Aerodynamics

Introduction to Aeronautical Engineering

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Previously

$$\sum F_{\parallel V} : \frac{W}{g}\frac{dV}{dt} = T\cos\alpha_t - D - W\sin\gamma$$

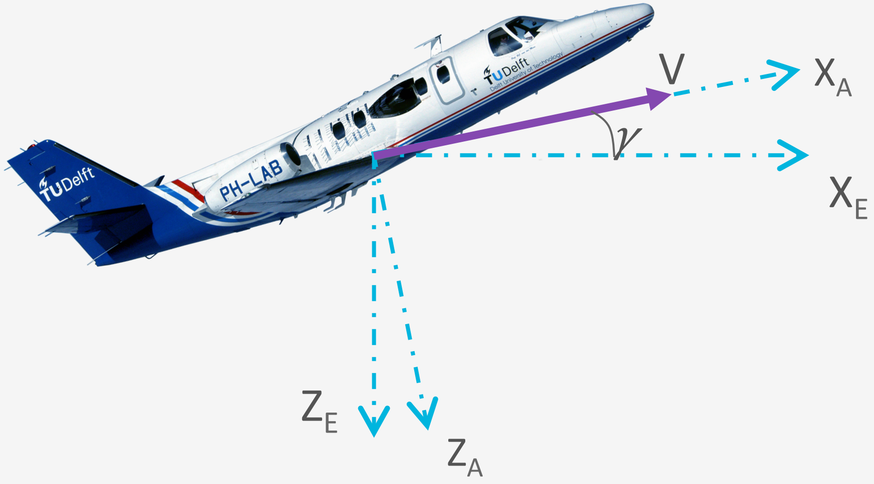
$$\sum F_{\perp V} : \frac{W}{g}V\frac{d\gamma}{dt} = L - W\cos\gamma + T\sin\alpha_t$$

