Using Physical Modeling Tools to Design Power Optimized Aircraft

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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 to see effects of design implementation
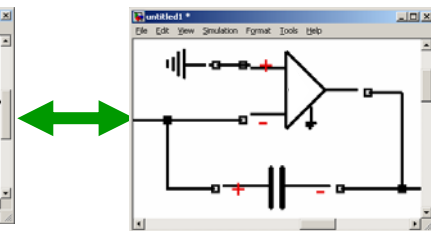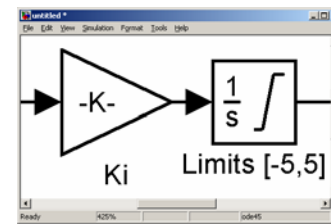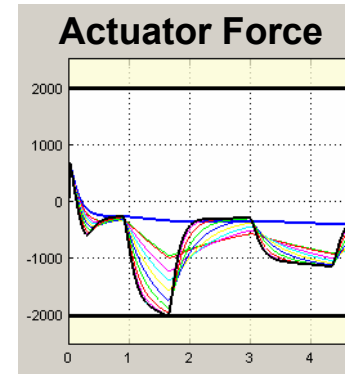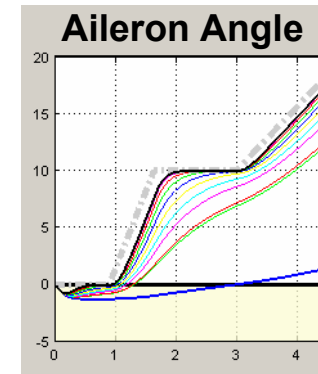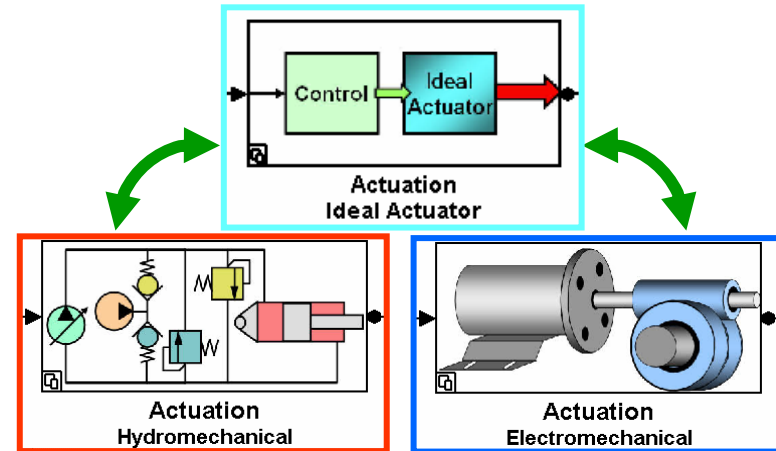
Agenda

- 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

- <u>Aircraft-level</u> 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
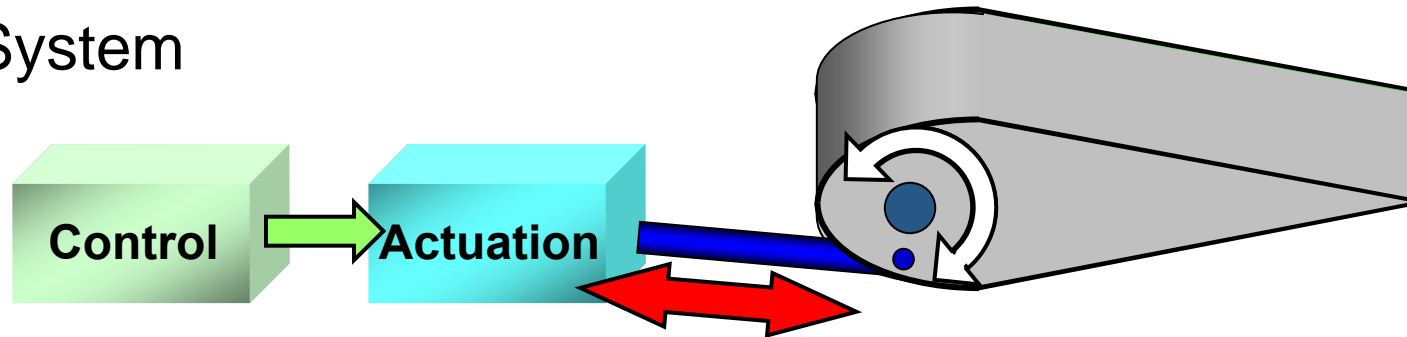
- ## Simulation goals

