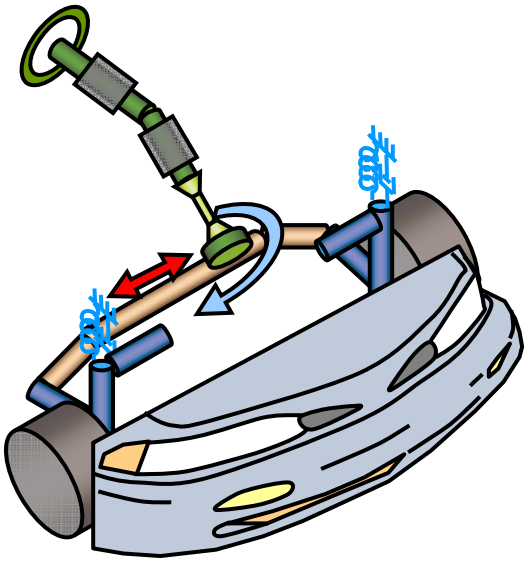
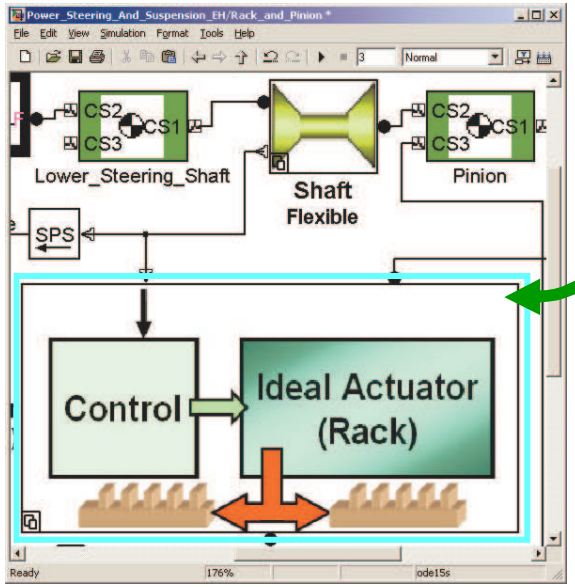
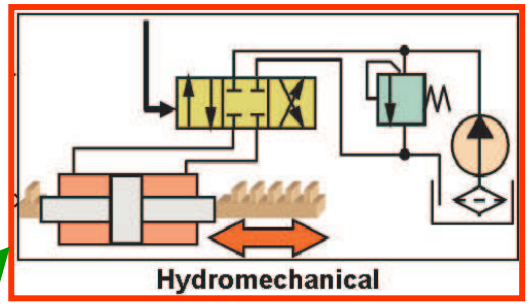
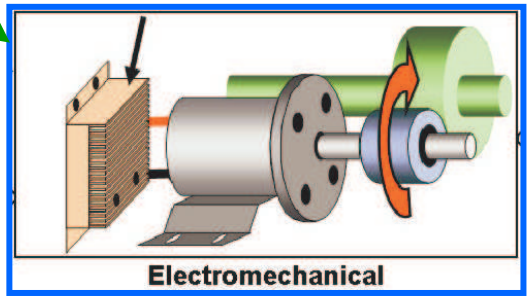
The MathWorks

MATLAB® & SIMULINK®









System-level design of electrohydraulic and mechatronic systems

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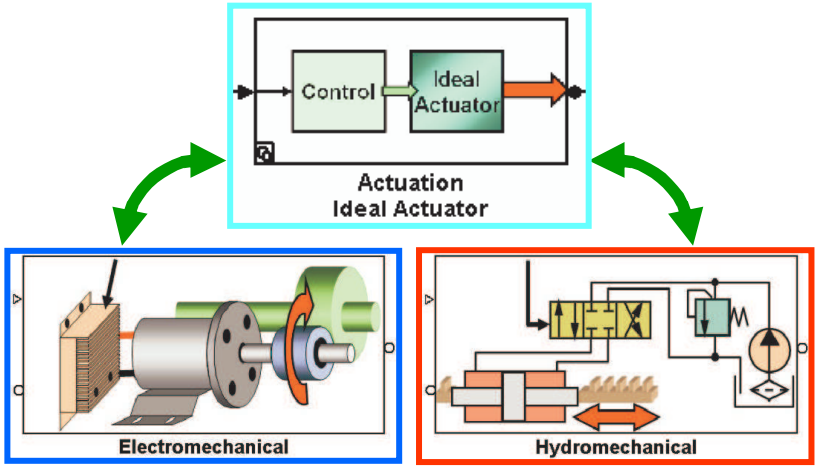
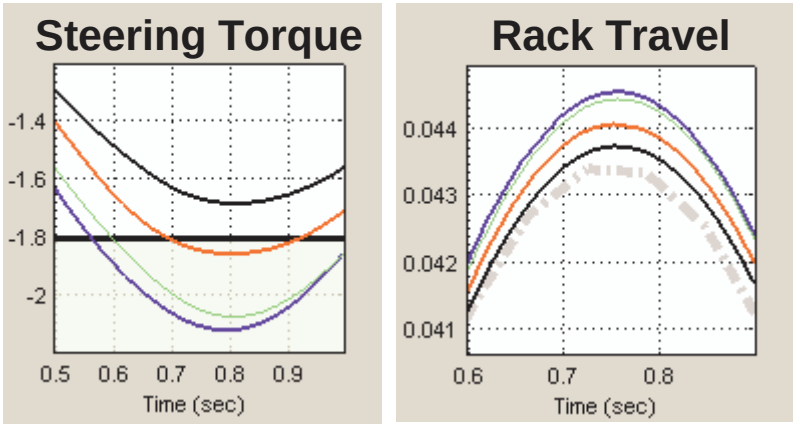
Key Points

