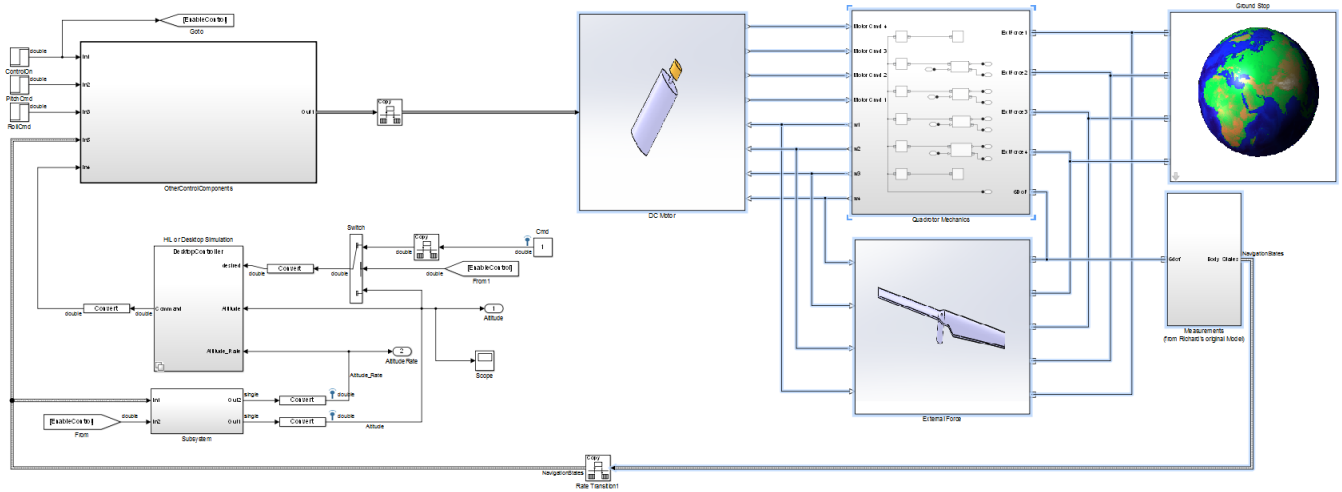

Modeling and Simulation for a Quadcopter

Selmane SEKKAI
Application Engineer
MathWorks
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Agenda

- Why quadcopter modeling and simulation?
- Model and simulate the behavior of the physical plant
- Refine model parameters using experimentation data
- Design the control system for quadcopter
- Key takeaways

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- Why quadcopter modeling and simulation?
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Why Quadcopter modeling and control?

- Quadcopters are a popular and relatively inexpensive platform to showcase Model Based Design
- Concepts of modeling, simulation and control can be applied to a variety of systems
- System highly unstable and difficult to control
- Quadcopters are fun to fly!

Why Quadcopter modeling and control?

Agenda

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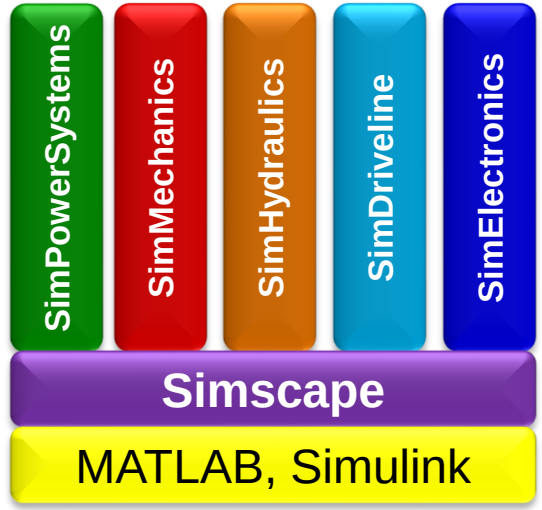
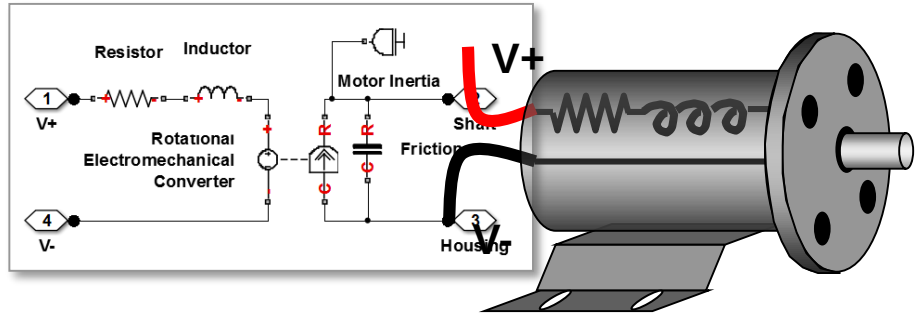
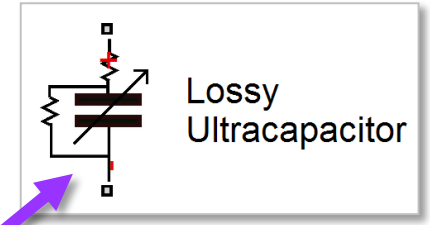
Introduction to Simscape



- Enables physical modeling (acausal) of multidomain physical systems
- Eases process of modeling physical systems
  - Build models that reflect structure of physical system
  - Leverage MATLAB to create reusable models
- Used by system and control engineers to build models with the same structure as the physical system



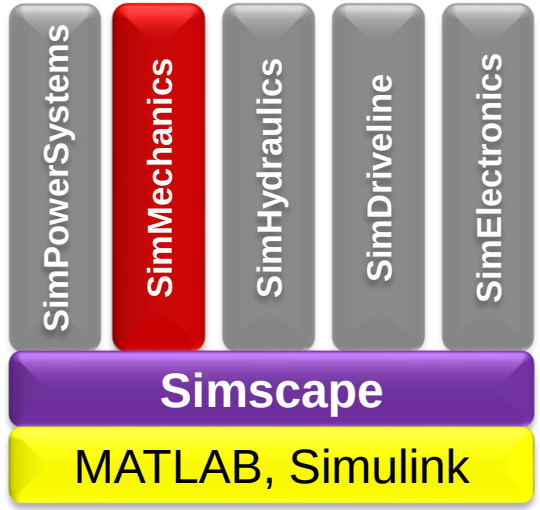
$$i = (C_0 + C_v v)\frac{dv}{dt} + \frac{v}{r_d}$$

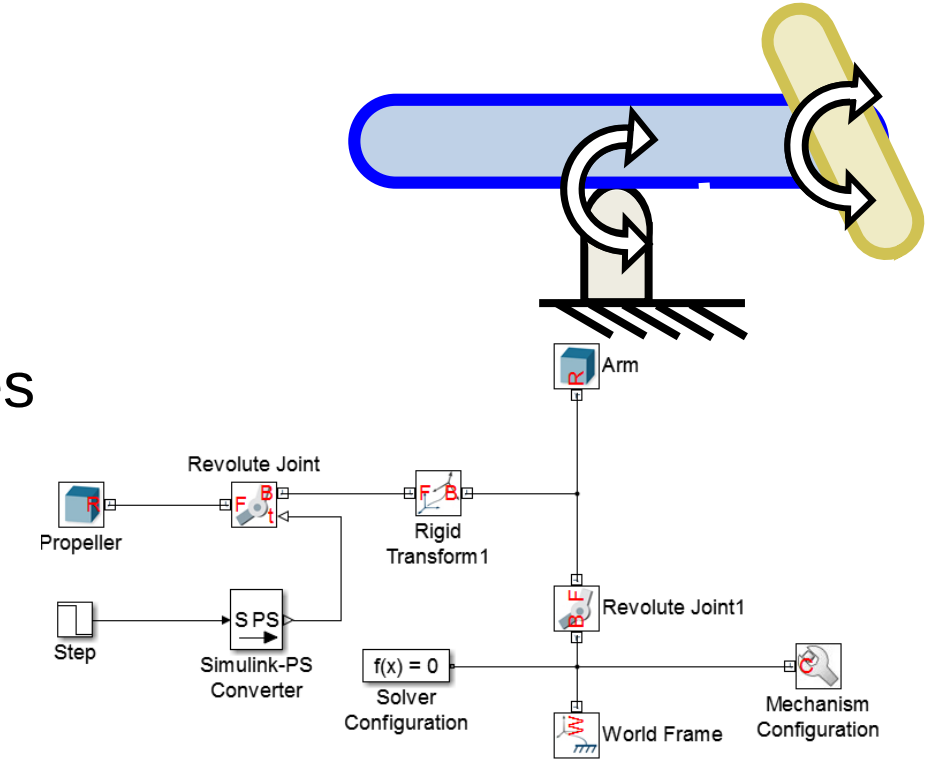



```
Editor - C:\+MyComponents\LossyUltraCapacitor.ssc
40  equations
41    i == (C0 + Cv*vc)*vc.der + vc/Rd;
42    v == vc + i*R;
43  end
```

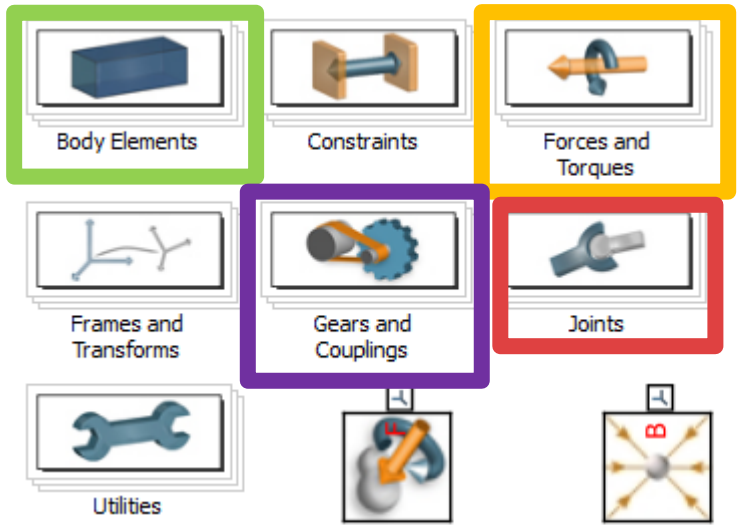
What is SimMechanics?

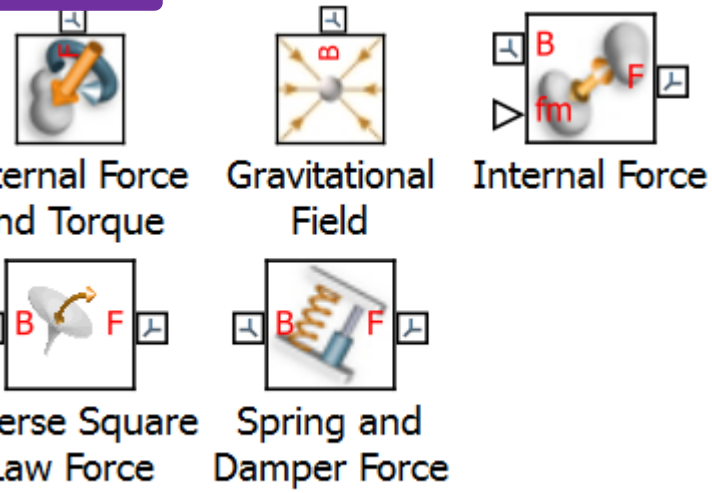
- Enables multibody simulation of 3D mechanical systems
- Construct model using bodies, joints, and forces
  - Model matches structure of system
  - No need to derive and program equations
- Enables import of CAD models
- Integrates with other physical modeling libraries
- Eases the control development in Simulink

