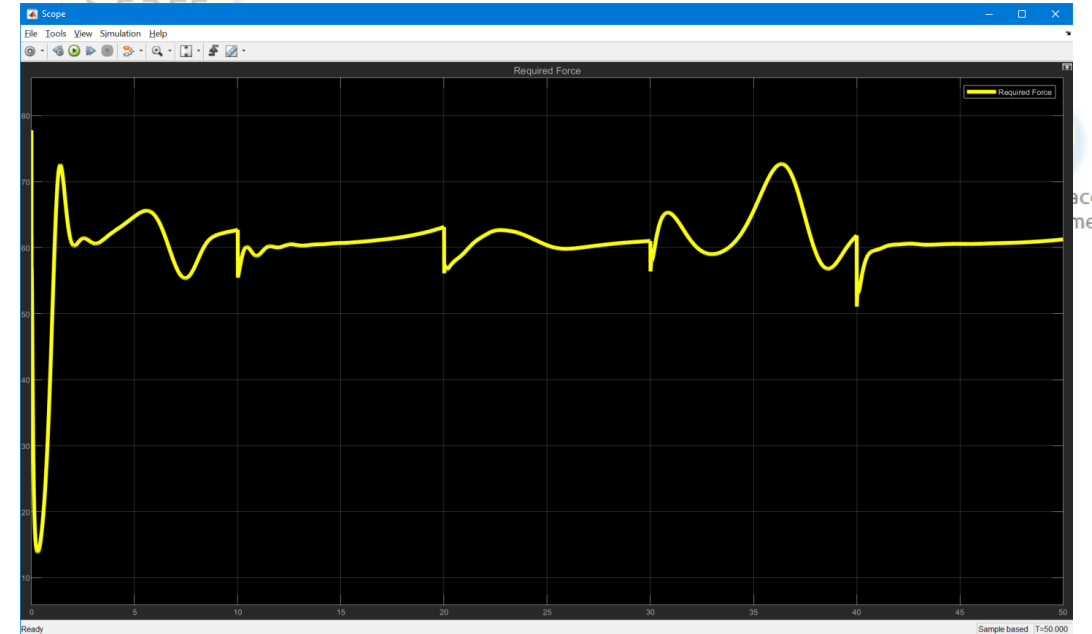
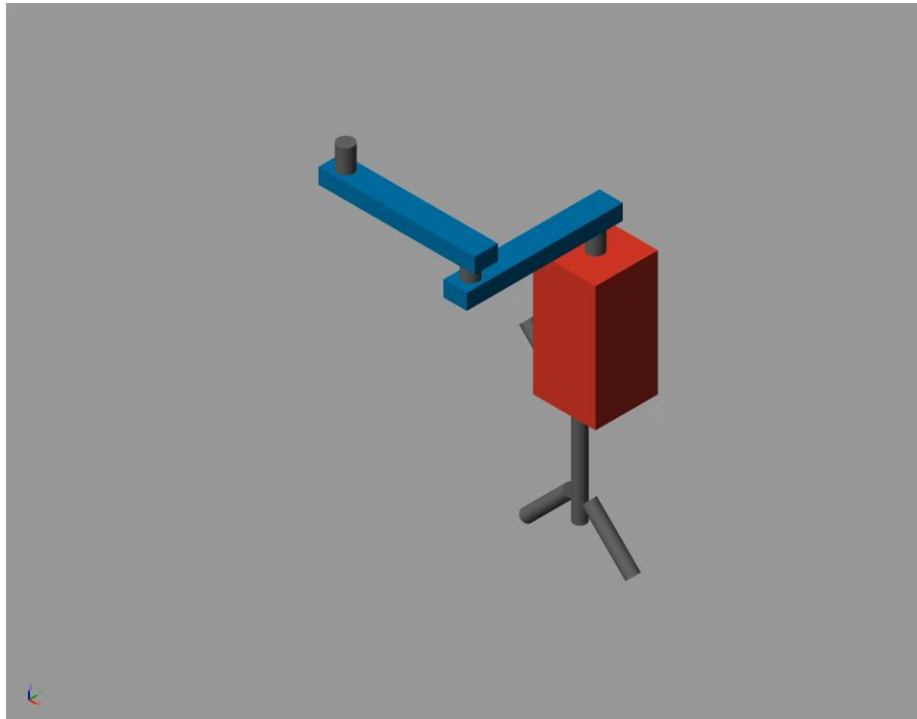
MDD in the design process

- Specification Phase:
 - Feasibility



MDD in the design process

- Specification Phase:
 - Feasibility
 - Identification of critical behavior



Module Implementation

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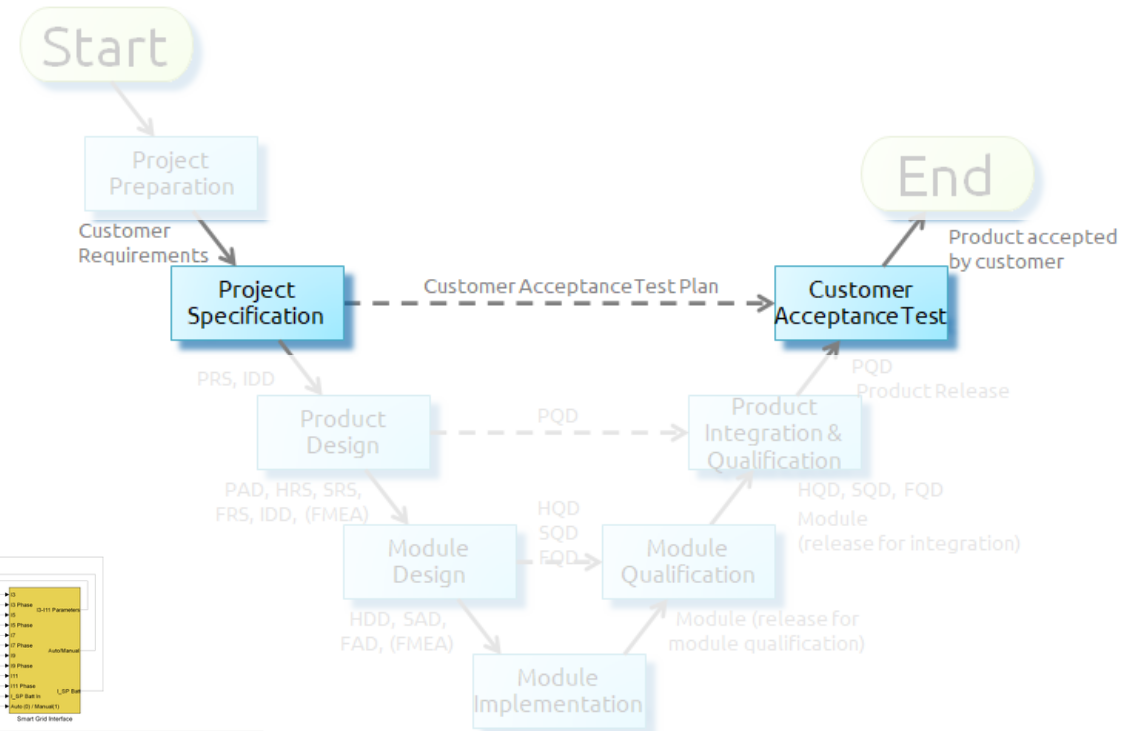
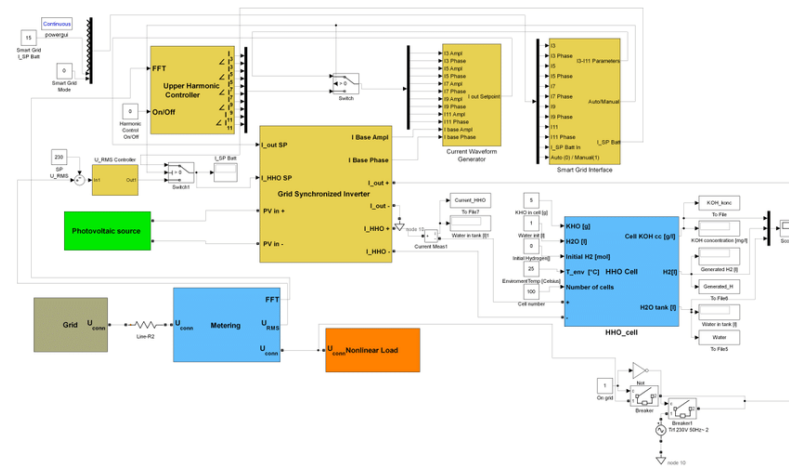
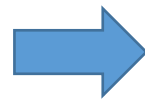
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MDD in the design process

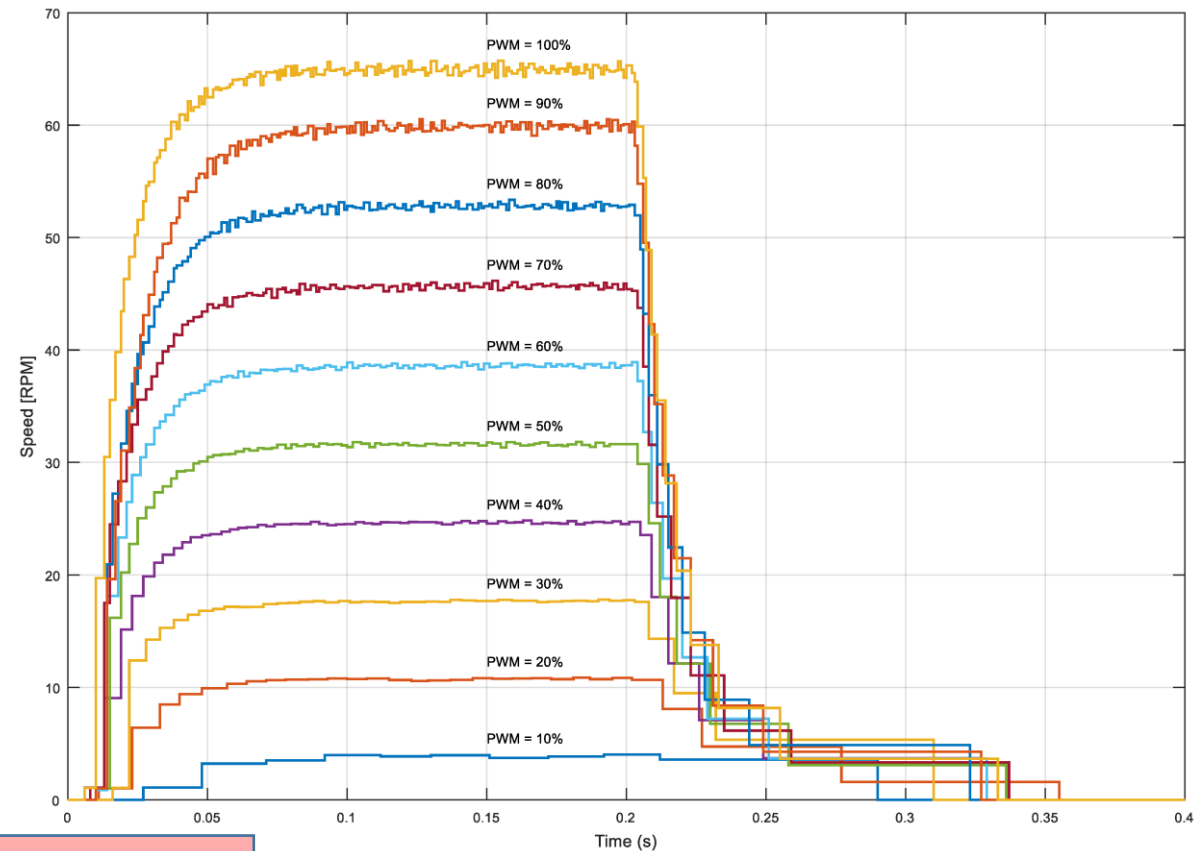
- Specification Phase:

- Feasibility
- Identification of critical behavior
- Model as Requirement



MDD in the design process

- Product level design:
 - Multidomain modeling and simulation
 - System level evaluation/optimization