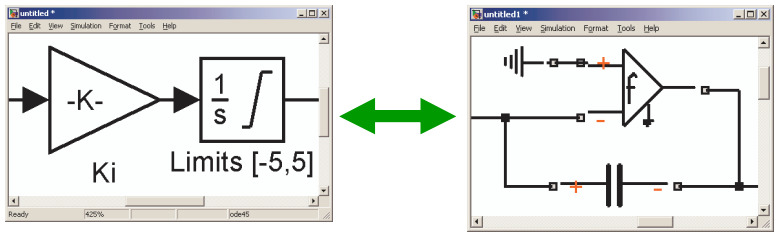
1. Testing different actuator designs in one environment saves time and encourages innovation



2. Optimizing systems with respect to design requirements leads to optimal design choices



3. Simulating at different levels of fidelity is required throughout the development process



Agenda

- Trends in the automotive industry 10 min
  - Industry trends
  - Strategies for improvement
  - How simulation can help
- Example: Power steering system 15 min
  - Model explanation
  - Tradeoff study
  - System optimization
  - Assess implementation effects
- Conclusions

Industry Trends

Environmental zone sign
Stuttgart, Germany

- System needs
  - Vehicles must produce less pollution
  - Vehicles must be more efficient

- Energy losses in vehicles
  - Friction and accessories reduce efficiency significantly

Losses due to friction = 10%
Fuel economy loss due to power steering pump = 1km/L

Argonne National Laboratory, 2006

- Strategies include advancing technology, vehicle-level design

Strategies for Improved Vehicle Design

- Technology: Electrical actuation
  - Fewer losses than hydraulic actuation
  - Only needs to be turned on when in use
  - Tend to be more reliable, cleaner, and safer

Electric Power Steering
BMW Z4 Coupe
Audi A3
Toyota Prius
Peugeot 307
Ford Escape
Chevrolet Cobalt

- Vehicle-level design and optimization
  - Integration with other systems
  - Optimization of integrated systems

Hybrid Electric Vehicles
Integrated power sources
Regenerative braking

- Simulation can help with each of these strategies

How Simulation Can Help

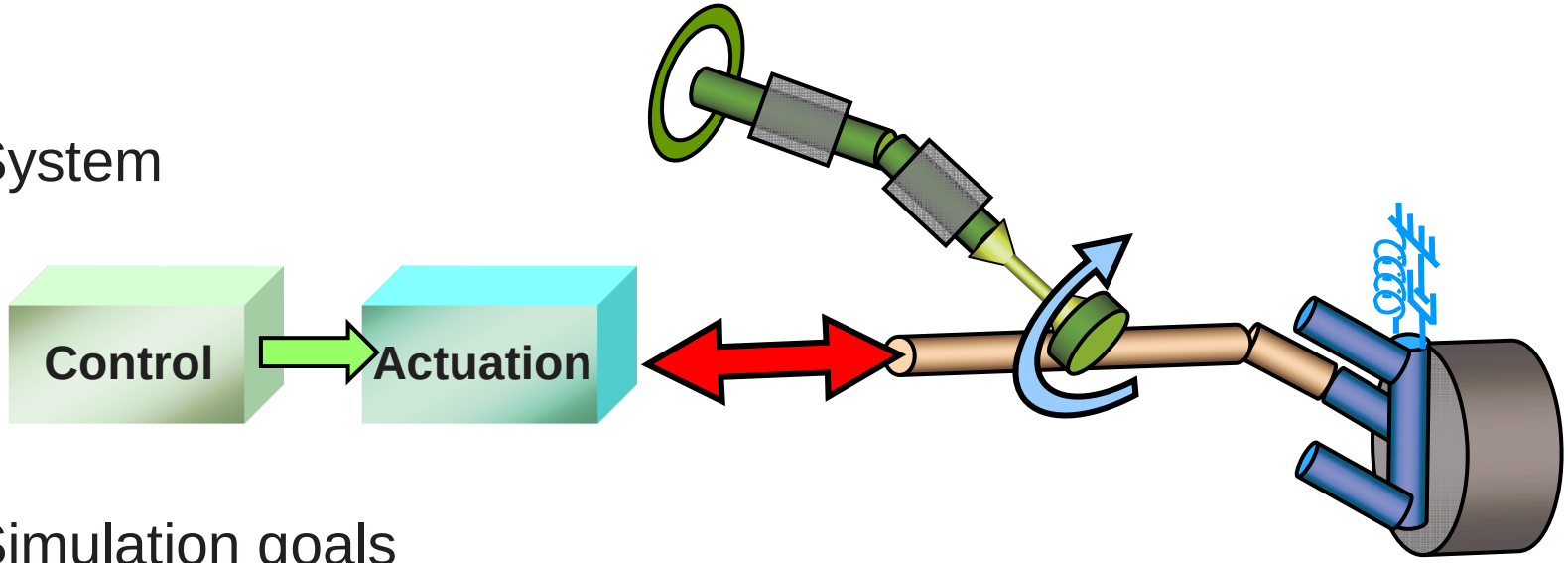
1. Tradeoff studies to test electrical and hydraulic systems
   - Determine actuator requirements
   - Test hydraulic and electrical actuator designs

