A UNIFIED CONTROL STRATEGY FOR FLIGHT DYNAMICS AND ACTUATORS

BASED ON DIRECT LOCAL ACCELERATION CONTROL

W. Meyer-Brügel and F. Silvestre

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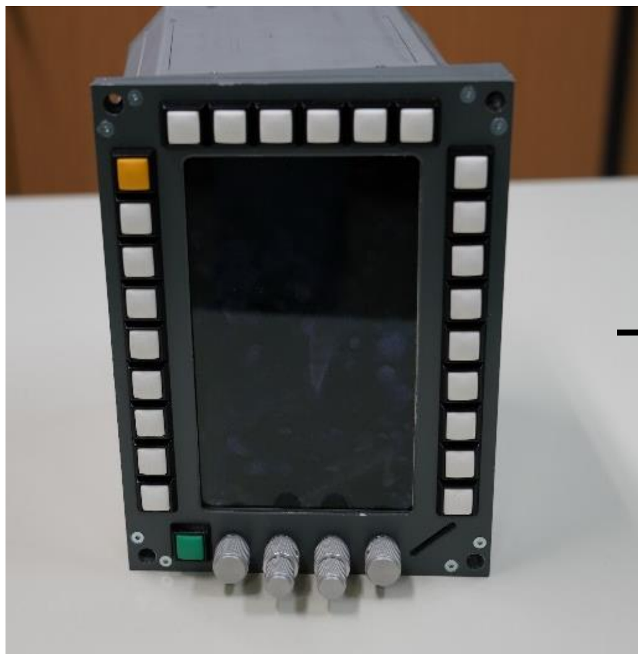
Actuator = Black Box?

