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Tuning Multi-Loop Compensators to Meet Time and Frequency Domain Requirements

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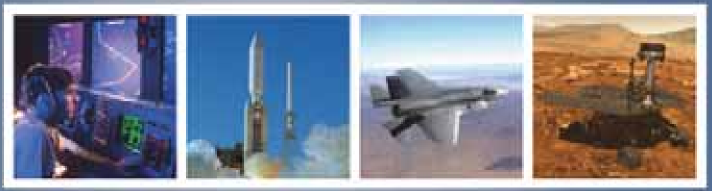
14 June 2006



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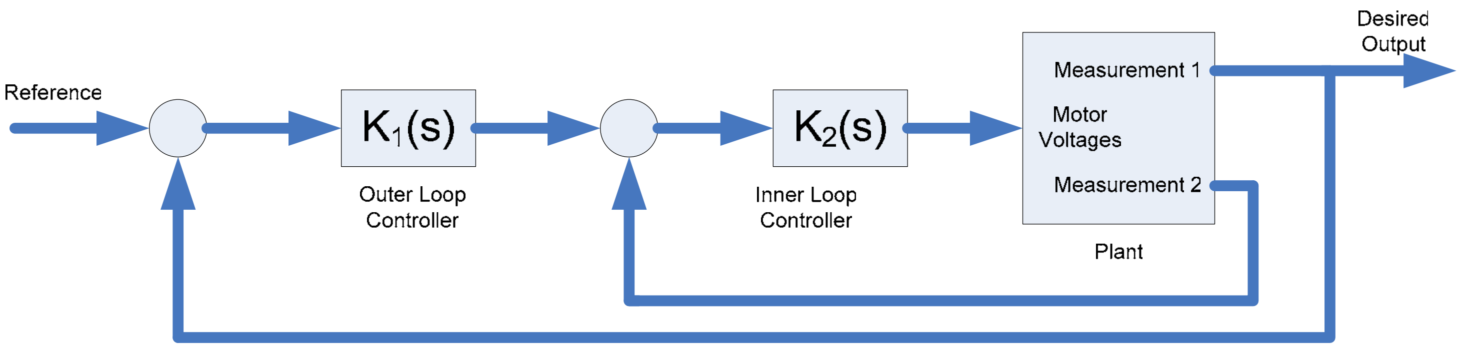
Presentation Overview

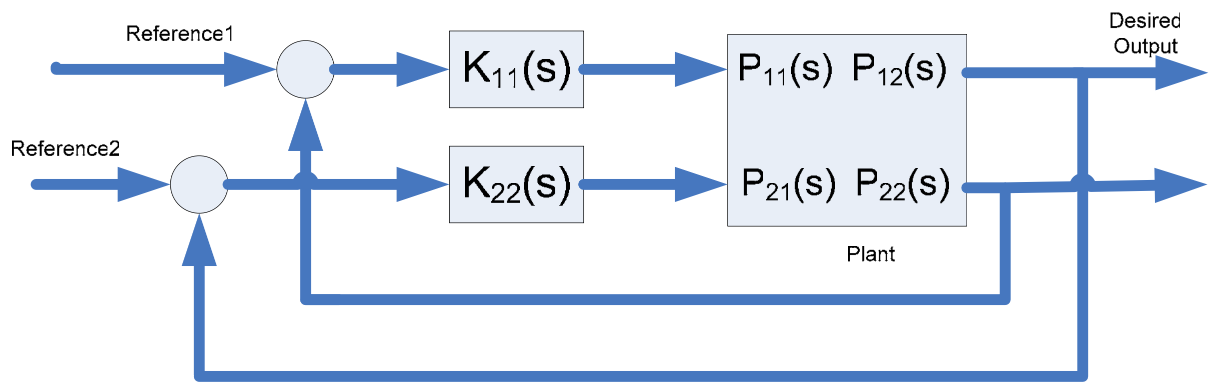
- Multi-loop control design
- Overview of multi-loop compensator design in Simulink®
- Guidance control system design using a Simulink model of an HL-20 lifting body

Multi-Loop Control Design

- Cascade Feedback Loops (Engine Control, Autopilot)



