MATLAB EXPO 2016
KOREA

4월 28일 (목)

등록 하기 matlabexpo.co.kr

Physical Modeling of Multi-Domain System

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Senior Application Engineer
MathWorks Korea

Agenda

- What is Physical Modeling? Why use Simscape?
- Landing Gear Modeling
  - Landing Gear Mechanism Modeling
  - Refine requirement and optimize mechanical design
  - Analyze hydraulic actuator designs
- Test system in various situations

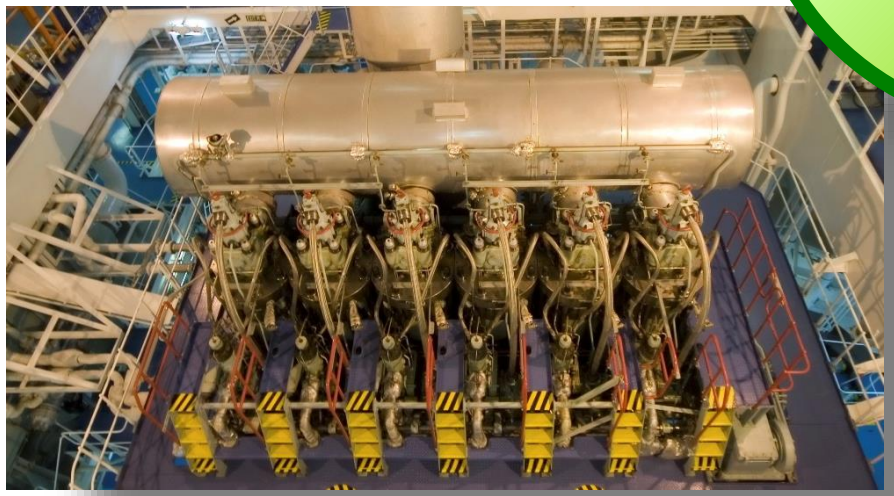


physical modeling = **Simulation models** based on **physical** connections

system is

too big

Power In Power Out



conditions are

too difficult

only get

one chance

Courtesy NASA/JPL-Caltech

too big

USER STORY

ABB Optimizes Ship Energy Flows

too difficult

USER STORY

DCNS Simulates Handling System

one chance

USER STORY

Lockheed Martin Develops MRO

Power Systems

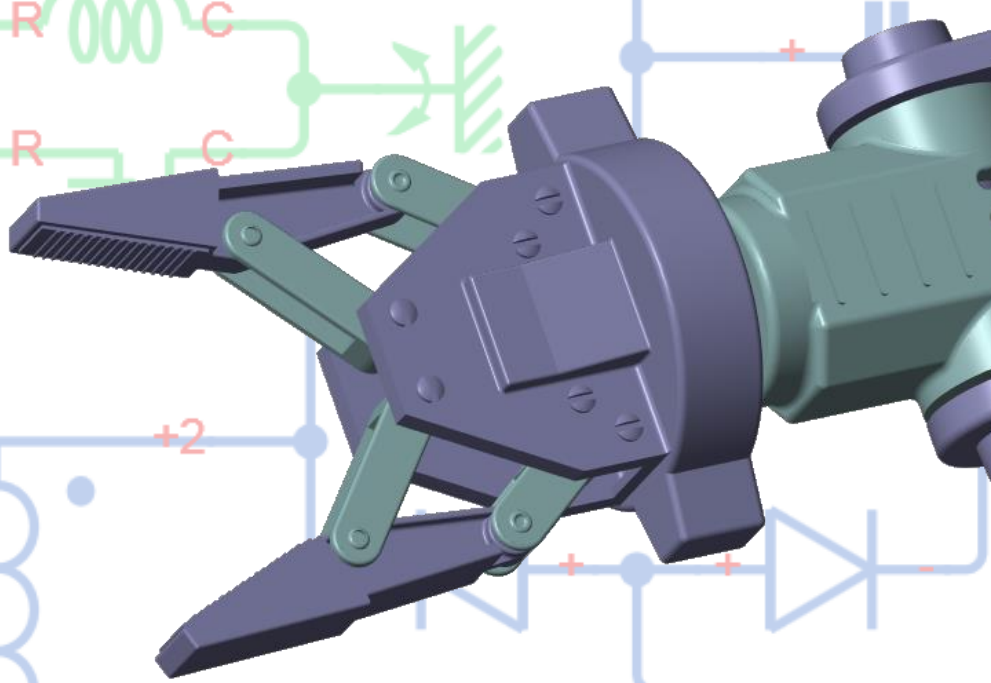
Electronics

Fluids

Multibody

Driveline

Simscape



Why use Simscape?

Makes modeling easy

Simscape handles equations automatically

Simulink Simscape

$$F_{Spring} = k_{Spring} * (z_{Car})$$

$$F_{Shock} = b_{Shock} * \left(\frac{dz_{Car}}{dt}\right)$$

$$\frac{d^2 z_{Car}}{dt^2} = \frac{-F_{Spring} - F_{Shock}}{m_{Car}}$$

Simscape handles equations automatically

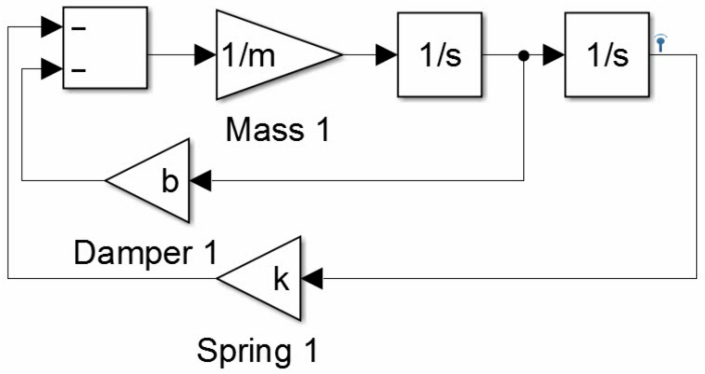
$$F_{Spring} = k_{Spring} * (z_{Car} - z_{Whl})$$

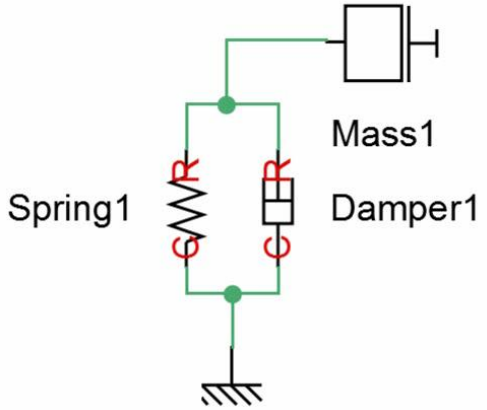
$$F_{Shock} = b_{Shock} * (\frac{dz_{Car}}{dt} - \frac{dz_{Whl}}{dt})$$

$$\frac{d^2 z_{Car}}{dt^2} = \frac{-F_{Spring} - F_{Shock}}{m_{Car}}$$

$$F_{Tire} = k_{Tire} * (z_{Whl}) + b_{Tire} * (\frac{dz_{Car}}{dt})$$

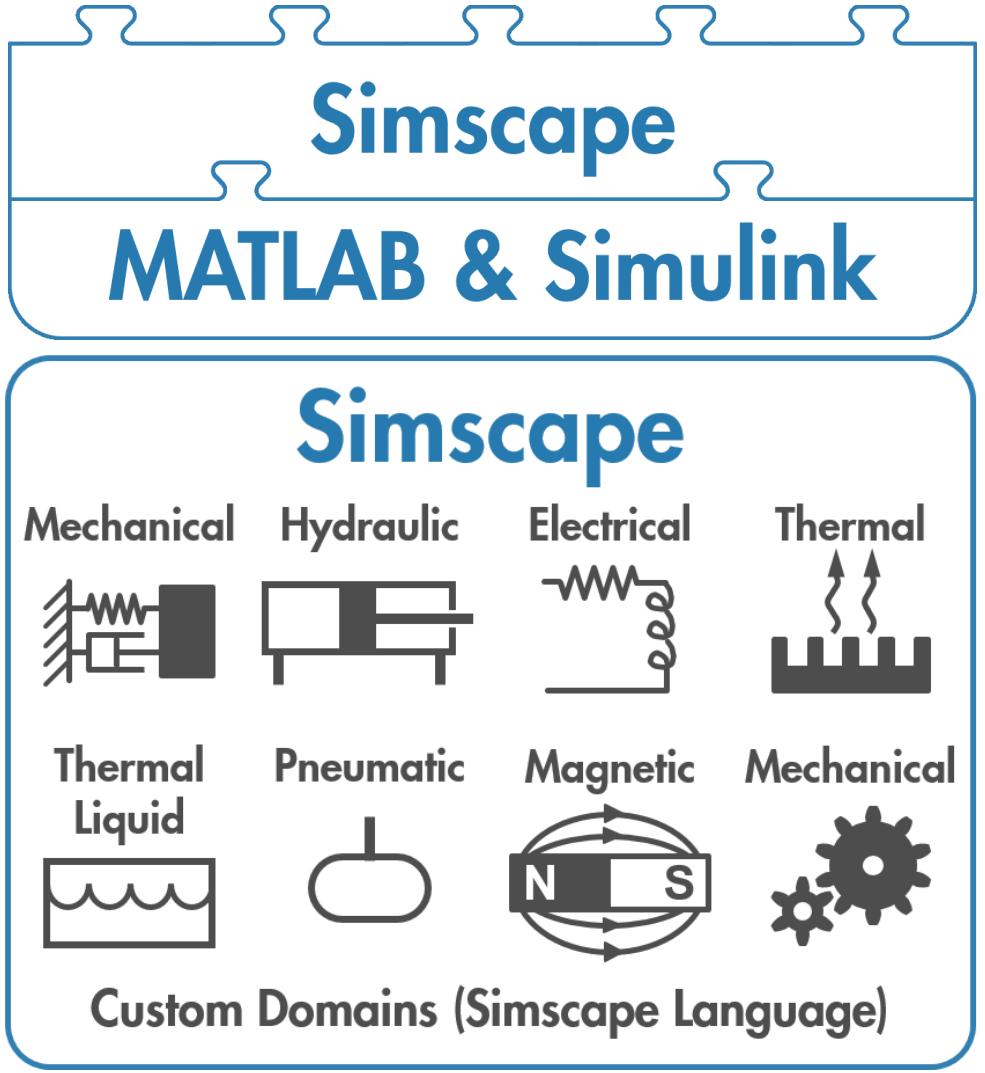
$$\frac{d^2 z_{Whl}}{dt^2} = \frac{F_{Spring} + F_{Shock} - F_{Tire}}{m_{Car}}$$





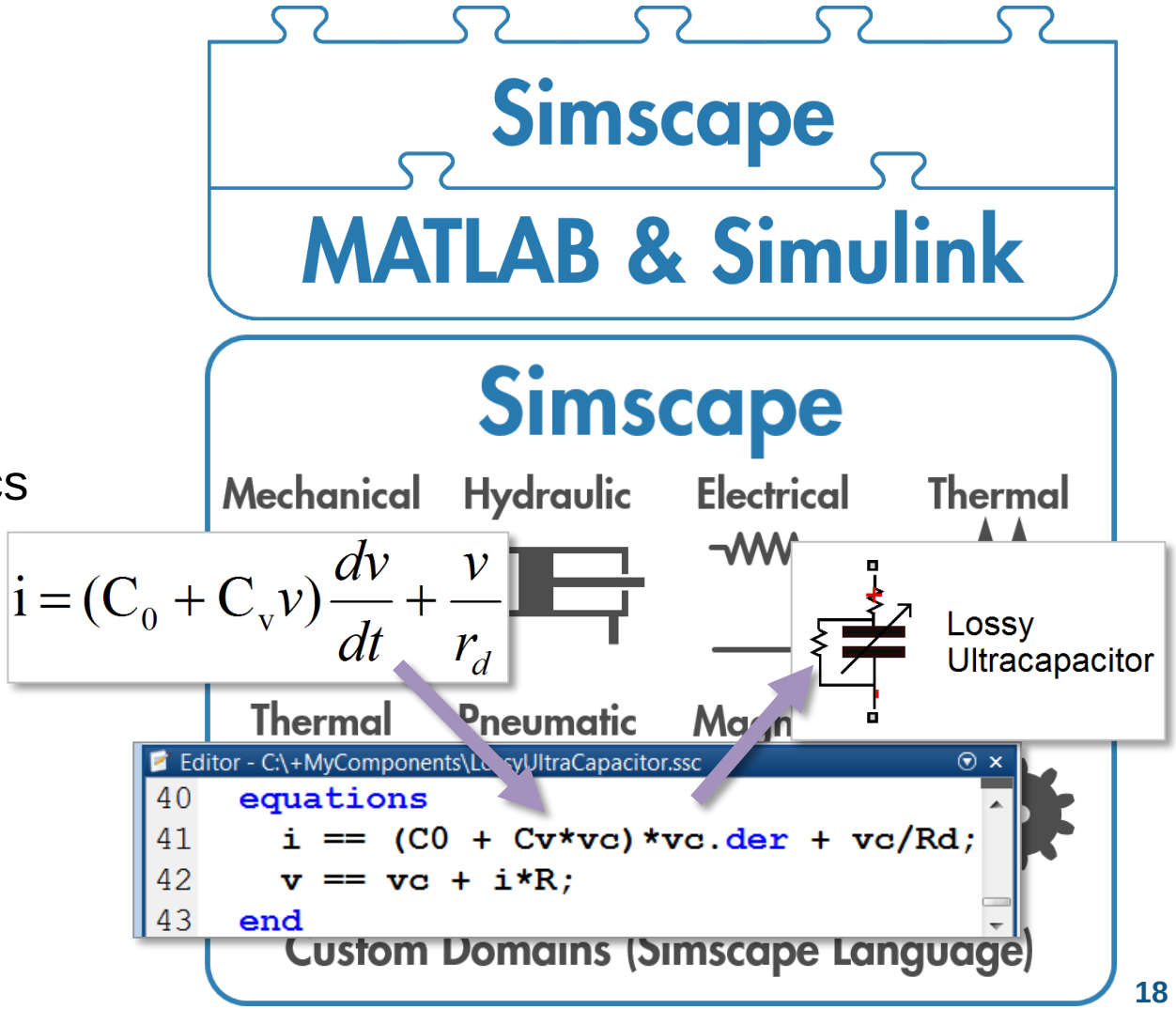
Simscape Summary

- Enables physical modeling (acausal) of multi-domain physical systems
- Simscape platform
  - Foundation libraries in 8 domains



Simscape Summary

- Enables physical modeling (acausal) of multi-domain physical systems
- Simscape platform
  - Foundation libraries in 8 domains
  - Language for defining custom blocks
    - Extension of MATLAB
  - Simulation engine and custom diagnostics



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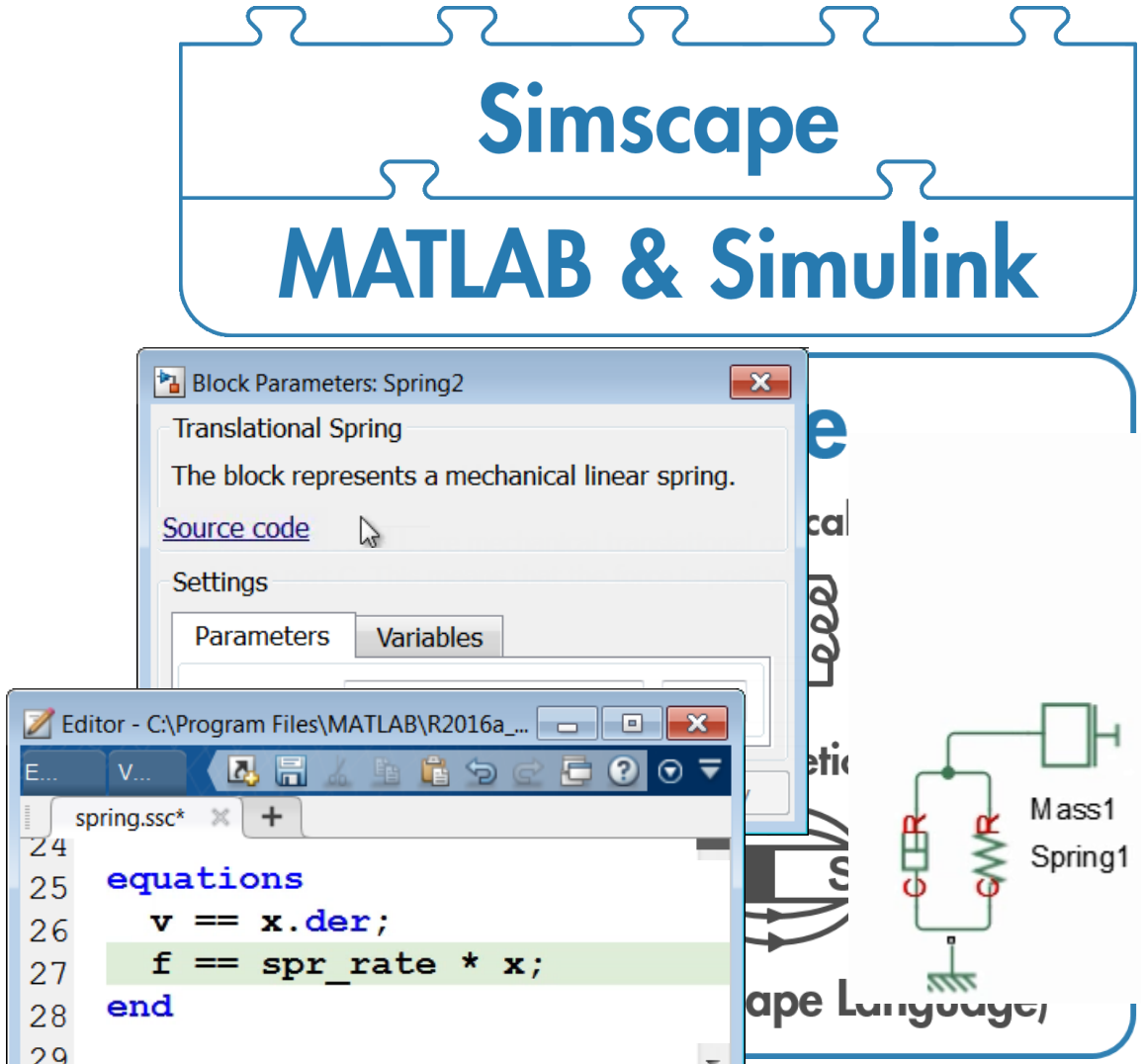
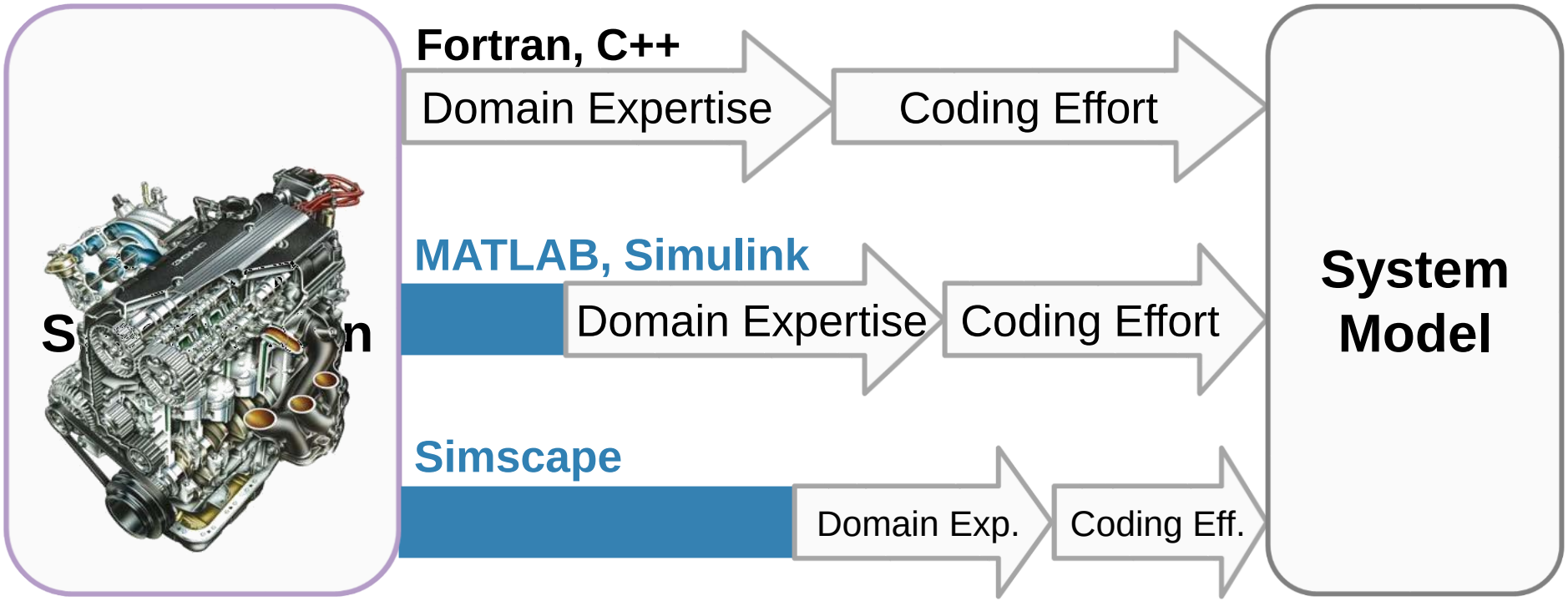
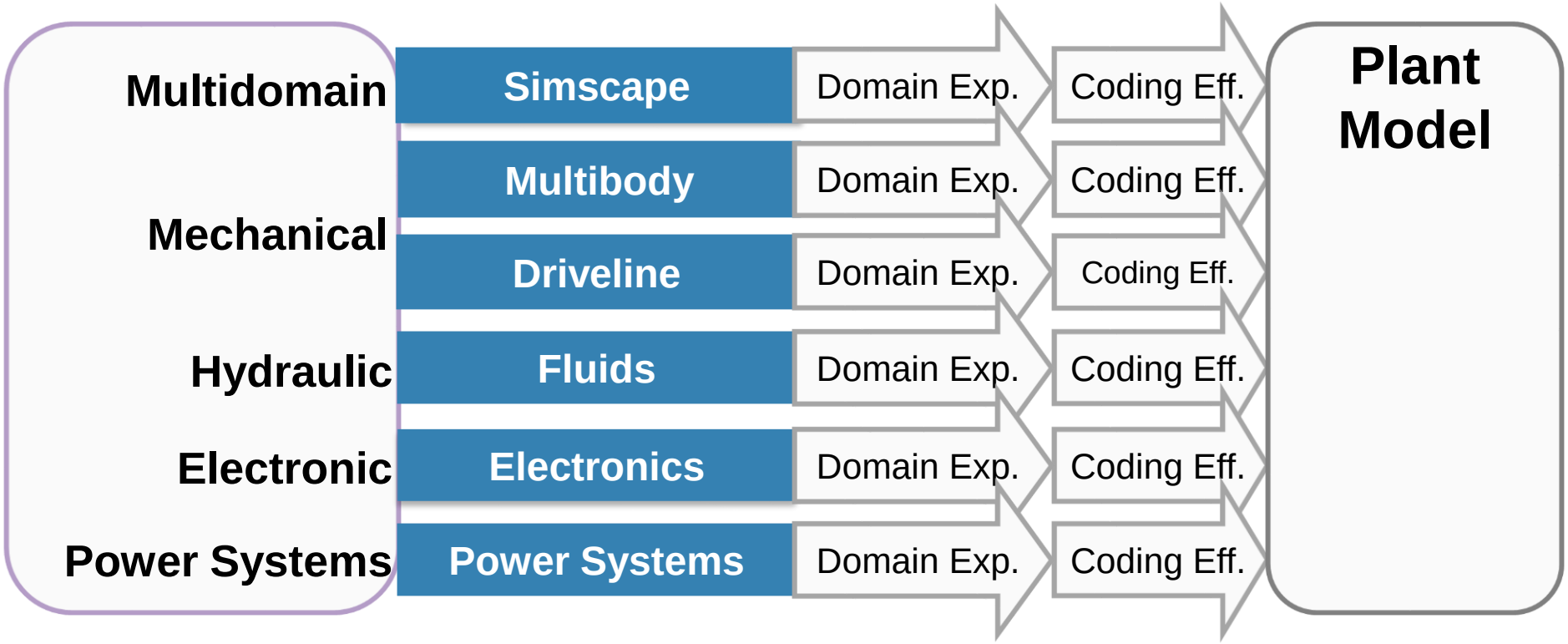


