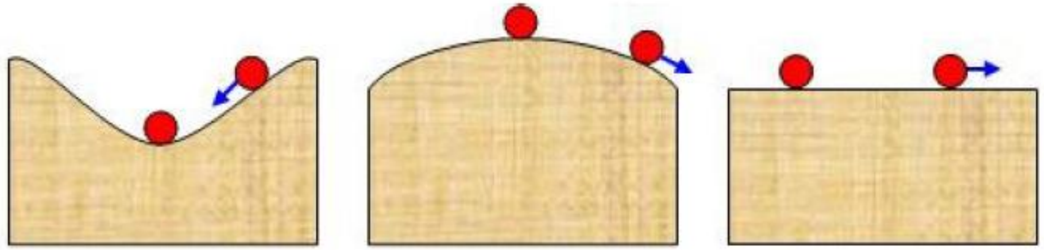
Performance


WHAT HAVE YOU
LEARNED ?

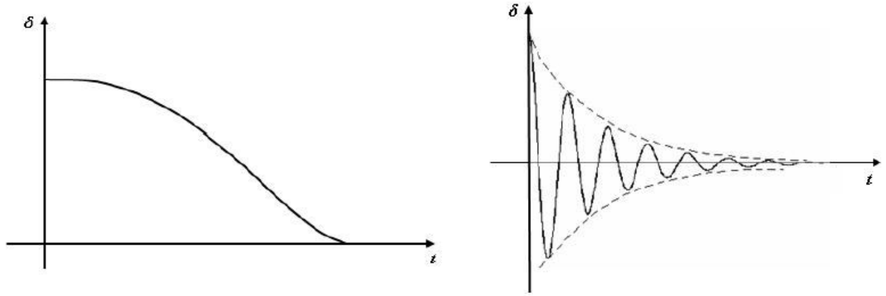
O que é estabilidade?

Estática



(a) – Estaticamente estável (b) – Estaticamente instável (c) – Estabilidade neutra

Dinâmica

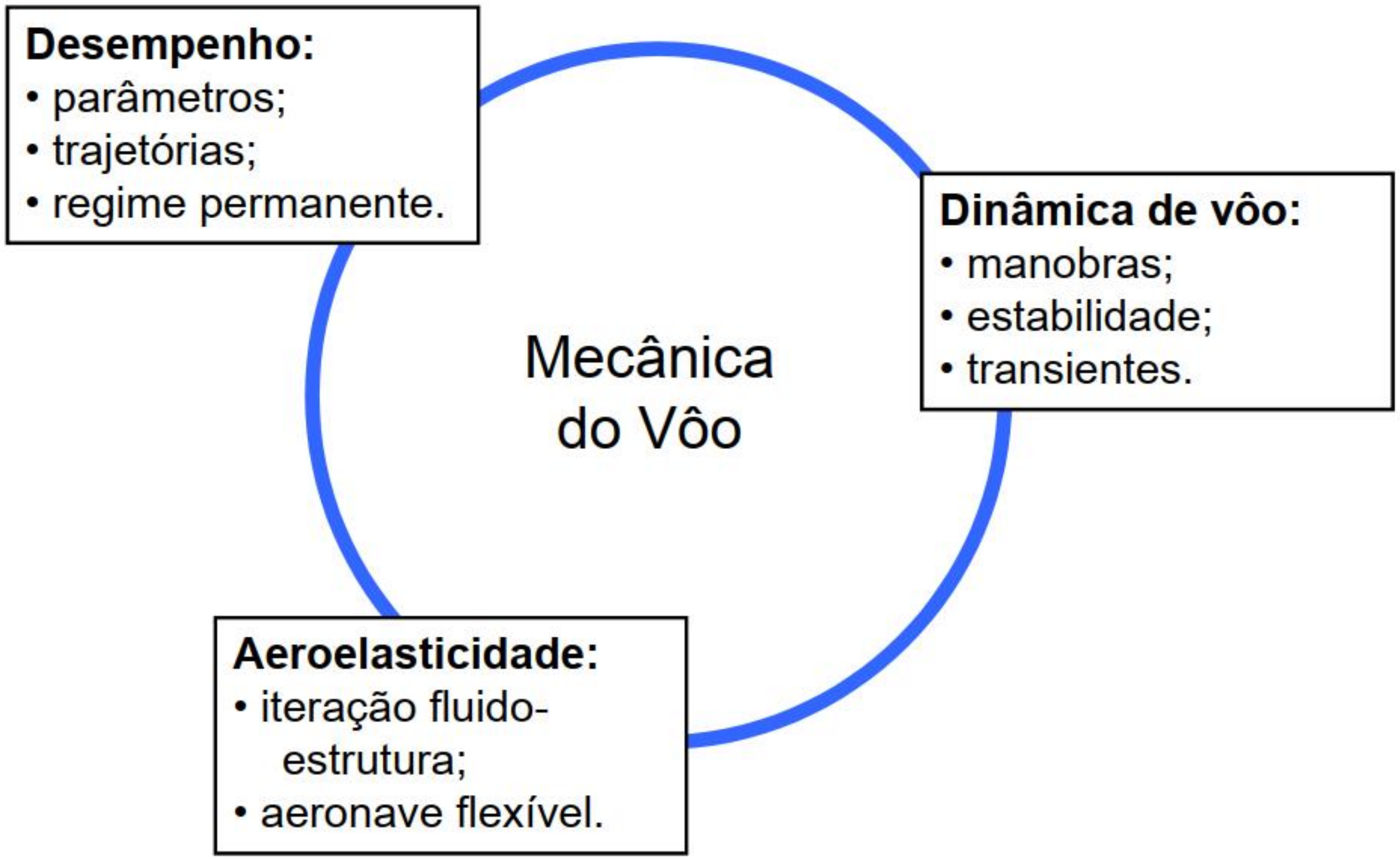


(a) – Movimento aperiódico (b) – Movimento oscilatório

Figura 5.3 – Exemplos de estabilidade dinâmica.

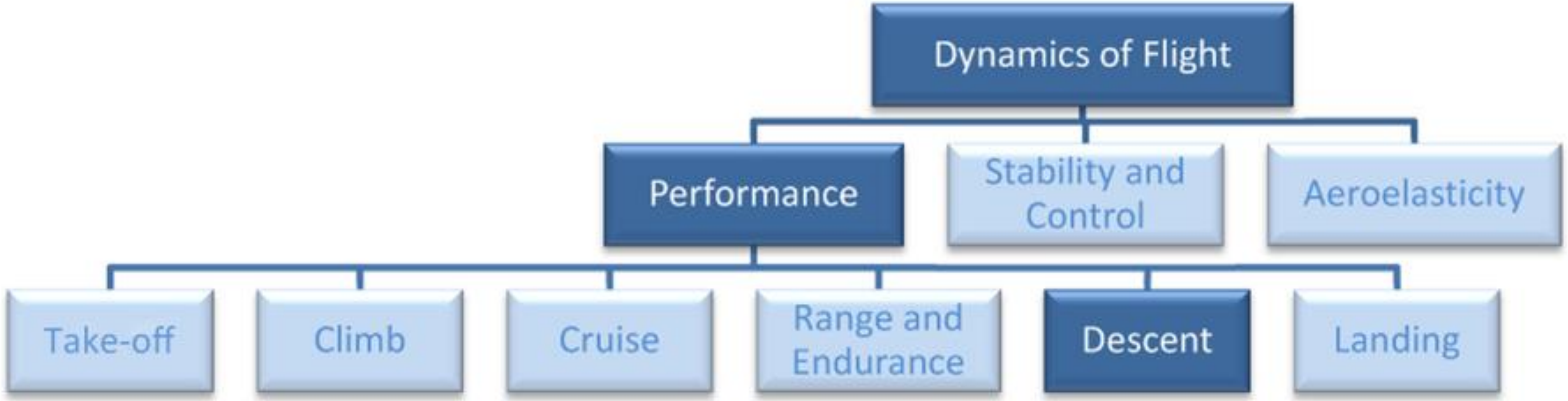
Figura 5.4 – Estabilidade dinâmica de uma aeronave com movimento oscilatório.

