Compressibility Drag

Lecture 6

ME EN 415
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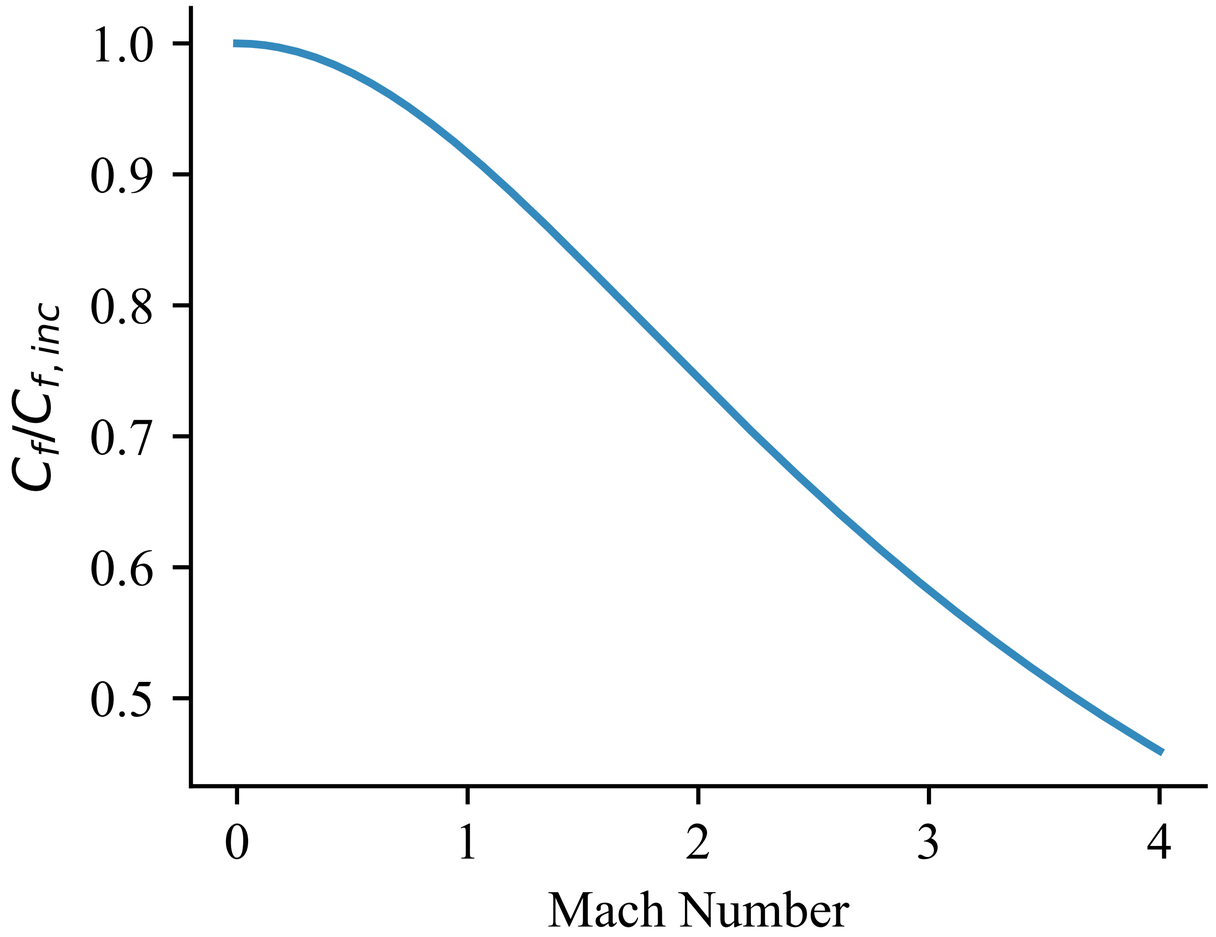
Drag Breakdown