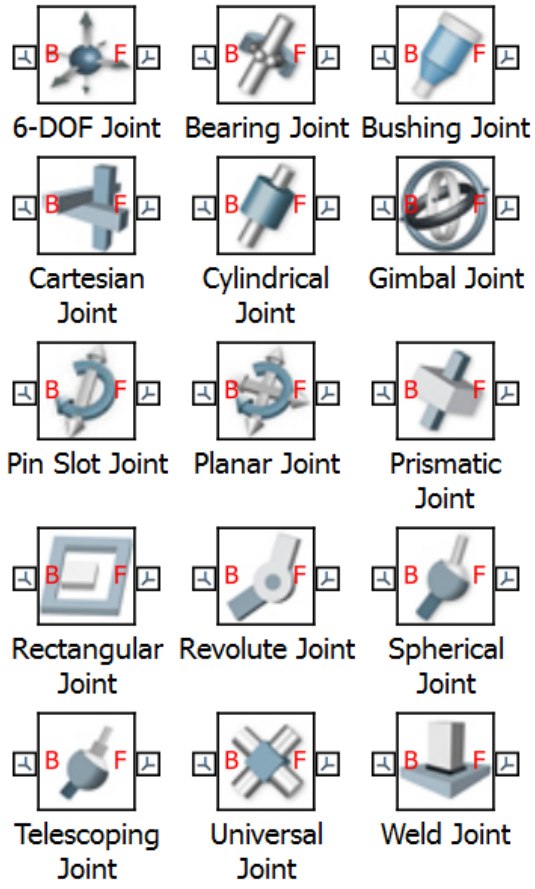


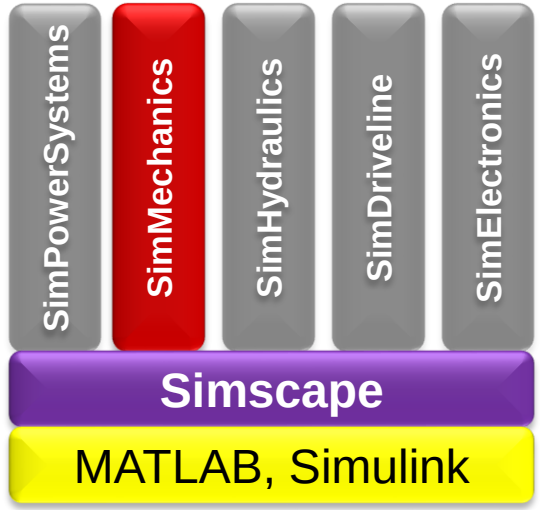


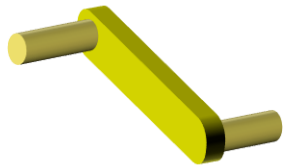
What is SimMechanics?