Conceito



Desempenho:
• parâmetros;
• trajetórias;
• regime permanente.
Dinâmica de vôo:
• manobras;
• estabilidade;
• transientes.
Mecânica do Vôo
Aeroelasticidade:
• iteração fluido-estrutura;
• aeronave flexível.

Conceito



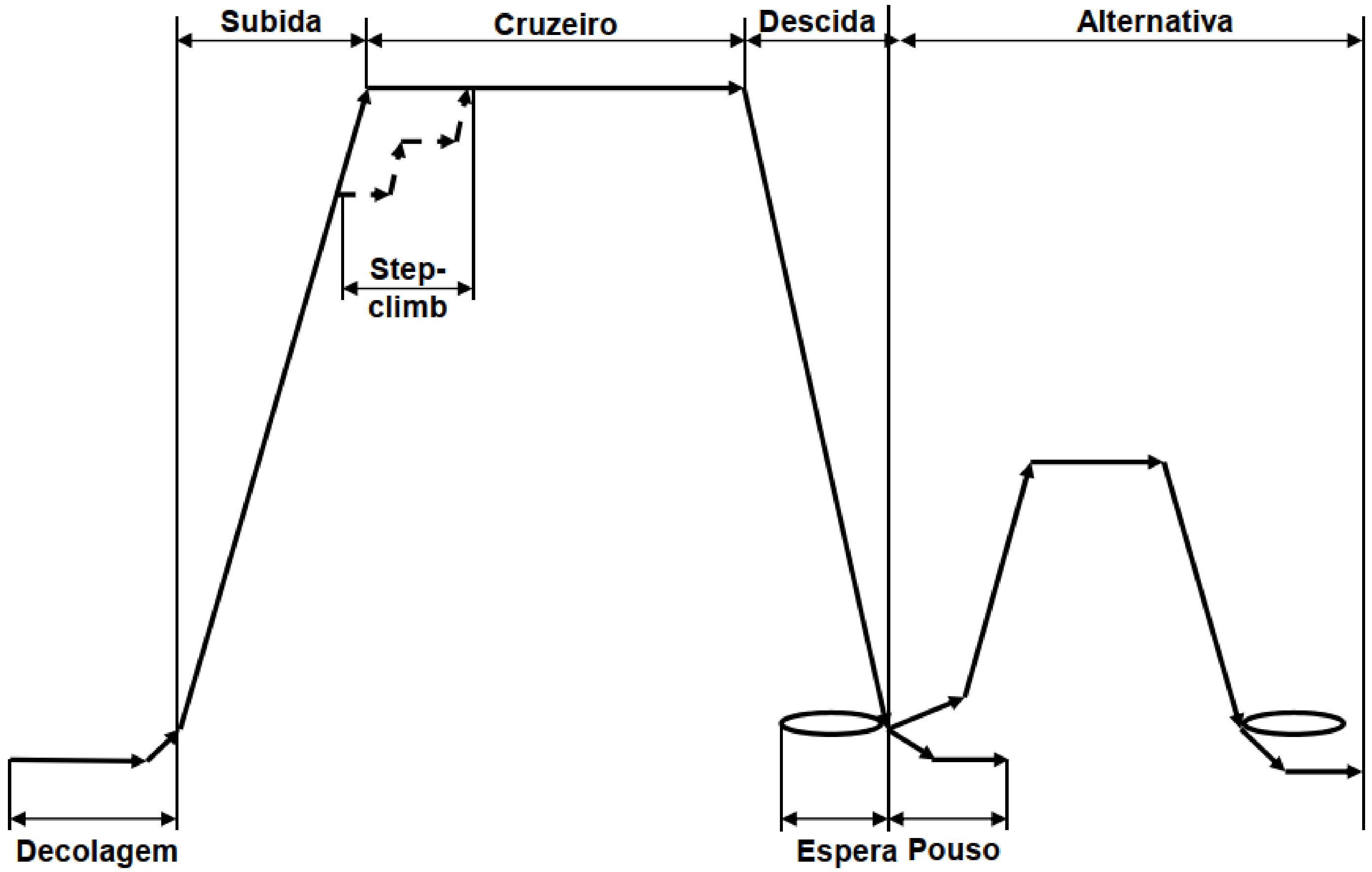
Dynamics of Flight
Performance
Stability and Control
Aeroelasticity
Take-off
Climb
Cruise
Range and Endurance
Descent
Landing