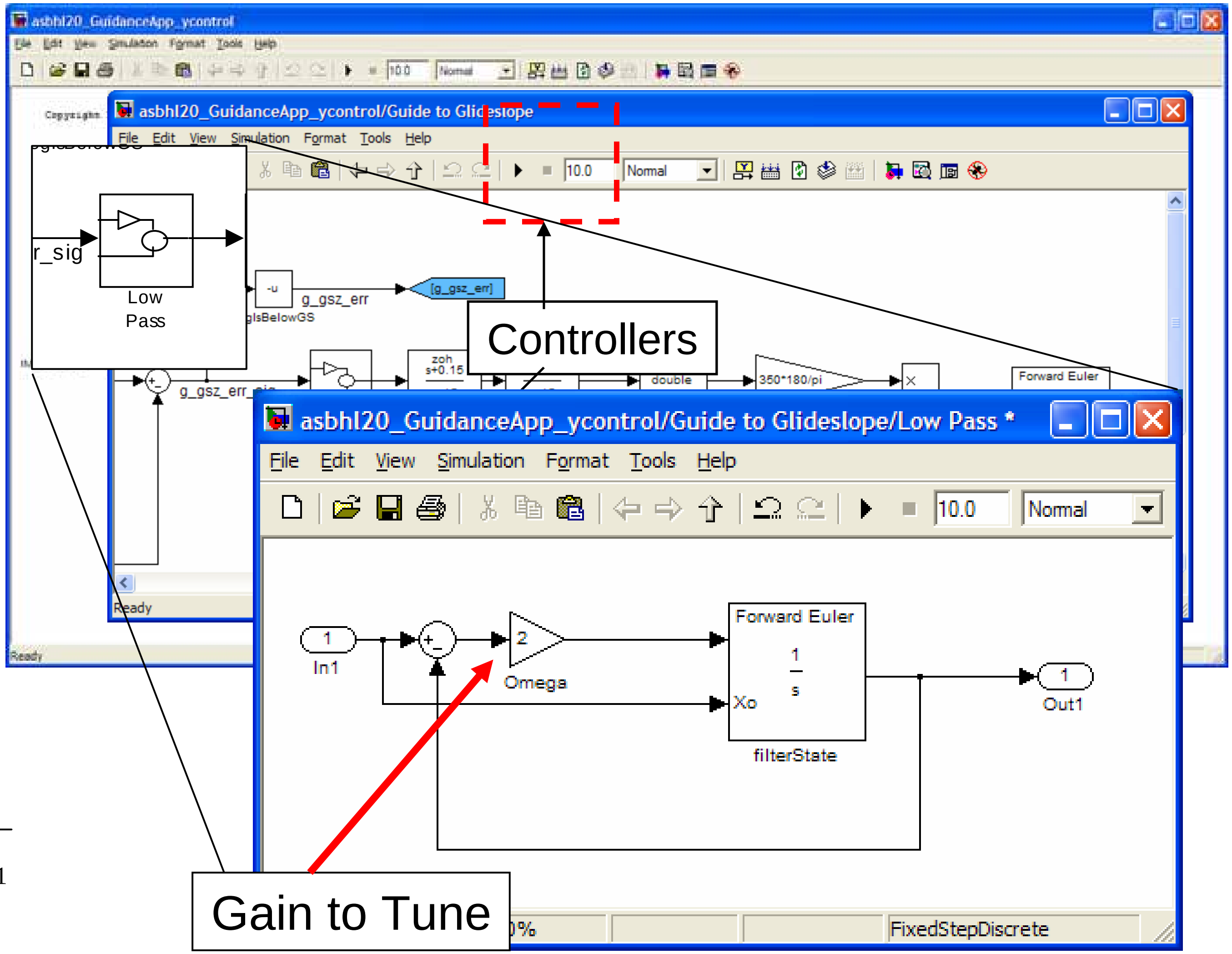
- Coupled Multi-Loop Control



Challenges of Multi-Loop Design

- Feedback structure may be fixed and controllers are distributed
- Multi-Loop Design has inherent loop interaction effects
- Many controllers are fixed structure, ex:

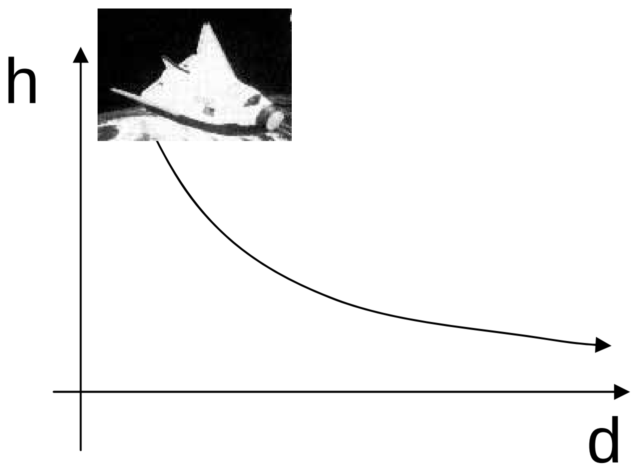
$$G(s) = \frac{\tau_1}{s + \tau_1}$$



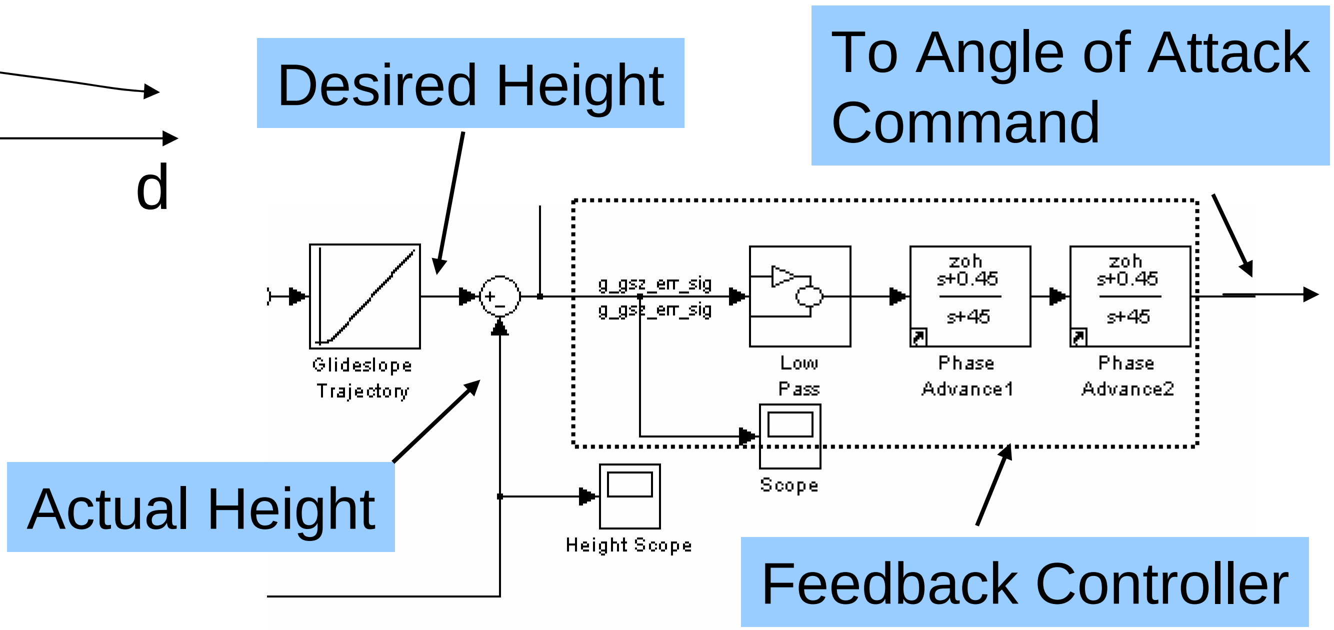
Application HL-20 Lifting Body

- Low cost re-entry vehicle
- Nose-first, horizontal, and unpowered landing
- Control system design tasks
  - Task 1: Flight control system design
  - Task 2: Guidance glideslope reference tracking and disturbance rejection
  - Task 3: Guidance yaw and roll corrections
  - Task 4: Landing gear control

