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Modelling and Validation Framework for Efficient Development of Consumer Appliances for Mass Production

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Prepared for: SWISSED 2019

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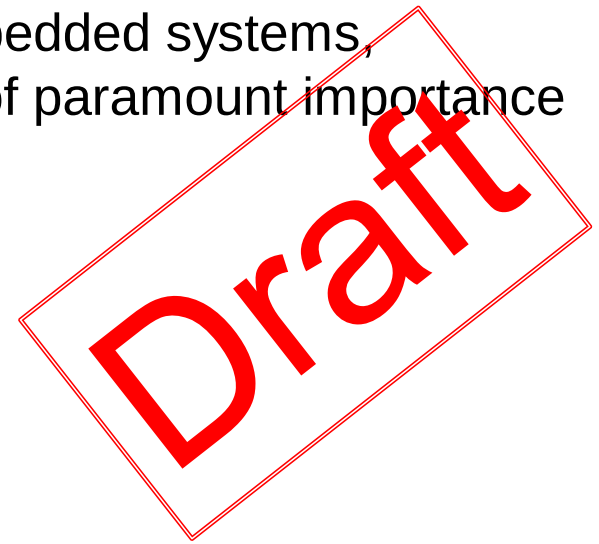
Outline

- Introduction and Motivation
- Methodology Blueprint
- Case Study: DC Motor Controller
- Conclusions

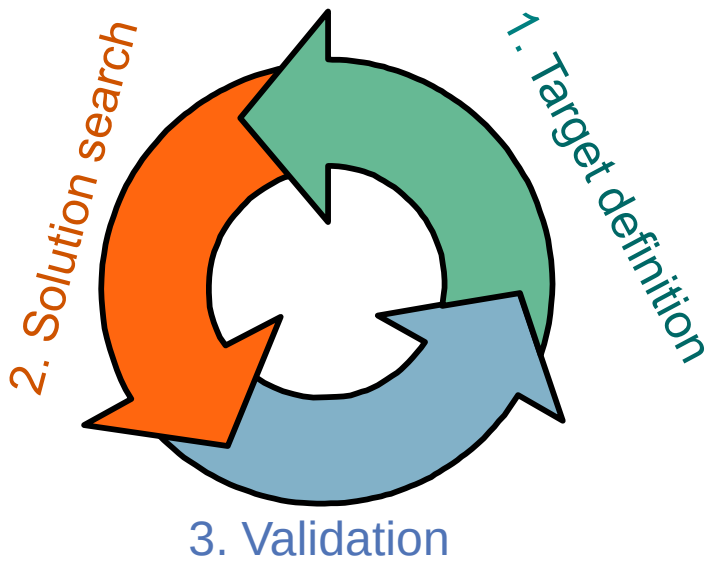
Introduction: Challenges and Motivation

- Development of consumer appliances is increasing challenging due to:
  - Their growing complexity
  - Strong competition and high customer expectations
  - Low-cost requirements and tight schedules
  - Challenges related to the mass production

- As modern customer appliances are based embedded systems, ensuring high-quality of embedded software is of paramount importance



Introduction:
Embedded SW for Consumer Appliances

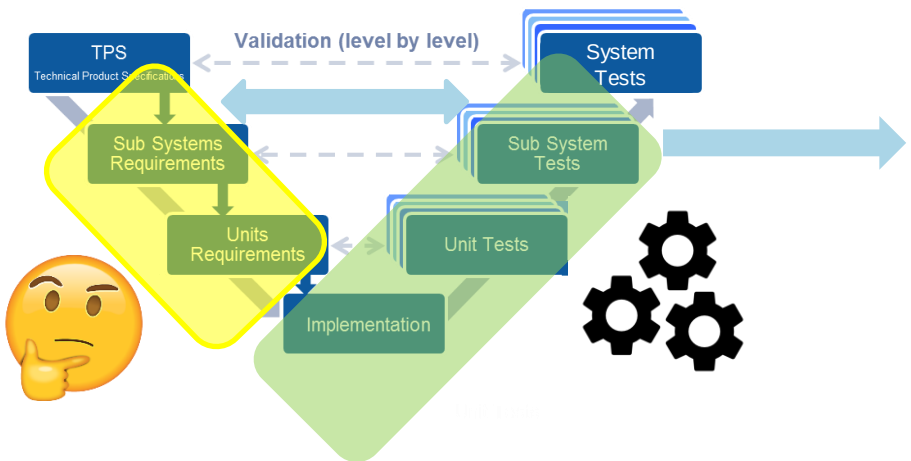


- Embedded SW development is an iterative process
- Validating the SW on a physical device after each iteration is:
  - Impractical
  - Time-consuming and
  - Sometimes impossible
- Modeling & simulation is a powerful tool to decrease the validation time and thus to significantly improve the overall efficiency