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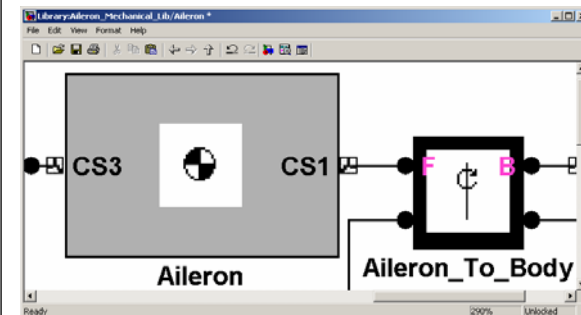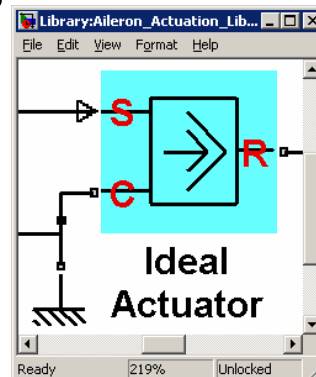 4. Assess effects of system implementation

Determining Actuation Requirements

Model:

θ_Aileron
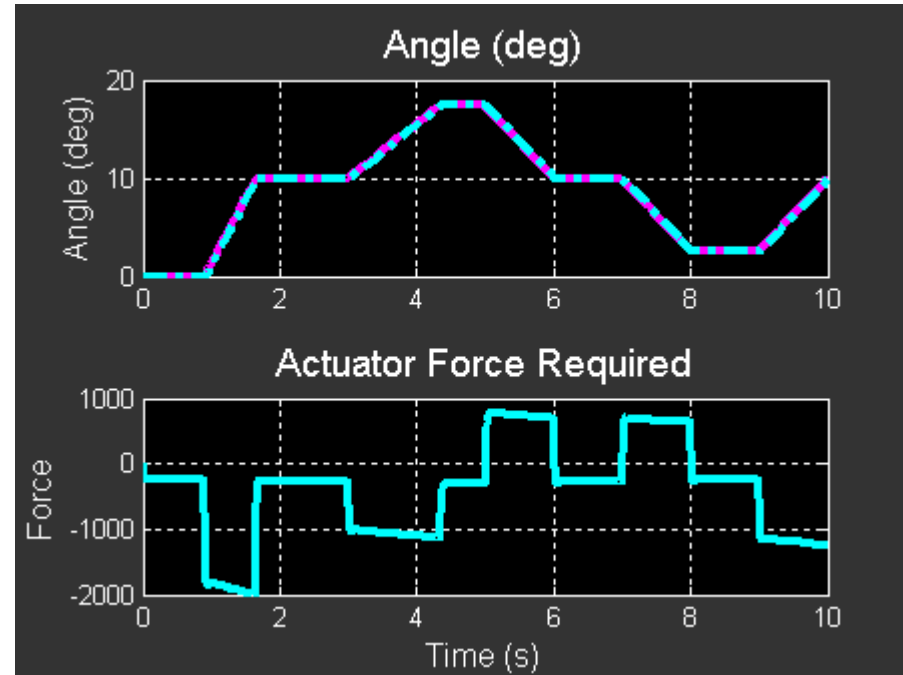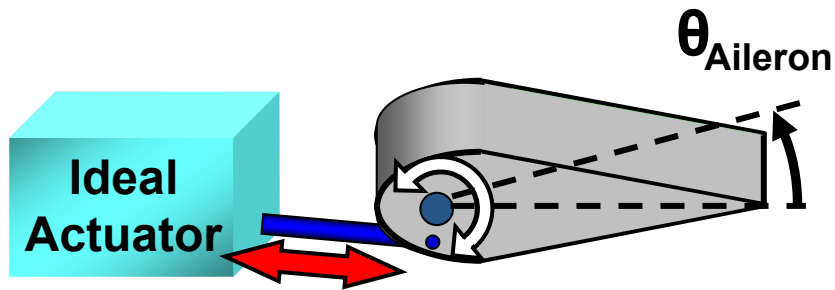
Ideal Actuator