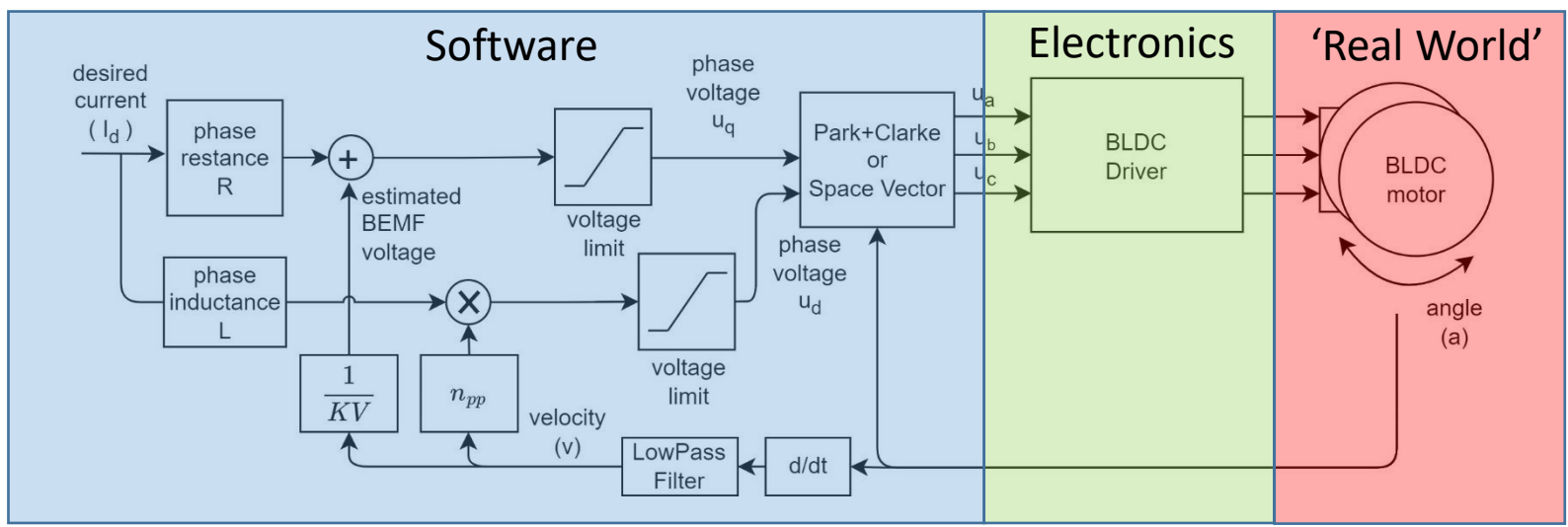


FAD, (FMEA) module qualification

Module Implementation

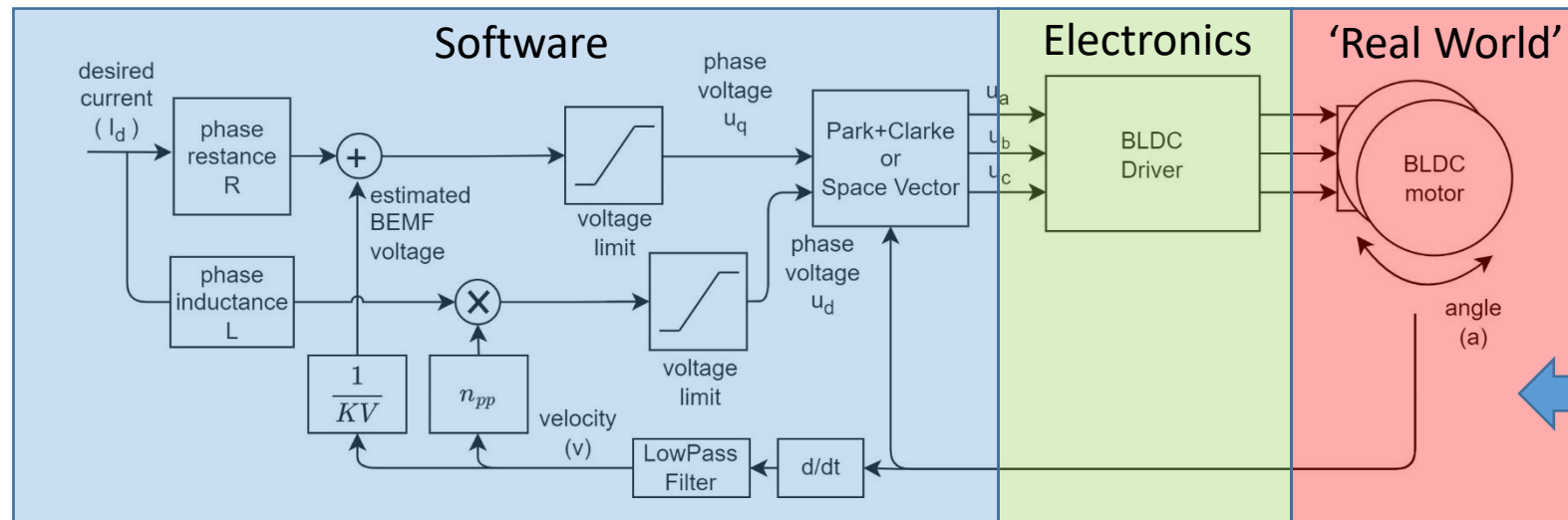
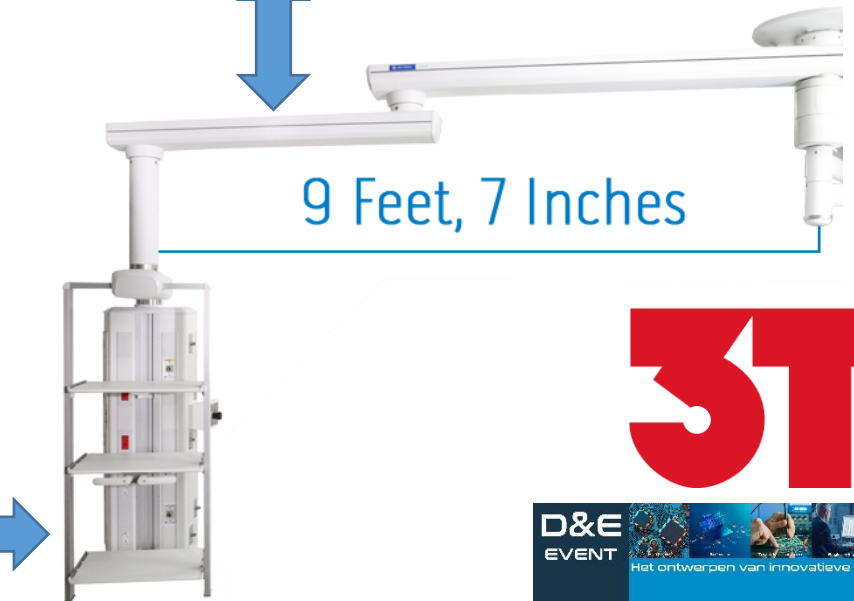
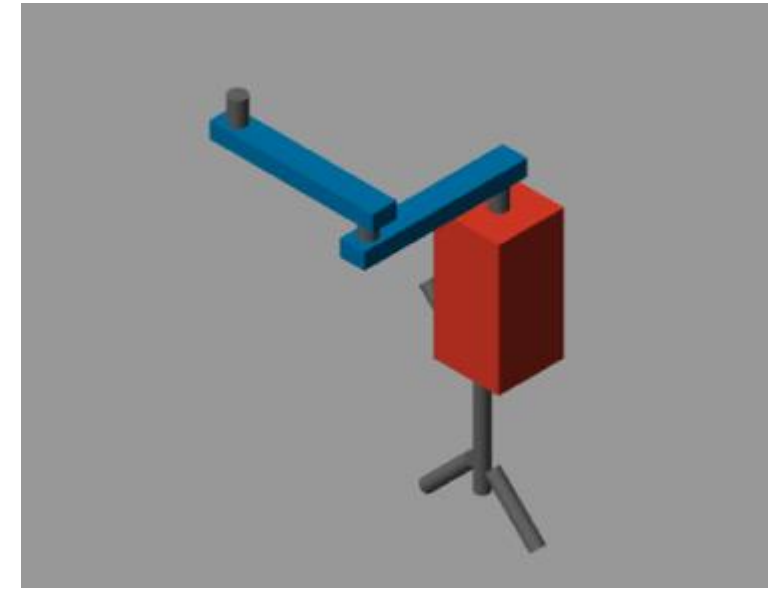


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MDD in the design process

- Product level design:
 - Multidomain modeling and simulation
 - System level evaluation/optimization
 - System level verification and integration
 - Multidisciplinary design language



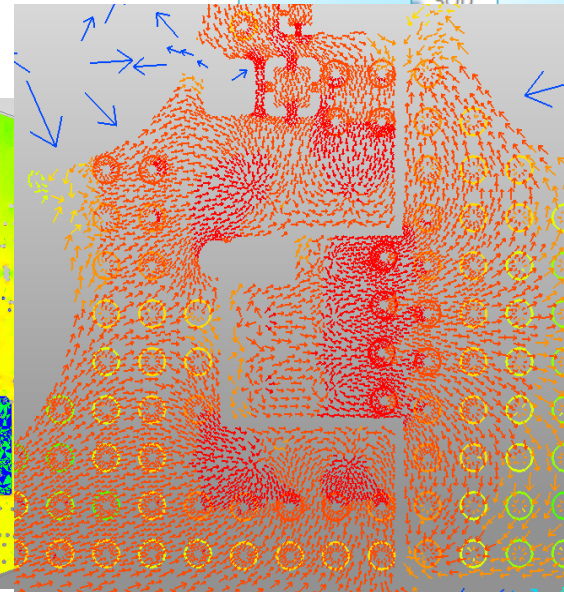
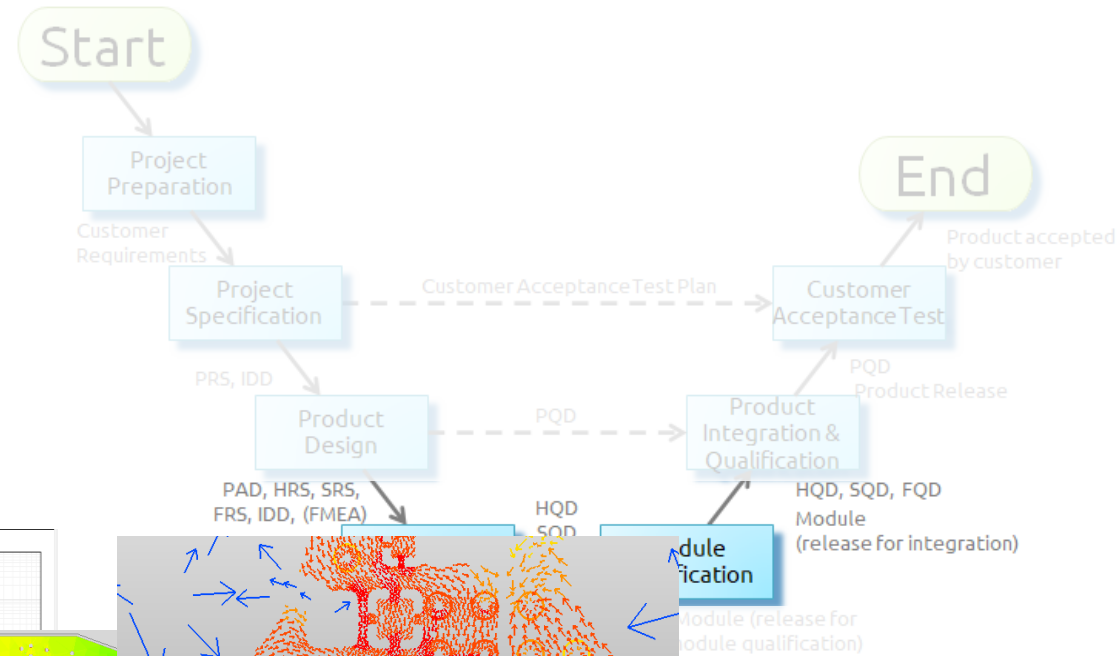
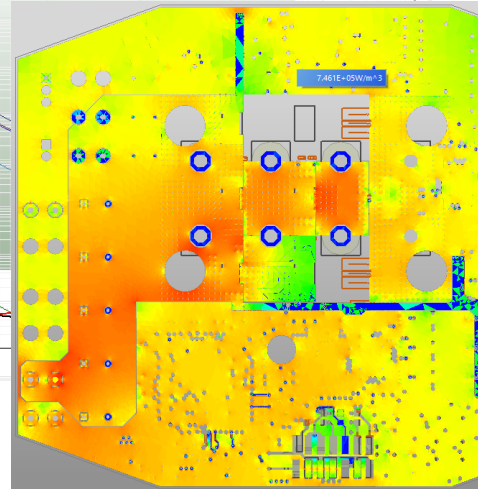
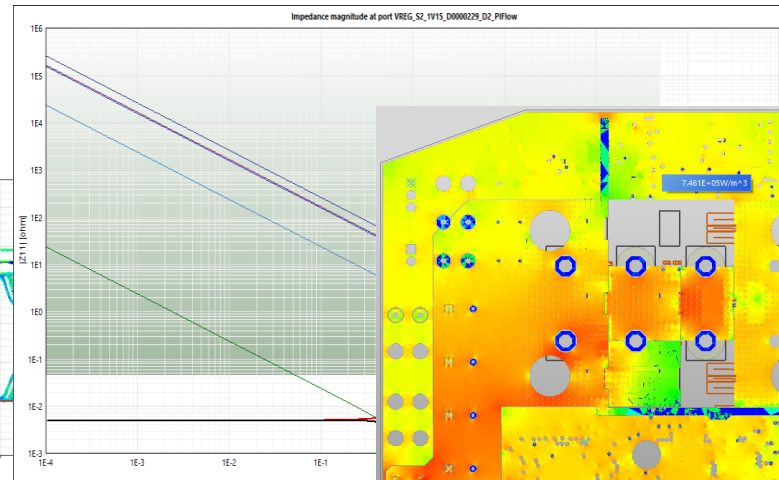
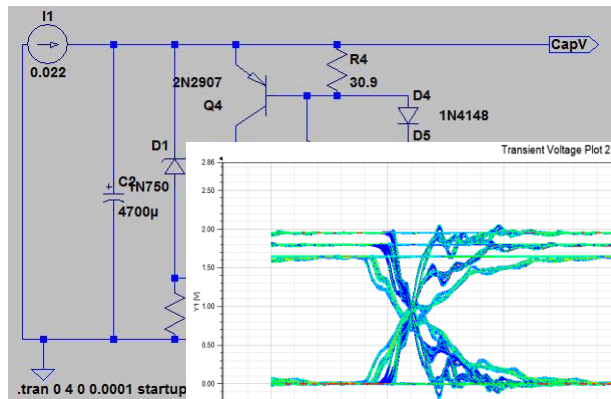
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MDD in the design process

