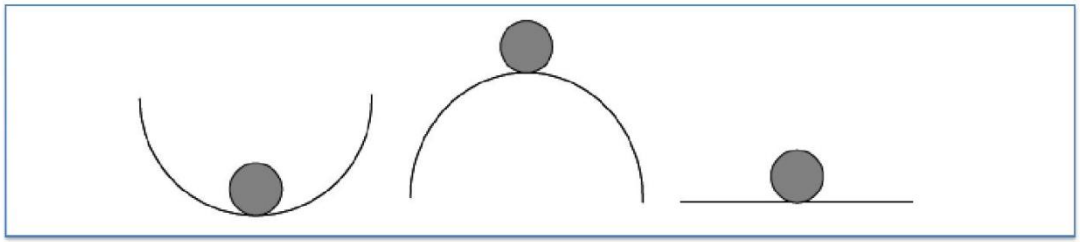
ESTABILIDAD DEL AVIÓN
1ra CLASE

ESTABILIDAD DEL AVIÓN

Estados de Equilibrio

Al aplicar un fuerza a la esfera que la hace moverse de su posición de equilibrio por su propio peso puede suceder:



Equilibrio ESTABLE:
La esfera vuelve a su posición original

Equilibrio INESTABLE
La esfera se aleja de su posición de origen

Equilibrio NEUTRO O INDIFERENTE
La esfera no se mueve por sí misma luego de retirada la fuerza

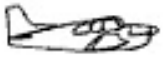
ESTABILIDAD ESTÁTICA LONGITUDINAL

Primary Control Surface	Airplane Movement	Axes of Rotation	Type of Stability
Elevator/ Stabilator	Pitch	Lateral	Longitudinal

ESTABILIDAD ESTÁTICA LONGITUDINAL

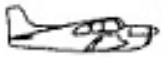
Sustentación = peso Empuje = Resistencia Momento resultante = 0

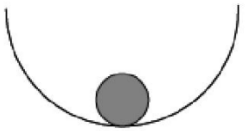
Avión en equilibrio



Avión perturbado

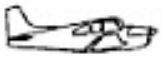
Avión vuelve a su posición de equilibrio





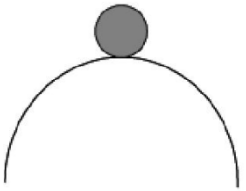
Equilibrio estático estable

Avión en equilibrio



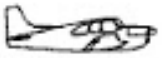
Avión, después de perturbado, se aleja de su posición de equilibrio

Avión continúa alejándose de su posición de equilibrio



Equilibrio estático inestable

Avión en equilibrio

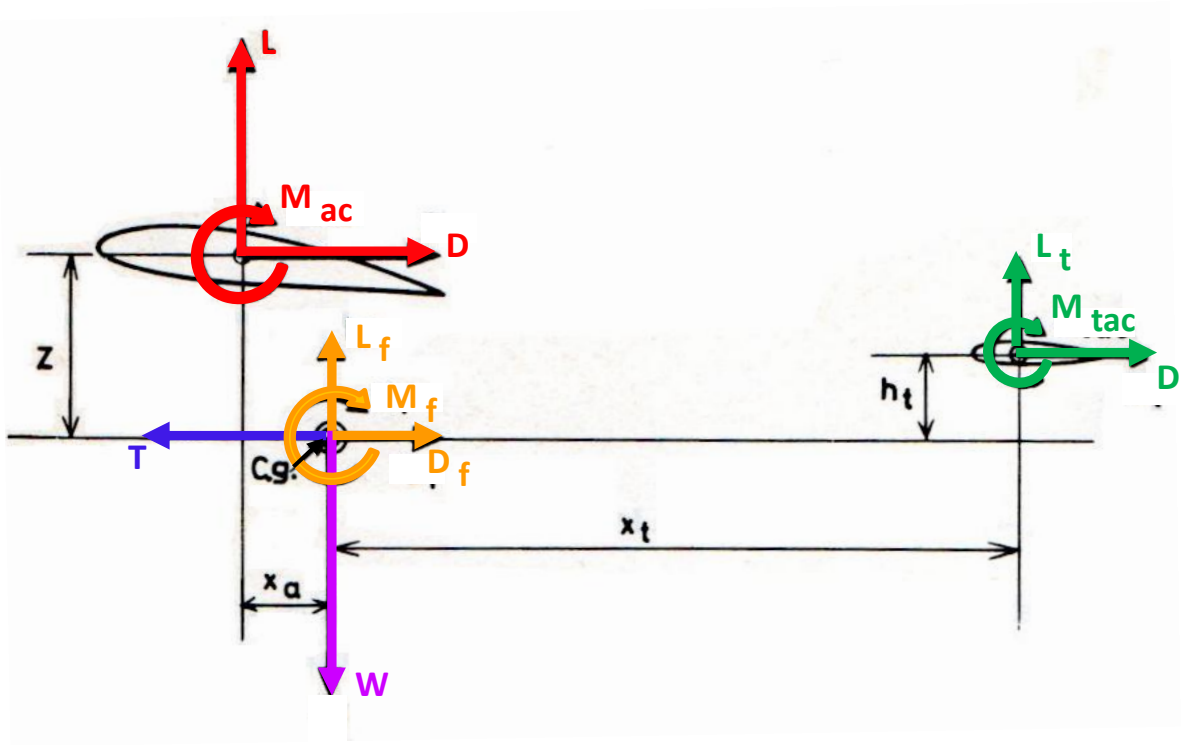


Avión perturbado

Avión perturbado mantiene la nueva posición de equilibrio

Equilibrio estático indiferente

ESTABILIDAD ESTÁTICA LONGITUDINAL



$+\leftarrow \quad \Sigma F_x = 0 \qquad \Sigma F_x = T - D - D_f - D_t = 0$

$+\uparrow \quad \Sigma F_z = 0 \qquad \Sigma F_z = L + L_f + L_t - W = 0$

$+\circlearrowleft \quad \Sigma M_{cg} = 0 \qquad \Sigma M_{cg} = M_{ac} + L \cdot x_a + D \cdot z + M_f + M_{tac} - L_t \cdot x_t + D_t \cdot h_t = 0$

