Aerodynamic Modeling

Uses and Methods

16.82

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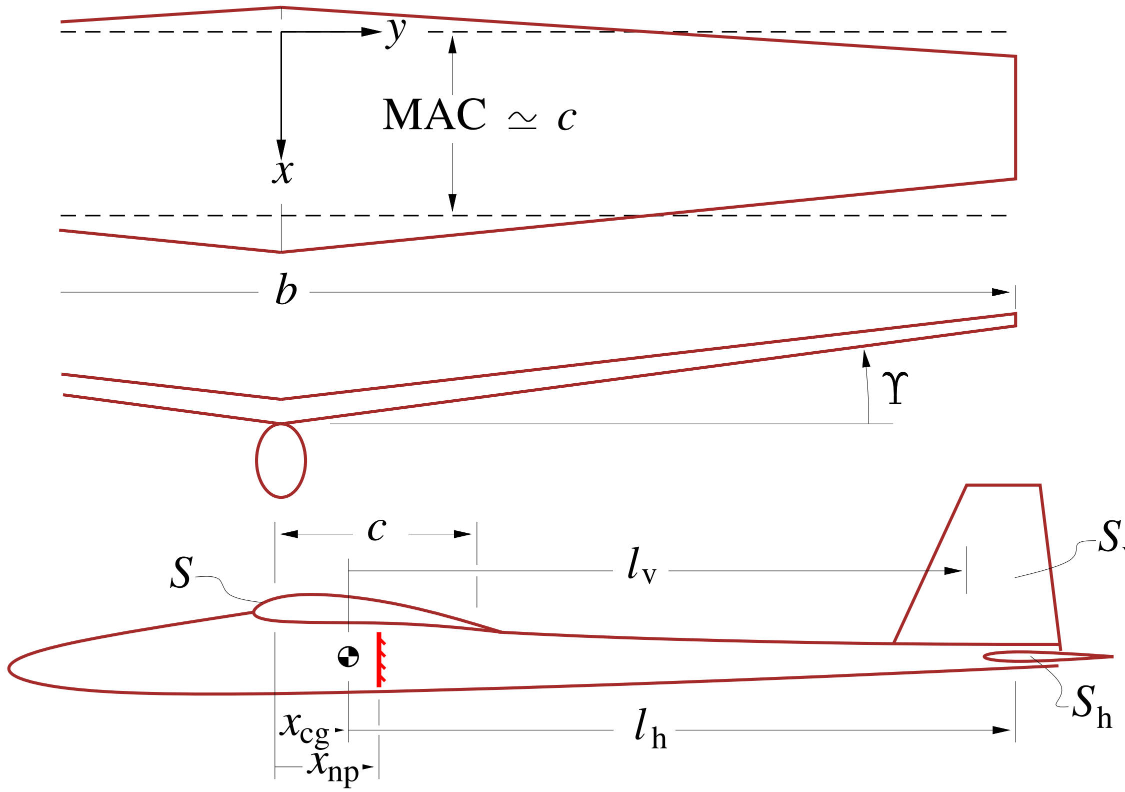
Aero Modeling Objectives

- Stability and Control
  - allowable CG range $\leftrightarrow$ HT sizing or rotor $\Delta T/W$ requirements
  - control schemes: control surfaces, power modulation, weight shift...
  - controllability in all operating modes, including takeoff and landing
  - controllability in emergencies (e.g. engine-out)
- Performance — I
  - $(L/D)_{\max}$ (range, duration)
  - $C_{D_{\min}}$ (max speed)
  - $C_{L_{\max}}$ (min speed, max G's)
  - determination of power requirements
- Performance — II
  - max α, β
  - max rotation rates
- Flight dynamics behavior
  - All-manual or partial computer control?
  - Stability augmentation?

Aero Modeling Approaches

- “Handbook” S&C techniques
  - historical design rules (tail volumes, stability margins, control throws, etc.)
  - stability characteristics estimation
  - spreadsheet weight tracking and management
- “Handbook” drag build-up estimation
  - strip methods (lifting line)
  - wetted-area + form-factor methods (Hoerner)
  - frontal-area methods (Hoerner)
- Numerical aero modeling
  - Vortex Lattice methods (VLM) $\leftarrow$ *method of choice for early design*
  - Panel methods
  - 3D RANS methods (“CFD”)
- Empirical corrections for roughness, excrescences, etc. (Hoerner)