2. System-level models
   - Required to test system integration
   - Few key parameters and quick simulation

3. Simulating at different levels of fidelity
   - Enable rapid iteration and test impact of design implementation
   - Reuse work done at system level (Model-Based Design)

Example: Power Steering System

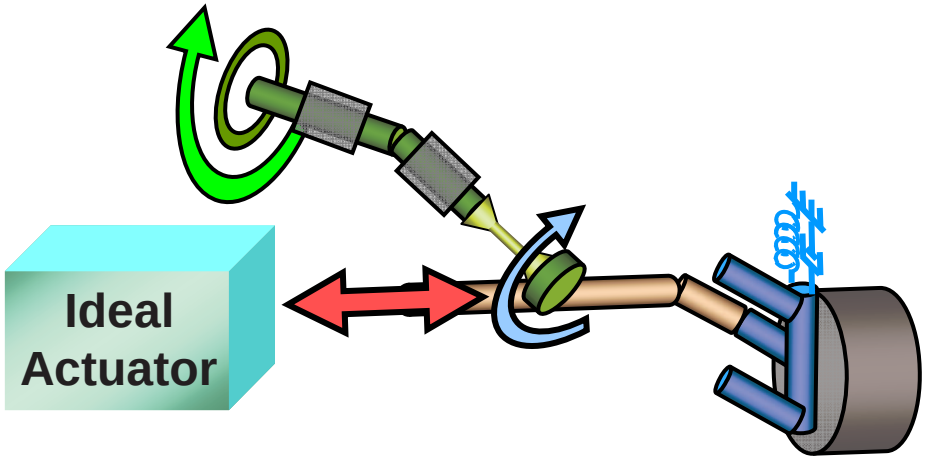
- System

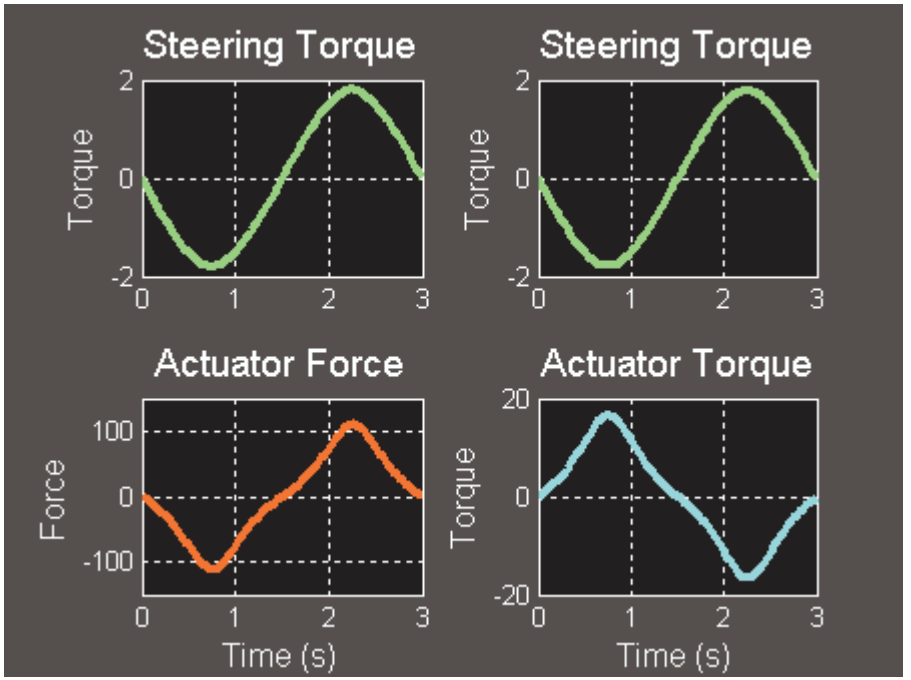


- Simulation goals
  1. Determine requirements for actuation systems
  2. Test performance with electrical or hydraulic actuation
  3. Optimize the actuation system
  4. Assess effects of system implementation

Determining Actuator Requirements

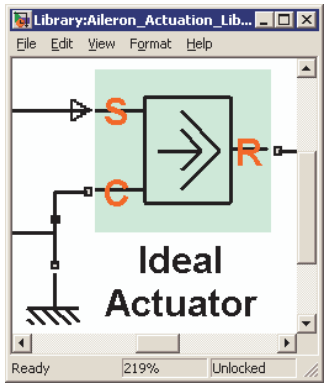
Model:

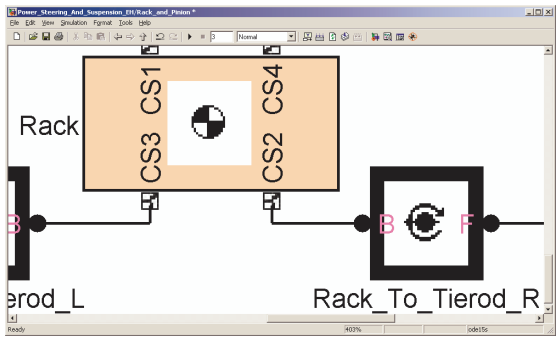




Problem: Determine the requirements for hydraulic and electric power steering actuators

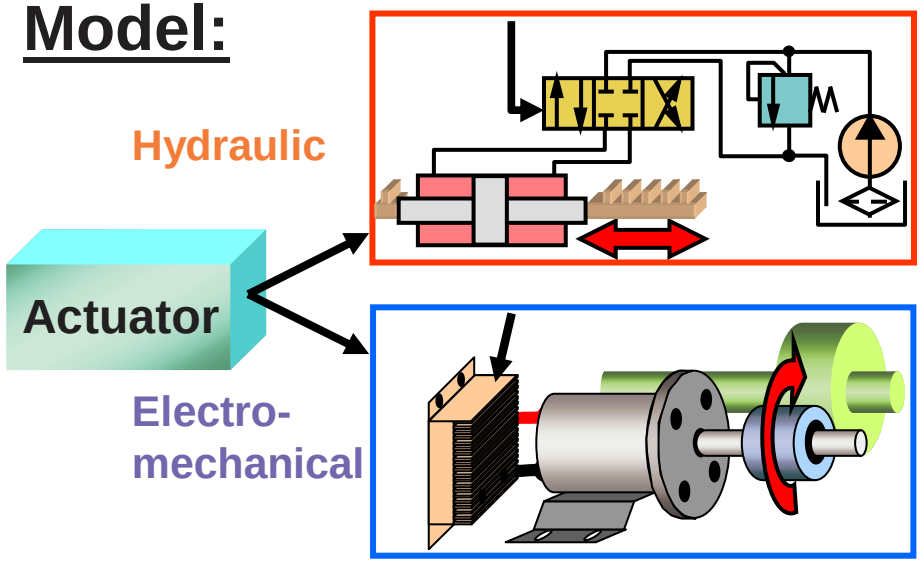
Solution: Use SimMechanics™ to model the steering system and Simscape™ for an ideal actuator