Flight Control System

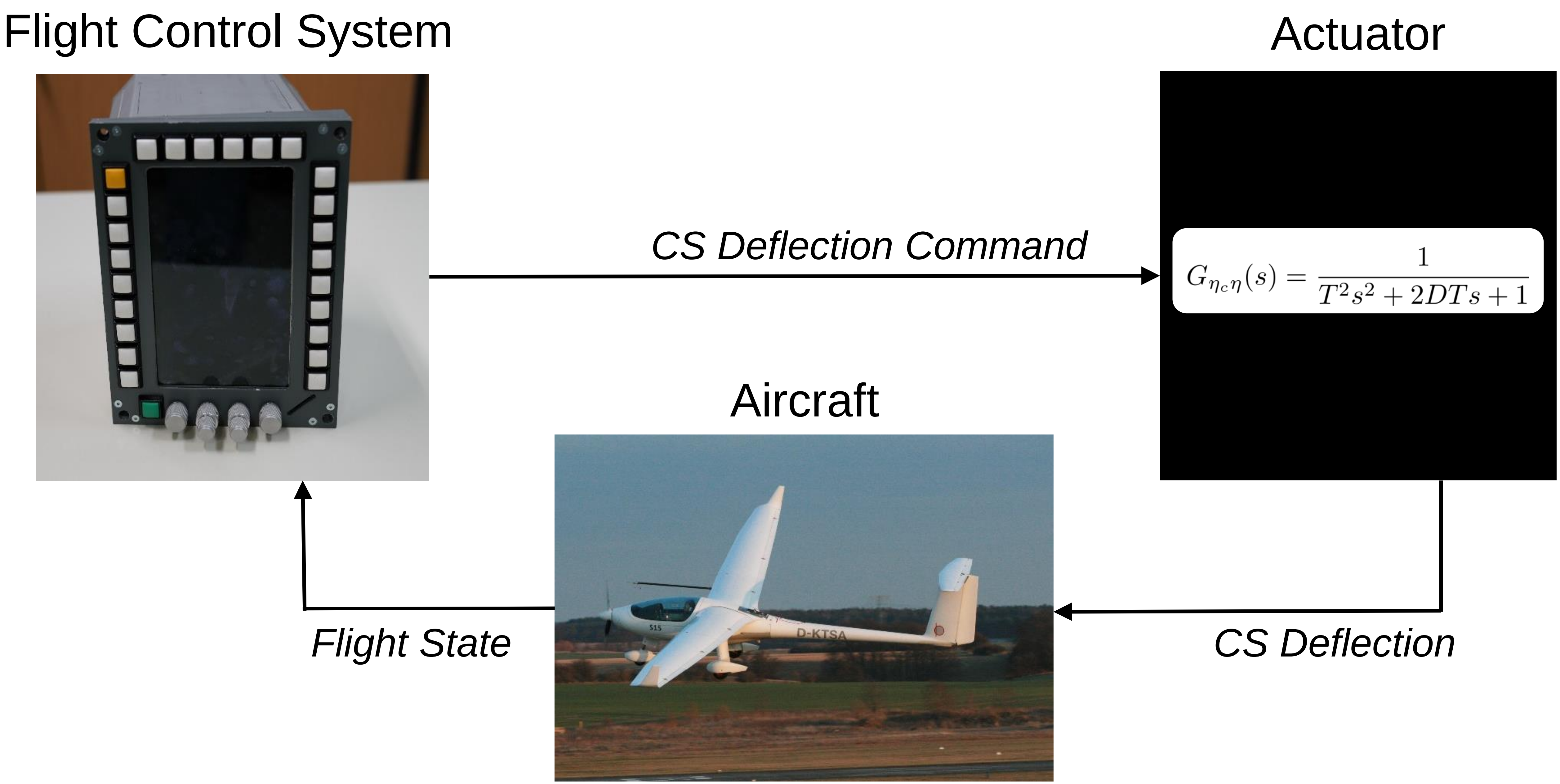


Control Surface Deflection