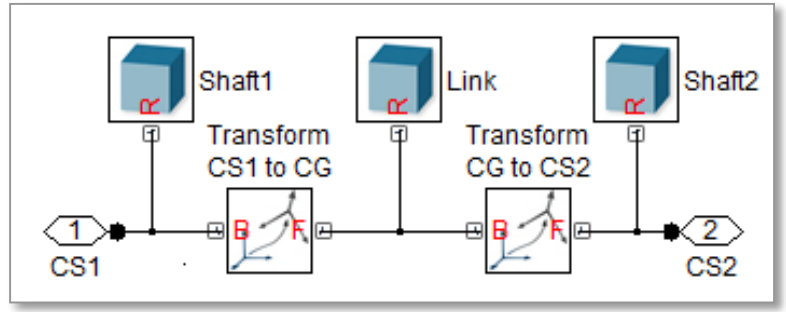






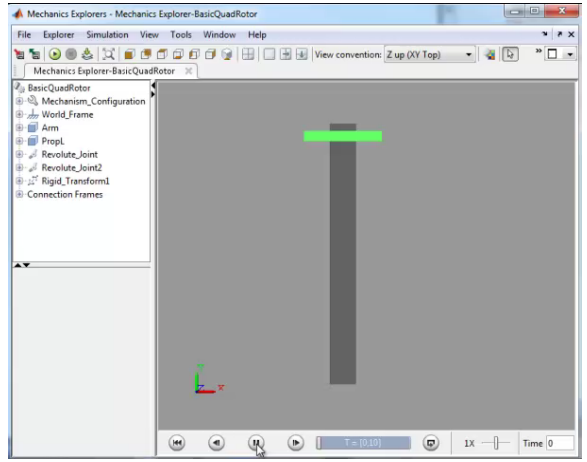




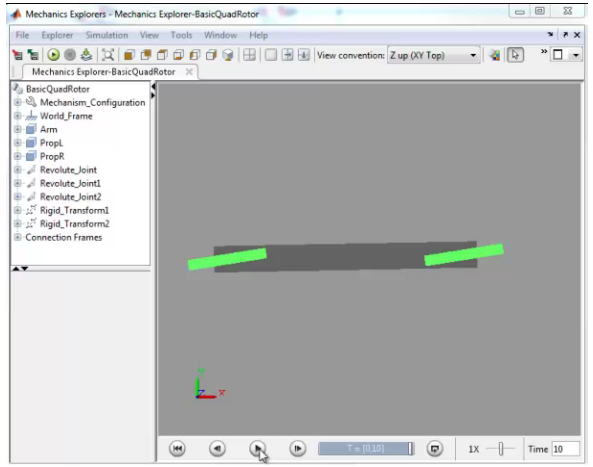


Model a simple quadcopter to verify concepts

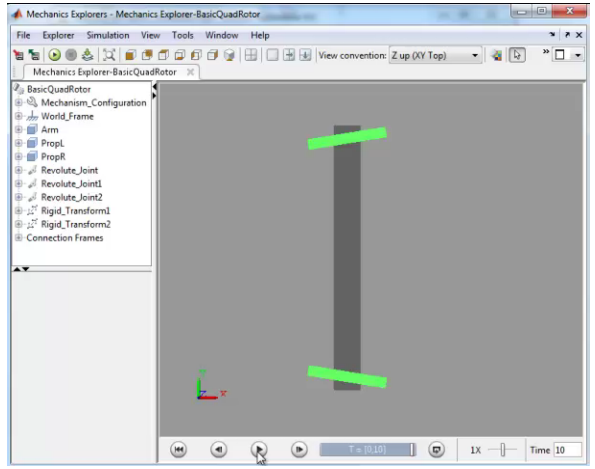
- One propeller to verify arm rotation



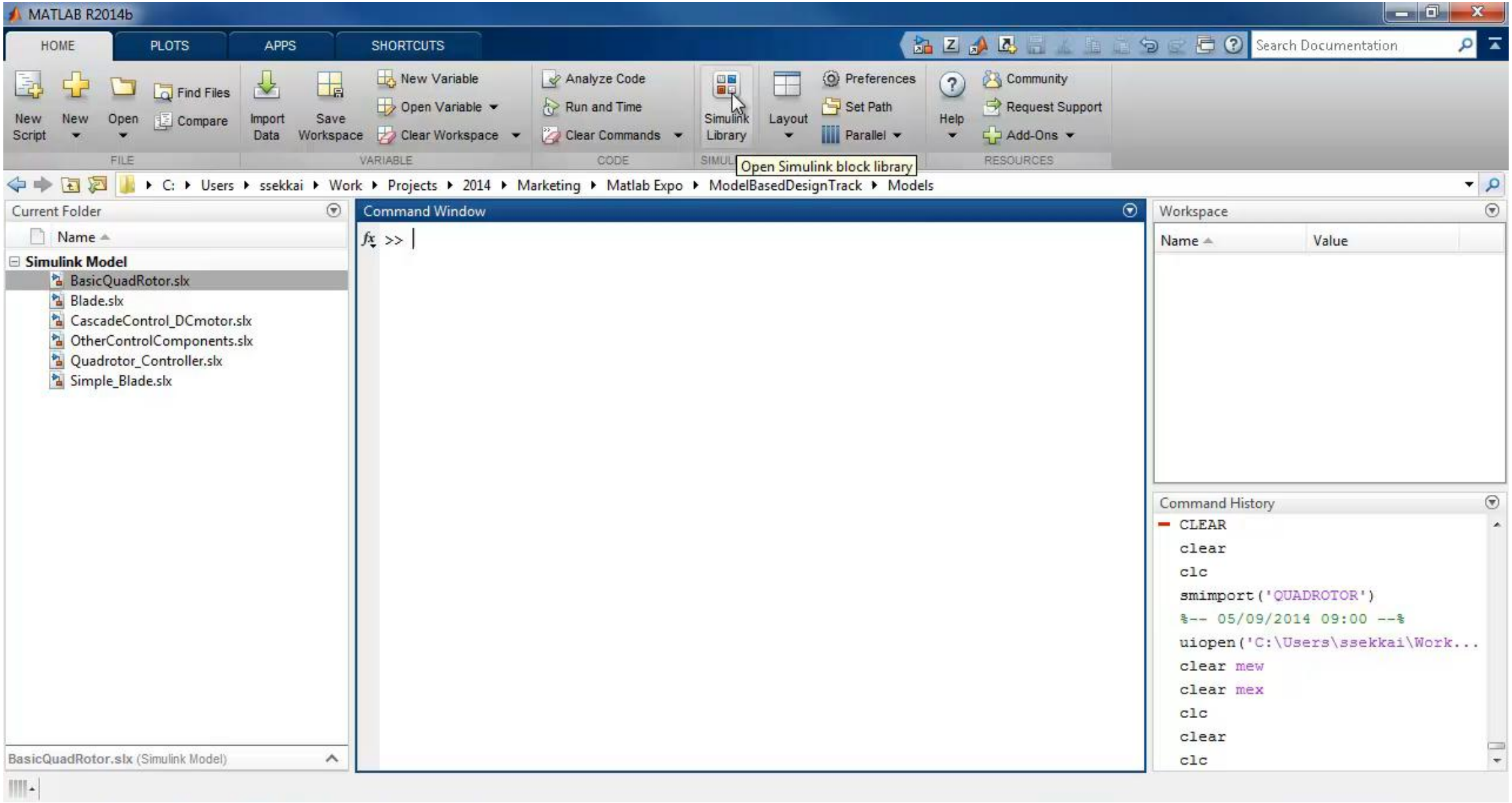
- Two propellers to verify arm motion



- Two propeller with same speed in opposite direction to verify arm stillness

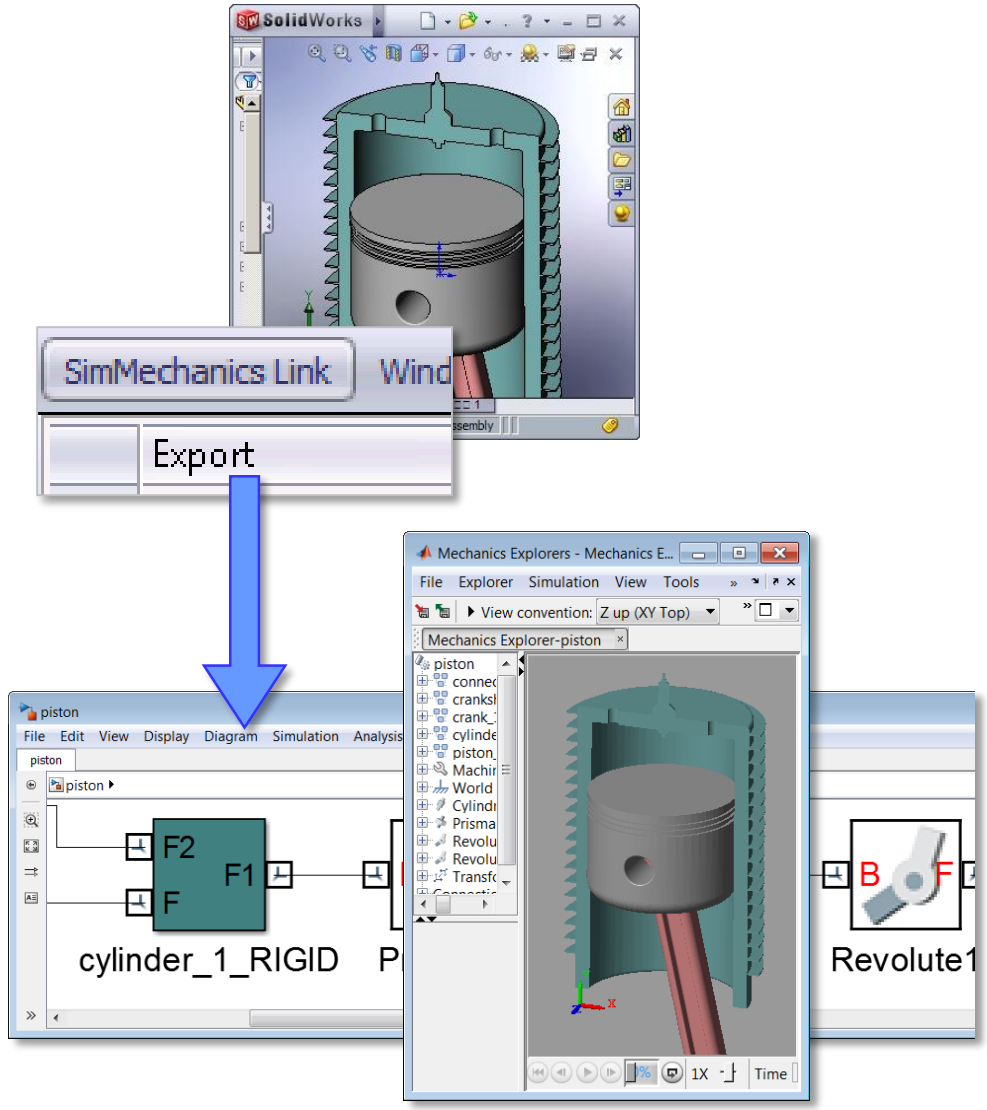


Model a simple quadcopter to verify concepts



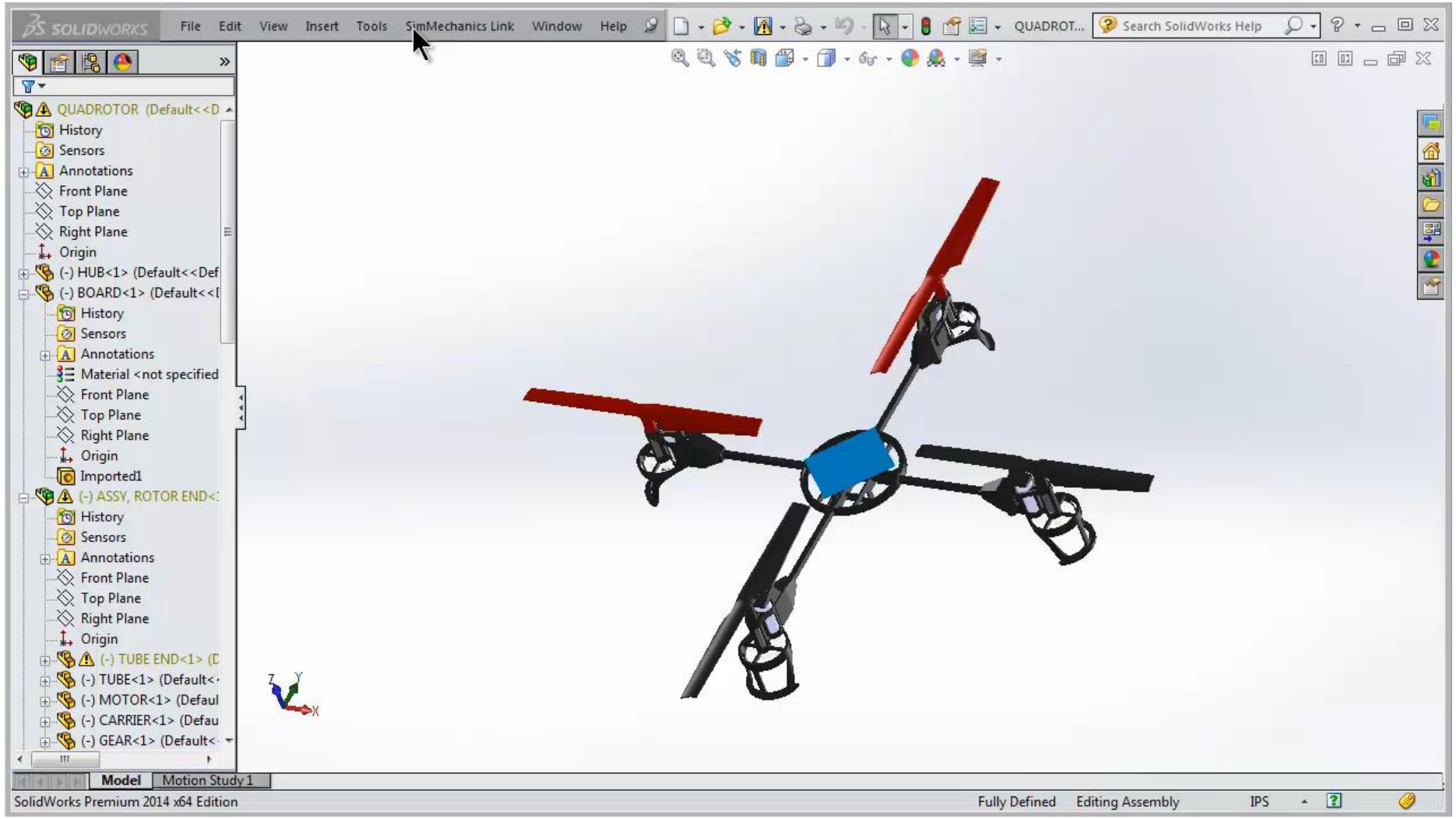
Import CAD Data Using SimMechanics Link

- Automatically create SimMechanics models from a CAD assembly
  - Converts mass and inertia to rigid bodies
  - Converts mate definitions to joints
  - Creates STL files for use with SimMechanics visualization
- Directly connects SolidWorks, ProEngineer and Inventor
- Public API for other CAD tools
- Free download from **www.mathworks.com**

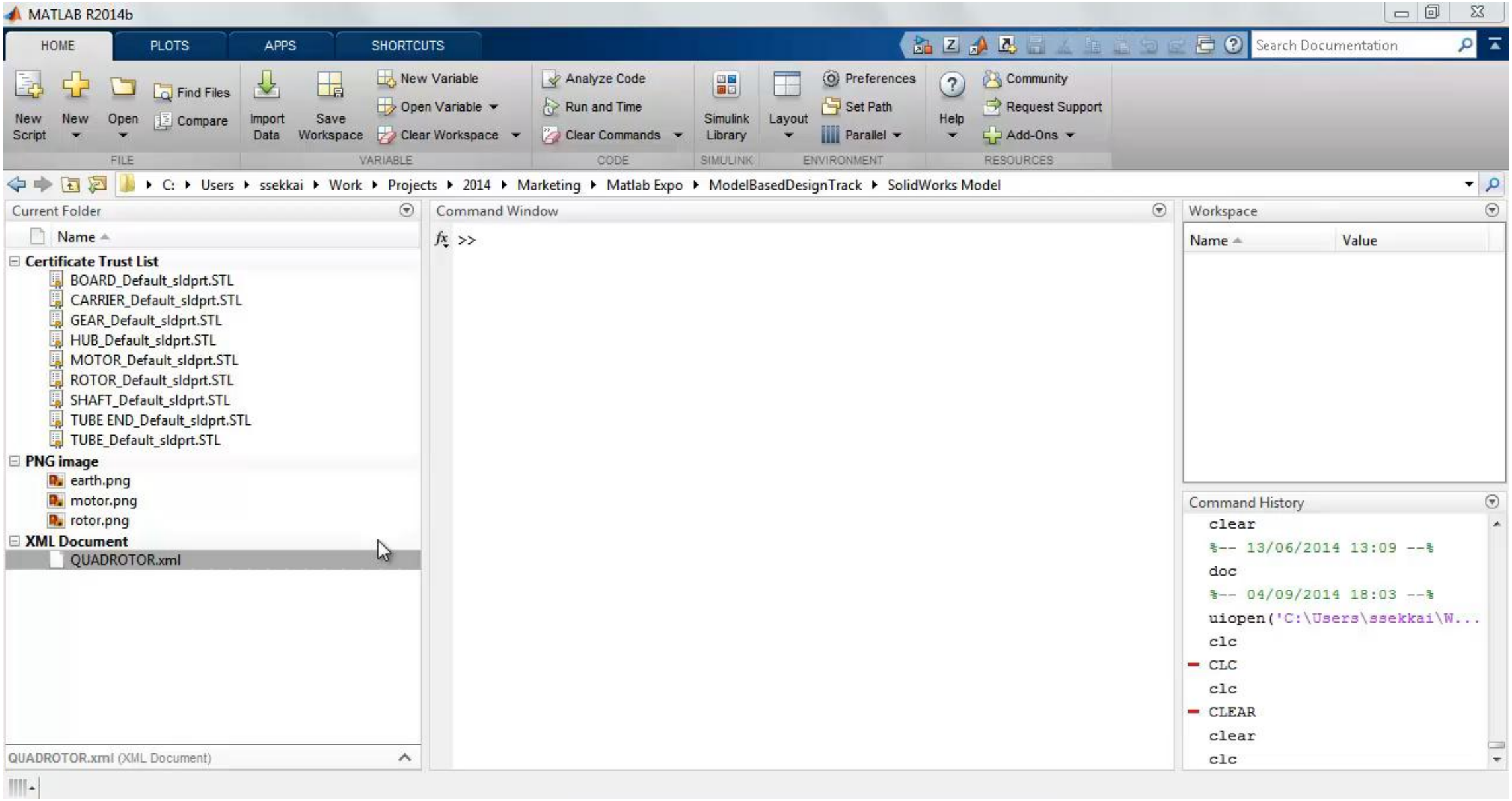


SimMechanics Link: Convert CAD Assembly to SimMechanics

- Use SimMechanics plugin to export from CAD to XML

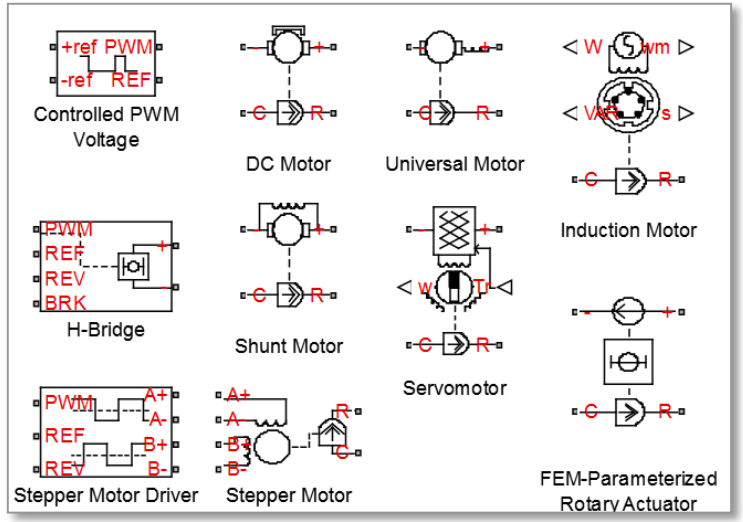


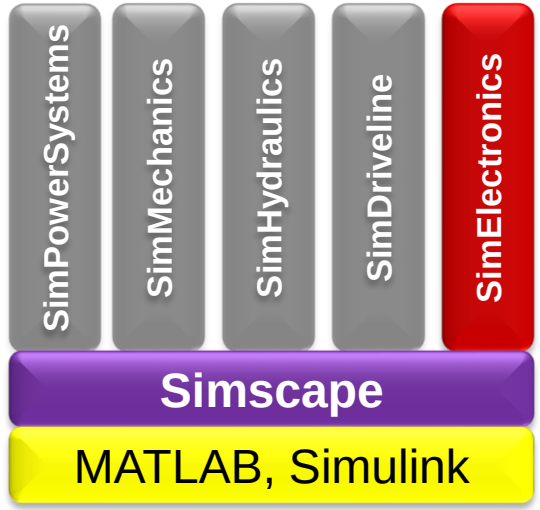
Create the SimMechanics model

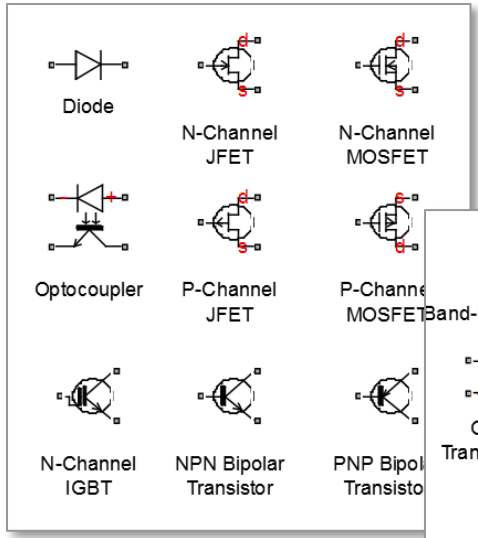


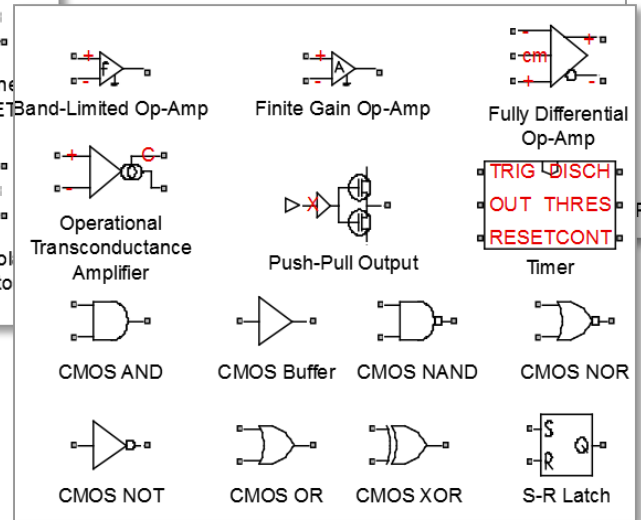
What is SimElectronics?