Introduction: Modeling & simulation

Model analysis:

- Simulation (experiment on a model) to understand the system or answer specific questions
- Sensitivity Analysis
- Model-Based Diagnosis
- Model Verification and Validation:
  - Are we building the system right?
  - Are we building the right system (requirements)?

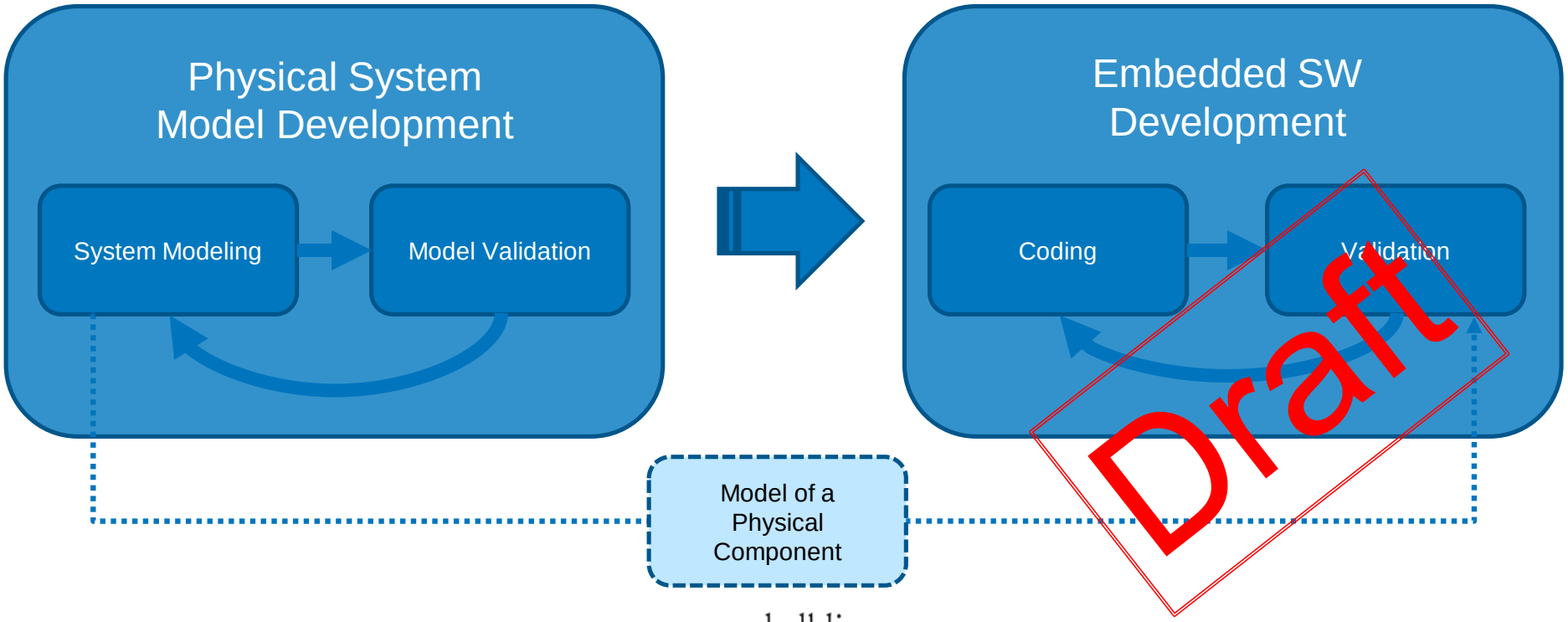


This gives inputs for:

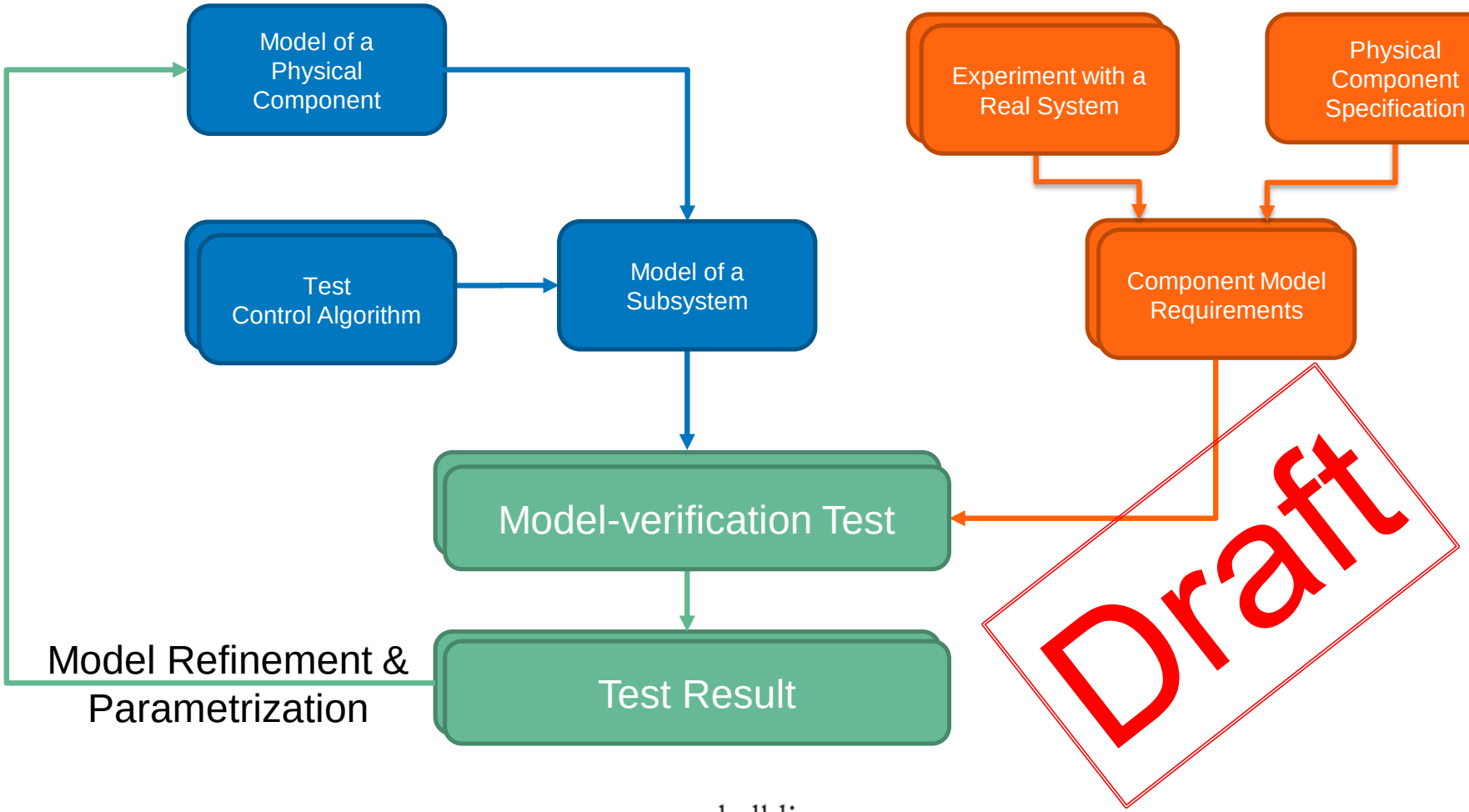
- **Risk analysis at an early stage** → modifications in the system architecture are less costly at early stages.
- Pinpoints weak and strong points of system early on
- Optimization of system
- Qualitative selection of critical tests to be performed on eventual prototype
- **Deep understanding of behavior of the system & reduced likelihood of unexpected behavior/failure**

Methodology: Overview

- Modeling of a physical system and its components
- SW development and verification using the model
- Automated SW testing after each SW change



