Using Physical Modeling Tools to Design Power Optimized Aircraft

Key Points

Actuation
Ideal Actuator

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

Actuation
Hydromechanical

Actuation
Electromechanical

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

Aileron Angle

Actuator Force

3. Simulating at different levels of fidelity is required to see effects of design implementation
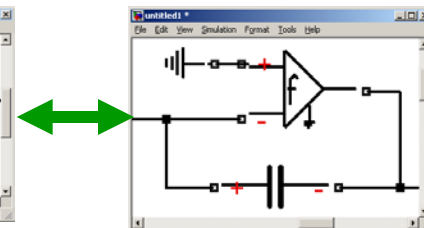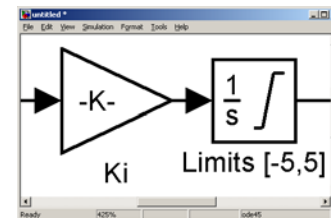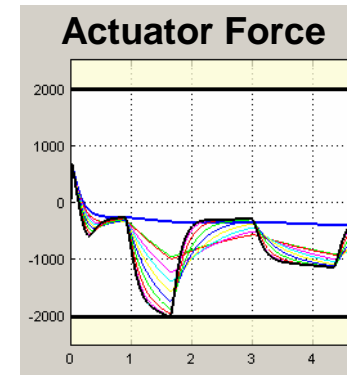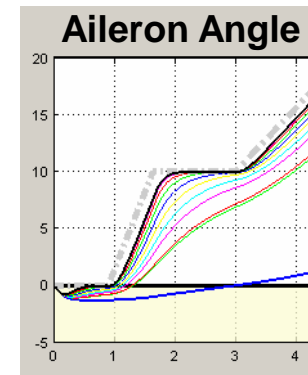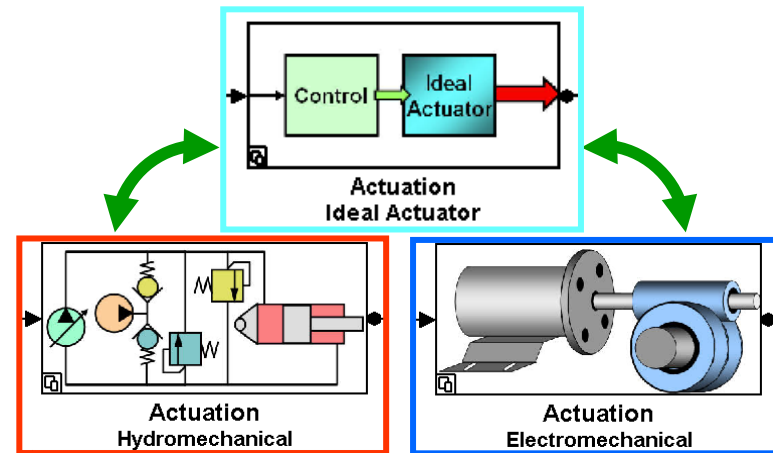
Agenda

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

Industry Trends

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

- Example goals
  - Clean Sky (for year 2020)
    - 50% reduction of CO_2 emissions
    - 80% reduction of nitrous oxide emissions
  - Power Optimized Aircraft (POA)
    - 25% cut in peak non-propulsive power
    - 5% reduction in fuel consumption

- Strategies include aircraft-level optimization, technology

"With 5-6°C warming … existing models … estimate an average 5-10% loss in global GDP."

Head of the Government Economic Service UK, 2006

Research project, EU and industry

Strategies for Improved Aircraft 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

- Aircraft-level optimization
  - Consolidation of power electronics
  - Localize hydraulic actuation

- Simulation can help with each of these strategies

**_Boeing 787_
Electrical Systems**
Brakes
Ice protection
Engine start
Environmental controls
Electrohydraulic pumps

**_Airbus 380_
Electrical Systems**
Primary flight control actuators
Thrust reverser actuation
Horizontal stabilizer backup

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
    – Must be done at aircraft level to optimize architecture
    – Few key parameters and quick simulation

