Estabilidade estática

$$M_{cg} = N x_a + C z_a + M_{ac} + M_{fus} + M_{nac} - N_t l_t + C_t z_t + M_{ac_t}$$

$$C_m = \frac{M}{q\,c\,S}$$

$$C_{m_{cg}} = C_n \frac{x_a}{c} + C_c \frac{z_a}{c} + C_{mac} + C_{m_{fus}} + C_{m_{nac}} - C_{n_t} \frac{l_t}{c}\frac{S_t}{S_w}\eta_t + C_{c_t}\frac{l_t}{c}\frac{S_t}{S_w}\eta_t + C_{mac_t}\frac{c_t}{c}\frac{S_t}{S_w}\eta_t$$

$$C_n = C_L \cos\alpha + C_D \sin\alpha$$
$$C_c = -C_L \sin\alpha + C_D \cos\alpha$$

$$\frac{dC_m}{dC_L} = \frac{x_a}{c} + C_L\left(2k - \frac{1}{a_w}\right)\frac{z_a}{c} + \left(\frac{dC_m}{dC_L}\right)_{fus} - \frac{a_t}{a_w} V_H\,\eta_t\left(1 - \frac{d\varepsilon}{d\alpha}\right)$$

$$\left(\frac{dC_m}{dC_L}\right)_w = \frac{x_a}{c} + C_L\left(2k - \frac{1}{a_w}\right)\frac{z_a}{c}$$

$$\left(\frac{dC_m}{dC_L}\right)_t = -\frac{a_t}{a_w}\,V_H\,\eta_t\left(1 - \frac{d\epsilon}{d\alpha}\right)$$

$$\left(\frac{dC_m}{dC_L}\right)_{fus} = \frac{k_f\,w_f^2\,L_f}{S_w\,c\,a_w}$$

$$C_{m\delta_e} = \frac{dC_m}{d\delta_e} = -a_t\,V_H\,\eta_t\,\tau \qquad \tau = \frac{d\alpha_t}{d\delta_e}$$

$$\left(\frac{dC_m}{dC_L}\right)_{free} = \left(\frac{dC_m}{dC_L}\right)_{fixed} + \left(\frac{dC_m}{dC_L}\right)_{elevator\ free}$$

$$\left(\frac{dC_m}{dC_L}\right)_{elevator\ free} = \frac{a_t}{a_w}\,\tau\,V_H\,\eta_t\,\frac{C_{h\alpha}}{C_{h\delta}}\left(1 - \frac{d\varepsilon}{d\alpha}\right)$$

$$\frac{dC_m}{dC_L} \approx \frac{x_{cg} - x_n}{c}$$

$$\eta_t = \frac{q_t}{q} \qquad V_H = \frac{l_t\,S_t}{c\,S}$$

$$k = \frac{1}{\pi AR\,e}$$

$$C_D = C_{D0} + k\,C_L^2$$

$$\frac{d\varepsilon}{d\alpha} = 4.44\left[K_{AR}\,K_\lambda\,K_h\,\cos(\Lambda_{c/4})\right]^{1.19}$$

$$K_\lambda = \frac{10 - 3\lambda}{7}$$

$$K_{AR} = \frac{1}{AR} - \frac{1}{1 + AR^{1.7}}$$

$$K_h = \frac{1 - |z_t/b|}{\left[2(x_{ac_t} - x_{ac_w})/b\right]^{1/3}}$$

$$\delta_f = -\frac{C_{h\alpha}}{C_{h\delta}}\alpha$$

Equações de movimento

$$\boldsymbol{f}_E = m\,\dot{\boldsymbol{V}}_E$$

$$\boldsymbol{f}_B = m\left(\dot{\boldsymbol{V}}_B + \boldsymbol{\omega}_B \times \boldsymbol{V}_B\right)$$

$$\boldsymbol{G}_B = \dot{\boldsymbol{h}}_B + \boldsymbol{\omega}_B \times \boldsymbol{h}_B$$