Methodology: Physical System Modeling



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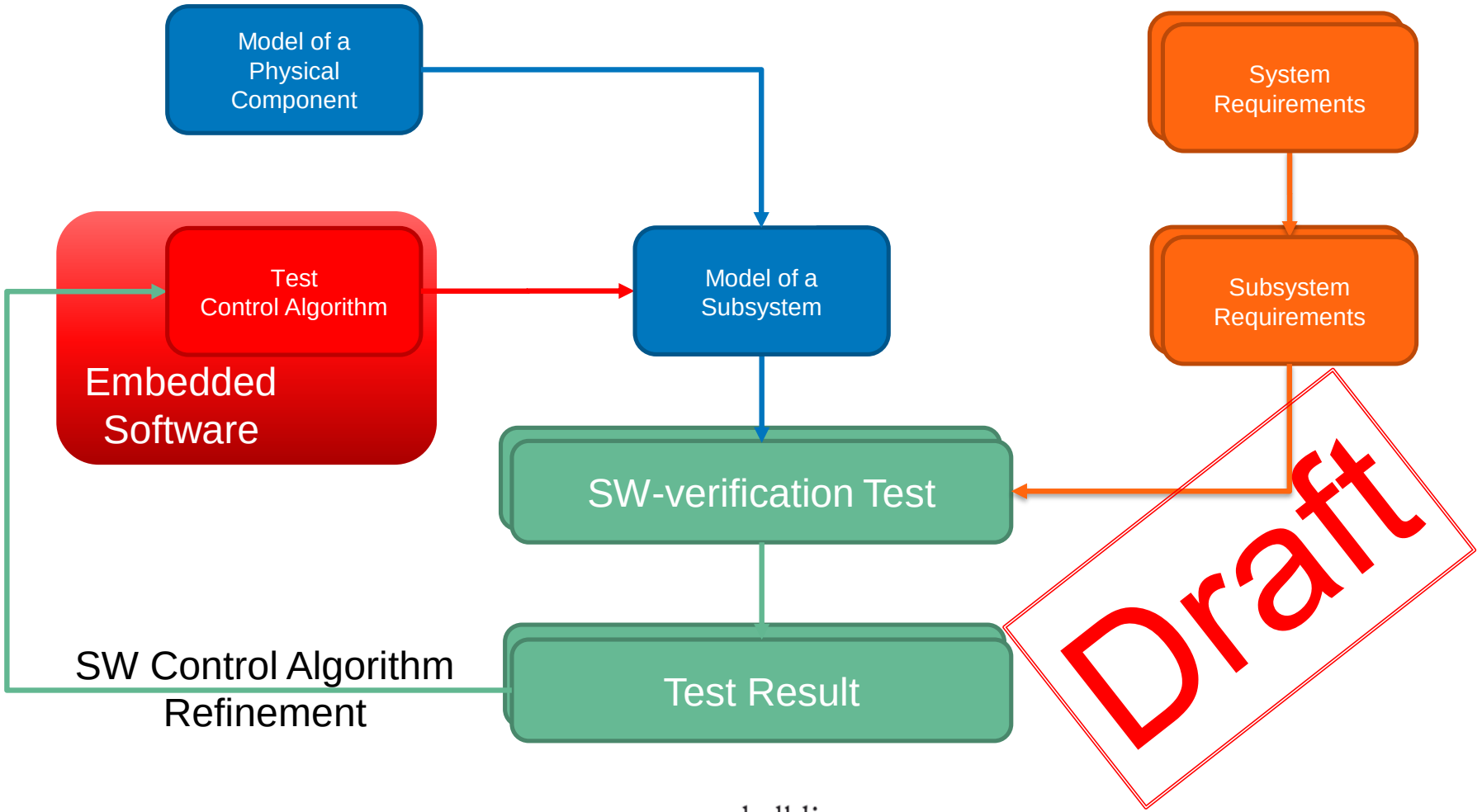
Methodology: SW Development and Validation