Problem: Determine the requirements for an aircraft aileron actuator

Solution: Use **SimMechanics™** to model the aileron and **Simscape™** to model an ideal actuator
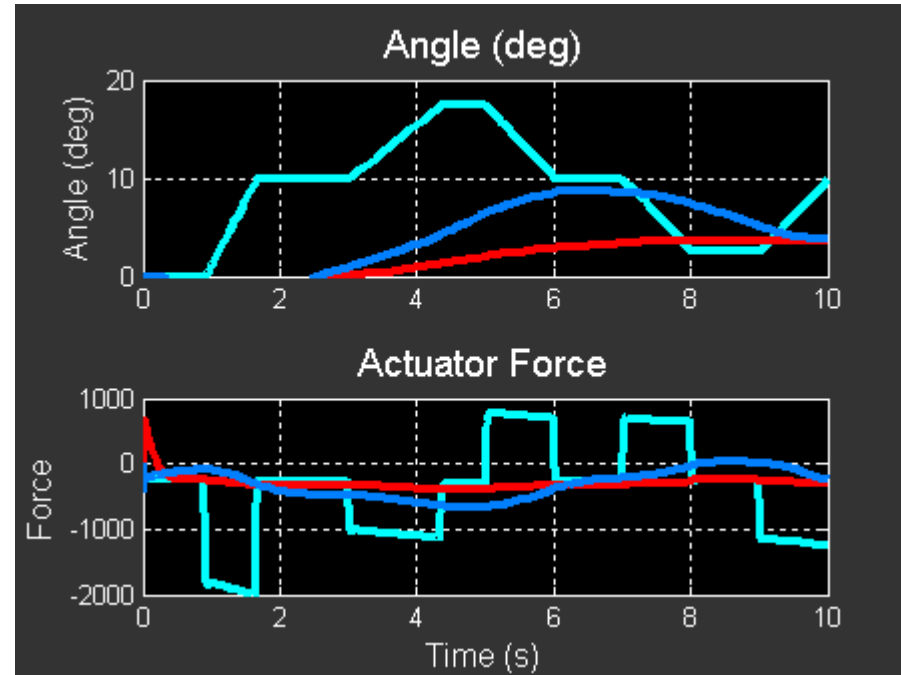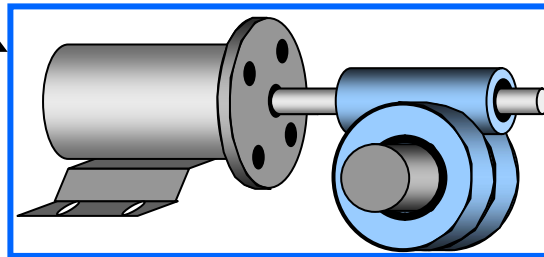
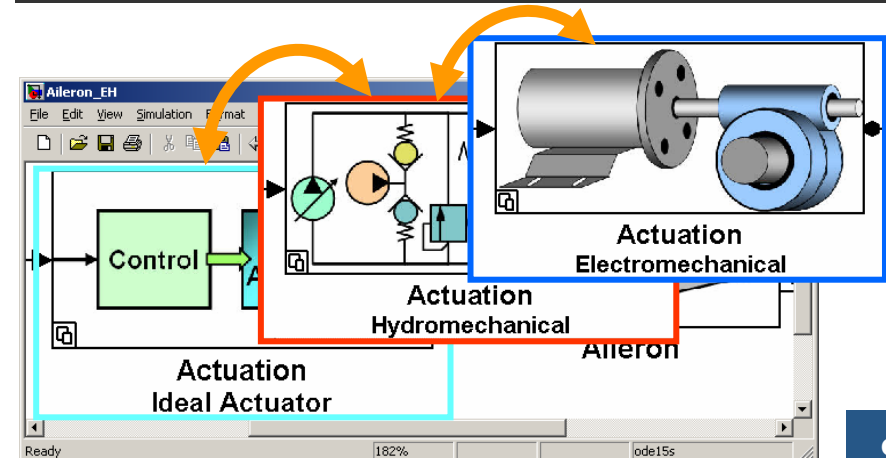# Test Electrical and Hydraulic Designs
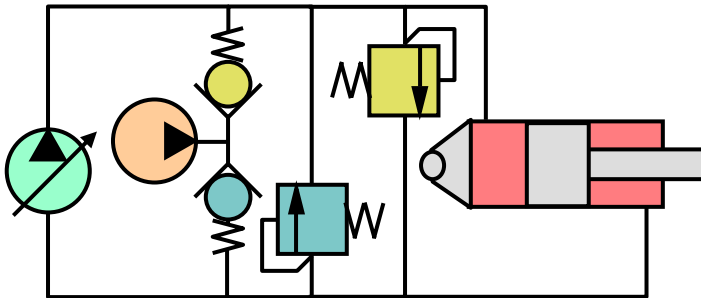
Model:

Hydraulic
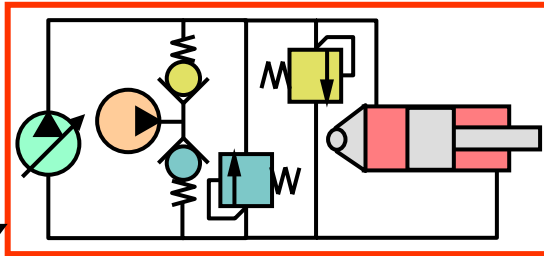
Actuator

Electro-mechanical

Problem: Test different actuator designs in the system

Solution: Use SimHydraulics® and Simscape to model the actuators, and configurable subsystems to exchange them
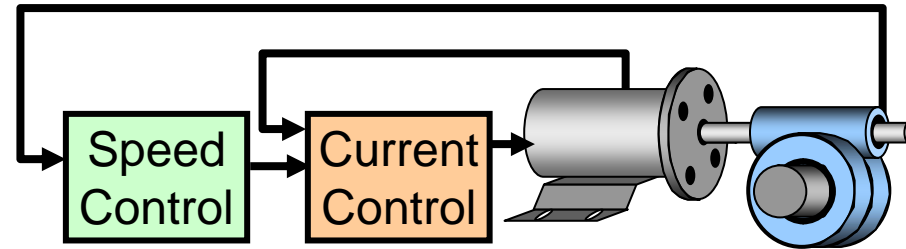