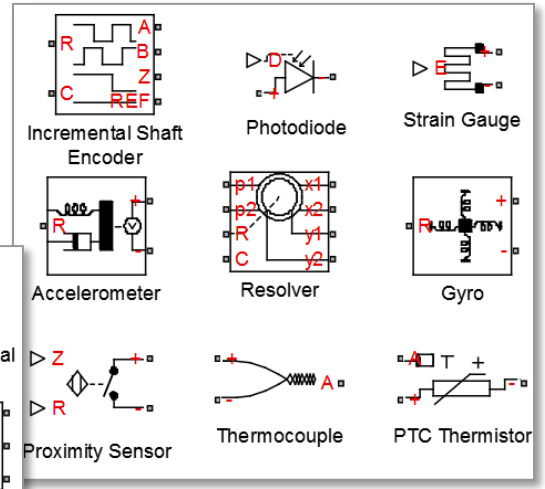
- More than 90 component models
  - Actuators, drivers
  - Sensors
  - Semiconductors
  - Integrated circuits
- Models look like schematics
  - Easy to read and interpret





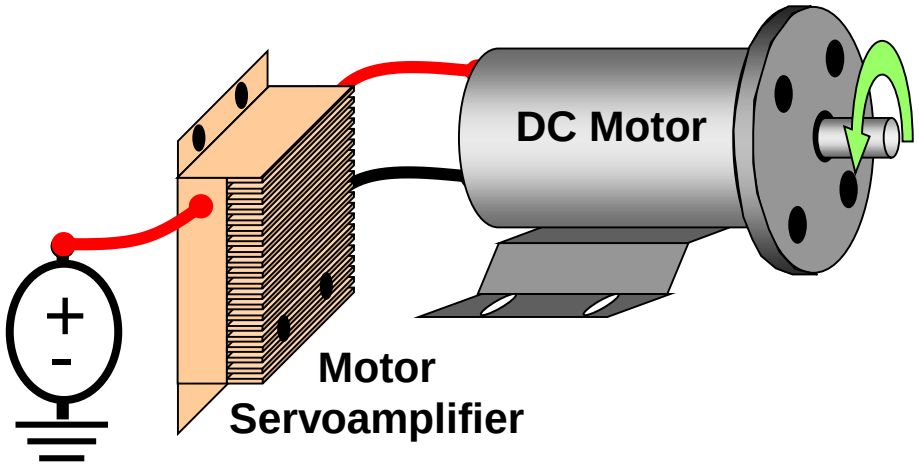


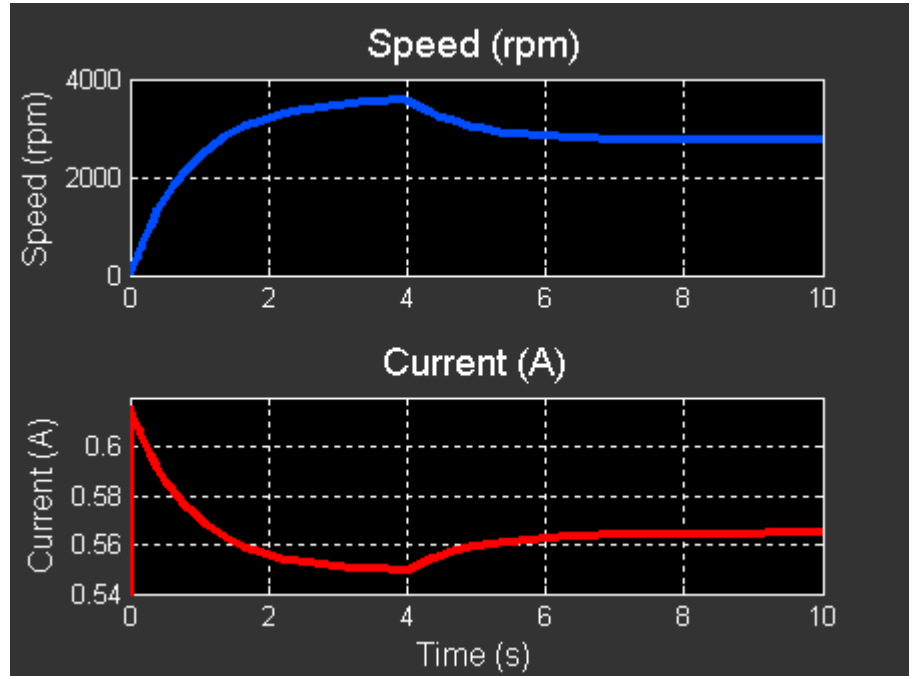




Model the quadcopter actuator : DC Motor

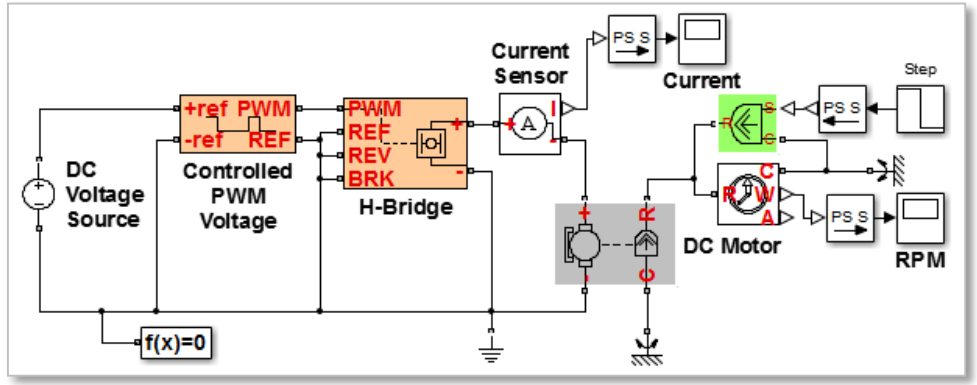
Model:



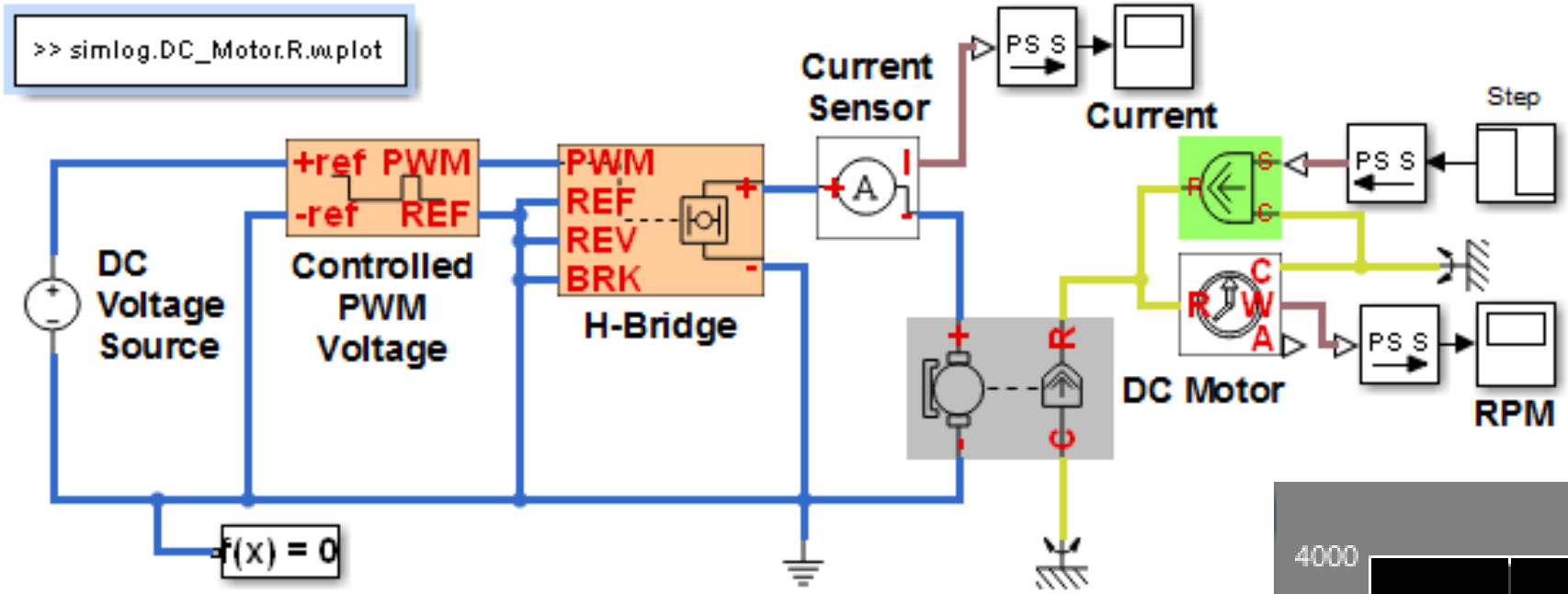


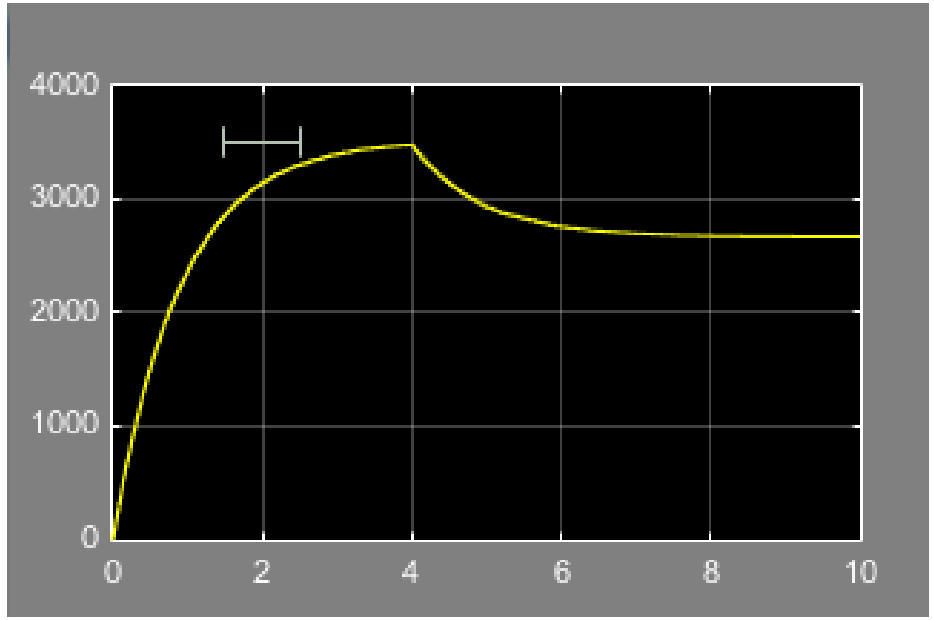
Problem: Model a DC motor with a PWM controller in the Simulink environment