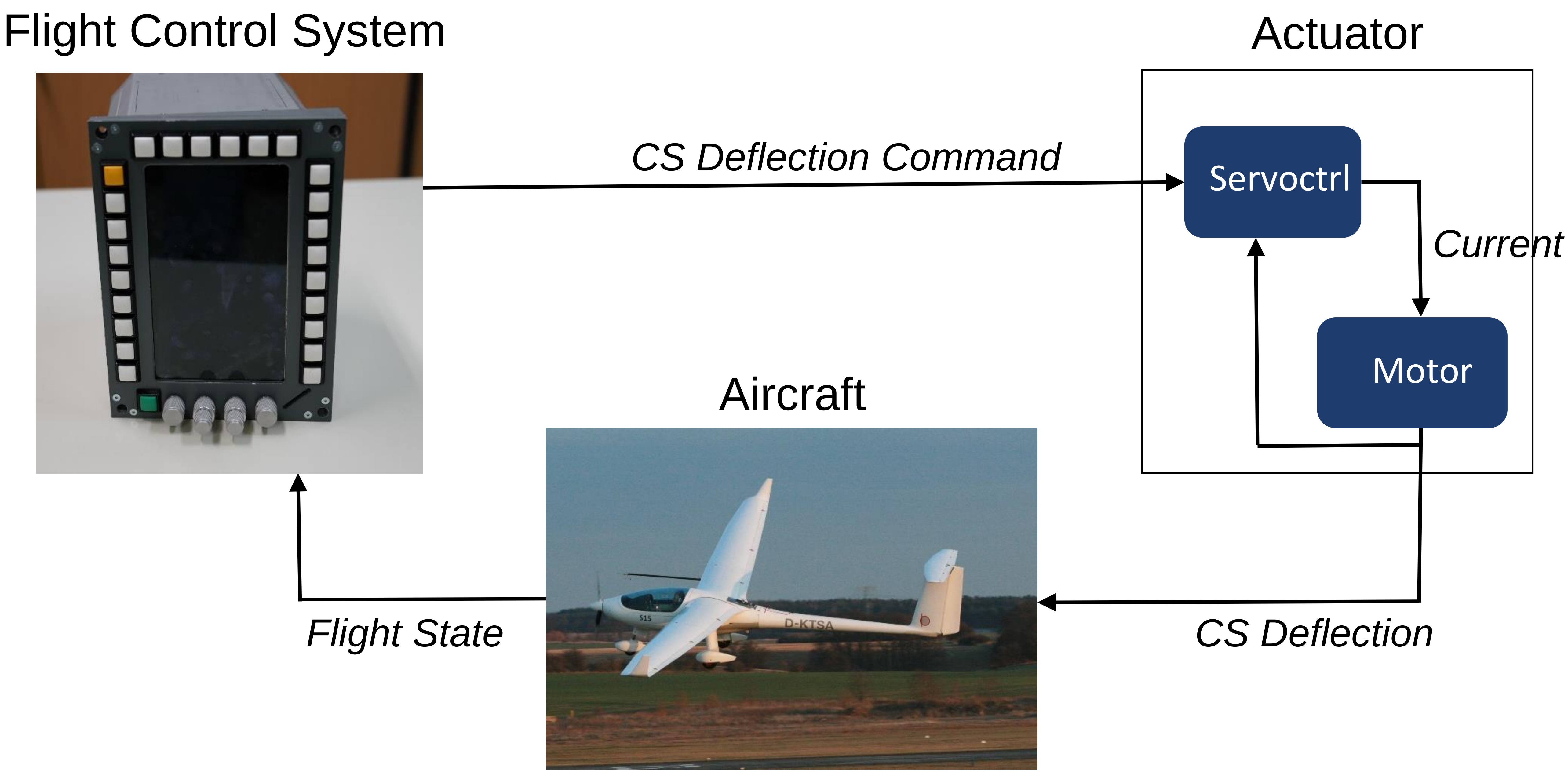
Aircraft

Flight State

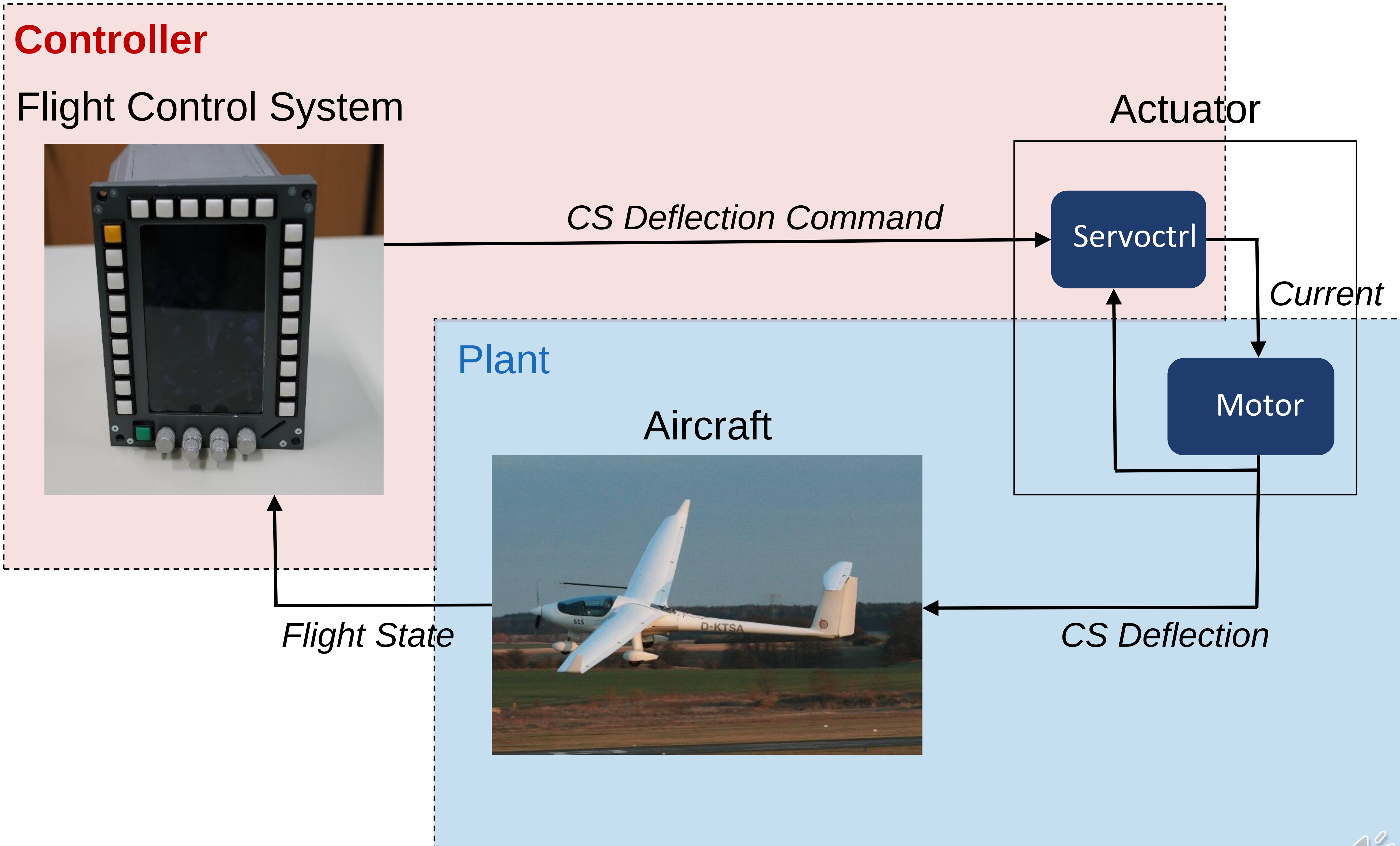
Actuator = Black Box?