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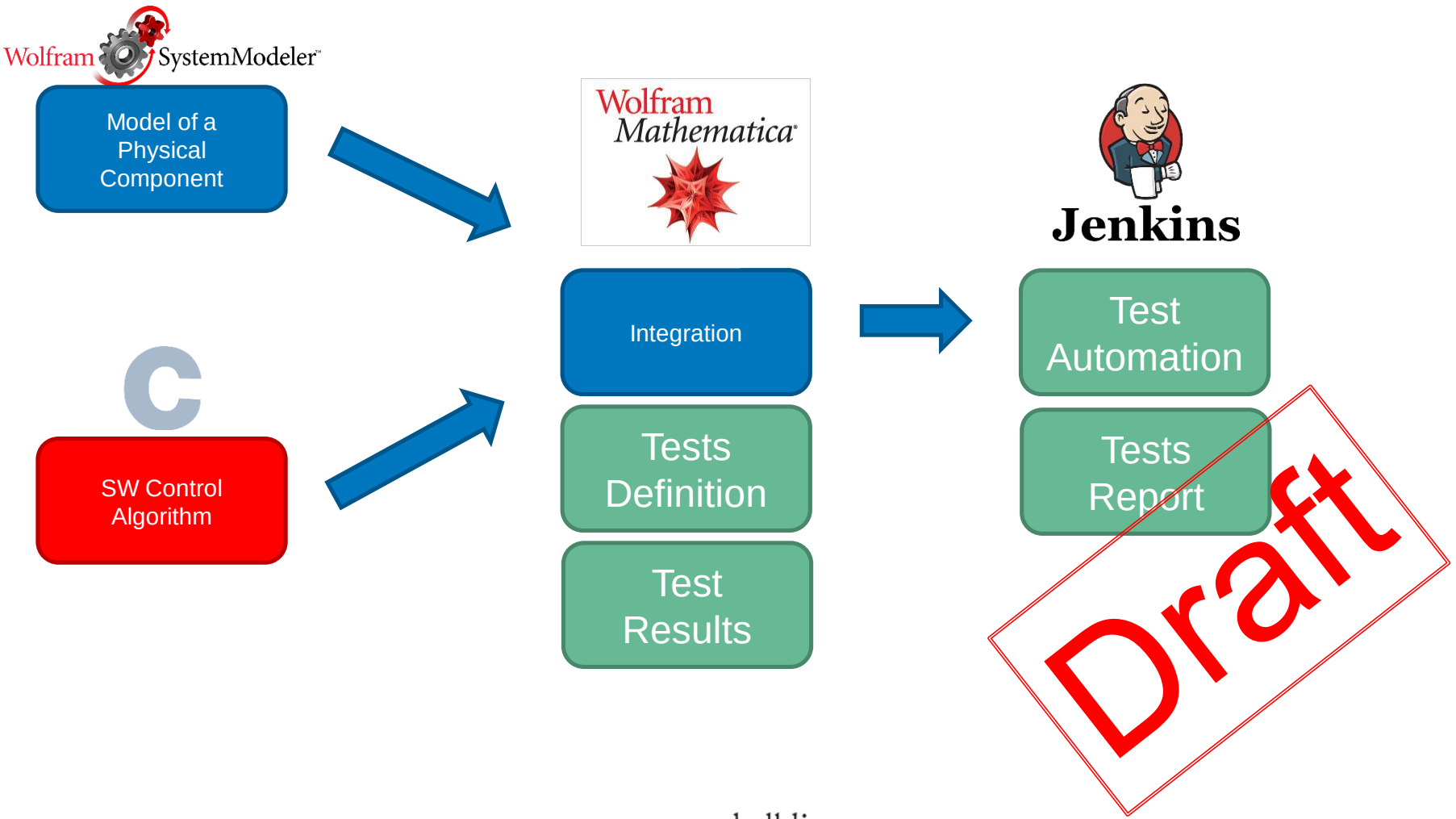