ESTABILIDAD ESTÁTICA LONGITUDINAL

$$M_{cg} = M_{ac} + L \cdot x_a + D \cdot z + M_f + M_{ac} - L_t \cdot x_t + D_t \cdot h_t = 0$$

$$M_{cg} = M_{ac} + L \cdot x_a + D \cdot z + M_f - L_t \cdot x_t = 0$$

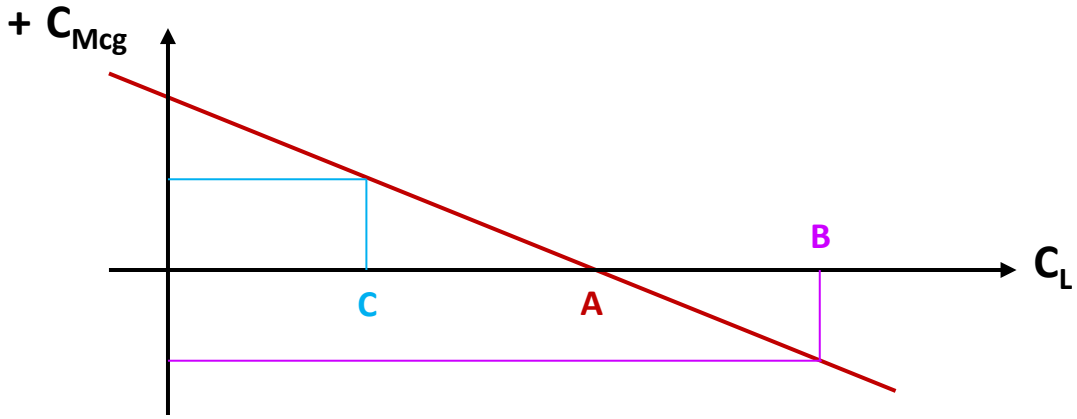
$$M_{cg} = C_{Mac} \cdot q \cdot S \cdot c + C_L \cdot q \cdot S \cdot x_a + C_D \cdot q \cdot S \cdot z + C_{Mf} \cdot q \cdot S \cdot c - C_{Lt} \cdot q_t \cdot S_t \cdot x_t = 0$$

Dividiendo miembro a miembro por $q \cdot S \cdot c$

$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_D \cdot \frac{z}{c} + C_{Mf} - C_{Lt} \cdot \frac{q_t}{q} \cdot \frac{S_t}{S} \cdot \frac{x_t}{c} = 0$$

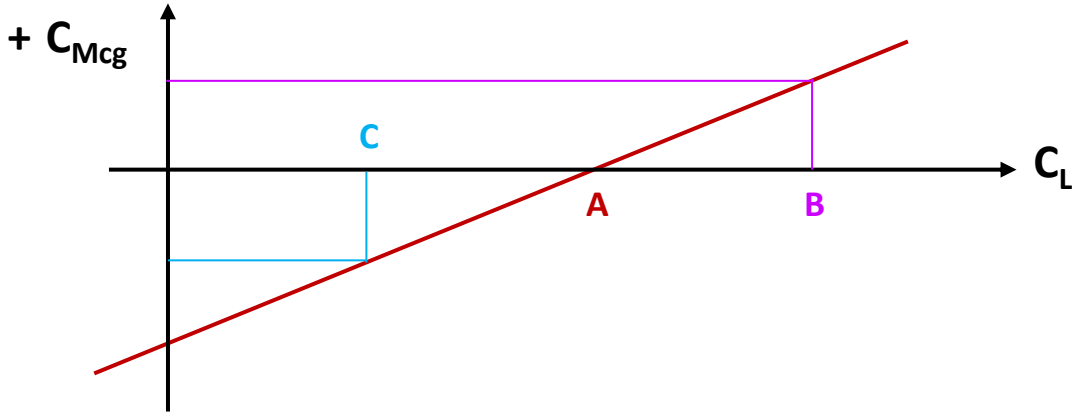
$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_D \cdot \frac{z}{c} + C_{Mf} - C_{Lt} \cdot \eta_t \cdot \overline{V} = 0$$

ESTABILIDAD ESTÁTICA LONGITUDINAL



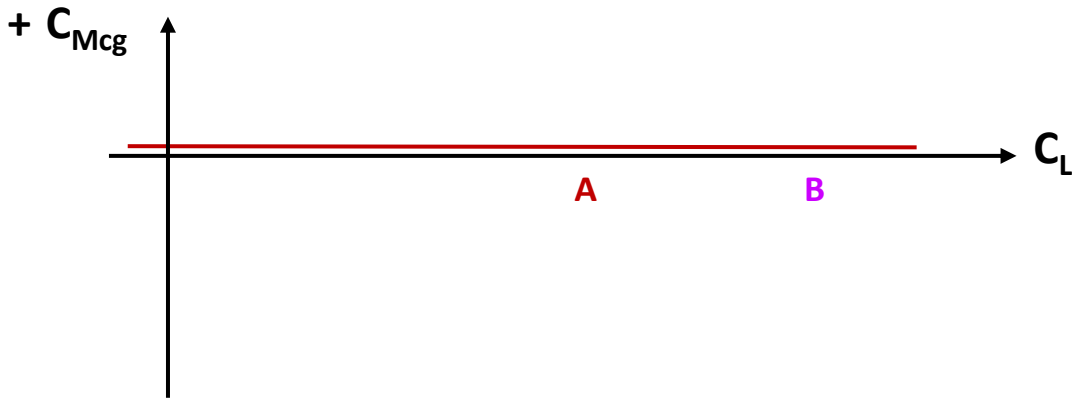
$$\frac{dC_{Mcg}}{dC_L} < 0$$

ESTABLE



$$\frac{dC_{Mcg}}{dC_L} > 0$$

INESTABLE



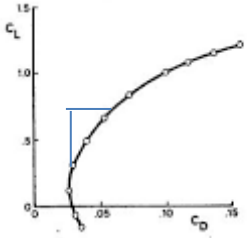
$$\frac{dC_{Mcg}}{dC_L} = 0$$

NEUTRO

ESTABILIDAD ESTÁTICA LONGITUDINAL

$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_D \cdot \frac{z}{c} + C_{Mf} - C_{Lt} \cdot \eta_t \cdot \overline{V} = 0$$

$$\frac{dC_{Mcg}}{dC_L} = \frac{dC_{Mac}}{dC_L} + \frac{dC_L}{dC_L} \cdot \frac{x_a}{c} + \frac{dC_D}{dC_L} \cdot \frac{z}{c} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$



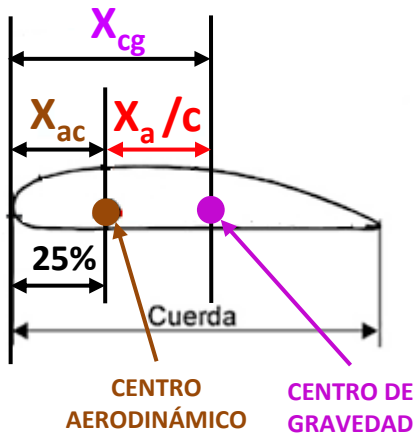
$$\frac{dC_{Mcg}}{dC_L} = \frac{x_a}{c} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$

- $\frac{x_a}{c}$ → ALA
- $\frac{dC_{Mf}}{dC_L}$ → FUSELAJE
- $\frac{dC_{Lt}}{dC_L}$ → EMPENAJE HORIZONTAL