Create Reusable System-Level Models



Models are easier to understand, reuse, and share with others

Optimize Your Entire Engineering System

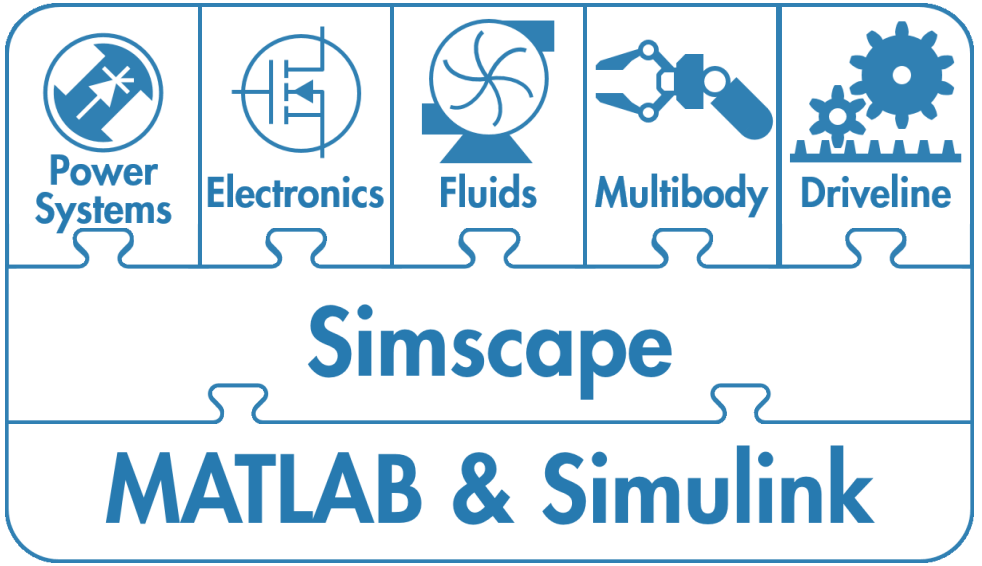


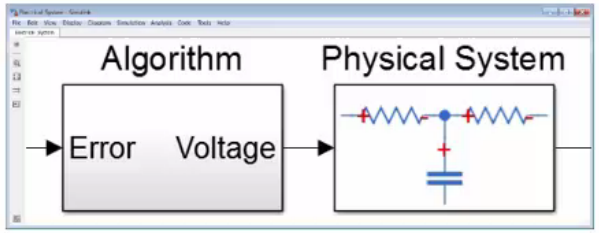
Simulate the entire system in a single environment

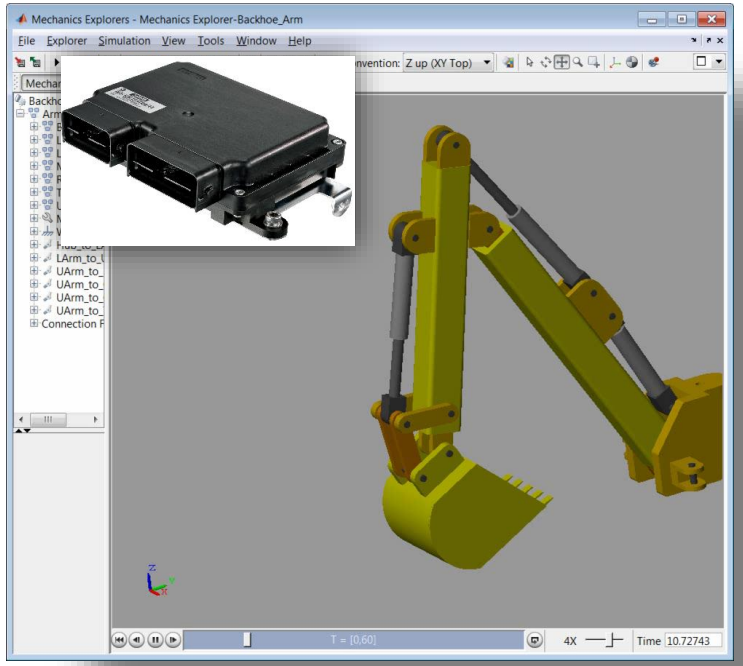
- Does not require learning multiple tools or co-simulation

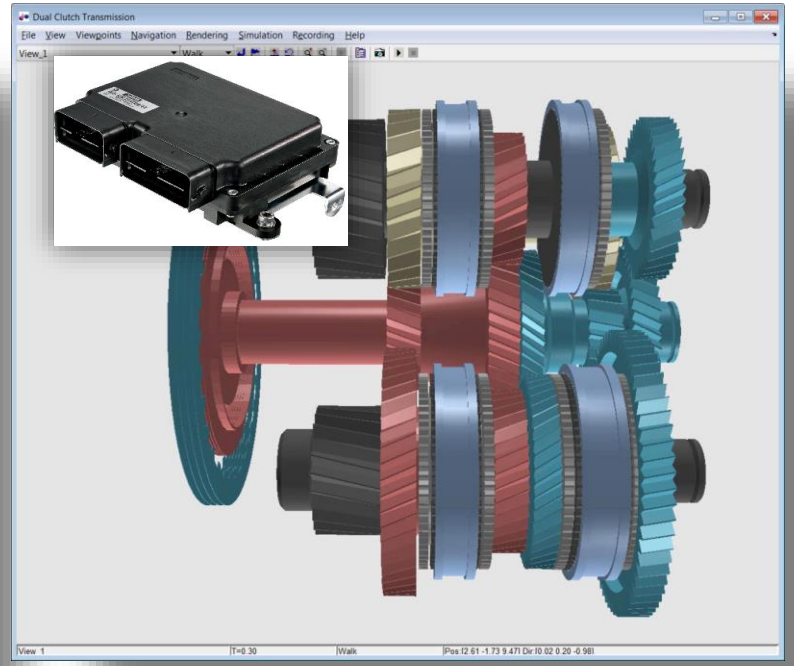
Simscape Summary

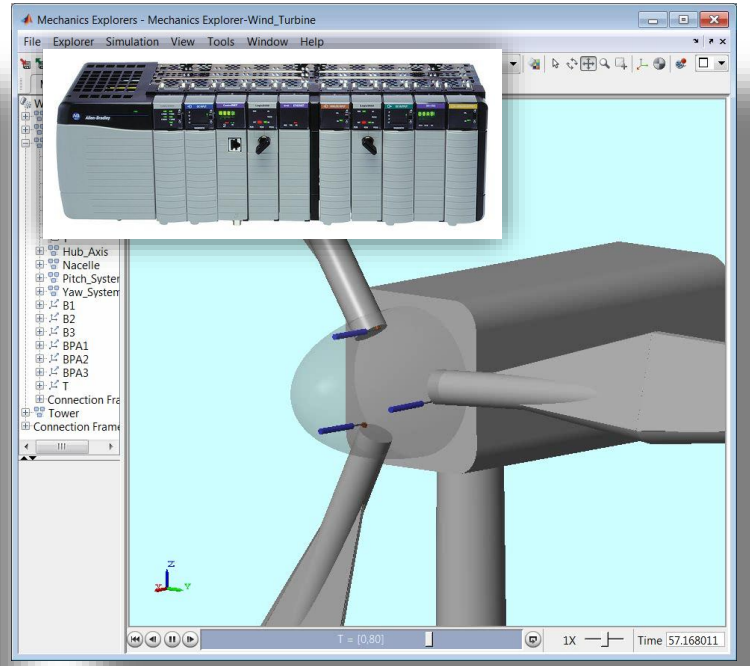
- Enables physical modeling (acausal) of multi-domain physical systems
- Simscape platform
  - Foundation libraries in 8 domains
  - Language for defining custom blocks
    - Extension of MATLAB
  - Simulation engine and custom diagnostics
- Simscape libraries
  - Extend foundation domains with components, effects, parameterizations
  - Models can be converted to C code











To develop controller…

Less clicking, More MATLAB&ting

Simscape + Simulink

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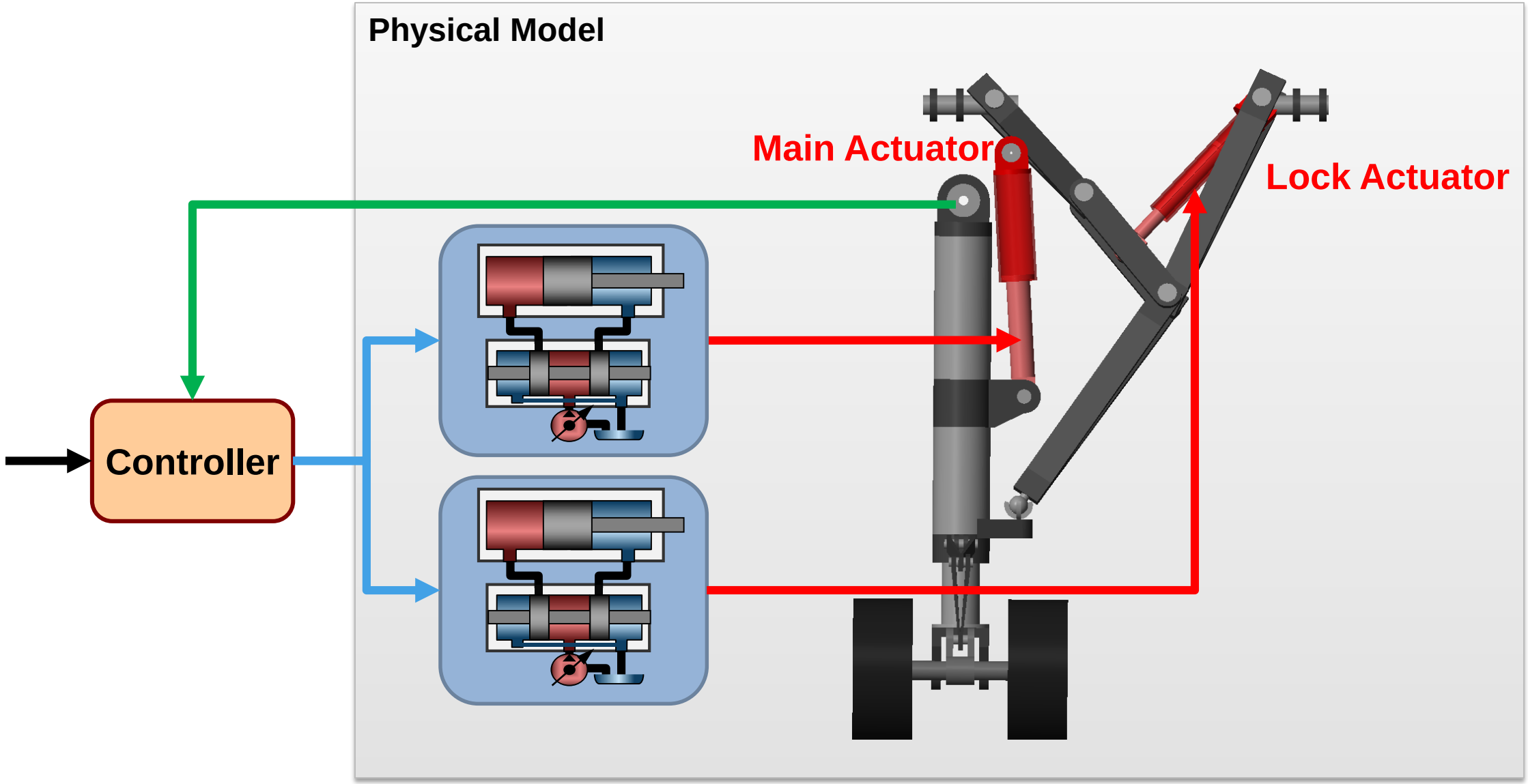
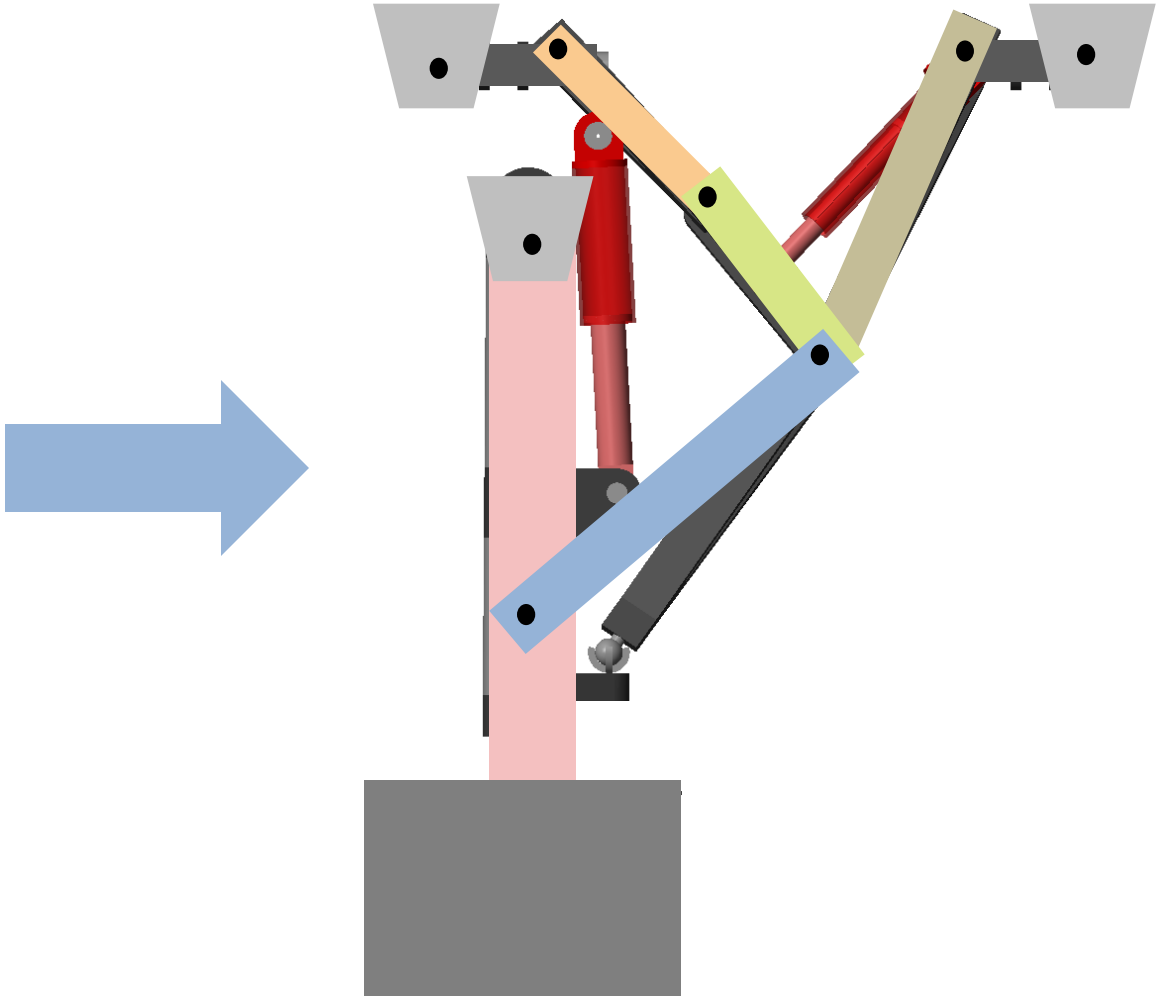
Landing Gear System



Landing Gear Mechanism Modeling

So, where do we really start?

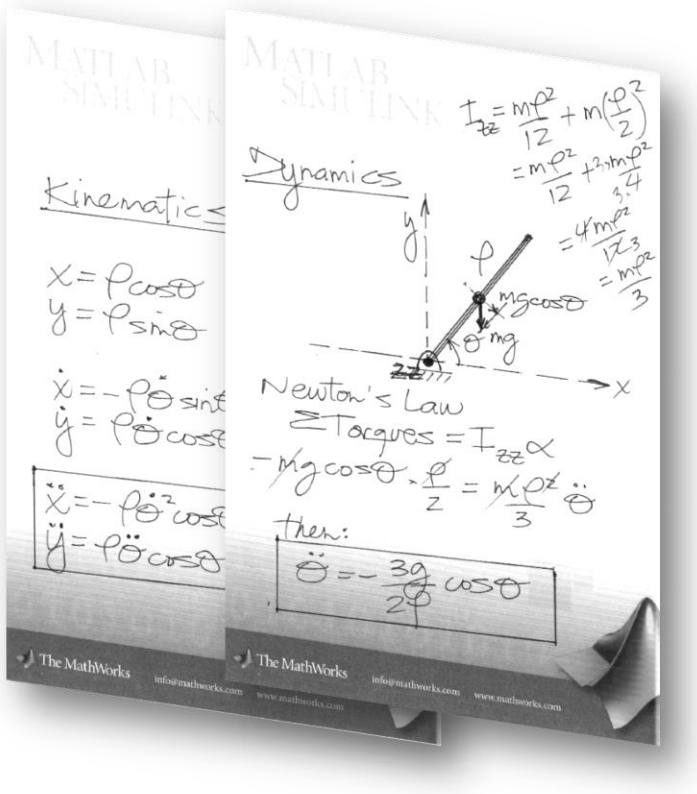


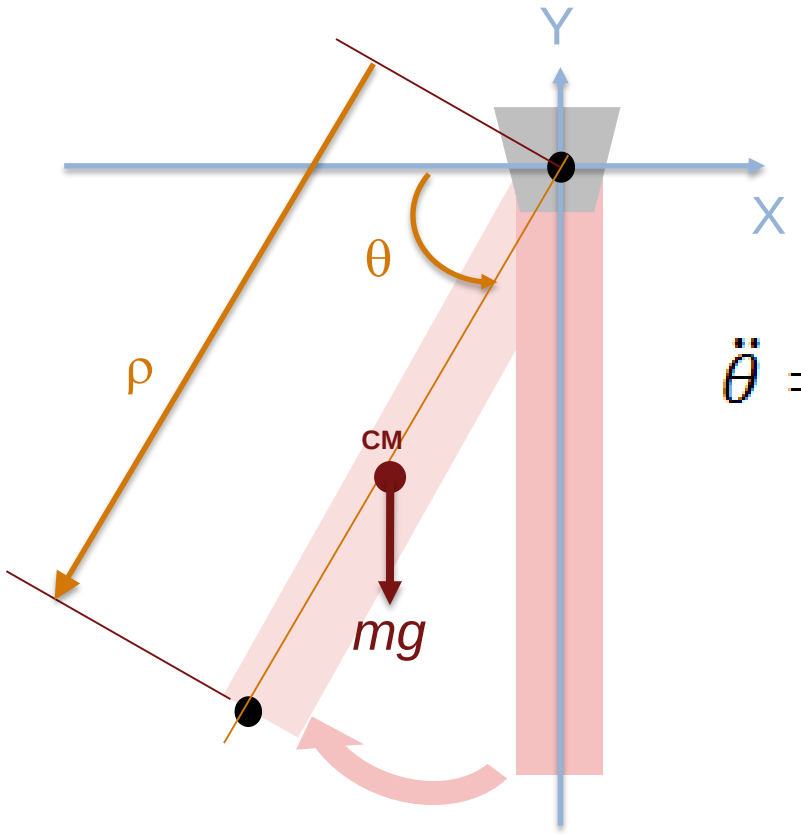
If possible, break down a big problem into “smaller”(i.e. more manageable) problems

*** Use a “divide and conquer” approach ***

Landing Gear Mechanism Modeling

So, where do we really start?