Solution: Use SimElectronics to model the mechatronic system



Model the quadcopter actuator : DC Motor





Agenda

- Why quadcopter modeling and simulation?
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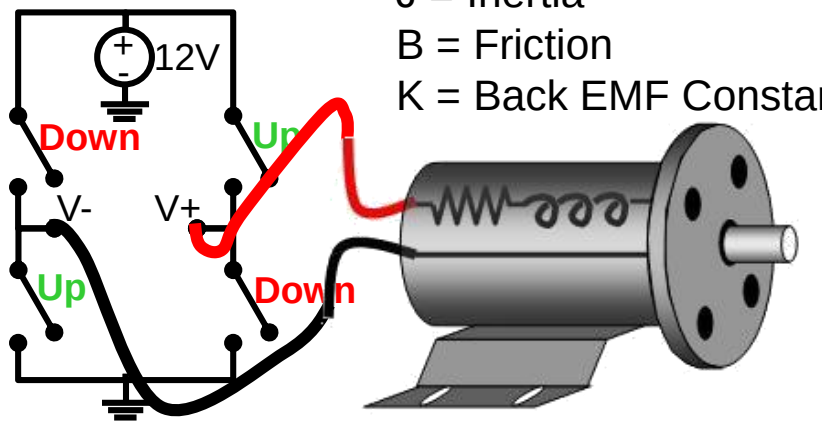
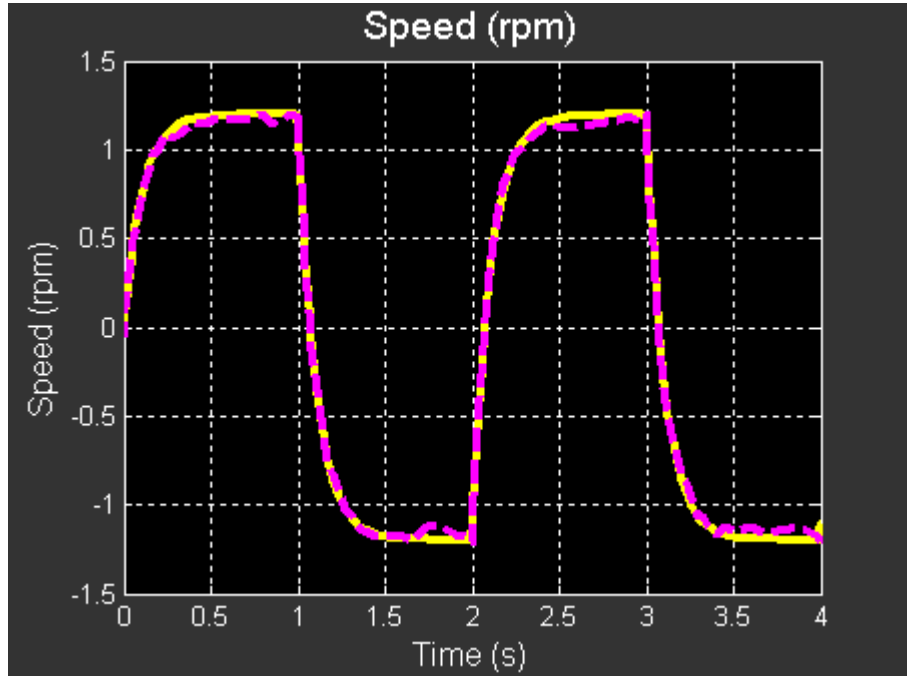
- Key takeaways

Estimating Parameters Using Measured Data

Model:

R = Resistance
L = Inductance
J = Inertia
B = Friction
K = Back EMF Constant





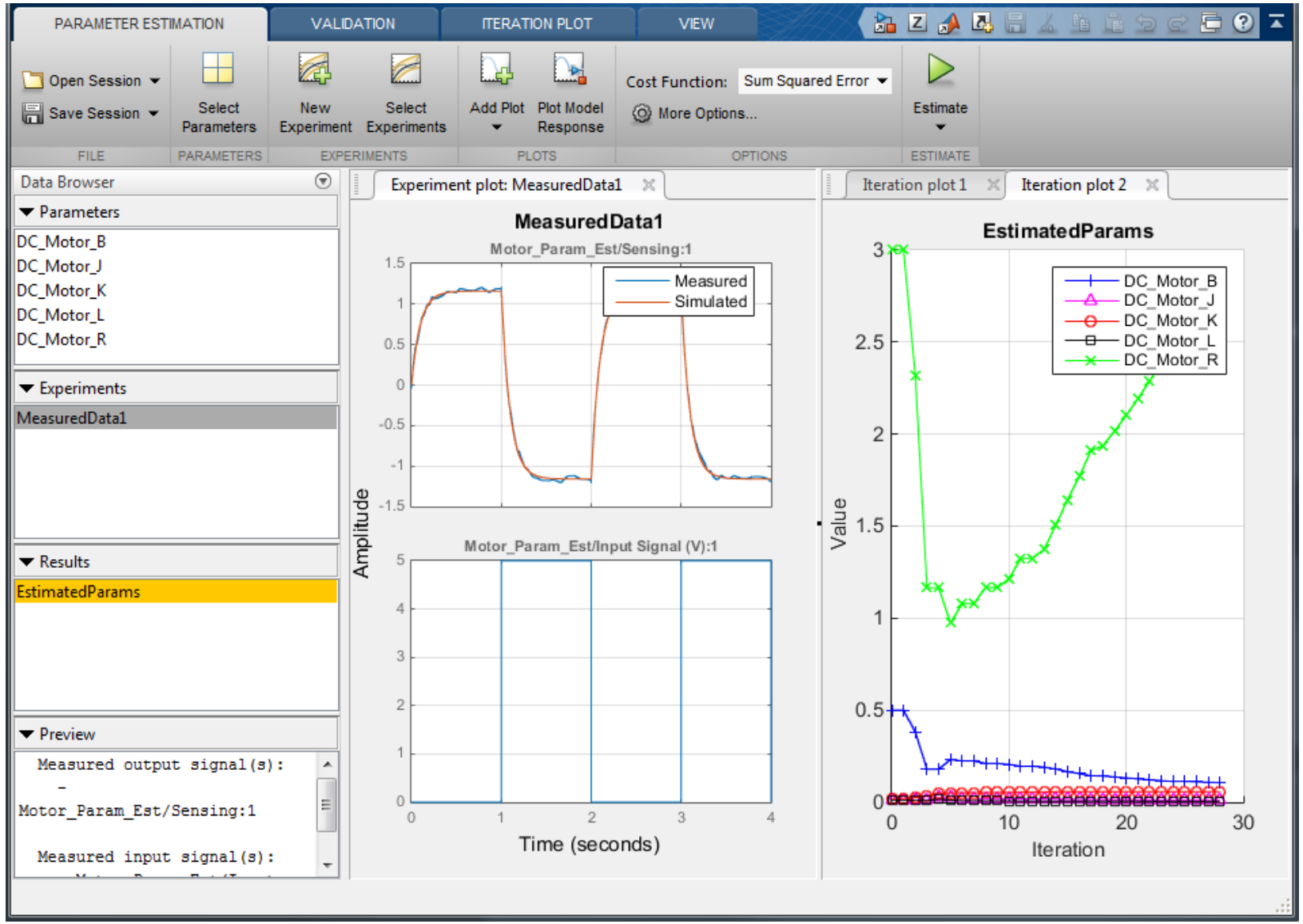
Problem: Simulation data does not match measured data because the parameters are incorrect

Solution: Use Simulink Design Optimization to automatically tune model parameters

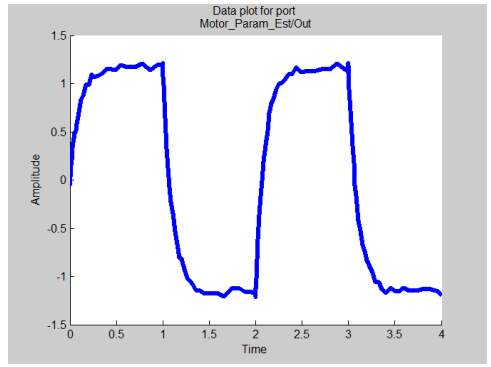
R	L	J	K	B
4.03	1e-4	0.11	0.45	1.07

Estimating Parameters Using Measured Data

New Parameter Estimation Tool in R2014b !



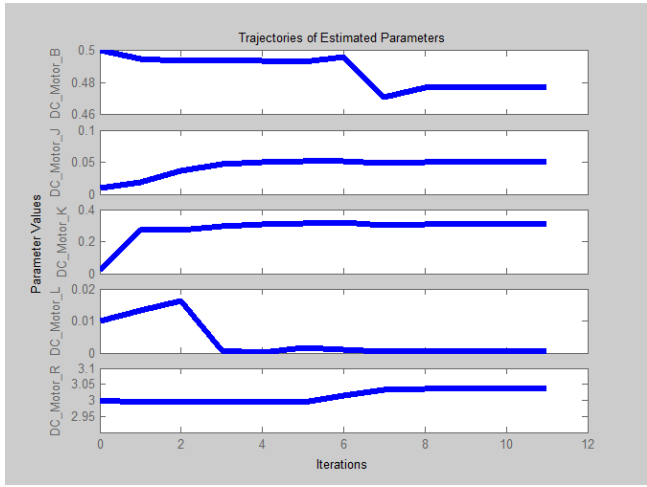
Estimating Parameters Using Measured Data



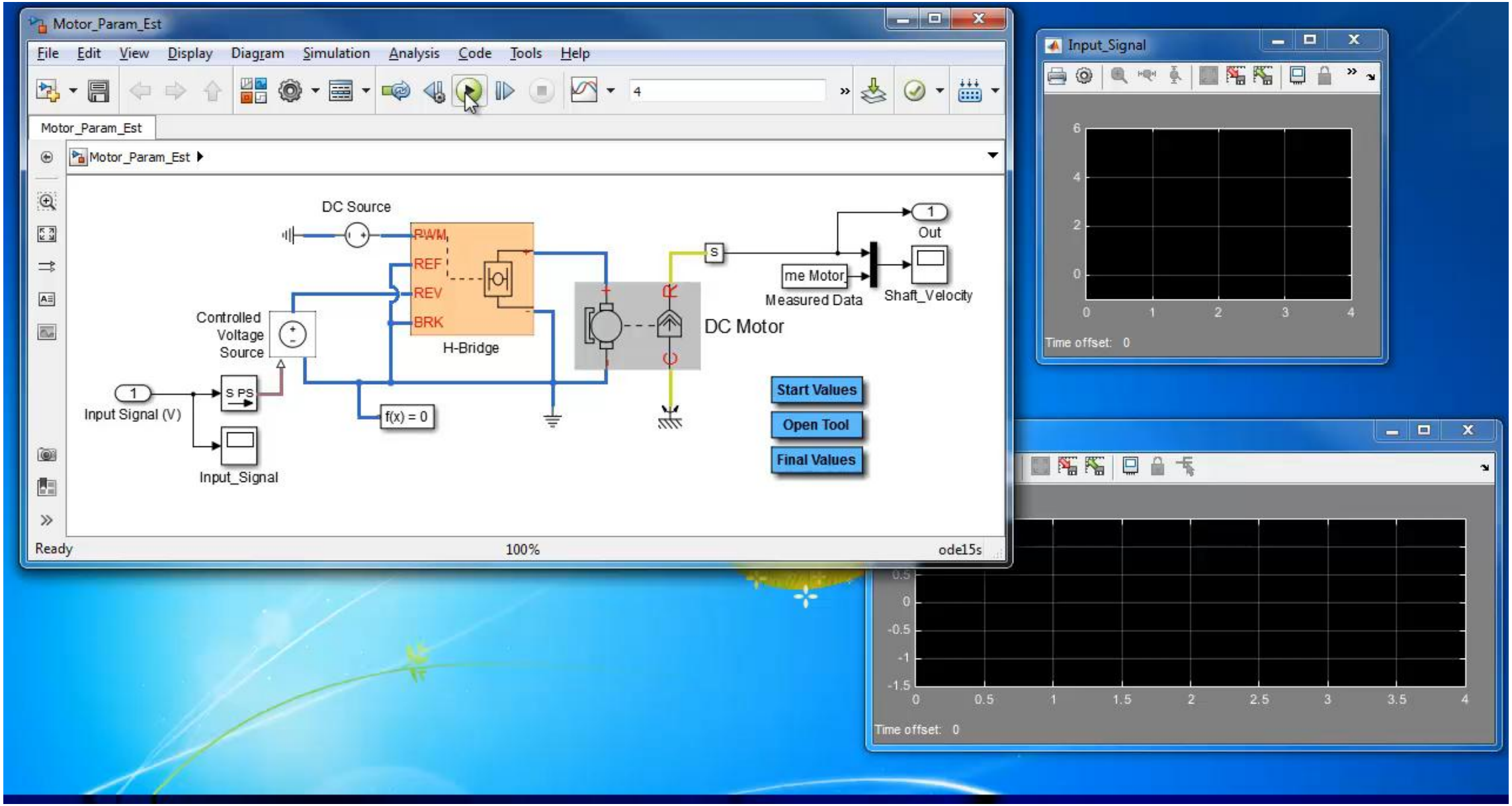
- Steps to Estimating Parameters

1. Import measurement data and select estimation data
2. Identify parameters to be estimated and their ranges
3. Perform parameter estimation
4. Validate estimation