CONTRIBUCIÓN DEL ALA

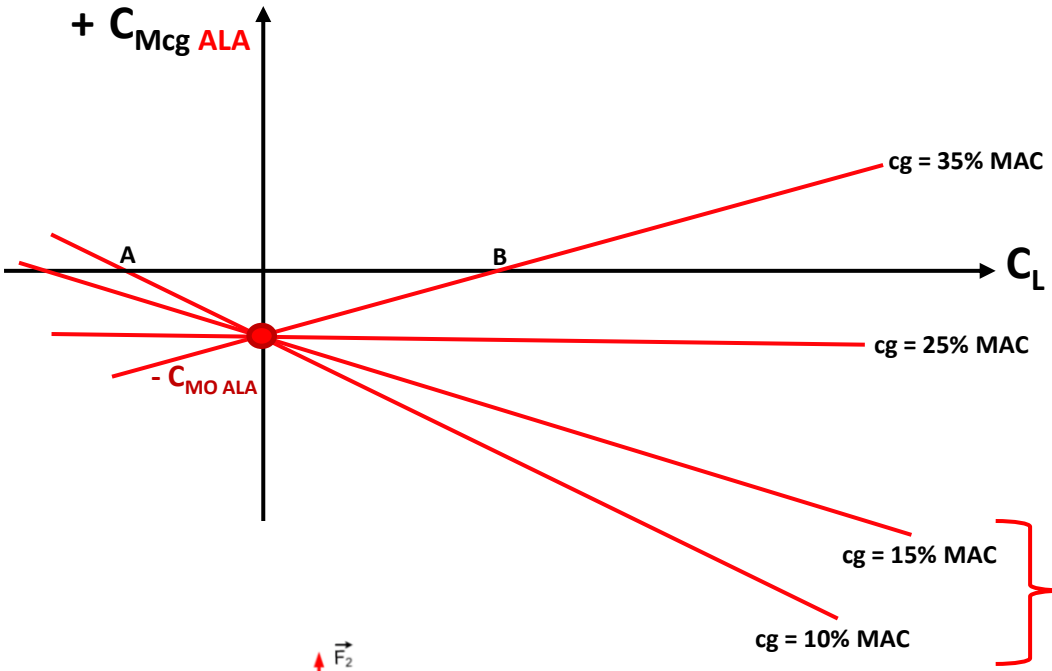
$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{ALA} = \frac{X_a}{c} = X_{cg} - X_{ac}$$

- > 0 INESTABLE
- < 0 ESTABLE
- = 0 NEUTRO



CONTRIBUCIÓN DEL ALA

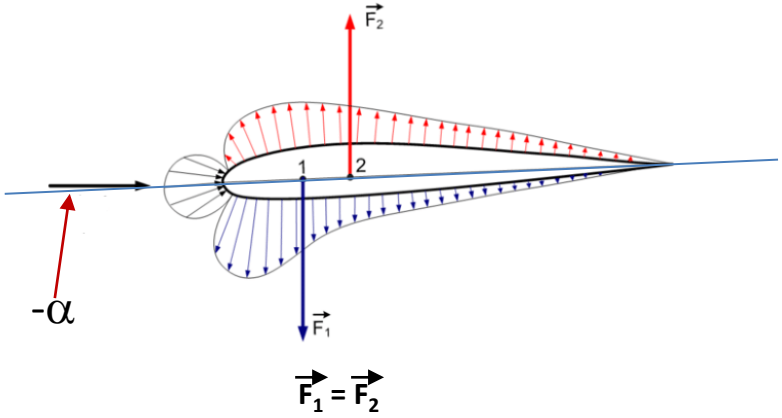
$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{ALA} = \frac{X_a}{c} = X_{cg} - X_{ac}$$



$\frac{dC_{Mcg}}{dC_L} = X_{cg} - X_{ac} > 0$ INESTABLE

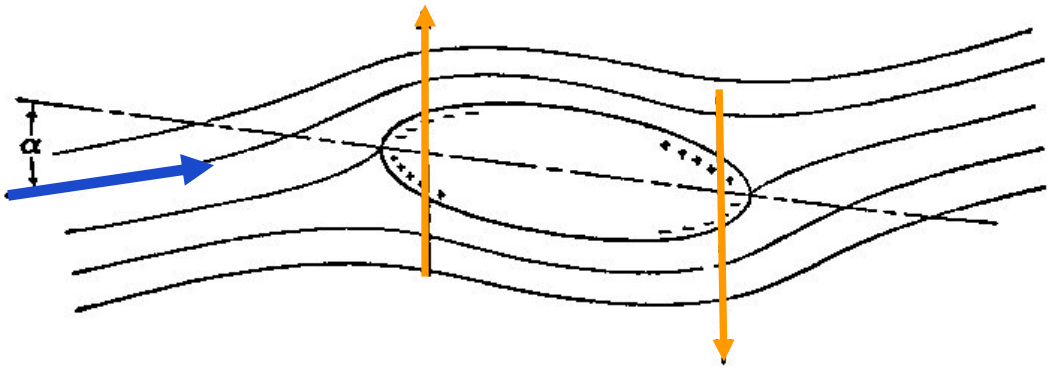
$\frac{dC_{Mcg}}{dC_L} = X_{cg} - X_{ac} = 0$ NEUTRO

$\frac{dC_{Mcg}}{dC_L} = X_{cg} - X_{ac} < 0$ ESTABLE



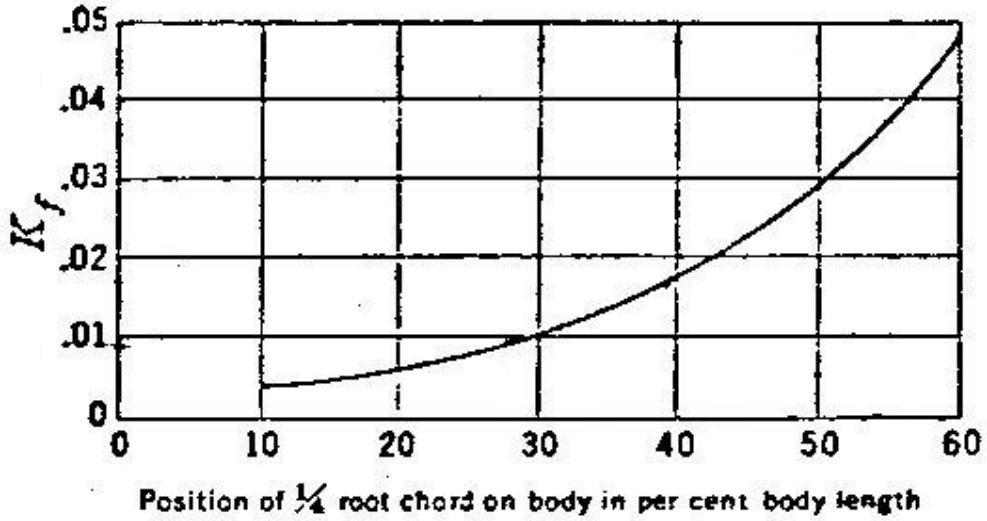
$\vec{F}_1 = \vec{F}_2$

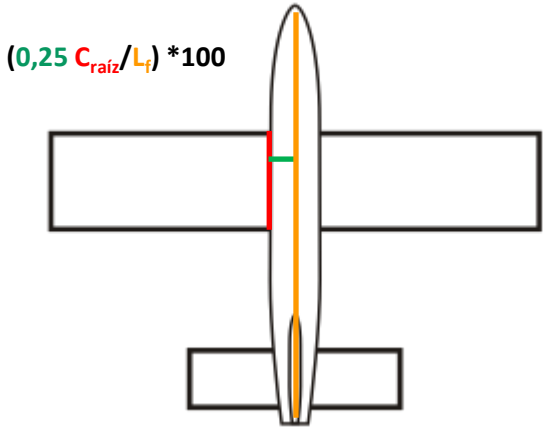
CONTRIBUCIÓN DEL FUSELAJE



$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{FUS} = \frac{K_f \cdot w_f^2 \cdot L_f}{S_w \cdot c \cdot a_w}$$

