Flight control architecture of the half-wing setup

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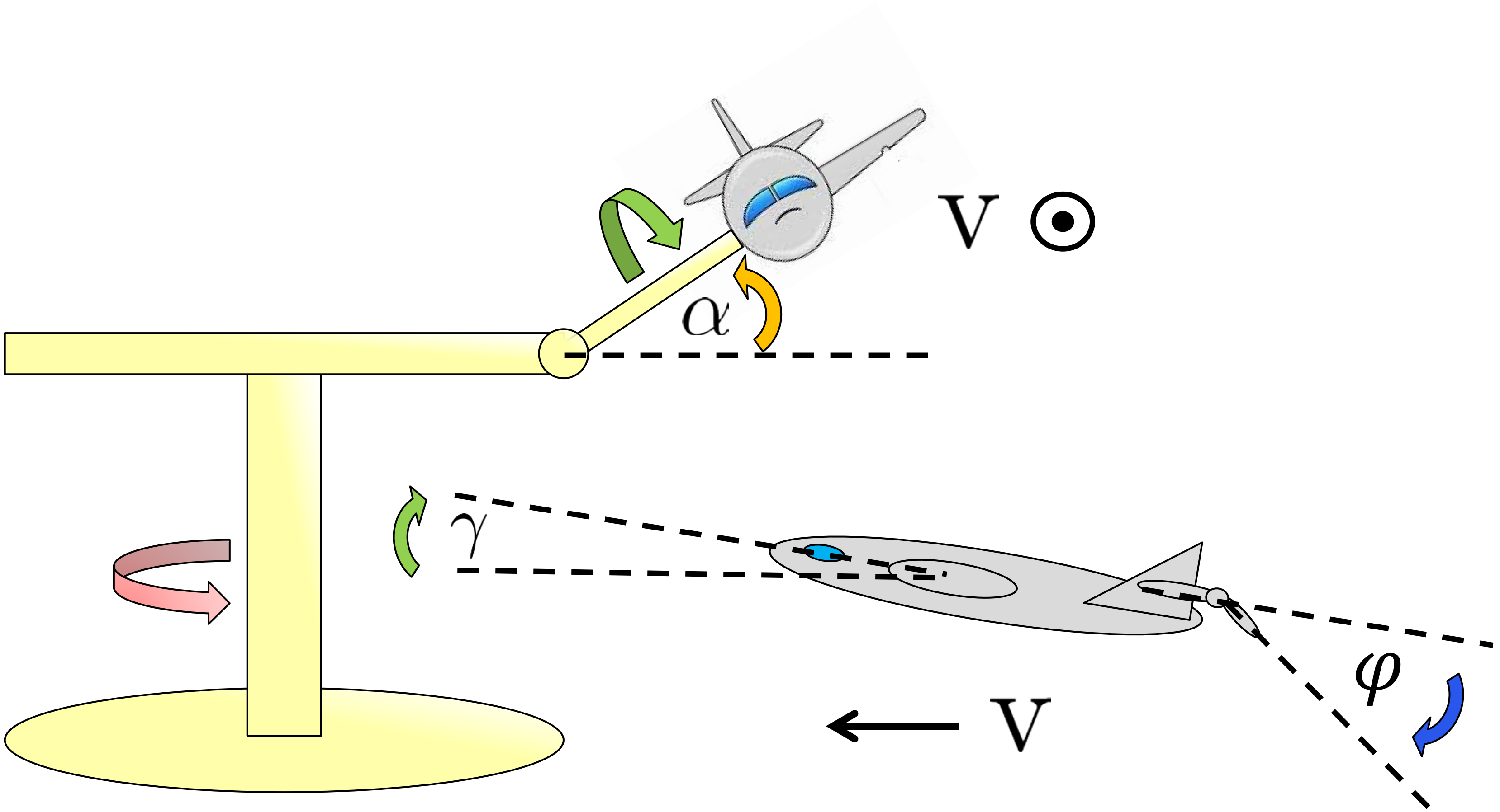
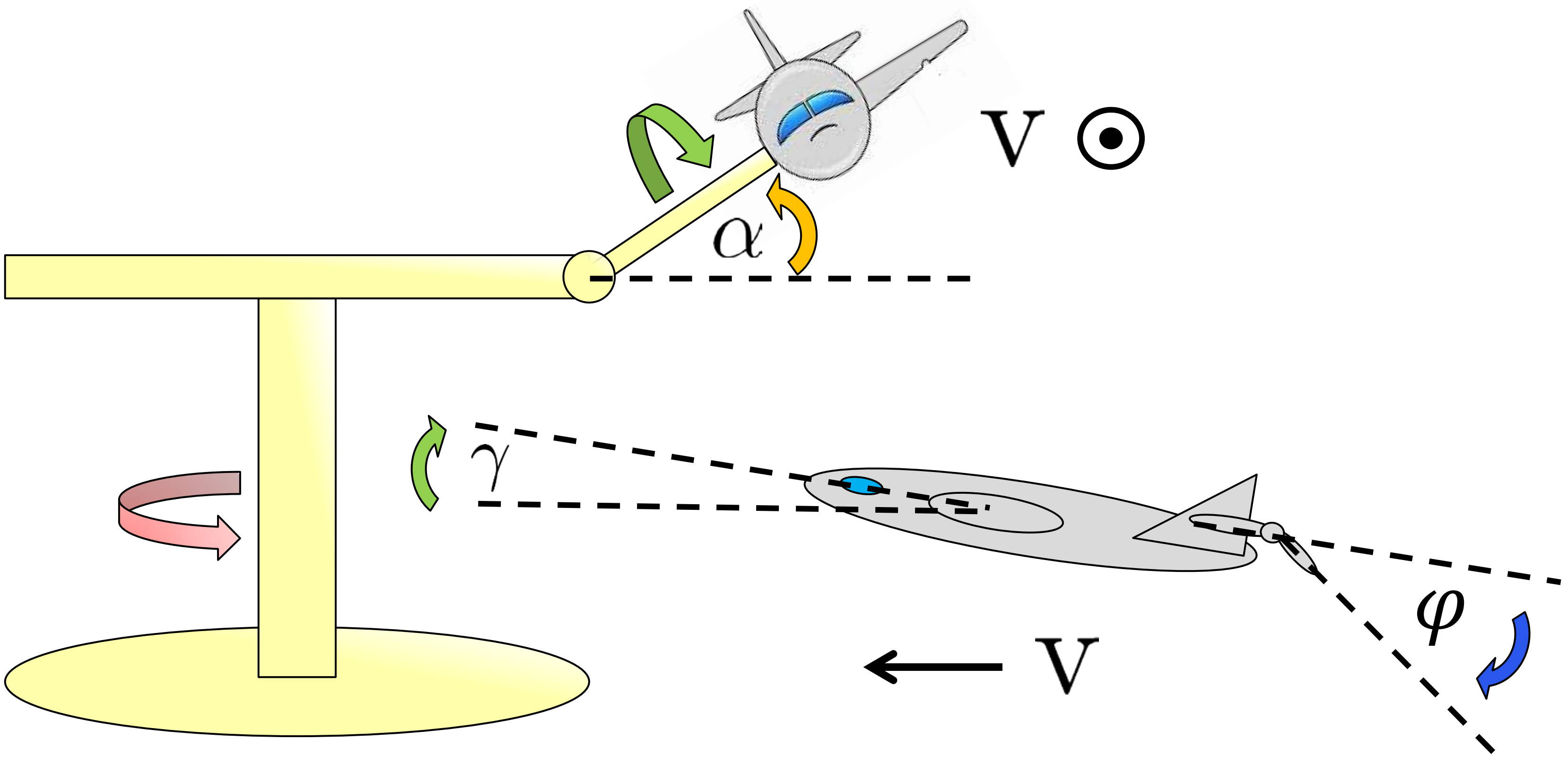
½ -Wing Carousel Setup