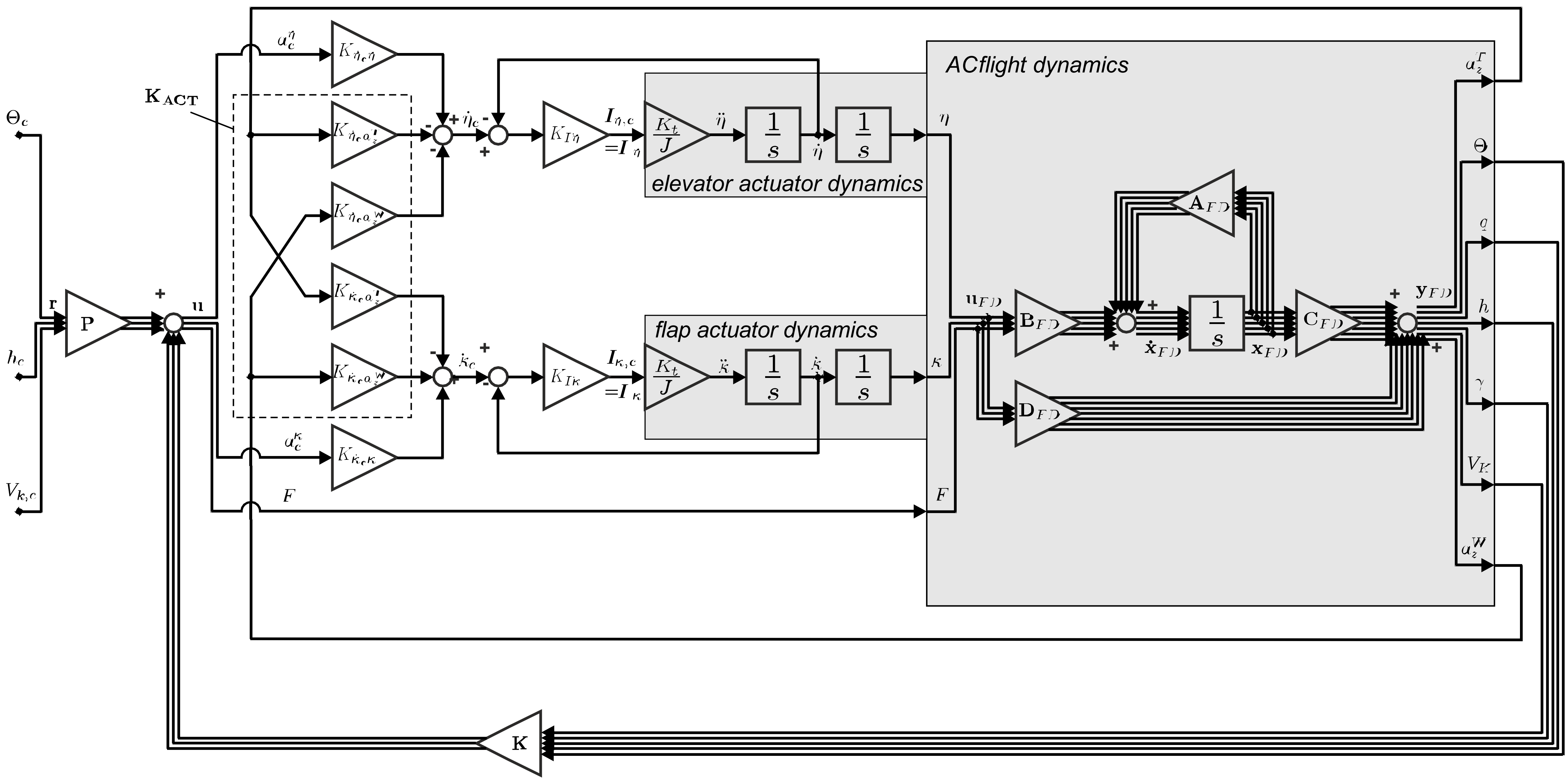
Internal Servo Controller



Cascaded Control Structure



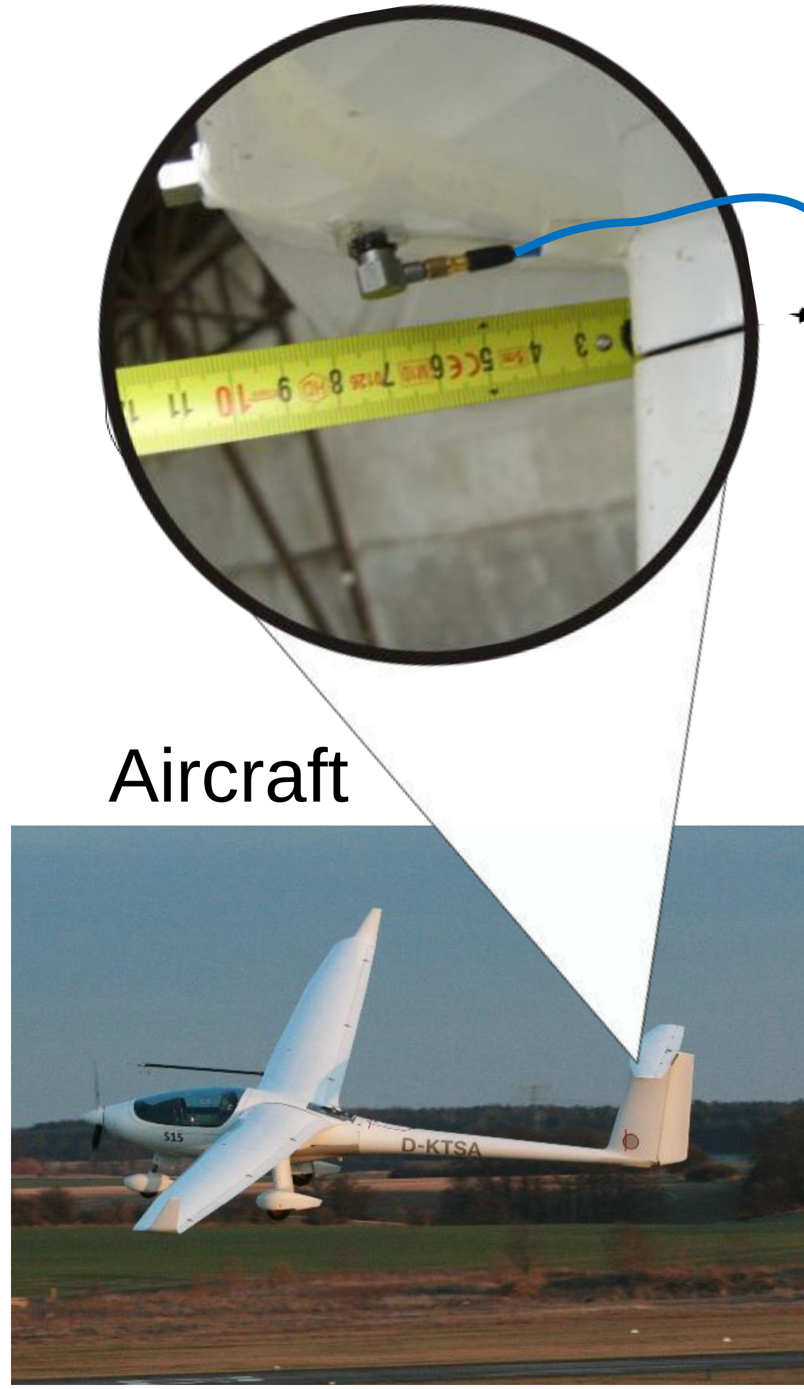
Proposed Control Structure



Local Acceleration Control

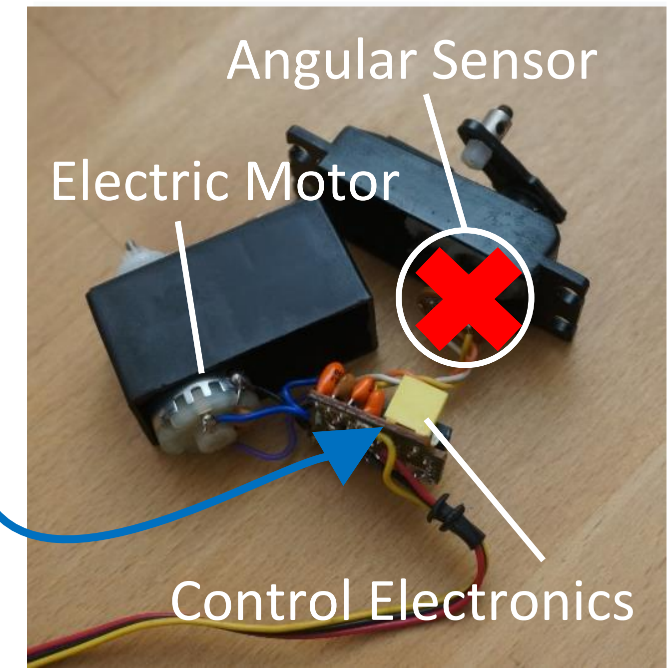
Flight Control System

Acceleration Sensor

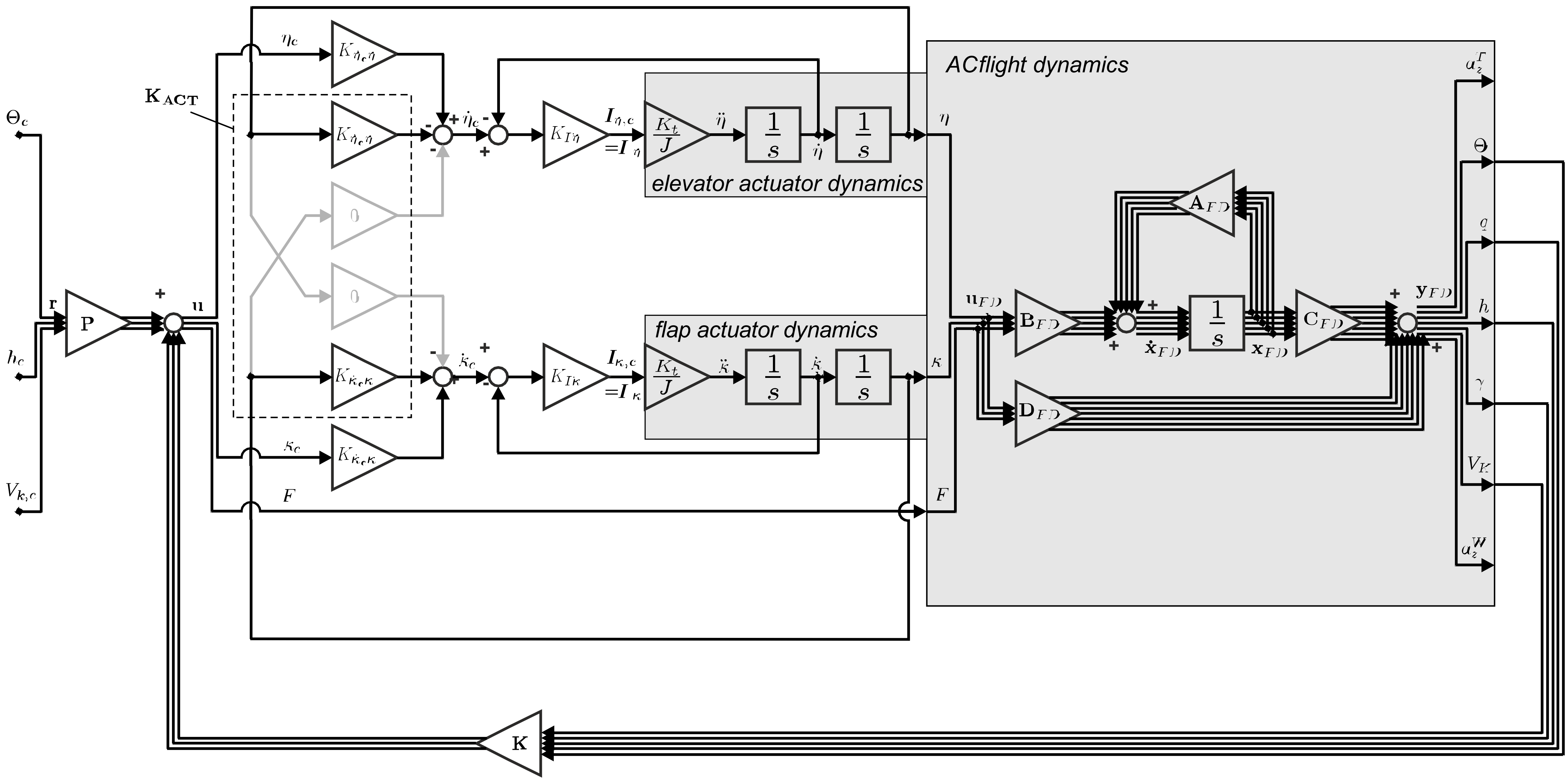


Aircraft

Actuator



Classical Control Structure



Design Procedure

- Accelerartion gains calculated to achieve same loop gain like classical control