> 0 INESTABLE

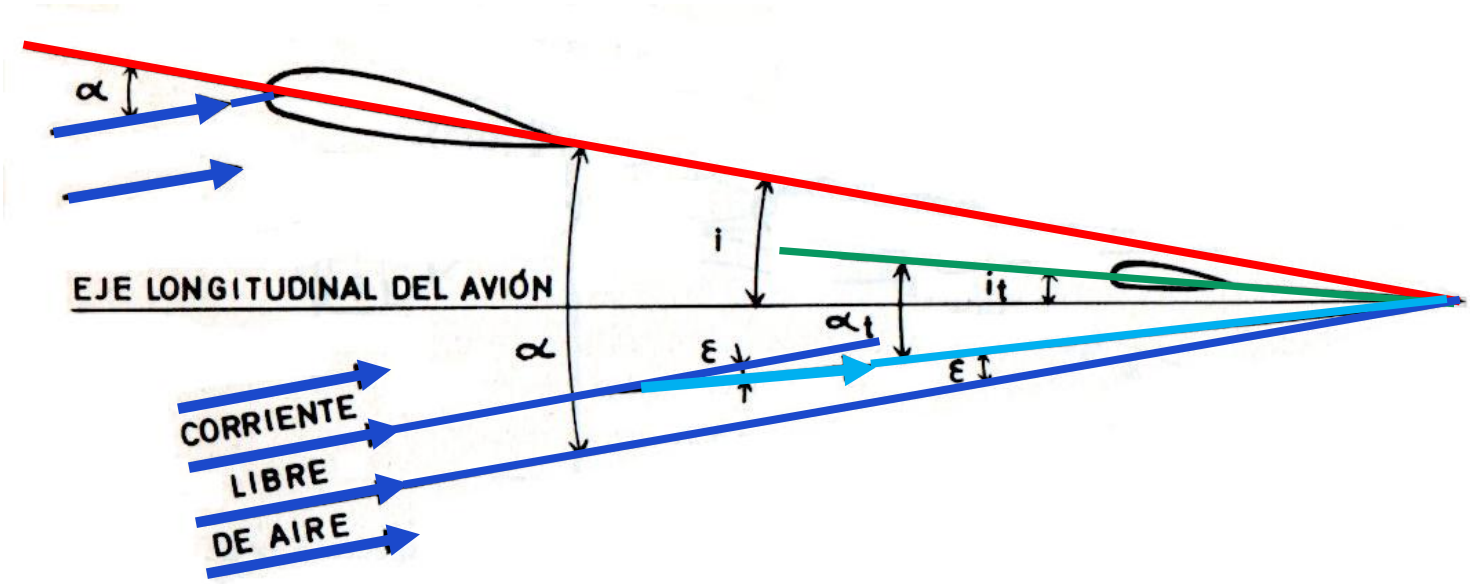




CONTRIBUCIÓN DEL FUSELAJE

CONTRIBUCIÓN DEL EMPENAJE HORIZONTAL

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH} = -\frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$



$$\alpha_t = \alpha - i + i_t - \varepsilon$$

ESTABILIDAD ESTÁTICA LONGITUDINAL

ESTABILIDAD ESTÁTICA LONGITUDINAL

CONTRIBUCIÓN DEL EMPENAJE HORIZONTAL

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH} = -\frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$

$$\alpha_t = \alpha - i + i_t - \varepsilon$$

$$C_{Lt} = a_t \cdot \alpha_t = a_t \cdot (\alpha - i + i_t - \varepsilon)$$

$$\frac{dC_{Lt}}{dC_L} = a_t \cdot \left[\frac{d\alpha}{dC_L} - \frac{d\varepsilon}{dC_L}\right]$$

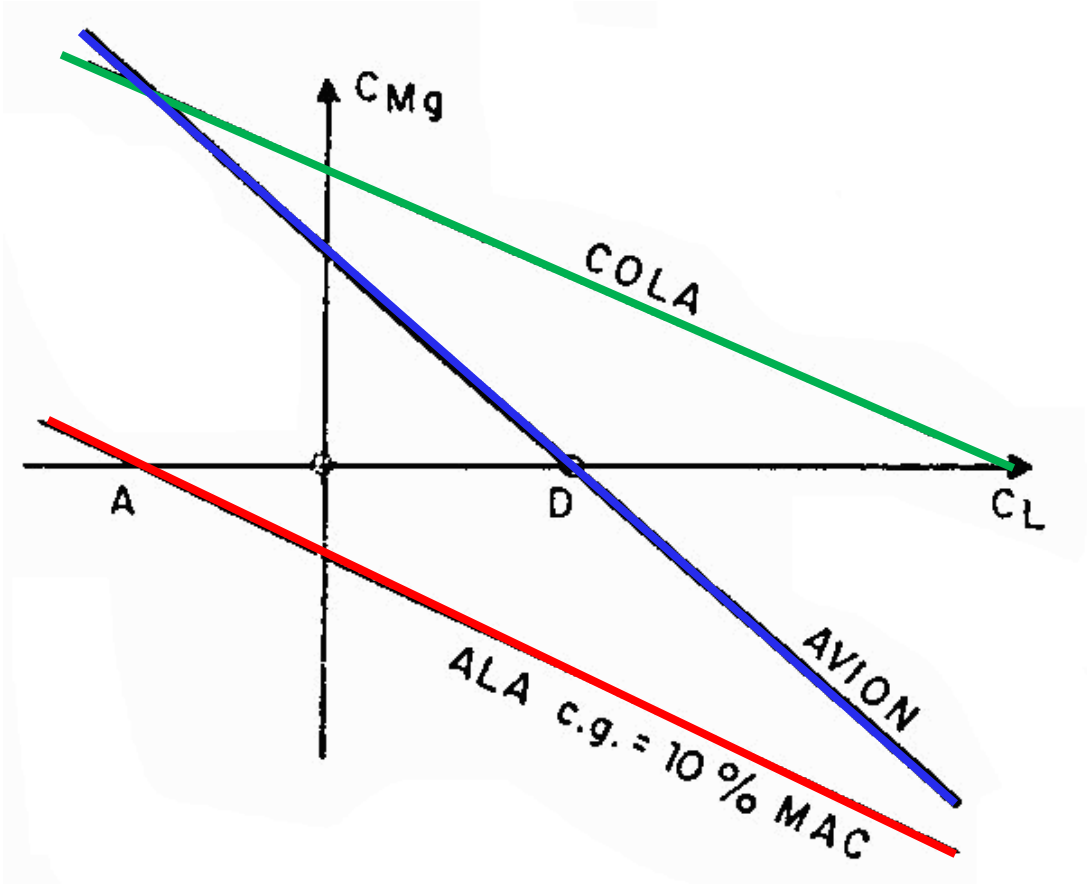
$$\frac{dC_{Lt}}{dC_L} = \frac{a_t}{a} \cdot \left[1 - \frac{d\varepsilon}{d\alpha}\right]$$