- Module design Electronics:
 - SPICE
 - SI & PI
 - Thermal
 - ...



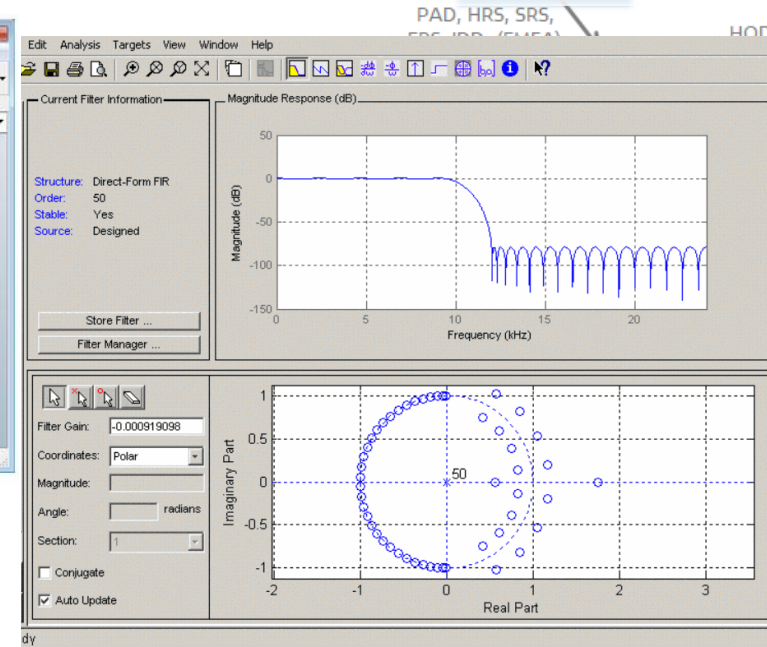
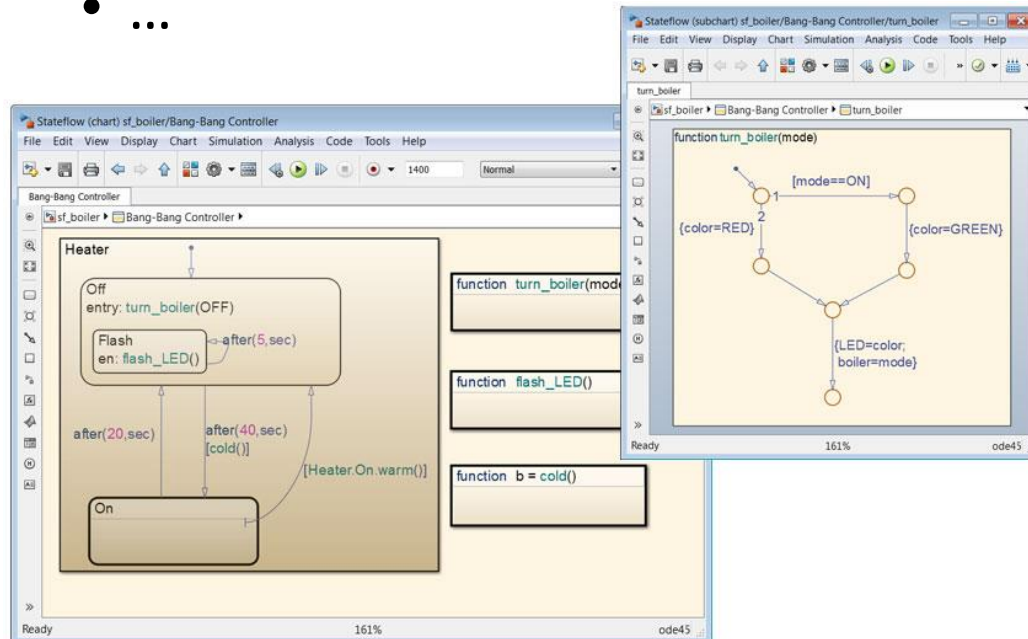
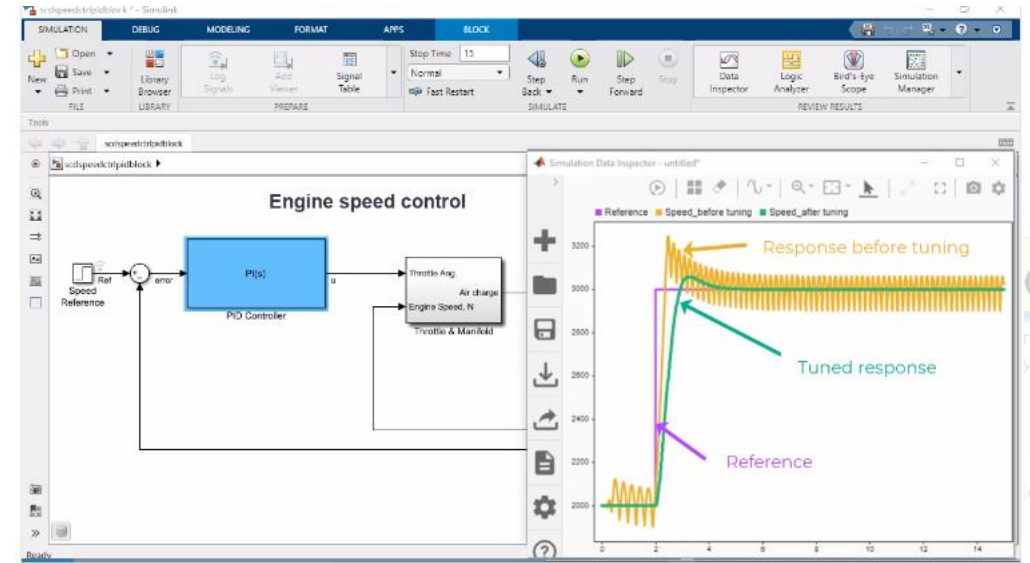
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MDD in the design process

- Module design Software:
 - State diagrams
 - Filters
 - Control Algorithms
 - ...



Module Qualification

Module (release for module qualification)

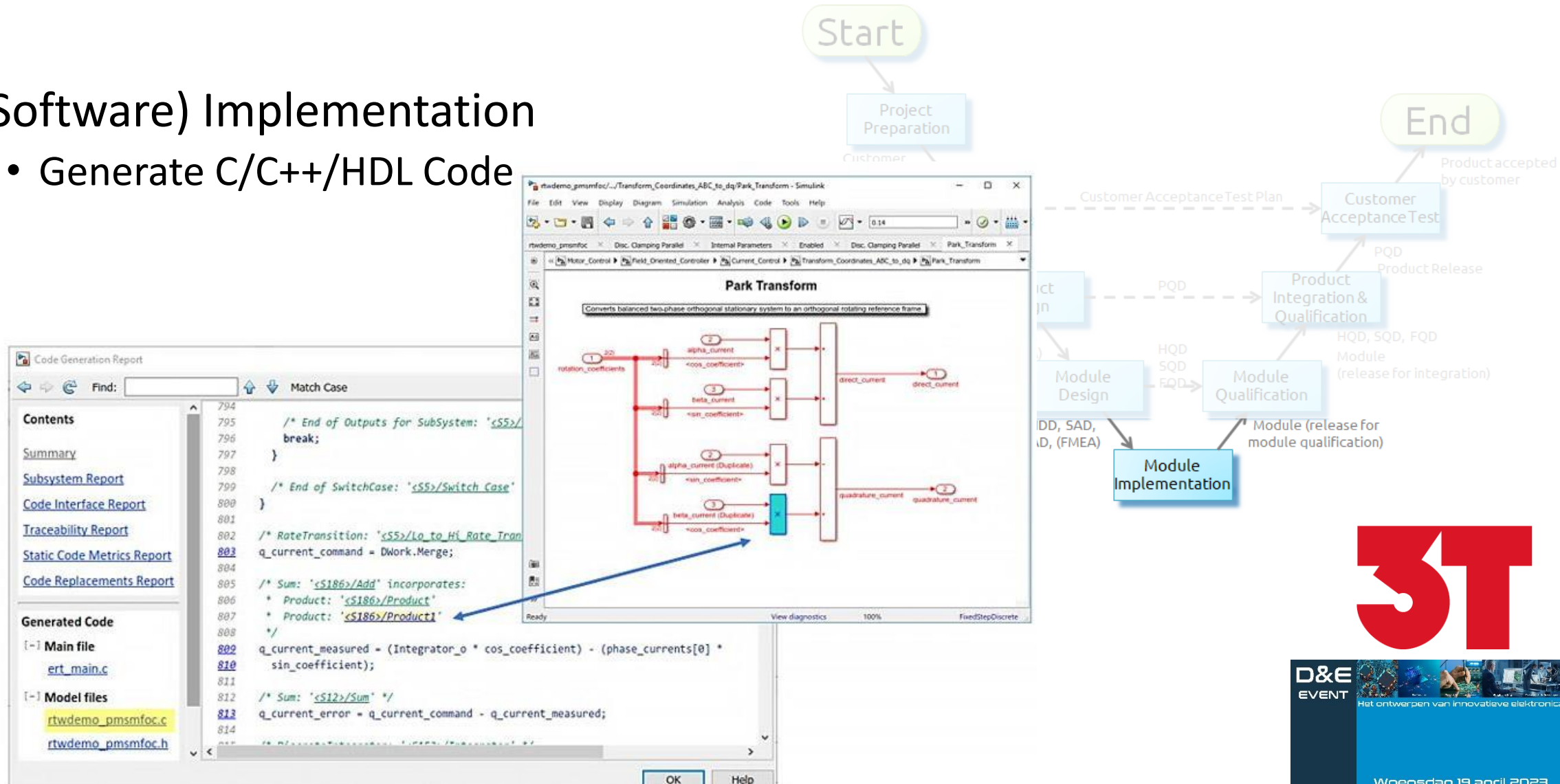
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MDD in the design process

