Wentworth Institute of Technology Workshops

System Modeling, Control Design and Hardware Integration with Simulink

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MathWorks
January 14, 2026

Agenda

- Understanding engineered systems
- Introduction to Model-Based Design and Simulink
- Simulink 101 – An Industry Standard tool for Model-Based Design
- Resources

To follow along

- Set up a MathWorks account if you don't have one
  - please use **Google Chrome** browser
  - go to https://www.mathworks.com/mwaccount/
  - Then open up MATLAB Online (https://matlab.mathworks.com/)
- Copy the exercise materials via GitHub
  - https://github.com/SidJawMW/WIT---Simulink-MBD-workshop

Agenda

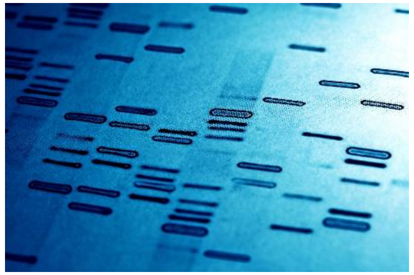
- **Understanding engineered systems**
- Introduction to Model-Based Design and Simulink
- Simulink 101 – An Industry Standard tool for Model-Based Design
- Resources

Engineered systems require system-level, multi-domain integration

Aerospace and Defense

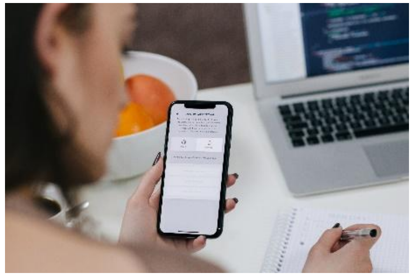
Automotive

Biological Sciences



Biotech and Pharmaceutical

Communications



Electronics

Energy Production

Financial Services

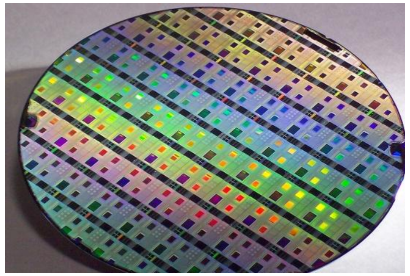
Industrial Machinery

Medical Devices

Metals, Materials, Mining

Neuroscience

Railway Systems



Semiconductors

Software and Internet

Engineered systems require system-level, multi-domain integration

Renewable Energy

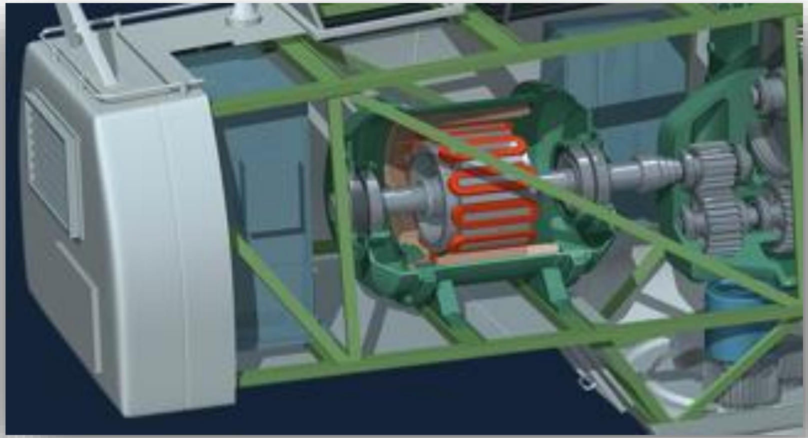
Wireless Communication

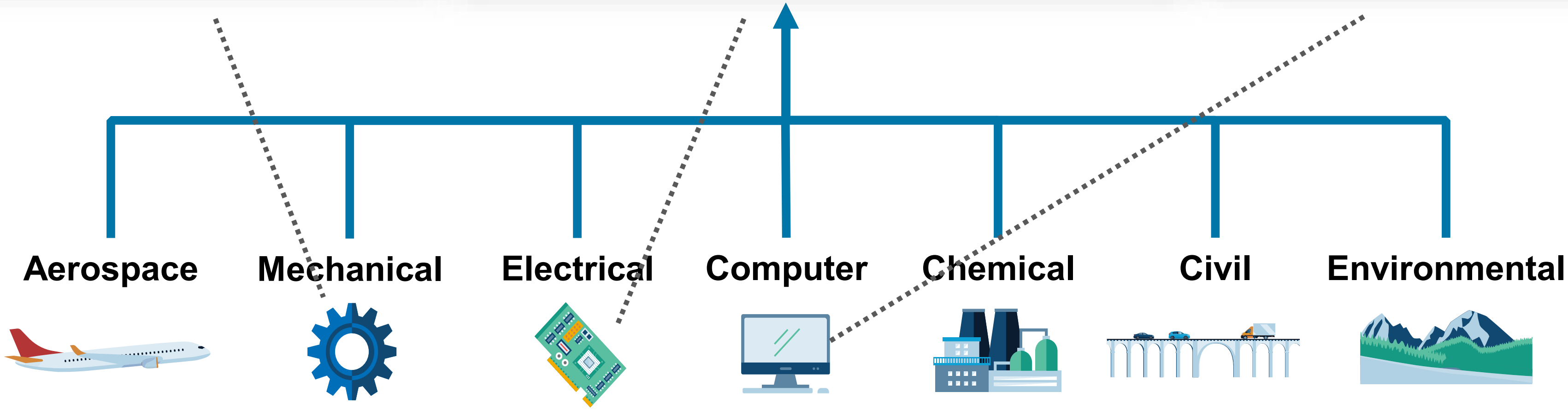
Aerial Robotics

Electric Vehicles

Engineered systems require system-level, multi-domain integration

Renewable Energy





Model-Based Design can help!

Agenda

- Understanding engineered systems
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Model-Based Design

Systematic use of **models** throughout the development process

Modeling

Simulation **Analysis**

+

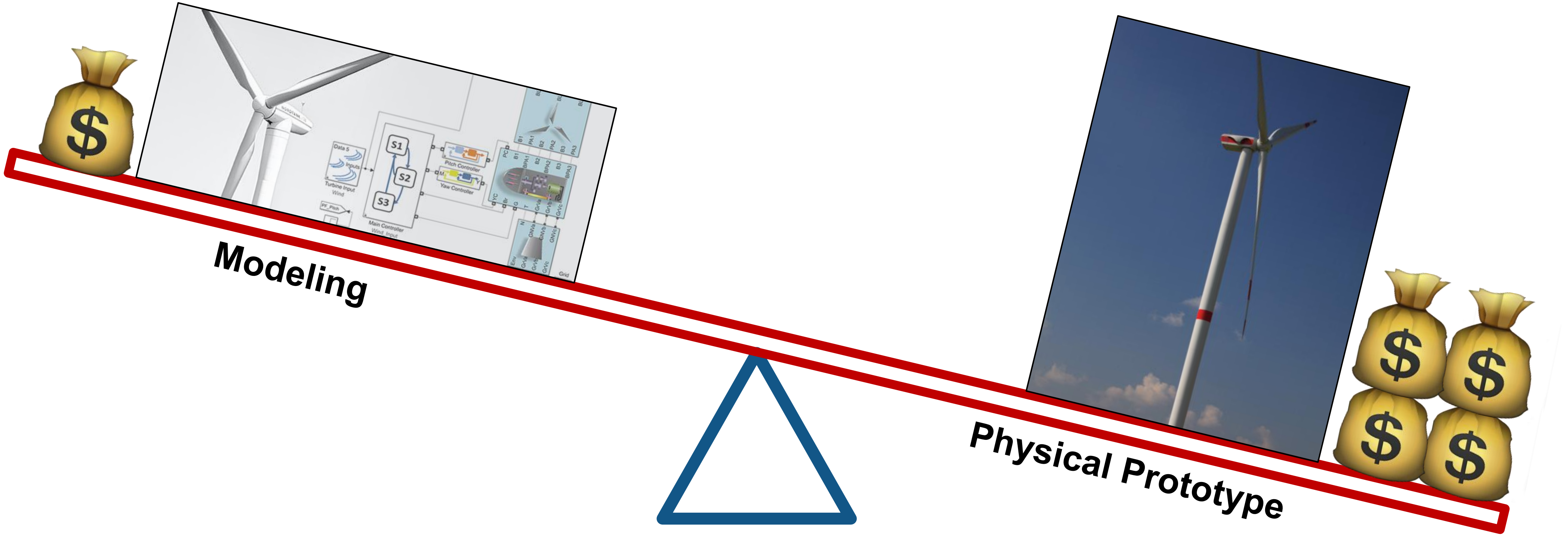
Automation

Coding **Verification**

Try out new ideas
Fast repeatable tests

Eliminate manual steps
and **human error**

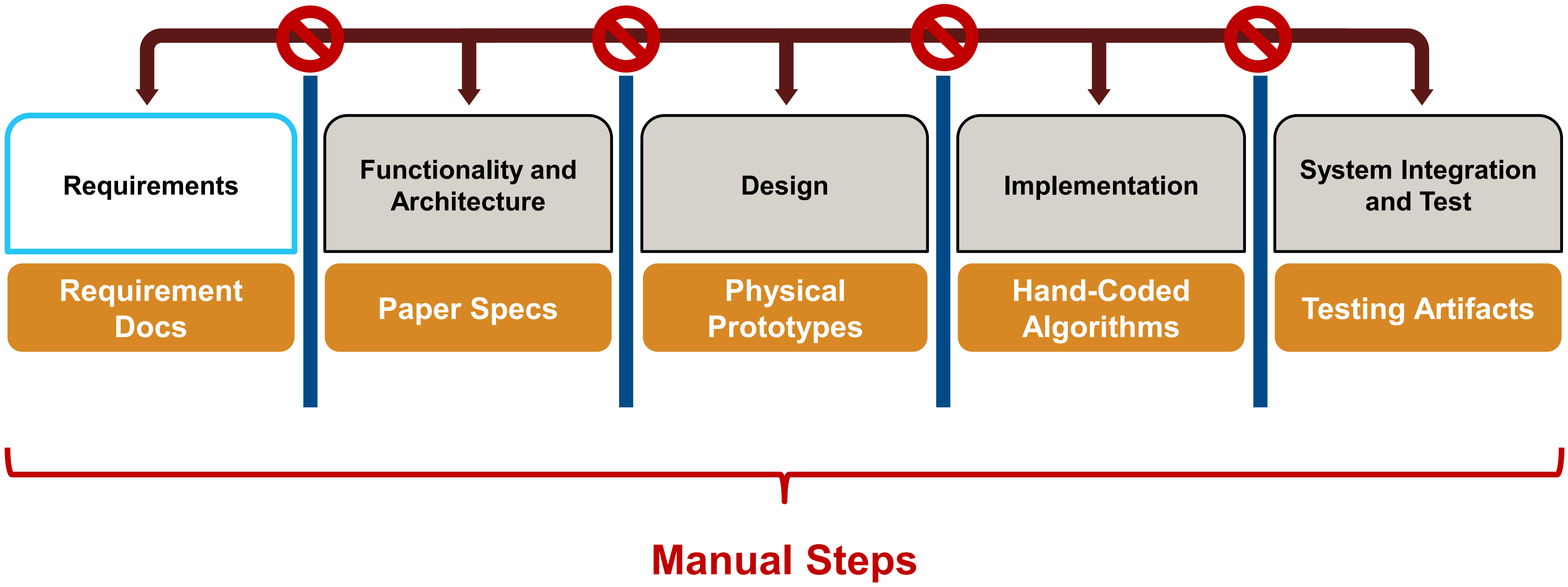
Physical prototypes are costly and iterate slowly



Design space exploration
Continuous design improvement

Costly and time-consuming to build
Hinders rapid iterations

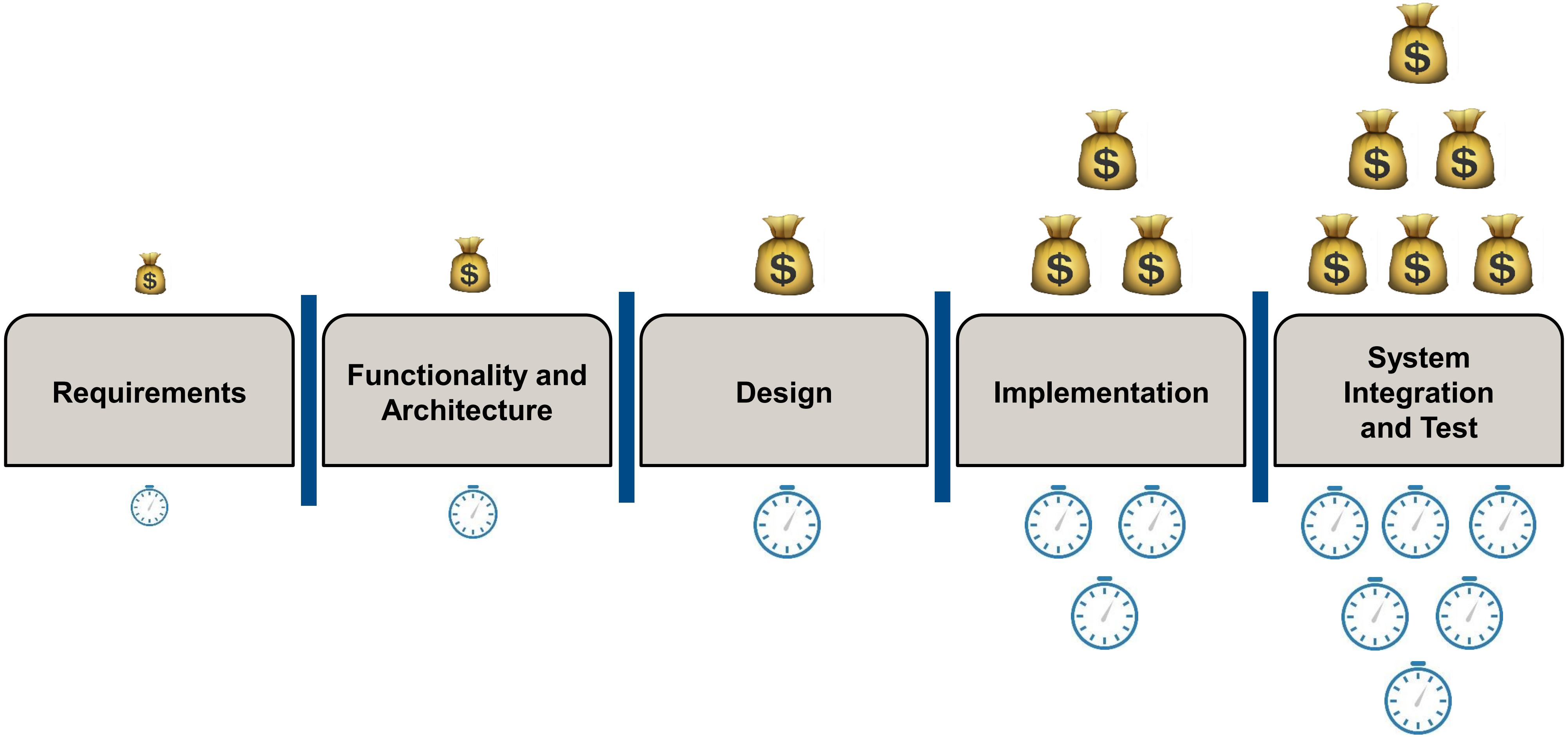
Requirements and artifacts are **hard** to **manage**, **change**, and **trace**



Manual steps introduce **errors** and **slow down** the development process

Issues found late in the process are more **costly** and **time-consuming** to fix

Cost to Fix Issues



Time to Fix Issues

Why Model-Based Design?