$$\mathbf{K}_{ACT}^{acc} = \begin{bmatrix} K_{\dot{\eta}_c a_z^T} & K_{\dot{\eta}_c a_z^W} \\ K_{\dot{\kappa}_c a_z^T} & K_{\dot{\kappa}_c a_z^W} \end{bmatrix} = \mathbf{K}_{ACT}^{class} \cdot \begin{bmatrix} \frac{\partial a_z^T}{\partial \eta} & \frac{\partial a_z^T}{\partial \kappa} \\ \frac{\partial a_z^W}{\partial \eta} & \frac{\partial a_z^W}{\partial \kappa} \end{bmatrix}^{-1}$$

- Decoupling of pitch, vertical and longitudinal DOF by Eigenstructure Assignment (inner step)

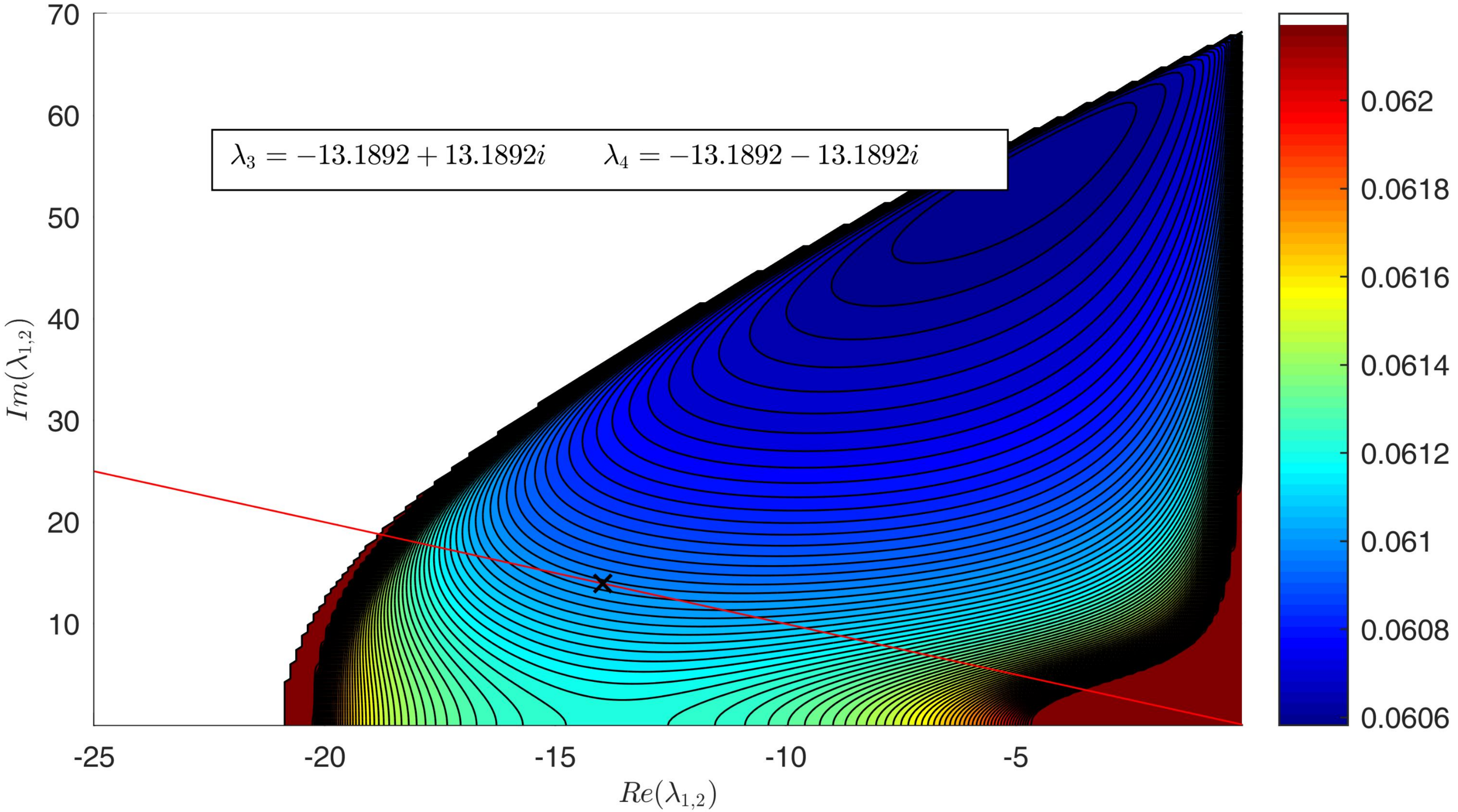
Pitch mode → $\lambda_{1,2}$; plunge mode → $\lambda_{3,4}$; speed dynamics → λ_5