3. Simulating at different levels of fidelity
    – Need to easily add fidelity to see impacts of implementation
    – Reuse work done at system level (Model-Based Design)

Example: Aileron Actuation System

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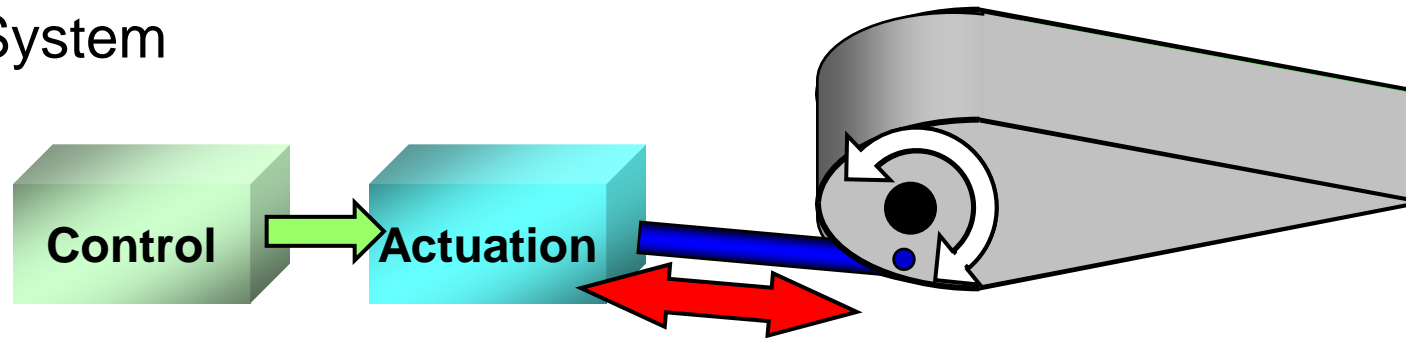
- Simulation goals
  1. Determine requirements for actuation system
  2. Test performance with electrical or hydraulic actuation
  3. Optimize the actuation system
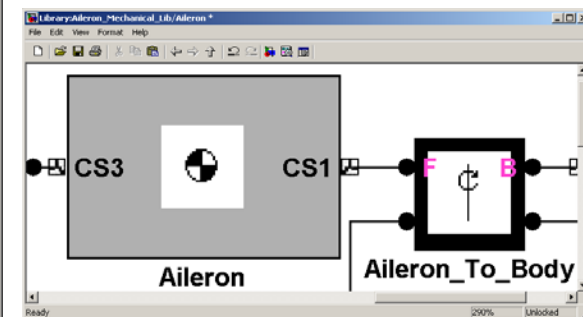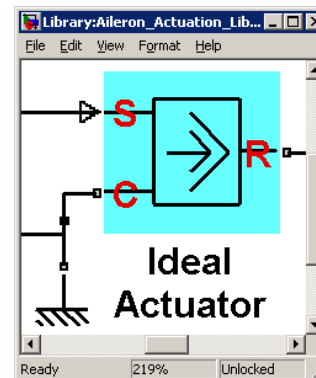 4. Assess effects of system implementation

Determing Actuation Requirements

Model:

$\theta_{Aileron}$

Ideal Actuator

Angle (deg)