$$\boldsymbol{h}_B = \boldsymbol{I}\,\boldsymbol{\omega}_B$$

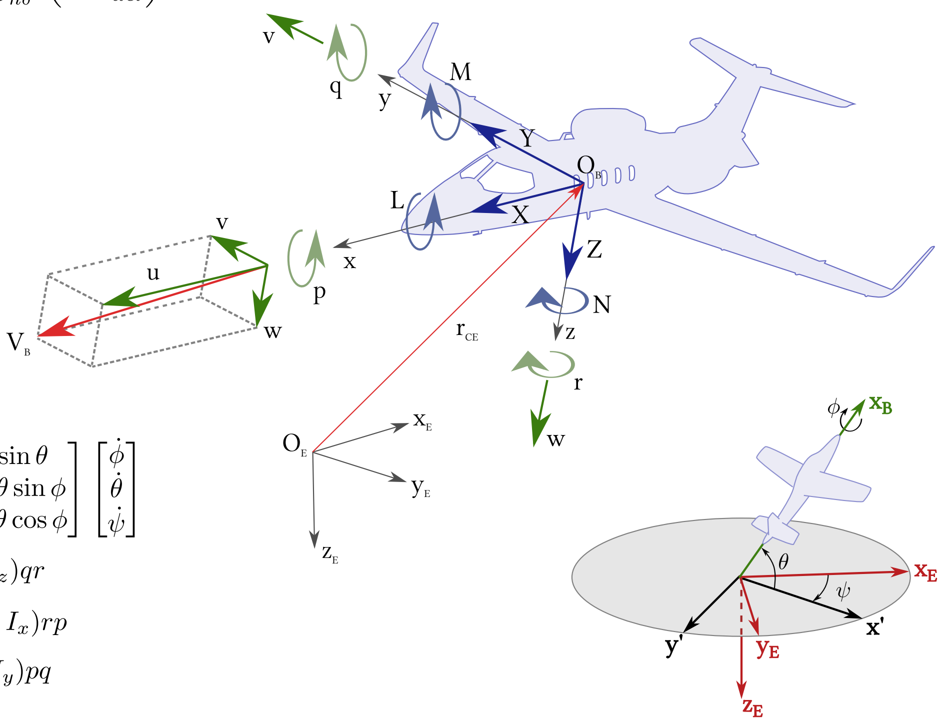
$$\boldsymbol{\omega}_B = \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} 1 & 0 & -\sin\theta \\ 0 & \cos\phi & \cos\theta\sin\phi \\ 0 & -\sin\phi & \cos\theta\cos\phi \end{bmatrix}\begin{bmatrix} \dot\phi \\ \dot\theta \\ \dot\psi \end{bmatrix}$$

$$L = I_x\dot p - I_{zx}(\dot r + pq) - (I_y - I_z)qr$$

$$M = I_y\dot q - I_{zx}(r^2 - p^2) - (I_z - I_x)rp$$

$$N = I_z\dot r - I_{zx}(\dot p + qr) - (I_x - I_y)pq$$

$$\boldsymbol{I} = \begin{bmatrix} I_x & -I_{xy} & -I_{xz} \\ & I_y & -I_{yz} \\ sym. & & I_z \end{bmatrix}$$



Ângulos de Euler

Longitudinal Equations, Eq. (4.9,18):

$$
\begin{bmatrix} \Delta\dot{u} \\ \dot{w} \\ \dot{q} \\ \Delta\dot{\theta} \end{bmatrix}
=
\begin{bmatrix}
\dfrac{X_u}{m} & \dfrac{X_w}{m} & 0 & -g\cos\theta_o \\
\dfrac{Z_u}{m-Z_{\dot{w}}} & \dfrac{Z_w}{m-Z_{\dot{w}}} & \dfrac{Z_q+mu_o}{m-Z_{\dot{w}}} & \dfrac{-mg\sin\theta_o}{m-Z_{\dot{w}}} \\
\dfrac{1}{I_y}\left[M_u+\dfrac{M_{\dot{w}}Z_u}{(m-Z_{\dot{w}})}\right] & \dfrac{1}{I_y}\left[M_w+\dfrac{M_{\dot{w}}Z_w}{(m-Z_{\dot{w}})}\right] & \dfrac{1}{I_y}\left[M_q+\dfrac{M_{\dot{w}}(Z_q+mu_o)}{(m-Z_{\dot{w}})}\right] & -\dfrac{M_{\dot{w}}\,mg\sin\theta_o}{I_y(m-Z_{\dot{w}})} \\
0 & 0 & 1 & 0
\end{bmatrix}
\begin{bmatrix} \Delta u \\ w \\ q \\ \Delta\theta \end{bmatrix}
+
\begin{bmatrix}
\dfrac{\Delta X_c}{m} \\
\dfrac{\Delta Z_c}{m-Z_{\dot{w}}} \\
\dfrac{\Delta M_c}{I_y}+\dfrac{M_{\dot{w}}}{I_y}\dfrac{\Delta Z_c}{(m-Z_{\dot{w}})} \\
0
\end{bmatrix}
$$