½ -Wing Carousel Setup

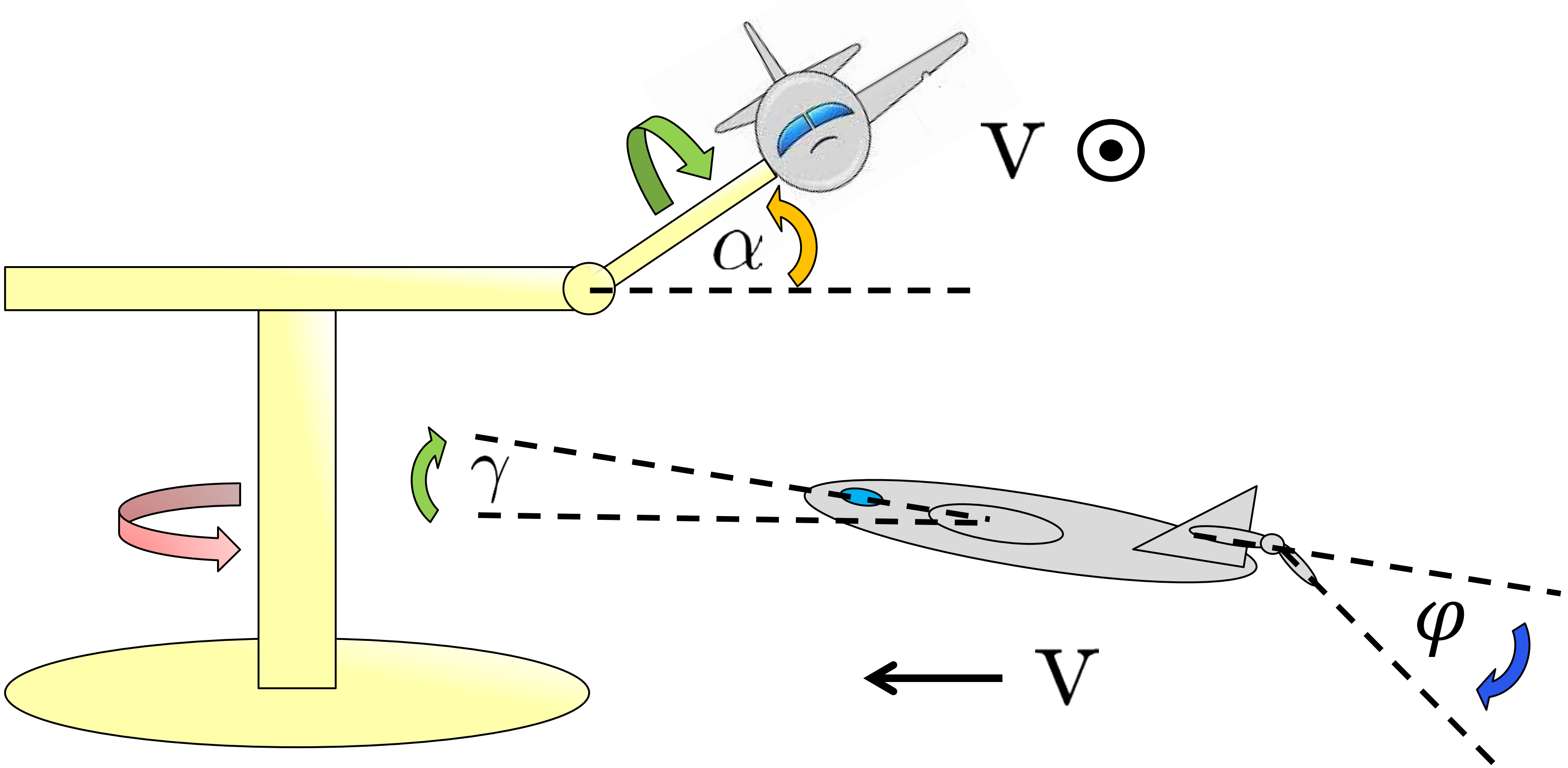
Goal 1

Control elevation angle α via elevator angle φ



½ -Wing Model

$$x = \begin{bmatrix} \gamma \\ \dot{\gamma} \\ \alpha \\ \dot{\alpha} \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} \qquad \dot{x} = \begin{bmatrix} \dot{\gamma} \\ \ddot{\gamma} \\ \dot{\alpha} \\ \ddot{\alpha} \end{bmatrix} = \begin{bmatrix} x_2 \\ \ddot{\alpha} \\ x_4 \\ \ddot{\theta} \end{bmatrix}$$



½ -Wing Model - Assumptions

$$x = \begin{bmatrix} \gamma \\ \dot{\gamma} \\ \alpha \\ \dot{\alpha} \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} \qquad \dot{x} = \begin{bmatrix} \dot{\gamma} \\ \ddot{\gamma} \\ \dot{\alpha} \\ \ddot{\alpha} \end{bmatrix} = \begin{bmatrix} x_2 \\ \ddot{\alpha} \\ x_4 \\ \ddot{\theta} \end{bmatrix}$$

Assumptions

Angle of attack = pitch angle

Lift force of half wing is in line with rotation center of γ

½ -Wing Model - ODE

$$x = \begin{bmatrix} \gamma \\ \dot{\gamma} \\ \alpha \\ \dot{\alpha} \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} \qquad \dot{x} = \begin{bmatrix} \dot{\gamma} \\ \ddot{\gamma} \\ \dot{\alpha} \\ \ddot{\alpha} \end{bmatrix} = \begin{bmatrix} x_2 \\ \ddot{\alpha} \\ x_4 \\ \ddot{\theta} \end{bmatrix}$$

$$\ddot{\gamma} = \frac{1}{I_{yy}} \Big[l_m m g \ \cos(\gamma) \\ -\rho A (l_a + l_r \cos(\alpha))^2 \omega^2 (C_{m0} + C_{m\gamma}\gamma + C_{m\dot{\gamma}}\dot{\gamma} + C_{m\varphi}\varphi) \Big]$$