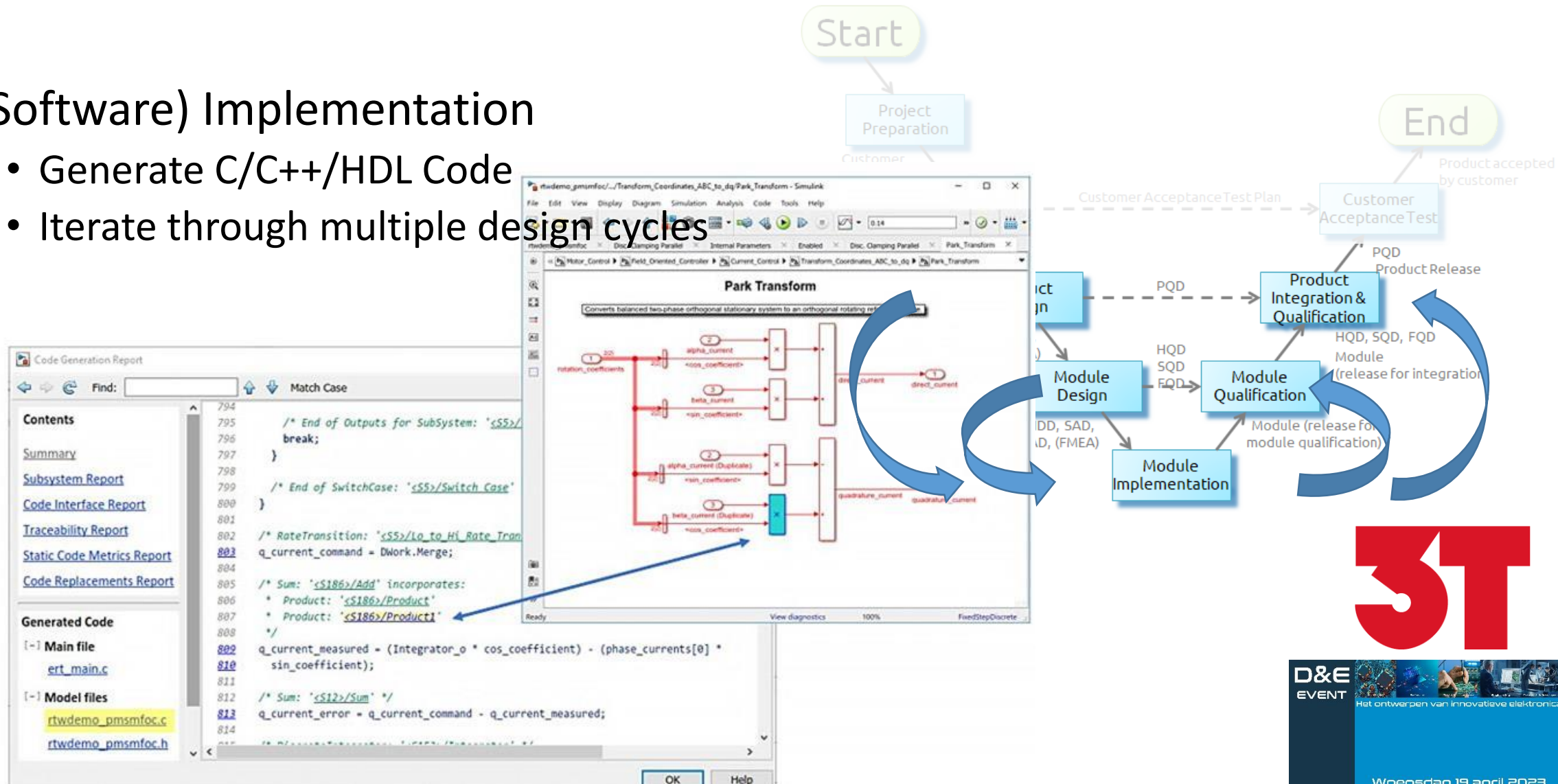
- (Software) Implementation
 - Generate C/C++/HDL Code



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MDD in the design process

- (Software) Implementation
 - Generate C/C++/HDL Code
 - Iterate through multiple design cycles



Project: Skytron Freedom



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Project: Skytron Freedom

The challenge:

- Easy positioning and movement of arm
 - Drift due to mechanical bending
 - Interacting with devices on arm cause movement
 - Accidental Impacts may have large consequences
- Intentional friction in joints
 - Takes quite some effort to move arm around
 - Wear on friction mechanism



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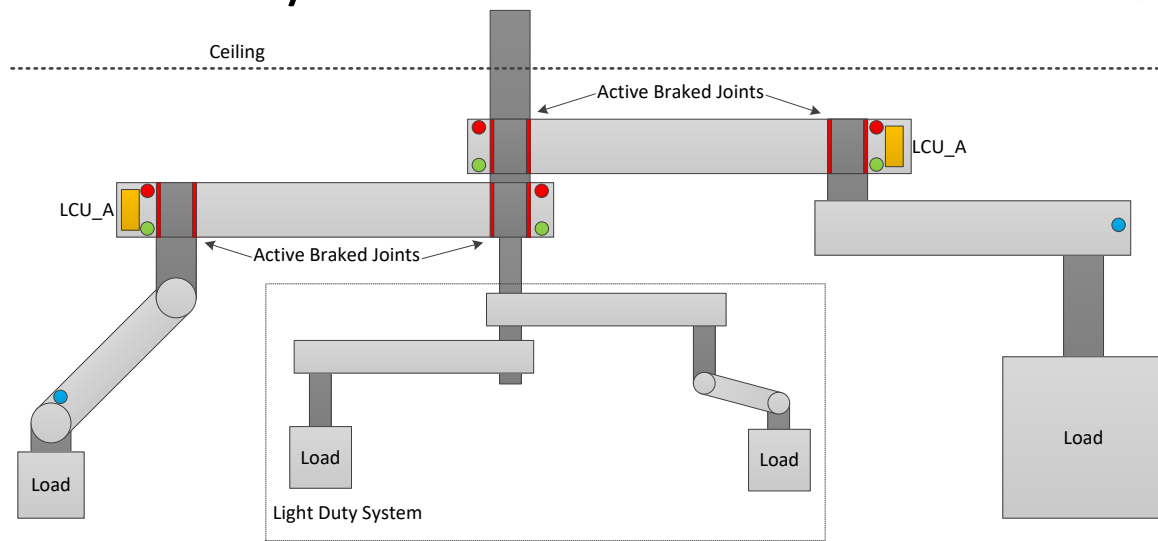
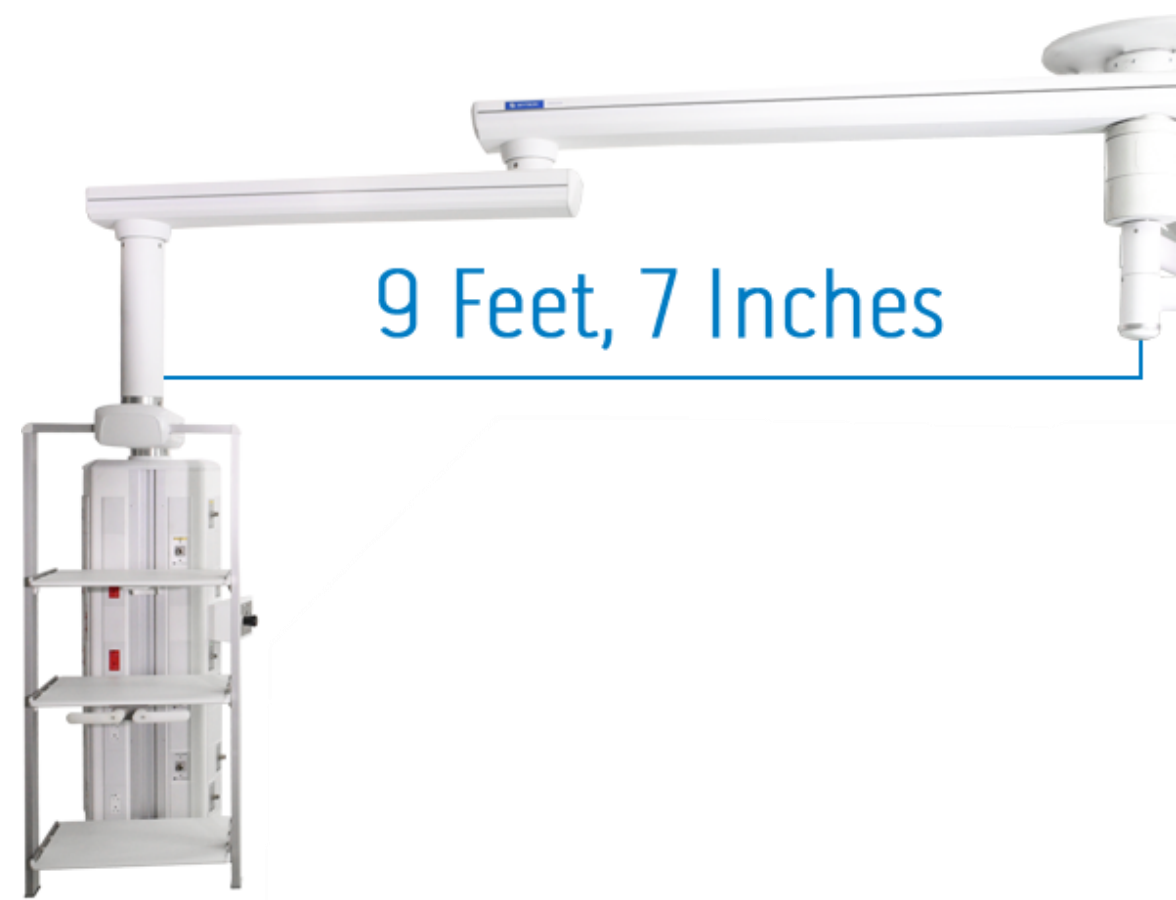
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Project: Skytron Freedom

The Solution:

- Smart Braking System
 - Easy to move when needed
 - Stable when stationary
 - No special user interaction needed
 - Sensor system to detect user intention



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Project: Skytron Freedom

Responsibilities:

- Customer will be responsible for:
 - mechanical design of system
 - user experience
- 3T to develop Electronics and embedded Software

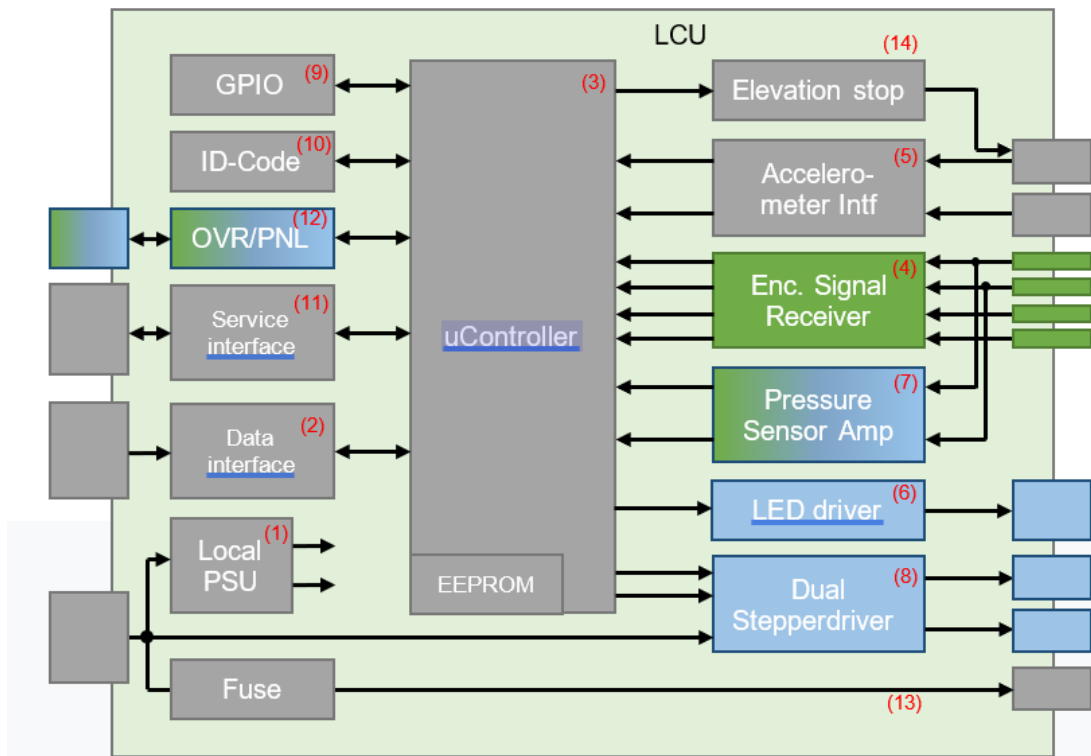
Goal of project: An excellent user experience

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Project: Skytron Freedom

Specification:

- Electronics



9 Feet, 7 Inches

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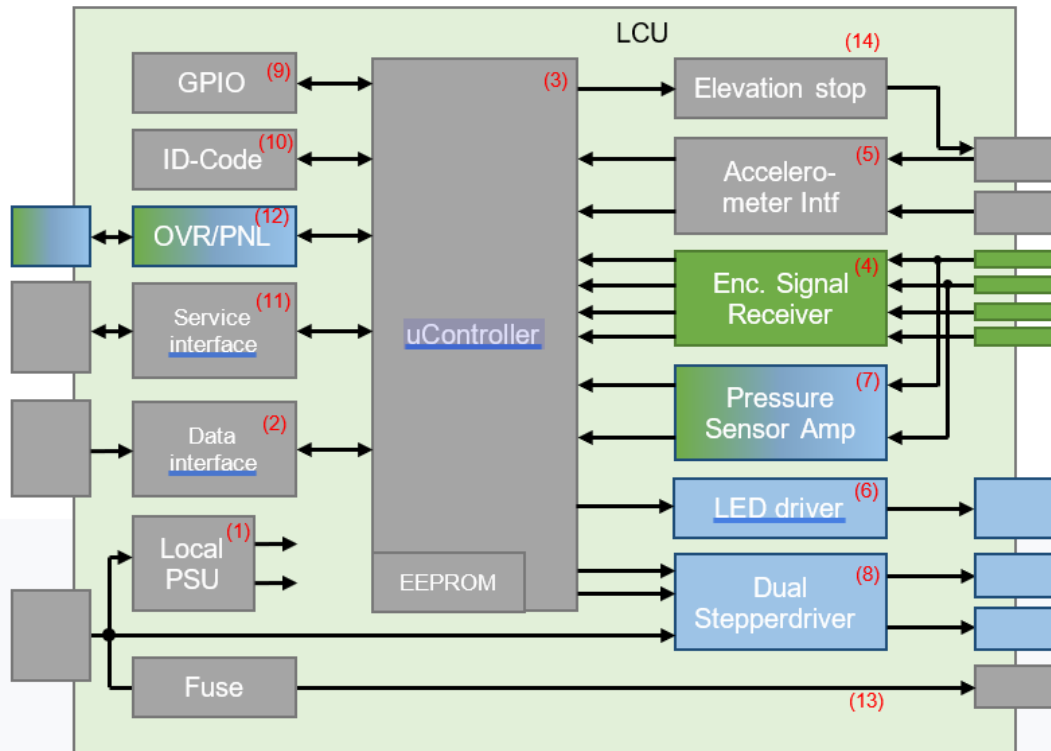
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Project: Skytron Freedom

Specification:

- Electronics



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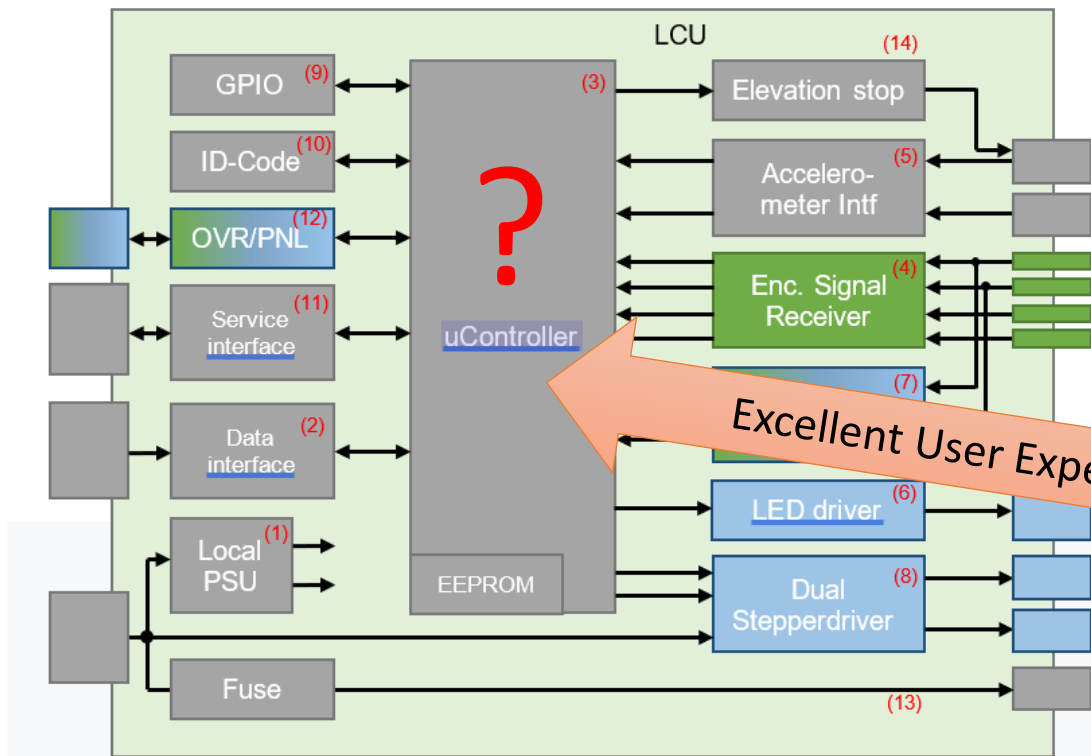
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Project: Skytron Freedom

Specification:

- Software specification



Excellent User Experience??



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Project: Skytron Freedom

Software specifications (?):

- Ensure all hardware interfaces are accessible and controllable
- The desired user experience of the end-product
- Mechanical design of brakes and arm not available at project start

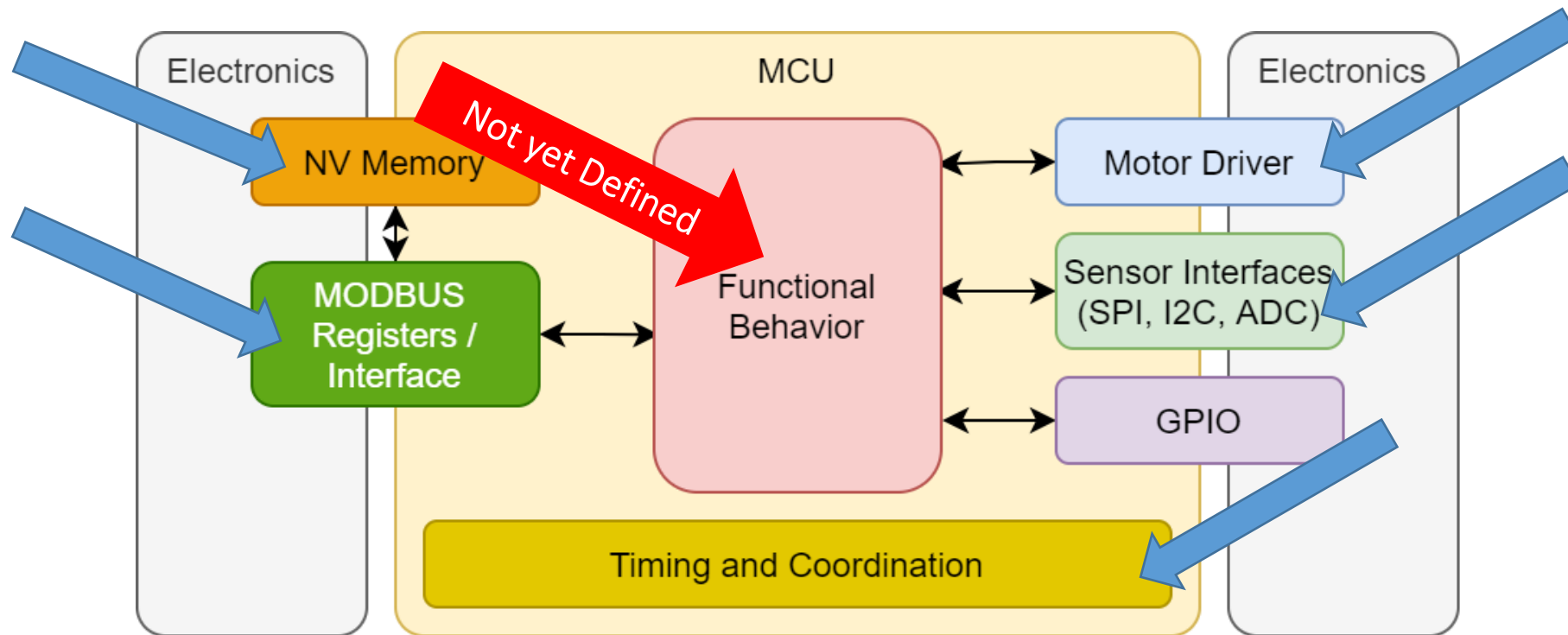
In other words, a lot still undetermined

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Project: Skytron Freedom

Development Strategy: Reduce development time and risk

- Use of existing design experience for electronics and software



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Project: Skytron Freedom

Development Strategy: Reduce development time and risk

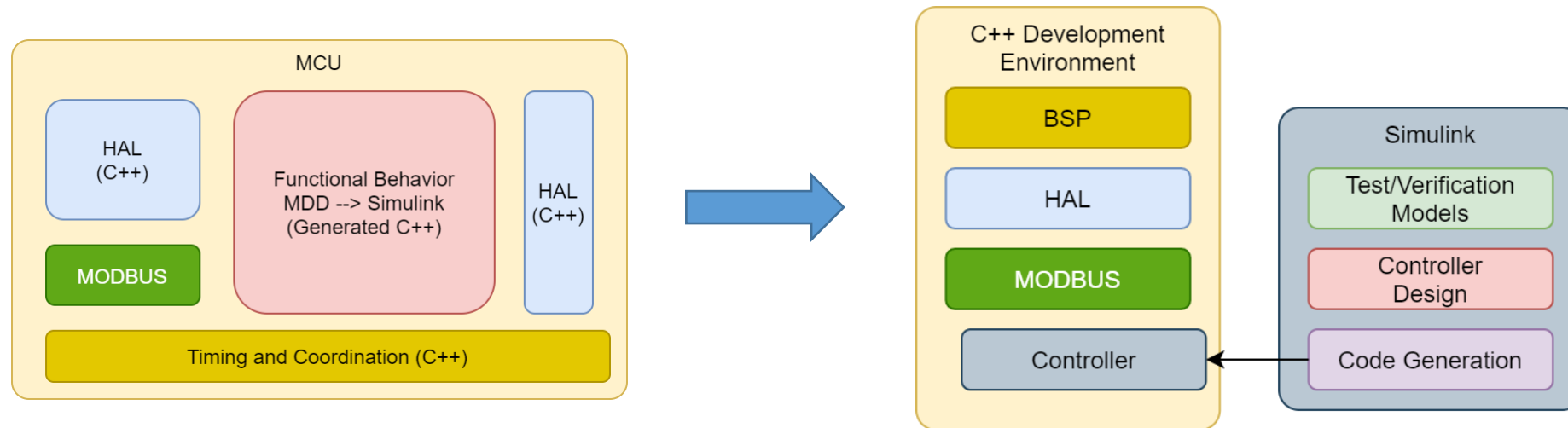
- Use MDD for Functional Behavior design and implementation
 - Common multidisciplinary language for communication
 - Evaluate against model and allow rapid iteration cycles
 - Ability to look deep inside model to gain insight and solve issues
 - Design engineer does not need to be a software engineer

A large, bold, red logo consisting of the numbers '3' and 'T' joined together.