Different variables

Independent: t

State: $\gamma \; V$

Other: $T \; L \; W \; D \; \alpha_T$



The lift-drag polar

$$C_D = C_{D_0} + \frac{C_L^2}{\pi A \phi}$$

Zero lift drag: C_{D_0}

Lift induced drag: $\frac{C_L^2}{\pi A \phi}$

Tip vortices

Tip vortices

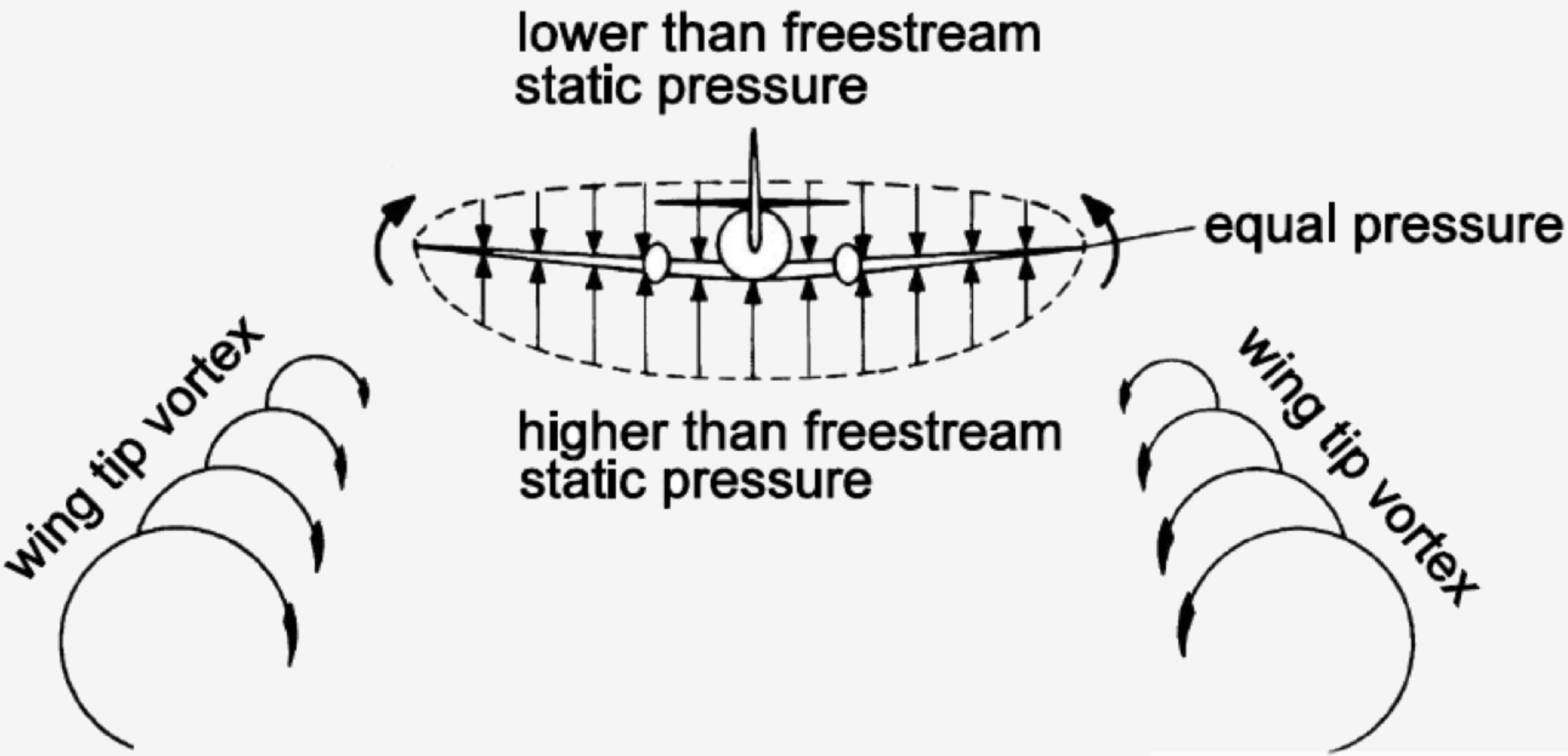
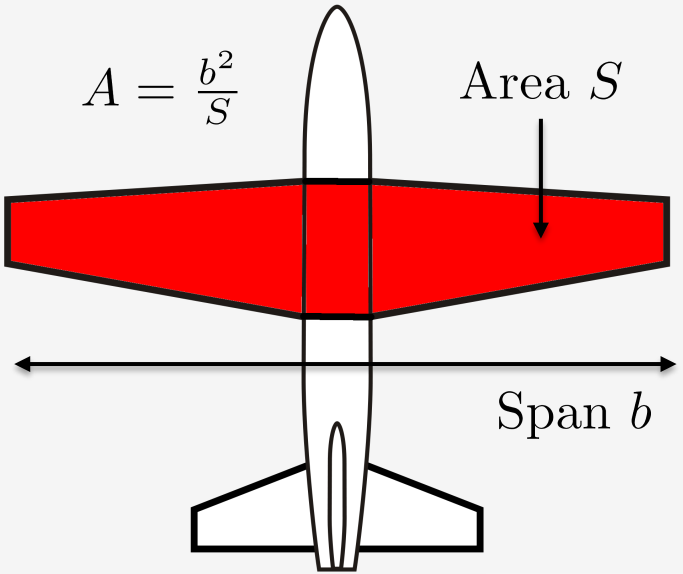


Image from 'Elements of Airplane Performance'