Parasitic Drag + Induced Drag + Compressibility Drag

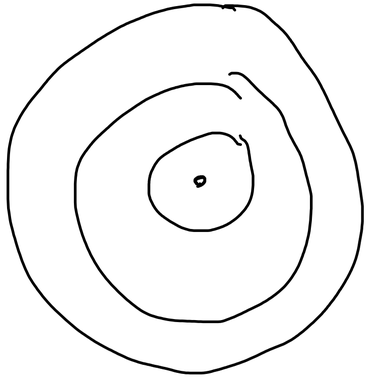
(first) A Correction to Parasitic Drag

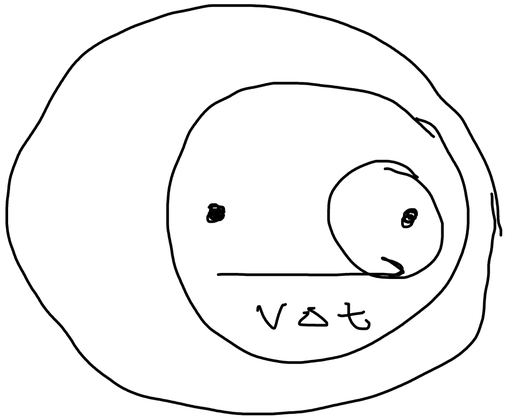
$$\frac{C_f}{C_{f\,inc}} = (1 + 0.144M^2)^{-0.65}$$