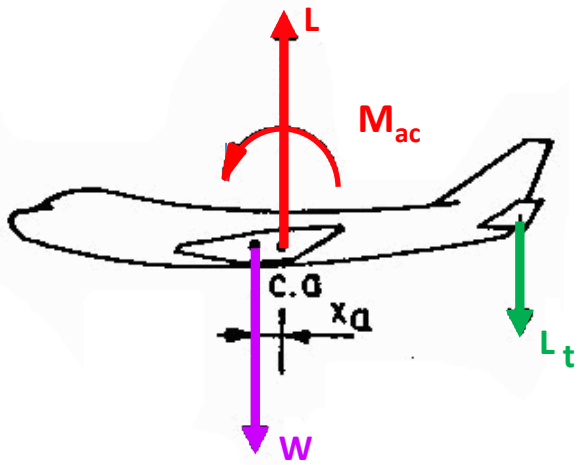
$$dC_L = a \cdot d\alpha$$

$$d\alpha = \frac{dC_L}{a}$$

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH} = -\frac{a_t}{a} \cdot \left[1 - \frac{d\varepsilon}{d\alpha}\right] \cdot \eta_t \cdot \overline{V}$$

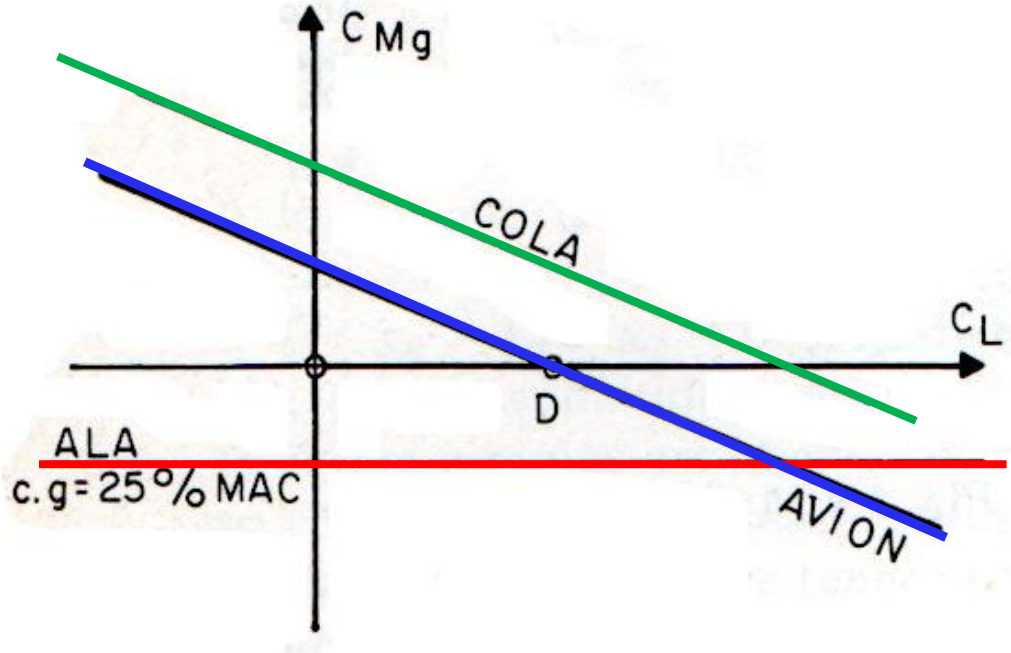
ESTABILIDAD ESTÁTICA DEL AVIÓN

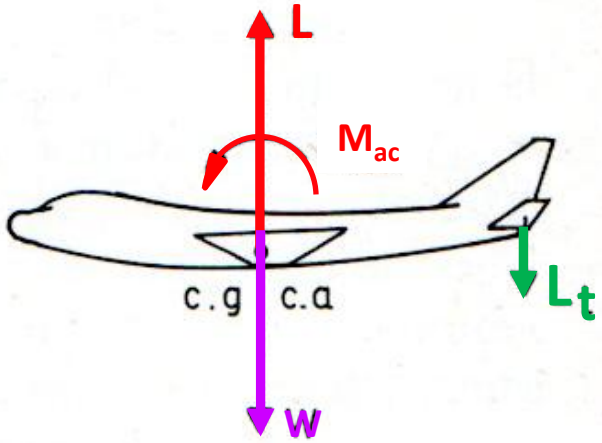




$$\Sigma M_{cg} = - M_{ac} - L \cdot x_a + L_t \cdot x_t = 0$$

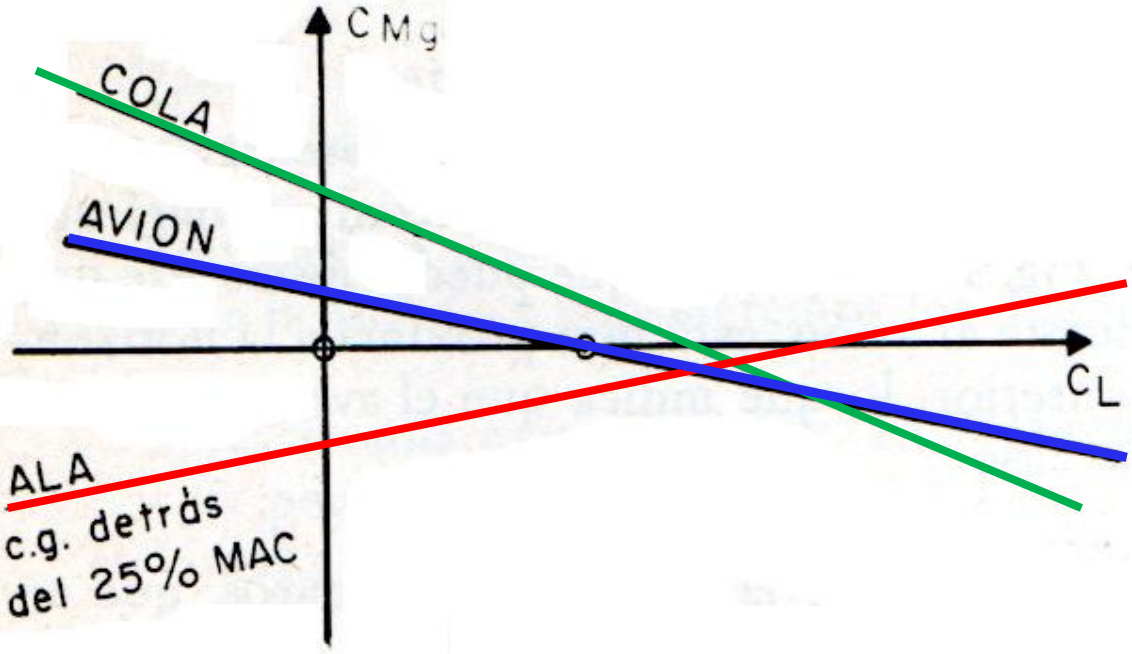
ESTABILIDAD ESTÁTICA DEL AVIÓN

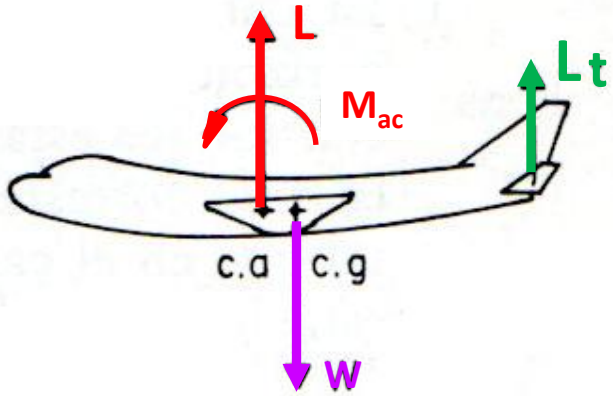




$$\Sigma M_{cg} = -M_{ac} - L x_a + L_t \cdot x_t = 0$$

ESTABILIDAD ESTÁTICA DEL AVIÓN





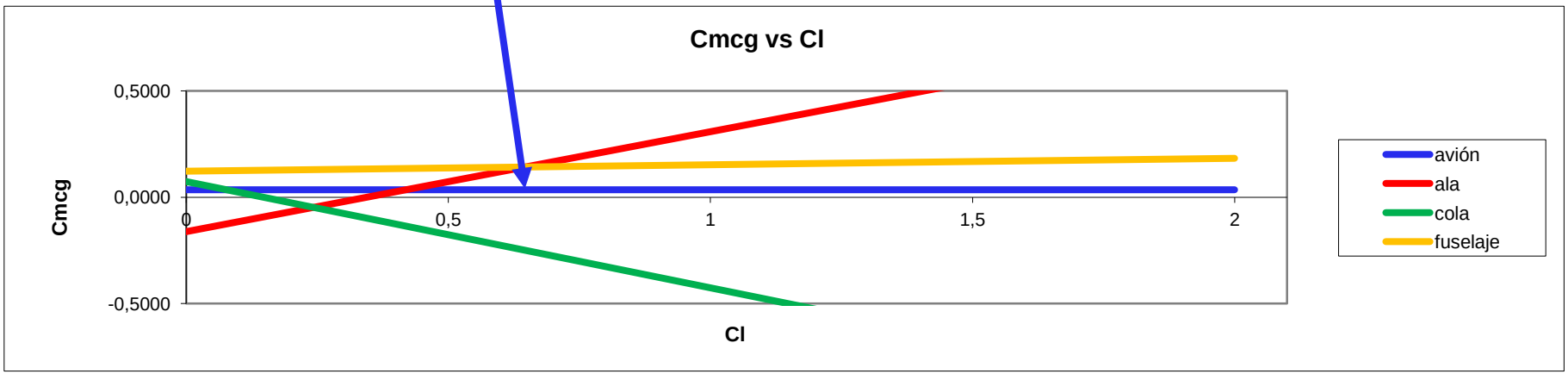
$$\Sigma M_{cg} = - M_{ac} + L \cdot x_a - L_t \cdot x_t = 0$$

PUNTO NEUTRO CON MANDOS FIJOS

$$\frac{dC_{Mcg}}{dC_L} = \frac{X_a}{c} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$