Conceito

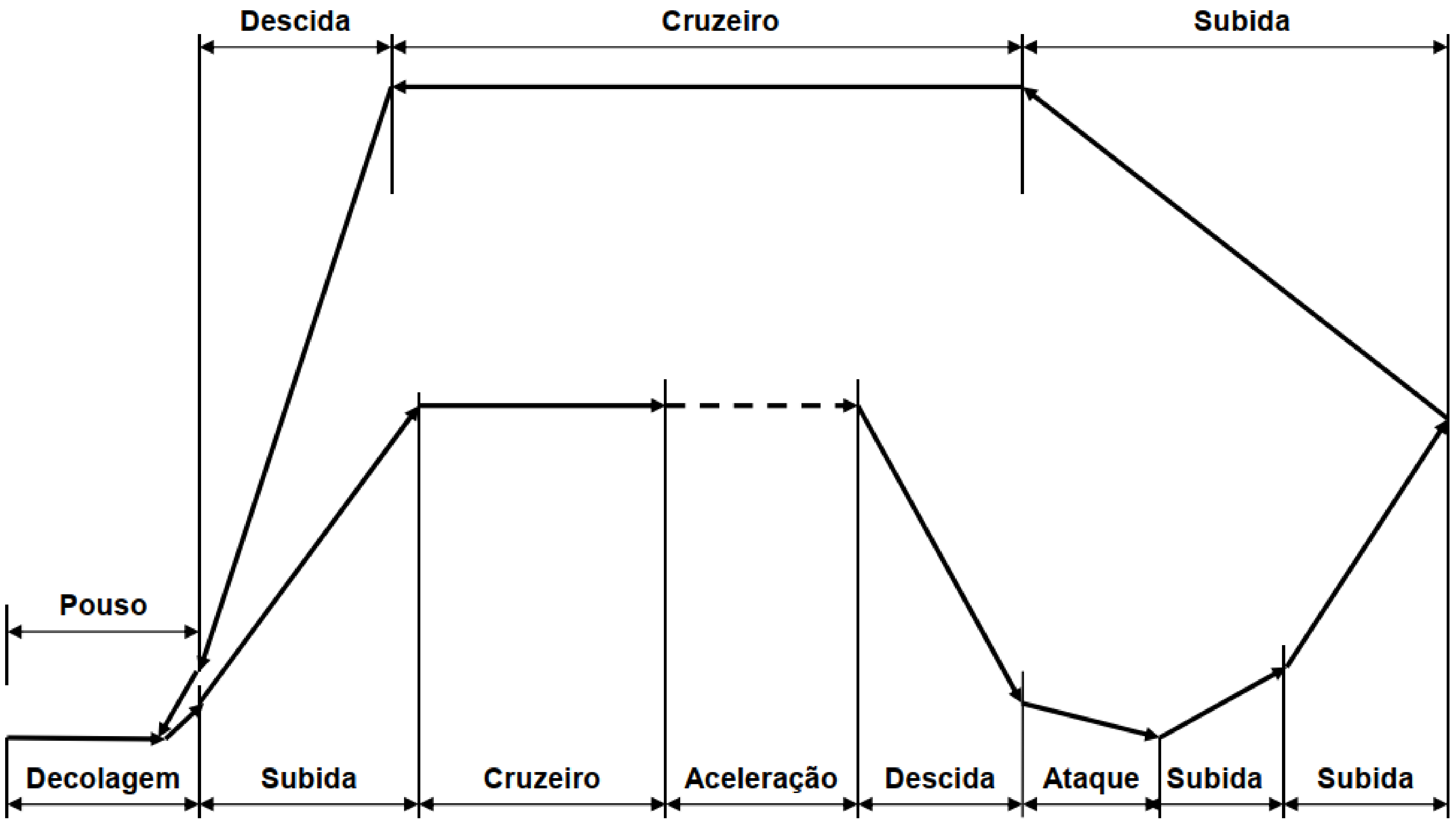
Desempenho de aeronaves

- Avalia o que a aeronave é capaz de fazer em voo (parâmetros do voo):
  - Tempos;
  - Distâncias;
  - Velocidades;
  - Consumo;
  - Pesos (massas) limites;
  - Carga paga.
- Avalia a trajetória (*flight-path*) da aeronave:
  - 2D: decolagem, subida, cruzeiro, descida, espera, pouso;
  - 3D: curvas.

Missões – Aeronave Civil



Missões – Aeronave Militar



Missões – Exemplos do Raymer

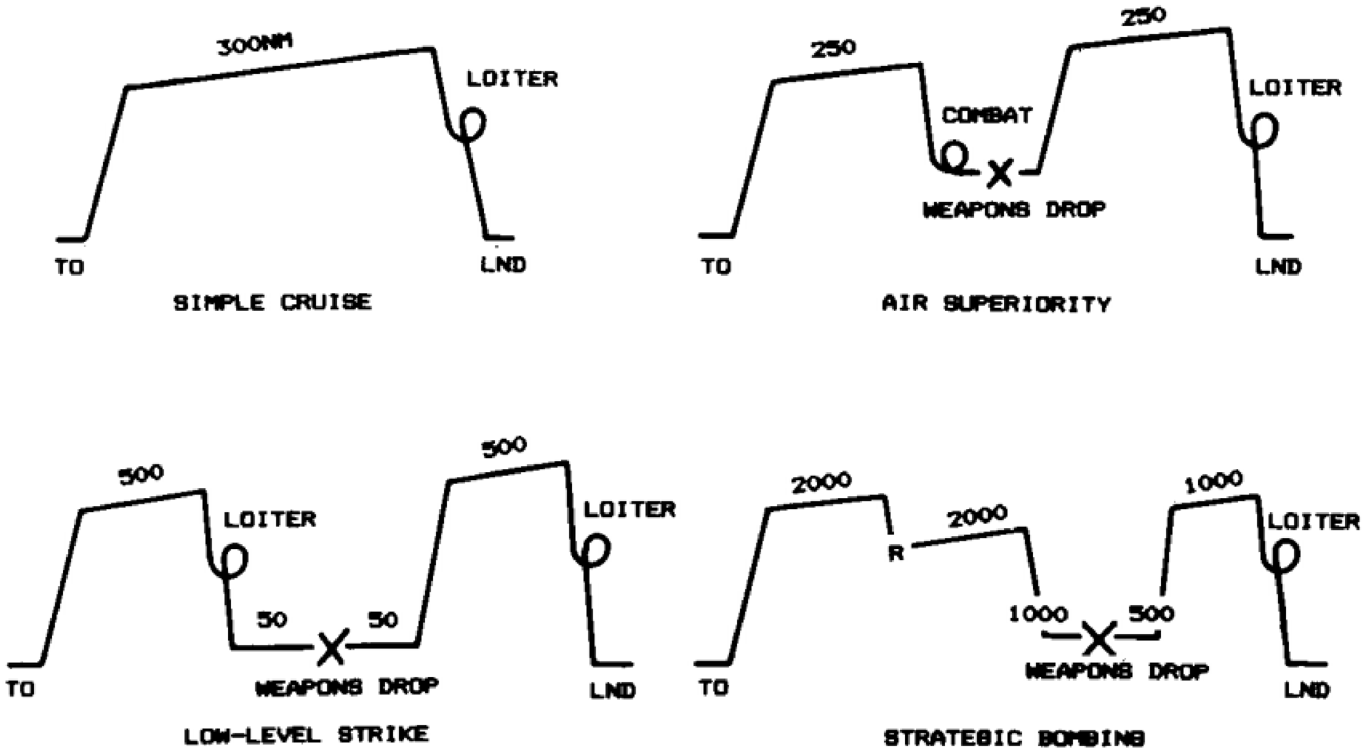
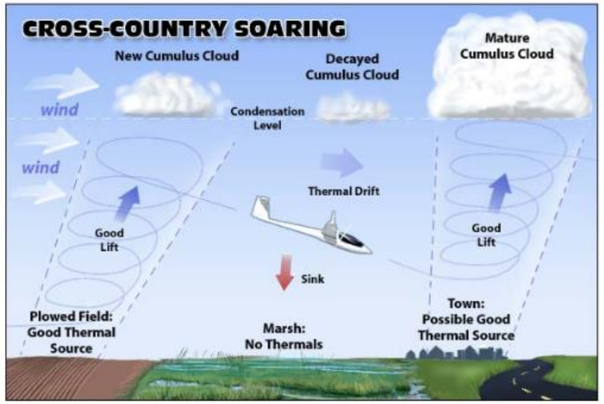
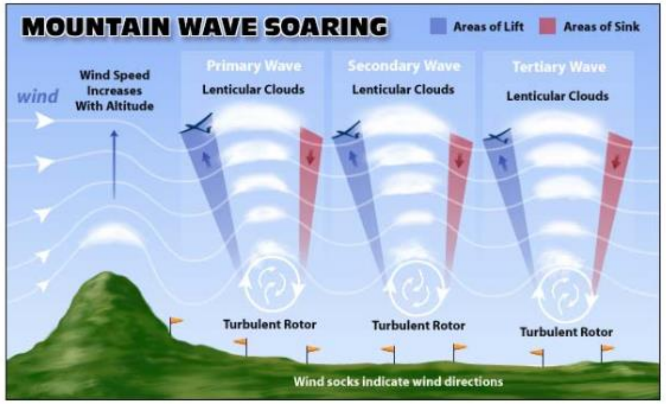


Fig. 3.2 Typical mission profiles for sizing.

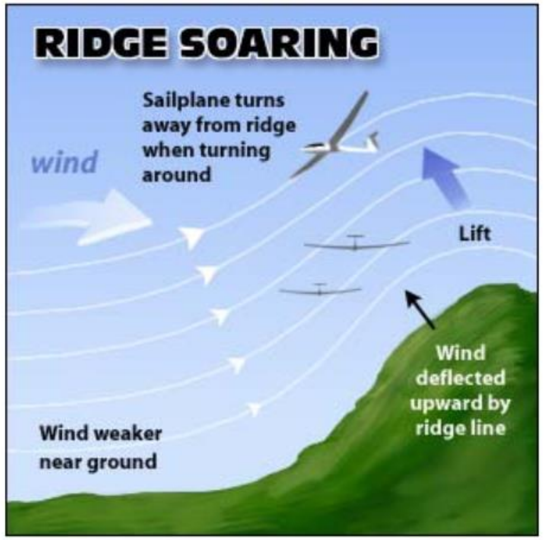
Missões – Planador



(a) Cross-country soaring through thermal lifts.



(b) Cross-country soaring through wave lifts.



(c) Cross-country soaring through ridge lifts.

Atmosfera padrão

- A composição química da atmosfera: 21% oxigênio, 78% de nitrogênio e 1% de outros gases;
- Aproximadamente 94%, ou seja, quase que toda a massa da atmosfera terrestre, concentra-se até o limite de 20km de altitude.