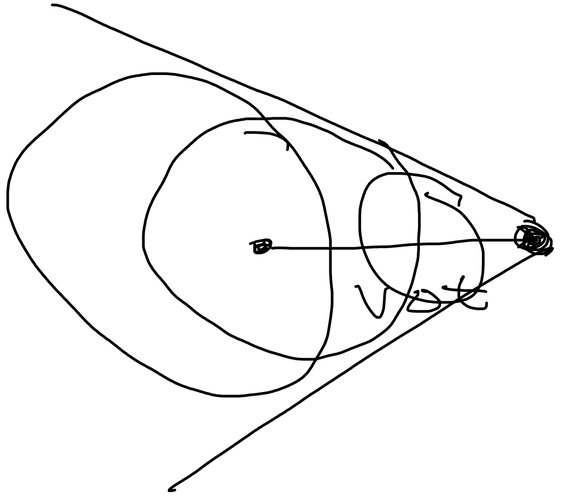


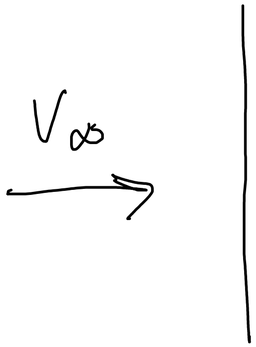
Shock Waves

Sound Waves

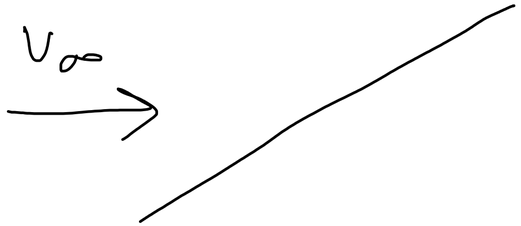








normal shock

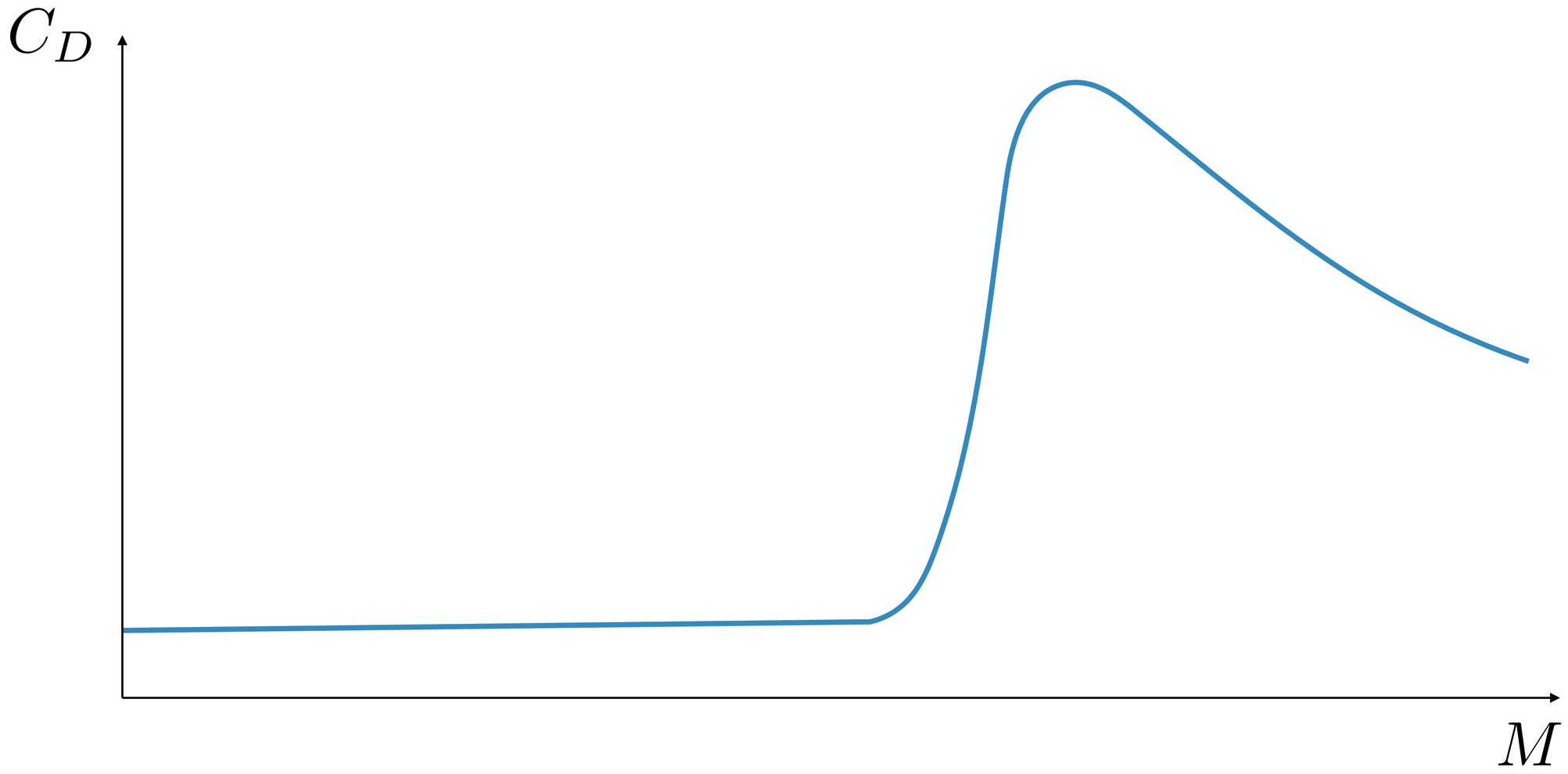


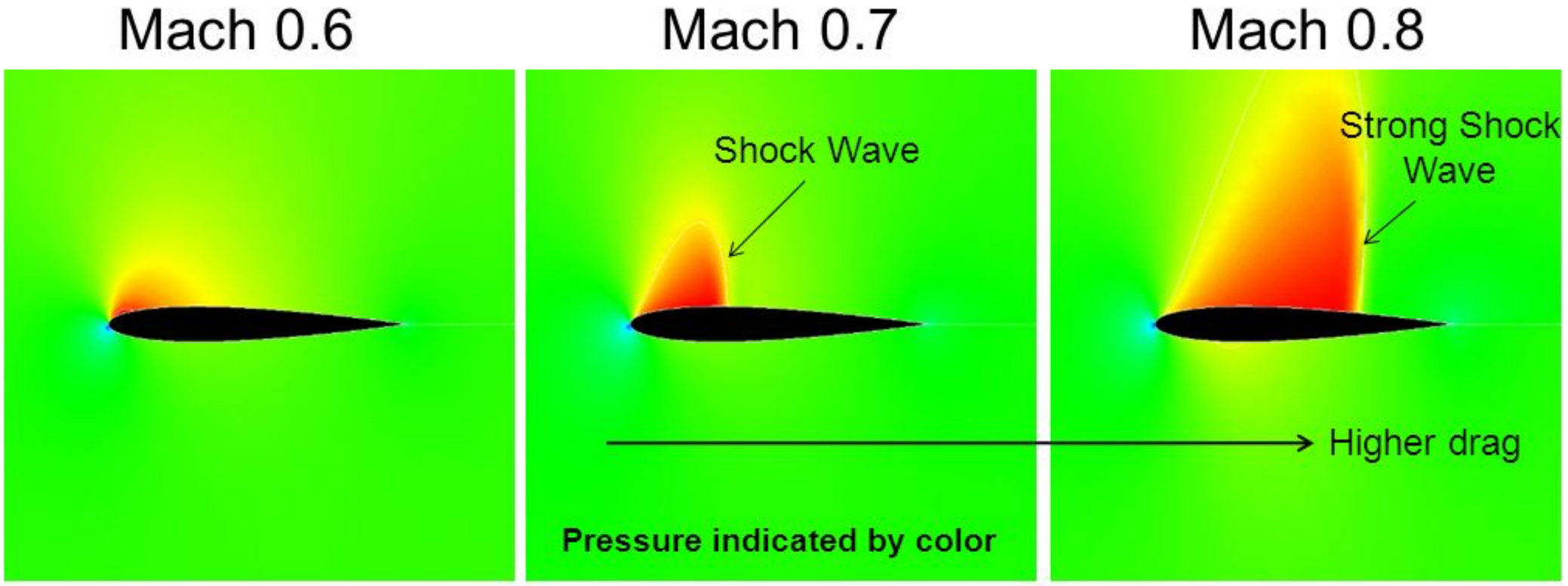