$$\frac{dC_{Mcg}}{dC_L} = X_{cg} - X_{ac} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$

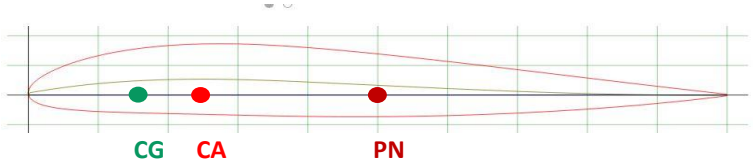
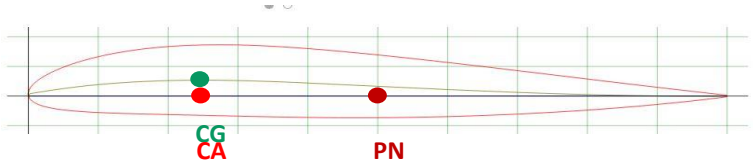
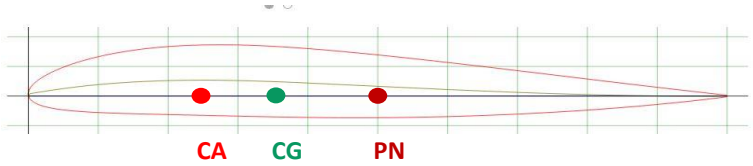
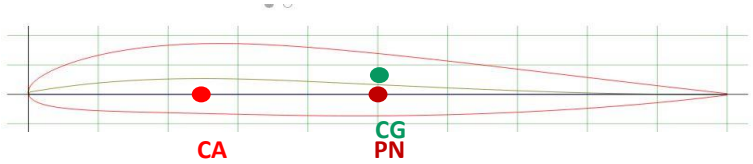
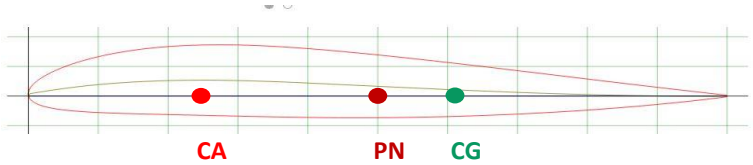
$$0 = N_o - X_{ac} + \frac{dC_{Mf}}{dC_L} - \frac{dC_{Lt}}{dC_L} \cdot \eta_t \cdot \overline{V}$$



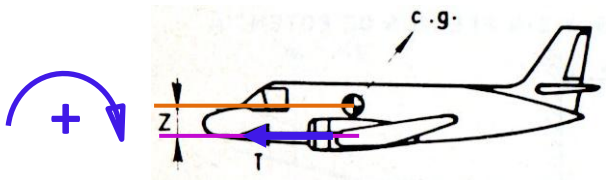
$$\frac{dC_{Mcg}}{dC_L} = X_{cg} - N_o \quad \text{AVIÓN}$$

- < 0 ESTABLE
- = 0 NEUTRO
- > 0 INESTABLE

CONTRIBUCIÓN DEL ALA Y ESTABILIDAD DEL AVIÓN

	CONTRIBUCIÓN DE ALA	ESTABILIDAD AVIÓN
	ESTABLE O POSITIVA	ESTABLE O POSITIVA
	INDIFERENTE O NEUTRA	ESTABLE O POSITIVA
	INESTABLE O NEGATIVA	ESTABLE O POSITIVA
	INESTABLE O NEGATIVA	INDIFERENTE O NEUTRA
	INESTABLE O NEGATIVA	INESTABLE O NEGATIVA