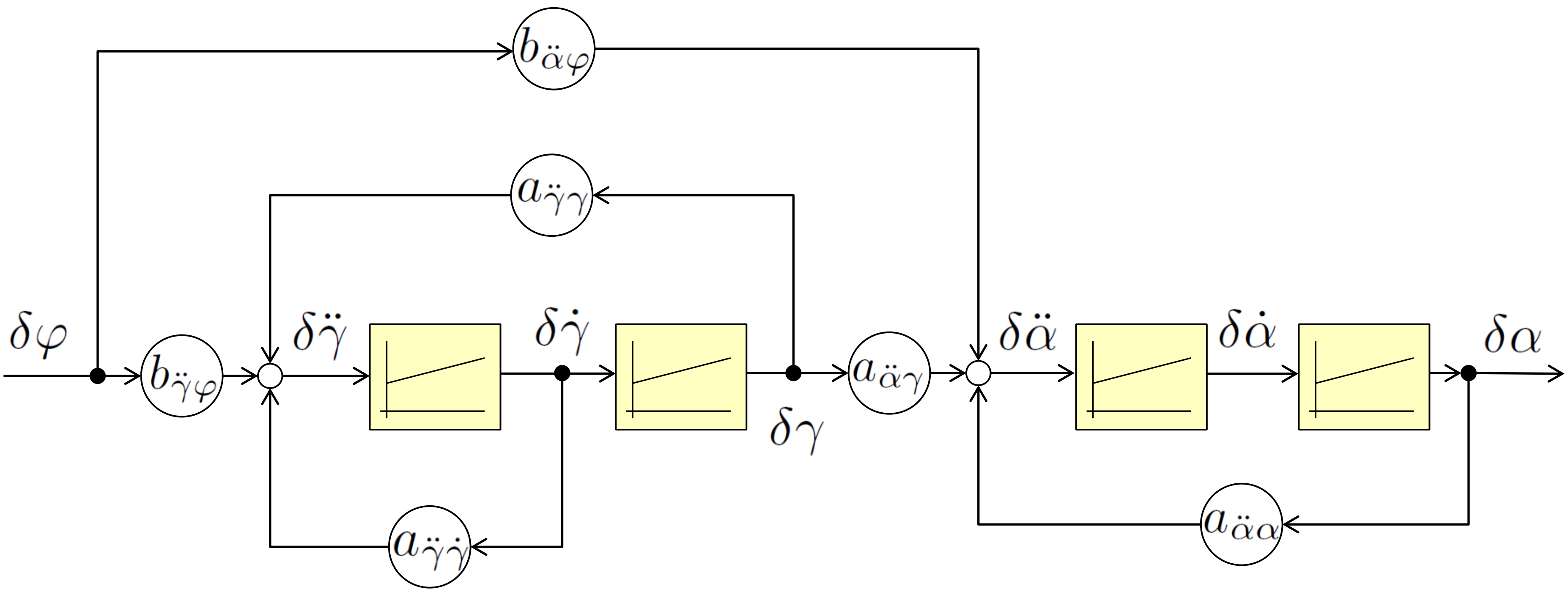
$$\ddot{\alpha} = \frac{l_r}{I_{xx}} \Big[-mg\cos(\alpha) - m(l_a + l_r \cos(\alpha))\omega^2 \sin(\alpha) \\ +\frac{1}{2}\rho A (l_a + l_r \cos(\alpha))^2 \omega^2 (C_{L0} + C_{L\gamma}\gamma + C_{L\varphi}\varphi) \Big]$$