Tip vortices

Aspect ratio and Span efficiency

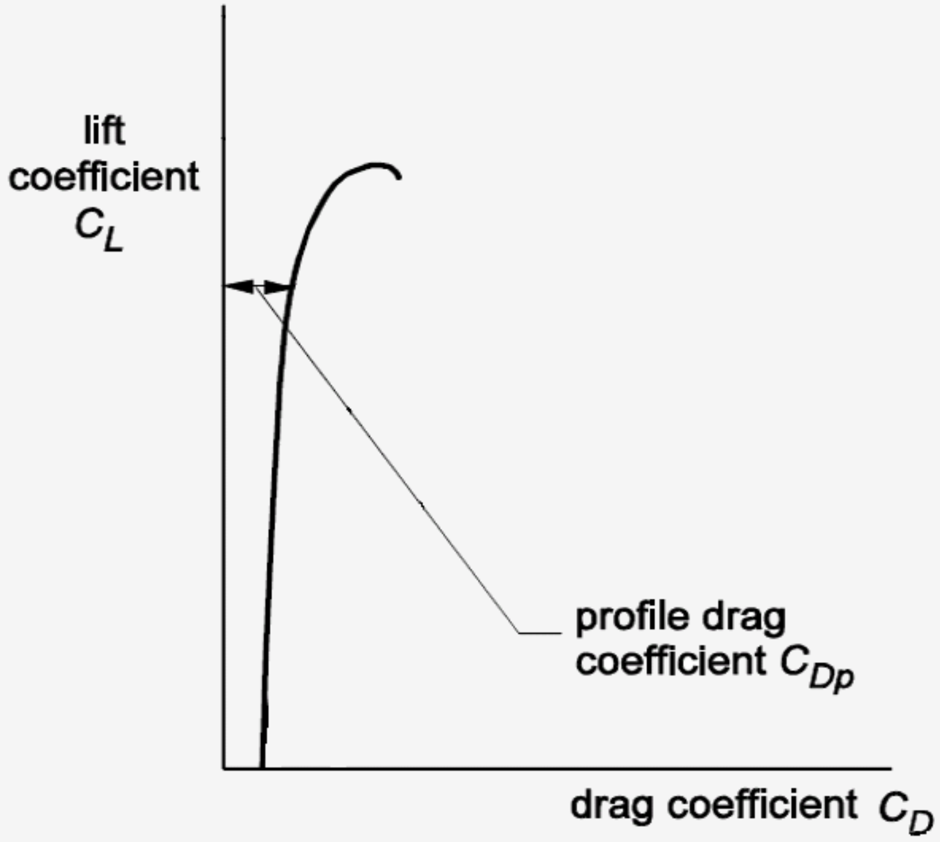
$$C_D = C_{D_0} + \frac{C_L^2}{\pi A \phi}$$



A = Aspect ratio (wing slenderness)

ϕ = Span Efficiency

Total drag polar



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Total drag polar

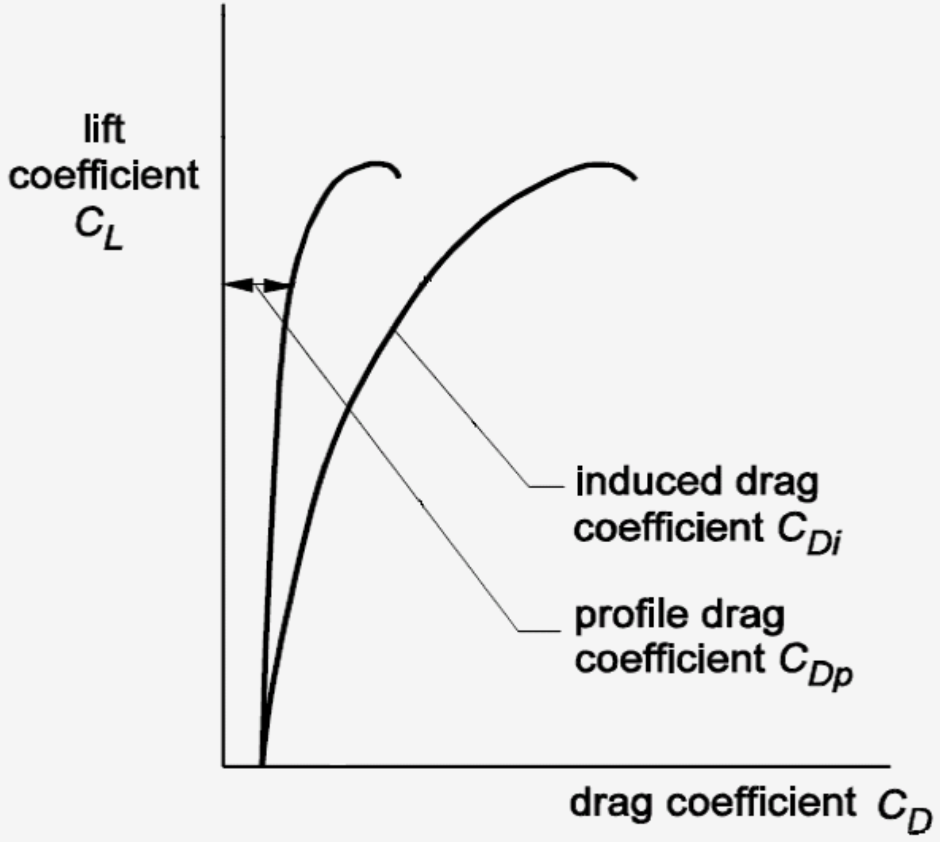


Image from 'Elements of Airplane Performance'