CONTRIBUCIÓN DE LA TRACCIÓN / EMPUJE

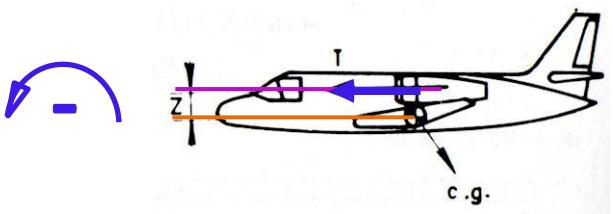


$$T \cdot Z = C_{Mcg} \cdot q \cdot S \cdot C$$

$$C_{Mcg} = \frac{T \cdot Z}{q \cdot S \cdot c} \qquad W = q \cdot S \cdot C_L$$

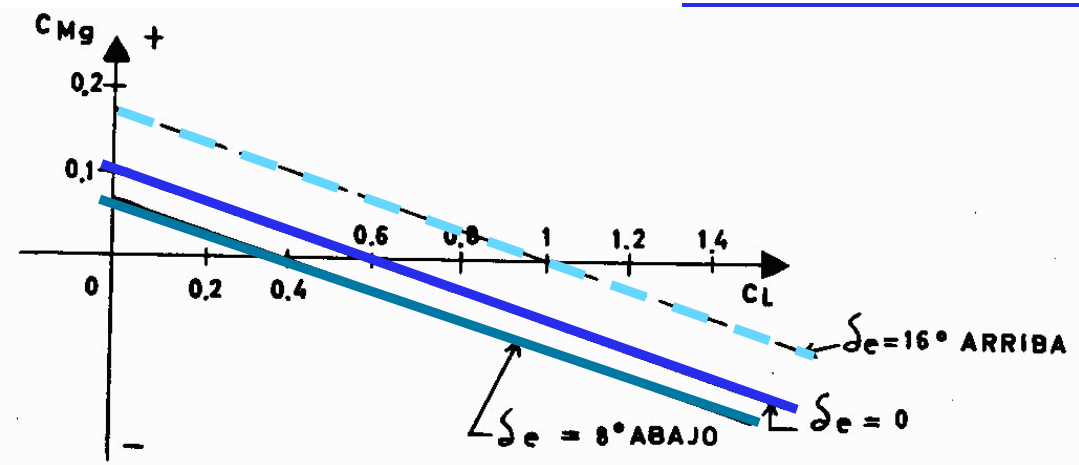
$$C_{Mcg} = \frac{T \cdot Z \cdot C_L}{W \cdot c}$$

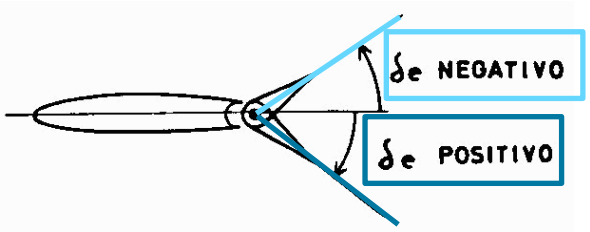
$$\left[\frac{dC_{Mcg}}{dC_L}\right]_T = \frac{T \cdot Z}{W \cdot C} \qquad > 0 \text{ INESTABLE}$$

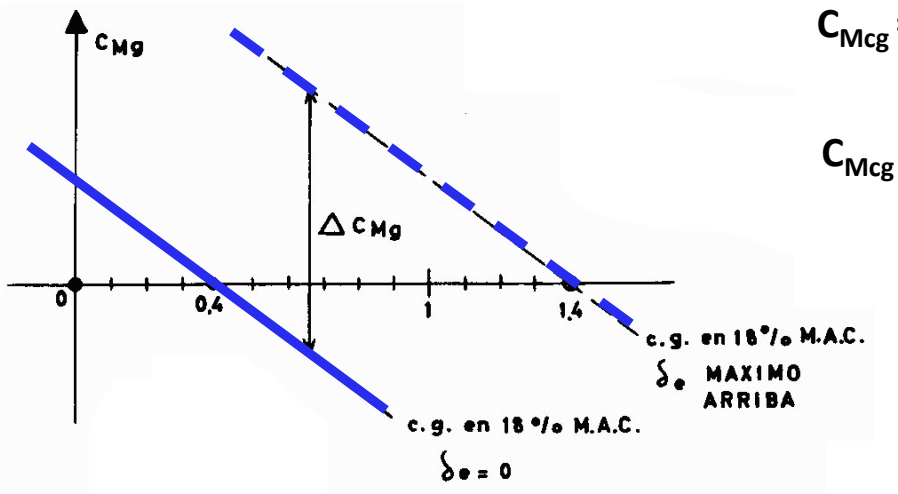


$$\left[\frac{dC_{Mcg}}{dC_L}\right]_T = -\frac{T \cdot Z}{W \cdot C} \qquad < 0 \text{ ESTABLE}$$

CONTROL LONGITUDINAL



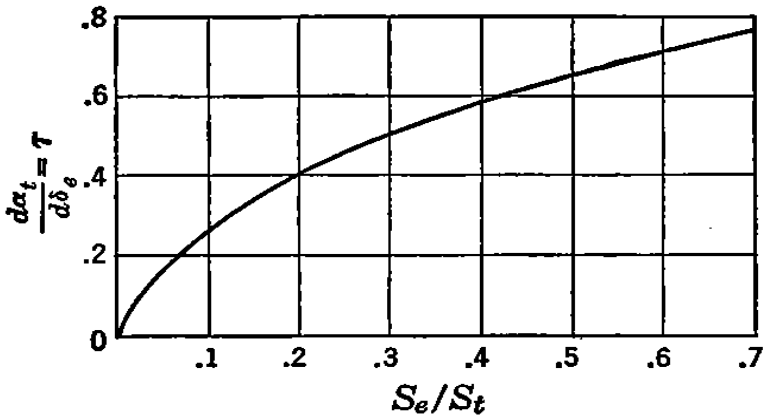




$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_{Mf} - C_{Lt} \cdot \eta_t \cdot \overline{V} = 0$$

$$C_{Mcg} = C_{Mac} + C_L \cdot \frac{x_a}{c} + C_{Mf} - a_t \cdot (\alpha - i + i_t - \varepsilon + \boxed{\tau \cdot \delta_e}) \cdot \eta_t \cdot \overline{V}$$

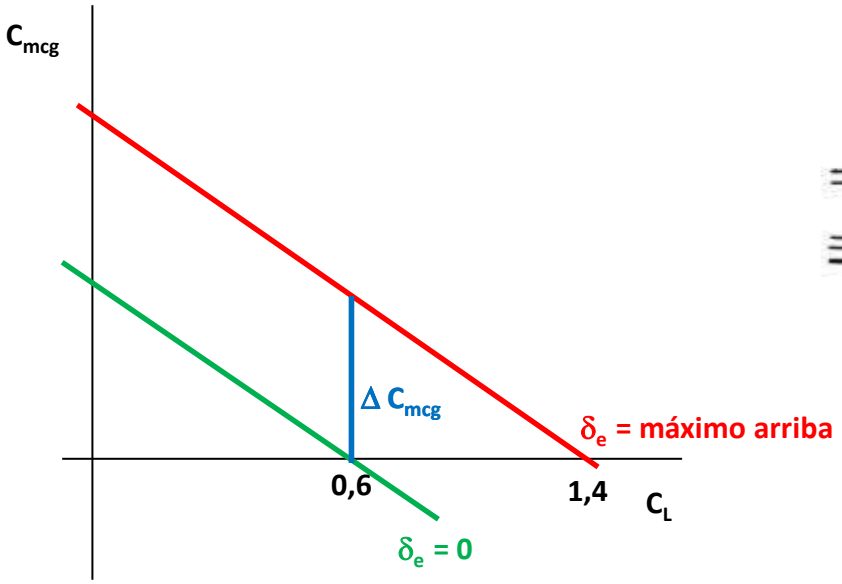
$$\tau = \frac{d\,\alpha_t}{d\,\delta_e} = \text{EFECTIVIDAD DEL TIMÓN}$$

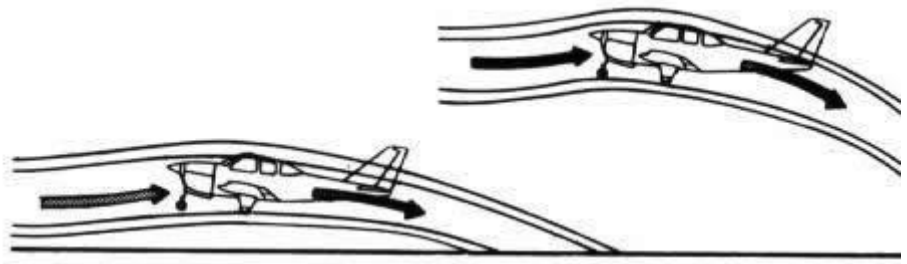


Límites posición delantera C.G.:

1) La deflexión total disponible del timón de profundidad.
2) La capacidad de aterrizar con efecto suelo.
3) La capacidad de maniobra en la configuración de aterrizaje.