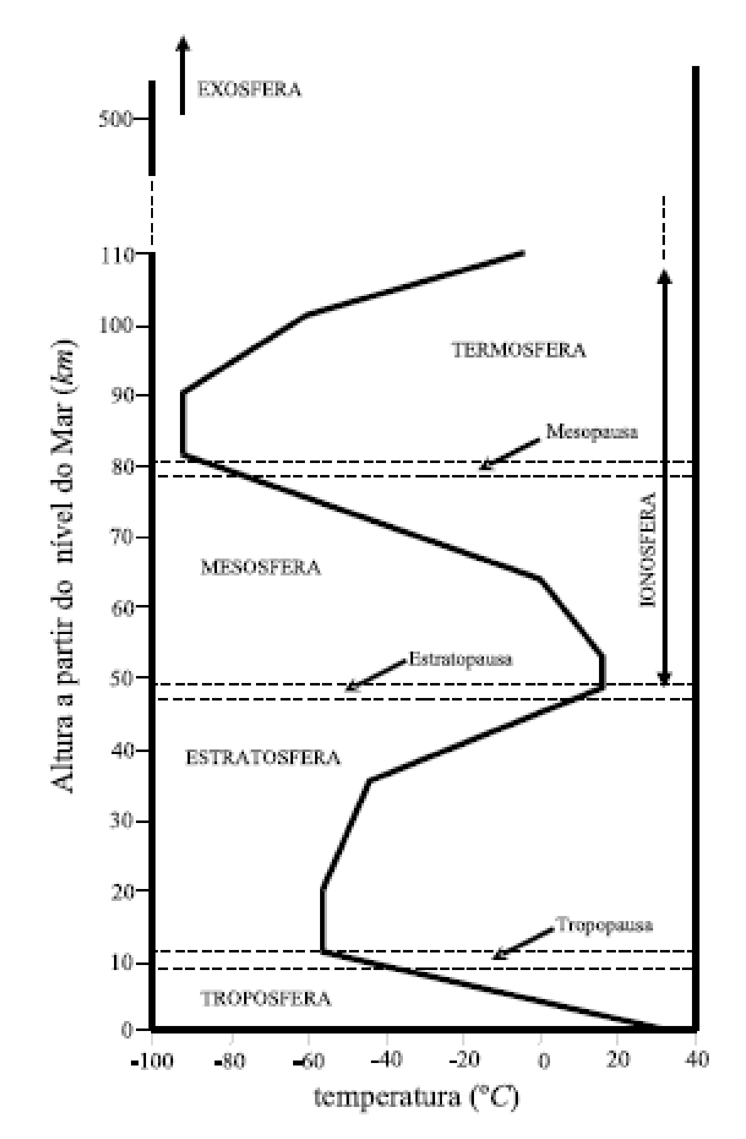
Camadas:

Troposfera: 0km à 10 ou 20km;

Estratosfera: 10 ou 20km à 50km;

Ionosfera: 50km à 500km (Mesosfera e Termosfera);

Exosfera: acima de 500km.



Voo nivelado em cruzeiro

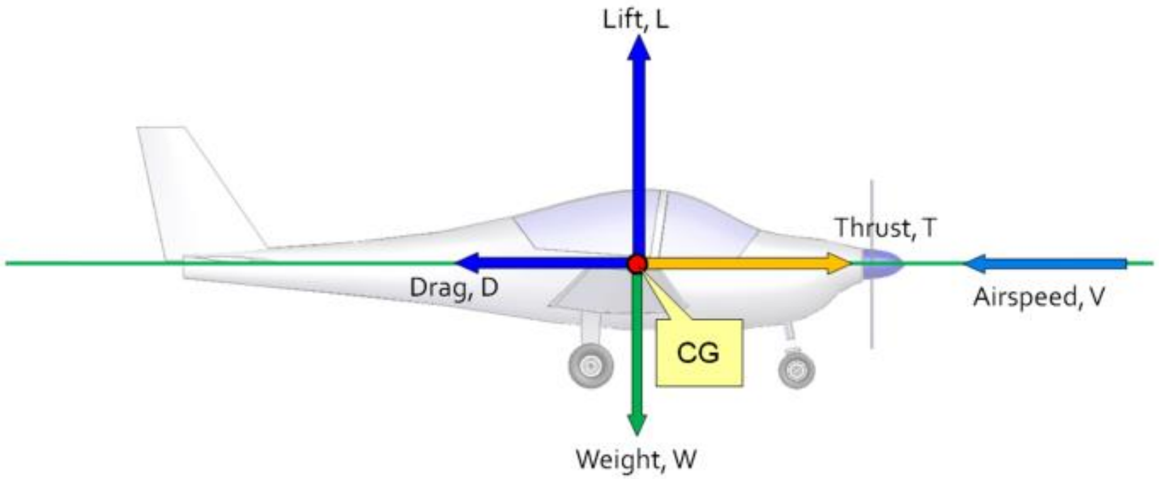


FIGURE 19-2 A two-dimensional free body of the airplane in level flight.