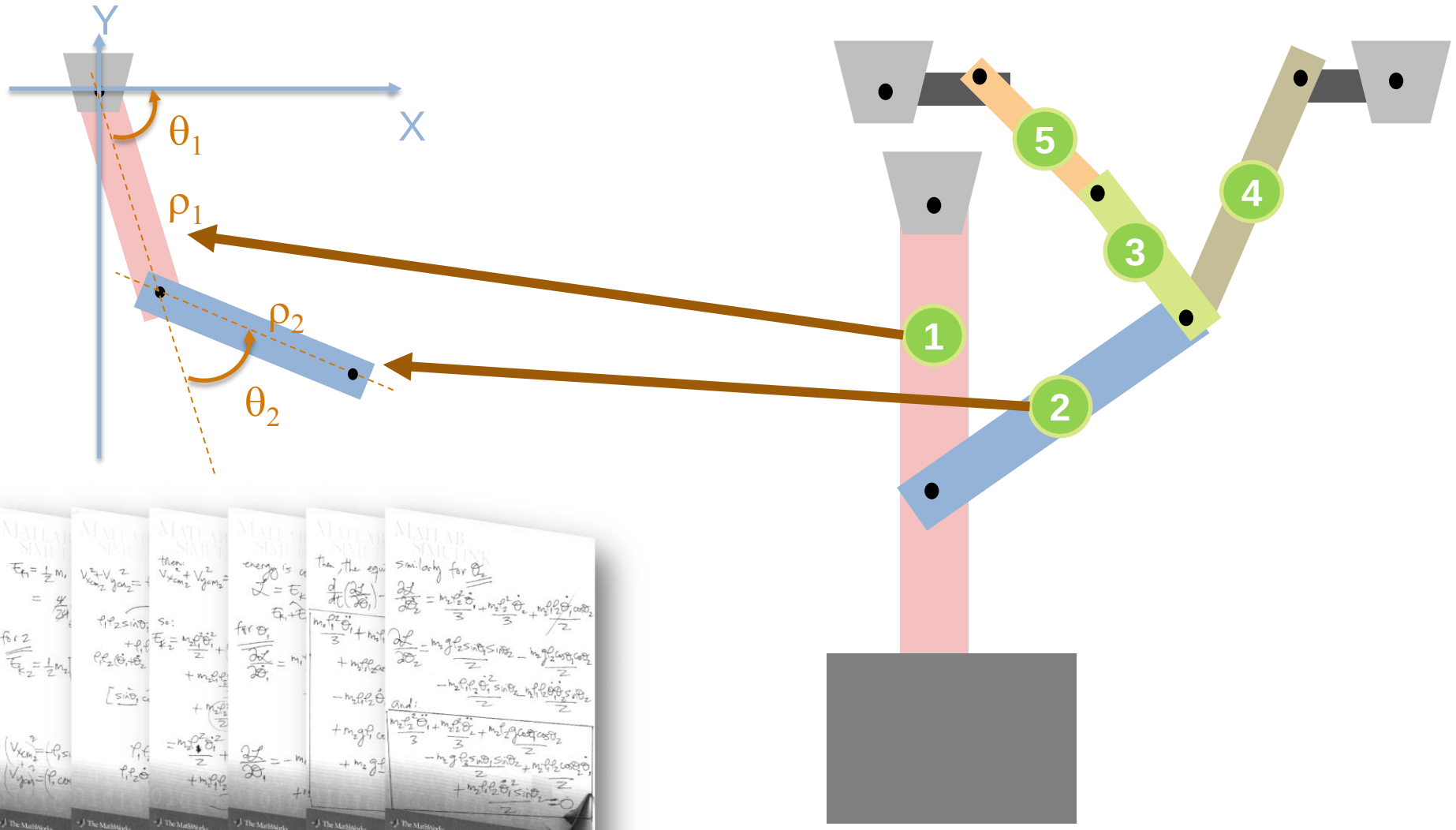


$$\ddot{\theta} = -\frac{3b}{m\rho^2}\dot{\theta} - \frac{3g}{2\rho}cos\theta$$

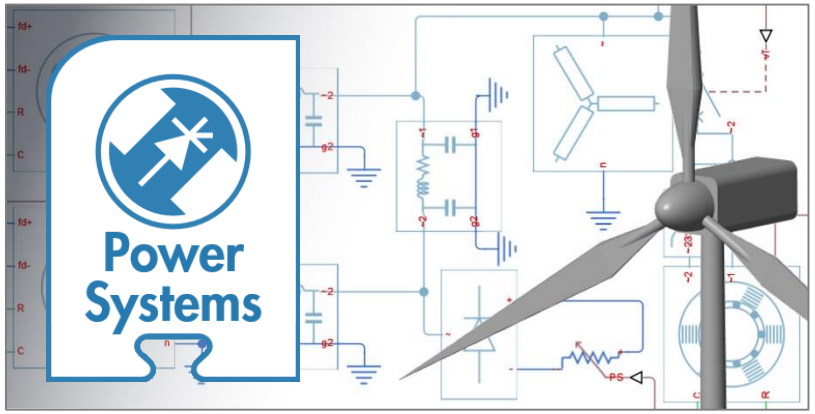
Understand the underlying mathematics/physics of the problem

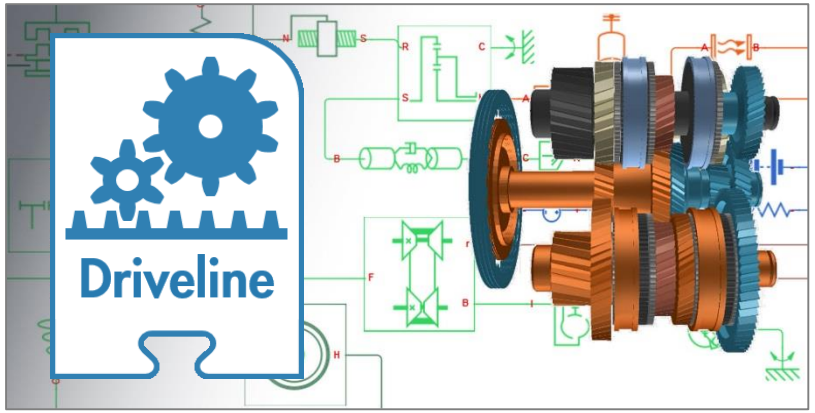
Landing Gear Mechanism Modeling

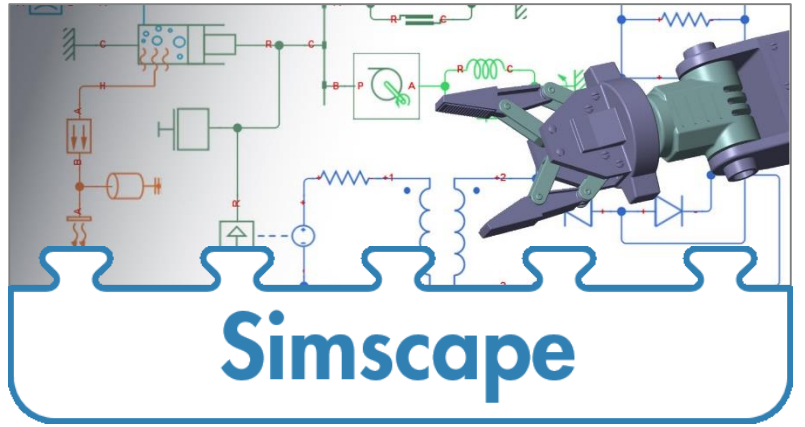
We need to “extend” the approach

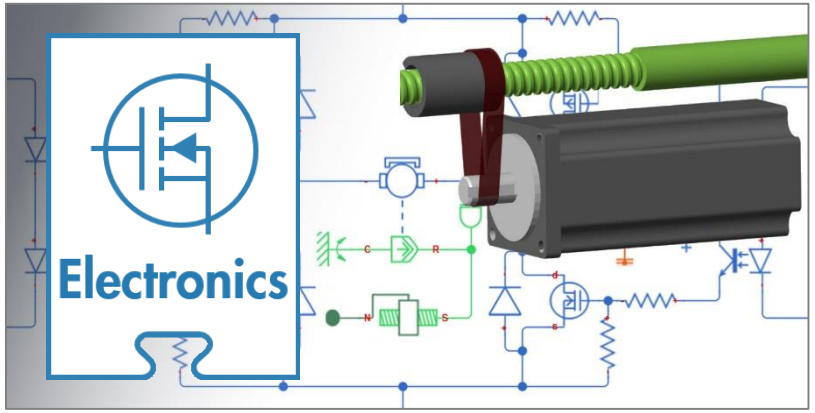


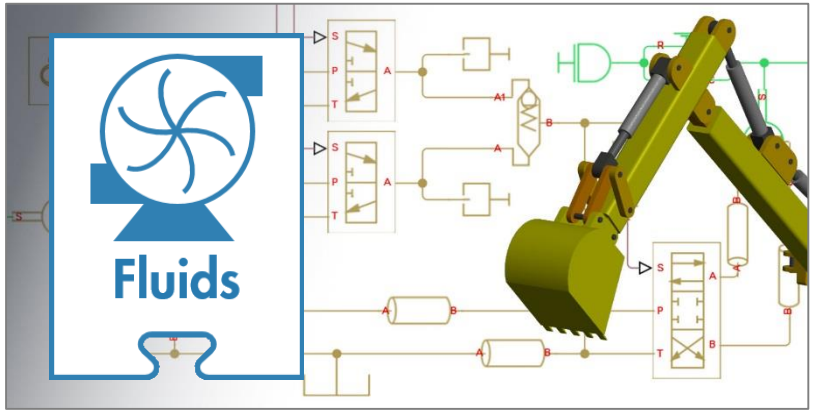
Simscape Products

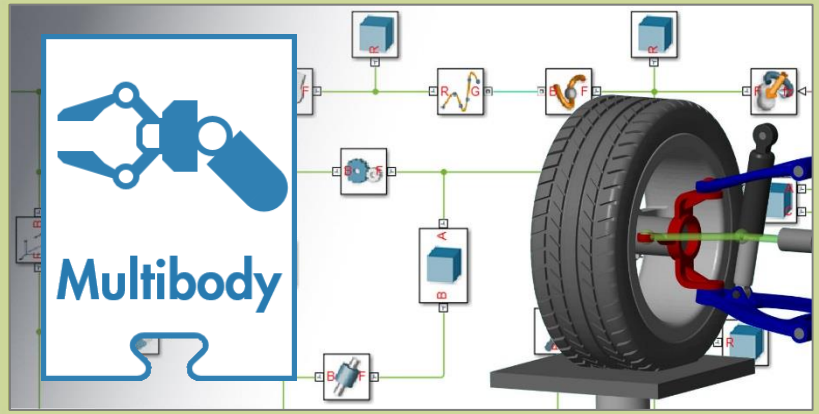






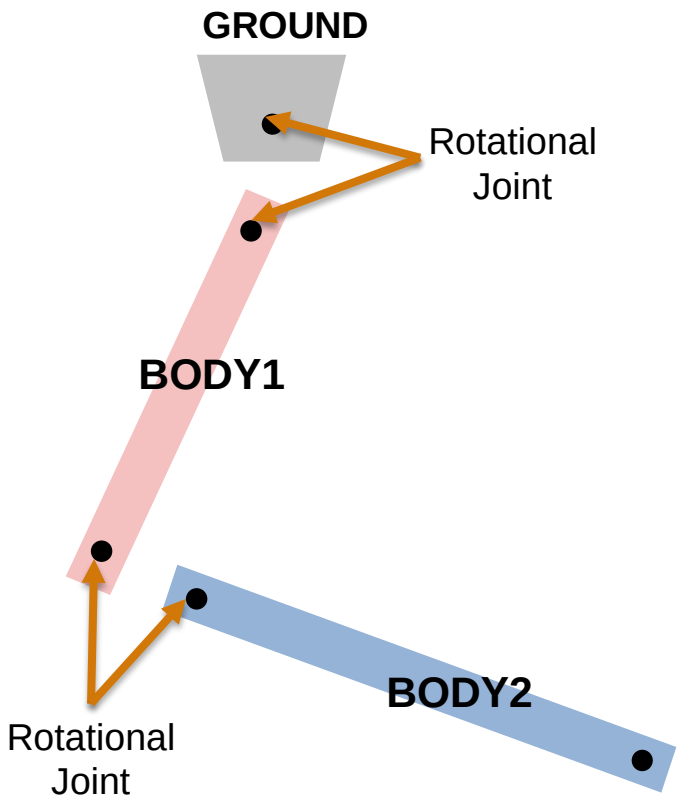


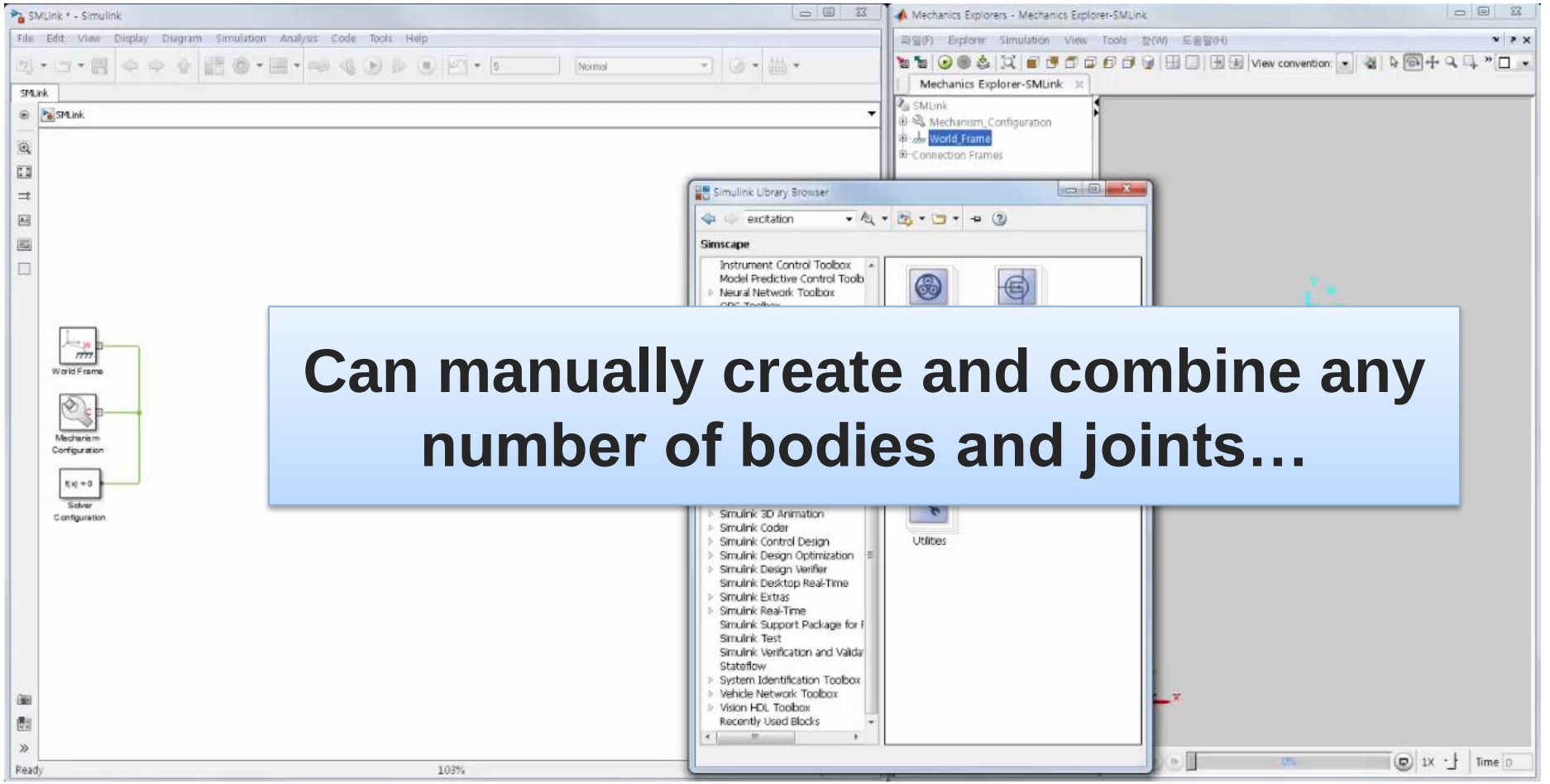




Landing Gear Mechanism Modeling

Simscape Multibody to model the dynamics of 3D mechanisms

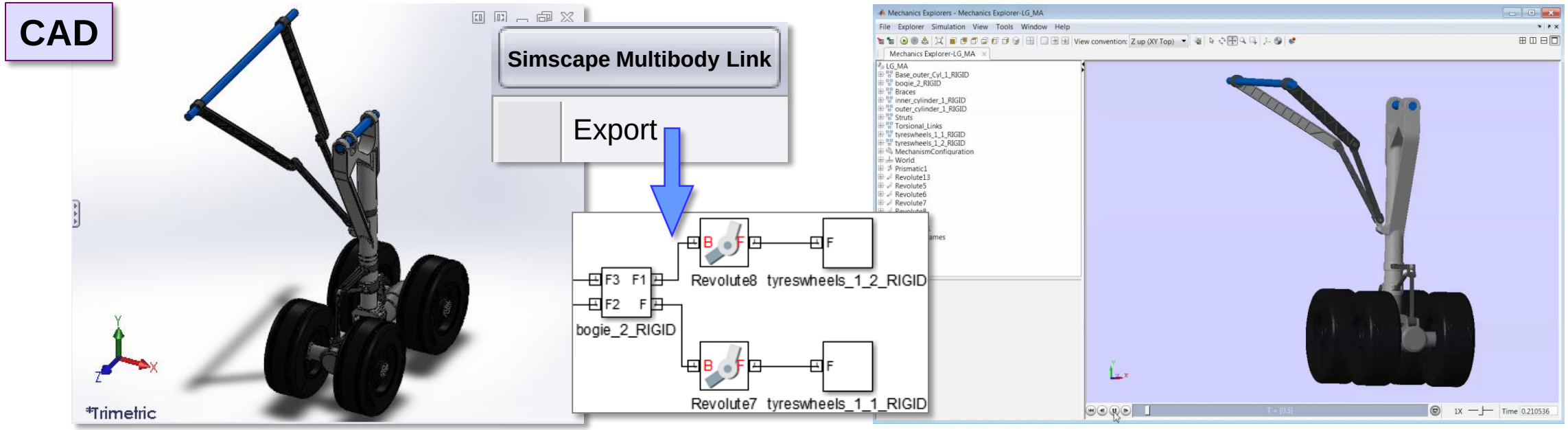




Landing Gear Mechanism Modeling

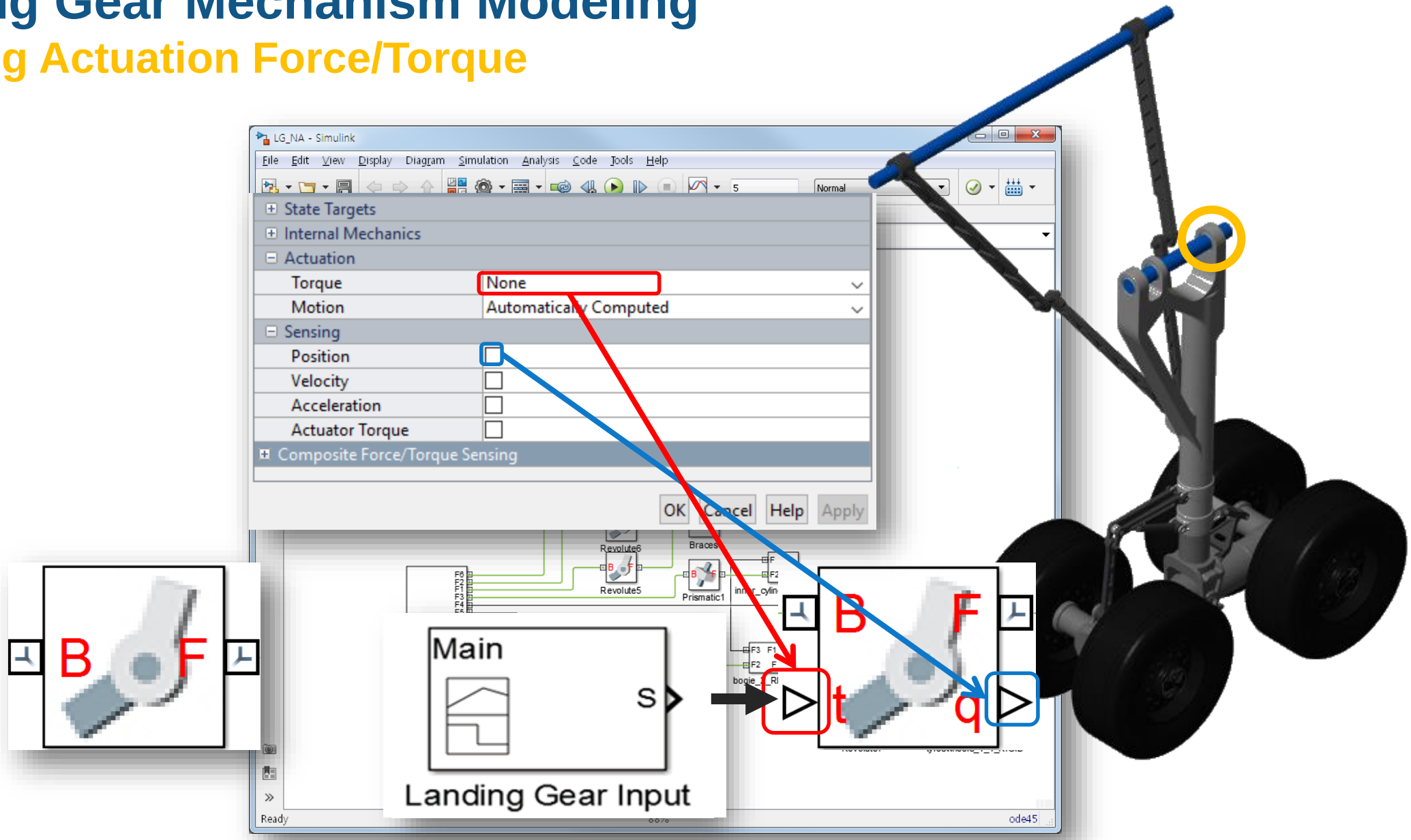
Landing Gear CAD Import using Simscape Multibody Link