HL-20 – Glideslope Control Problem

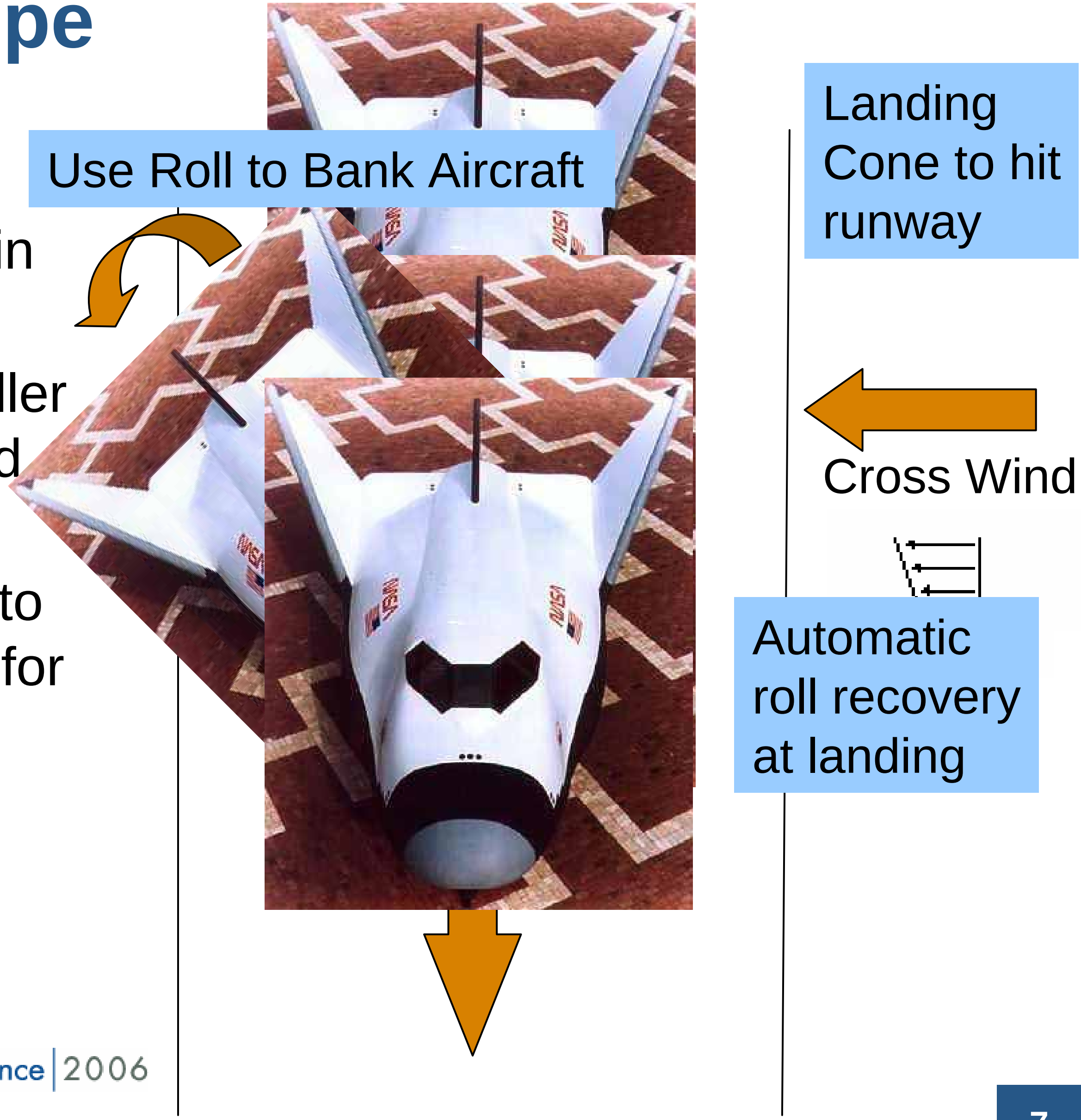


Goal: Build a feedback controller to control the height of the aircraft given the distance to the runway