Systematic use of **models** throughout the development process

Modeling

➕

Automation

Why Model-Based Design?

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Modeling

Simulation **Analysis**

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Automation

Why Model-Based Design?

Systematic use of **models** throughout the development process

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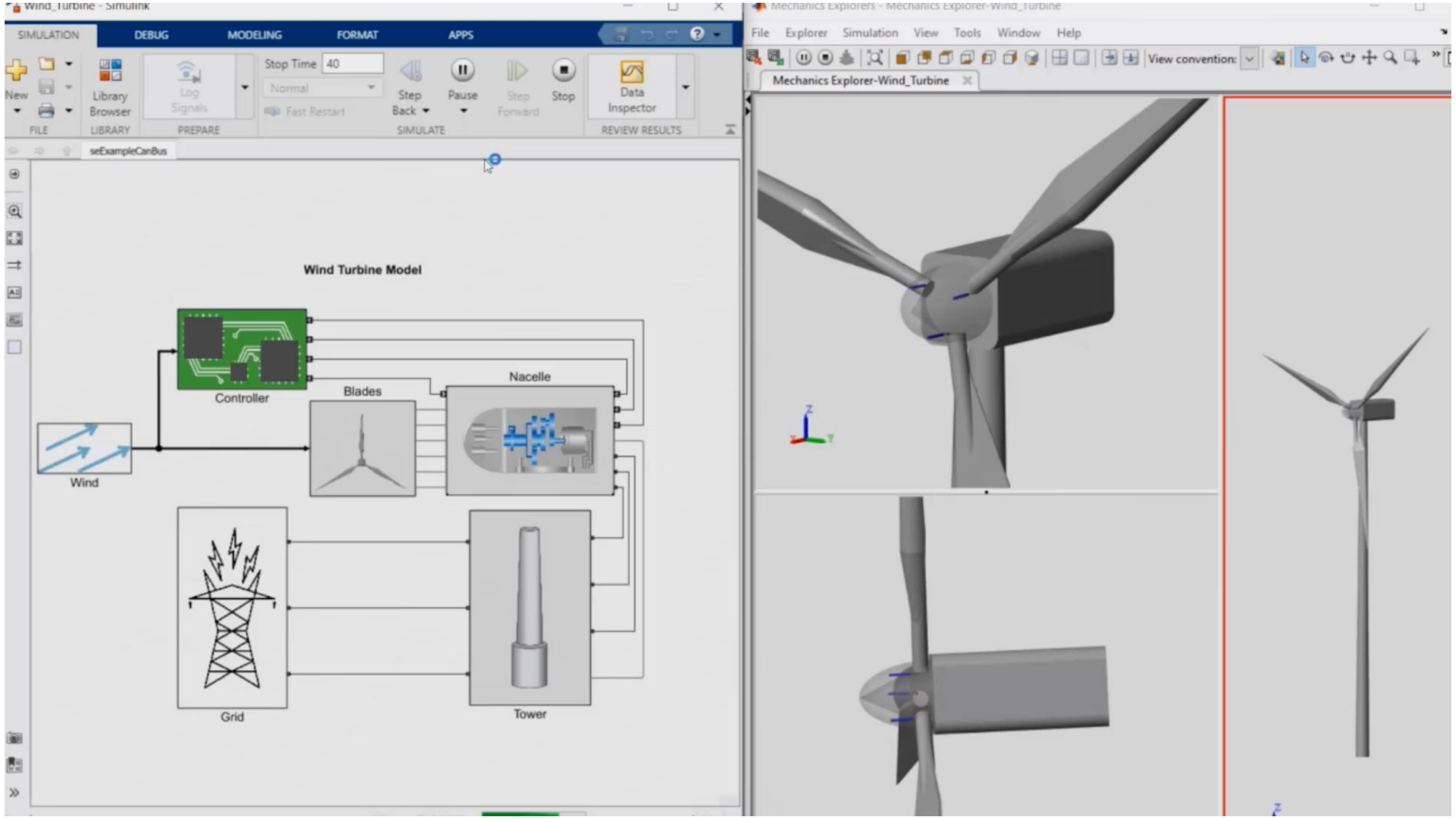
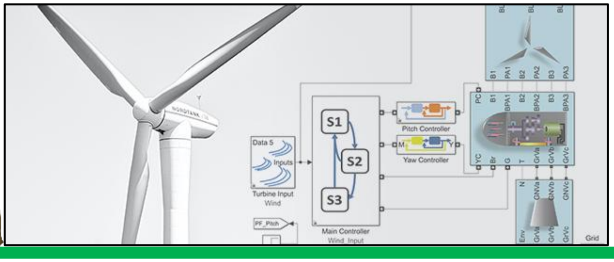
Coding | Verification



Modeling and simulation help **cut costs** and **speed up** design iterations



Physical Prototype

Modeling

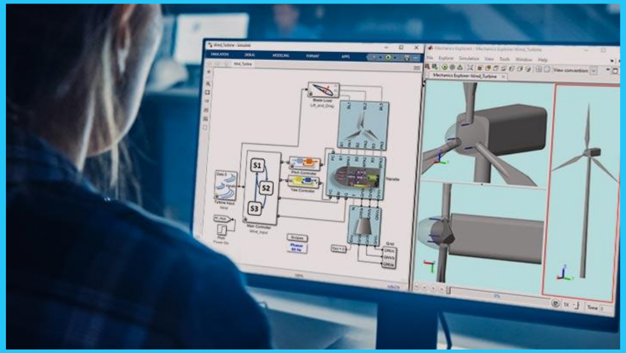
Simulation **Analysis**

Rapid prototyping and testing

Requirements **capture** and artifact **traceability** throughout the process

Model-Based Design

Requirements | **Functionality and Architecture** | **Design** | **Implementation** | **System Integration and Test**



Models are at the **center** of your development process

Create a **digital thread**

Model-Based Design

Systematic use of **models** throughout the development process

Modeling

Simulation **Analysis**

+

Automation

Coding **Verification**

=

Short **agile** iteration cycles

Saved time and cost

Minimal defects and **high quality**

End to end advanced air mobility development at Supernal

"Complete flight simulation of autonomous vehicle operation using photorealistic environment"

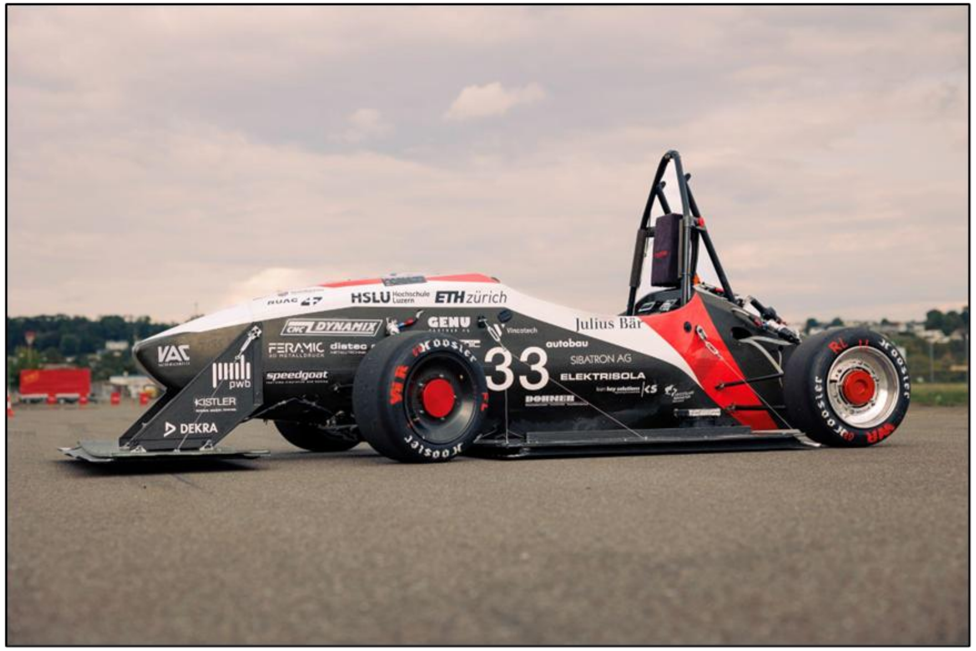
User story: ETH Zurich SAE competition team uses Model-Based Design to develop motor controllers

AMZ Racing – Zurich, Switzerland

Formula SAE Electric

<u>**AMZ Racing Designed the Motor Controller to Achieve 0 to 100 km/h in 0.956 Seconds**</u>

Use **Simulink for system simulations** including, FOC Motor control model, physical model and **closed loop controller** to optimize parameters. **Generated HDL code to run motor controllers on FPGAs.**



Such project-based learning outcomes using Model-Based Design prepare students for industry

“Simulink knowledge coming out of University has also been very beneficial as I have regularly interacted with large Software models developed using this platform.”

- Graham Iles, Mercedes AMG HPP

Where Are They Now Blog

Industry professionals talk about how learning MATLAB and Simulink in their student life helped them in their first job in the industry

Visit https://blogs.mathworks.com/racing-lounge/category/where-are-they-now/

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- **Simulink 101 – An Industry Standard tool for Model-Based Design**
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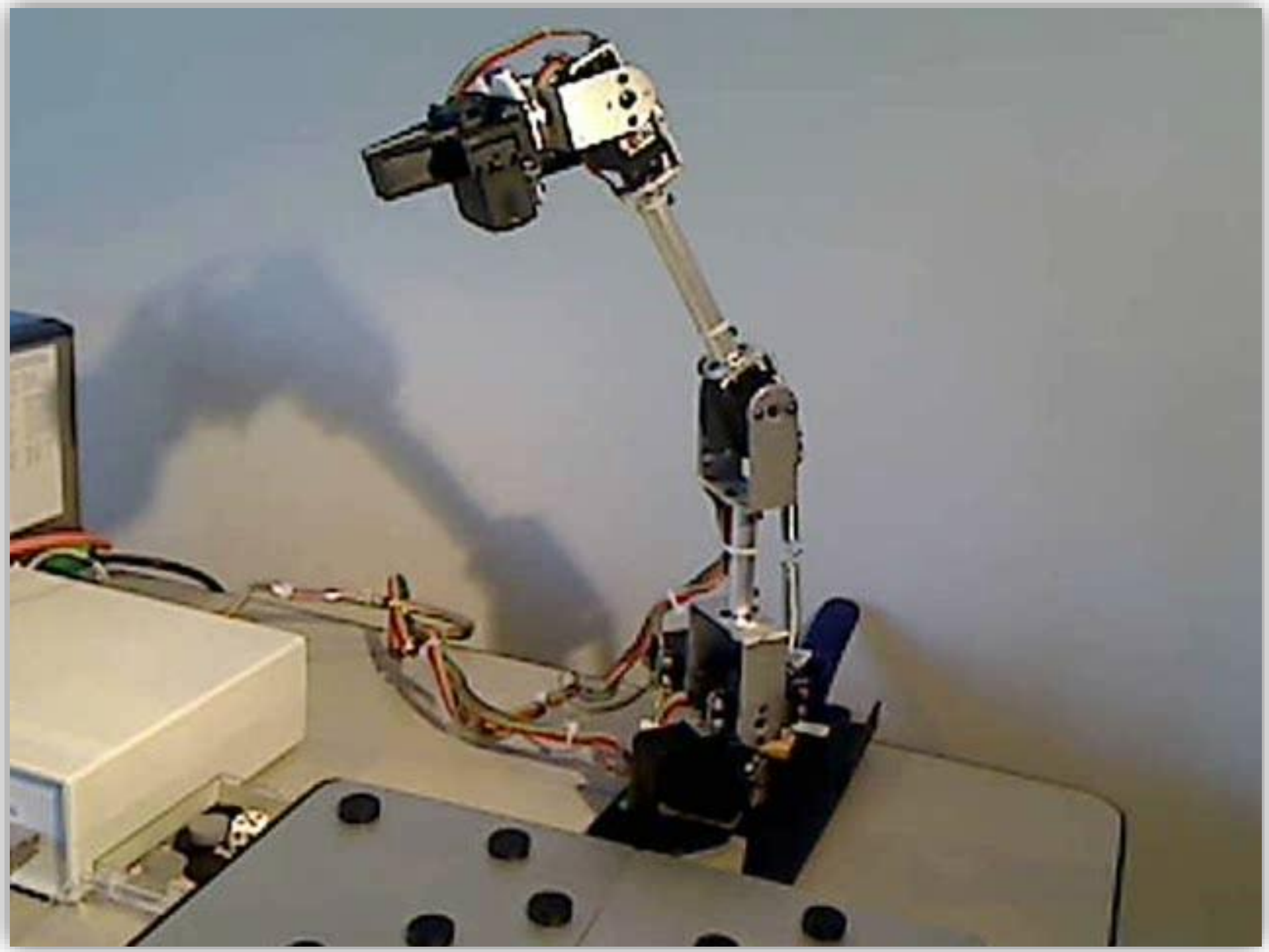
Let's look at a simple pick and place robot…