R	L	J	K	B
3	0.01	0.01	0.02	0.5



Estimating Parameters Using Measured Data



Estimating Parameters Using Measured Data

- Advantages of Simulink Design Optimization
  - Enables quick and easy comparison with measured data to ensure simulation matches reality.
  - Automatic tuning of parameters saves time
  - Optimization algorithms reveal parameter sensitivity and help improve model parameterization

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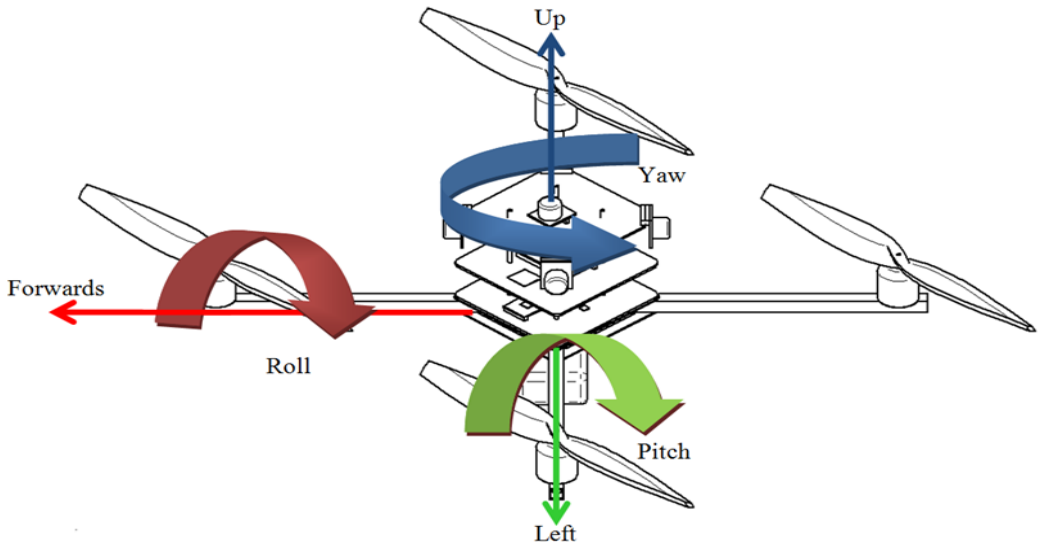
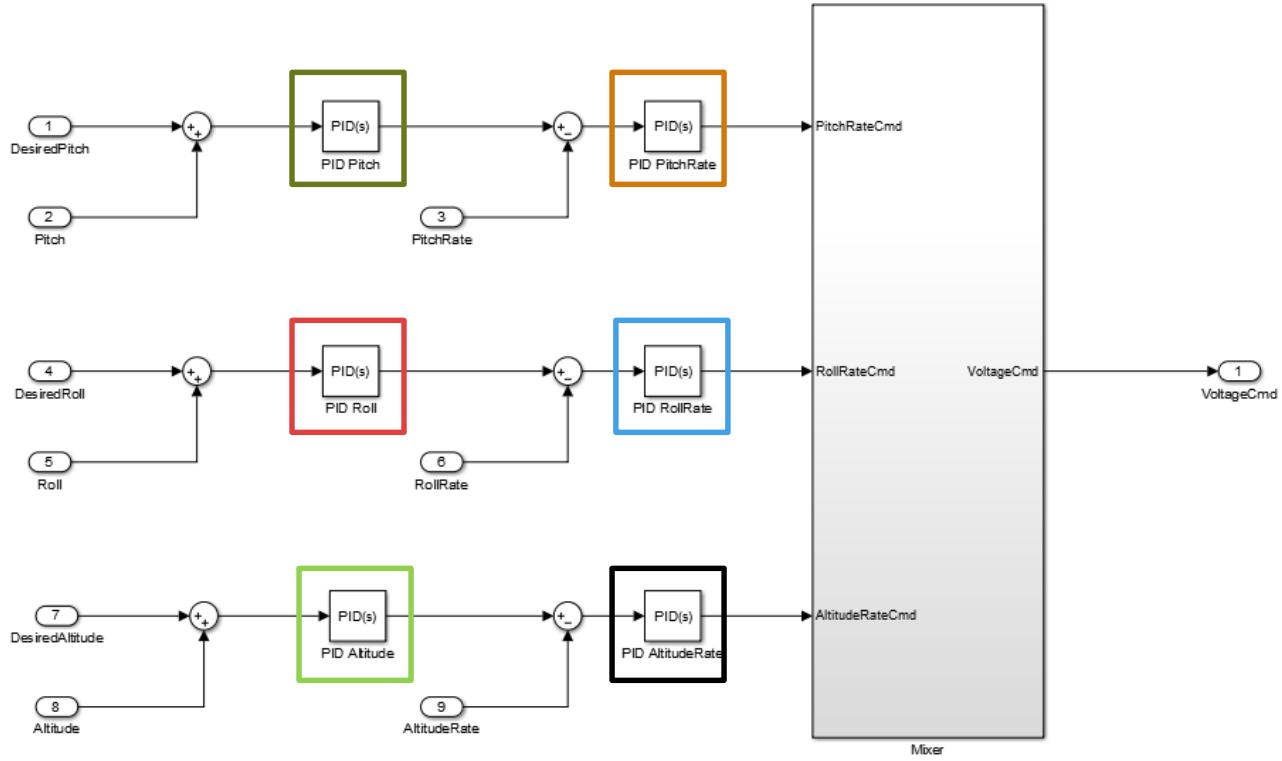
Design Control System

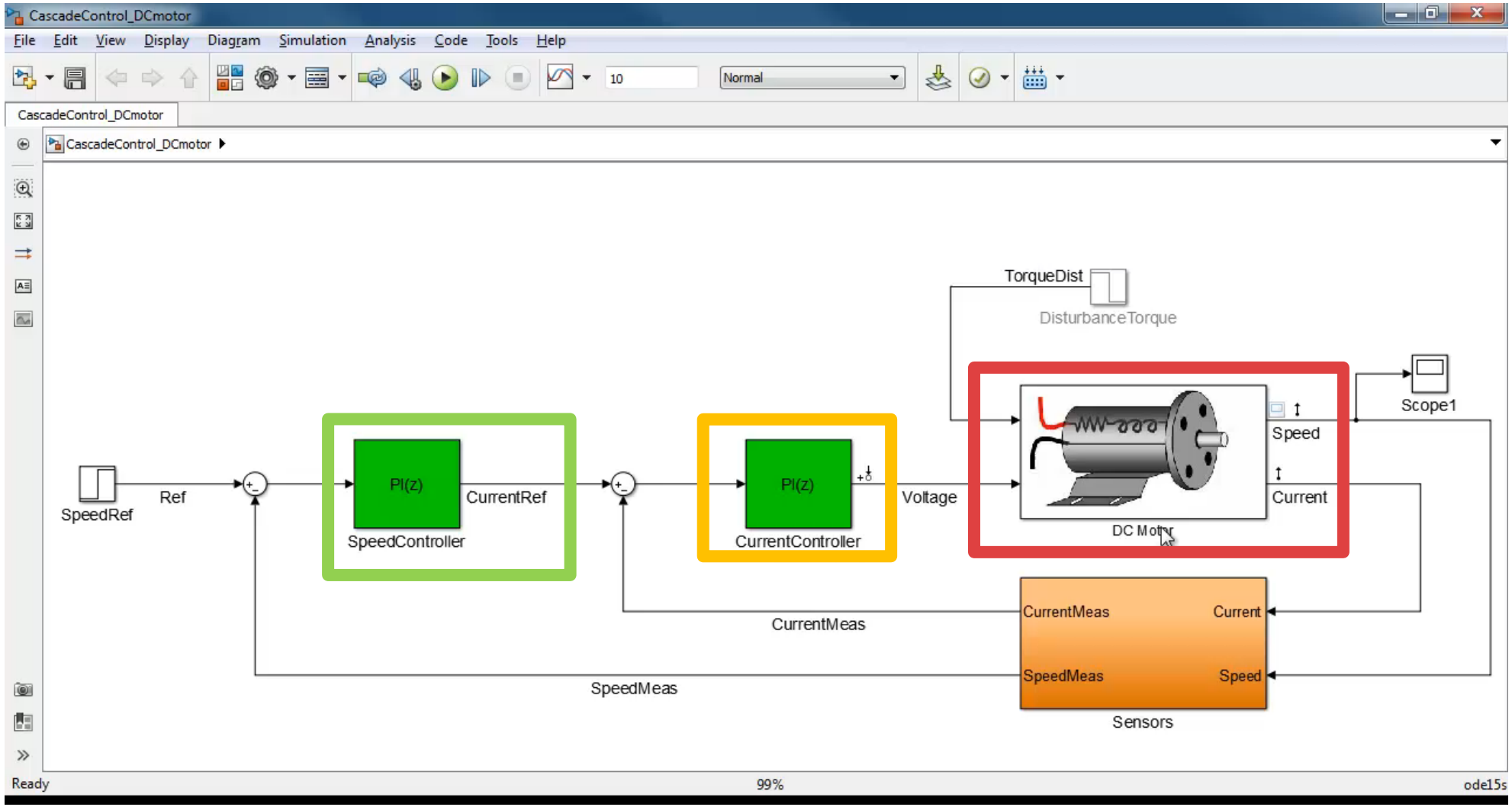
- Create cascaded control system on rate and position feedback
- Tune PID controllers using advanced techniques





Design Control System

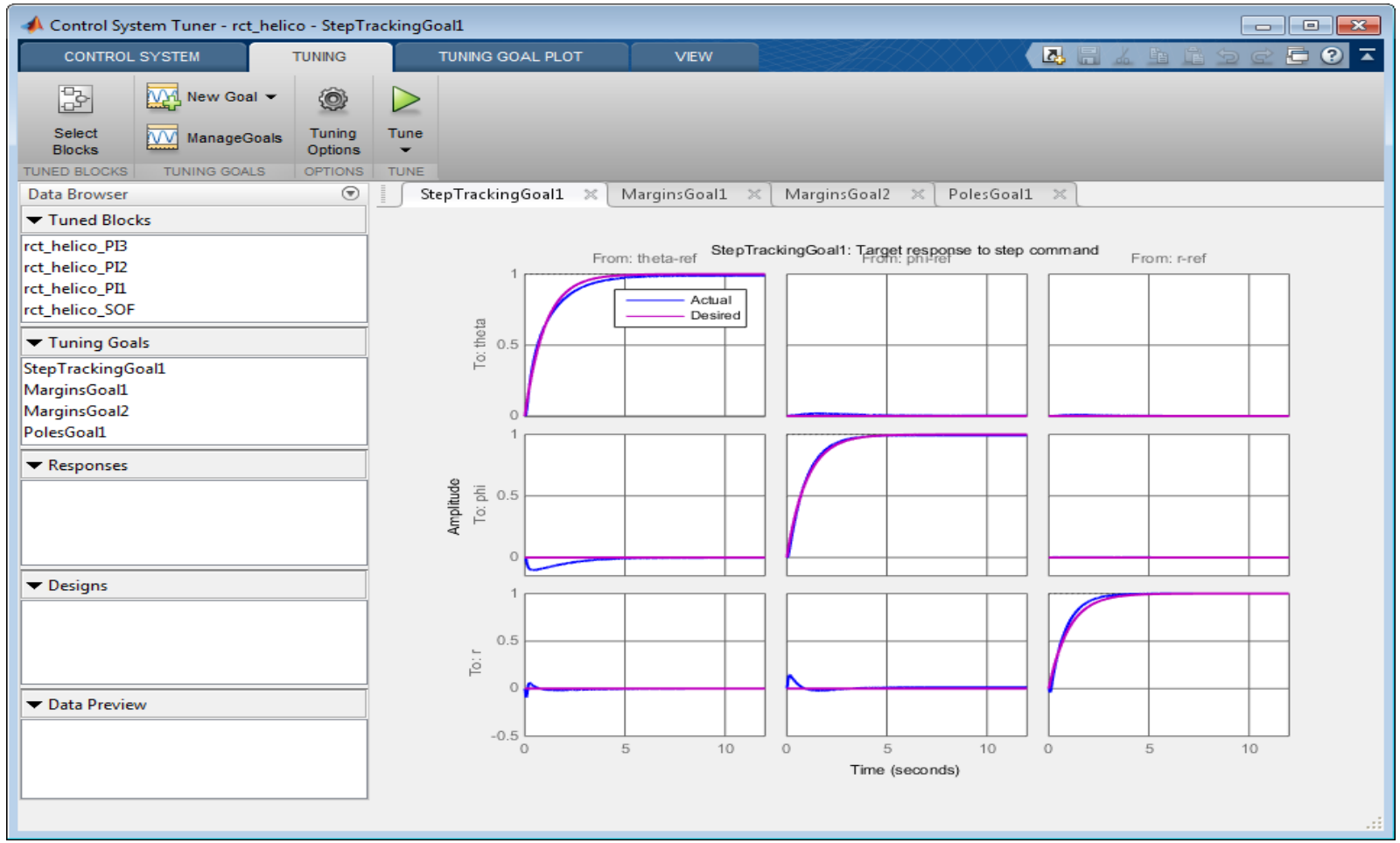
- For single PID loops, there is PID Tuner…



Design Control System

Since R2014a !