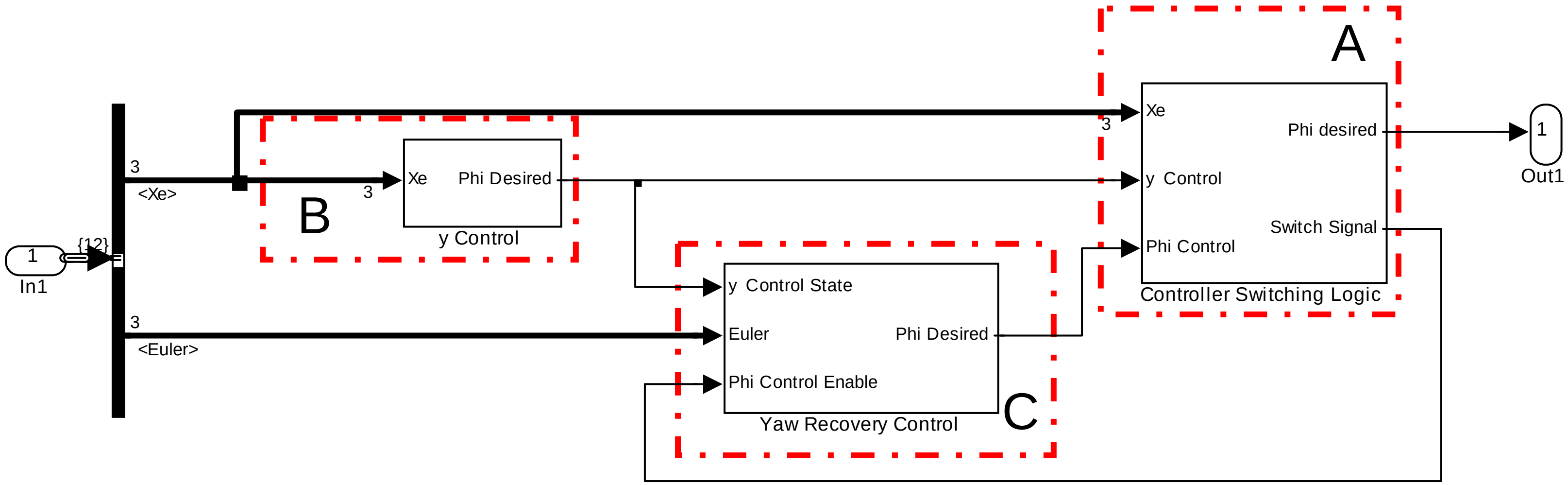
Lateral Glideslope Regulation

- Flight path must remain within the cone
- Need to devise controller to reject the cross wind disturbance
- Nearing landing need to recover any roll angle for a clean landing

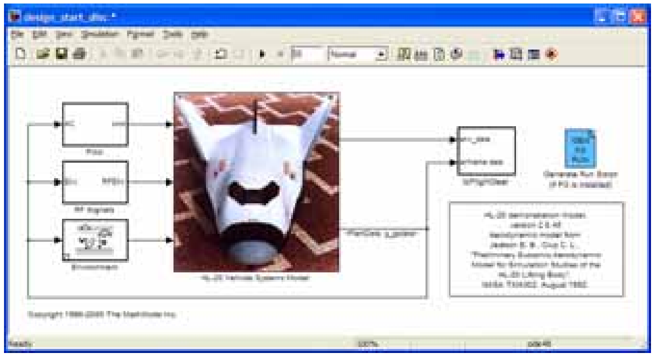


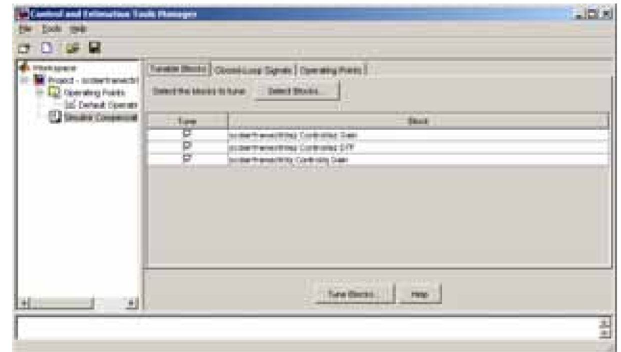
Side Gust Control

- Build a bump-less transfer controller (A) to switch between
  - (B) Controlling the drift of the aircraft due to cross wind
  - (C) Recovering the roll angle at landing