$$y = \begin{bmatrix} 1 & 0 & 1 & 0 \end{bmatrix} x$$

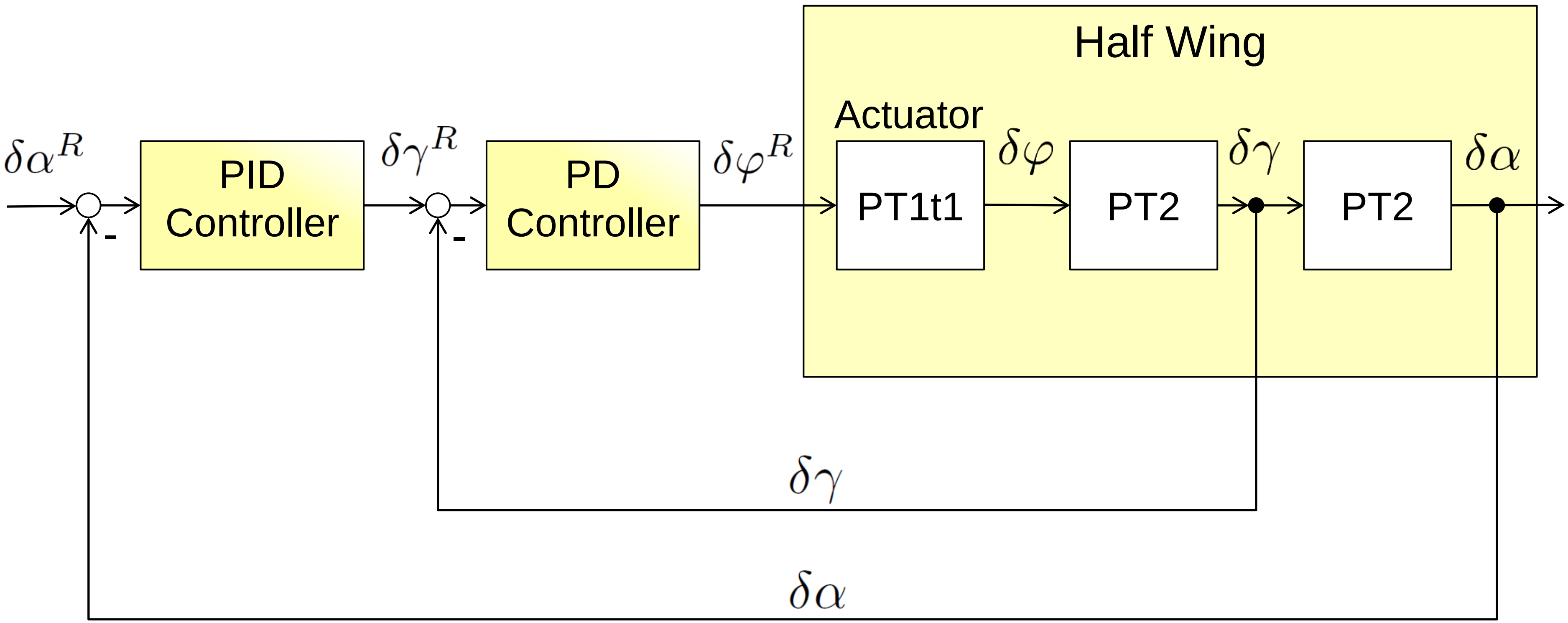
Linearization

at steady state with $\alpha = 0$

$$\delta \dot{x} = \begin{bmatrix} \delta\dot{\gamma} \\ \delta\ddot{\gamma} \\ \delta\dot{\alpha} \\ \delta\ddot{\alpha} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ a_{\ddot{\gamma}\gamma} & a_{\ddot{\gamma}\dot{\gamma}} & 0 & 0 \\ 0 & 0 & 0 & 1 \\ a_{\ddot{\alpha}\gamma} & 0 & a_{\ddot{\alpha}\alpha} & 0 \end{bmatrix} \begin{bmatrix} \delta\gamma \\ \delta\dot{\gamma} \\ \delta\alpha \\ \delta\dot{\alpha} \end{bmatrix} + \begin{bmatrix} 0 \\ b_{\ddot{\gamma}\varphi} \\ 0 \\ b_{\ddot{\alpha}\varphi} \end{bmatrix} \delta\varphi$$


$b_{\ddot{\alpha}\varphi}$
$a_{\ddot{\gamma}\gamma}$
$\delta\varphi$
$b_{\ddot{\gamma}\varphi}$
$\delta\ddot{\gamma}$
$\delta\dot{\gamma}$
$\delta\gamma$
$a_{\ddot{\alpha}\gamma}$
$\delta\ddot{\alpha}$
$\delta\dot{\alpha}$
$\delta\alpha$
$a_{\ddot{\gamma}\dot{\gamma}}$
$a_{\ddot{\alpha}\alpha}$

Cascaded Control Loop



Outlook for Control of Half Wing

Model

Verification & Identification

Methods

- Cascaded PID
- LQR + KF
- MPC + KF
- NMPC + EKF/UKF/MHE

Thank you
for
your attention