Project: Skytron Freedom

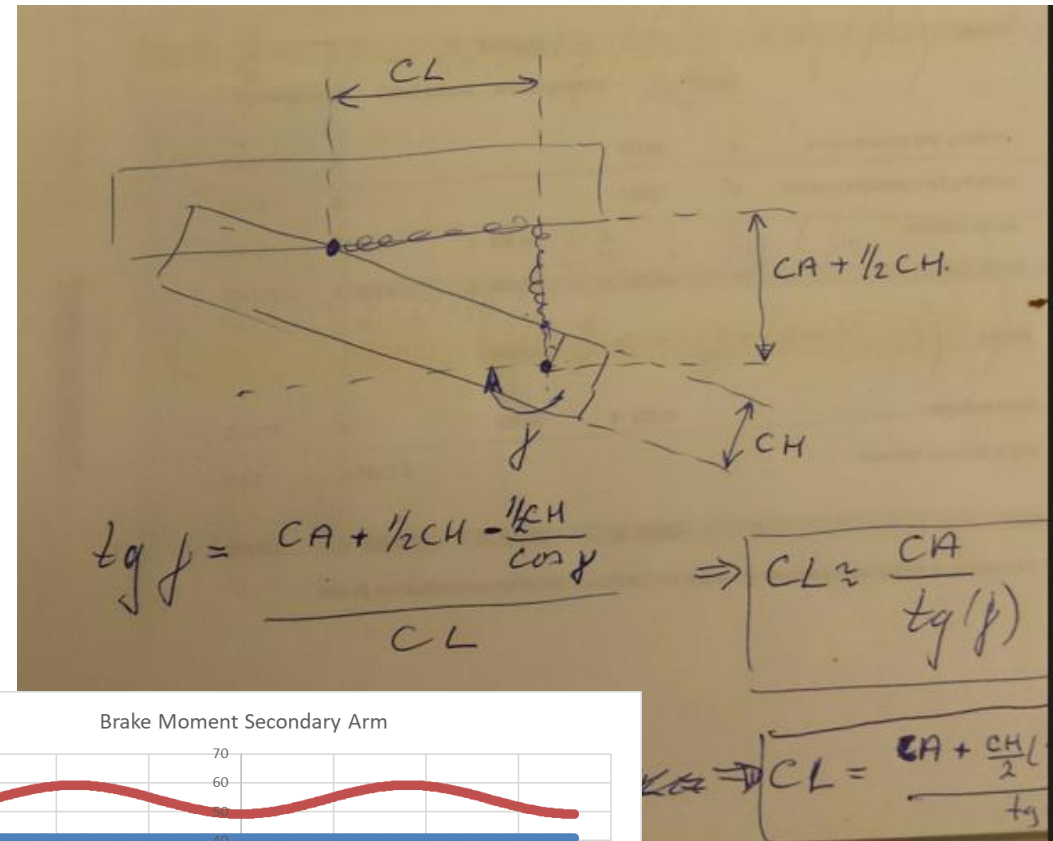
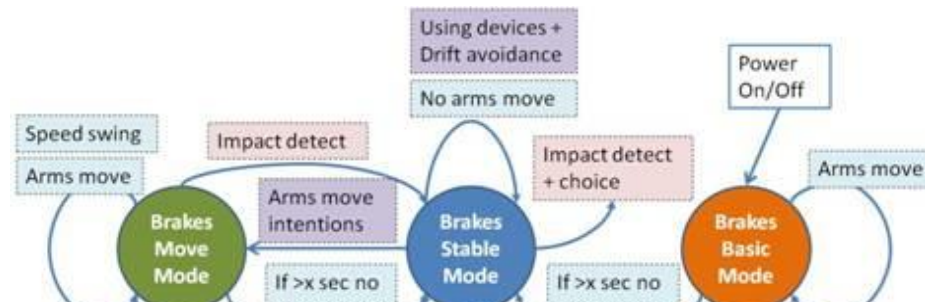
Development Strategy: Reduce development time and risk

- Functional Behavior will be generated C++ function to be included in C++ project



Project: Skytron Freedom

Customer's Language



Aanpassen Brake Moment:

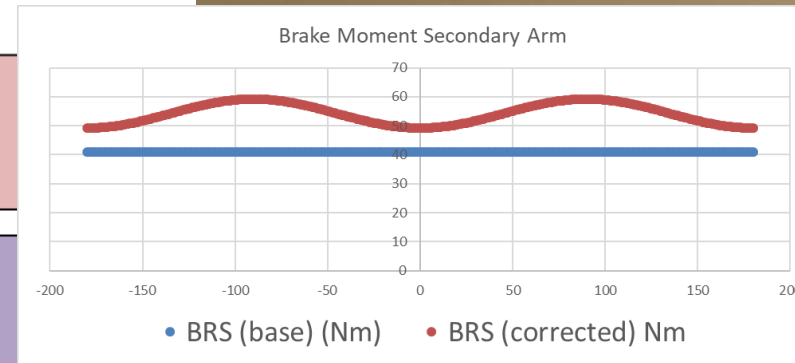
BRP-mimp: Brake = ALS(IMDM=true; BRP-brake-max; Brake (last))

BRP-stab: Brake = ALS(STAB=true; BRP-stab; Brake (last))

Aanpassen Brake Moment:

BRS-mimp: Brake = ALS(IMDM=true; BRS-brake-max; Brake (last))

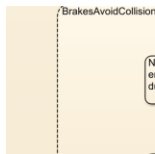
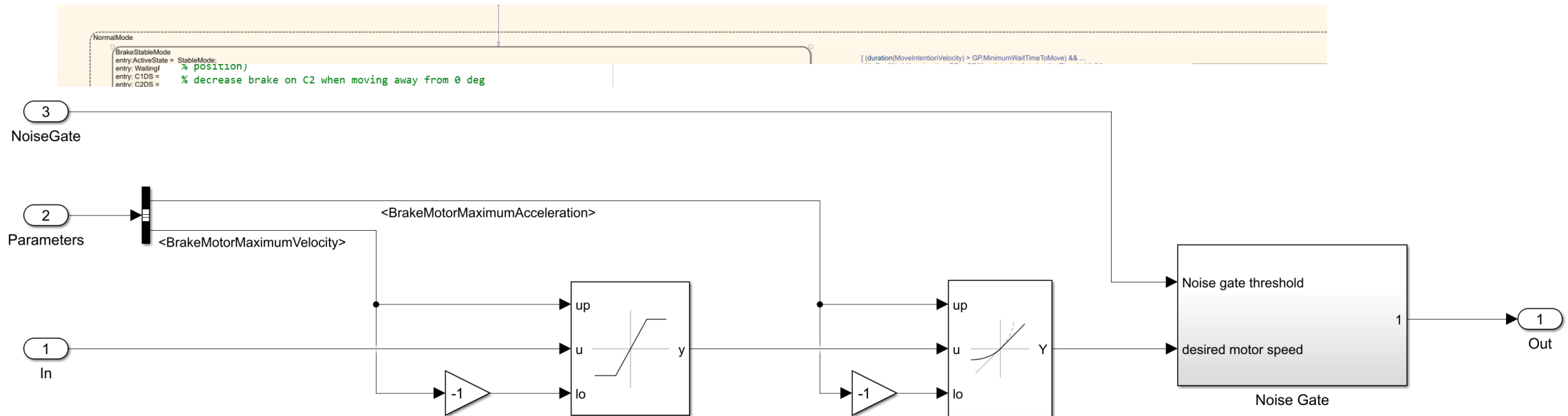
BRS-stab: Brake = ALS(STAB=true; BRS-stab; Brake (last))



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	D
	(mg)	(mg)	(mg)	(rad)	(rad)	(rad)	(rad/msec)	(rad/msec)	(rad/msec)		MOVE	MOVE	ROTATE	ROTATE		STABLE	D
	Ax	Ay	Az	Ha	Hb	Hc	Ha	Hb	Hc		intent	active	pendant	carrier		pendant	H
47	3.267	-1.930	0.000	-1.300	-1.981	-1.539	3.728	22.371	22.371							JA	
48	3.118	-1.782	0.000	-1.300	-1.981	-1.545	3.728	26.099	22.371							JA	
49	2.970	-1.633	-0.015	-1.300	-1.969	-1.545	0.000	33.556	26.099				JA				
50	3.118	-1.782	0.000	-1.300	-1.969	-1.551	0.000	37.284	29.827				JA				



Project: Skytron Freedom



```

case MoveMode
a = C2.EffectiveArmLength * ElevationCorrection * sin(C2.Position);
b = max([(C1.EffectiveArmLength + C2.EffectiveArmLength * ElevationCorrection * cos(C2.Position)) 0.001]);
c = a/b;
C1DS.BrakeTarget = GP.TargetForceMoveMode * b * sqrt(c*c+1) + max(0, C1.CorrectionBrakeTorqueAmplitude * (cos(2 * C2.AbsolutePosition) - cos(2 * pi * C1.CorrectionBrakeTorqueFactor / 180)));
C2DS.BrakeTarget = (GP.TargetForceMoveMode + DeflectionCorrectionMoveMode * 0.5 * (1-cos(2*C2.AbsolutePosition))) * C2.EffectiveArmLength * ElevationCorrection;

```



Project: Skytron Freedom

1
Setp

2
Feedback

Block Parameters: C1 Force controller

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: PD Form: Parallel

Time domain:

Continuous-time

Discrete-time

Discrete-time settings

PID Controller is inside a conditionally executed subsystem

Sample time (-1 for inherited): Ts 0.01

Compensator formula

$$P + D \frac{1}{T_s} \frac{z-1}{z}$$

Main Initialization Saturation Data Types State Attributes

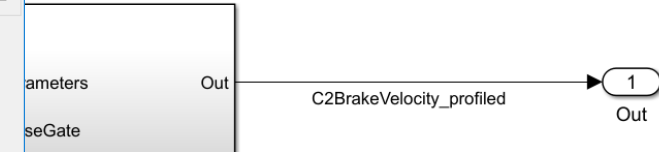
Controller parameters

Source: external

Use filtered derivative

Enable zero-crossing detection

OK Cancel Help Apply

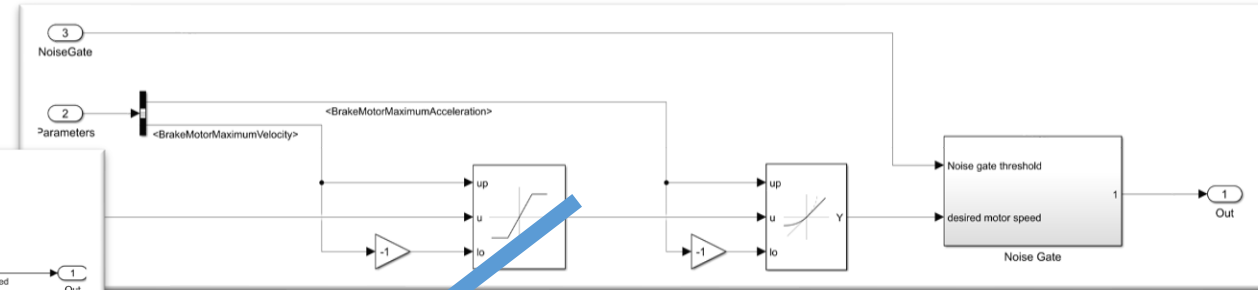
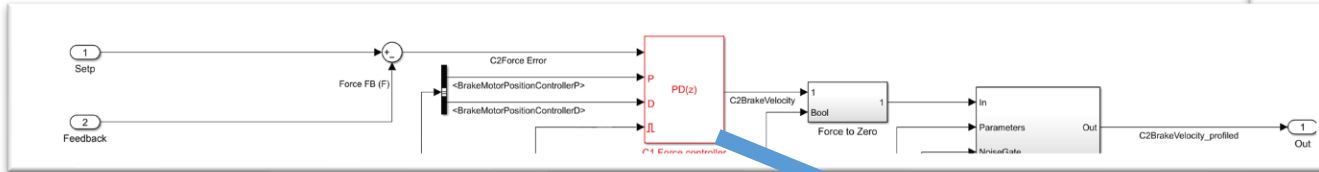


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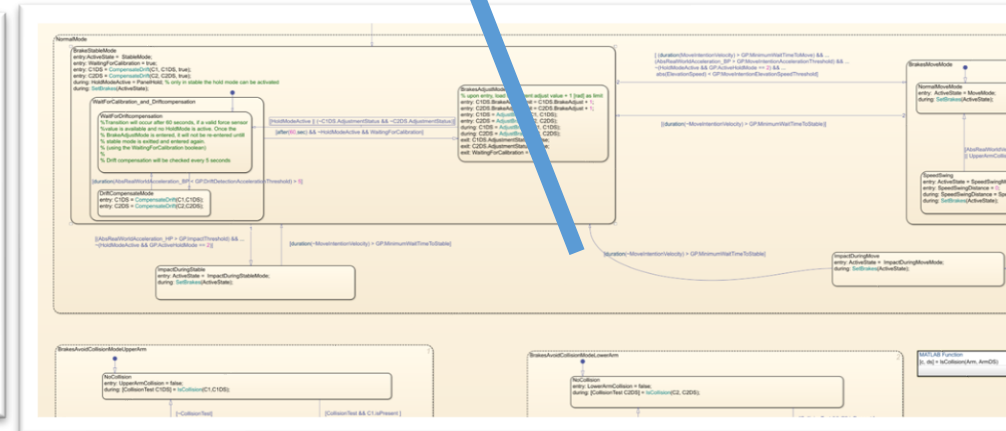
Project: Skytron Freedom