Total drag polar

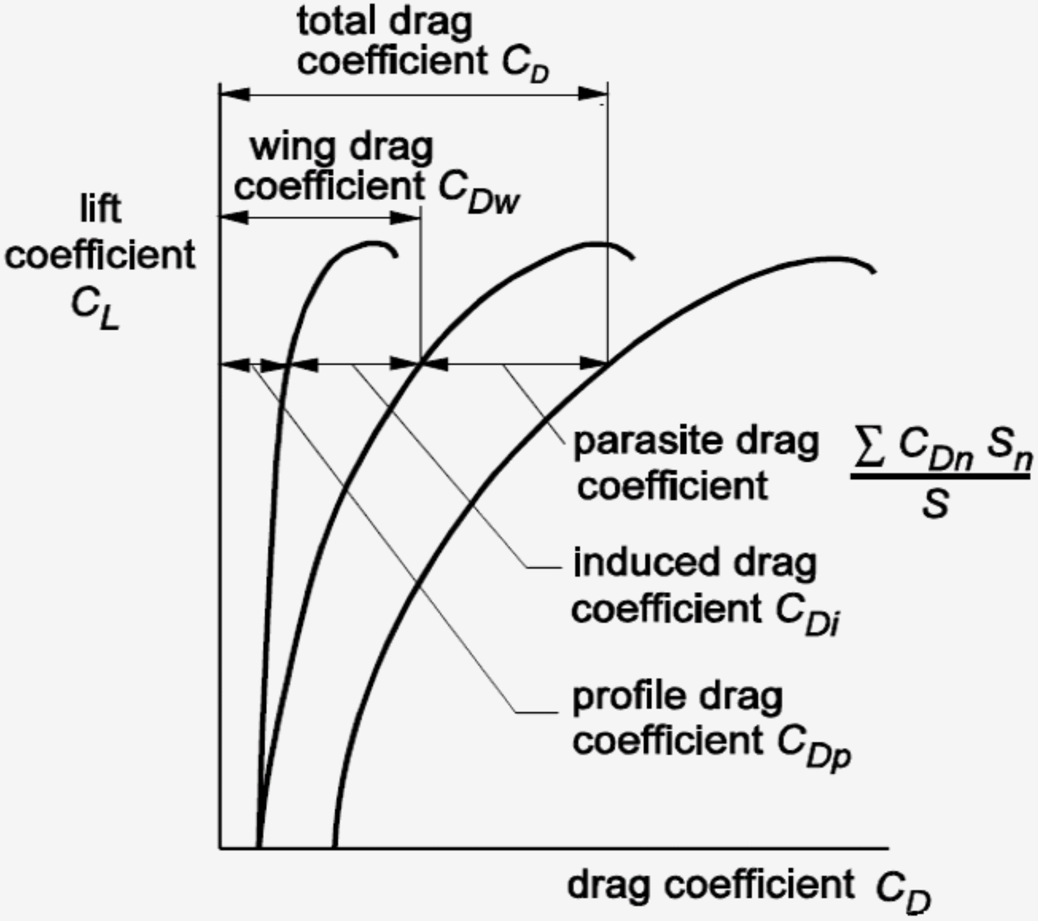


Image from ‘Elements of Airplane Performance’