V cte => a = 0

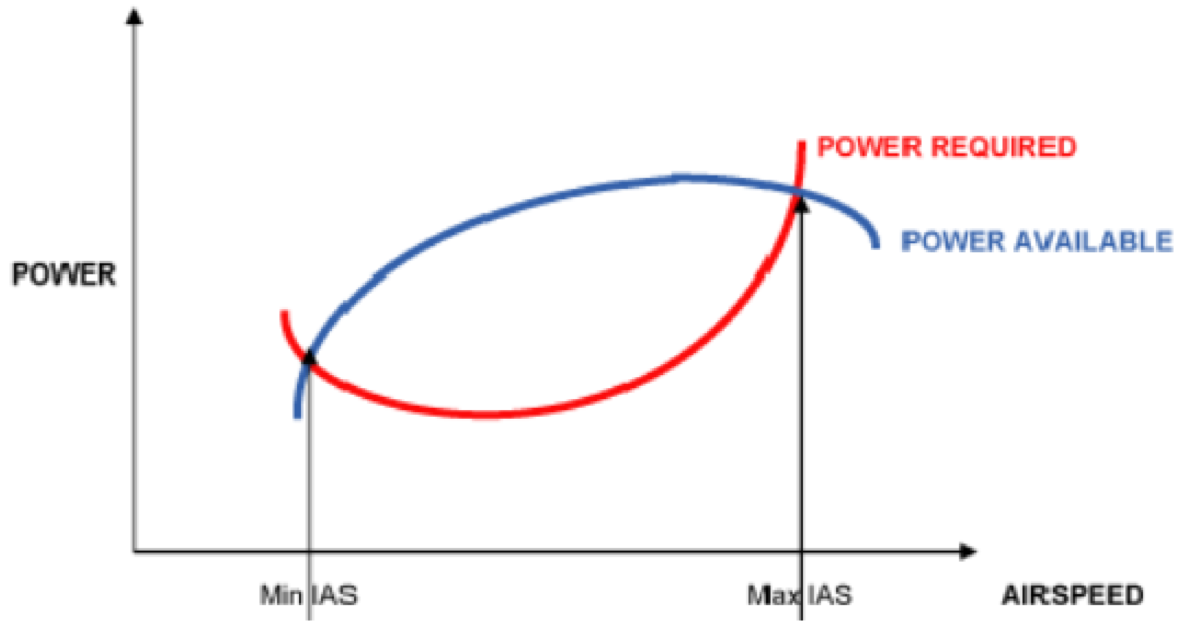
$$L = W$$

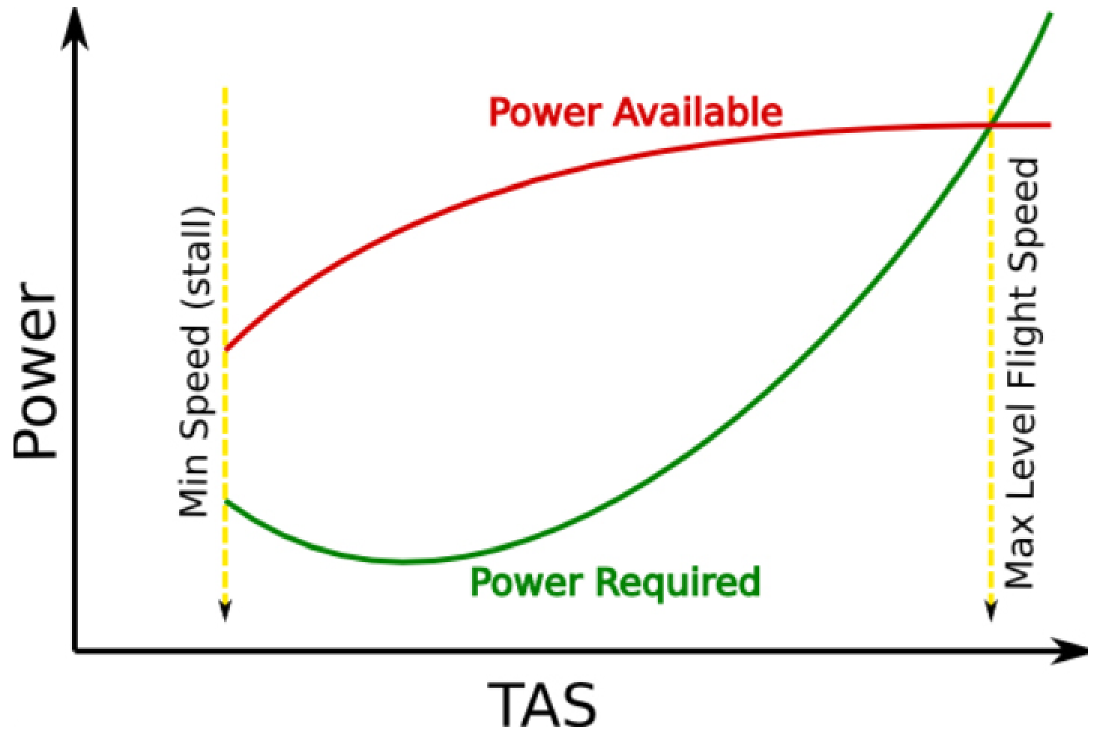
$$D = T$$

D = CD * q *Sw
D*V = CD * q *Sw *V
PR (potência requerida) = D*V

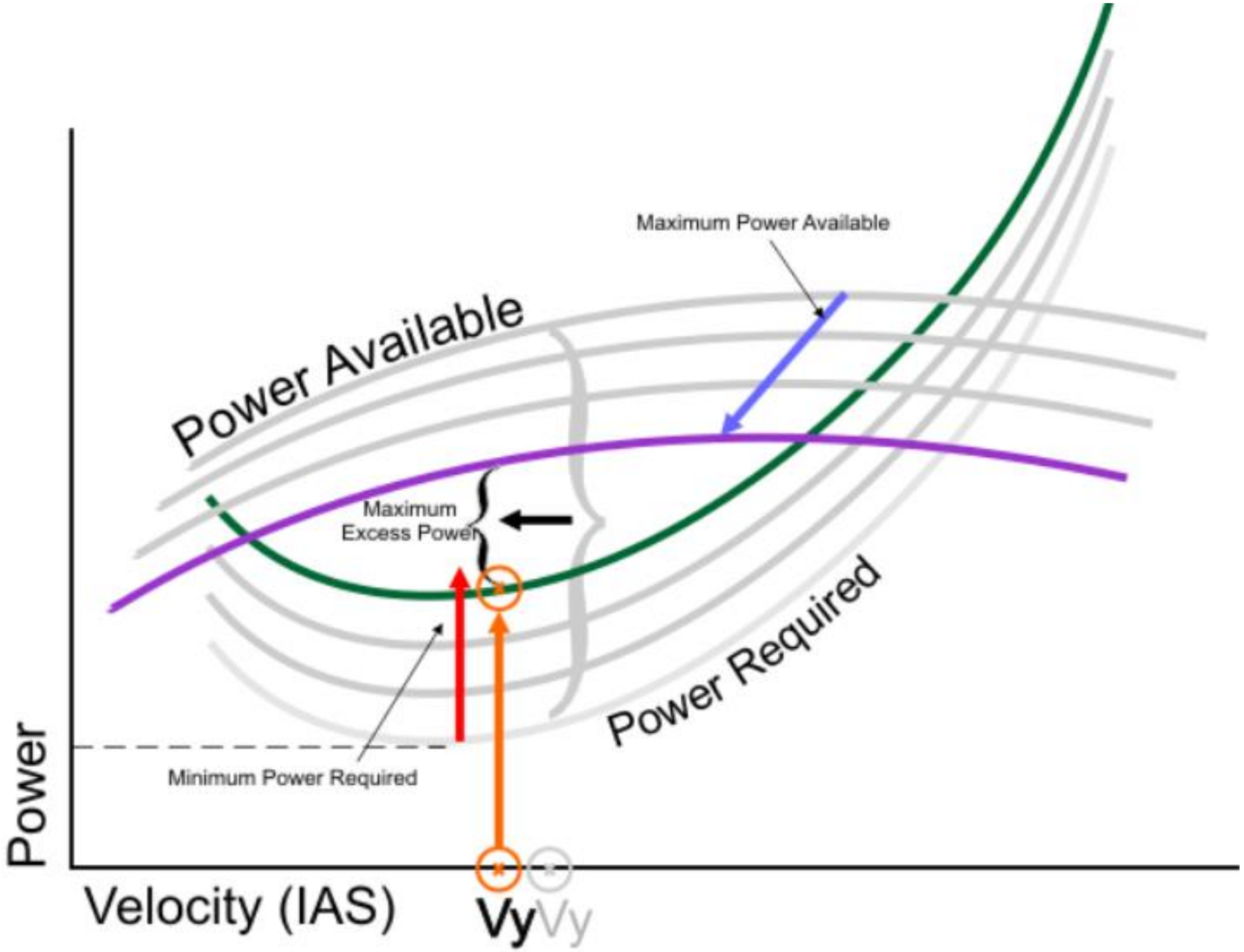
PD (potência disponível) = T*V

Voo nivelado em cruzeiro

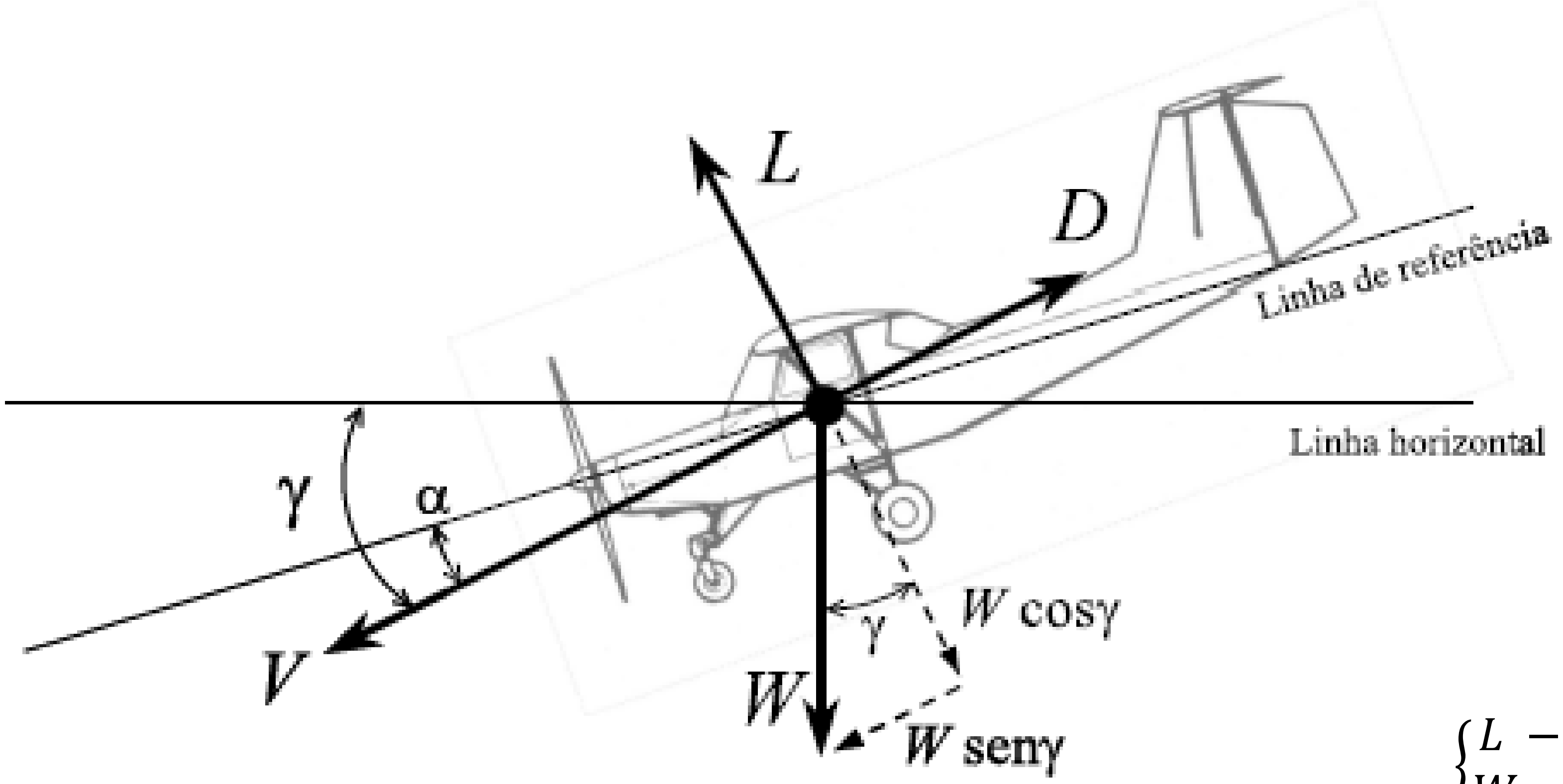




Voo nivelado em cruzeiro

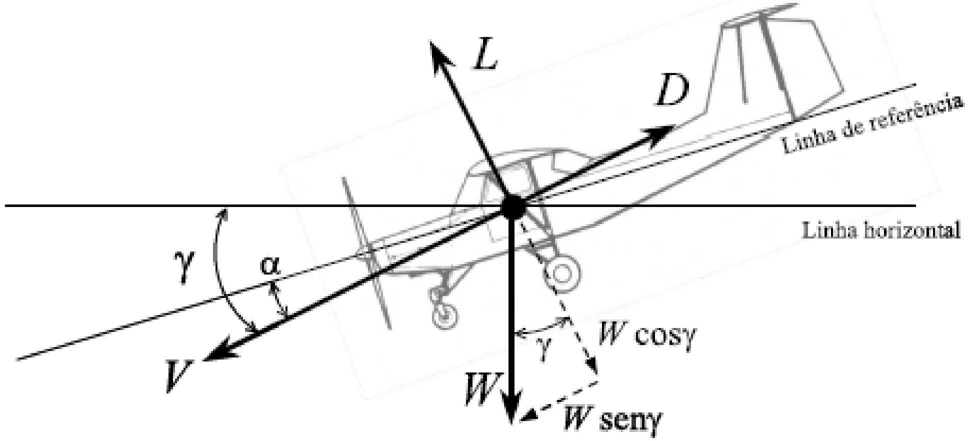


Voo em descida



$$\begin{cases} L - W\ cos\gamma = 0 \\ W\ sen\gamma - D = 0 \end{cases}$$

Voo em descida



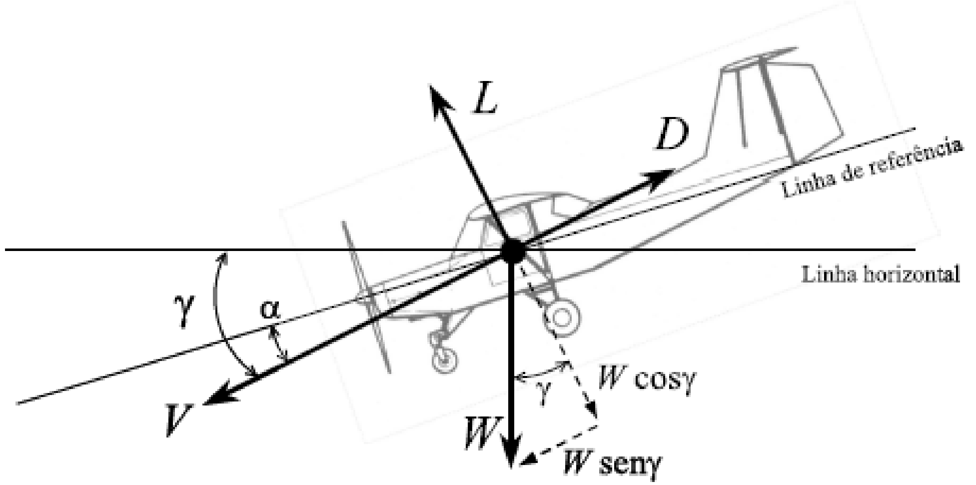