9

Actuator System-Level Designs

- Hydrostatic transmission

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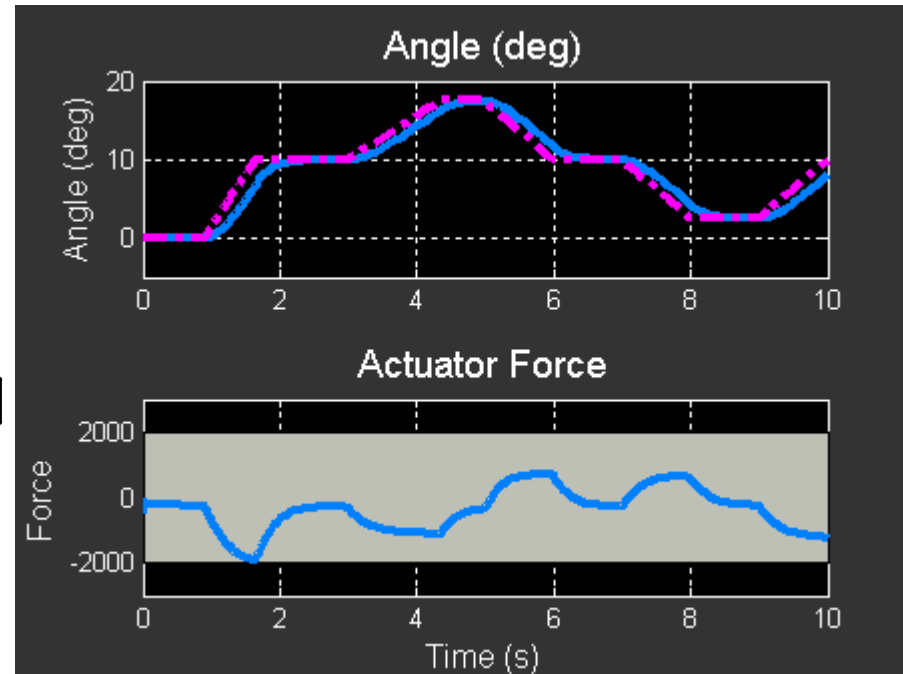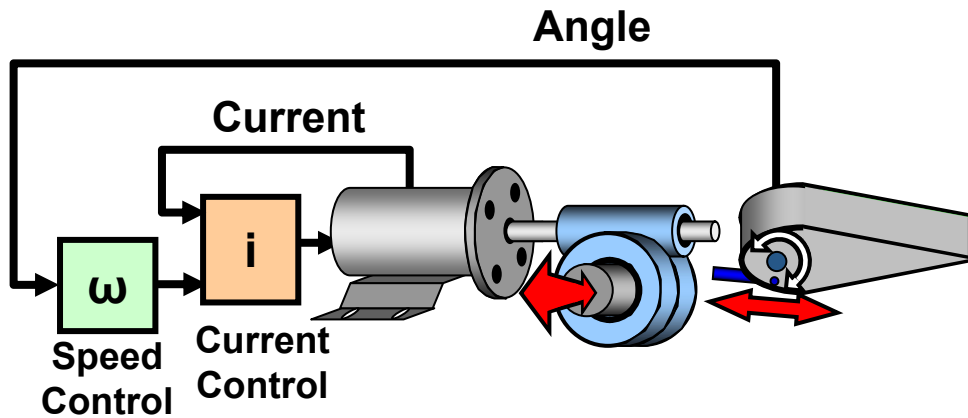 - Speed controller

- Electromechanical system

  - DC Motor
  - Worm gear
  - Current sensor
    and current controller
  - Hall effect sensor
    and speed controller