Still parabolic

$$C_D = C_{D_0} + \frac{C_L^2}{\pi A \phi}$$

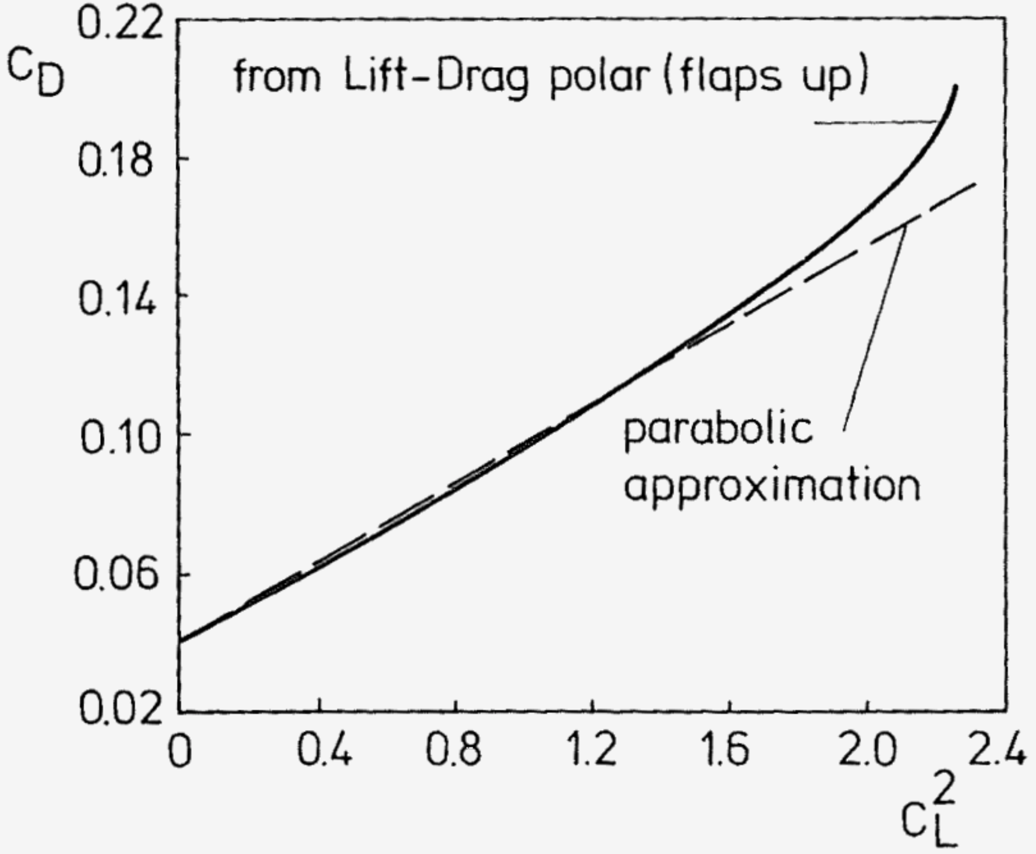


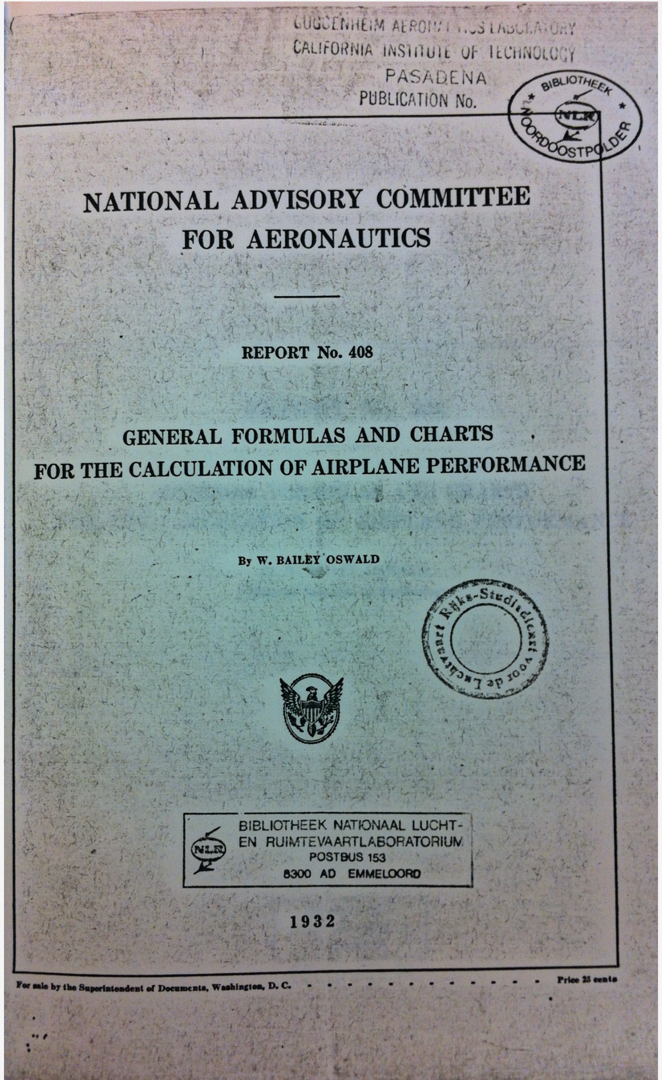
Image from ‘Elements of Airplane Performance’