- 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



Landing Gear Mechanism Modeling

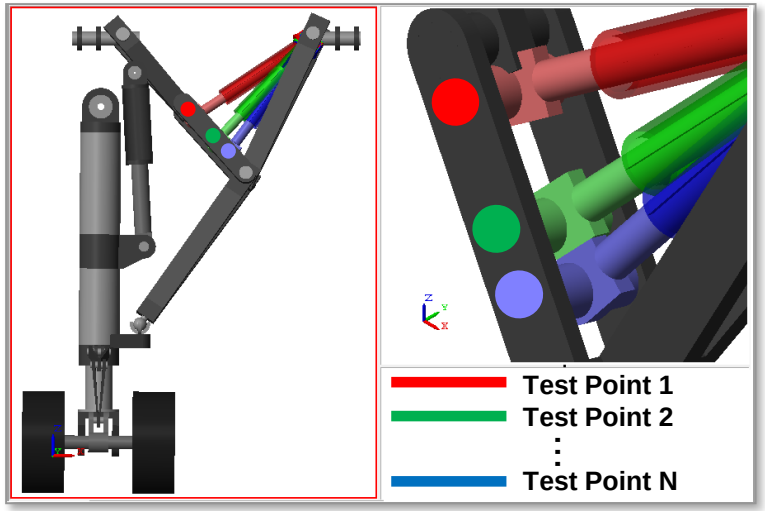
Applying Actuation Force/Torque

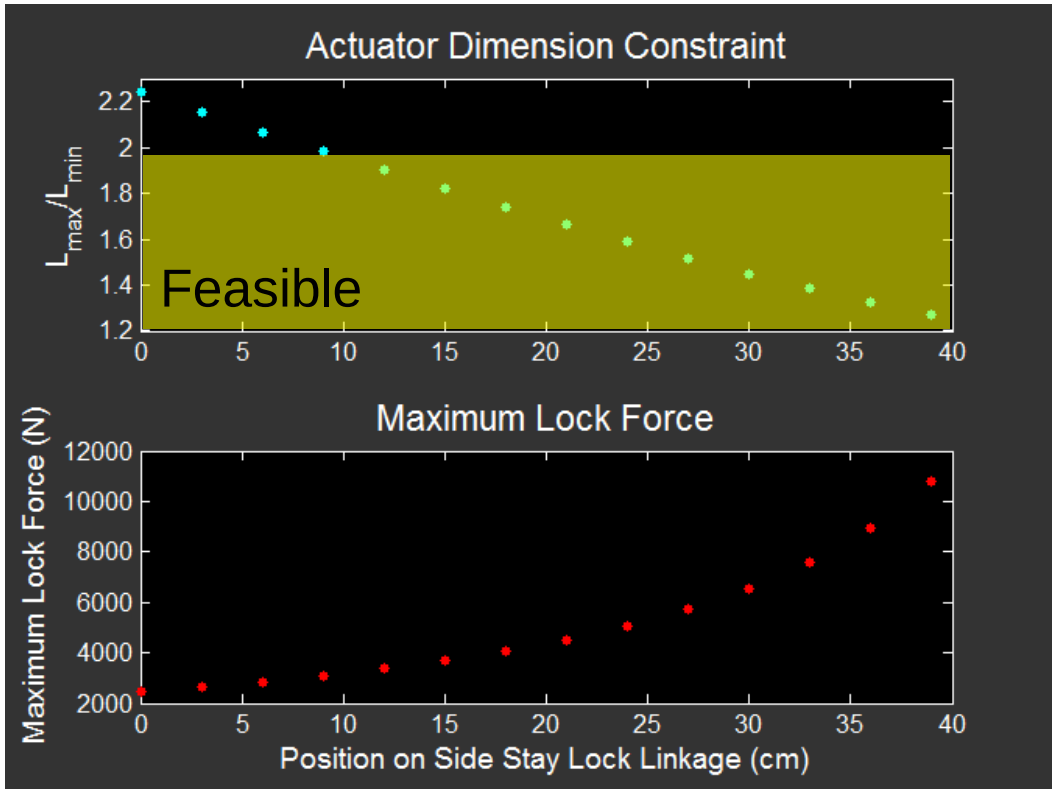


Optimizing System in Mechanics

Optimizing Lock Linkage Design

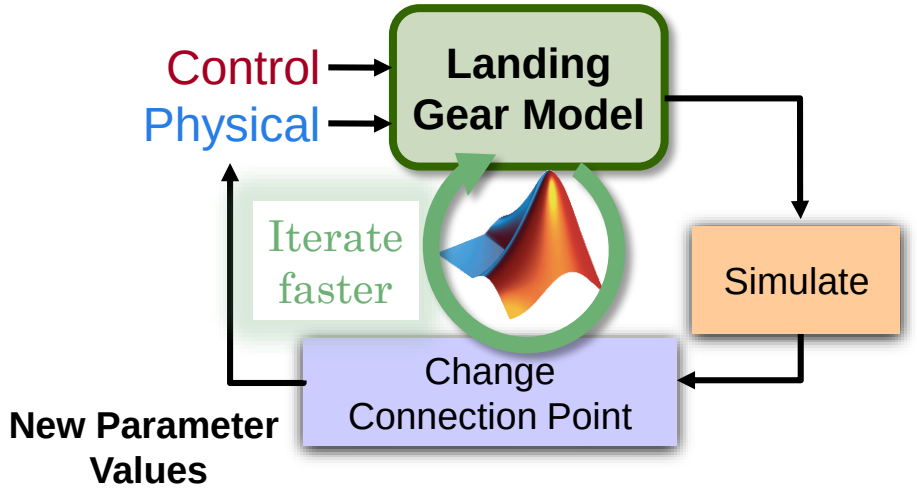
Model:





Problem: Evaluate lock linkage connection points to find optimal location that meets requirements

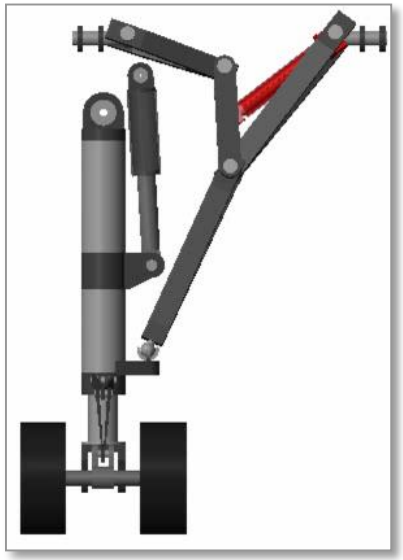
Solution: Parameterize Simscape Multibody™ model and automate tests using MATLAB®

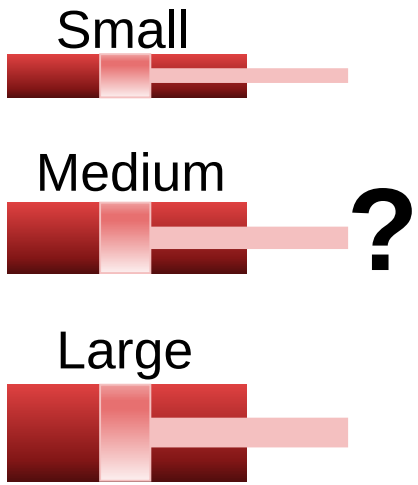


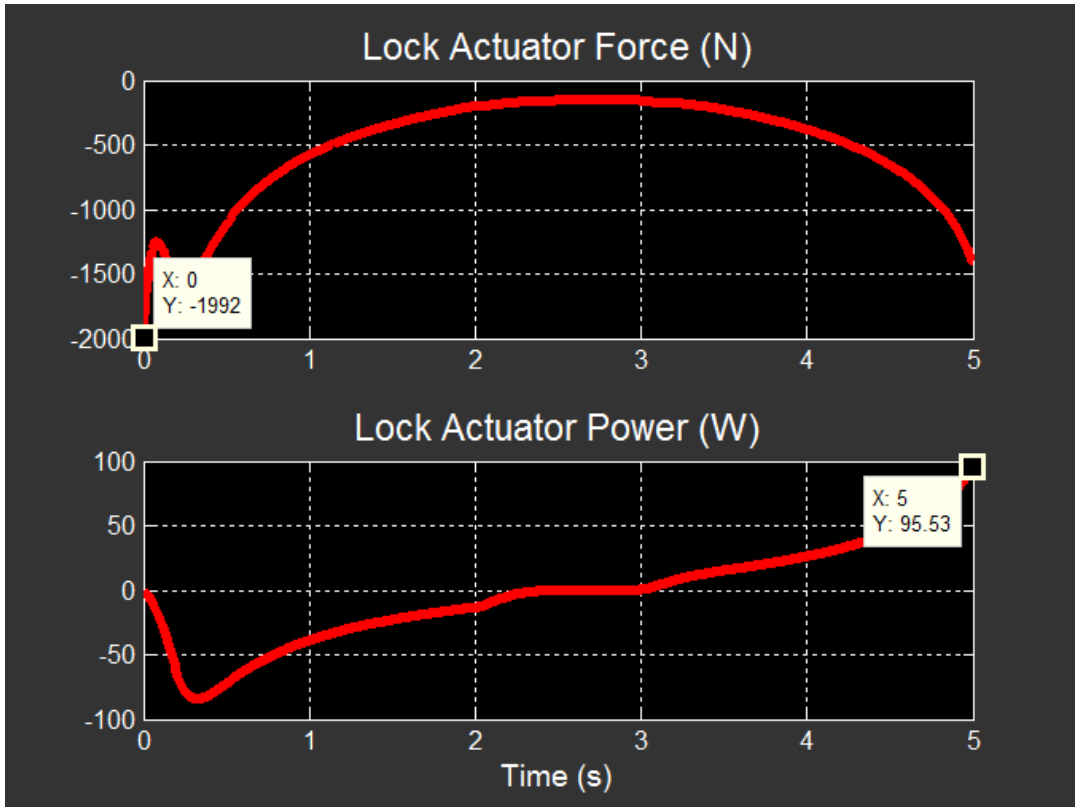
Optimizing System in Mechanics

Refine Lock Actuator Requirements

Model:

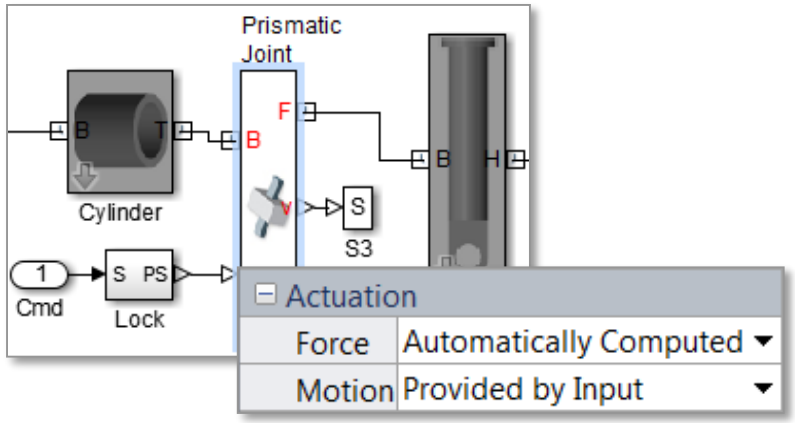






Problem: Determine size requirements for hydraulic actuator

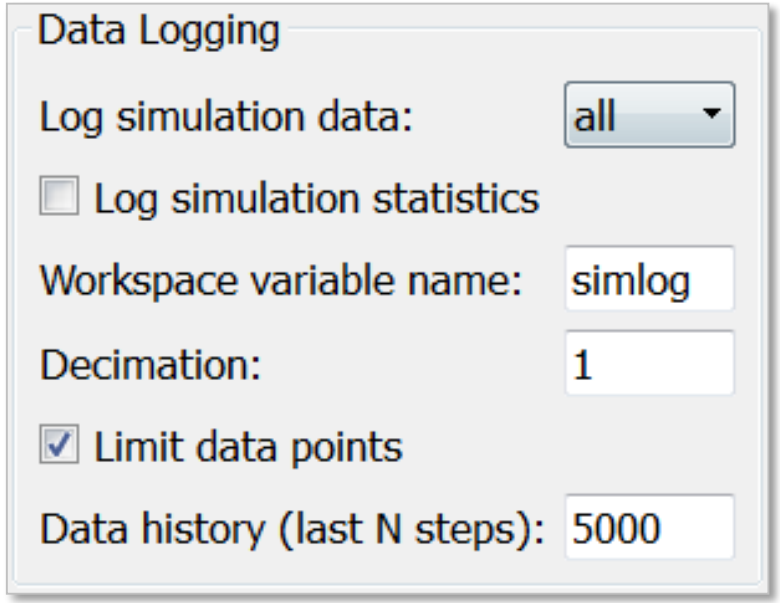
Solution: Use Simscape Multibody to determine hydraulic force and power required for prescribed motion

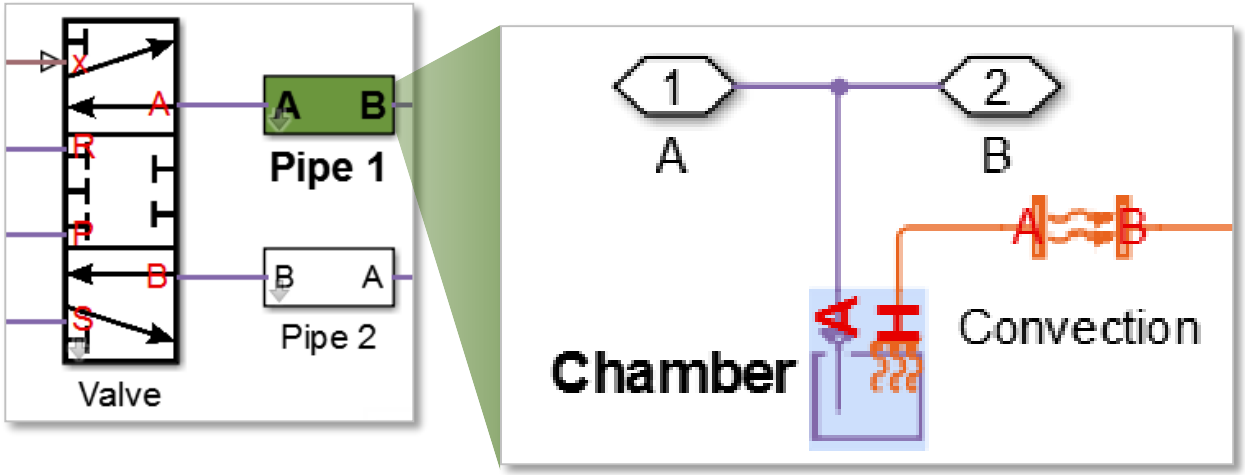


Reviewing Simulation Results

Logging Simscape Variables

- All variables automatically logged to MATLAB Workspace
  - Structure based on model hierarchy
  - Values, time, units
- Only use sensors when signals are necessary
  - Scopes
  - Feedback signals
- Spend more time analyzing, less time simulating



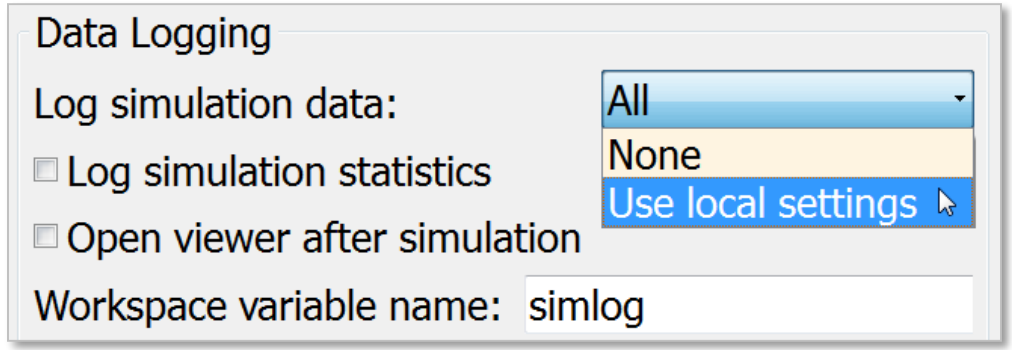


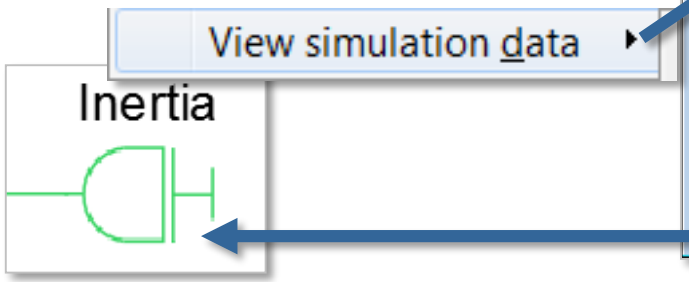
>> simlog.Pipe_1.Chamber.A.p.plot;

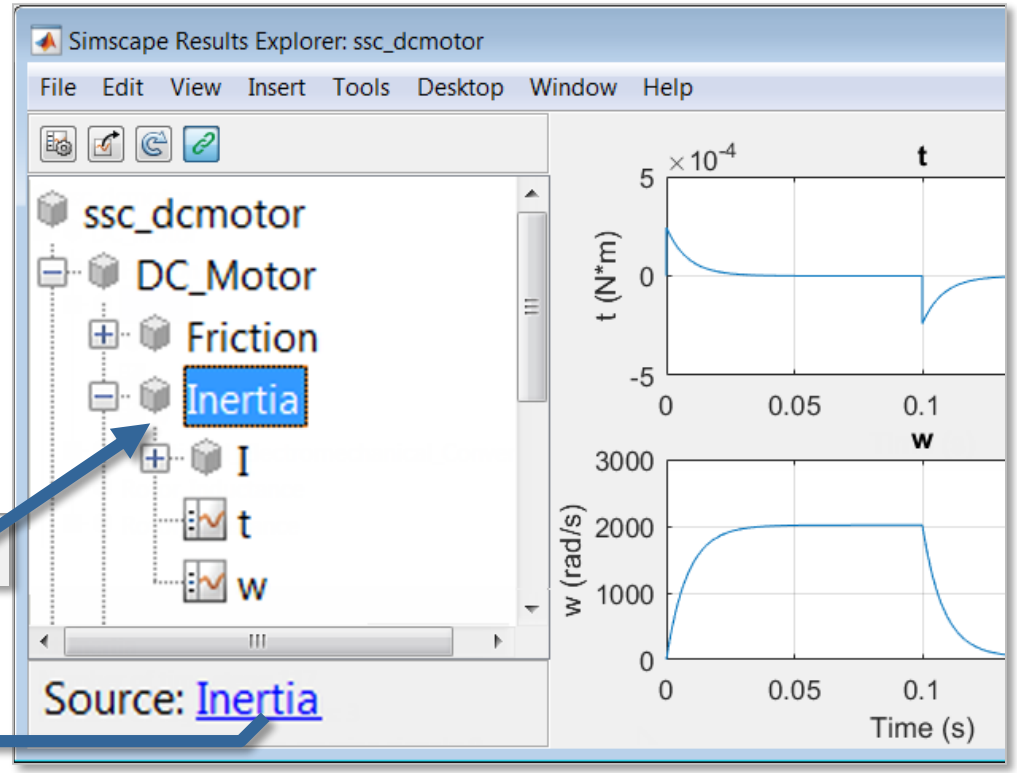
Reviewing Simulation Results

Simscape Data Logging

- Log Simscape results to MATLAB workspace
  - Log all or only selected blocks
  - Variables, zero-crossing statistics
- Review results in Simscape Results Explorer
  - Explore results in tree view
  - Navigate between model and results
- Fewer blocks in model, efficient analysis