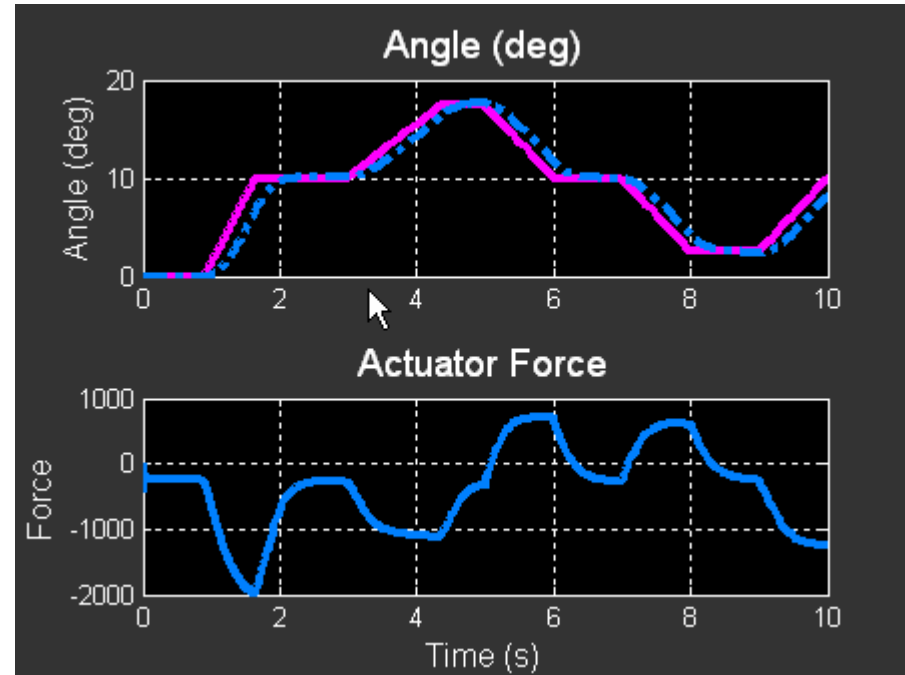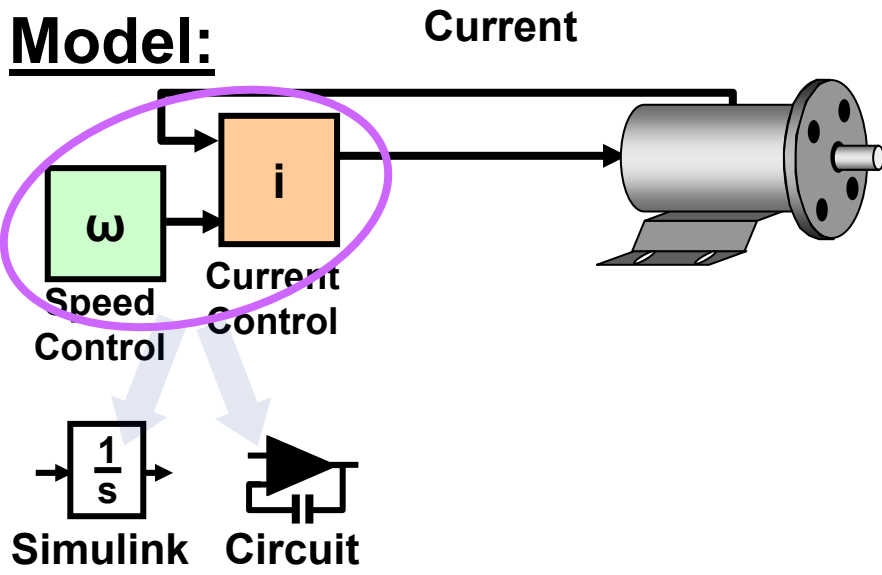# Optimize System Performance

Model:

Problem: Optimize the speed controller to meet system requirements

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

K_p	K_i
23.4	3.67

Assess Implementation Effects

Model:

Current

Speed Control

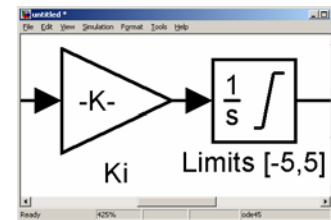**Current Control**

ω   i

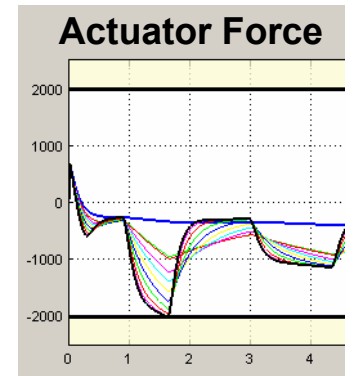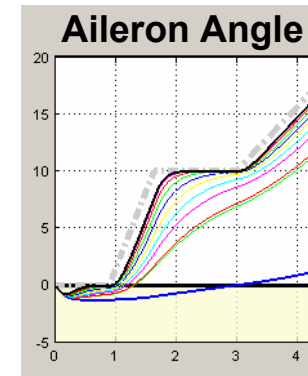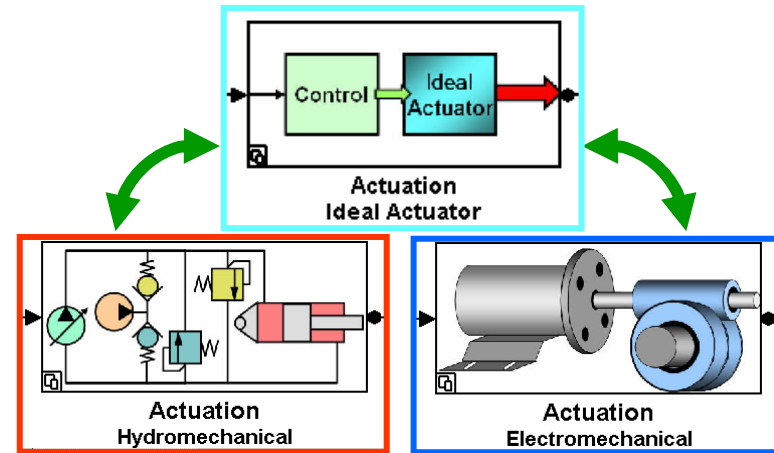$\frac{1}{s}$

Simulink   **Circuit**

Problem: **Assess the effects of design implementation on system performance**

Solution: Use **Simscape** to add a the analog circuit implementation

Angle (deg)

Actuator Force

Time (s)

-K-
Ki

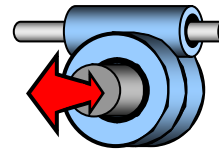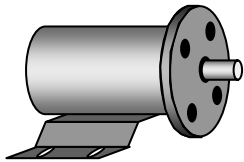$\frac{1}{s}$
Limits [-5,5]

ω   i

12
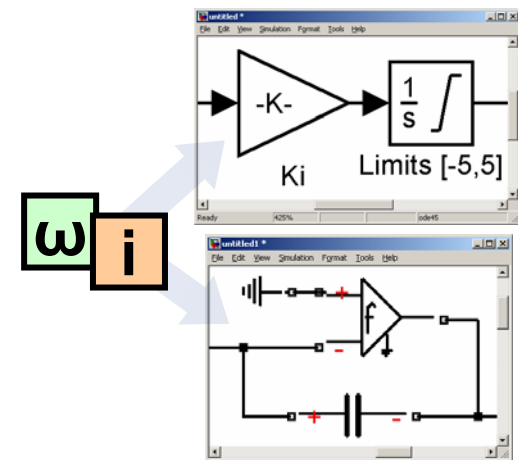
Conclusion

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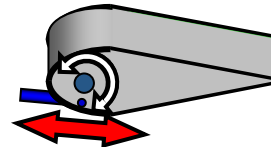

Actuation
Ideal Actuator

Actuation
Hydromechanical

Actuation
Electromechanical

Aileron Angle

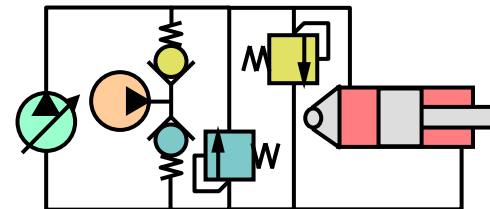Actuator Force
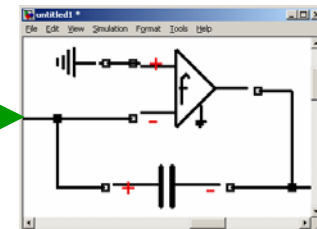
MathWorks Products Used

- ## Simscape
  - Multidomain physical systems

- ## SimMechanics
  - 3-D mechanical systems

- ## SimHydraulics
  - Hydraulic (fluid power) systems

- ## Simulink Response Optimization

SimPowerSystems™ SimMechanics SimDriveline SimHydraulics

Simscape

MATLAB, Simulink