W. Bailey Oswald

Aeronautical engineer at NACA

$$C_D = C_{D_0} + \frac{C_L^2}{\pi A e}$$

e = Oswald efficiency factor



NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

REPORT No. 408

GENERAL FORMULAS AND CHARTS
FOR THE CALCULATION OF AIRPLANE PERFORMANCE

By W. BAILEY OSWALD

1932

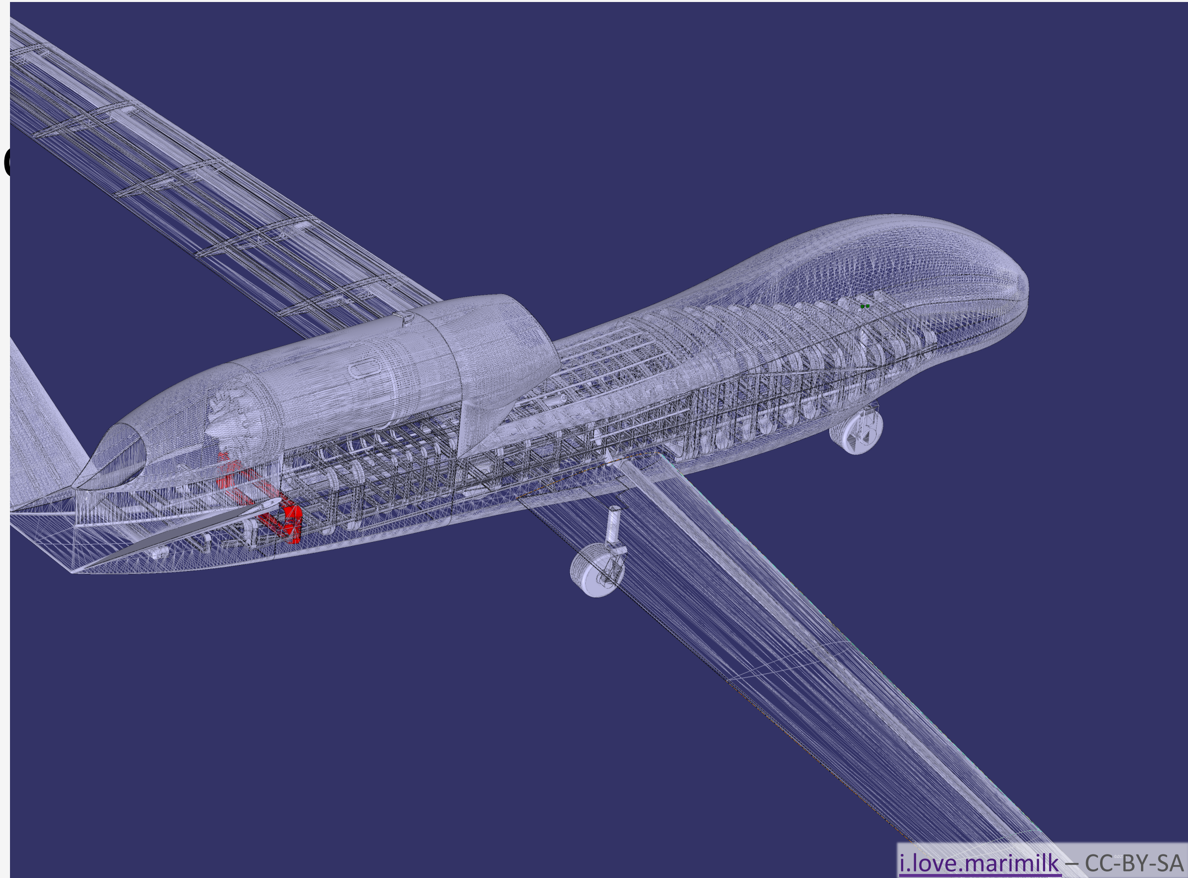
For sale by the Superintendent of Documents, Washington, D. C. Price 25 cents