Actuator Force Required
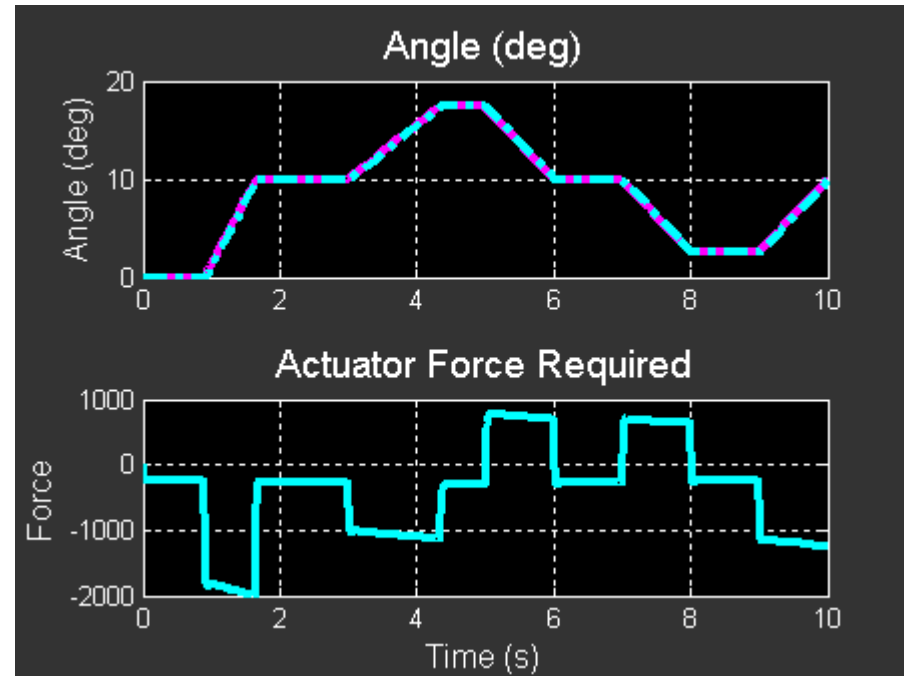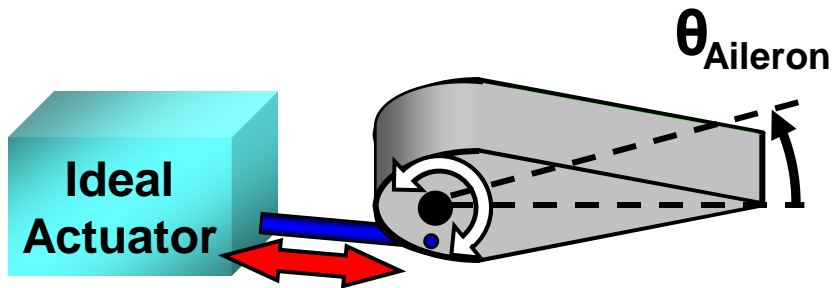
Problem: **Determine the requirements for an aircraft aileron actuator**

Solution: **Use SimMechanics to model the aileron and Simscape to model an ideal actuator**

Ideal Actuator

Aileron   Aileron_To_Body

Test Electrical and Hydraulic Designs

Model:

Hydraulic
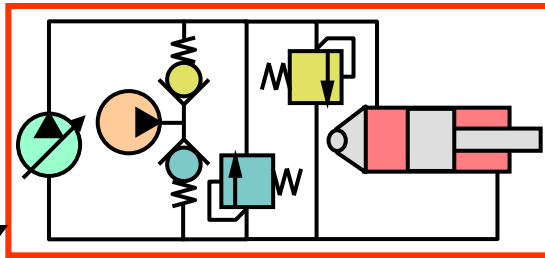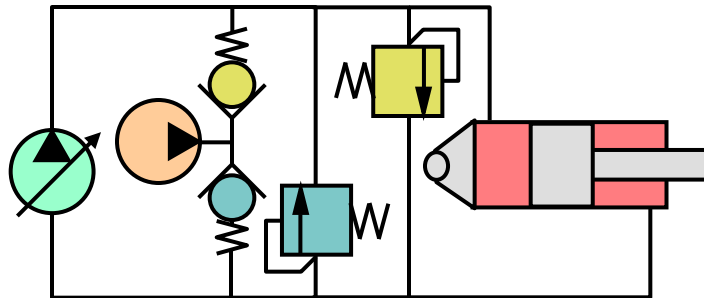
Actuator