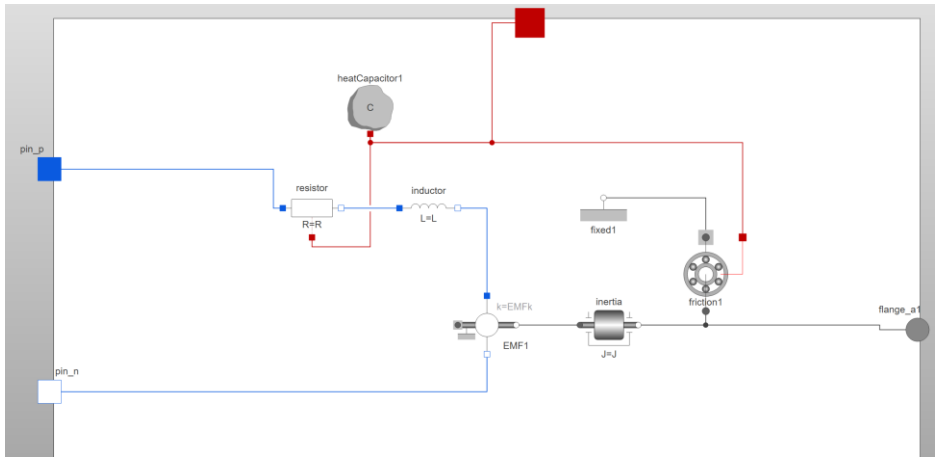
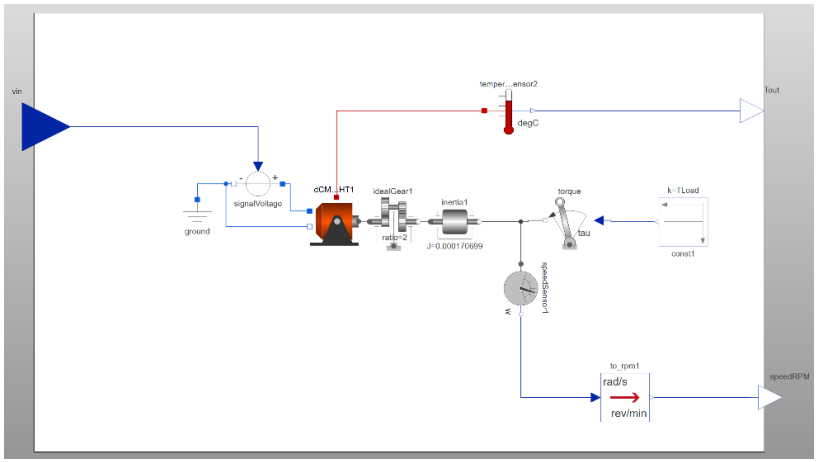
Methodology: Tool Chain