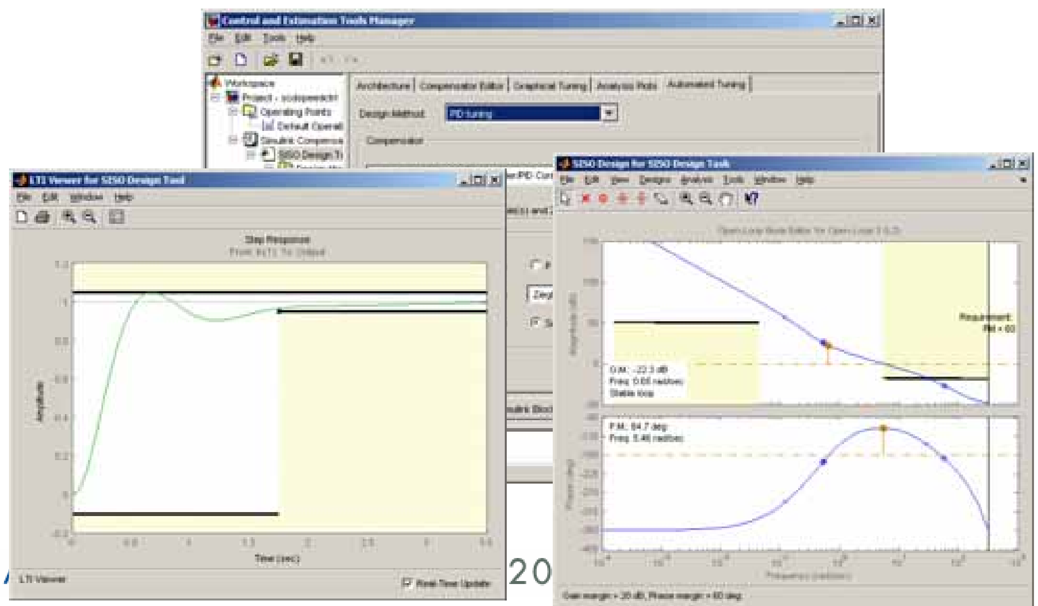
Designing Compensators in Simulink® in R2006a





1. Build a control system in Simulink – model plant and layout control structure

2. From Simulink Control Design pick blocks to tune and auto-linearize model



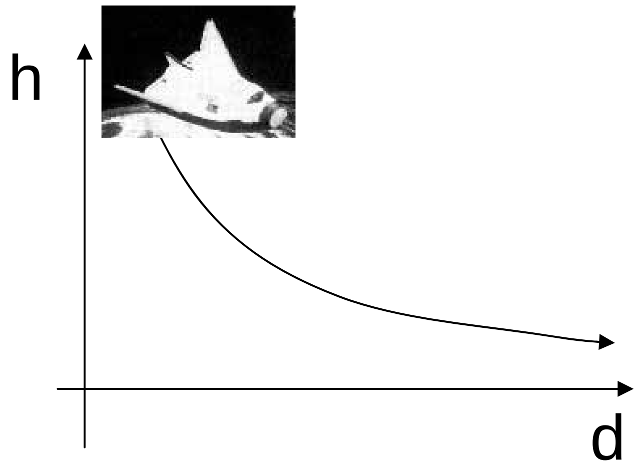
3. Tune blocks using graphical design
- **One-click automated design**
- **Interactive design**
- **Simulink Response Optimization to meet time and frequency requirements**

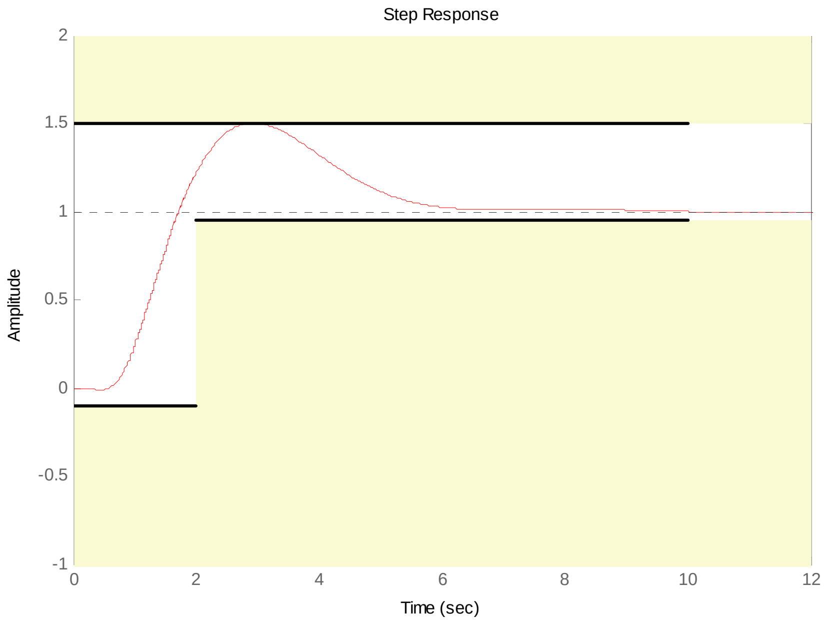
4. Write block parameters directly back to Simulink