Electro-mechanical
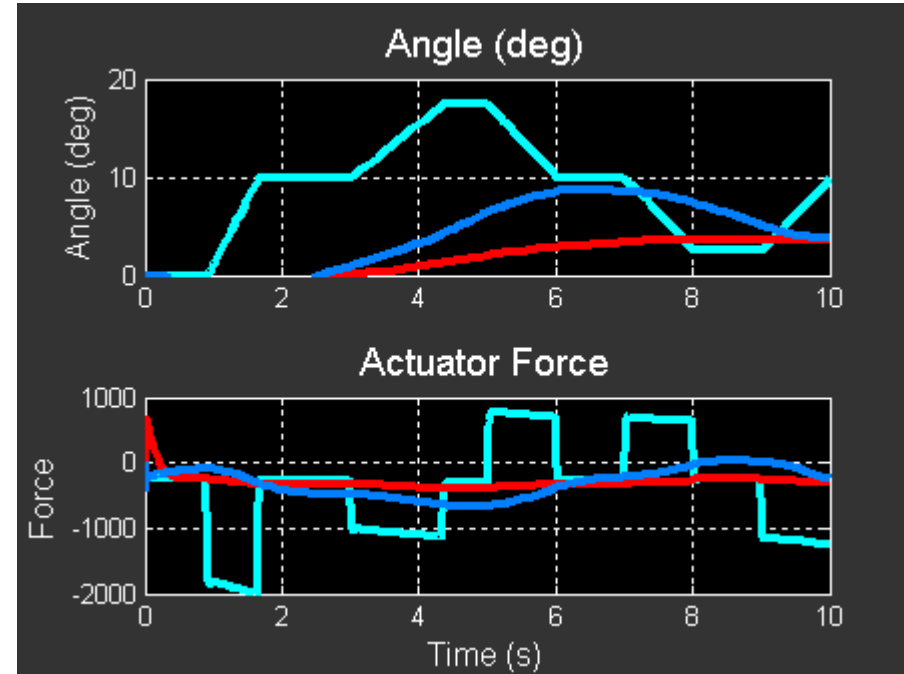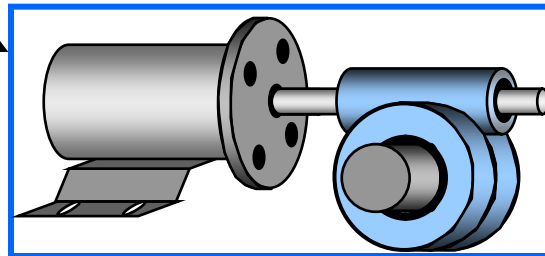
Problem: Test different actuator designs in the system

Solution: Use **SimHydraulics** and **SimElectronics** to model the actuators, and **configurable subsystems** to exchange them
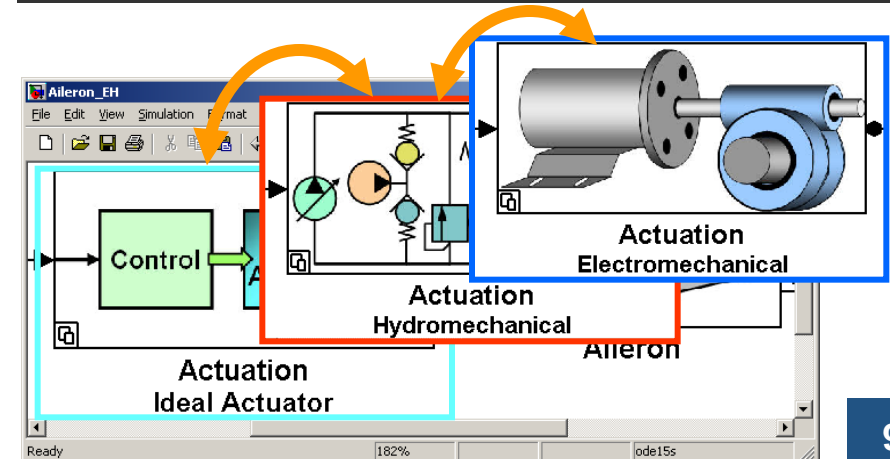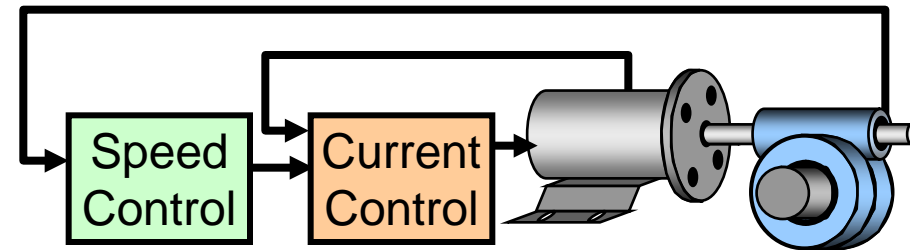
Actuator System-Level Designs