CONTROL LONGITUDINAL





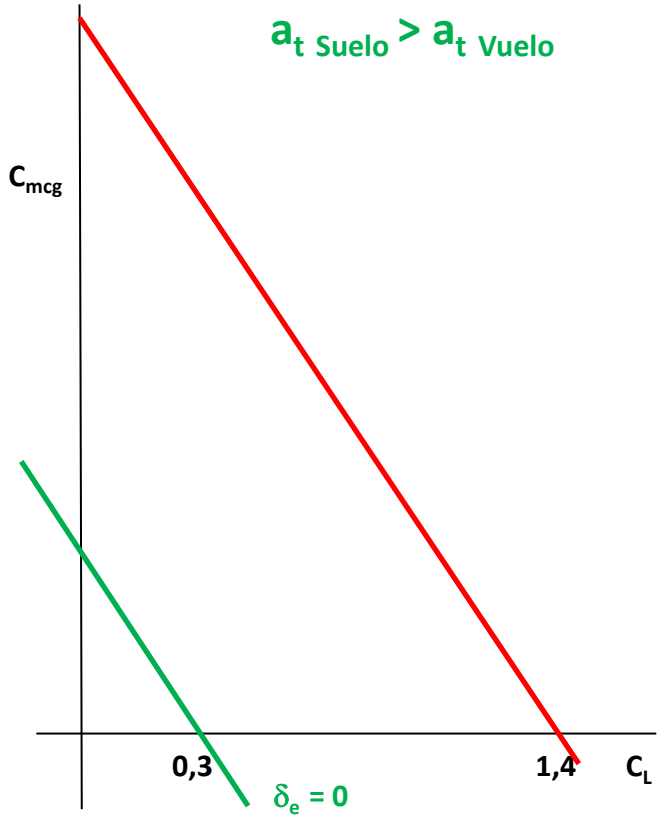
$\varepsilon_{Suelo} < \varepsilon_{Vuelo}$

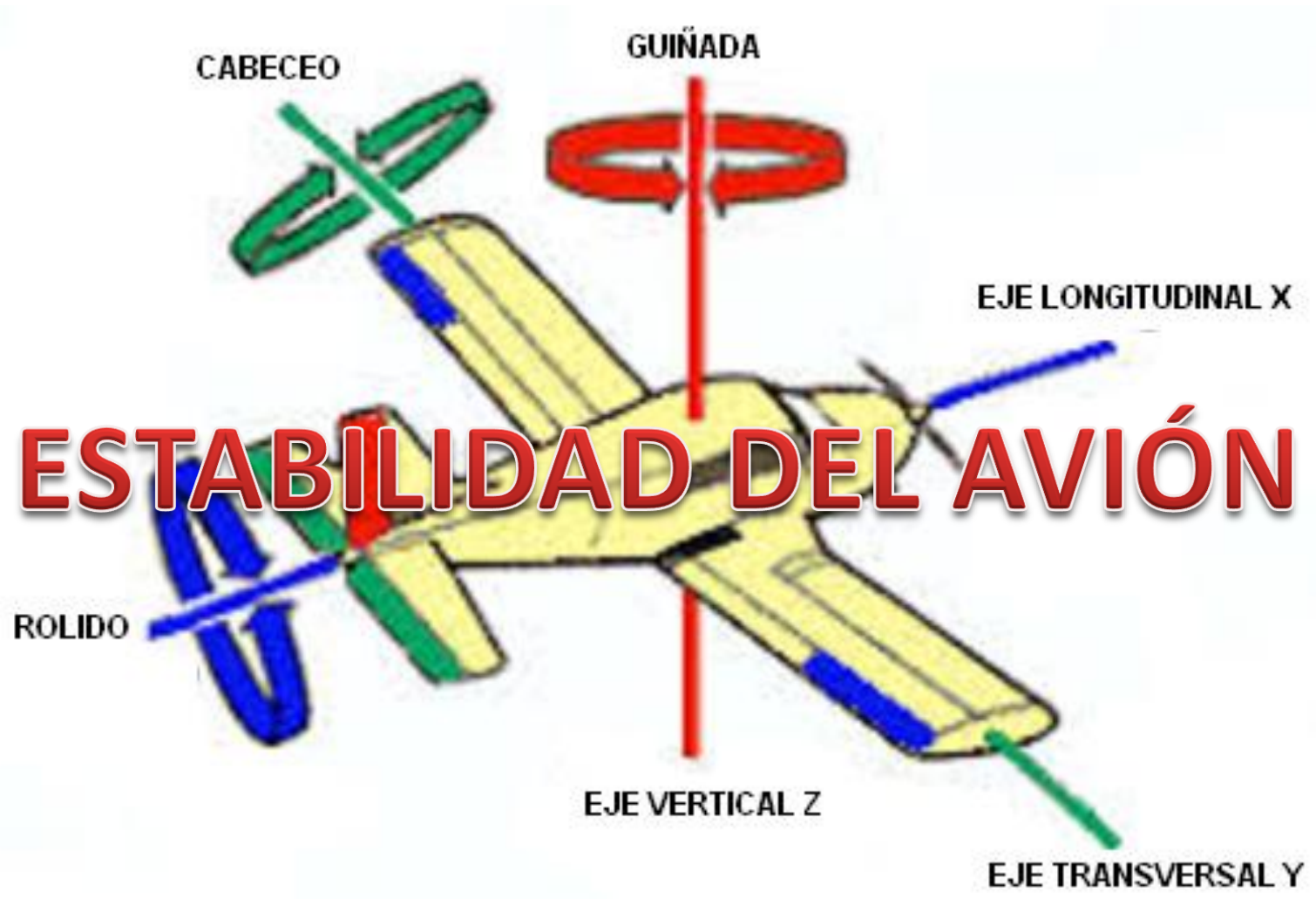
$a_{Suelo} > a_{Vuelo}$

$a_{t\ Suelo} > a_{t\ Vuelo}$

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH} = -\frac{a_t}{a}\cdot\left[1-\frac{d\varepsilon}{d\alpha}\right]\cdot\eta_t\cdot\overline{V}$$

$$\left[\frac{dC_{Mcg}}{dC_L}\right]_{EH\ Suelo} > \left[\frac{dC_{Mcg}}{dC_L}\right]_{EH\ Vuelo}$$





ESTABILIDAD DEL AVIÓN