$$\begin{cases} L - W\cos\gamma = 0 \\ W\,\mathrm{sen}\gamma - D = 0 \end{cases} \Rightarrow \begin{cases} L = W\cos\gamma \\ D = W\,\mathrm{sen}\gamma \end{cases} \Rightarrow \tan\gamma = \frac{D}{L} = \frac{1}{\left(\frac{L}{D}\right)} = \frac{1}{\left(\frac{C_L}{C_D}\right)}$$

$$\gamma_{MIN} = \left(\frac{C_L}{C_D}\right)_{MÁX}$$

$$dist_{percorrida} = \mathrm{V}\cos\gamma * \Delta t$$

A maior distância percorrida ocorre no menor ângulo de planeio, portanto no maior L/D.

Voo em descida



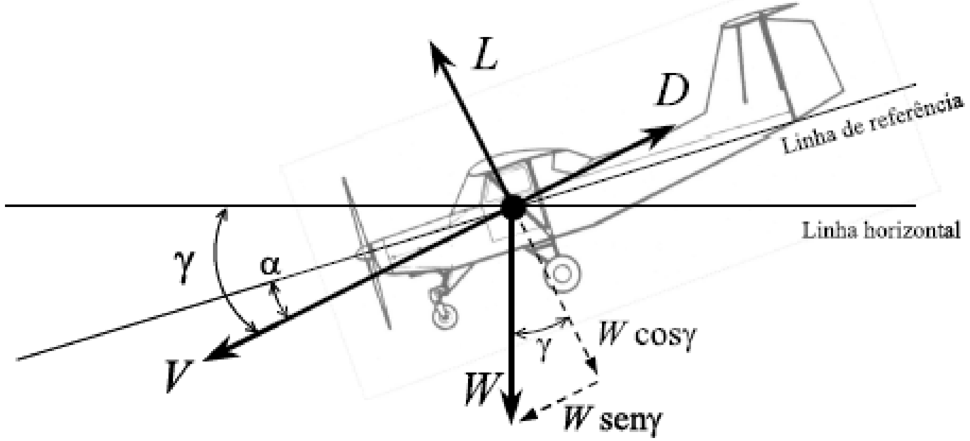
$$\gamma_{MIN} = \left(\frac{C_L}{C_D}\right)_{MÁX}$$