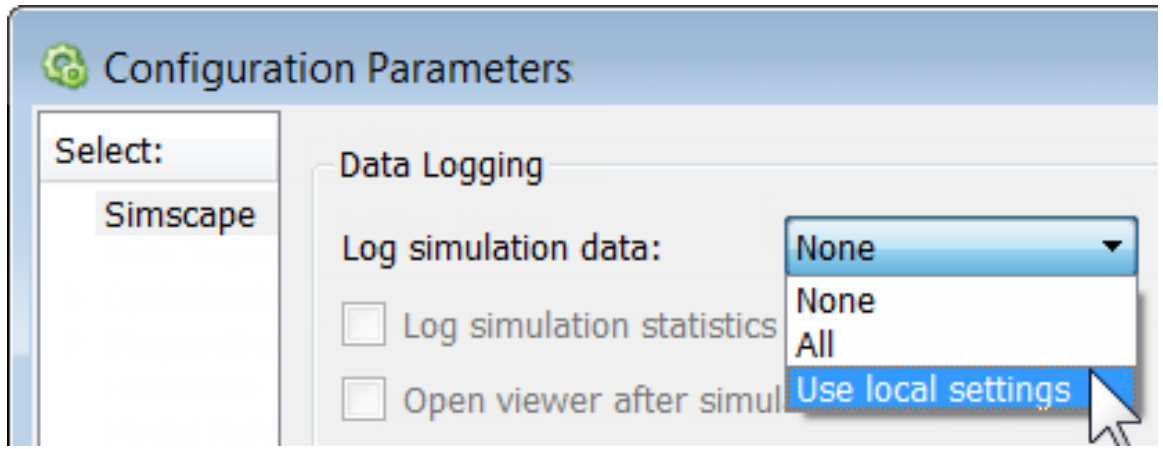


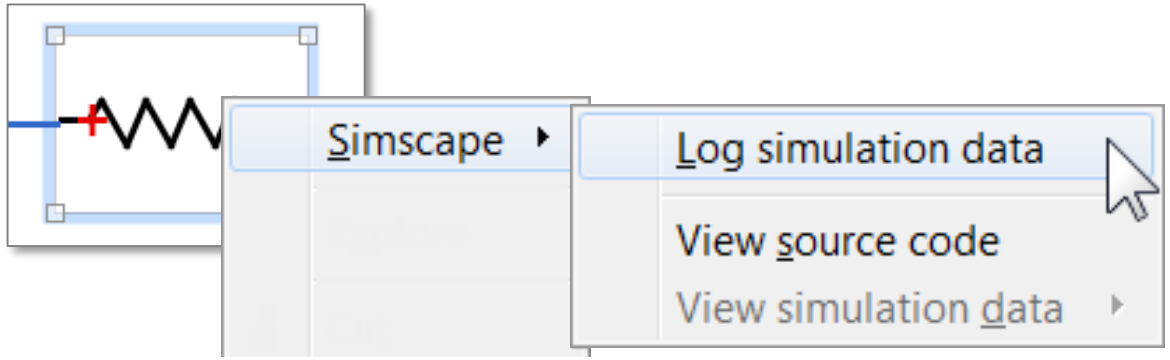



```
>> sscexplore(simlog)
```

Simscape Logging

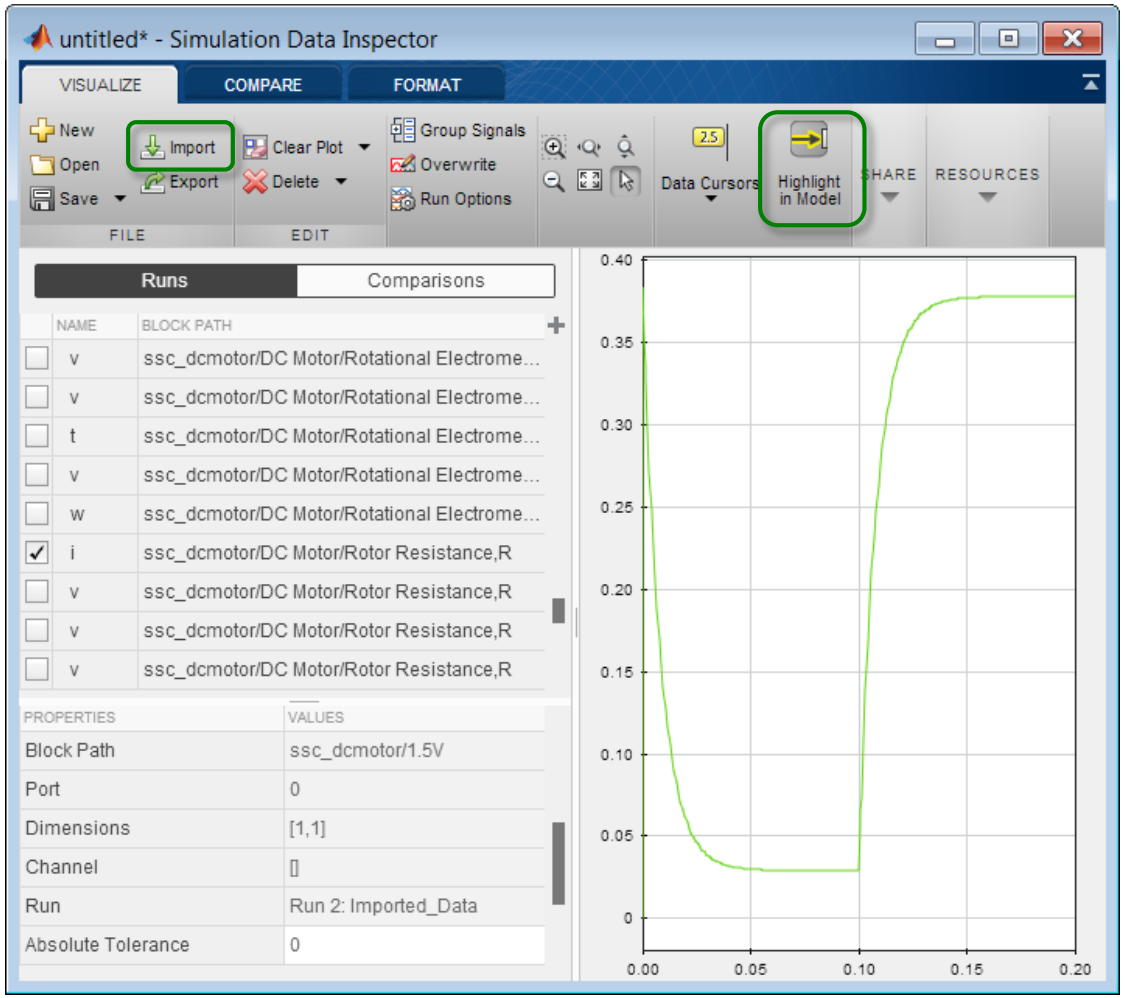
- Use local settings option added to selectively log simulation results
- Select results to log per block via right-click





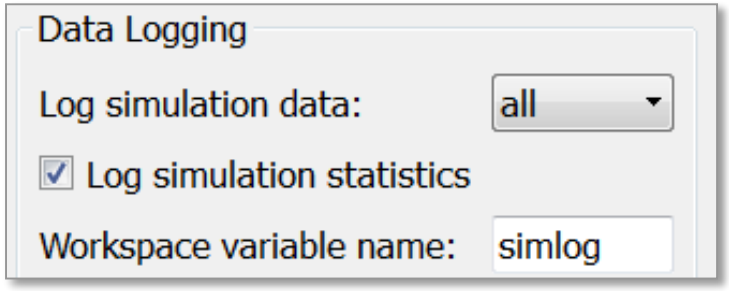
Simscape Logging in Simulink Data Inspector

- Simscape results can be imported directly into Simulink Data Inspector
  - Import simlog
  - Can navigate from SDI to model

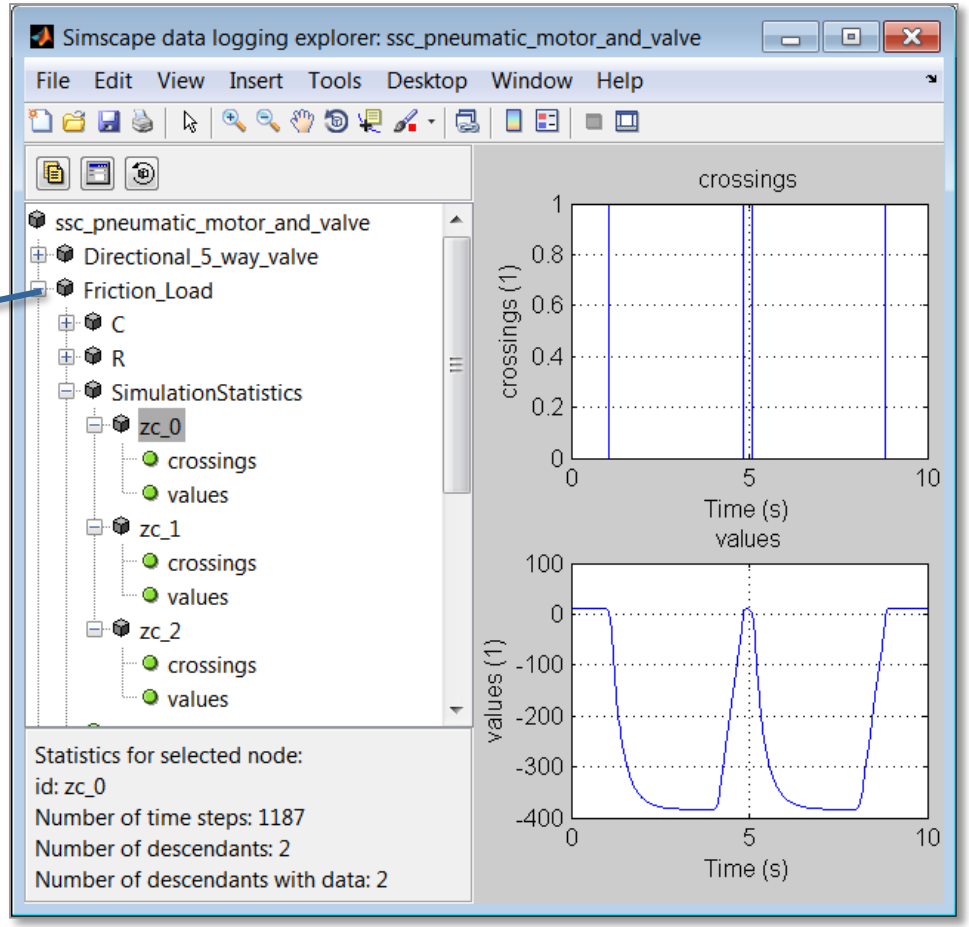


Zero-Crossing Statistics

- Log zero-crossing statistics for Simscape networks
  - Shows when ZCs occur
  - Can help indicate location of simulation bottlenecks

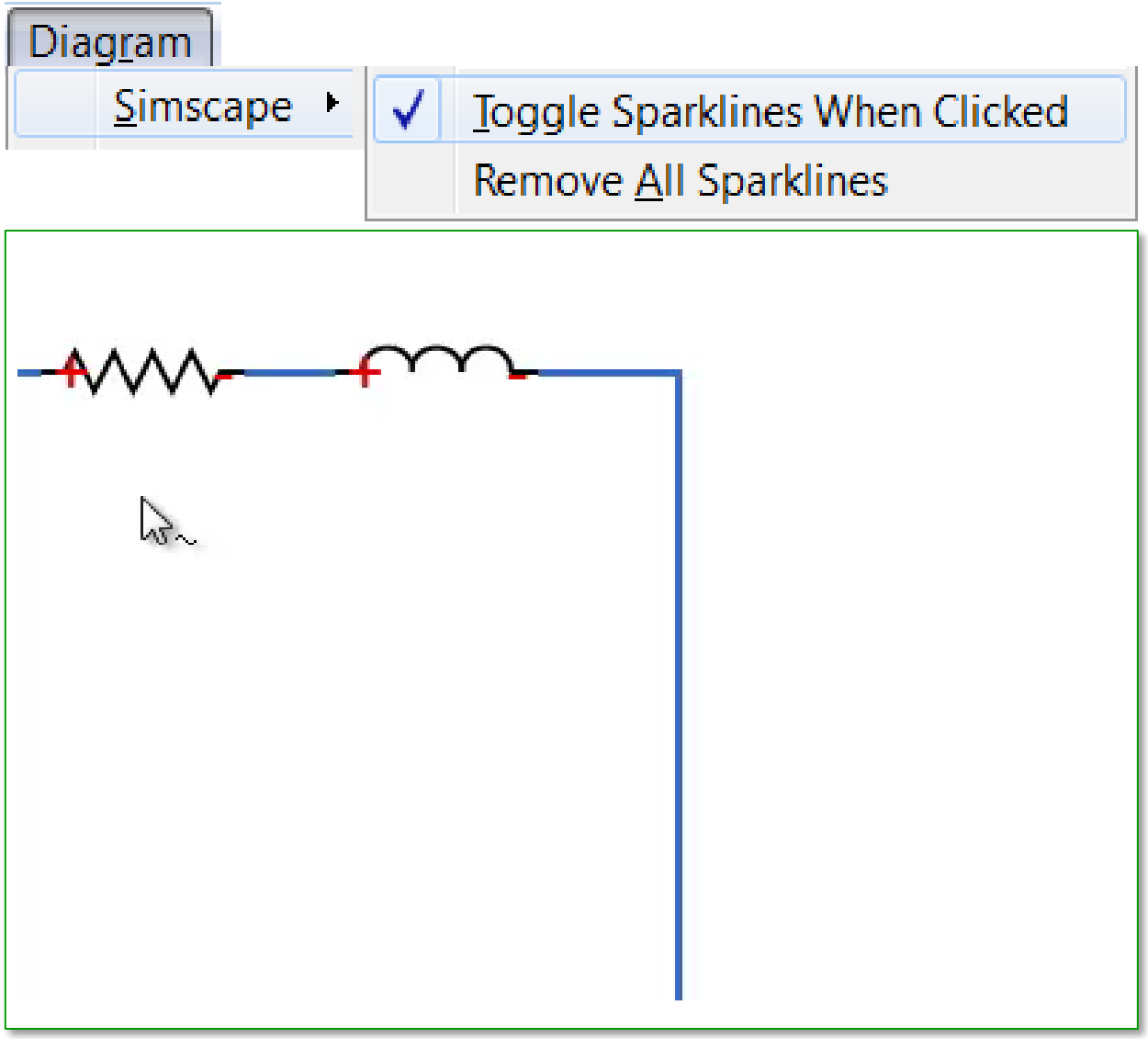



```
equations
  if (abs(w) <= vel_thr)
      % Linear region
      t == brkwy_trq_th * w / vel_thr;
  elseif w > 0
      t == visc_coef * w + Col_trq + ...
          (brkwy_trq - Col_trq) * exp(-t
  else
      t == visc_coef * w - Col_trq - ...
          (brkwy_trq - Col_trq) * exp(-t
  end
end
```



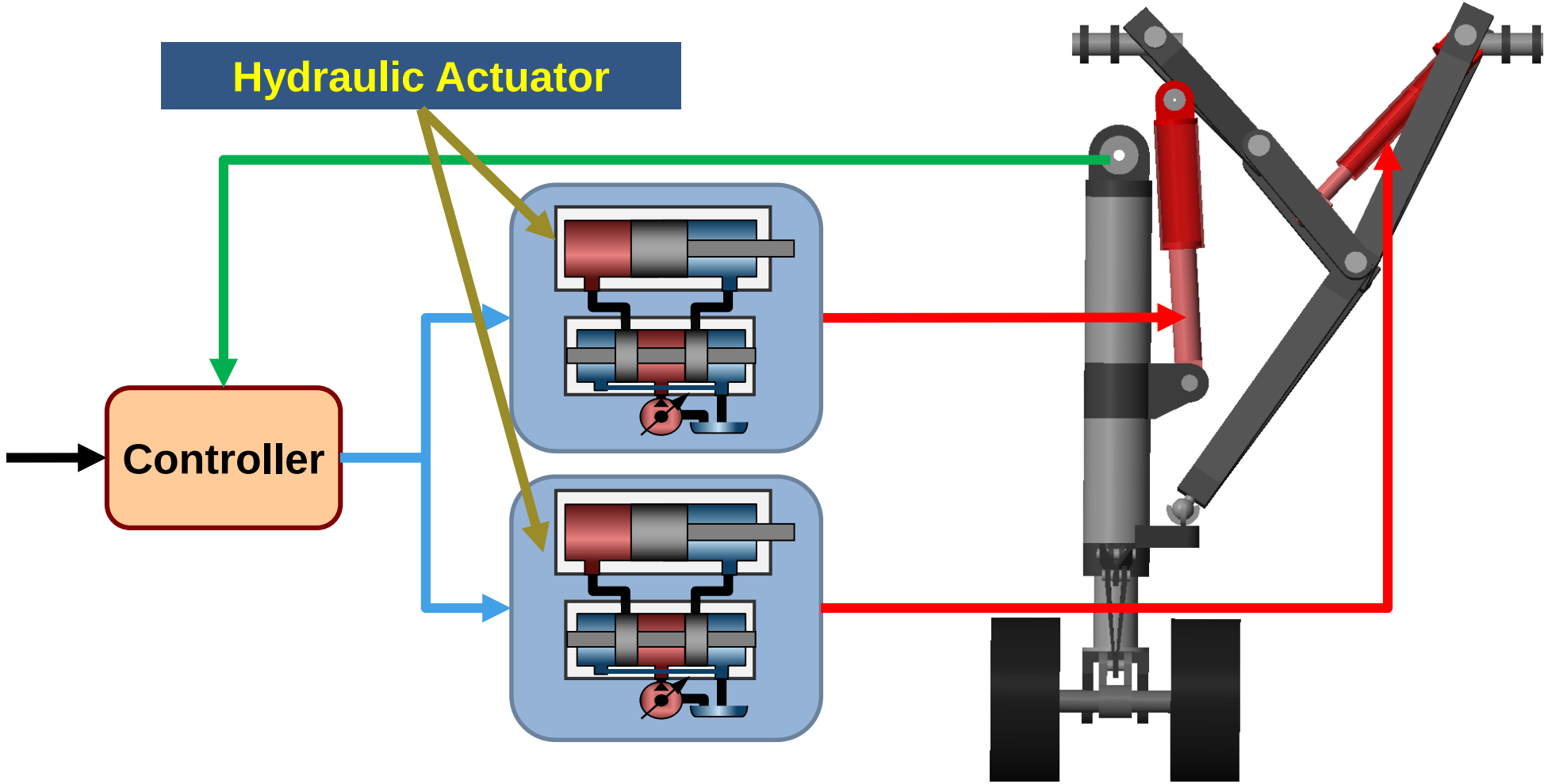
Sparkline Plots for Logged Data

- Quickly scan simulation results directly on model canvas
  1. Click to show plots
  2. Cursor shows values
  3. Select variables
  4. Direct link to plot variable in Simscape Results Explorer