- Hydrostatic transmission

    - Variable-displacement pump
    - Double-acting
      hydraulic cylinder
    - Replenishing valves
    - Pressure-relief valves
    - Charge pump
    - Speed controller
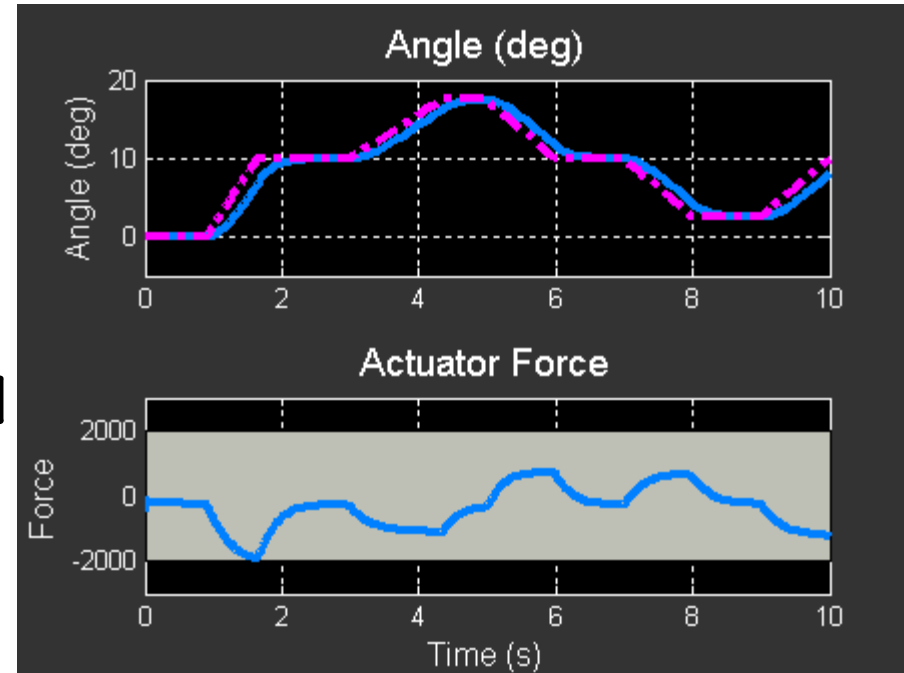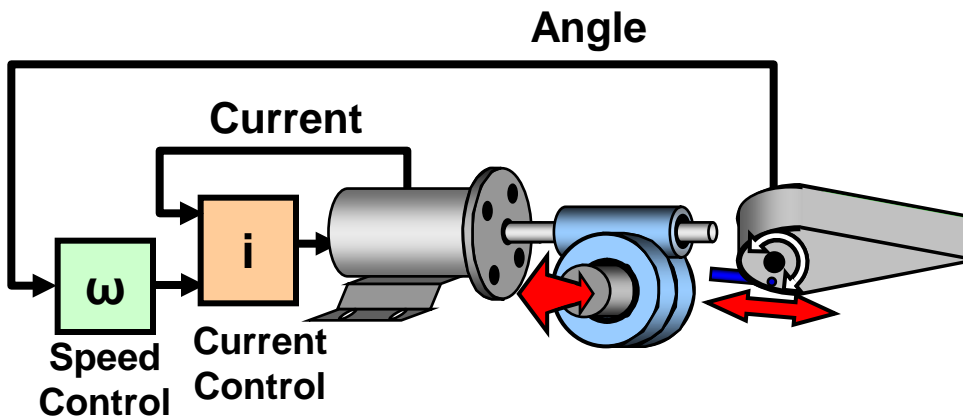
- Electromechanical system