$$C_L = CD0 + k{C_L}^2$$

$$\gamma_{MIN} = \left(\frac{C_L}{C_D}\right)_{MÁX} = \frac{d}{dC_L}\left(\frac{CD0 + kC_L^2}{C_L}\right) = 0$$

$$C_L = \sqrt{\frac{CD0}{k}}$$

Voo em descida



$$\gamma_{MIN} = \left(\frac{C_L}{C_D}\right)_{MÁX}$$

$$C_L = CD0 + kC_L{}^2$$

$$\gamma_{MIN} = \left(\frac{C_L}{C_D}\right)_{MÁX} = \frac{d}{dC_L}\left(\frac{CD0 + kC_L^2}{C_L}\right) = 0$$

$$C_L = \sqrt{\frac{CD0}{k}}$$

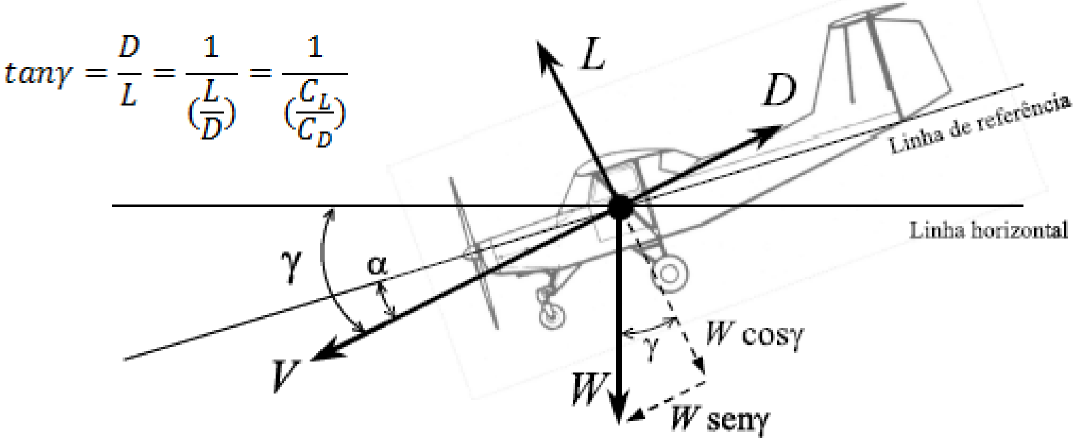
$$L = W\ cos\gamma$$

$$\frac{1}{2}\rho V^2 * S_W * C_L = W\ cos\gamma$$

$$V = \sqrt{\frac{2\ W\ cos\gamma}{\rho * S_W * C_L}}$$

$$V_{\gamma MIN} = V_{maior\ alcance} = \sqrt{\frac{2\ W\ cos\gamma}{\rho * S_W}} \sqrt[4]{\frac{k}{CD0}}$$

Voo em descida



$$RD\ (Razão\ de\ descida) = V\ sen\gamma = V\ \frac{C_D}{C_L} cos\gamma$$

$$tan\gamma = \frac{D}{L} = \frac{1}{(\frac{L}{D})} = \frac{1}{(\frac{C_L}{C_D})}$$

$$V = \sqrt{\frac{2\ W\ cos\gamma}{\rho * S_W * C_L}}$$

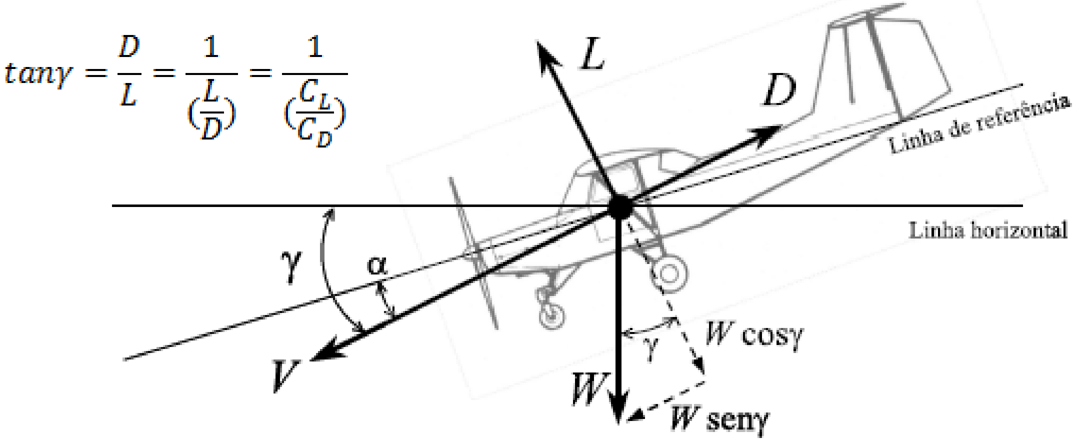
$$RD = \sqrt{\frac{2W\ {C_D}^2\ cos^3\gamma}{\rho * S_W * {C_L}^3}}$$

γ pequeno

$$RD = \sqrt{\frac{2W}{\rho S_W} \frac{{C_D}^2}{{C_L}^3}}$$

A maior autonomia (tempo de voo) ocorre com a menor RD, que ocorre quando $(\frac{CL^{1.5}}{CD})$ é máximo

Voo em descida



$$RD\ (Razão\ de\ descida) = V\ sen\gamma = V\ \frac{C_D}{C_L} cos\gamma$$

$$V = \sqrt{\frac{2\ W\ cos\gamma}{\rho * S_W * C_L}}$$

$$tan\gamma = \frac{D}{L} = \frac{1}{(\frac{L}{D})} = \frac{1}{(\frac{C_L}{C_D})}$$

$$RD = \sqrt{\frac{2W\ {C_D}^2\ cos^3\gamma}{\rho * S_W * {C_L}^3}} \xrightarrow{\gamma \text{ pequeno}} RD = \sqrt{\frac{2W}{\rho S_W} \frac{{C_D}^2}{{C_L}^3}}$$

A maior autonomia (tempo de voo) ocorre com a menor RD, que ocorre quando $(\frac{CL^{1.5}}{CD})$ é máximo

$$\left(\frac{CL^{1.5}}{CD}\right)_{MAX} \Rightarrow \begin{cases} C_L = \sqrt{\frac{3CD0}{k}} \\ C_D = 4CD0 \end{cases} \longrightarrow V_{RDMIN} = \sqrt{\frac{2\ W}{\rho * S_W}} \sqrt[4]{\frac{k}{3CD0}}$$