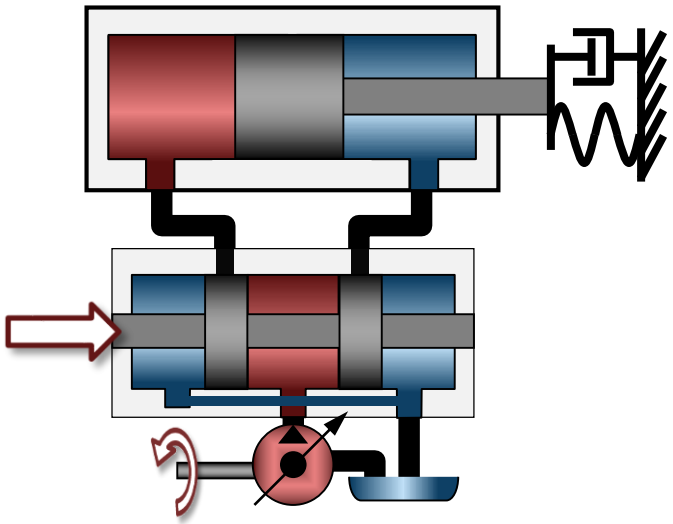
Landing Gear System

Hydraulic Actuator Model



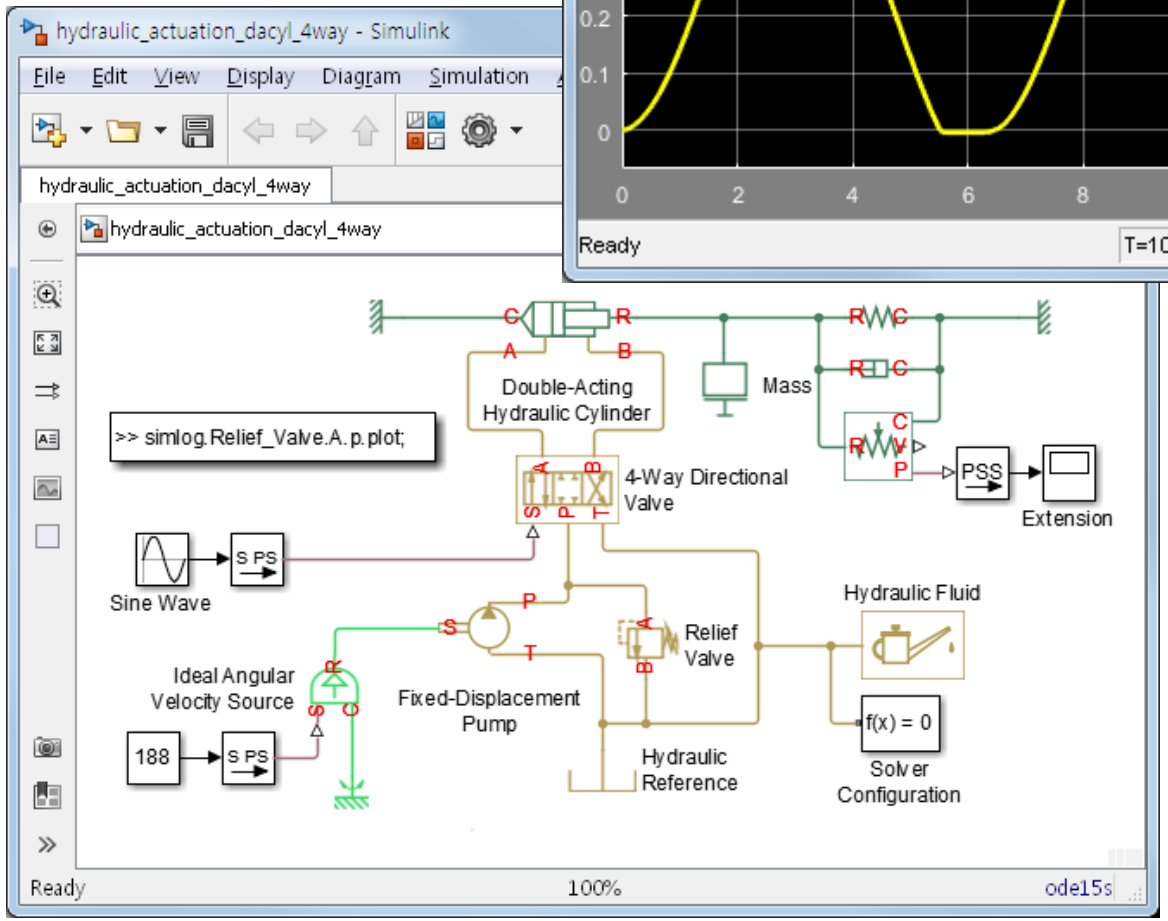
Modeling Hydraulic Actuation System

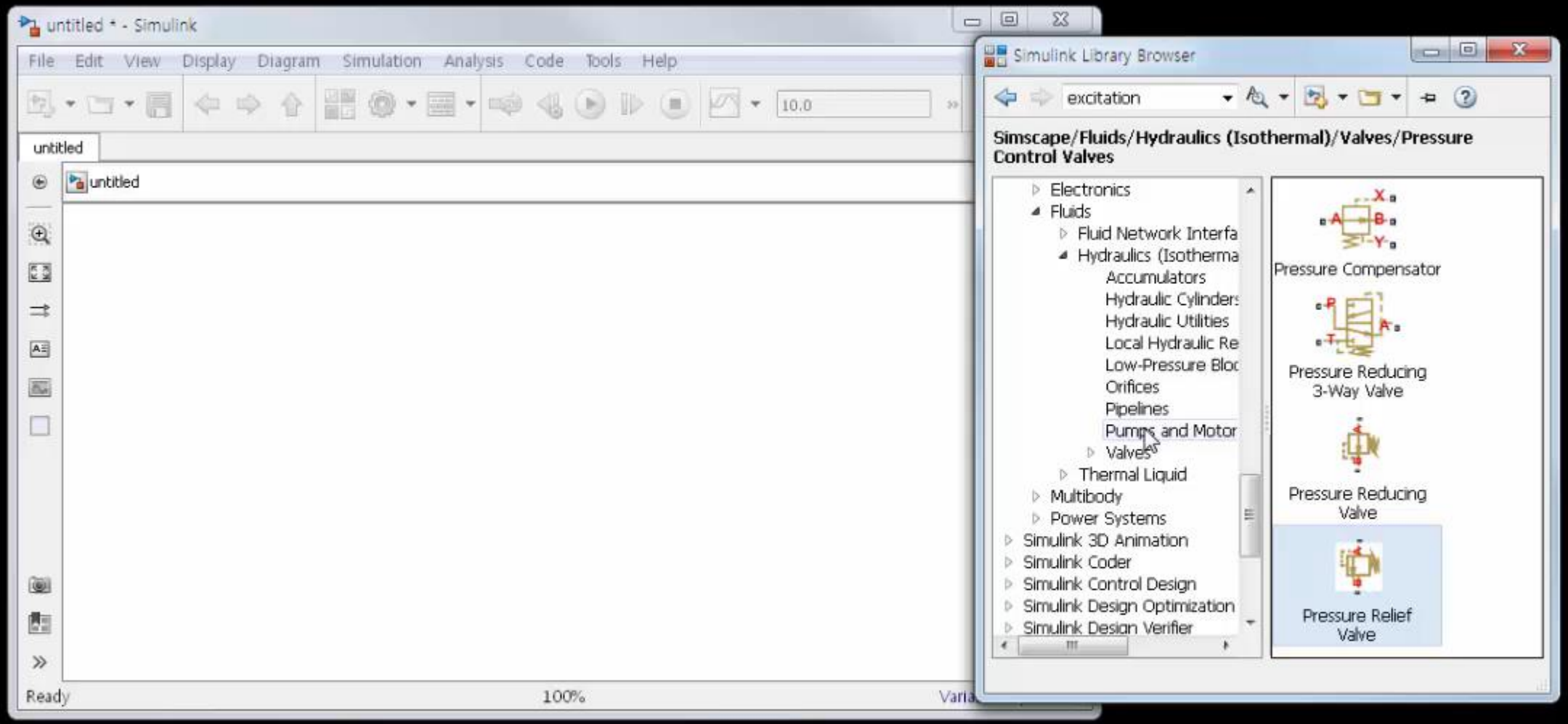
Model:



Problem: Model a hydraulic actuation system within the Simulink environment

Solution: Use Simscape Fluids to model the hydraulic system

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Fluids
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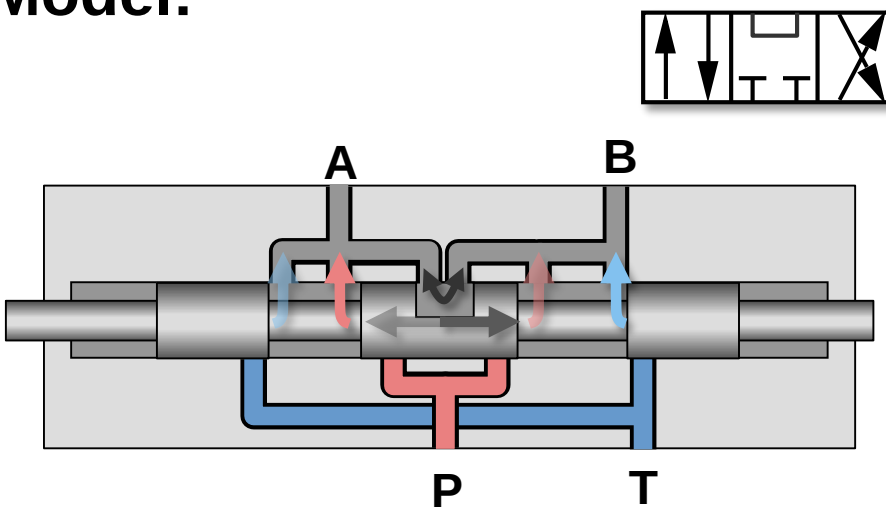
Accumulators
Hydraulic Cylinders
Hydraulic Utilities
Local Hydraulic Re
Low-Pressure Bloc
Orifices
Pipelines
Pumps and Motor
Valves
Thermal Liquid
Multibody
Power Systems
Simulink 3D Animation
Simulink Coder
Simulink Control Design
Simulink Design Optimization
Simulink Design Verifier
Pressure Compensator
Pressure Reducing 3-Way Valve
Pressure Reducing Valve
Pressure Relief Valve

Modeling Hydraulic Actuation System

Custom Four-Way Valve

Model:

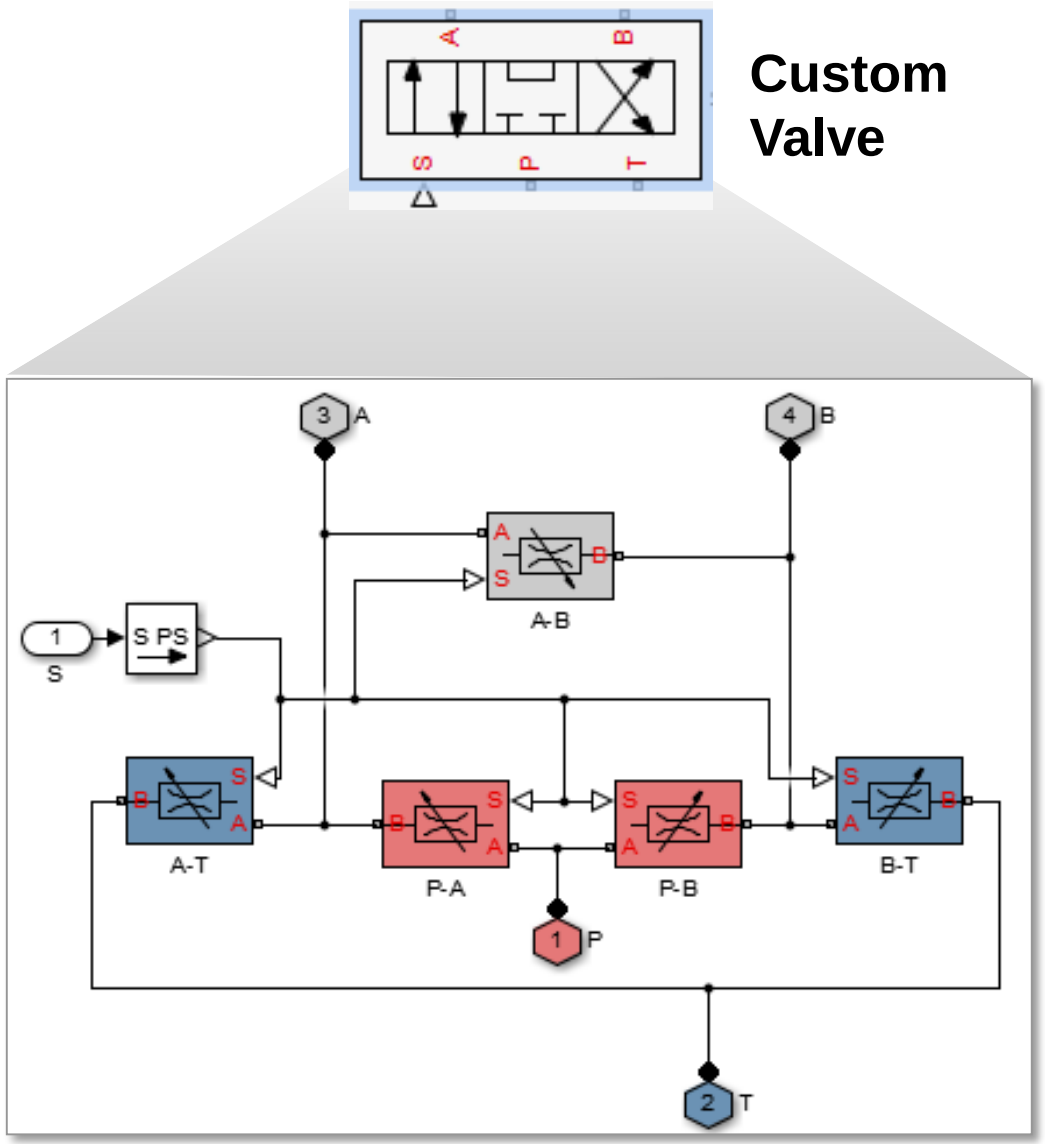


Problem:

Model a custom four-way directional valve within the Simulink environment

Solution:

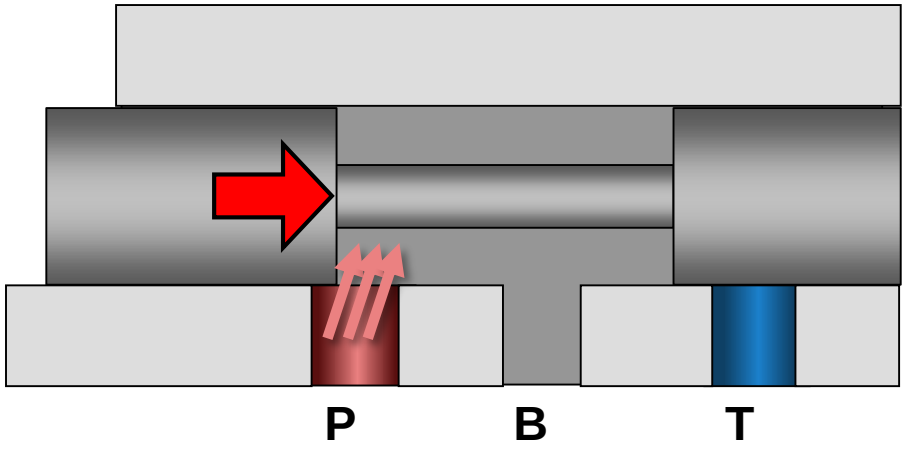
Use Simscape Fluids to model the four-way directional valve



Hydraulic Actuator Modeling

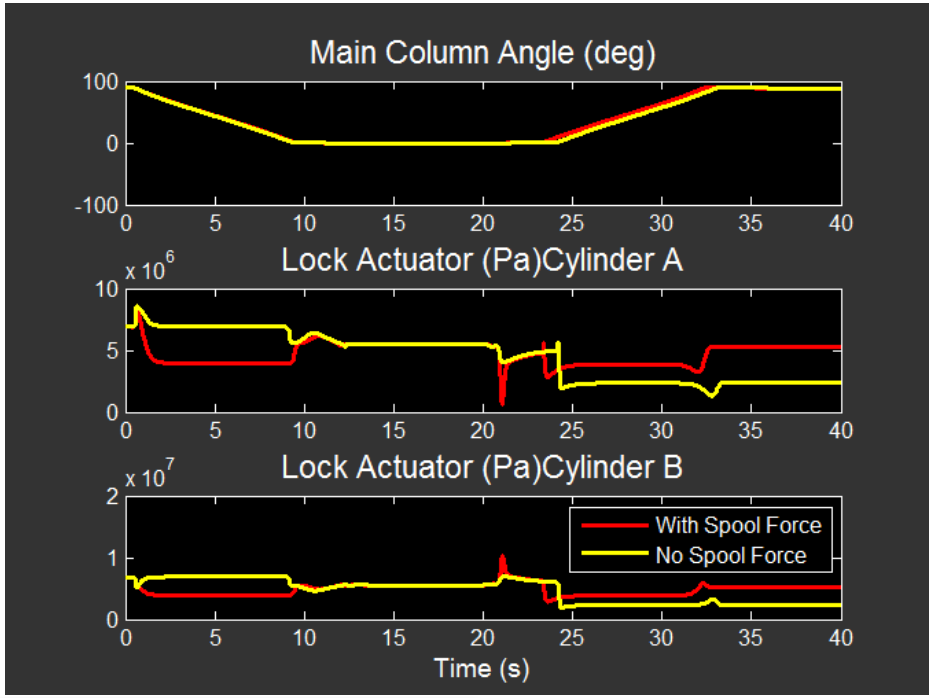
Spool Axial Hydraulic Forces

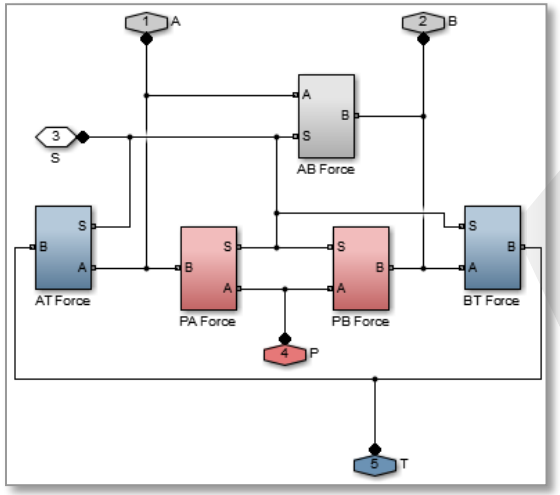
Model:

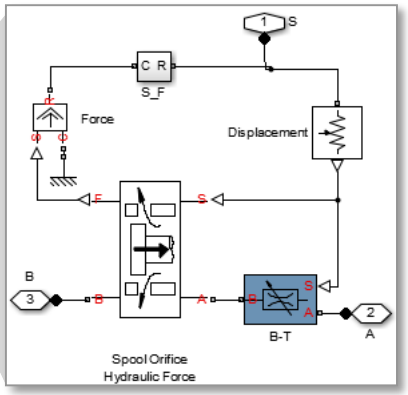


Problem: Include the hydraulic axial forces on the spool to add more fidelity

Solution: Use SimHydraulics to include the hydraulic forces on the spool

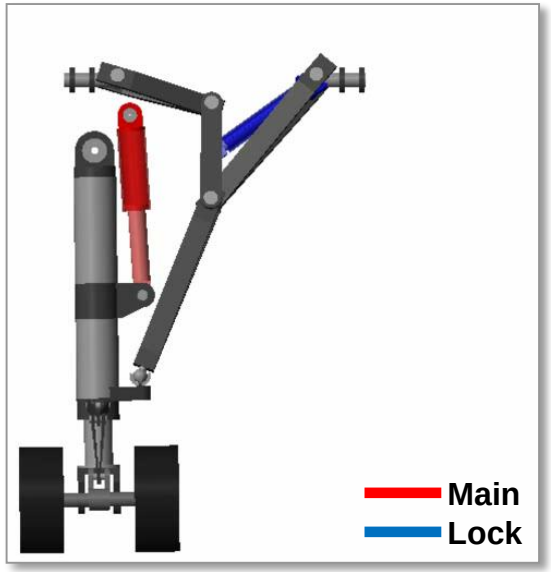






Refine Main Actuator Requirements

Model:



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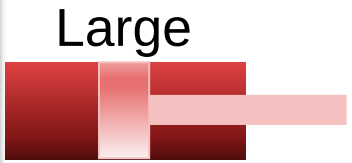
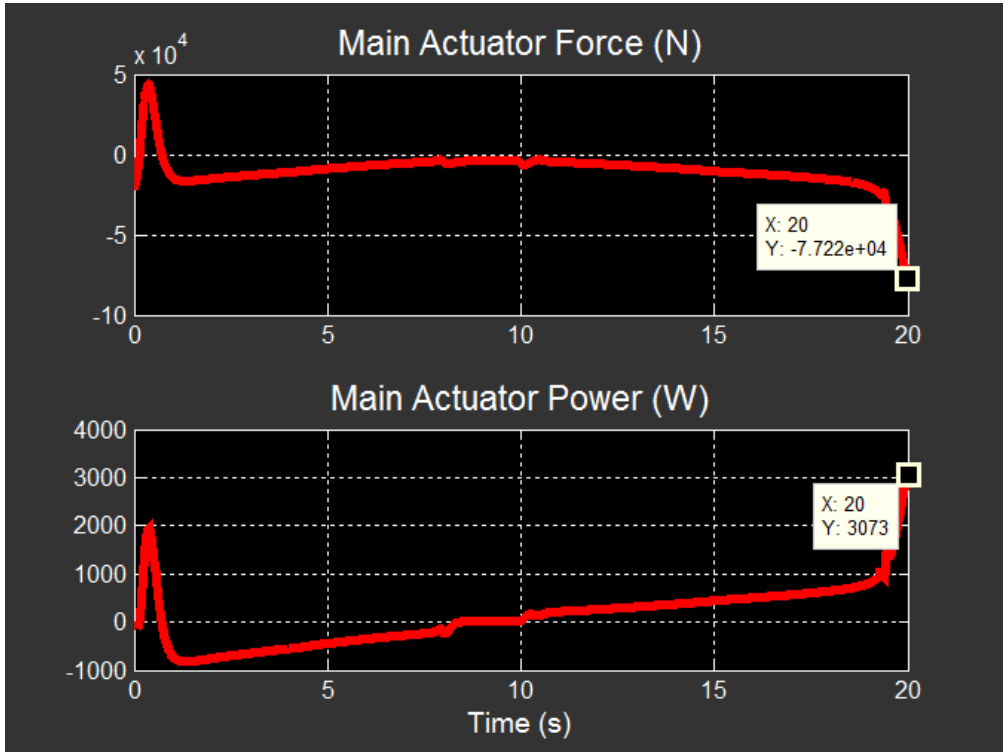
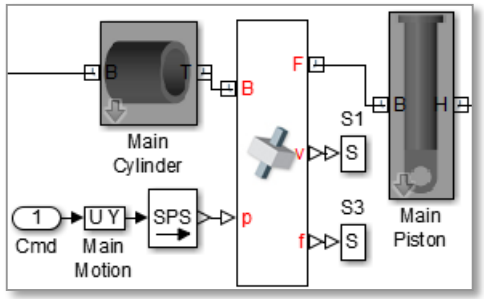