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

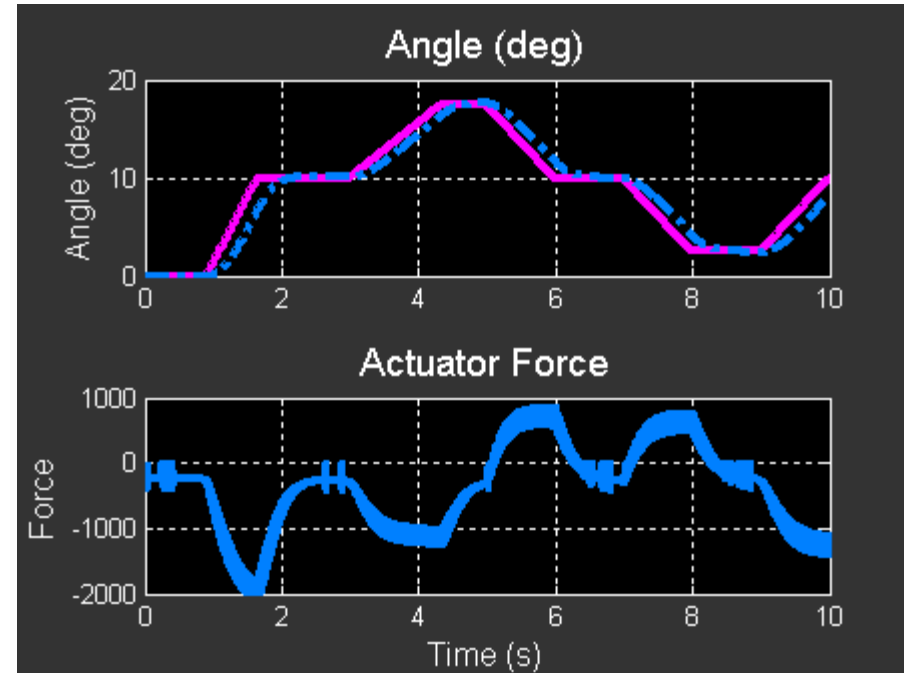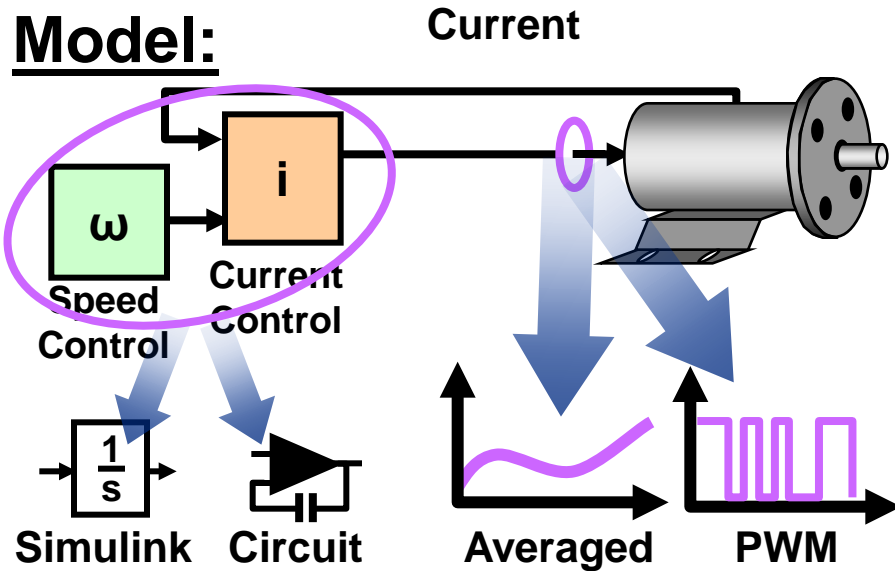# Optimize System Performance

Model:

Angle

Current

i

ω

Speed Control

Current Control

Problem: Optimize the speed controller to meet system requirements

Solution: Use [Simulink Design Optimization](#) to tune the controller parameters

ω

Speed Control

K_p	K_i
23.4	**3.67**

Assess Implementation Effects

Model:

Current

ω — Speed Control

i — Current Control

Simulink   Circuit   Averaged   PWM

Problem: Assess the effects of design implementation on system performance

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

-K- Ki   1/s Limits [-5,5]