Handbook S&C Techniques — I

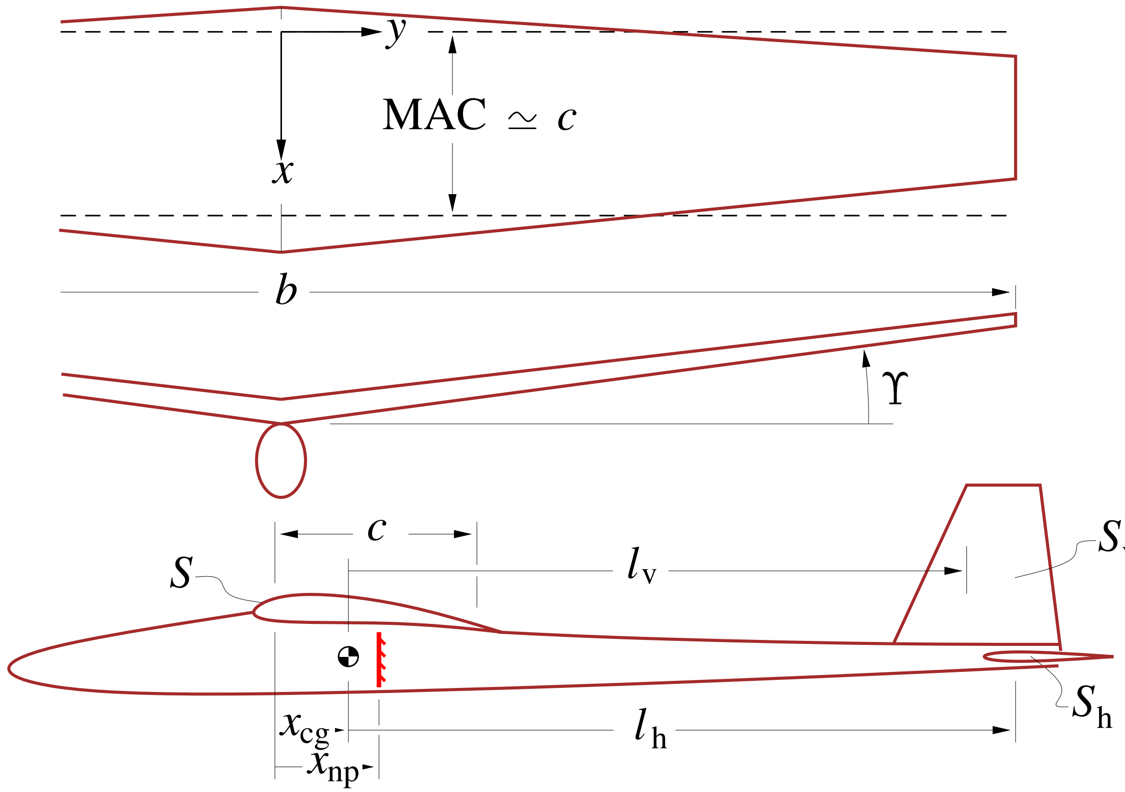


Examples (from Unified Engineering):

$$V_h \equiv \frac{S_h \, \ell_h}{S \, c} \simeq 0.3 \ldots 0.6$$

$$\frac{x_{np}}{c} \simeq \frac{1}{4} + \frac{1 + 2/AR}{1 + 2/AR_h} \left(1 - \frac{4}{AR + 2}\right) V_h$$

Handbook S&C Techniques — II



Examples (from Etkin, FVA):

$$C_{L_\alpha} \simeq \frac{2\pi}{1 + 2/AR}$$

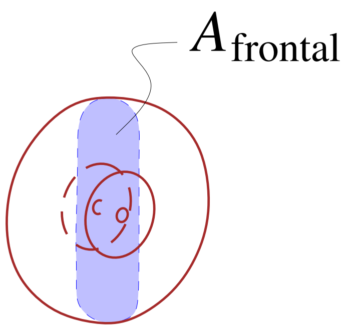
$$C_{m_\alpha} \simeq C_{L_\alpha} \frac{\ell_{\mathrm{cg}}}{c} - (C_{L_\alpha})_{\mathrm{h}} \, \mathrm{V_h} \left(1 - \frac{\mathrm{d}\varepsilon}{\mathrm{d}\alpha}\right) + (C_{m_\alpha})_{\mathrm{fuse}}$$

$$C_{n_r} \simeq -2(C_{L_{\mathrm{v}}})_{\mathrm{v}} \frac{\ell_{\mathrm{v}}}{b} + (C_{n_r})_{\mathrm{fuse}}$$

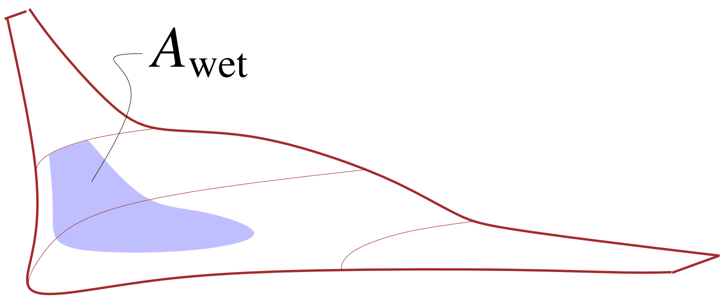
Handbook Drag Build-Up

$$C_D \equiv \frac{D}{\frac{1}{2}\rho V^2 S} = \frac{\Sigma\, CDA}{S} + c_{d_\mathrm{w}}(C_L, Re_c)\,\frac{S_\mathrm{w}}{S} + c_{d_\mathrm{h}}(Re)\,\frac{S_\mathrm{h}}{S} + c_{d_\mathrm{v}}(Re)\,\frac{S_\mathrm{v}}{S} + \frac{C_L^2}{\pi\, AR\, e}$$

$$c_{d_\mathrm{w}} = (c_{d_\mathrm{w}})_\mathrm{clean}\left(1 + f_\mathrm{excr}\right)$$



$$CDA = A_\mathrm{frontal}\, C_{D_\mathrm{frontal}}$$ (bluff component)



$$CDA = A_\mathrm{wet}\, \bar{C}_f\, K_f$$ (streamlined component)

Numerical Aero Modeling

Vortex Lattice Method (VLM)

- Simple to set up
- Very fast ($<$ 1 second)
- Poorly handles body/surface interactions
- Gives only C_L, C_m, C_{D_i}

Panel Method

- Relatively complex to set up
- Fast ($<$ 1 minute)
- Models most interactions
- Gives only C_L, C_m, C_{D_i}

3D RANS ("CFD")

- Complex to set up
- Slow (hours)
- Models all interactions
- Gives C_L, C_m, C_D