Model-Based Design

Systematic use of **models** throughout the development process

Modeling

Simulation **Analysis**

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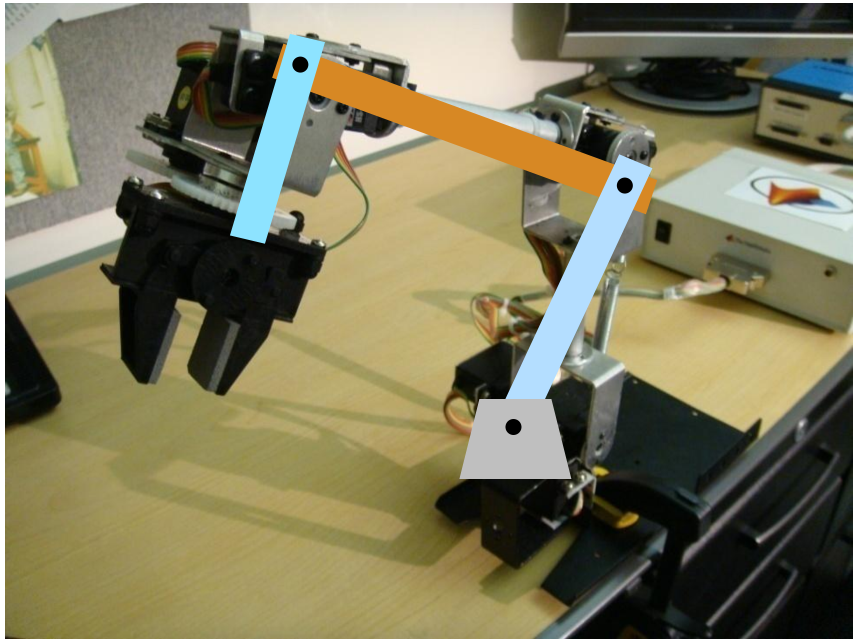
Automation

Coding **Verification**

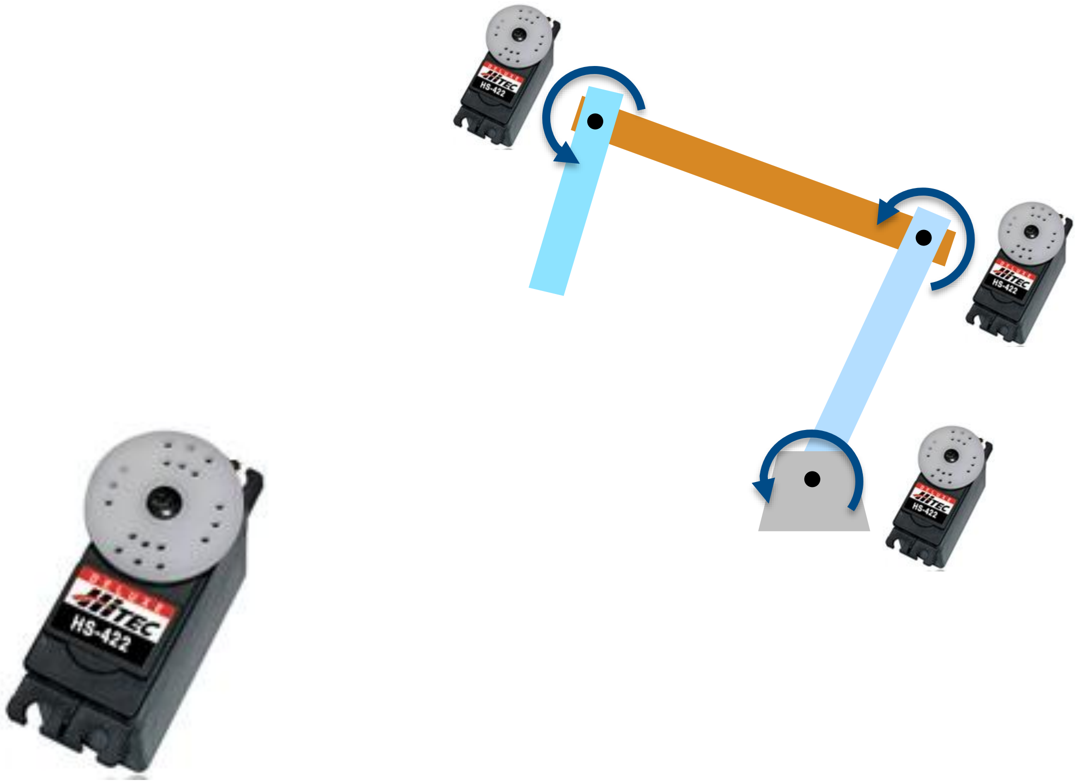
To model the system, let’s break it down into its subcomponents



Modeling

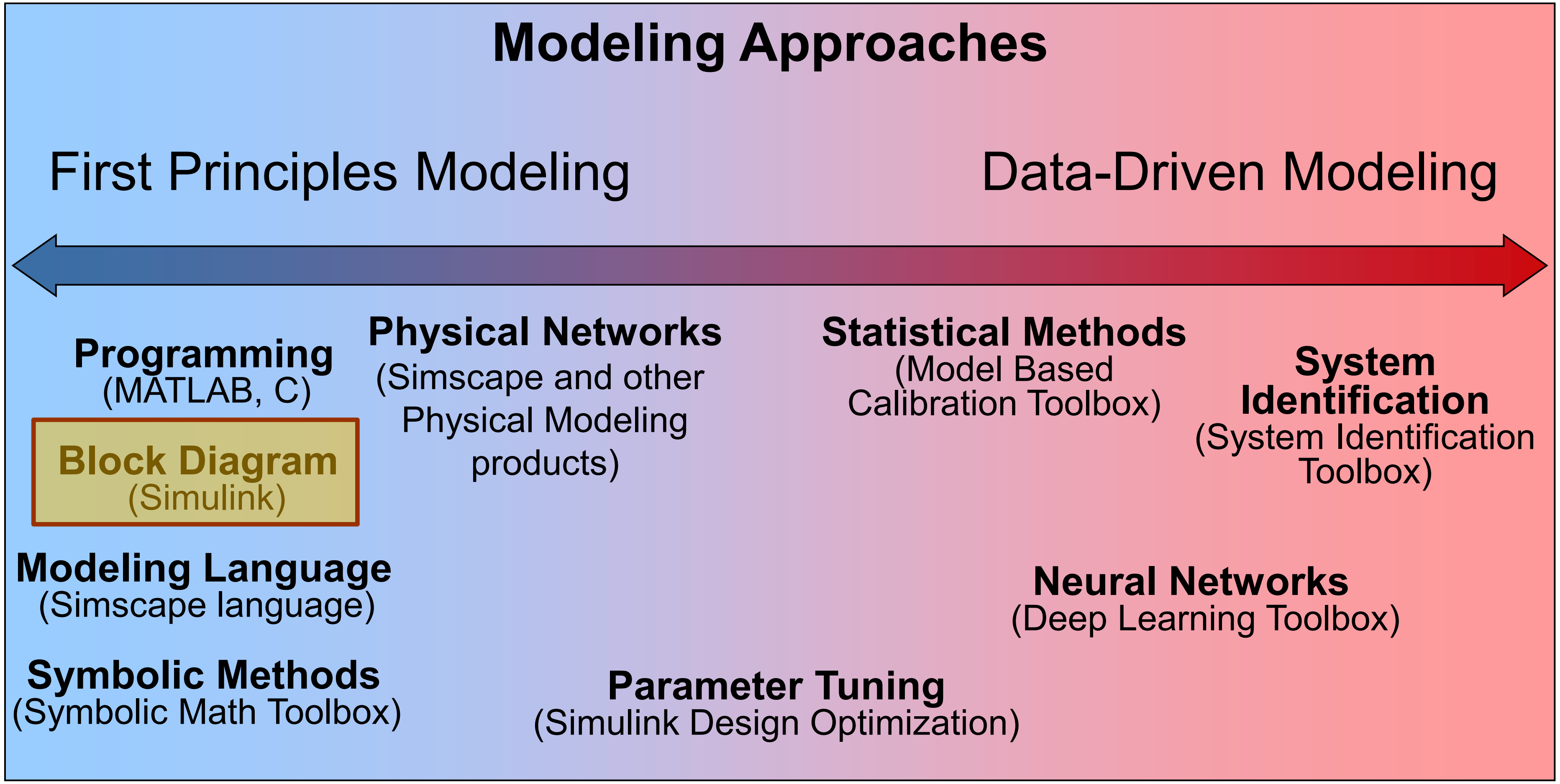
Simulation Analysis

To model the system, let's break it down into its subcomponents



Let's model the DC motor!