$$\begin{bmatrix} Y0 \\ U0 \end{bmatrix} = \begin{matrix} \Theta \\ q \\ h \\ \gamma \\ V_K \\ \eta \\ \eta_k \\ F \end{matrix} \overset{\begin{matrix} \lambda_{1,2} & \lambda_{3,4} & \lambda_5 \end{matrix}}{\begin{pmatrix} \star & 0 & \star \\ 1 & \star & 0 \\ \star & 1 & \star \\ 0 & \star & 0 \\ \star & \star & \star \\ \star & \star & \star \\ \star & \star & \star \\ 0 & 0 & 1 \end{pmatrix}}$$

- Optimization of Pole Locations $\lambda_{1,2}, \lambda_{3,4}$ (outer step)

$$F_{cost} = \left\| G_{\Theta\eta}(s) \right\|_2 + \left\| G_{h\kappa}(s) \right\|_2 \qquad (D(\lambda_{1,2}) = D(\lambda_{3,4}) = 0.7)$$

Cost Function



Results

- Same pole locations result for classical and acceleration based control law:

  $\lambda_{1,2} = -13.2784 \pm 13.2784\mathrm{i}\ \mathrm{rad\,s^{-1}}$ $\lambda_{3,4} = -13.1269 \pm 13.1269\mathrm{i}\ \mathrm{rad\,s^{-1}}$

- Reason:
  - local acceleration is linear combination of state variables,
  - optimum independend of choosen state representation