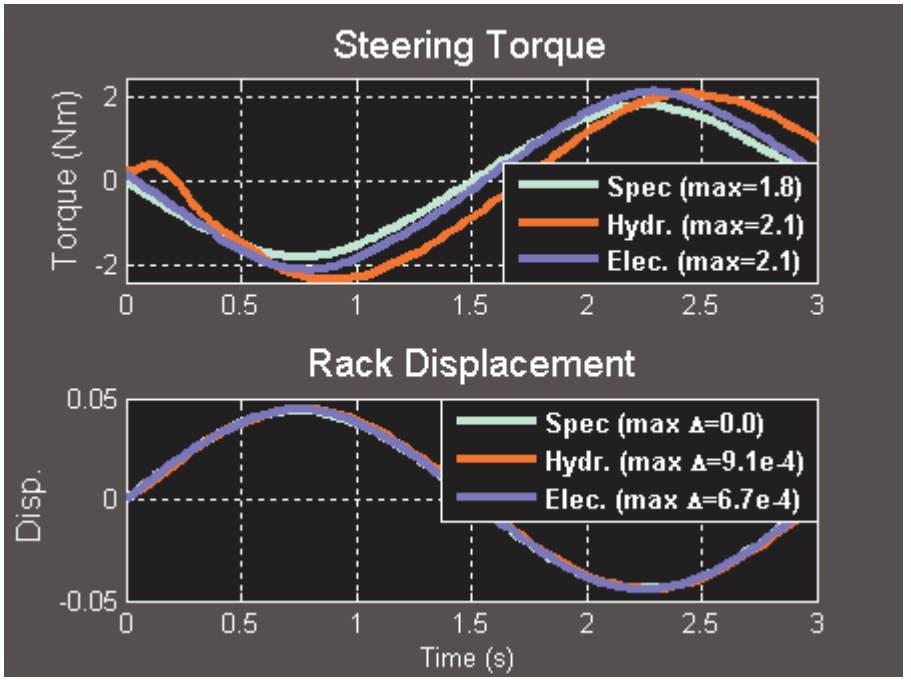




Test Electrical and Hydraulic Designs

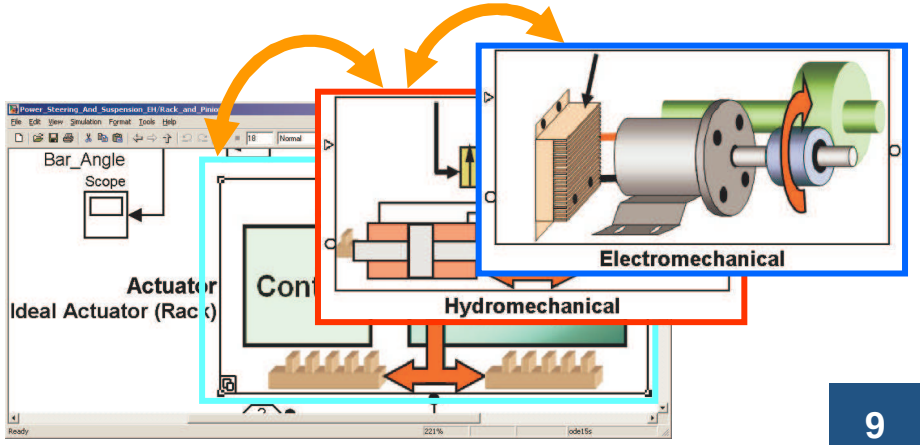
Model:





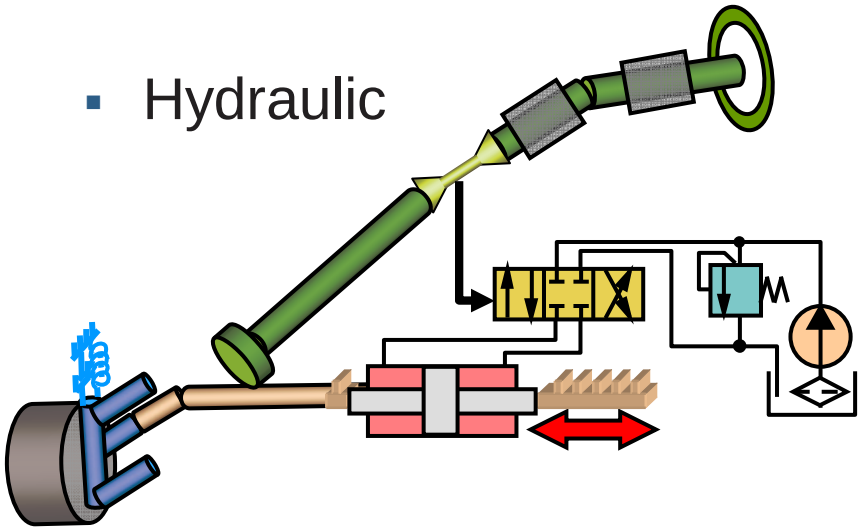
Problem: Test different actuator designs in the system

Solution: Use SimHydraulics™ and SimElectronics™ to model the actuators, and configurable subsystems to exchange them



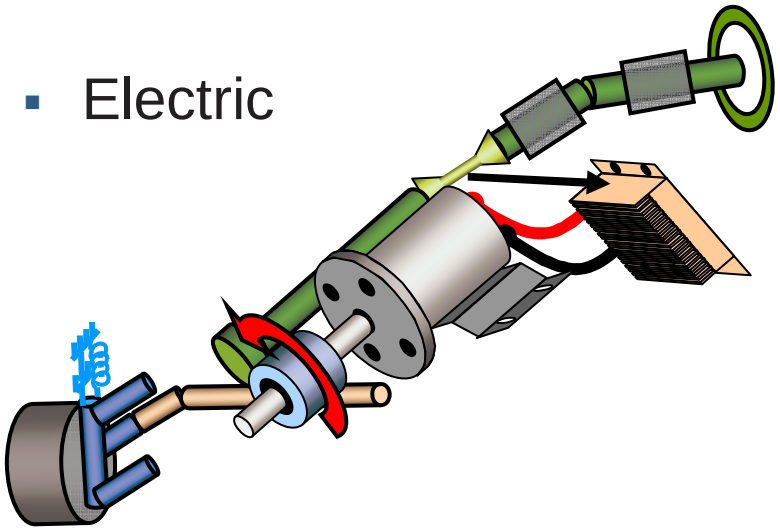
Actuator System-Level Designs

- Hydraulic



  - Valve position controller
  - Directional valve
  - Double-acting hydraulic cylinder
  - Fixed-displacement pump
  - Pressure-relief valves