There are several approach to modeling dynamic systems



Modeling

Simulation Analysis

We know the governing equations for a DC motor

$$V = K\omega + iR + L\frac{di}{dt}$$

$$J\frac{d\omega}{dt} = Ki - b\omega - T_{Load}$$

$$\frac{di}{dt} = \frac{1}{L}(V - K\omega - iR)$$

$$\frac{d\omega}{dt} = \frac{1}{J}(Ki - b\omega - T_{Load})$$

$$\boxed{i = \int \frac{1}{L}(V - K\omega - iR)dt}$$

$$\boxed{\omega = \int \frac{1}{J}(Ki - \mathrm{b}\omega - T_{Load})dt}$$

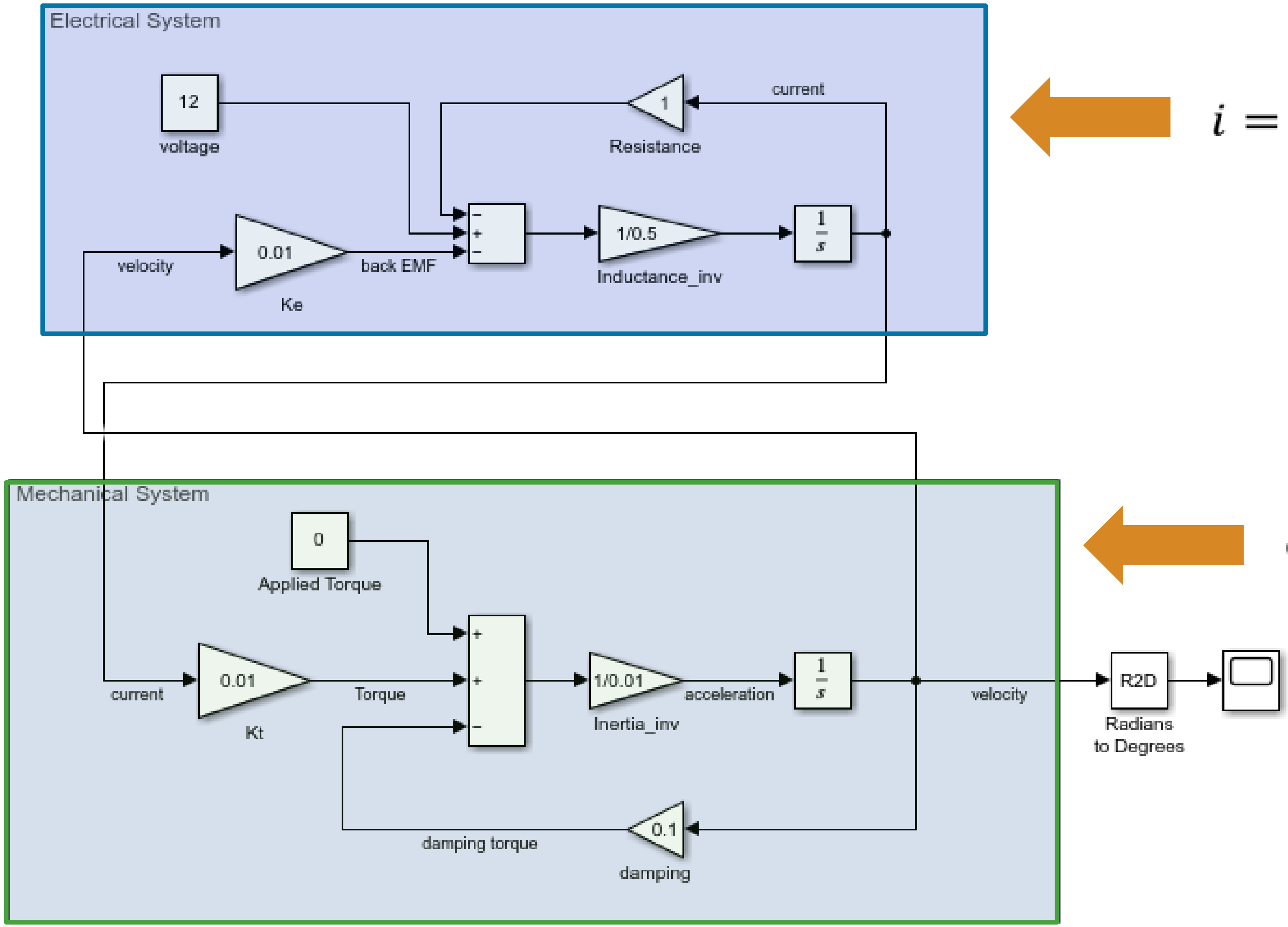
Electrical

Mechanical

Modeling

Simulation Analysis

Let’s model these equations in Simulink



$$i = \int \frac{1}{L}(V - K\omega - iR)dt$$

Electrical

$$\omega = \int \frac{1}{J}(Ki - \mathrm{b}\omega - T_{Load})dt$$

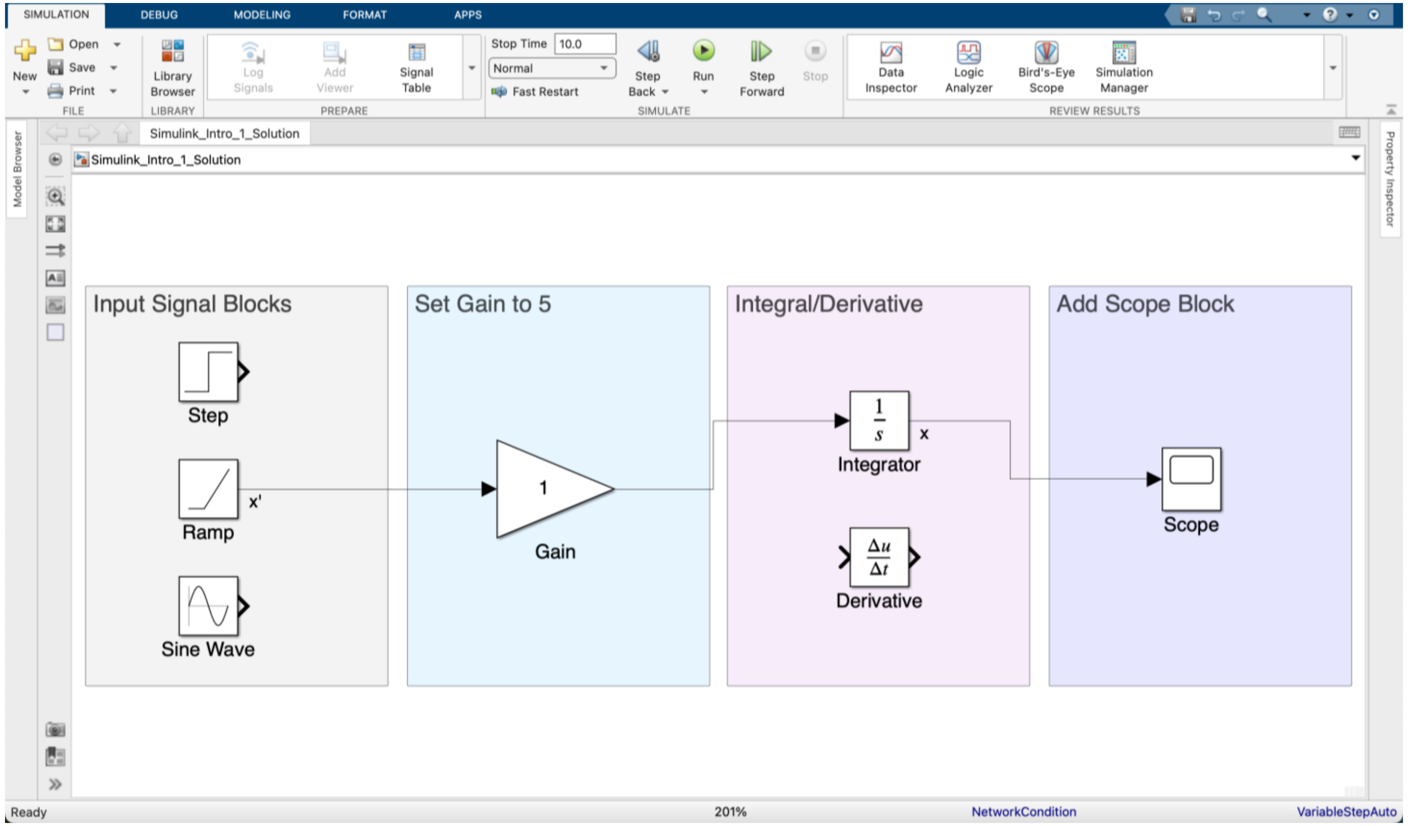
Mechanical

Modeling

Simulation **Analysis**

Exercise 1: Introduction to Simulink

- Open: **Ex1_Simulink_Intro.slx**
- Connect Input blocks to Gain and Integral/Derivative blocks
- Add a Scope block and connect signals to view them
- Adjust Stop Time to change simulation duration

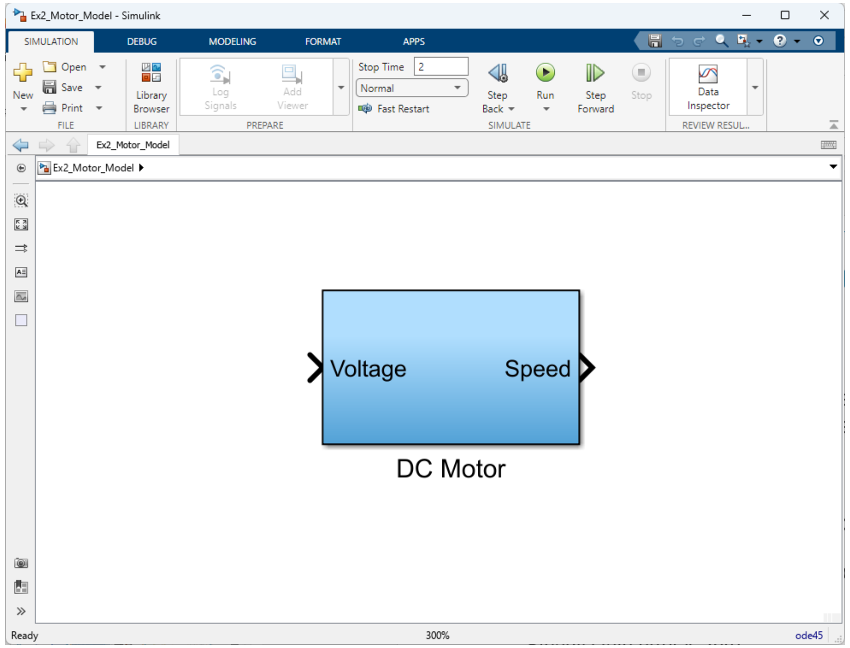


Modeling

Simulation Analysis

Exercise 2: Motor Control Design with Simulink

- Open: **Ex2_Motor_Model.slx**
- Simulate the model with a reference step input
- Construct a PID controller with base Simulink blocks
- Add tuning knobs from dashboard library to tune gains
- Use scope blocks to see motor output, reference input, controller output
- Tune the controller for these specifications
  - **Overshoot <15%**
  - **Rise time< 0.25 sec**
  - **Steady state error is zero**
  - **Settling time <1.5 sec**
- How about including real world entities: delays, sensor noise, controller saturation…



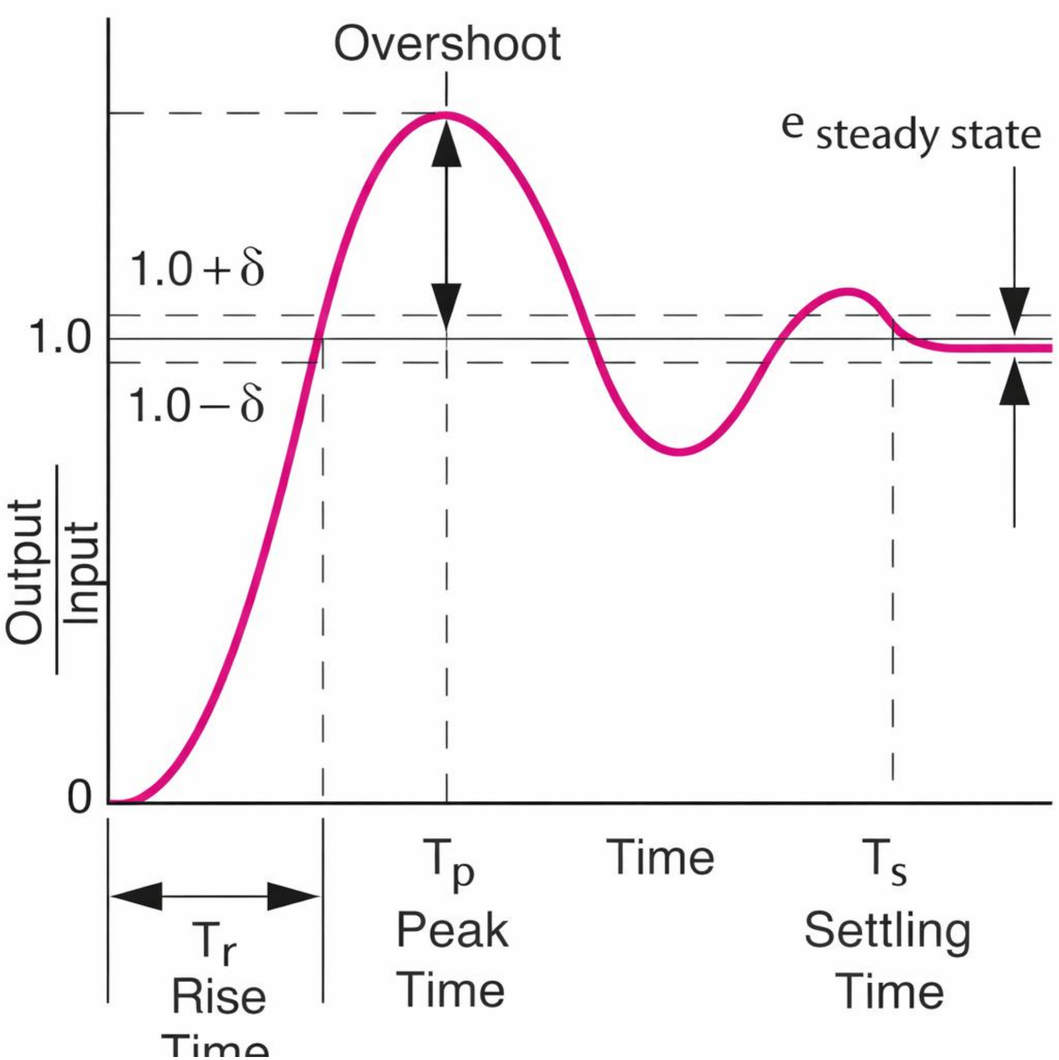
CL RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Decrease
Kd	Small Change	Decrease	Decrease	No Change

PID tuning cheat sheet

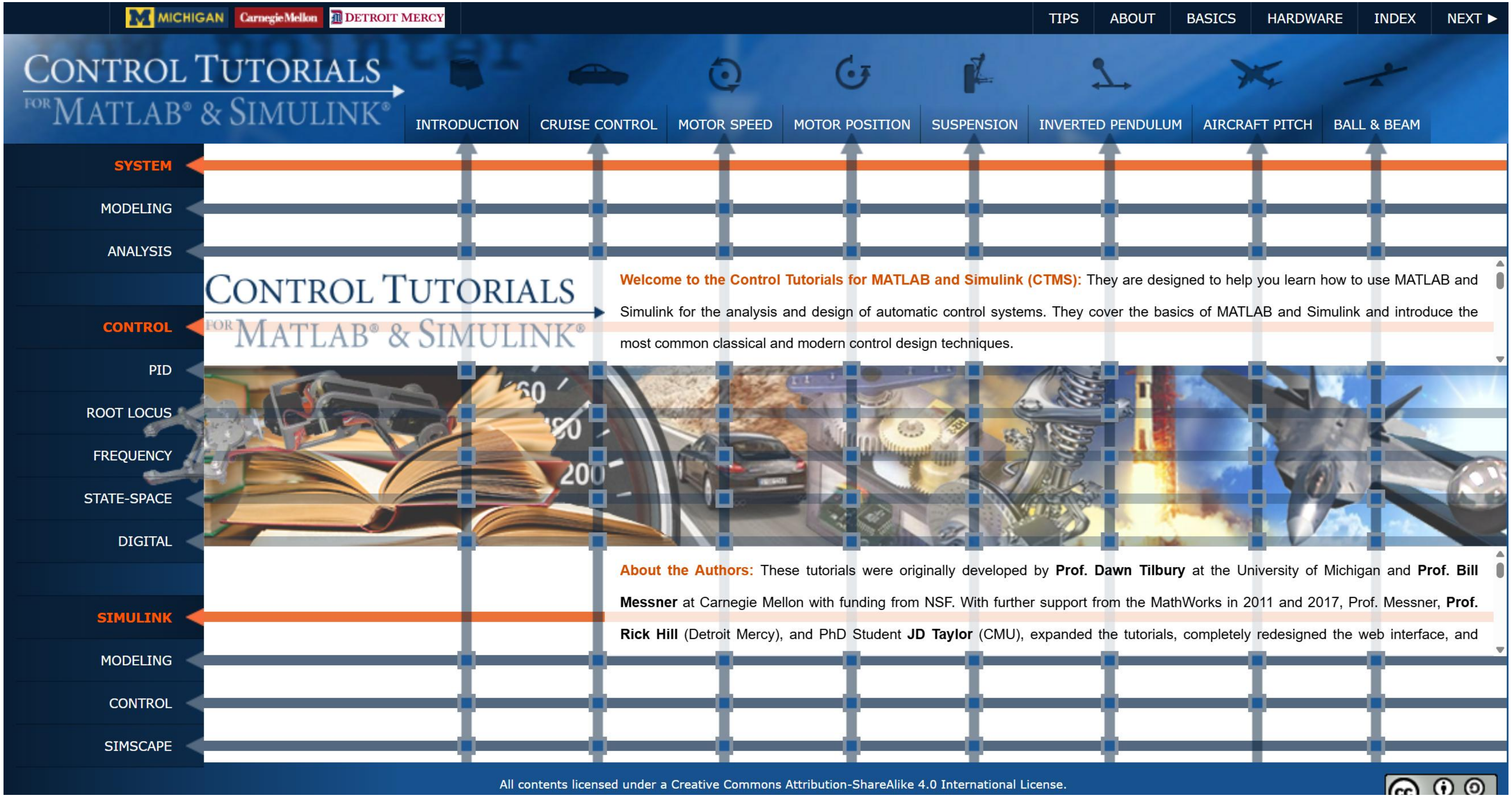
Modeling

Simulation **Analysis**

Step response characteristics

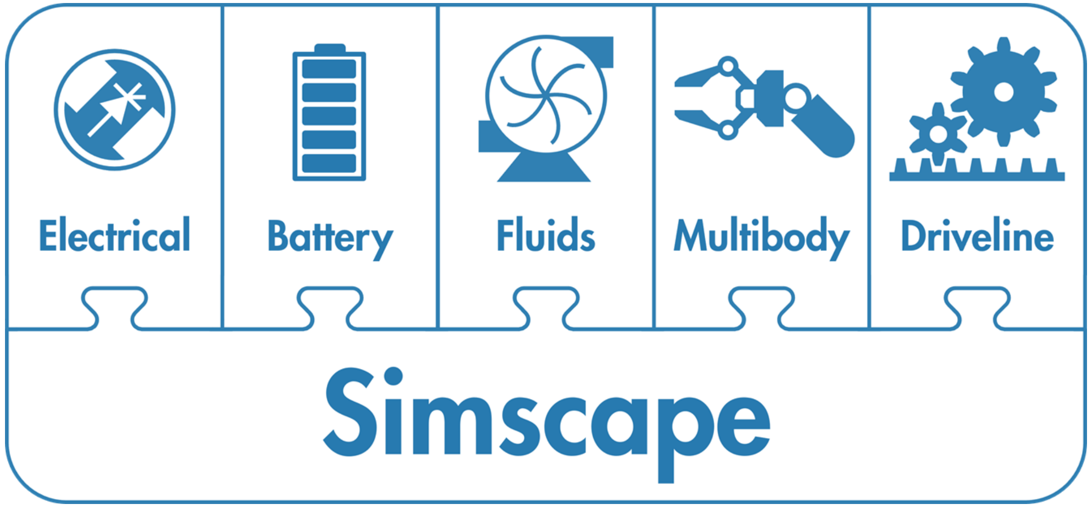


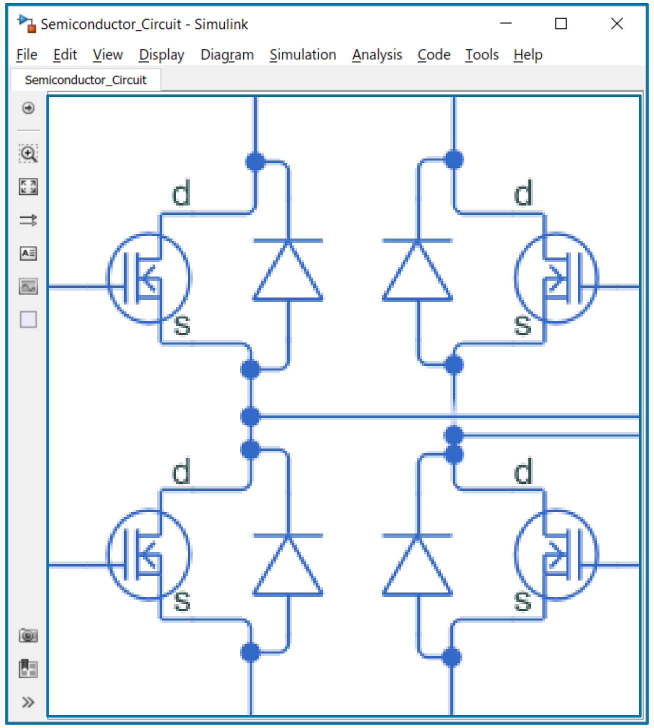
Controls tutorials with MATLAB and Simulink