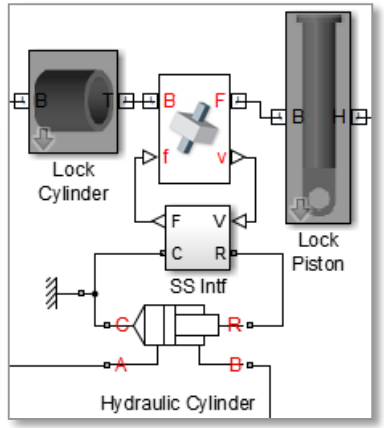


Problem: Determine main actuator and pump size requirements

Solution: Use Simscape Fluids to model lock actuator and Simscape Multibody to determine main hydraulic force and power required for prescribed motion



Main actuator (Prescribed Motion)



Lock actuator (Hydraulic)

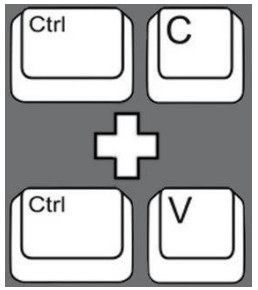
Agenda

- What is Physical Modeling? Why use Simscape?
- Landing Gear Modeling
  - Landing Gear Mechanism Modeling
  - Refine requirement and optimize mechanical design
  - Analyze hydraulic actuator designs
- Test system in various situations

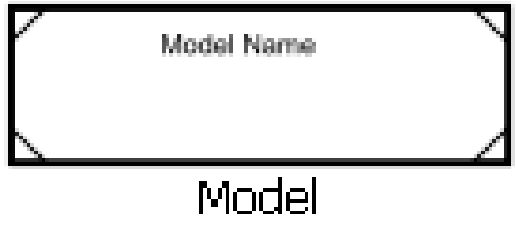
Before system-level test with physical model,

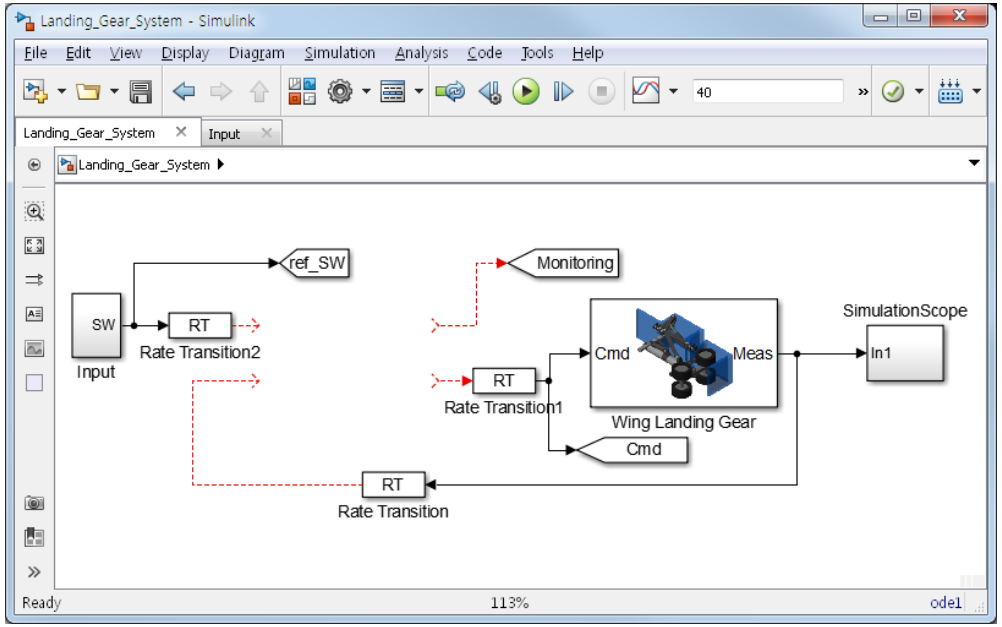
You need to integrate controller with physical model

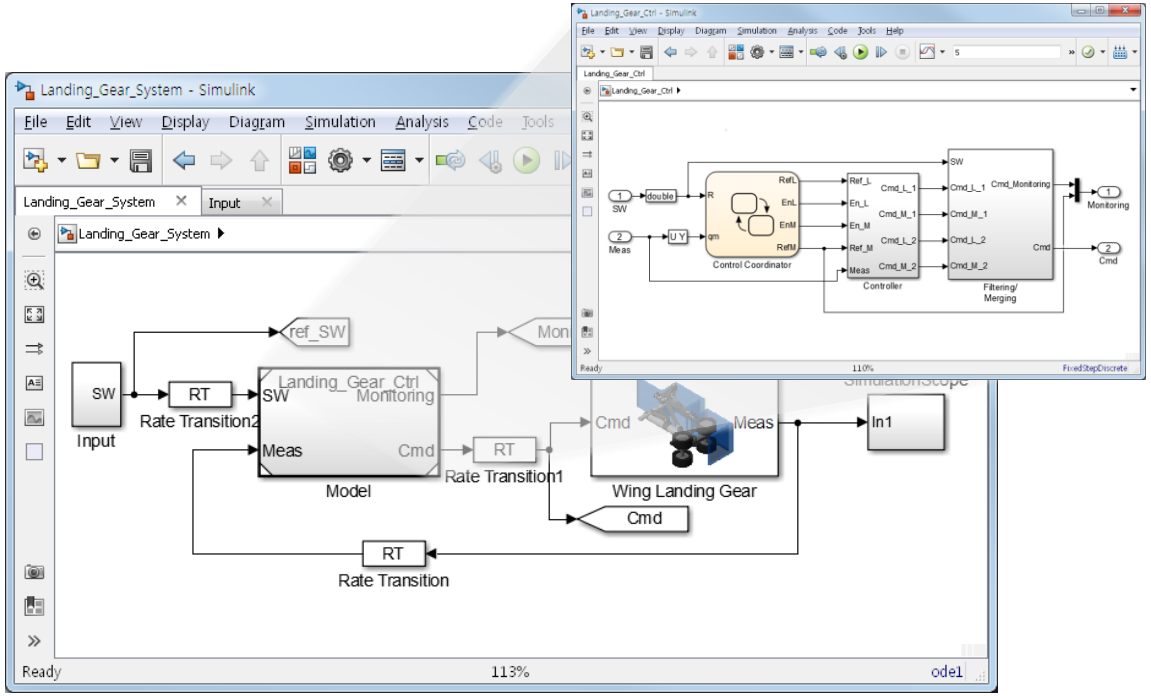
1) Merging controller with physical model



or

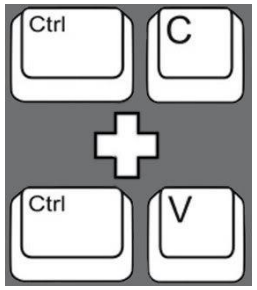


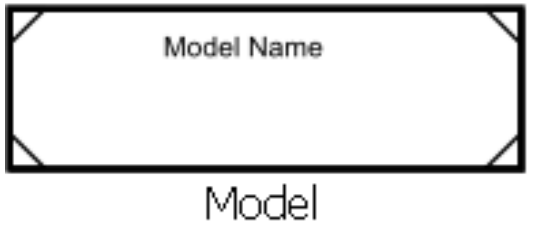


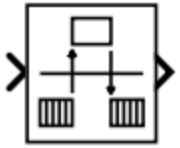


Before system-level test with physical model,

You need to integrate controller with physical model

1) Merge controller with physical model 

or 

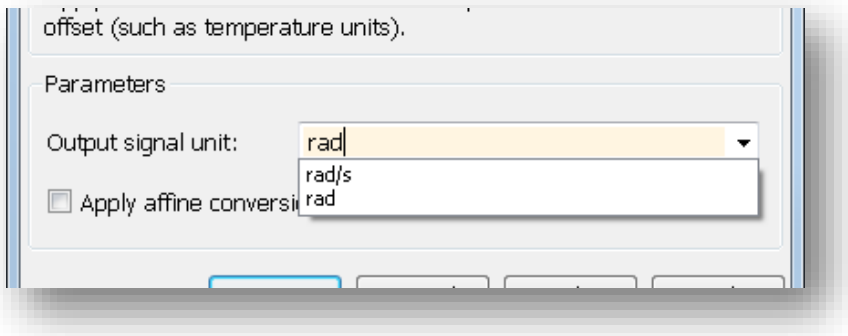
2) Add 

to a point where sample time changes

3) Use 

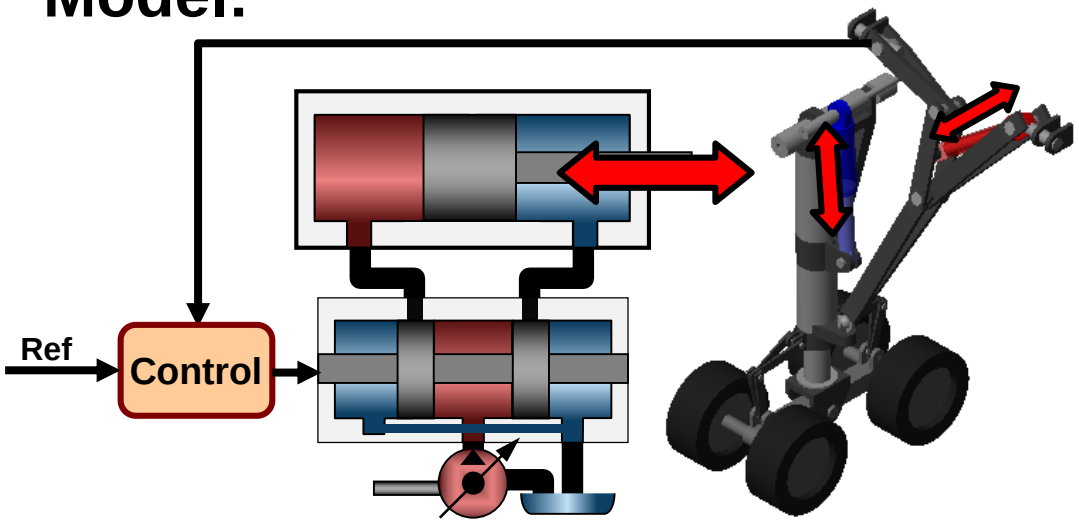
to convert Simulink signal to Simscape signal

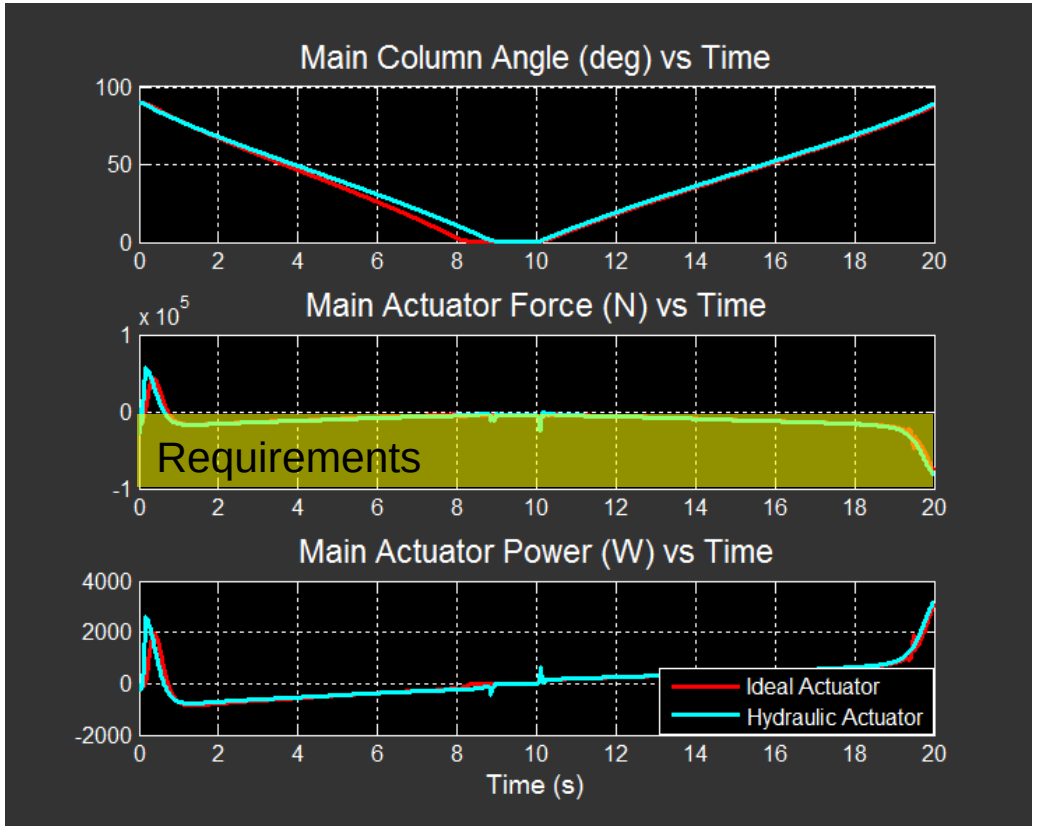
4) Don’t forget to set unit of a converted signal



Design and Test Hydraulic Main and Lock Actuator System

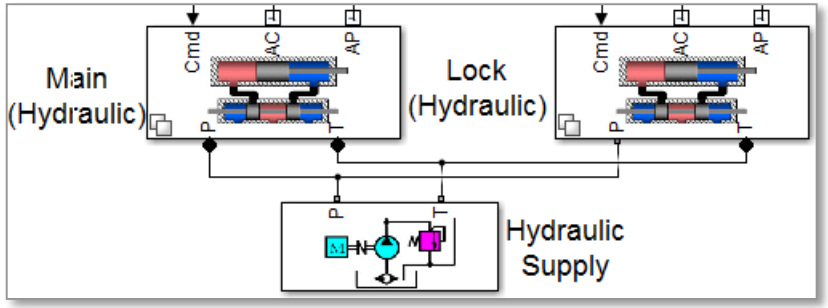
Model:





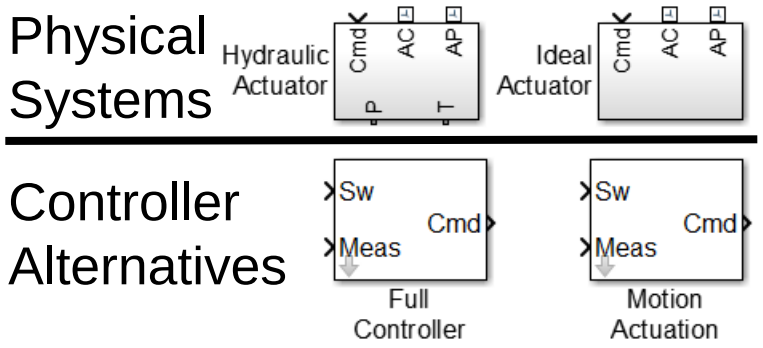
Problem: Design hydraulic main/ lock actuator and test it against requirements

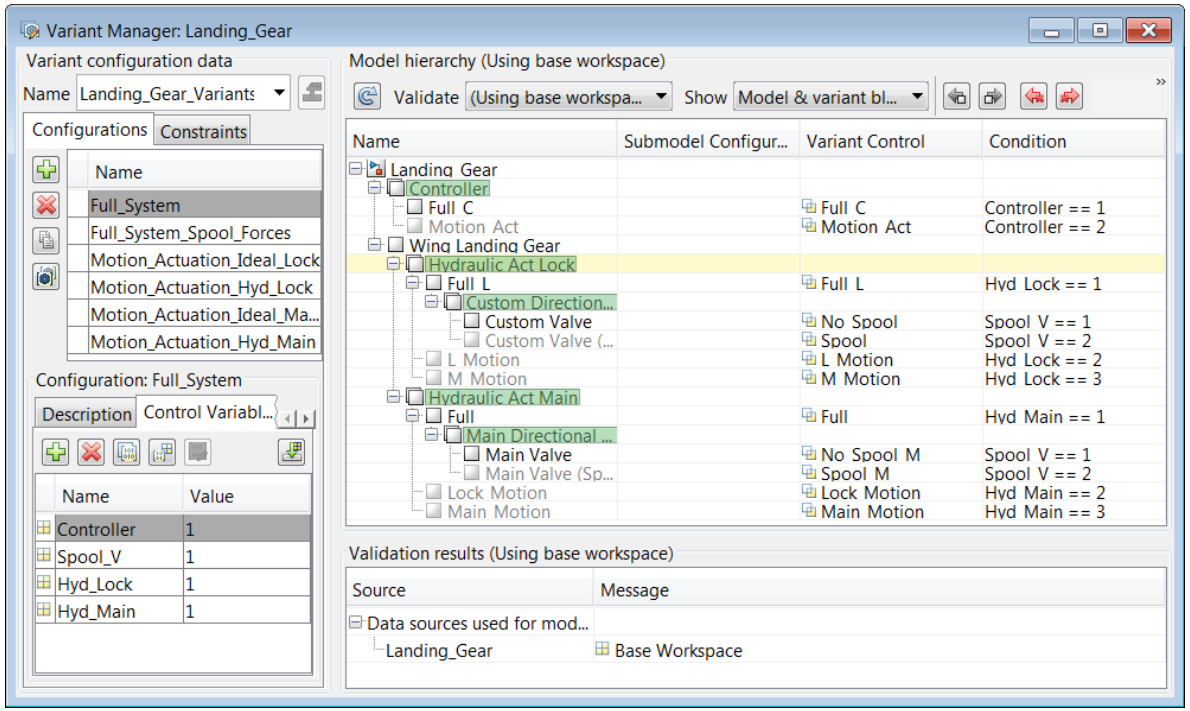
Solution: Use Simscape Fluids to model the hydraulic actuators and integrate with Simscape Multibody model of landing gear



Managing Design Variants

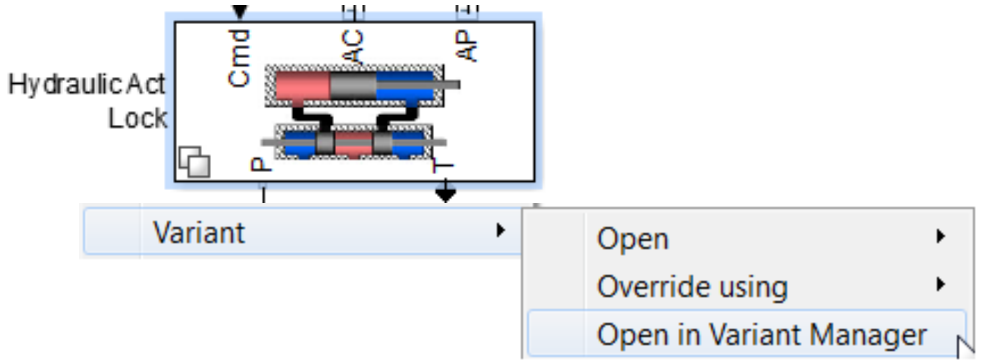
Situation:





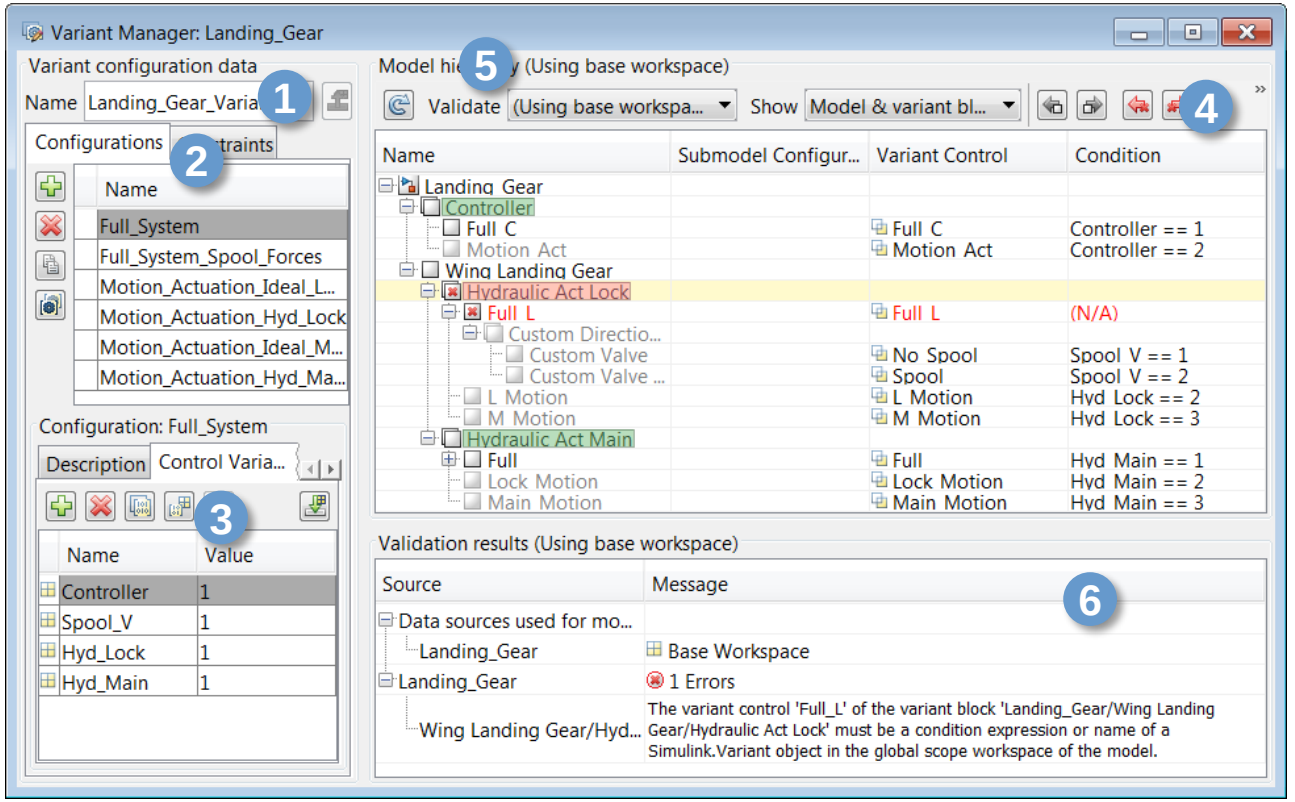
Problem: Test different alternatives for physical systems and controllers in a single model

Solution: Use Variants to model different configuration and manage it using Variants Manager



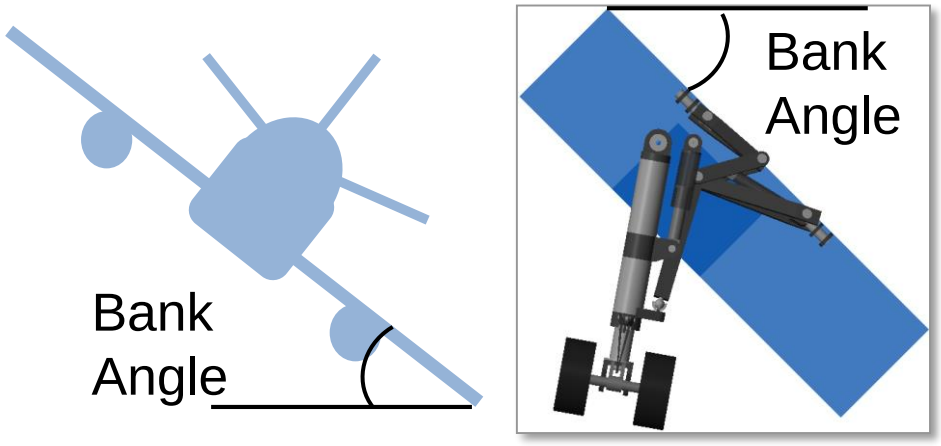
Managing Design Variants

1. Define variant configuration data
2. Create configurations
3. Set control variables
4. Visualize, explore and set variant properties
5. Select the configuration
6. View diagnostics for selected configuration



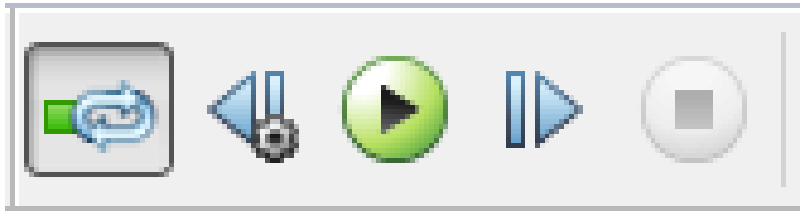
Fast Restart

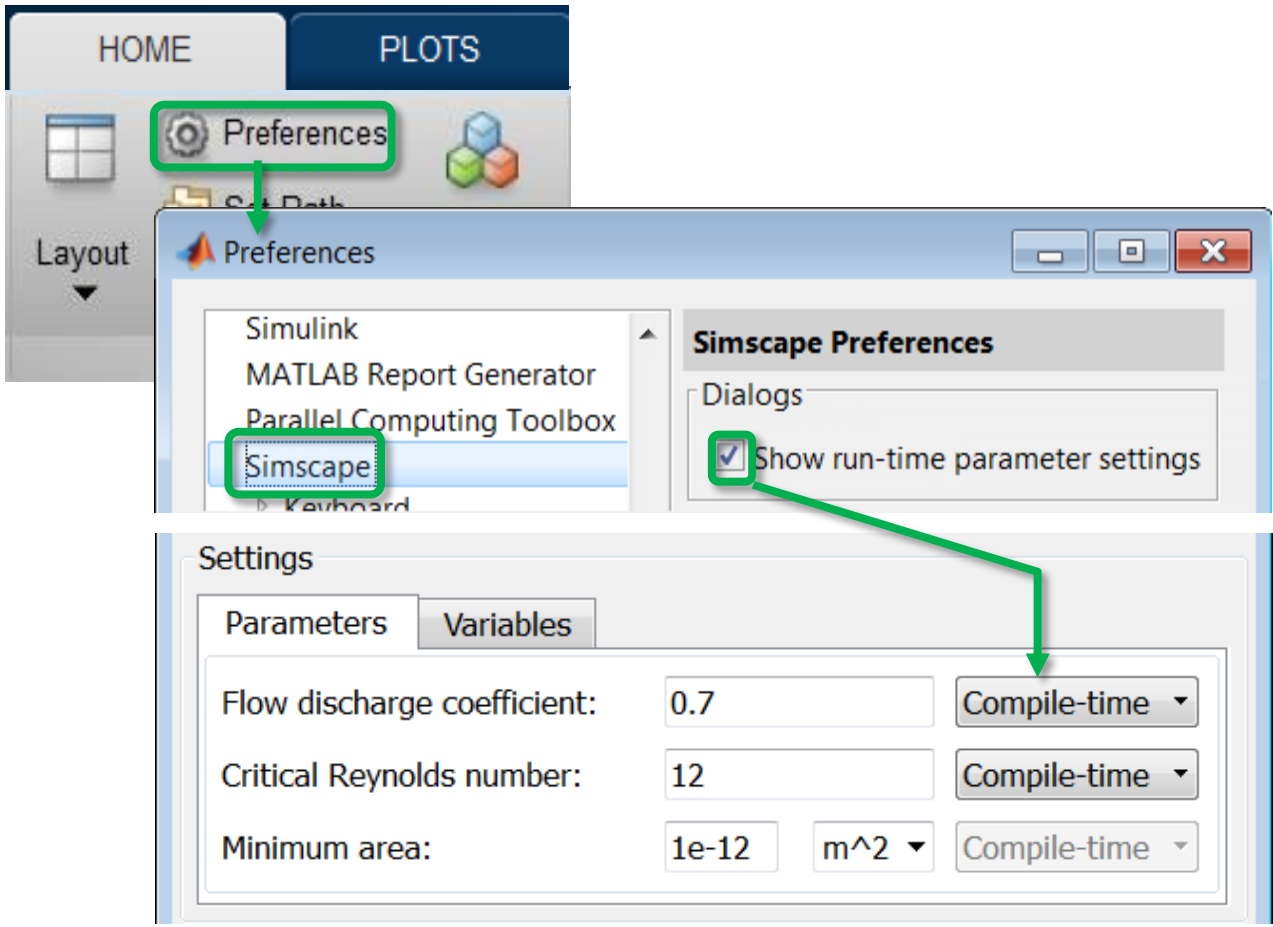
Model:



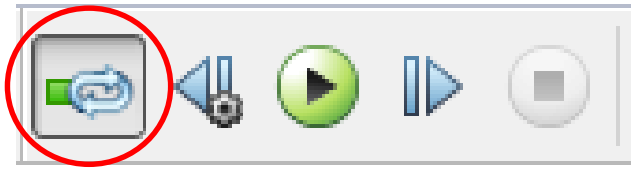
Problem: Minimize the simulation time on iterative tests to determine controller robustness to changes to airplane bank angle.

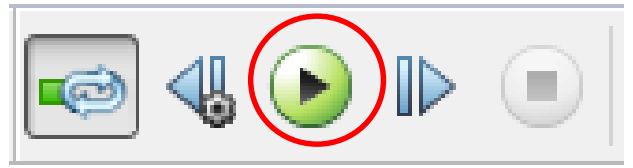
Solution: Fast Restart
& Run-Time Parameters

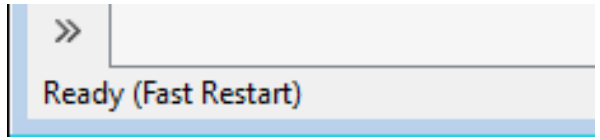


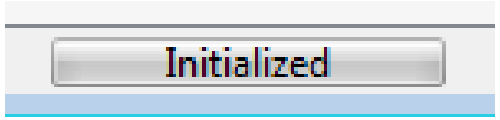


Fast Restart



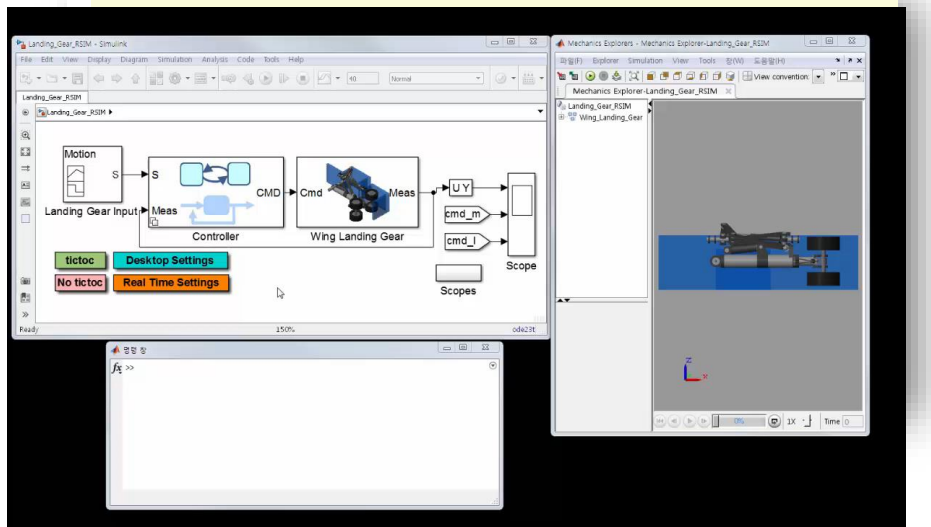


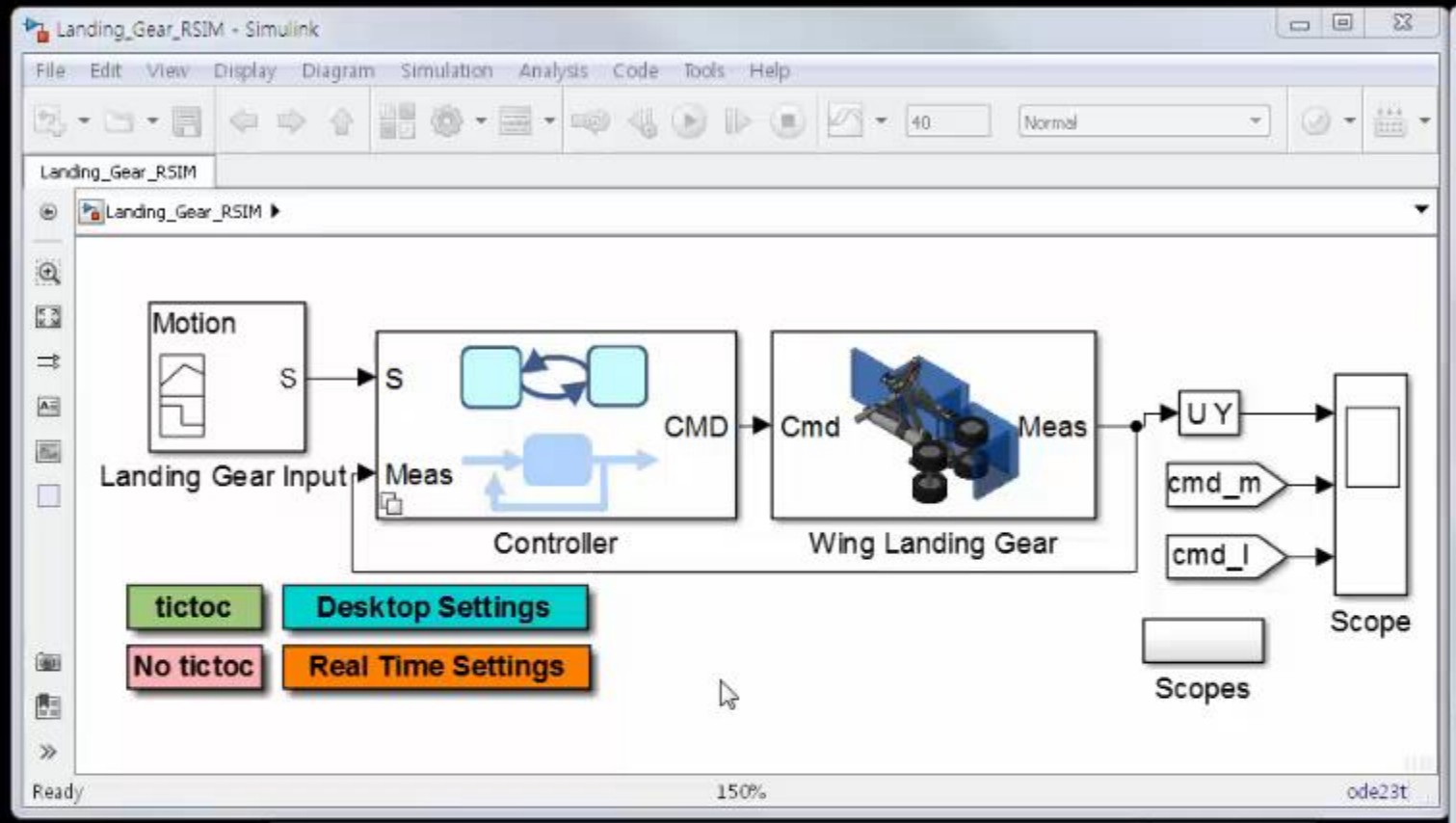




- Run consecutive simulations more quickly
  - Efficiently run multiple interactive simulations
  - Saves simulation time eliminating recompilation between simulation runs
  - Improves calibration workflows where the user is tuning block parameters between runs

- Programmatically run consecutive simulations more quickly
  - Enable fast restart from command line using set_param
  - Simulate a model in fast restart using sim and cvsim commands




Landing_Gear_RSIM - Simulink
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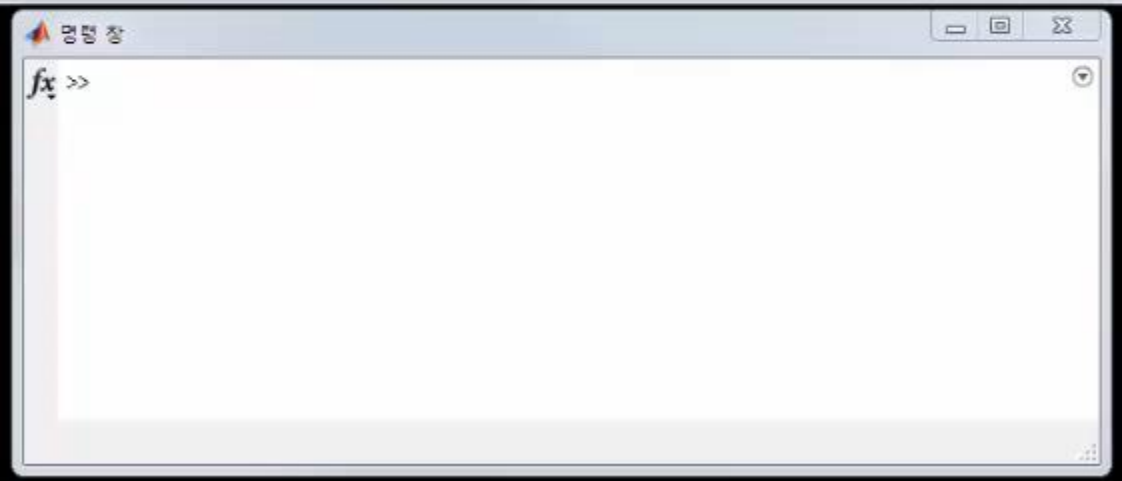
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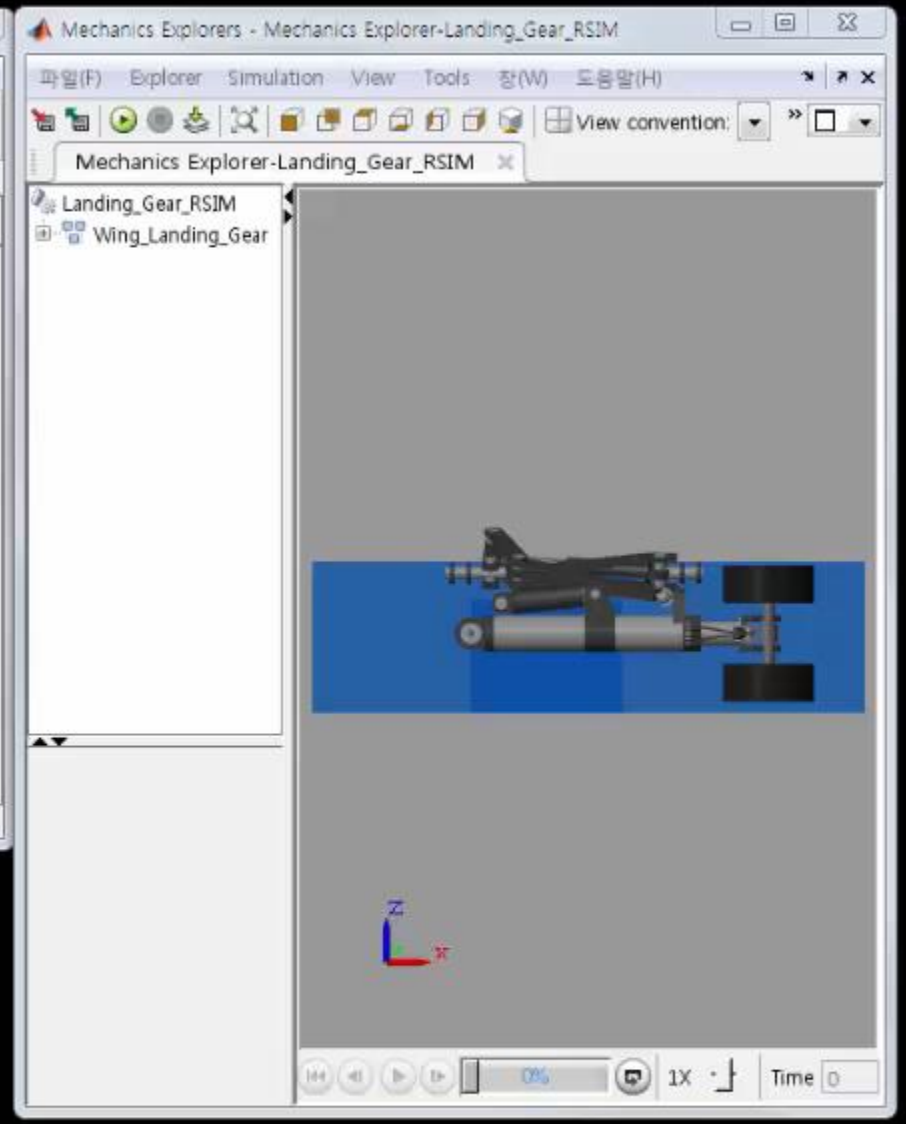
Mechanics Explorers - Mechanics Explorer-Landing_Gear_RSIM
파일(F) Explorer Simulation View Tools 창(W) 도움말(H)
View convention:
Mechanics Explorer-Landing_Gear_RSIM
Landing_Gear_RSIM
Wing_Landing_Gear
1X
Time 0

Simscape Run-Time Parameters

- Change parameter values without recompiling the model

- Uses:
  - Fast Restart in Simulink
  - Model Reference
  - HIL (SLRT or ERT target)

- Scope
  - Nearly all Foundation Library parameters
  - All Variable initial conditions
  - Very few Simscape Add-on Product blocks
  - No Simscape Multibody blocks

Why model the physical system?

Too big, too difficult, one chance, …

Why Simscape?

Makes modeling easy

Develop controller

Find best design