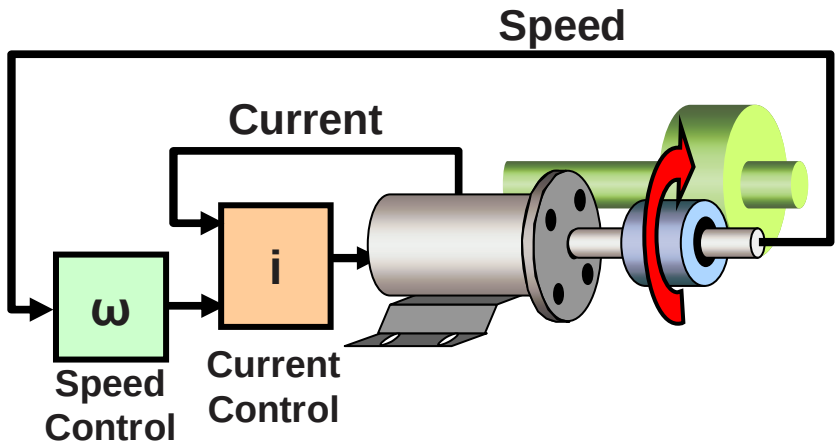
- Electric

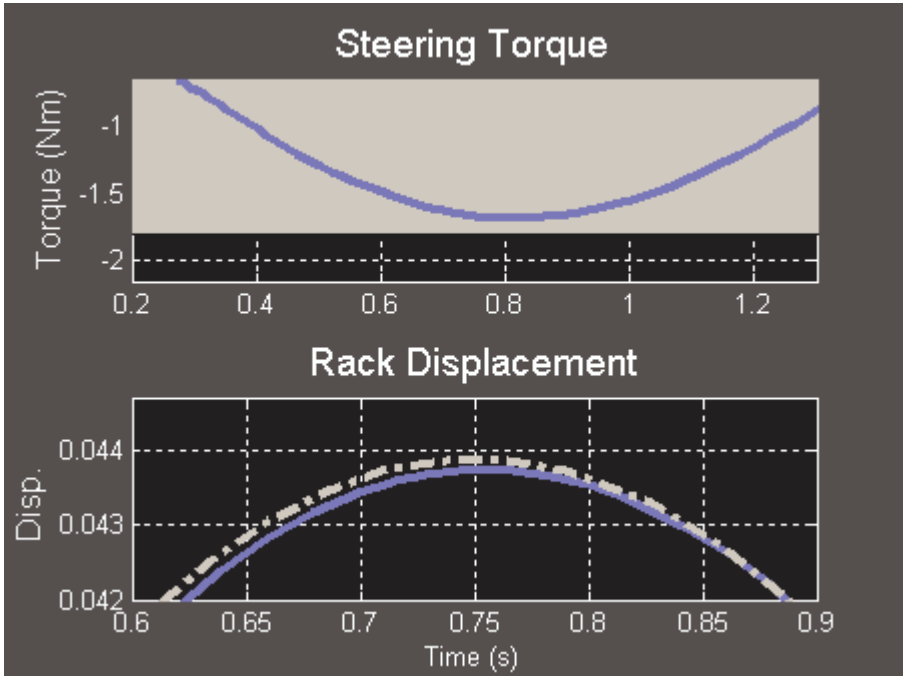


  - DC Motor
  - Current sensor and current controller
  - Hall effect sensor and speed controller
  - PWM and H-bridge driver

Optimize System Performance

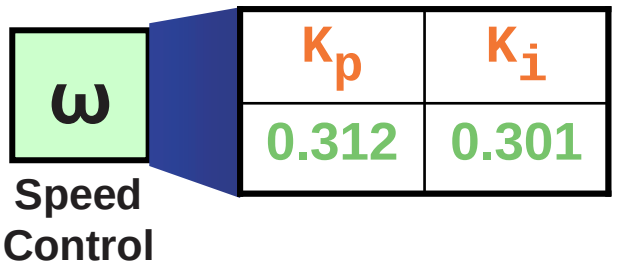
Model:





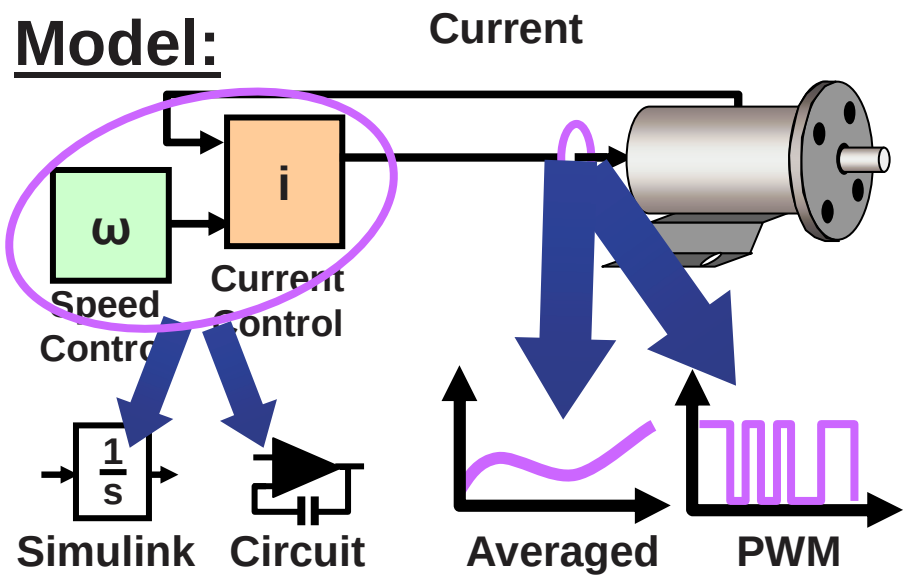
Problem: Optimize the speed controller to meet system requirements