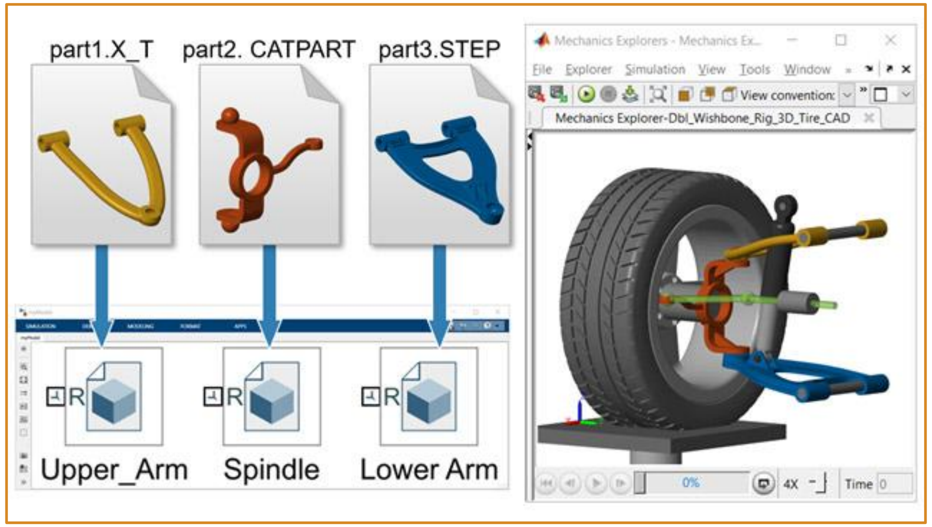


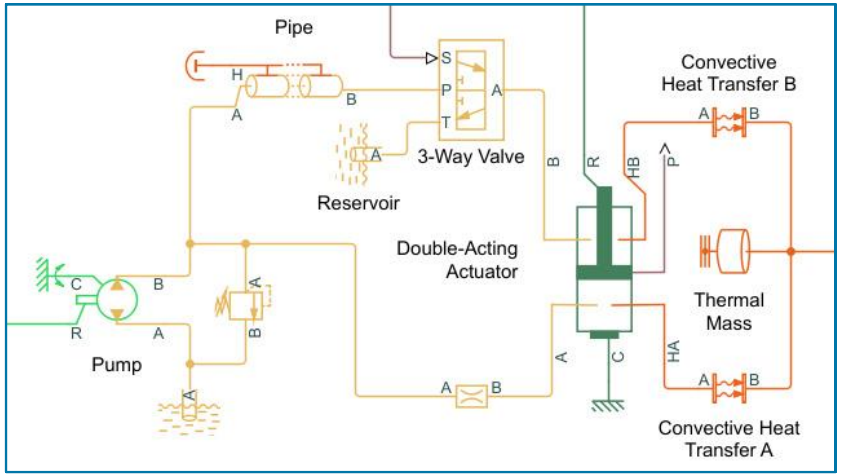
Simscape
Overview

- Simscape enables you to rapidly create models of physical systems within the Simulink environment

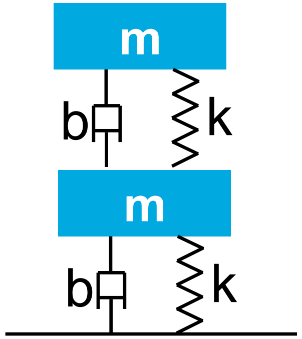








MATLAB, Simulink, and Simscape for Physical Modeling



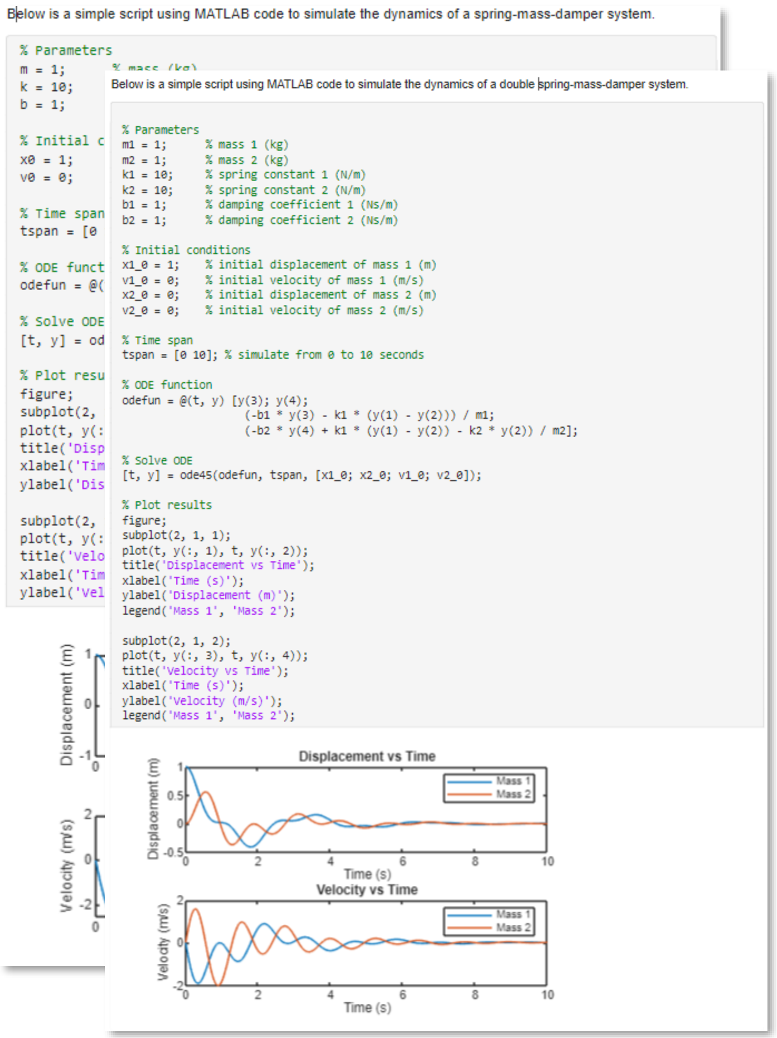
$$F_{Spring} = k_{Spring} * (x_{Mass})$$

$$F_{Damper} = b_{Damper} * (\frac{dx_{Mass}}{dt})$$

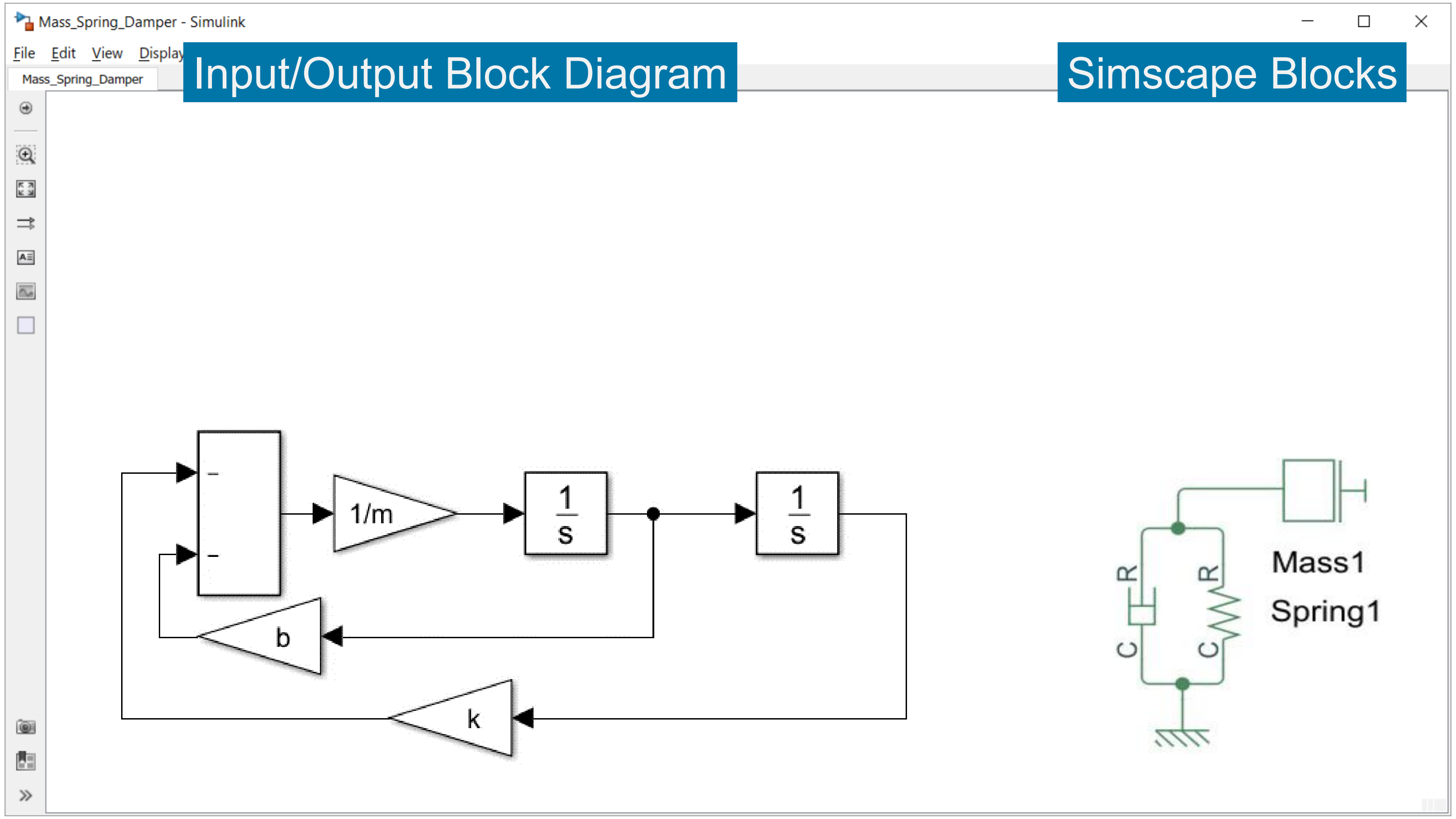
$$\frac{d^2 x_{Mass}}{dt^2} = \frac{-F_{Spring} - F_{Damper}}{m_{Mass}}$$

$$F_{Spring2} = k_{Spring} * (x_{Mass})$$

....