Total drag polar

In essence a parabolic e

To be more accurate:

Saving 1% drag is significant



Simple equation, complex phenomena

Drag vs. speed

One part increases with V

One part decreases with V

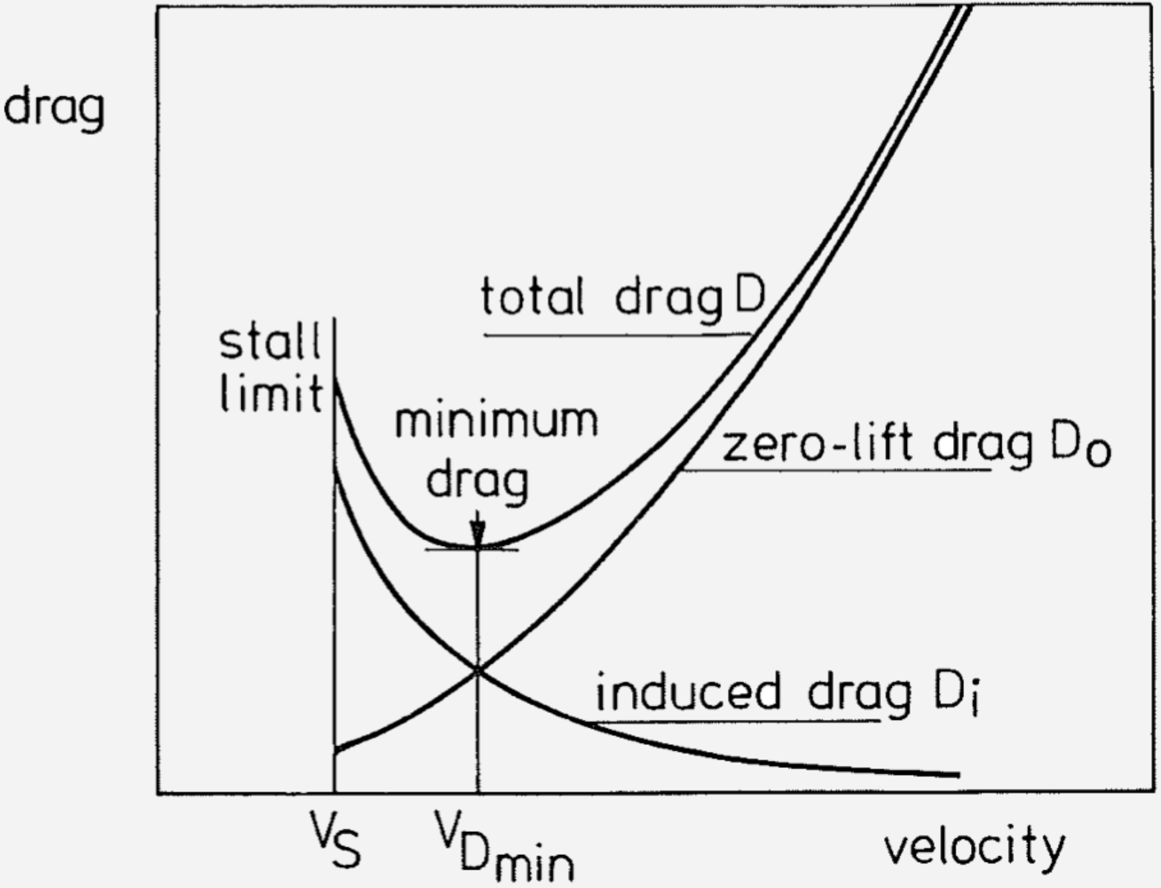


Image from 'Elements of Airplane Performance'

Aircraft morphology

$$D = D(V)$$

Low aspect ratio

High aspect ratio

Recap

$$C_D = C_{D_0} + \frac{C_L^2}{\pi A e}$$

OR

$$C_D = C_{D_0} + k_1 C_L + k_2 C_L^2$$

$$D = D(V)$$

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Challenge the future