oblique shocks

https://youtu.be/gWGLAAYdbbc

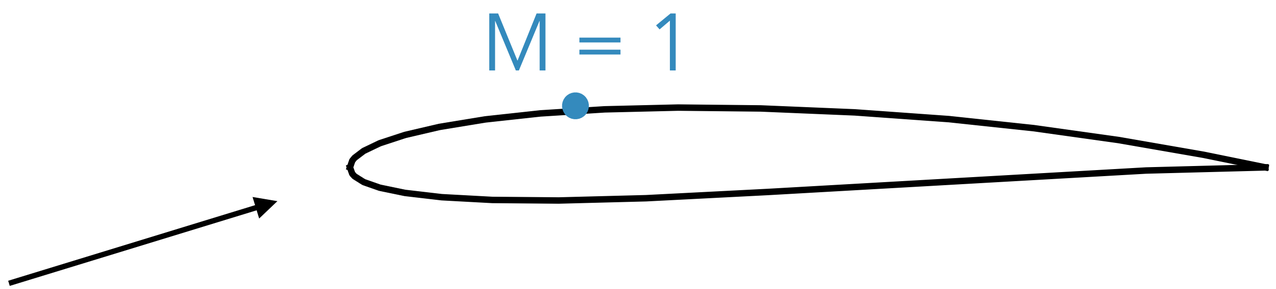
Transonic Wave Drag

Drag Rise

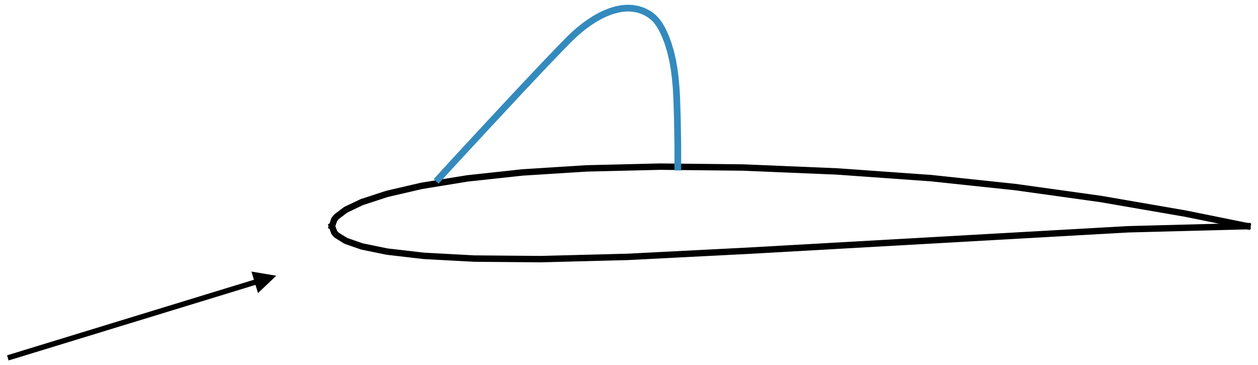




Harold Youngren

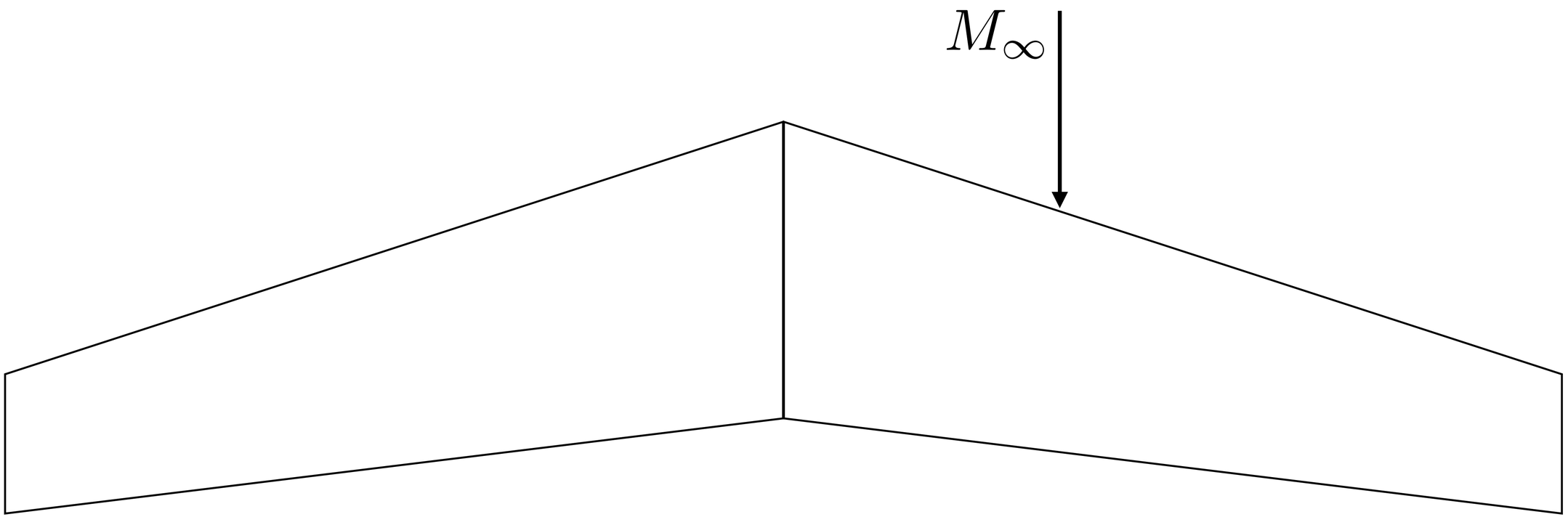


crest critical Mach number M_{cc}