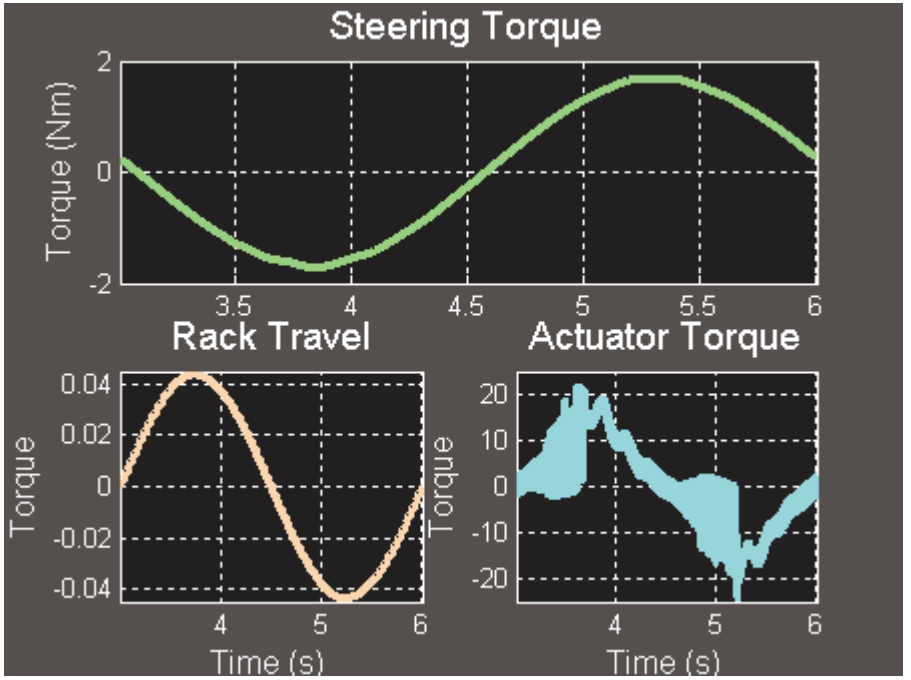
Solution: Use Simulink Response Optimization™ to tune the controller parameters



Assess Implementation Effects

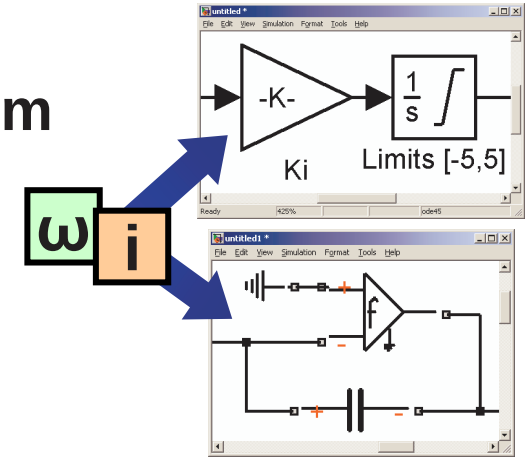
Model:

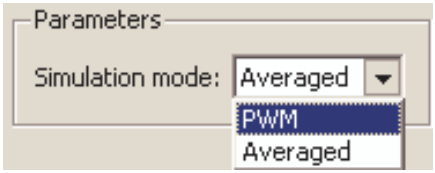




Problem: Assess the effects of design implementation on system performance

Solution: Use SimElectronics™ to add a PWM signal and analog circuit implementation