MATLAB

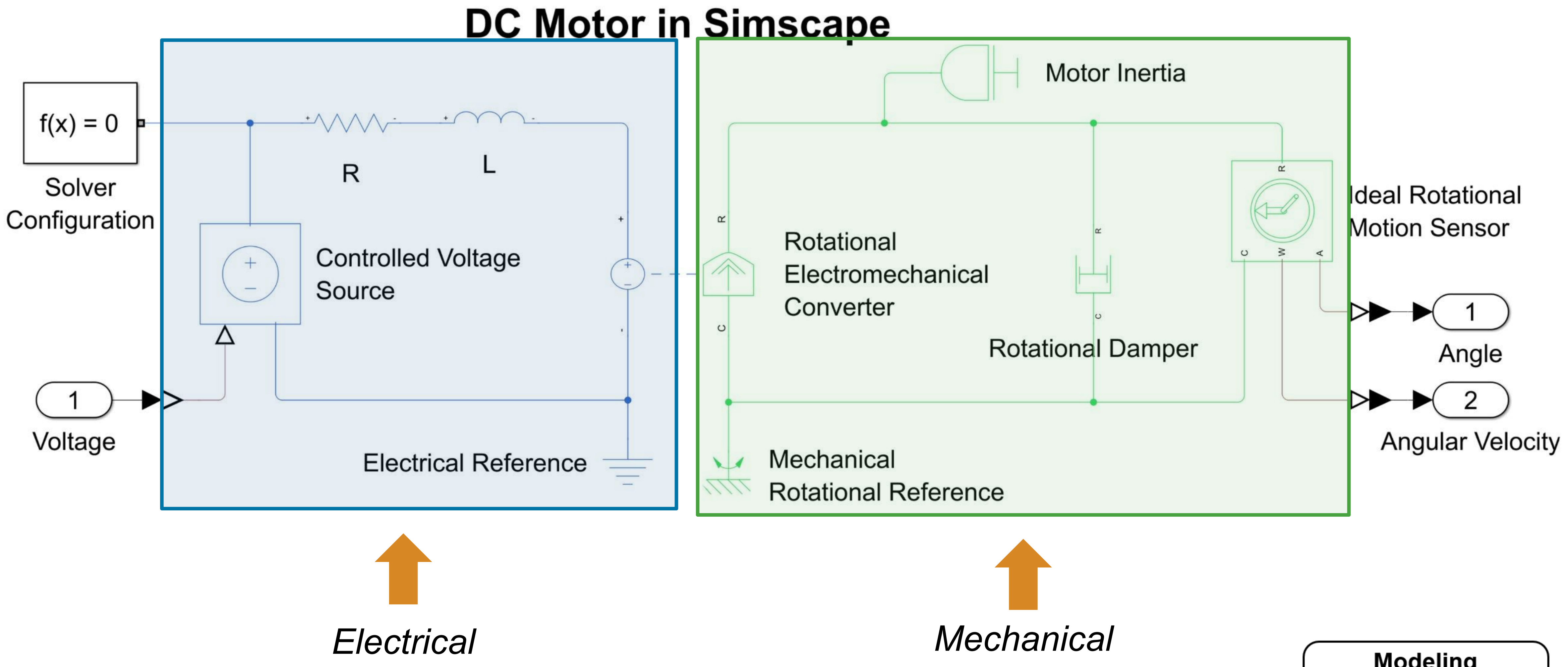


Input/Output Block Diagram

Simscape Blocks

Simulink

Physical Network Model of a DC Motor using Simscape

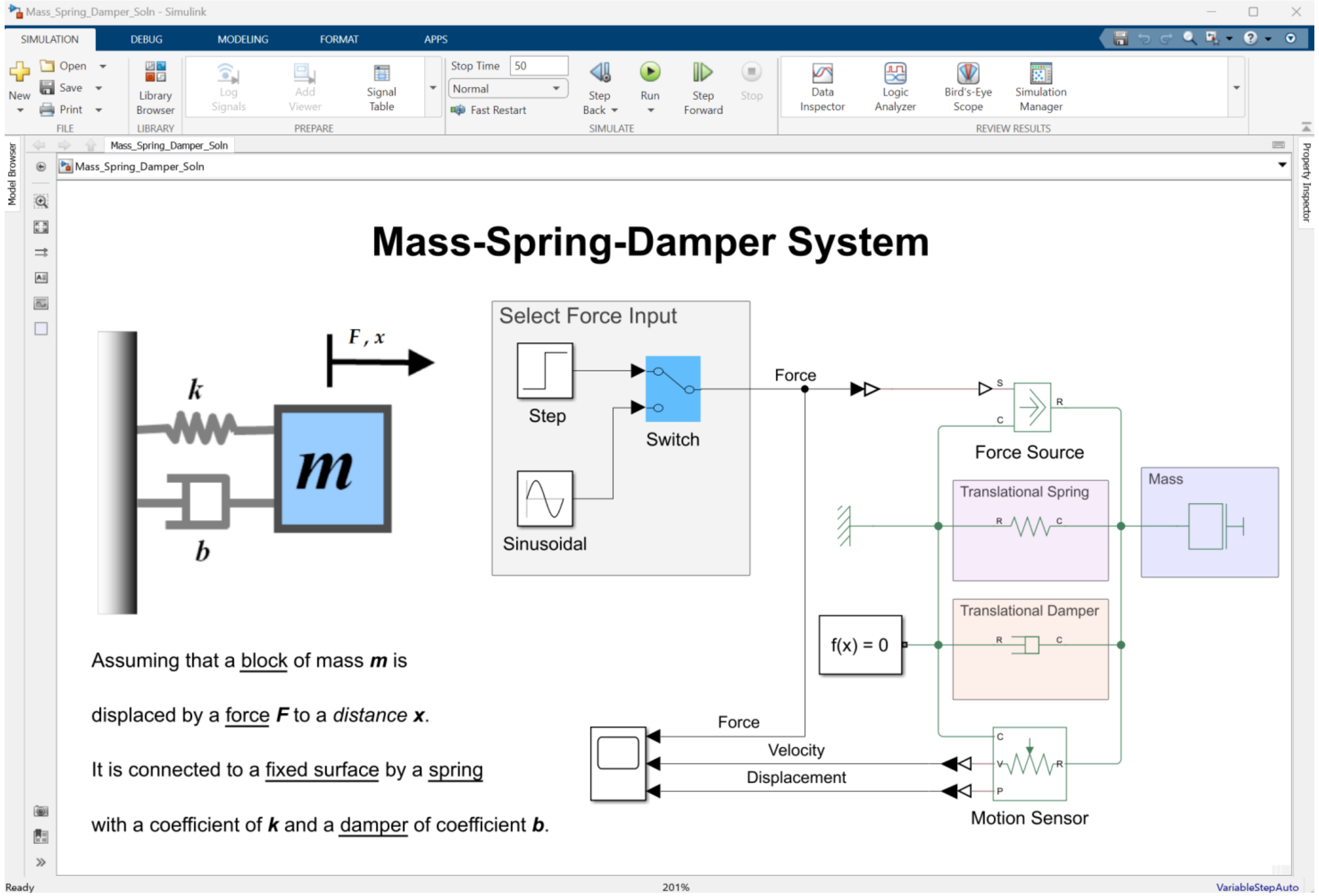


Modeling

Simulation Analysis

Exercise 3: Mass-Spring Damper

- Open: **Ex3_Mass_Spring_Damper.slx**
- Add Translational Spring, Translational Damper, and Mass blocks
- Edit block parameters and view results in Scope block

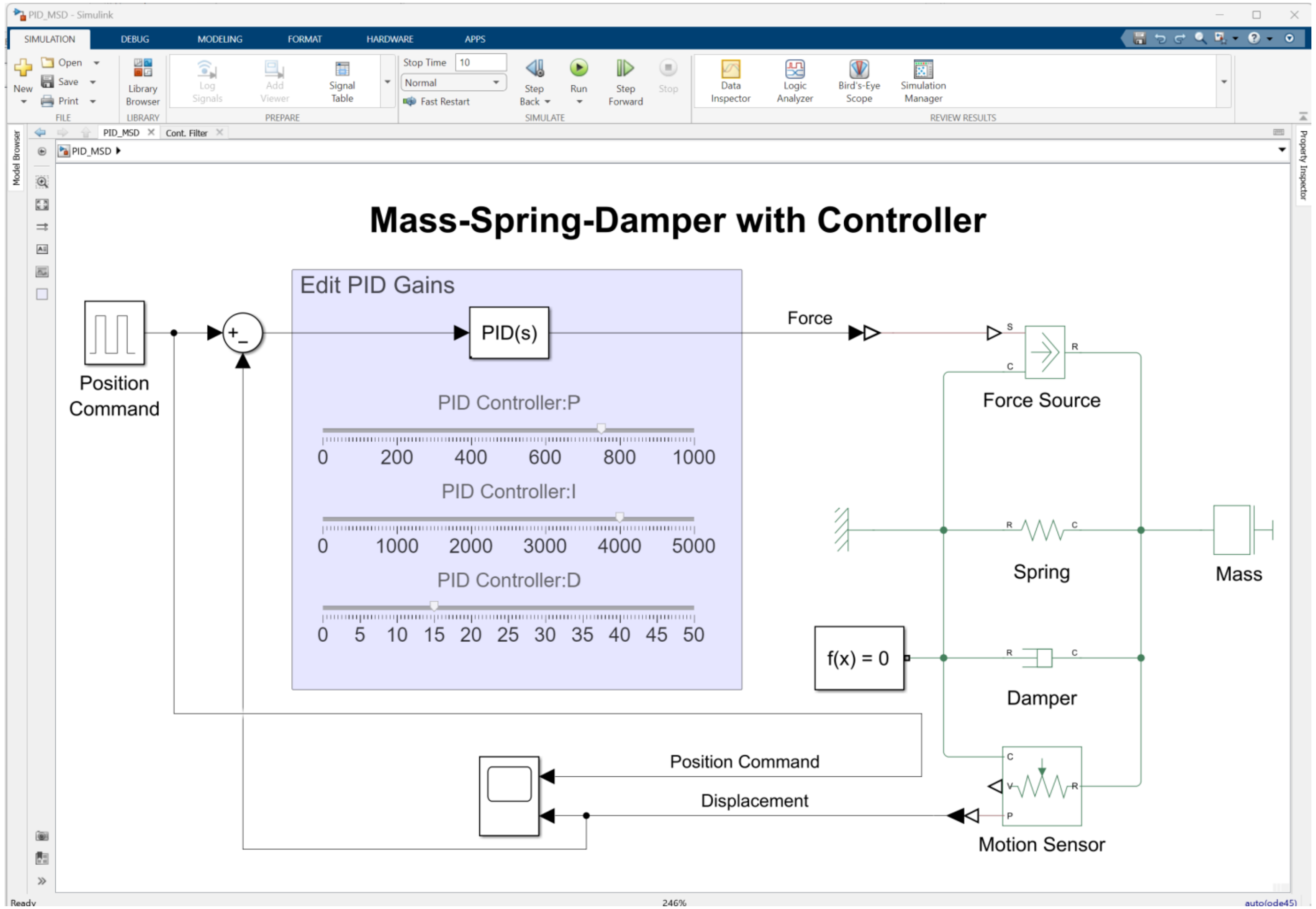


Modeling

Simulation **Analysis**

Exercise 4: Mass Spring Damper with Controller

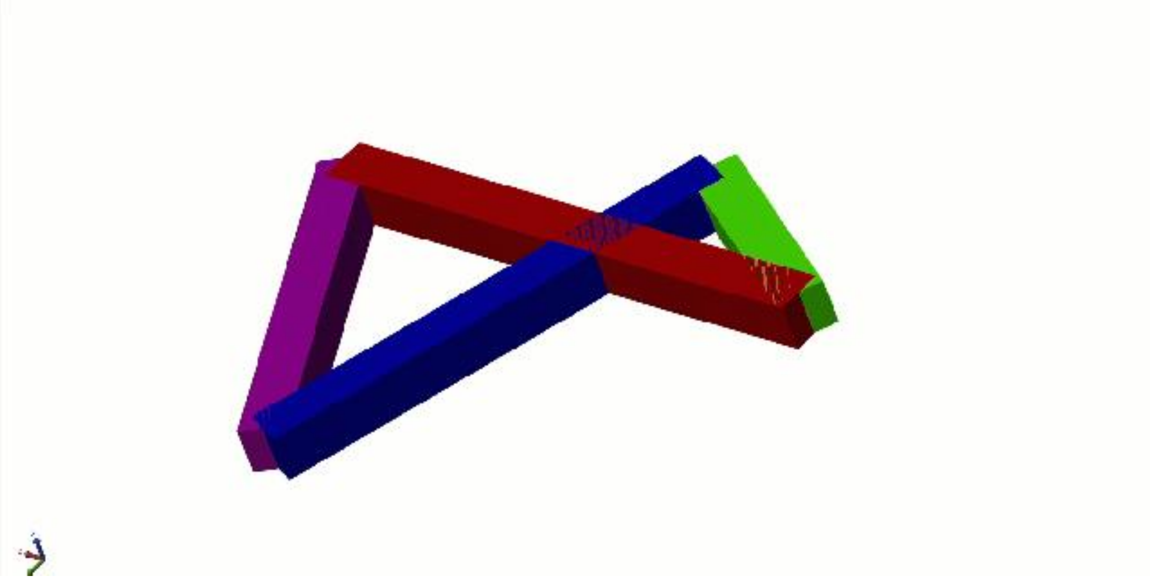
- Open: **Ex4_PID_MSD.slx**
- Edit desired position commands or change input block
- Use sliders to adjust PID gains
- View results in Scope block



Modeling
Simulation
Analysis

Exercise 5: Modeling a linkage with Simscape Multibody

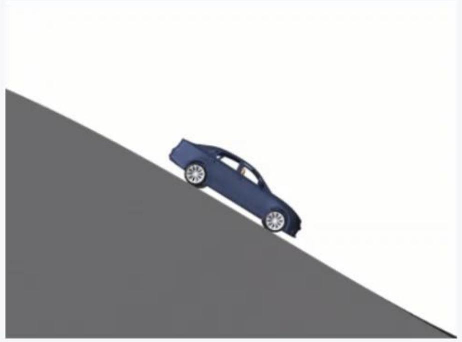
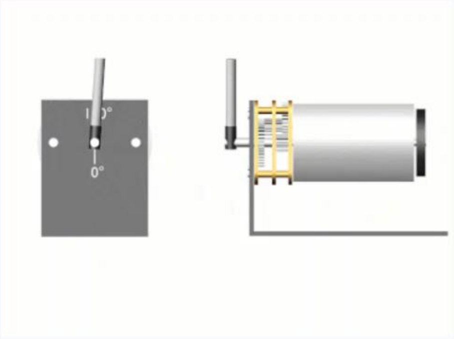
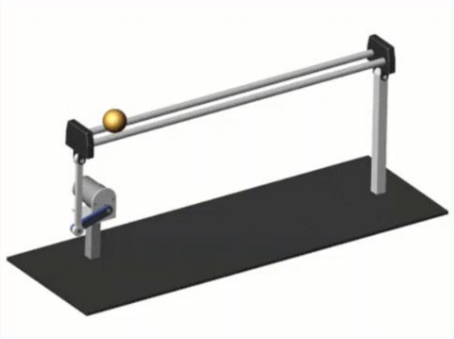
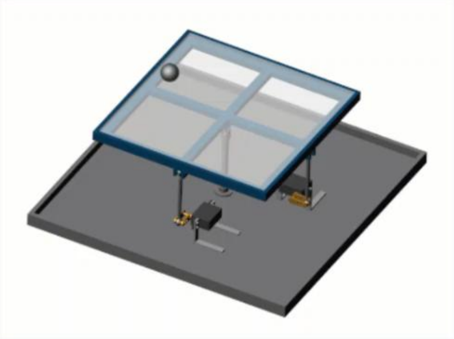
- Open a Simscape Multibody model in Simulink
- Set up 4 interconnected linkages (fixed, input, coupler, output) with the following measurements
  - **Fixed – [12 1 1] cm**
  - **Input – [5 1 1] cm**
  - **Coupler– [8 1 1] cm**
  - **Output– [10 1 1] cm**
- Connect them using revolute joints
- Set velocity target of 120 deg/sec for the input linkage.
- Simulate the model!