$$\Delta\dot{x}_E = \Delta u\cos\theta_o + w\sin\theta_o - u_o\,\Delta\theta\sin\theta_o$$

$$\Delta\dot{z}_E = -\Delta u\sin\theta_o + w\cos\theta_o - u_o\,\Delta\theta\cos\theta_o$$

$$
\begin{bmatrix} \dot{v} \\ \dot{p} \\ \dot{r} \\ \dot{\phi} \end{bmatrix}
=
\begin{bmatrix}
\dfrac{Y_v}{m} & \dfrac{Y_p}{m} & \left(\dfrac{Y_r}{m}-u_o\right) & g\cos\theta_0 \\
\left(\dfrac{L_v}{I'_x}+I'_{zx}N_v\right) & \left(\dfrac{L_p}{I'_x}+I'_{zx}N_p\right) & \left(\dfrac{L_r}{I'_x}+I'_{zx}N_r\right) & 0 \\
\left(I'_{zx}L_v+\dfrac{N_v}{I'_z}\right) & \left(I'_{zx}L_p+\dfrac{N_p}{I'_z}\right) & \left(I'_{zx}L_r+\dfrac{N_r}{I'_z}\right) & 0 \\
0 & 1 & \tan\theta_0 & 0
\end{bmatrix}
\begin{bmatrix} v \\ p \\ r \\ \phi \end{bmatrix}
+
\begin{bmatrix}
\dfrac{\Delta Y_c}{m} \\
\dfrac{\Delta L_c}{I'_x}+I'_{zx}N_c \\
I'_{zx}\Delta L_c+\dfrac{\Delta N_c}{I'_z} \\
0
\end{bmatrix}
$$

$$\dot{\psi} = r\sec\theta_o$$

$$\Delta\dot{y}_E = u_o\psi\cos\theta_o + v$$

$$I'_x = (I_xI_z - I_{zx}{}^2)/I_z$$

$$I'_z = (I_xI_z - I_{zx}{}^2)/I_x$$

$$I'_{zx} = I_{zx}/(I_xI_z - I_{xz}{}^2)$$

Table 10.8 *Spiral mode time constant*

Flight phase category	*Minimum value of T_s (seconds)* Level 1	Level 2	Level 3
A, C	17.3	11.5	7.2
B	28.9	11.5	7.2

Table 10.6 *Roll subsidence mode time constant*

		Maximum value of T_r (seconds)		
Aircraft class	*Flight phase category*	*Level 1*	*Level 2*	*Level 3*
I, IV	A, C	1.0	1.4	—
II, III	A, C	1.4	3.0	—
I, II, III, IV	B	1.4	3.0	—

Table 10.9 *Dutch roll frequency and damping*

		Minimum values							
		Level 1			*Level 2*			*Level 3*	
Aircraft class	*Flight phase*	ζ_d	$\zeta_d\omega_d$	ω_d	ζ_d	$\zeta_d\omega_d$	ω_d	ζ_d	ω_d
I, IV	CAT A	0.19	0.35	1.0	0.02	0.05	0.5	0	0.4
II, III	CAT A	0.19	0.35	0.5	0.02	0.05	0.5	0	0.4
All	CAT B	0.08	0.15	0.5	0.02	0.05	0.5	0	0.4
I, IV	CAT C	0.08	0.15	1.0	0.02	0.05	0.5	0	0.4
II, III	CAT C	0.08	0.10	0.5	0.02	0.05	0.5	0	0.4

$$\mathcal{L}^{-1}\left\{\frac{a+bi}{s+\sigma+\omega i}+\frac{a-bi}{s+\sigma-\omega i}\right\} = 2\exp(-\sigma t)\left[a\cos(\omega t)+b\sin(\omega t)\right]$$

$$
\begin{bmatrix} p \\ q \\ r \end{bmatrix}
=
\begin{bmatrix}
1 & 0 & -\sin\theta \\
0 & \cos\phi & \cos\theta\sin\phi \\
0 & -\sin\phi & \cos\theta\cos\phi
\end{bmatrix}
\begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}
$$