- For everything else, there is Control System Tuner



System Identification into PID Tuner

Since R2014a !

Goal:

- Tune PID Controllers for Simulink models with discontinuities such as PWM and Stateflow logic

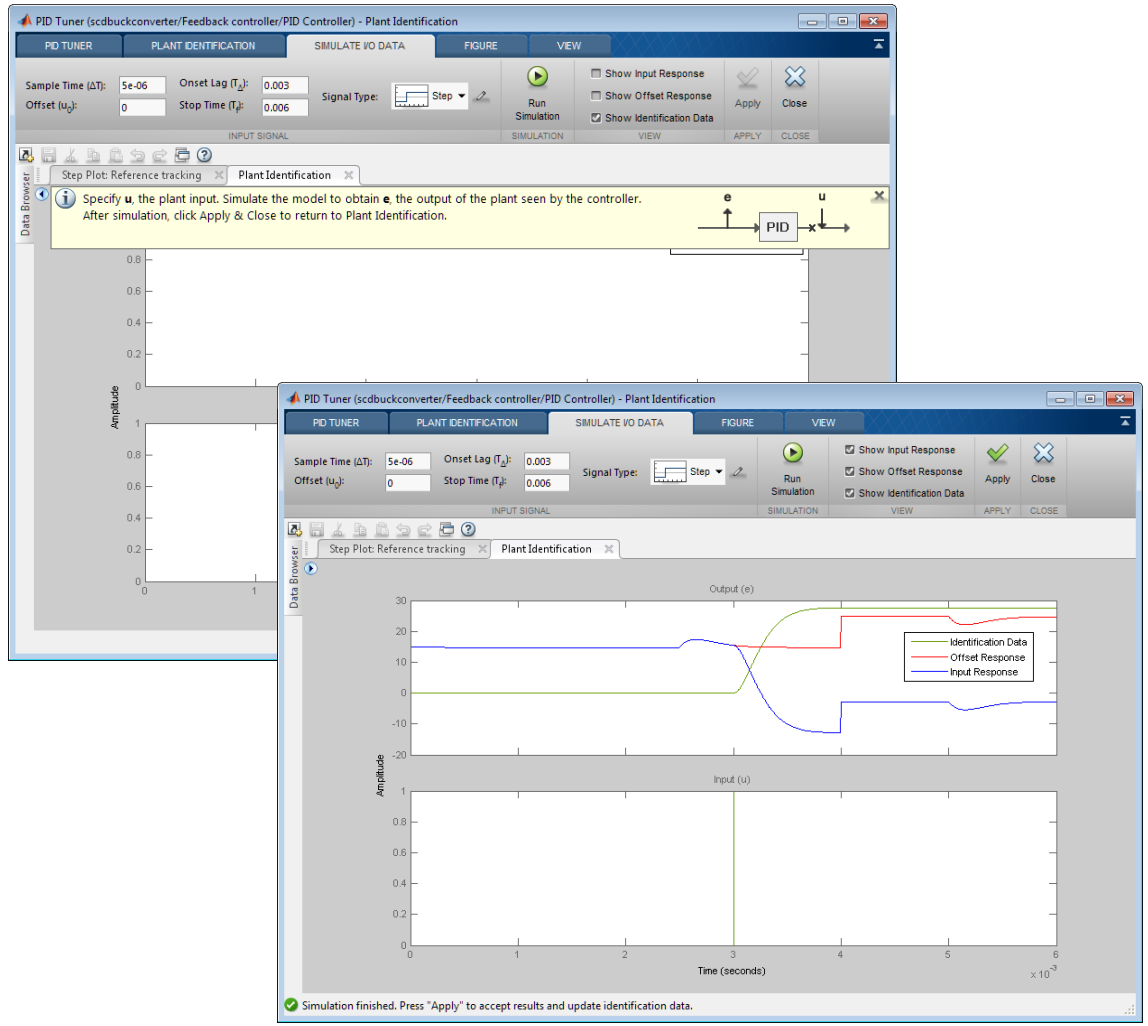
What?

- Compute plant transfer function from **simulation** input-output data when exact linearization fails

How?

- Inject a step or an impulse at the plant input

- Interactively or automatically fit the transfer function to simulation input-output data