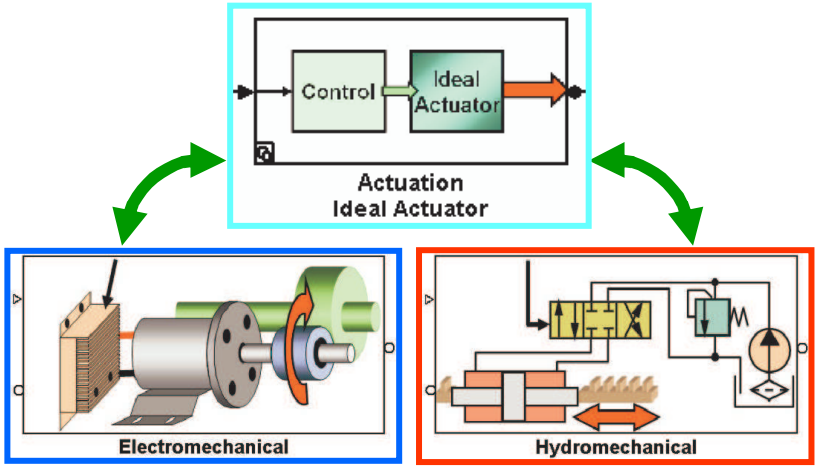


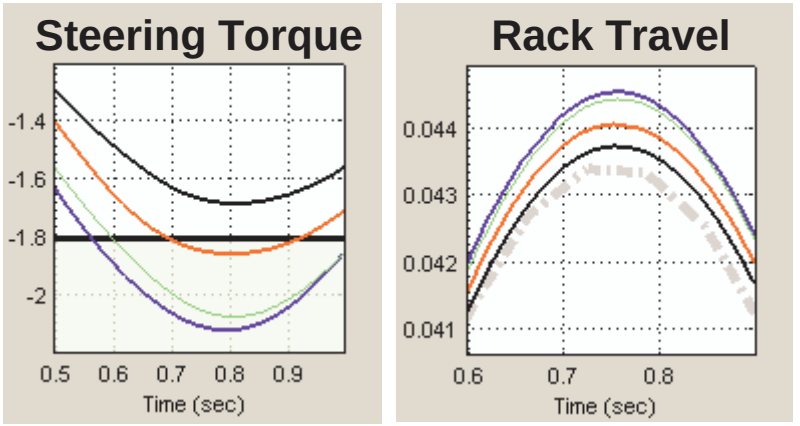
Conclusion

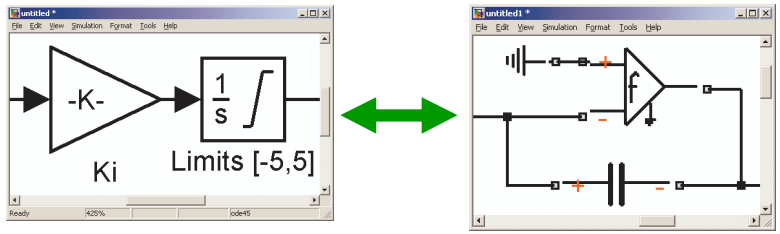
1. Testing different actuator designs in one environment saves time and encourages innovation

2. Optimizing systems with respect to design requirements leads to optimal design choices

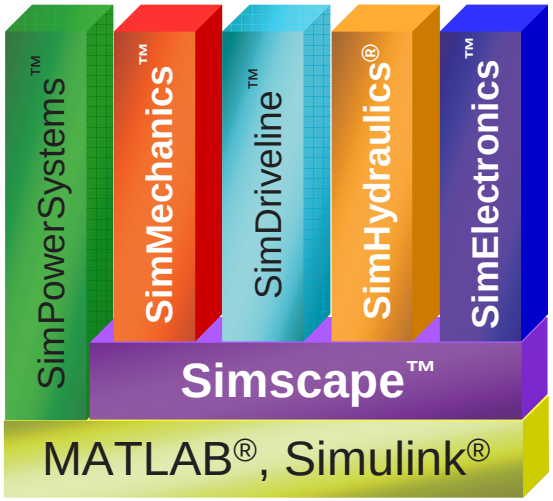
3. Simulating at different levels of fidelity is required throughout the development process



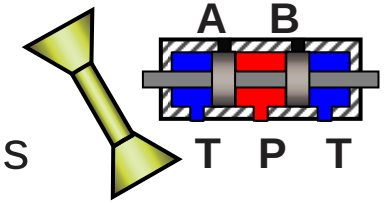




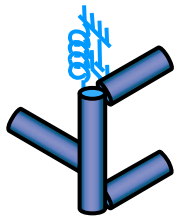
MathWorks Products Used



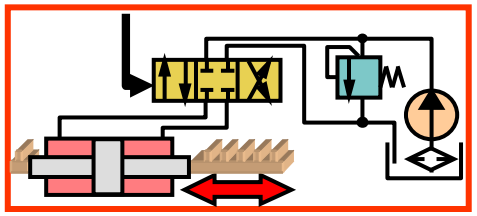
- Simscape™
  - Multidomain physical systems



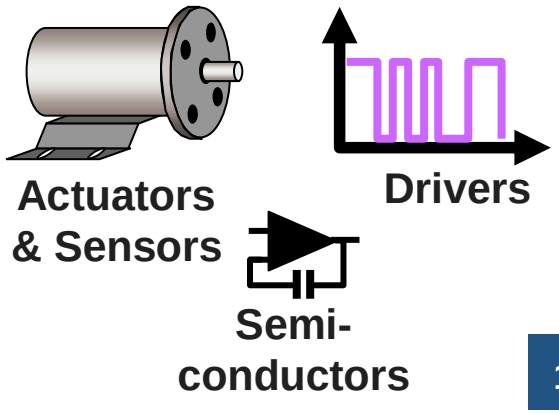
- SimMechanics™
  - 3-D mechanical systems



- SimHydraulics®
  - Hydraulic (fluid power) systems



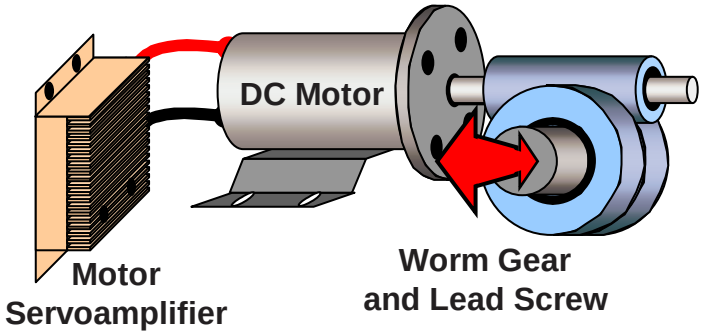
- SimElectronics™ (new)
  - Electronic and electromechanical systems



- Simulink Parameter Estimation
- Simulink® Response Optimization™

Physical Modeling Master Class (4:00 – 5:30PM)

- Build up pieces of power steering system (electric, hydraulic)
- Tune parameters using measurement data
- Build custom components (valves, etc.)



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