Modeling

Simulation Analysis

Virtual hardware labs for control design

CruiseControl.slx	DCMotorControl.slx	InvertedPendulum.slx
		
RotaryPendulum.slx	BallAndBeam.slx	BallAndPlate.slx
		

Model-Based Design

Systematic use of **models** throughout the development process

Modeling

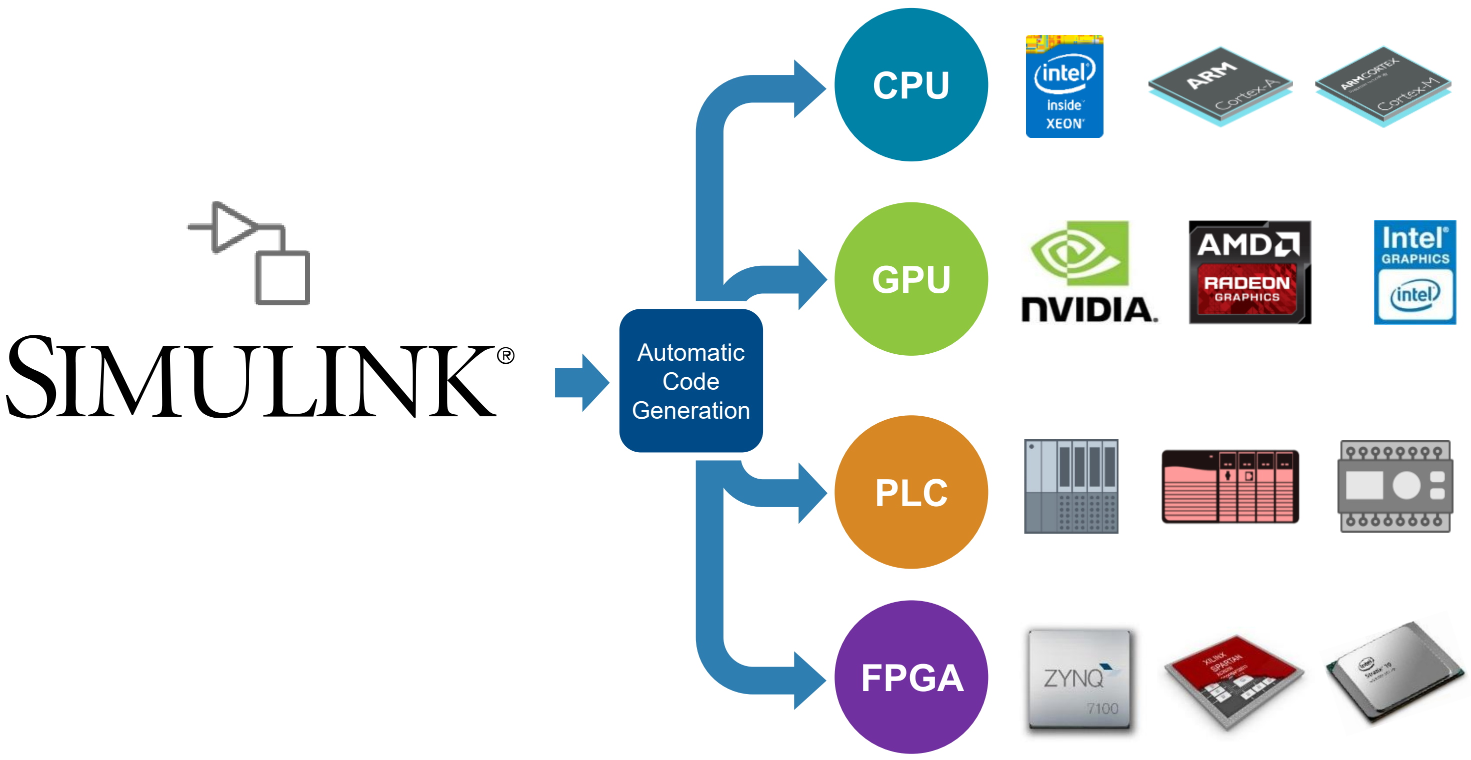
Simulation | Analysis

+

Automation

Coding | Verification

Automatically generate code for prototyping and production



Reliable and **high performance**, with **flexible** choice of targets

MathWorks supports a variety of low-cost hardware

Arduino

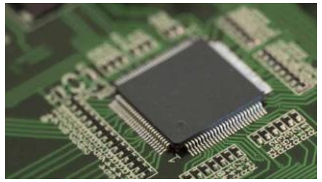
Lego EV3

Raspberry Pi

Android/iOS Devices

Kinect for Windows

BeagleBone Black



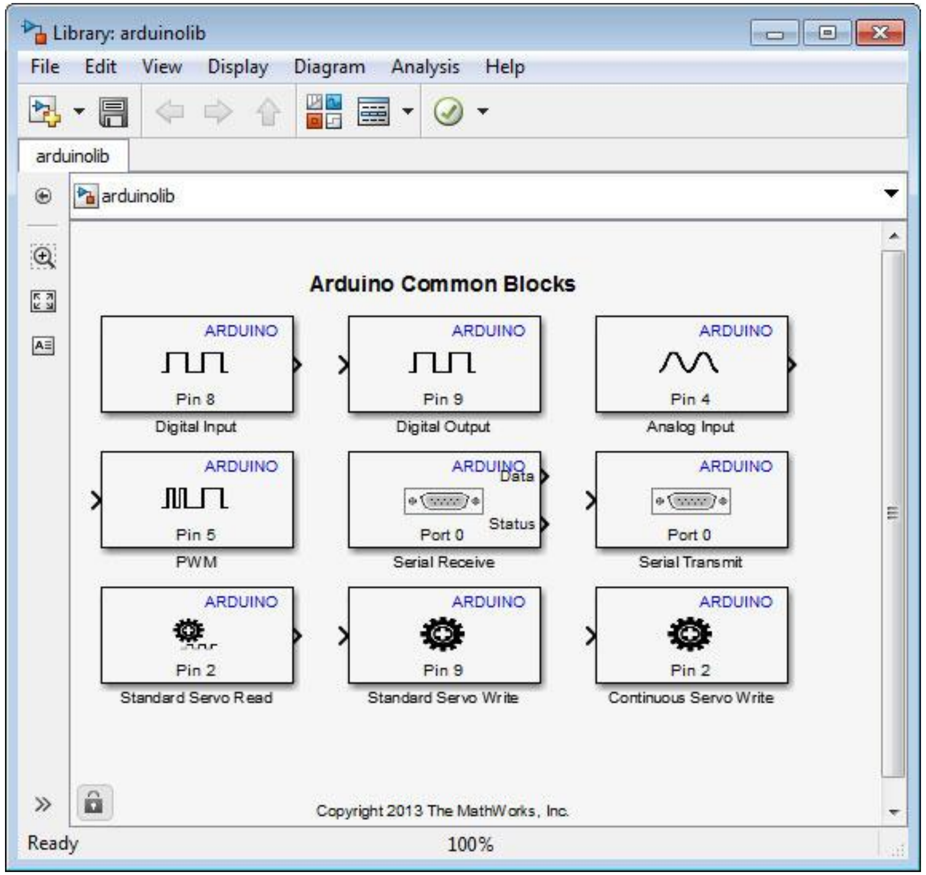
Texas Instruments

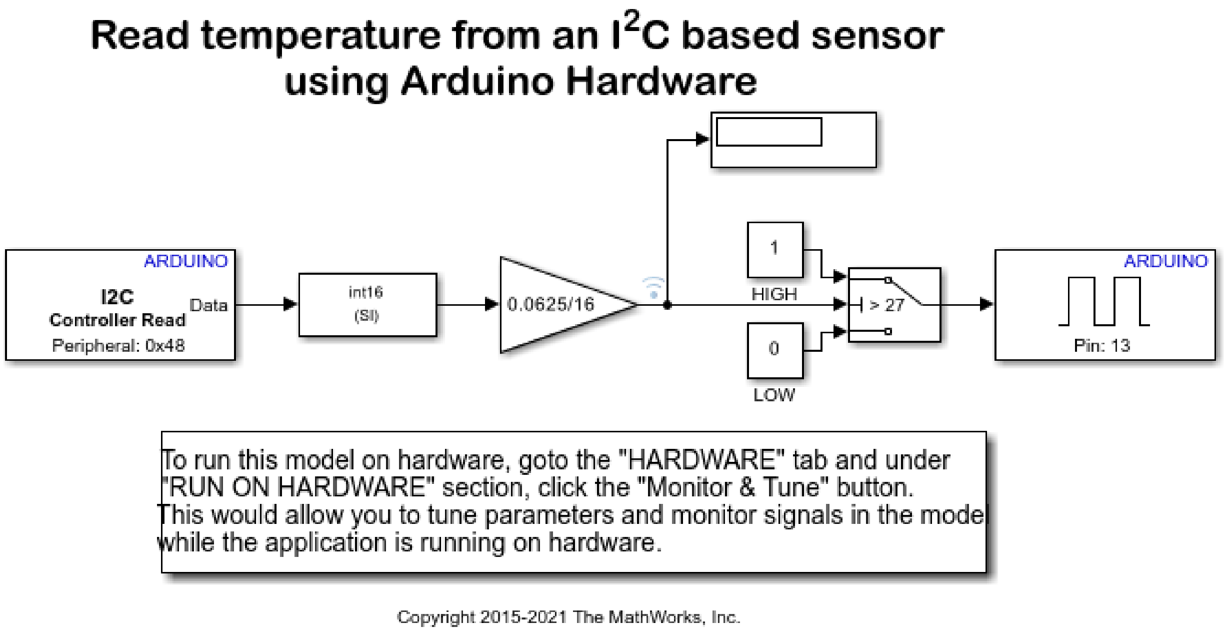
STM Electronics

Freescale

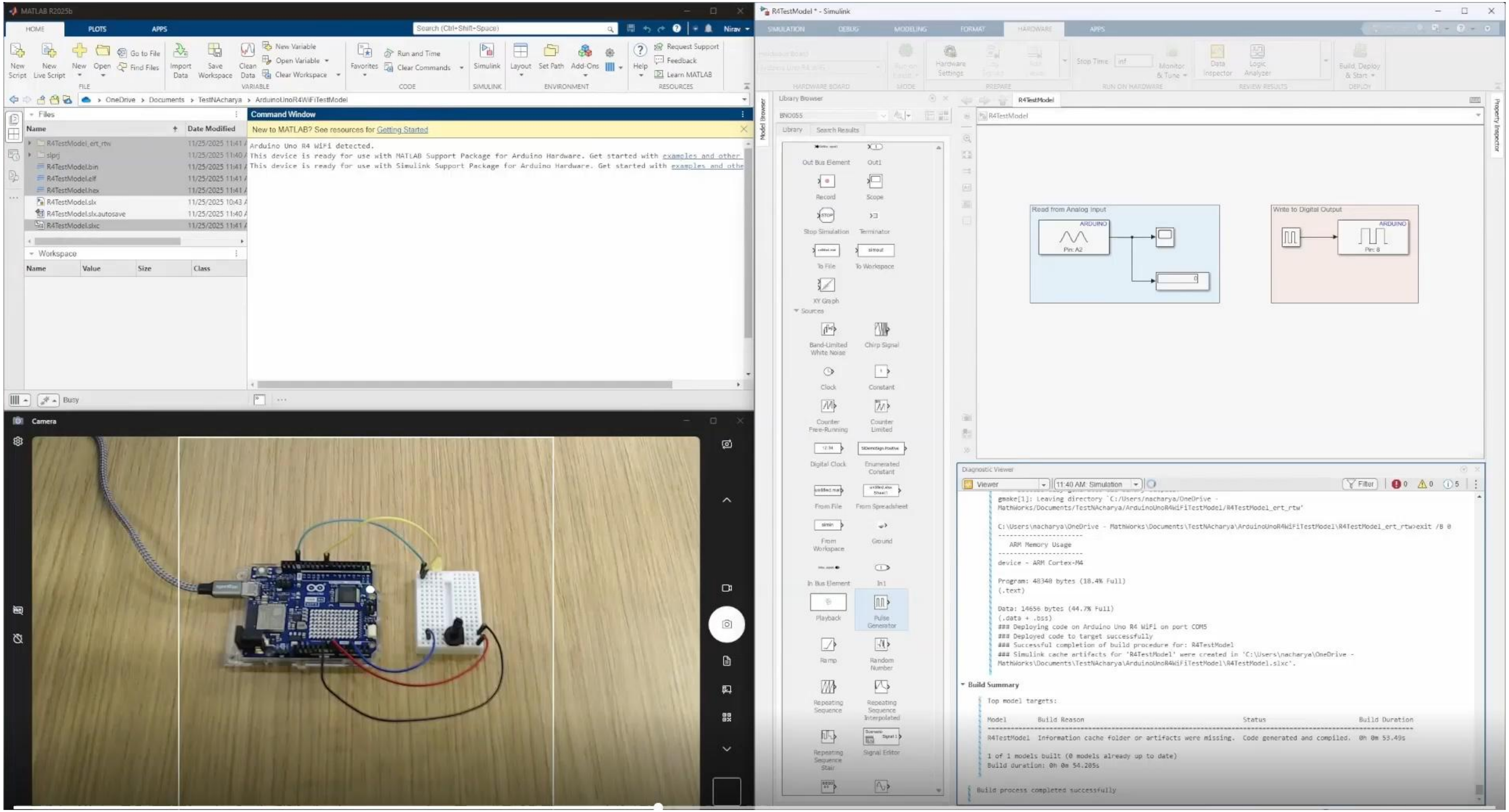
Zynq SDR

Interact with hardware using Simulink/Simulink Online

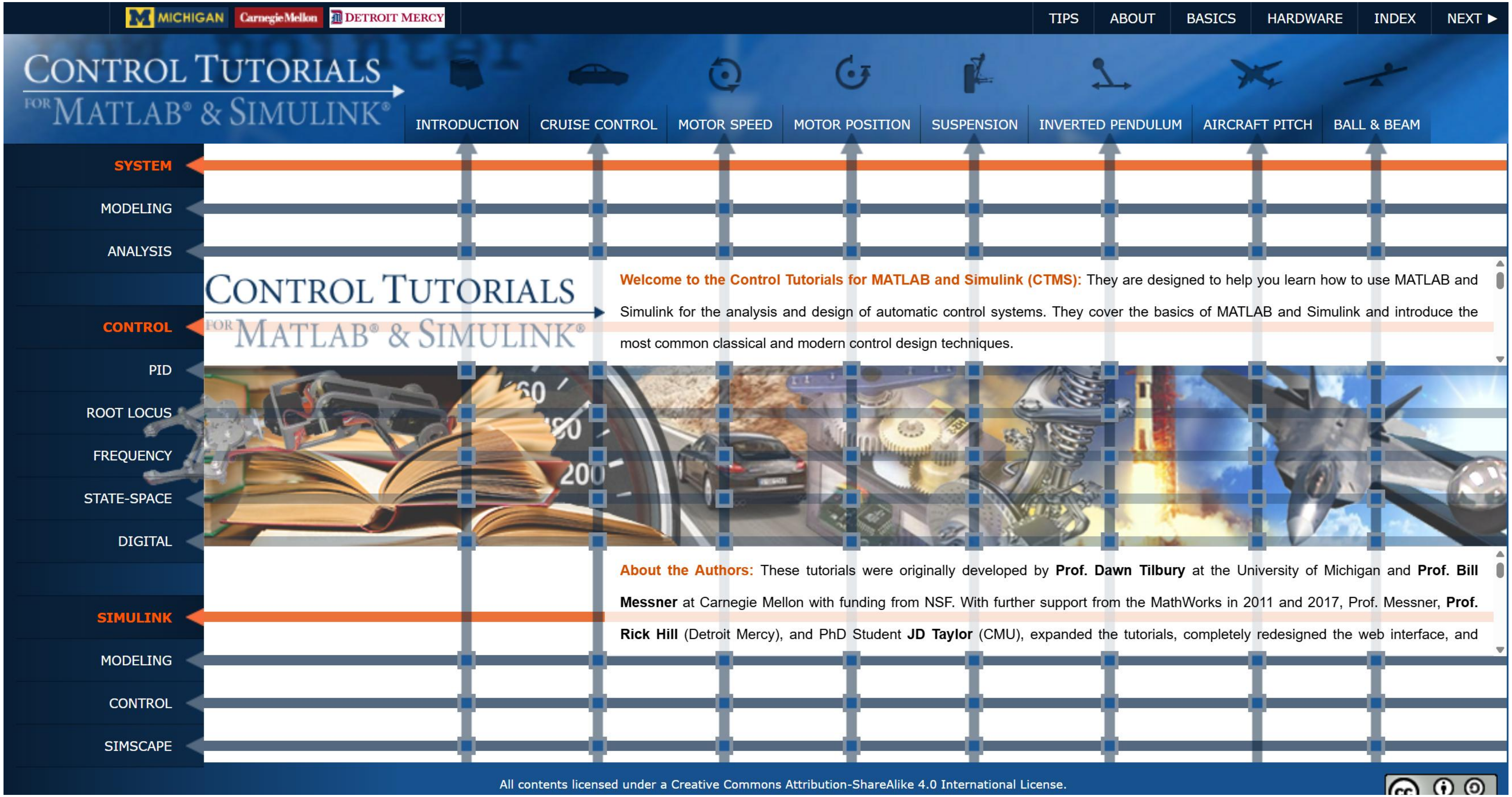




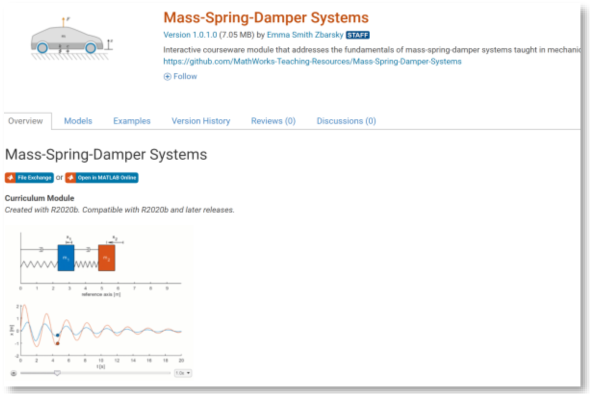
Control an LED from Simulink!



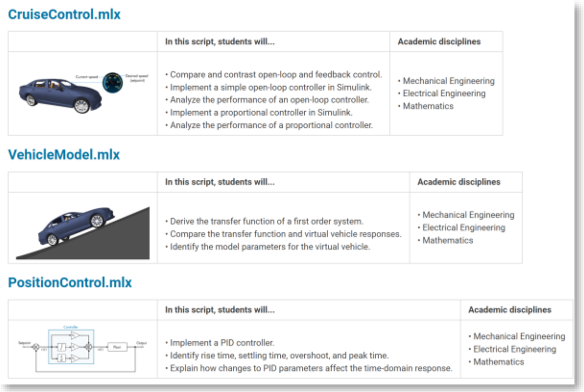
Controls tutorials with MATLAB and Simulink



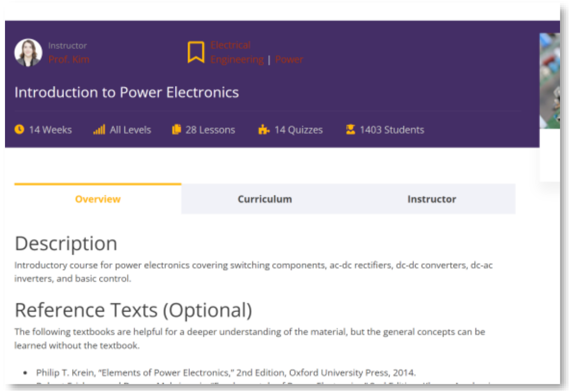
Modular courseware and virtual labs



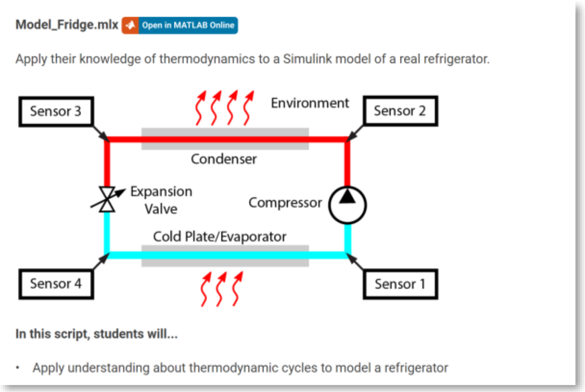
[Mass-Spring-Damper Systems]



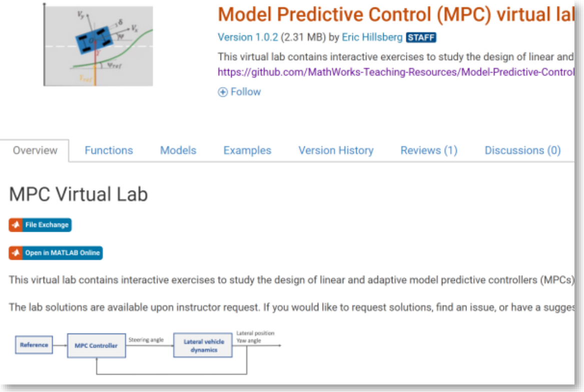
[Virtual Hardware and Labs for Controls]



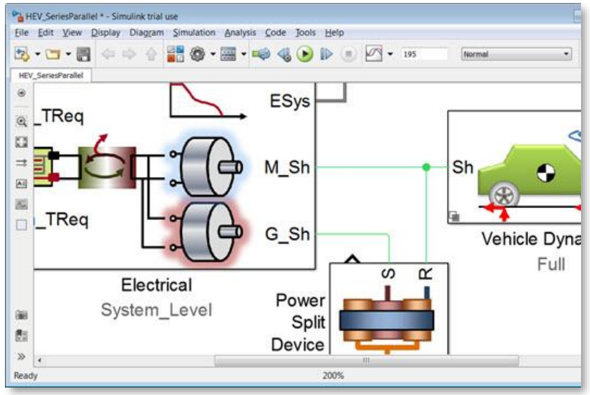
[Introduction to Power Electronics]



[Thermodynamics]

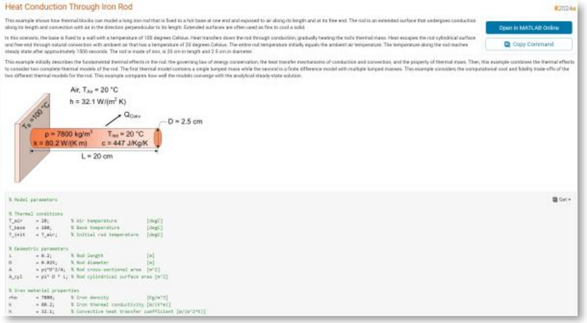


[Model Predictive Control]

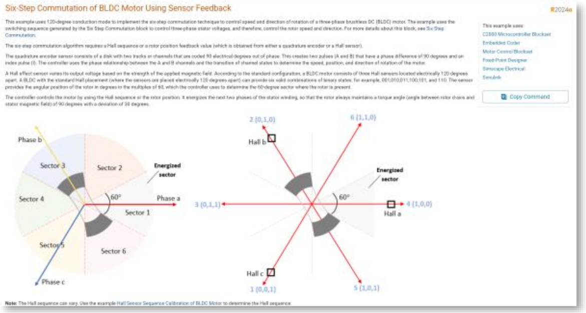


[Hybrid-Electric Vehicle Model in Simulink & Simscape]

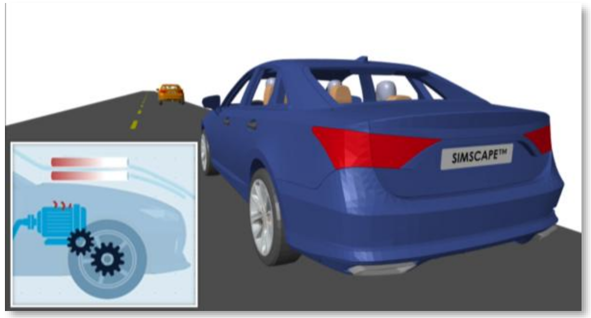
Reference examples in documentation and file exchange