The Design of the Functional Behavior

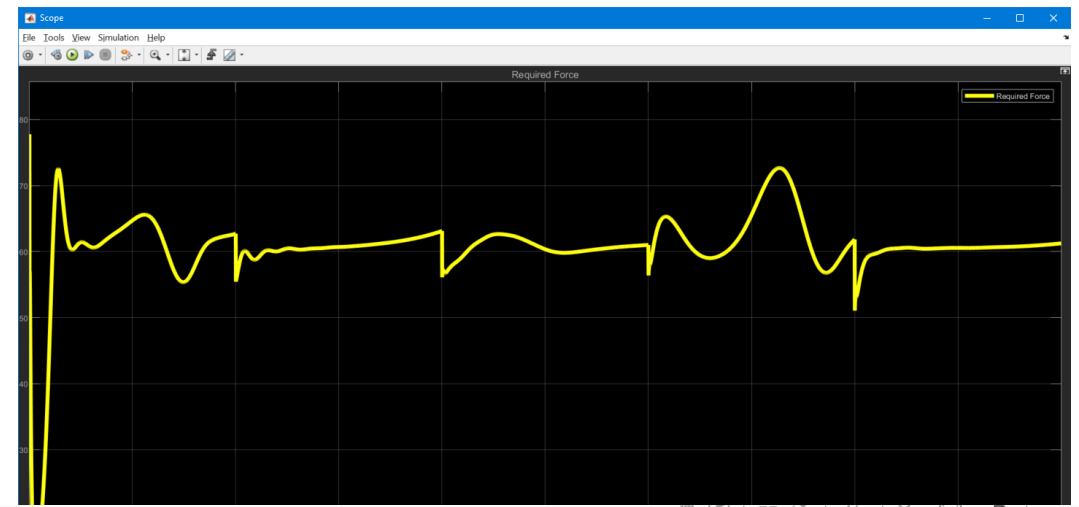
```
% decrease brake on C2 when moving away from 0 deg
if C2.Velocity * C2.AbsolutePosition < 0
    DeflectionCorrectionNovelMode = 135/250 * LoadParams.Weight;
else
    DeflectionCorrectionNovelMode = -1 * 135/250 * LoadParams.Weight * GP.TargetForceNovelMode / 200;
end

switch(inp)
case {InitMode, InitBrakesMode, BasicMode}
    a = C2.EffectiveArmLength * ElevationCorrection;
    b = C1.EffectiveArmLength;
    c = a/b;
    C1DS.BrakeTarget = 1.2 * GP.TargetForceStableMode * C1DS.TargetForceCompensation * b * sqrt(c*c+1);
    C2DS.BrakeTarget = 1.2 * GP.TargetForceStableMode * C2DS.TargetForceCompensation * C2.EffectiveArmLength * ElevationCorrection;
case StableMode
    a = C2.EffectiveArmLength * ElevationCorrection * sin(C2.Position);
    b = max([(C1.EffectiveArmLength + C2.EffectiveArmLength * ElevationCorrection * cos(C2.Position)) 0.001]);
    c = a/b;
    C1DS.BrakeTarget = GP.TargetForceStableMode * C1DS.TargetForceCompensation * b * sqrt(c*c+1);
case NovelMode
    a = C2.EffectiveArmLength * ElevationCorrection * sin(C2.Position);
    b = max([(C1.EffectiveArmLength + C2.EffectiveArmLength * ElevationCorrection * cos(C2.Position)) 0.001]);
    c = a/b;
    C1DS.BrakeTarget = GP.TargetForceNovelMode * b * sqrt(c*c+1) + max(0, C1.ConnectionBrakeTorqueAmplitude * (cos(2 * C2.AbsolutePosition) - cos(2 * pi * C1.ConnectionBrakeTorqueFactor / 180)));
    C2DS.BrakeTarget = (GP.TargetForceNovelMode + DeflectionCorrectionNovelMode * 0.5 * (1-cos(2*C2.AbsolutePosition))) * C2.EffectiveArmLength * ElevationCorrection;
```

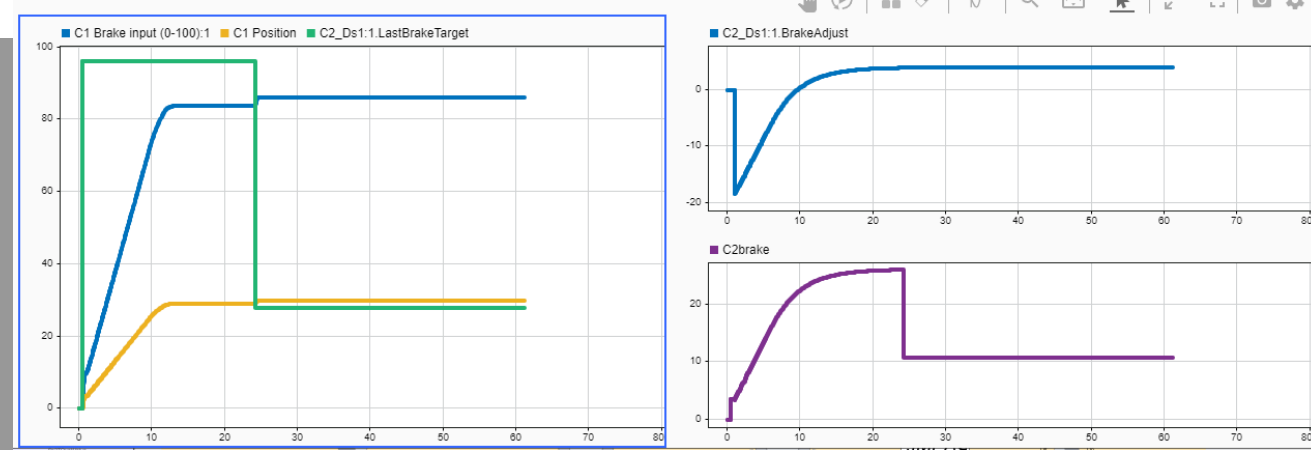
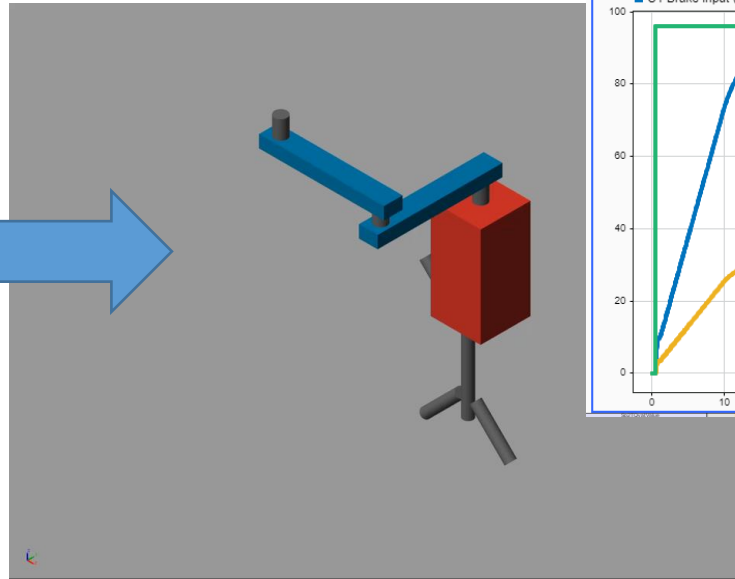


Project: Skytron Freedom

- Simulate against model of 'real world'



DESIGN



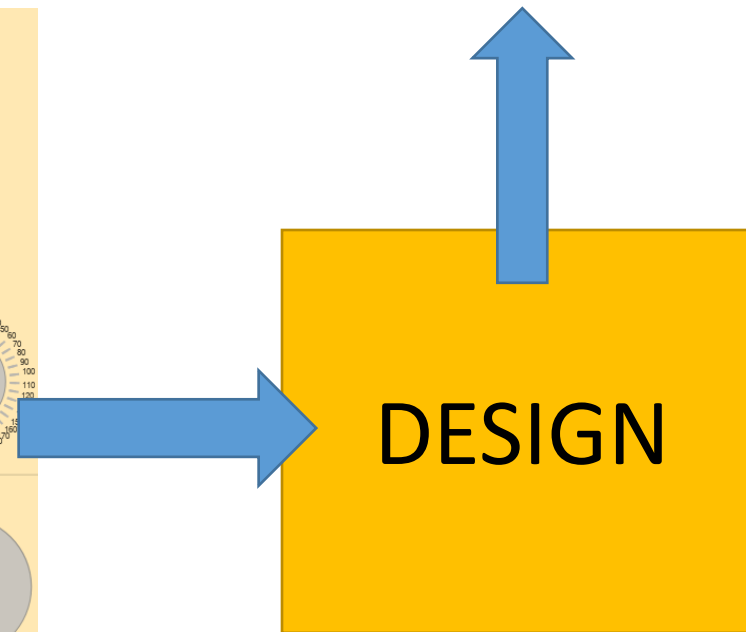
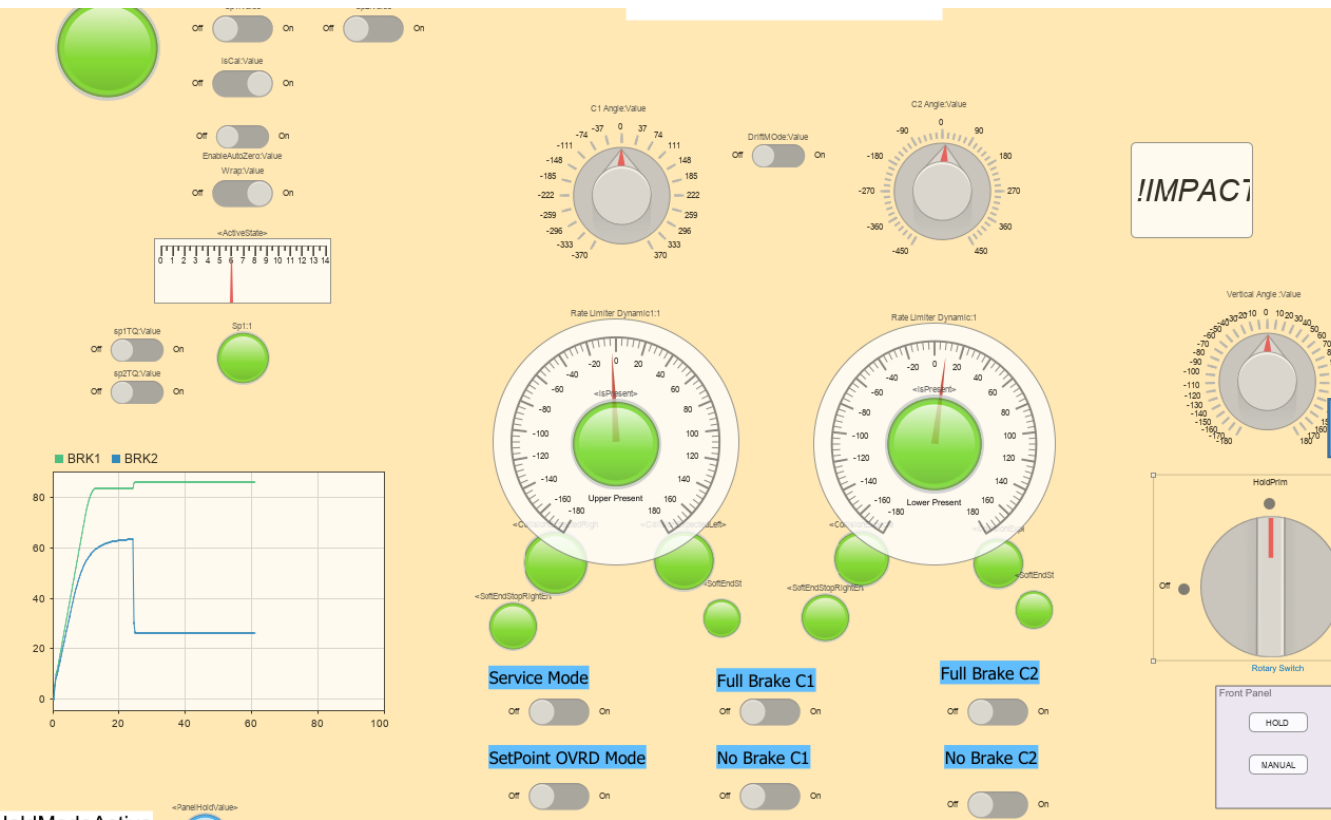
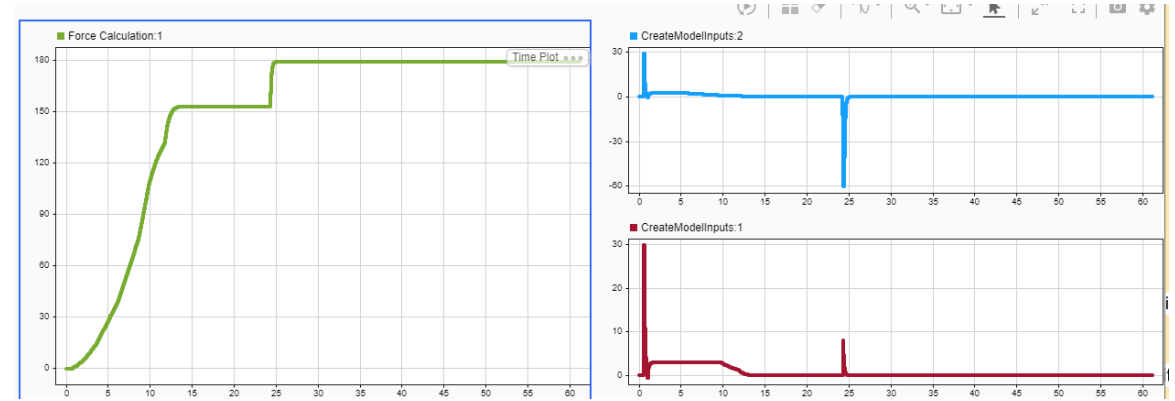
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Project: Skytron Freedom