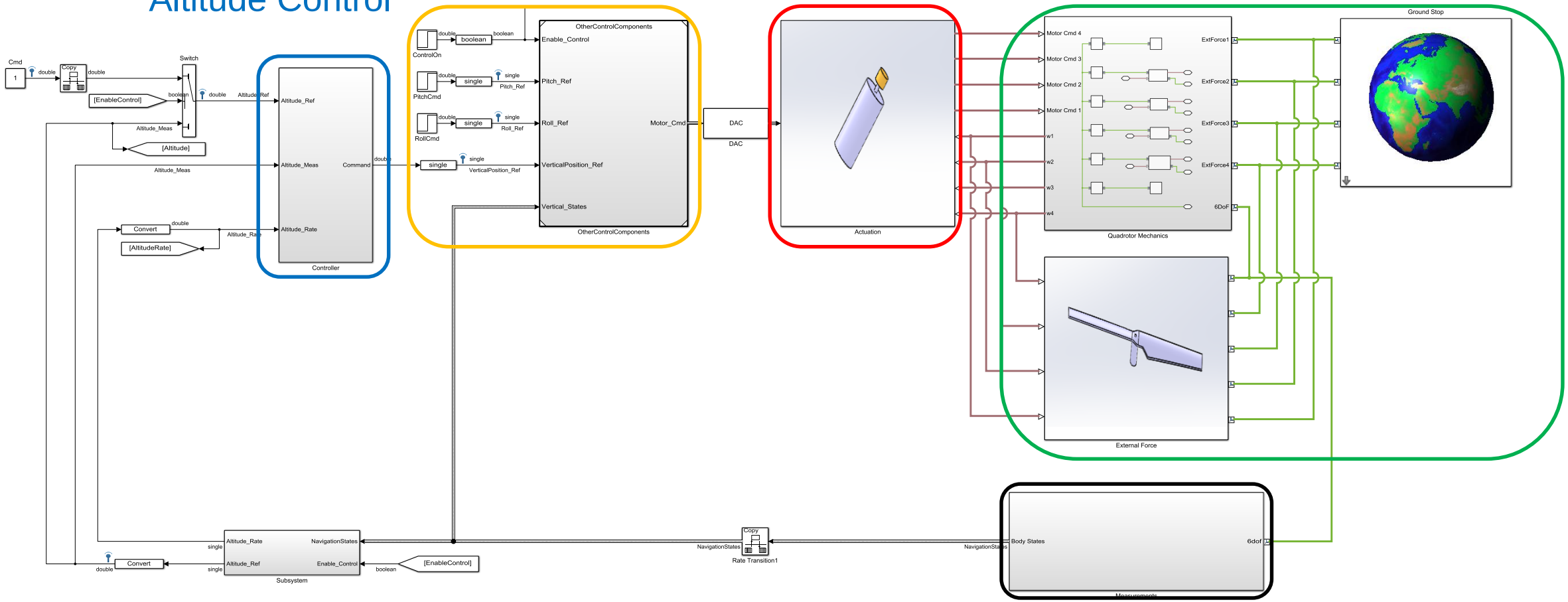
System Identification into PID Tuner

Other Control

Electrical Actuation

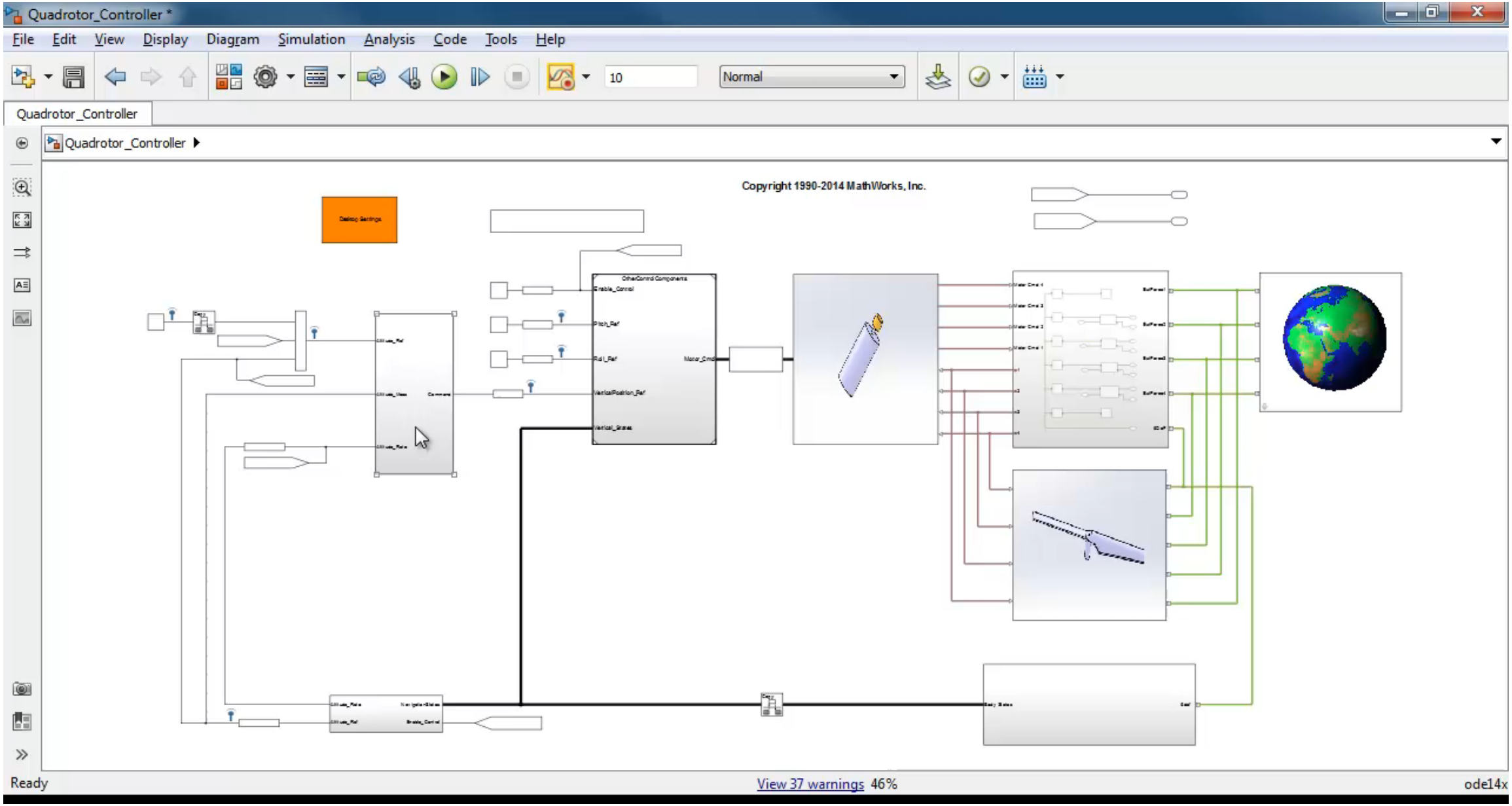
Mechanical System

Altitude Control



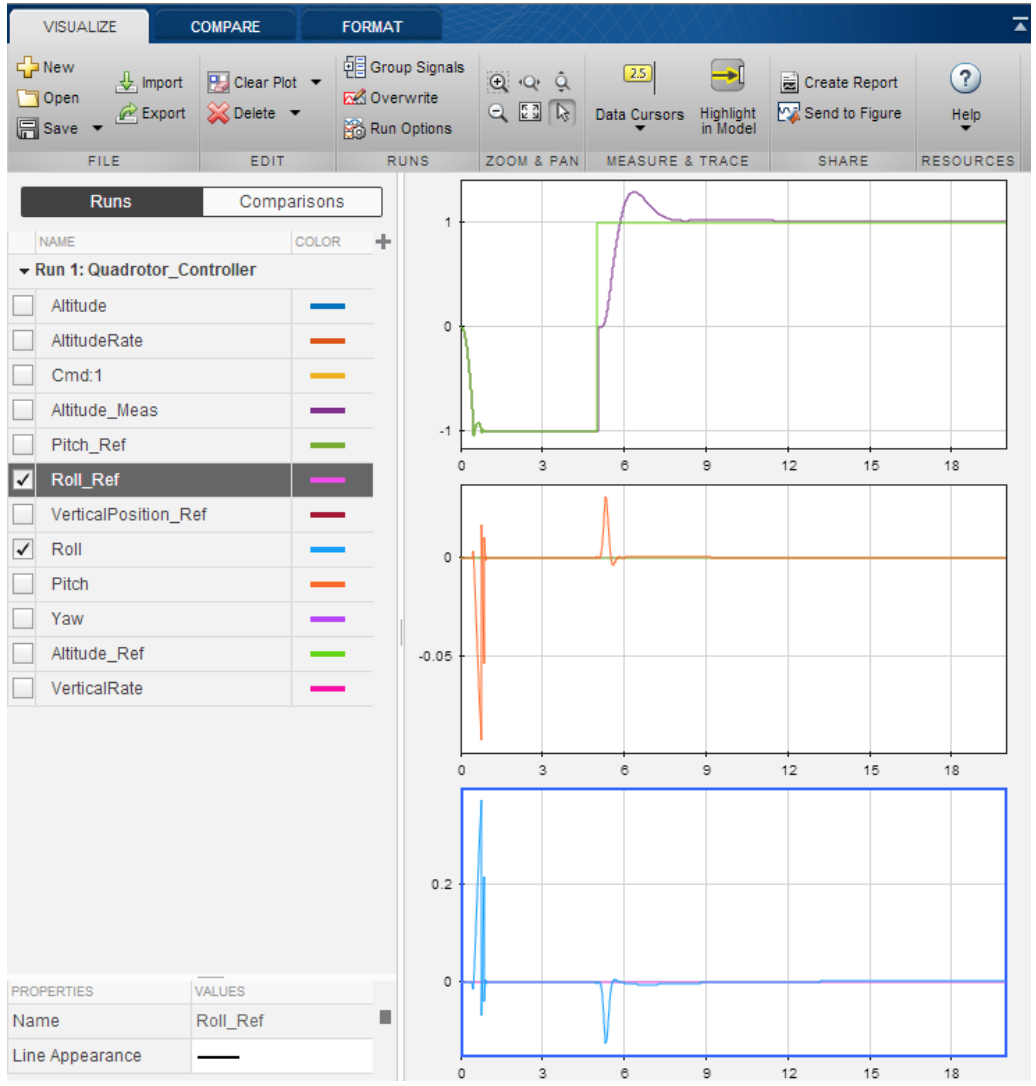
Measurement

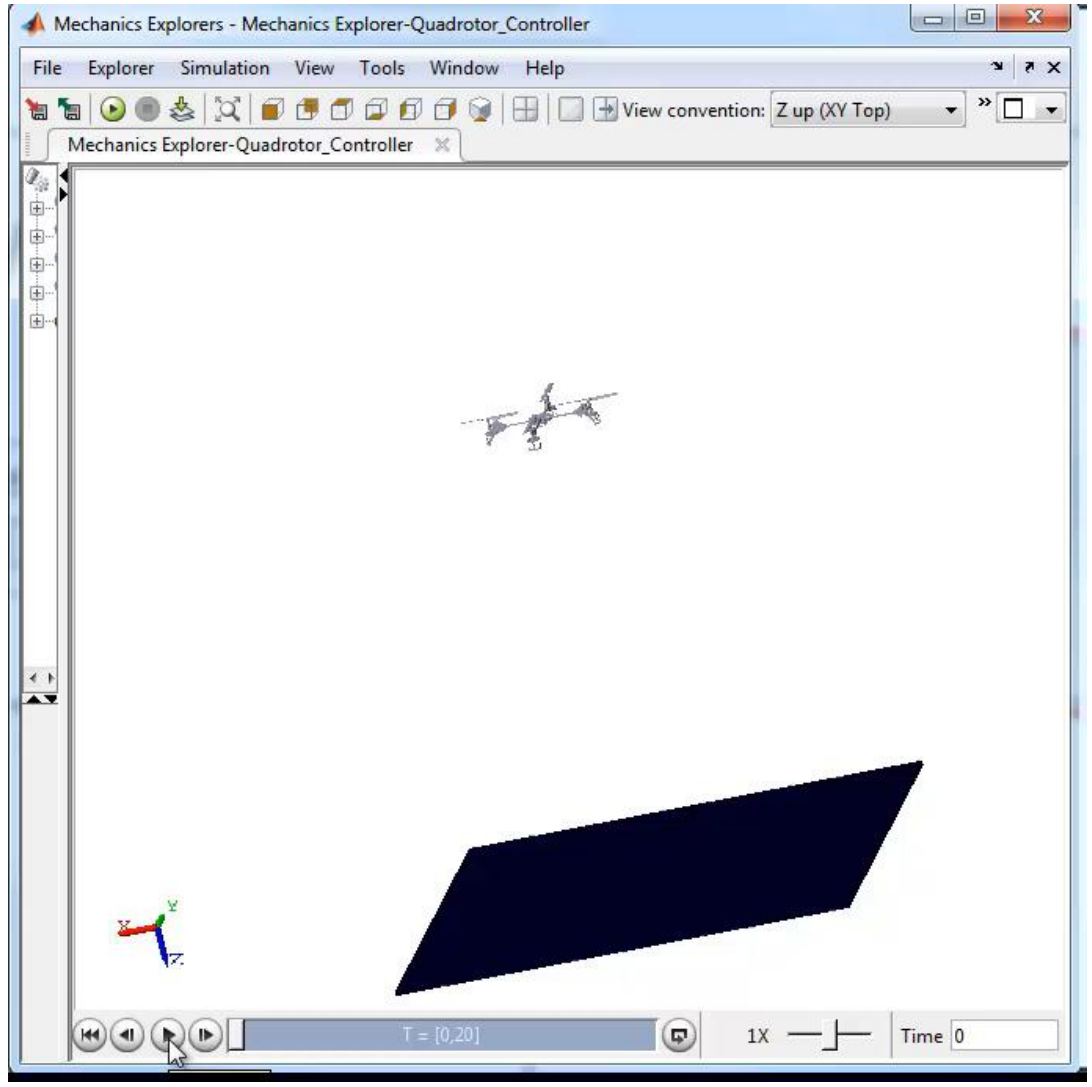
System Identification into PID Tuner



System Level Simulation

New Simulation Data Inspector in R2014b !





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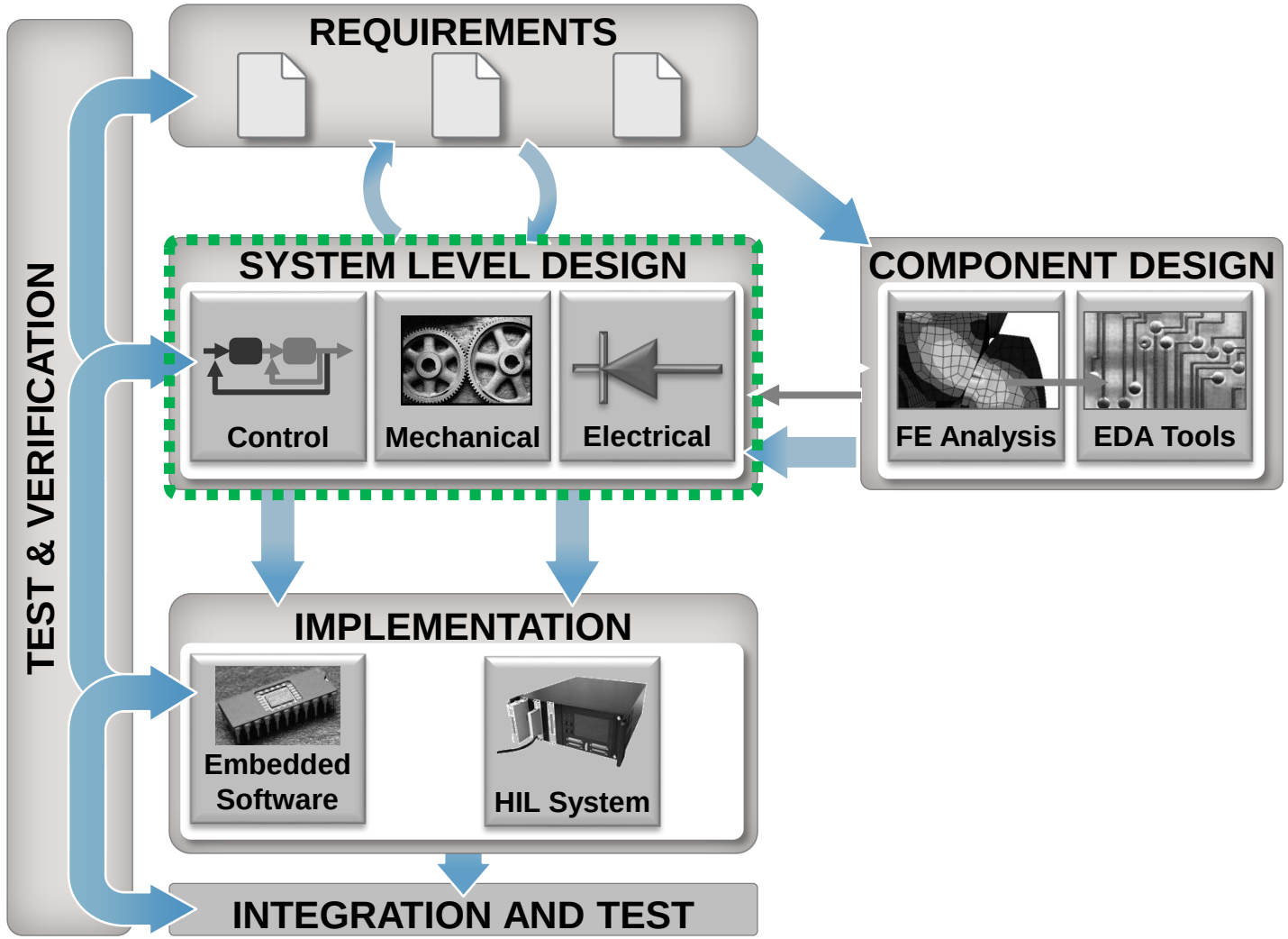
- Key takeaways

Key takeaways

Model-Based Design Process



Key takeaways

- Simulink and physical modelling tools help you understand concepts and model your physical systems
- Simulink Design Optimization and Parameter Estimation tool allow refining model parameters' using experimental data
- Advanced control tools enable faster control system design within Simulink

"…Now it's your turn, try these tools for a better simulation experience"

Questions?