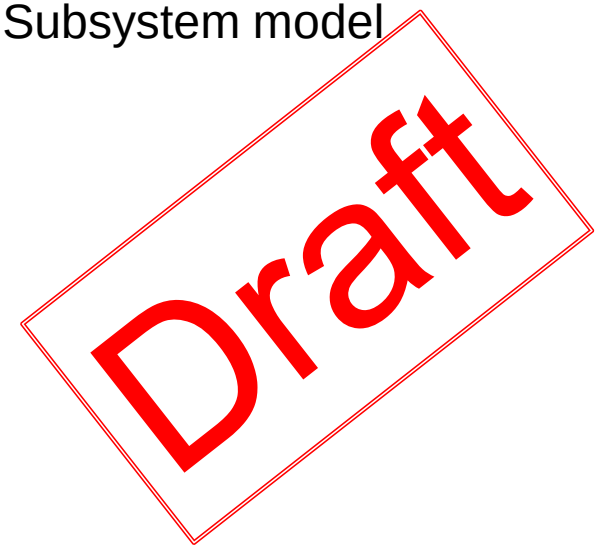
Case Study: DC Motor Controller



DC Motor Model



Subsystem model



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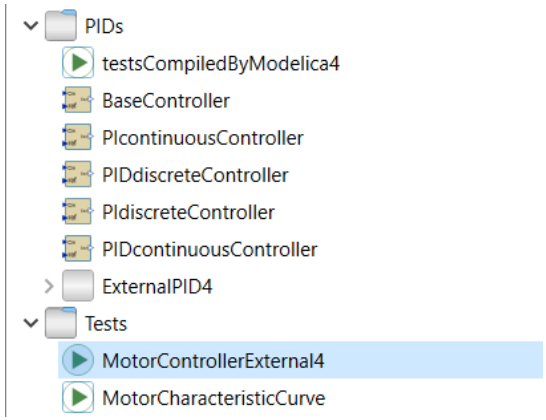
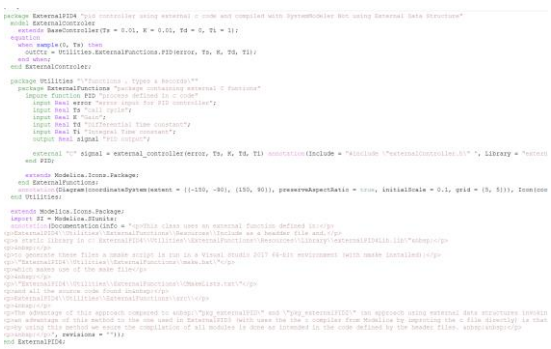
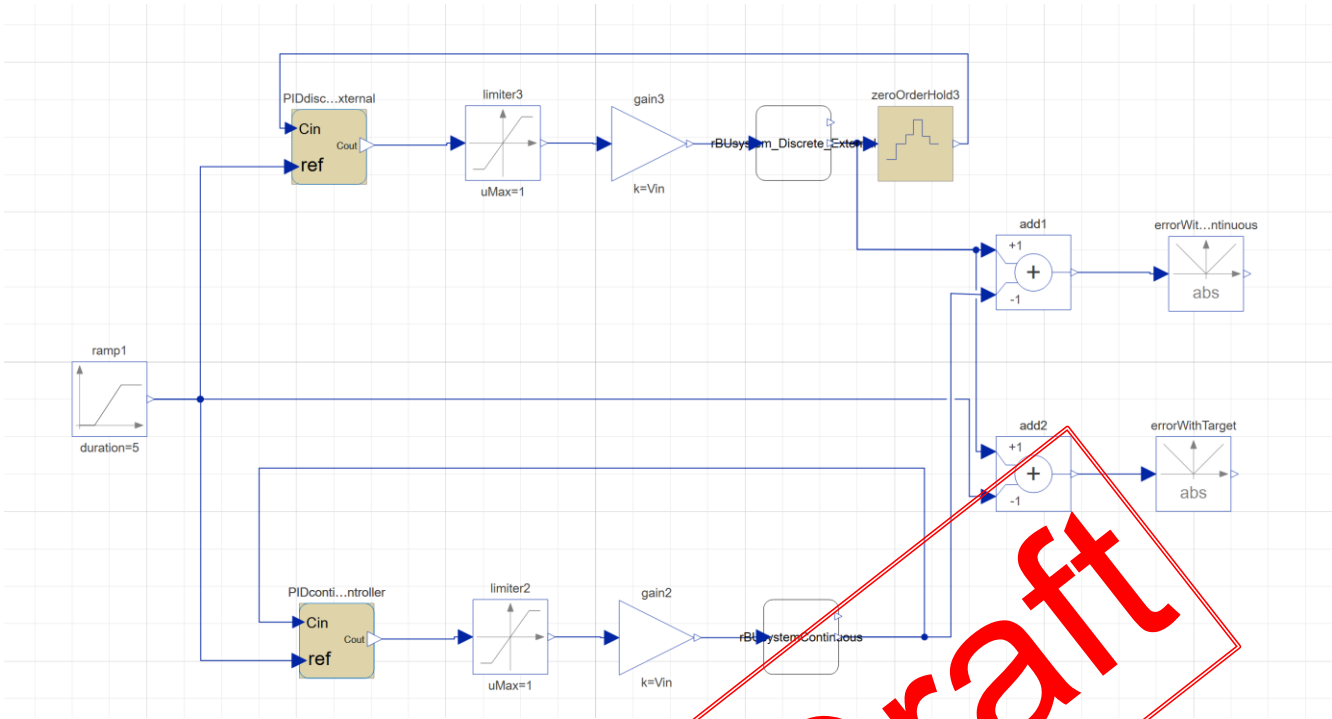
Case Study: DC Motor Controller