- Simulate against specific scenario's

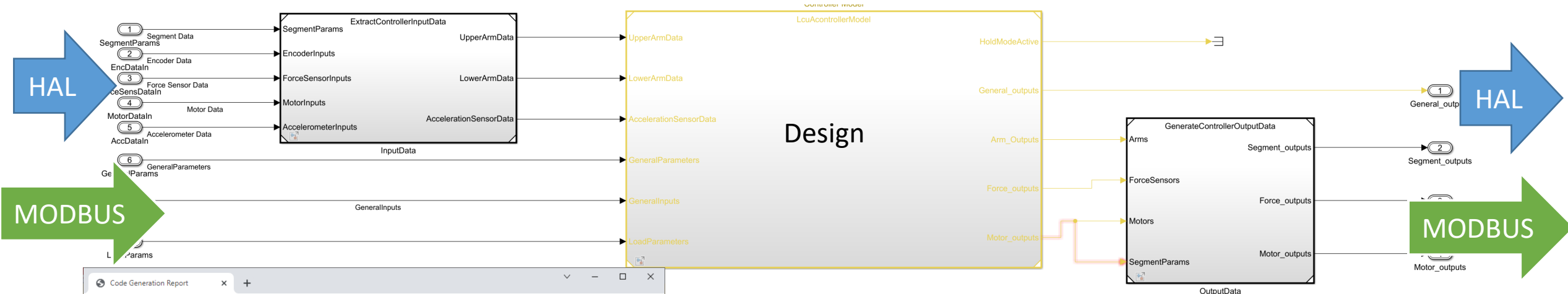


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Project: Skytron Freedom



Code Generation Report

File | D:/Projects/IHB%20ML/work/LcuAController_ert_rtw/html/index.html

LcuAController

Content

- Summary
- Subsystem Report
- Code Interface Report
- Traceability Report
- Static Code Metrics Report
- Code Replacements Report
- Coder Assumptions

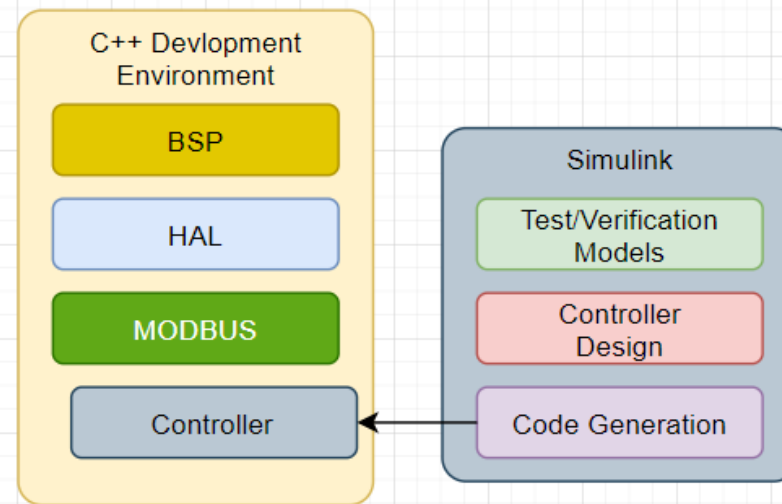
Code

- Main file
 - ert_main.cpp
- Model files
 - LcuAController.cpp
 - LcuAController.h
 - LcuAController_private.h
 - LcuAController_types.h
- Shared files
 - rtwtypes.h
 - zero_crossing_types.h

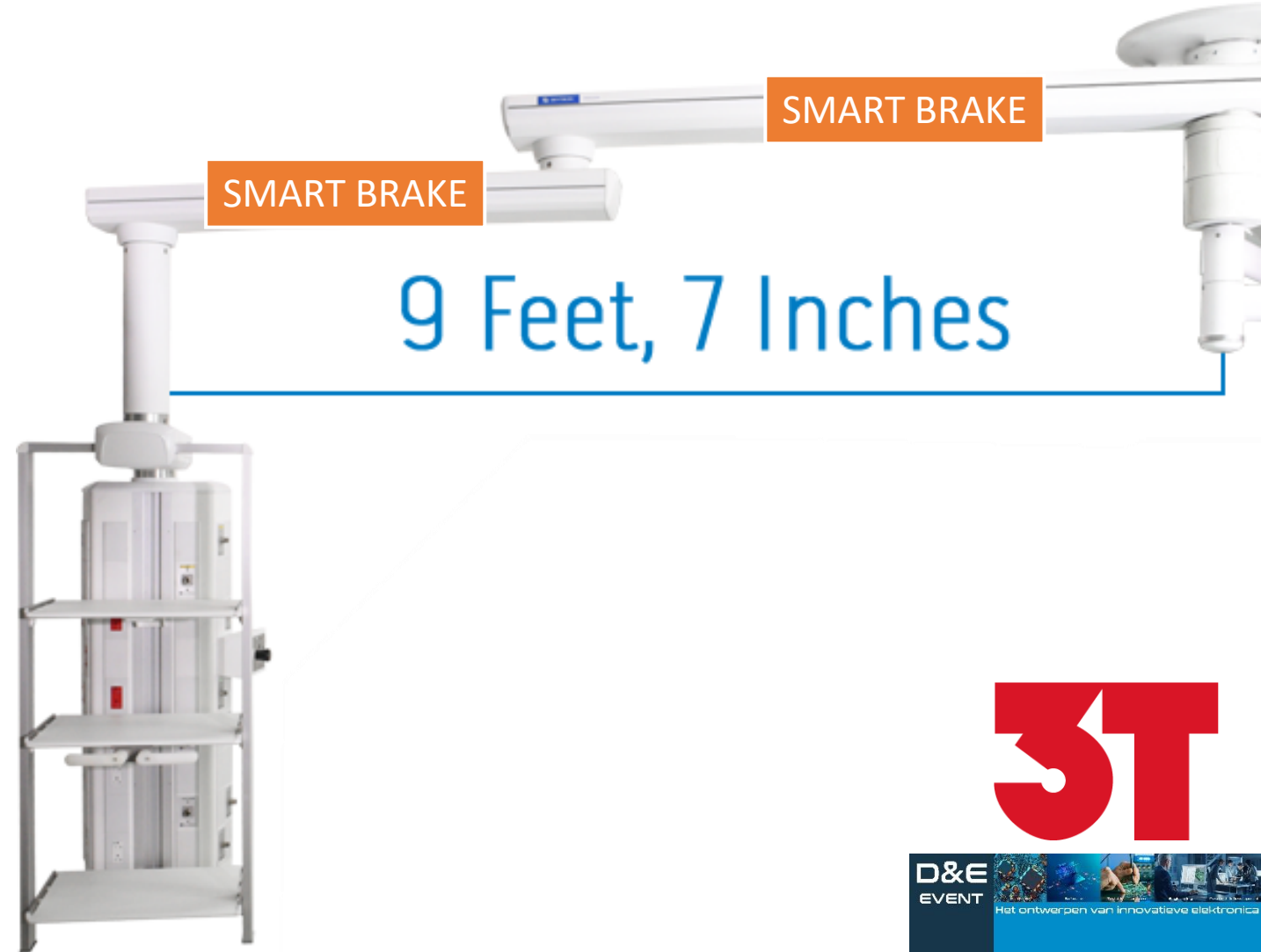
```

68      &rtb_controllerModel_04[0], &rtb_controllerModel_05[0]);
69
70      // ModelReference: '<Root>/OutputData' incorporates:
71      //   Input: '<Root>/SegmentParams'
72      //   Output: '<Root>/Force_outputs'
73      //   Output: '<Root>/Motor_outputs'
74      //   Output: '<Root>/Segment_outputs'
75
76      OutputData#MLO833.step(&rtb_controllerModel_03[0], &rtb_controllerModel_04[0],
77      &rtb_controllerModel_05[0], &LcuAController_U.SegmentData[0],
78      &LcuAController_Y.Segment_outputs[0], &LcuAController_Y.Force_outputs[0],
79      &LcuAController_Y.Motor_outputs[0]);
80  }
81
82  // Model initialize function
83  void ModelClass::initialize()
84  {
85      // Model initialize function for ModelReference Block: '<Root>/Controller Model'
86
87      // Set error status pointer for ModelReference Block: '<Root>/Controller Model'
88      Controller_Model#MLO831.setErrorStatusPointer(rtmGetErrorStatusPointer
89      (&LcuAController_M));
90      Controller_Model#MLO831.initialize();
91
92      // Model initialize function for ModelReference Block: '<Root>/InputData'
    
```

Ln 73 Col 37



Project: Skytron Freedom



3T

D&E
EVENT

Het ontwerpen van innovatieve elektronica

Woensdag 19 april 2023
1931 Congressentrum 's-Hertogenbosch

Project: Skytron Freedom

Integration:

- Comparison between model and mechanical system
 - Optimize system and model
- Rapid design iterations to achieve the *Excellent user Experience*

A large, bold, red logo consisting of the characters '3' and 'T' in a stylized, blocky font.

Project: Skytron Freedom

Reduced time and risk;

- Design and design-changes represented in common language
- The design has already gone through several evaluation and optimization cycles
- (Major) Changes in high level structure can be made fairly easy without too much pain
- Understanding and solving integration issues without needing access to system
- SW development not longer limited to SW designers



How to reach us

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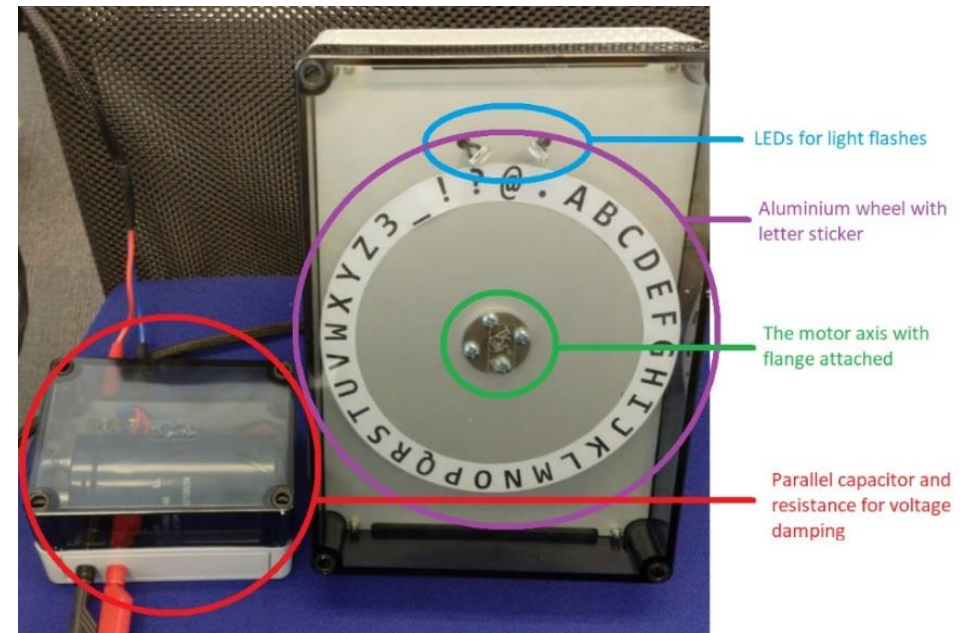
www.3T.nl

We're at stand number 2

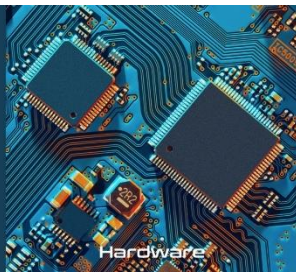
With an FPGA based MDD demonstration!



KENDRION



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Hardware



Software



Test & Measurement



Engineering



Research & Development

Het ontwerpen van
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Woensdag 19 april 2023
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