Design Goals

- Robustness Requirement:
  - AoA Loop maintain a phase margin > 35 degrees
  - Phi Loop maintain a phase margin > 40 degrees
- Closed Loop Performance

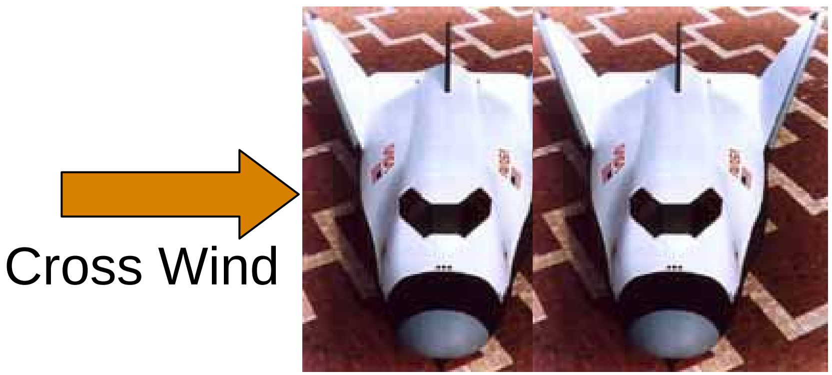
Height reference tracking

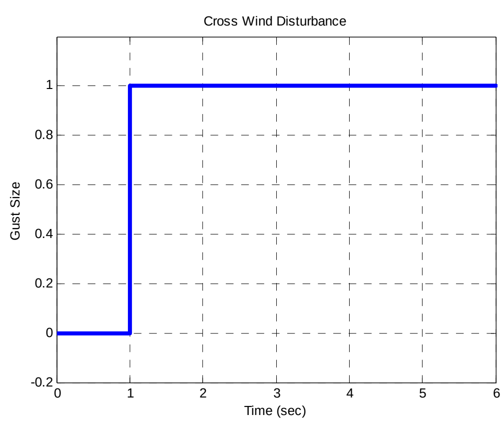


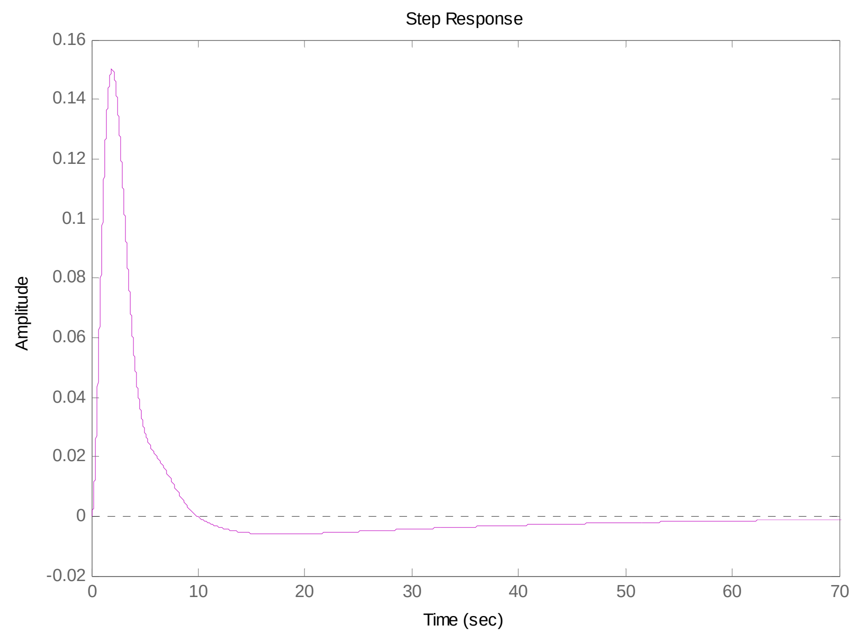


Closed Loop Performance Goals

Disturbance rejection:
Side wind gust to lateral glideslope deviations







Conclusions – Simulink Tools for Control Design

- New integrated workflow interface centered around Simulink in R2006a
- Build any control structure in Simulink and tune the compensators using these tools
- Tune multi-loop control systems in a single design environment
- Use graphical numerical optimization for compensator tuning, including frequency domain requirements