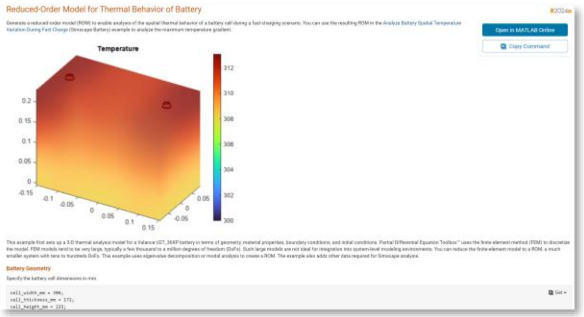
Heat Conduction Through Iron Rod



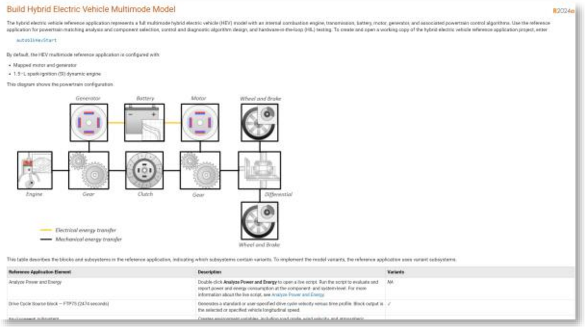
Six-Step Commutation of BLDC Motor Using Sensor Feedback



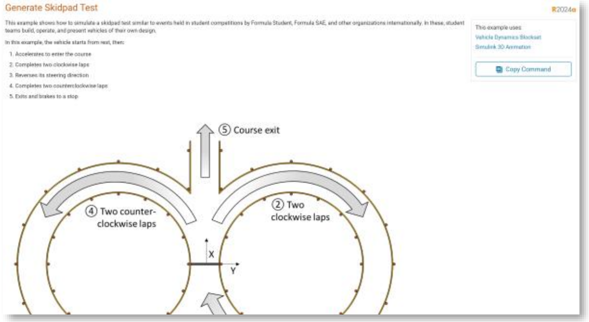
Battery Electric Vehicle with Motor Cooling in Simscape



Reduced-Order Model for Thermal Behavior of Battery



Build Hybrid Electric Vehicle Multimode Model

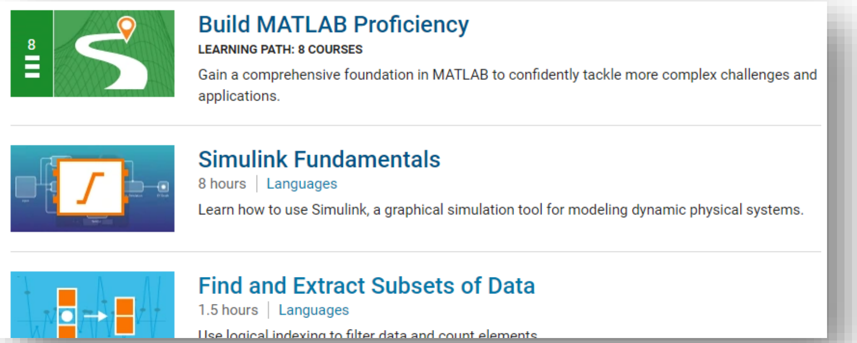


Generate Skidpad Test

Examples with Extended Descriptions and Educational Materials

Self-Paced Online Courses

http://matlabacademy.mathworks.com



- MATLAB and Simulink online training courses at 44 Short Courses
  - 12 Learning Paths
- Offers learning flexibility for:
  - upskilling/reskilling
  - exploring new topics and ideas
  - meeting prerequisites for instructor-led courses or consulting engagements
- Choose to take individual lessons, short courses, or full learning paths
- Wide range of available topics—new courses and topics added every few months

Short courses (1-3 hours)

- MATLAB Onramp
- Simulink Onramp
- Circuit Simulation Onramp
- Machine Learning Onramp
- Power Systems Simulation Onramp
- Image Processing Onramp
- System Composer Onramp
- Object Oriented Programming Onramp
- App Building Onramp
- Simscape Onramp
- Stateflow Onramp

Long courses (7-10 hours)

- Simulink Fundamentals
- Image Processing with MATLAB
- Deep Learning with MATLAB
- Machine Learning with MATLAB

MathWorks Education Application Engineer *sjawahar@mathworks.com*

consult with faculty and researchers to support them with their STEM initiatives,

including integrating computational or systems thinking into their curriculum and research

Take a minute to submit a survey!