SW Controllers and Tests



System integration script



Subsystem simulation

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Case Study: DC Motor Controller

```
sim = SystemModelSimulate[[redacted]Tests.MotorCharacteristicCurve"];
speed = sim[{"mechanicalPowerSensor.relSpeedSensor.w_rel"}][1];
efficiency = sim[{"efficiency.y"}][1];
torque = sim[{"ramp.y"}][1];
current = sim[{"dCMotor_HT1.resistor.p.i"}][1];

data = sim["RawData", {"ramp.y", "mechanicalPowerSensor.relSpeedSensor.w_rel", "dCMotor_HT1.resistor.p.i", "efficiency.y"}][All, All, 2];

workingPoint = (Mean /@ (Select[data', Round[#[1], 0.0001] == 0.11 &]')) {1000, 60/(2 π), 1, 100};

stall = (Mean /@ (Select[data', Round[#[2], 1] == 0 && #[1] > Evaluate@(workingPoint[1] / 1000) &]')) {1000, 60/(2 π), 1, 100};

noLoad = (Mean /@ (data[All, Evaluate@Flatten@Position[data[2], Max[data[2]]]])) {1000, 60/(2 π), 1, 100};

Evaluate@{workingPoint, stall, noLoad}'
```

```
{{110, 453.024, 0}, {8032, 0, 10670}, {5.564, 22.313, 0.225}, {69.28, 0, 0}}
```

```
{TestID → "motor model", SameTest → (Norm[#1[1] - #2[1]] < 30 && Norm[#1[2] - #2[2]] < 250 && Norm[#1[3] - #2[3]] < 0.5 && Norm[#1[4] - #2[4]] < 0.05 &)}
```

Success ✓ Details »

Add Messages | Add Options | Rerun

```
(*(*compile source code found within the class *)
dir=FileNameDrop@SystemModel["DLESystemModeling.Components.PIDs.ExternalPID4.Utilities.ExternalFunctions"]["SourceFile"];
RunProcess[dir<>"\make.bat","StandardOutput",ProcessDirectory→ dir];*)

(*compile and run modelica*)
sim2 = SystemModelSimulate["[redacted]Tests.MotorControllerExternal4"];
errorTarget = sim2["RawData", {"errorWithTarget.y"}];
Table[Max[Select[errorTarget[1], #[1] > tmin &][All, 2]], {tmin, 0.1, 2}]
```

```
{100, 30}
```

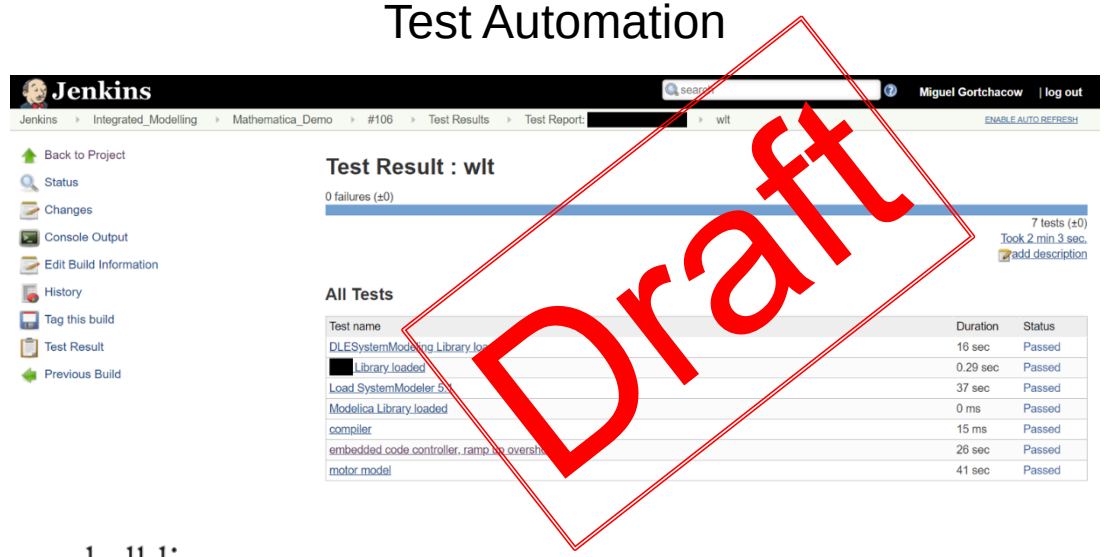
```
{TestID → "embedded code controller, ramp up overshoot", SameTest → ( #1[1] < #2[1] && #1[2] < #2[2] &)}
```

Success ✓ Details »

Add Messages | Add Options | Rerun

Tests definition

Test Automation



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Conclusions

- Development of consumer appliances requires systematic application of Model Based Systems Engineering (MBSE) principles through all the stages of the product development
- Using our approach to embedded SW development and validation, we can significantly improve our overall efficiency and thus meet the challenge of balancing the time, quality and cost
- Successful application of this approach to a wide range of products has resulted in high-quality consumer appliances and customer satisfaction

Thank You for the Attention

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