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

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"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
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:

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
- 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.

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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

**Problem:** Optimize the speed controller to meet system requirements

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

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Model:

Model: \omega \rightarrow \text{Current Control} \rightarrow i \rightarrow \text{Current} \rightarrow \text{Angle}

\text{Speed Control} \rightarrow \omega

Solution parameters:

- \( K_p = 23.4 \)
- \( K_i = 3.67 \)
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Assess Implementation Effects

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

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

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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 Response Optimization

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