Voo em descida

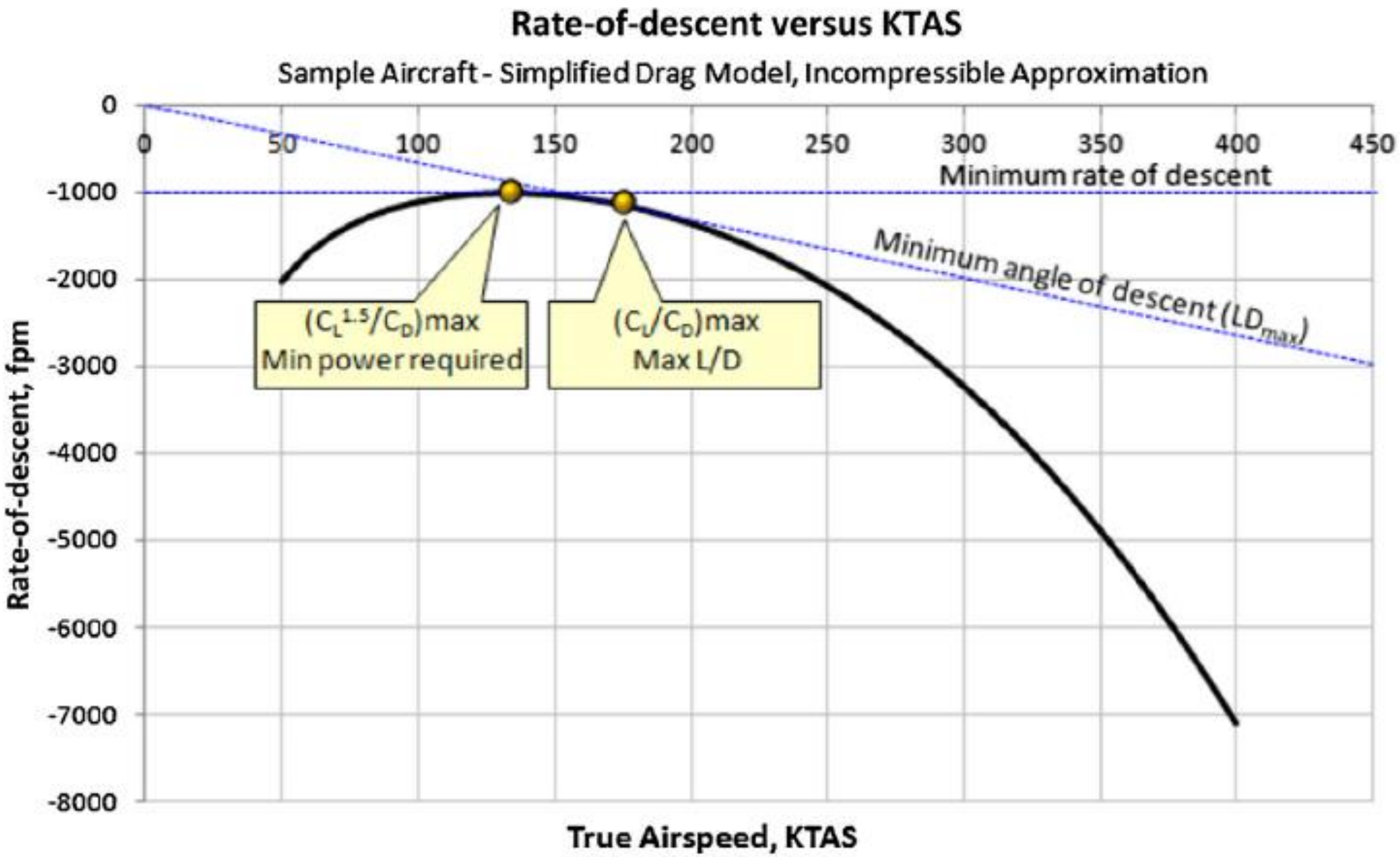


FIGURE 21-6 Important characteristics extracted from the flight polar (at S-L).

Voo em descida

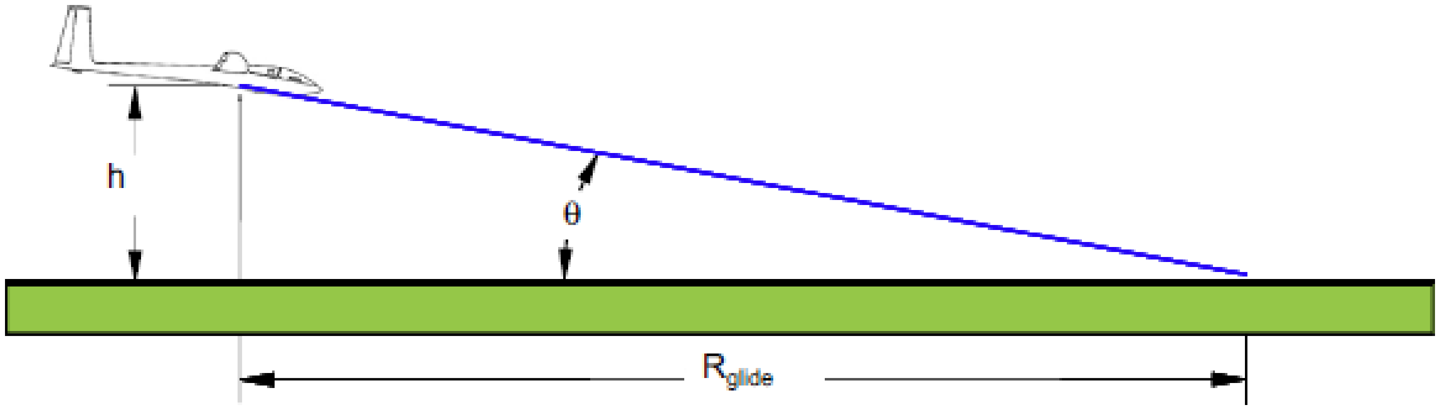


FIGURE 21-7 Distance covered during glide can be estimated using the L/D ratio.

EXAMPLE 21-5

Determine the maximum glide distance for the sample aircraft flying at 30,000 ft.

Solution

Using the maximum LD calculated in EXAMPLE 19-7 we get ($LD_{max} = 15.45$):

Voo em descida

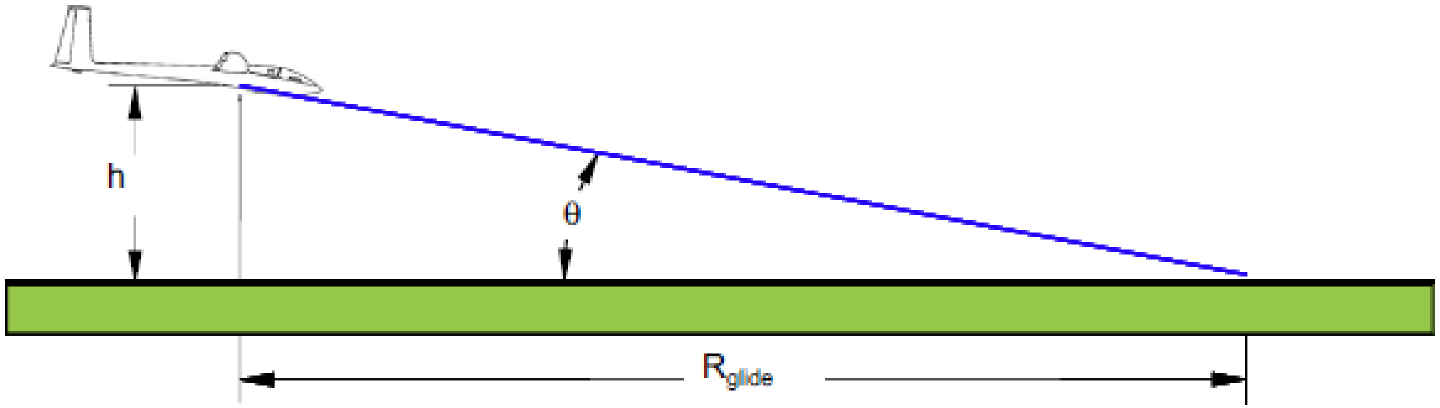


FIGURE 21-7 Distance covered during glide can be estimated using the L/D ratio.

EXAMPLE 21-5

Determine the maximum glide distance for the sample aircraft flying at 30,000 ft.

Solution

Using the maximum LD calculated in EXAMPLE 19-7 we get ($LD_{max} = 15.45$):

$$R_{glide} = h \cdot \left(\frac{L}{D}\right)_{max}$$
$$= 30{,}000 \times (15.45)$$
$$= 463{,}500 \text{ ft } (76.3 \text{ nm})$$