ω i

Parameters
Simulation mode: Averaged
PWM
Averaged

12

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 to see effects of design implementation
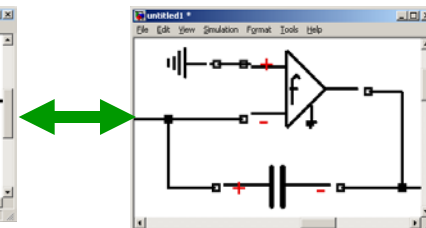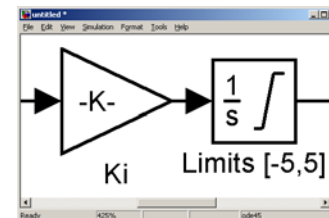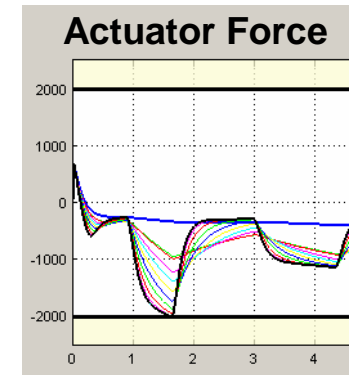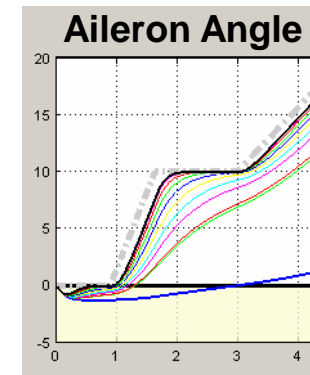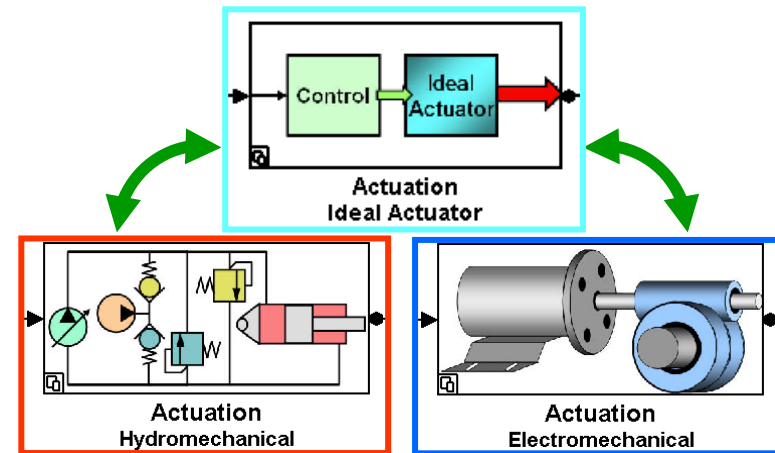
MathWorks Products Used

- ## Simscape
  - Multidomain physical systems

- ## SimMechanics
  - 3-D mechanical systems

- ## SimHydraulics
  - Hydraulic (fluid power) systems

- ## SimElectronics (new)
  - Electronic and electromechanical systems

- ## Simulink Design Optimization

SimPowerSystems · SimMechanics · SimDriveline · SimHydraulics · SimElectronics

Simscape

MATLAB, Simulink
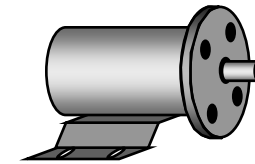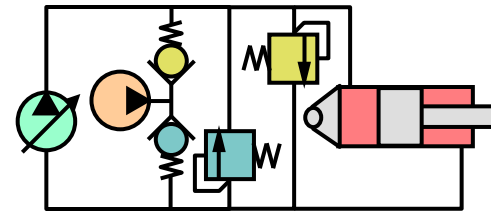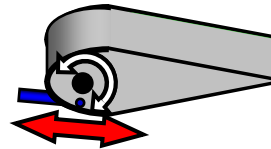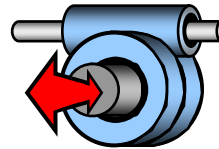
Actuators & Sensors

Drivers

Semi-conductors