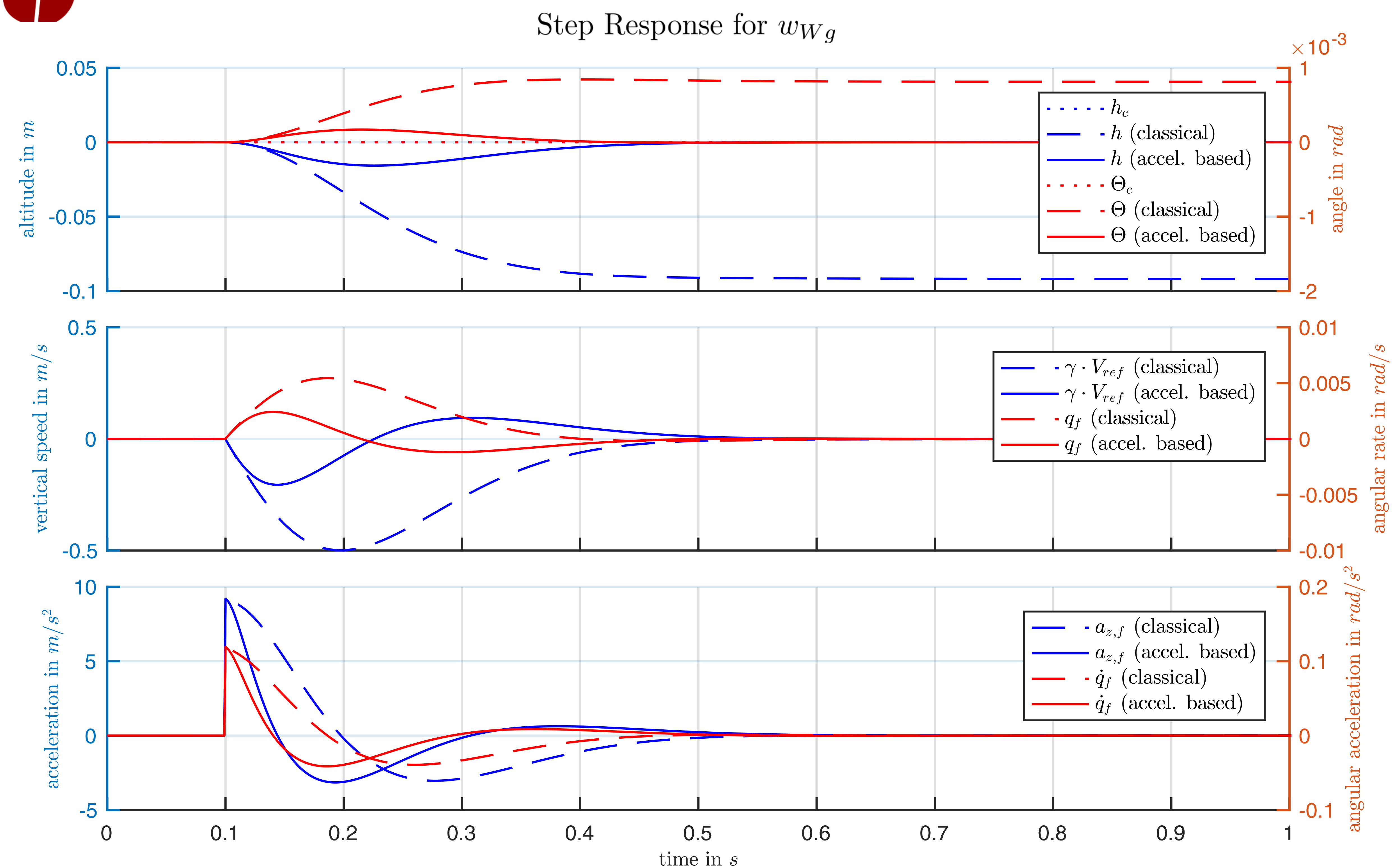
➡ Same reference transfer behaviour

- But:
  - Local acceleration contains gust and flightstate influence

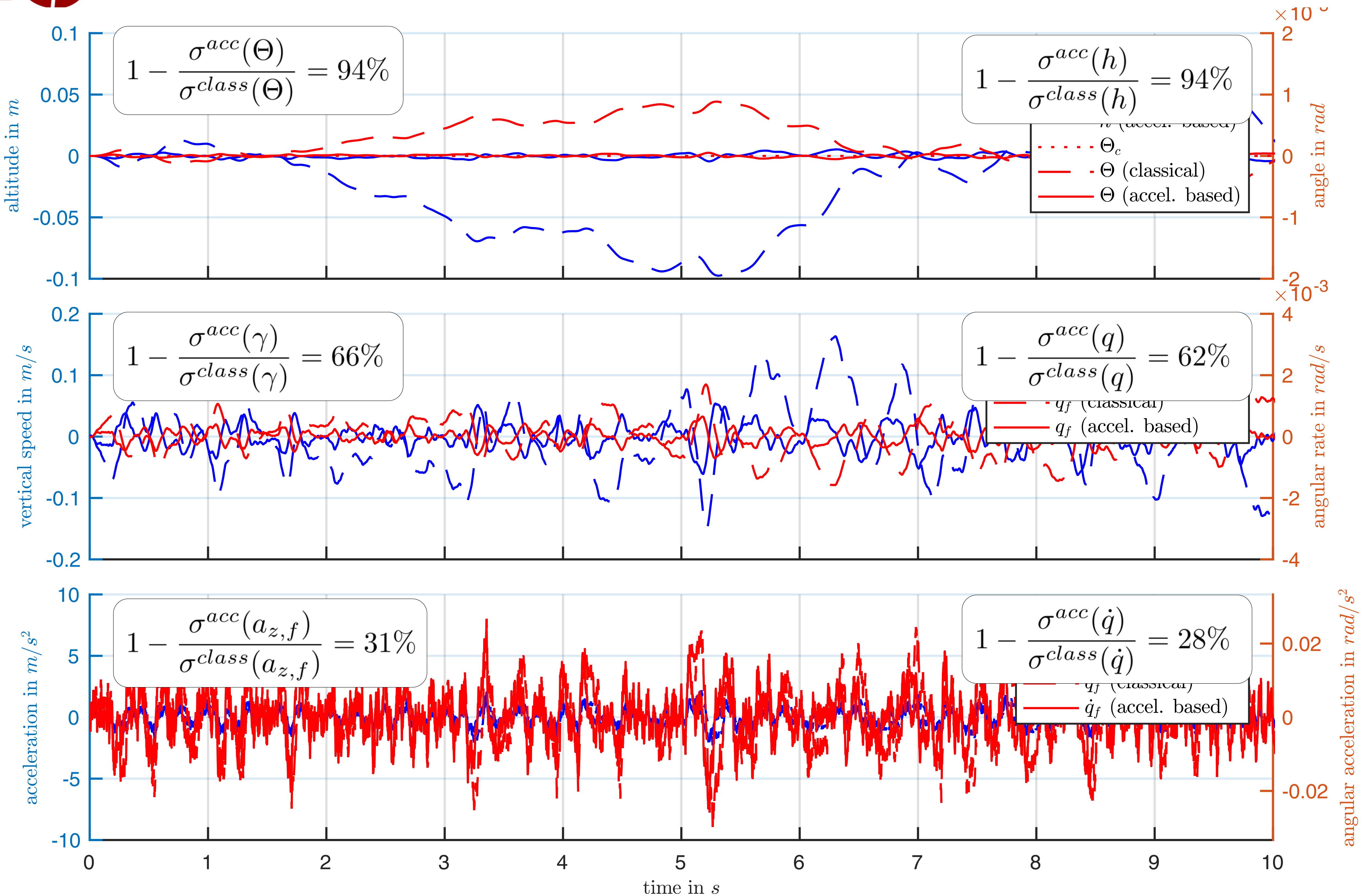
➡ Improved disturbance supression

➡ Improved robustness

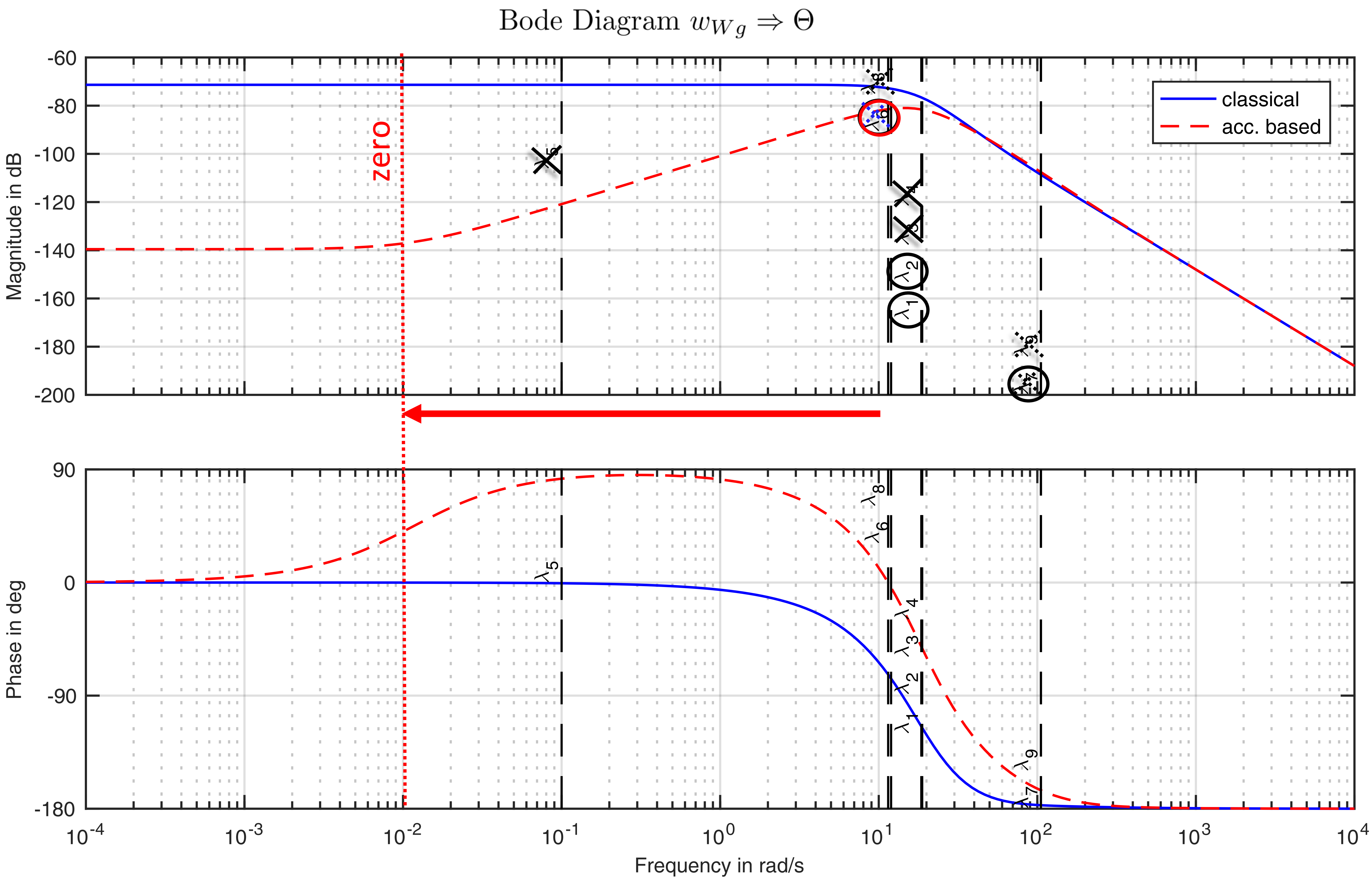
Vertical Wind Step



Dryden Turbulence

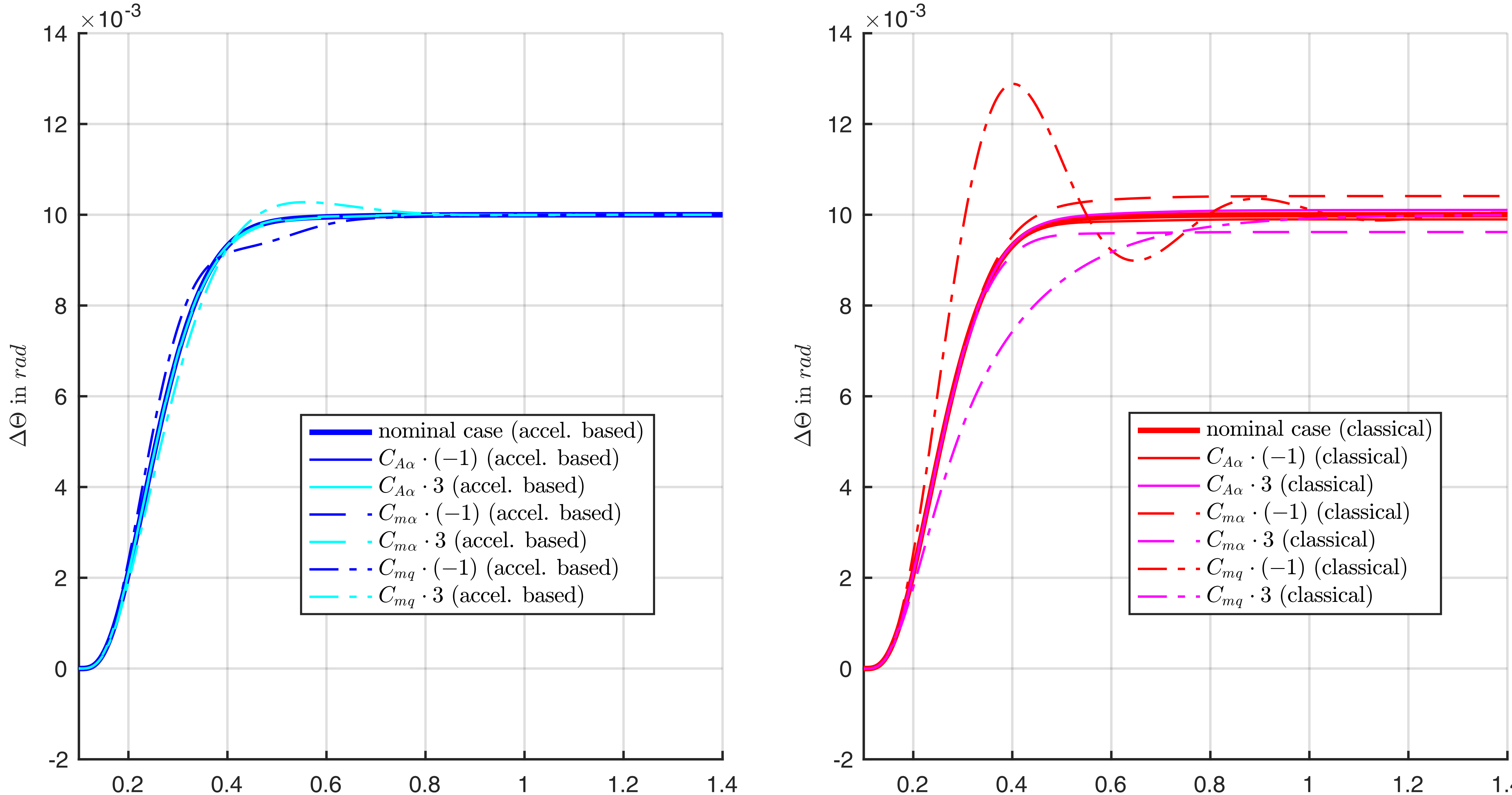


Frequency Response



Robustness

Step Response $\Theta_c \Rightarrow \Theta$



Summary and Outlook

Findings

- Noval control structure proposed, weekening separation between flight control and actuator control
- Changing feedback variables does not affect achievable dynamics
- Improves disturbance rejection and robustness

Further Work

- Extend optimization to servo control gains
- Investigation and modelling of higher frequency dynamics
- Extension to aeroelastic control