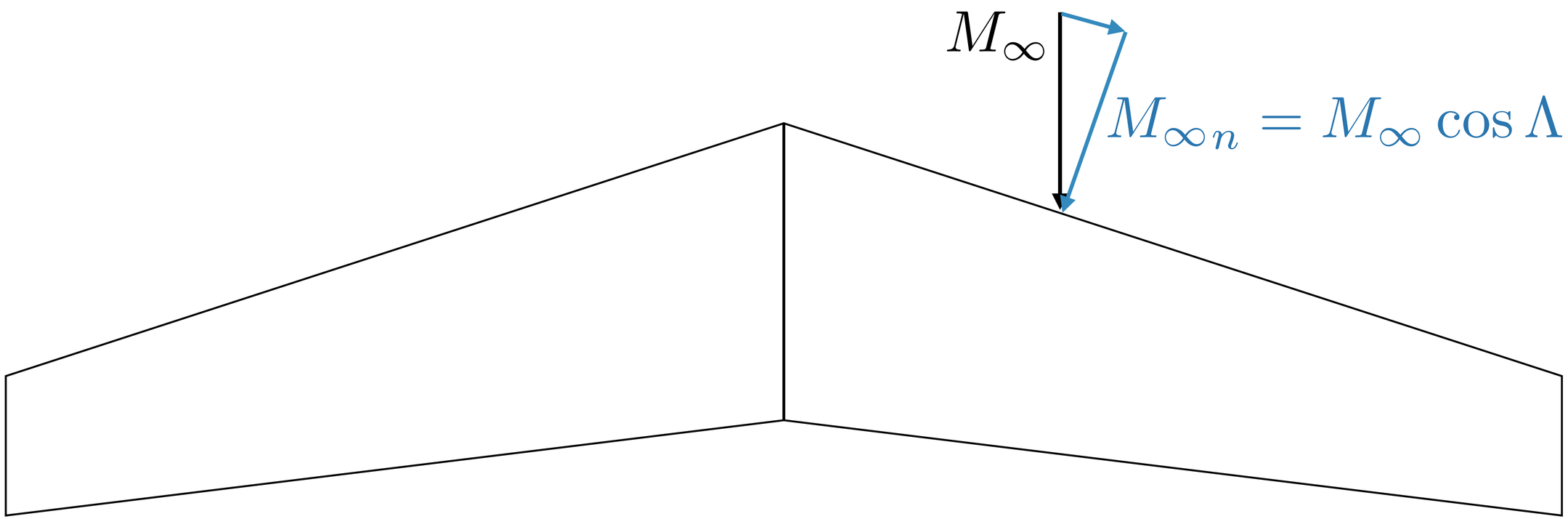


drag divergence Mach number M_{DD}

Simple Sweep Theory



Simple Sweep Theory



Drag divergence Mach number

$$M_{DD} = \frac{0.95}{\cos\Lambda} - \frac{t/c}{cos^2\Lambda} - \frac{C_L}{10\cos^3\Lambda}$$

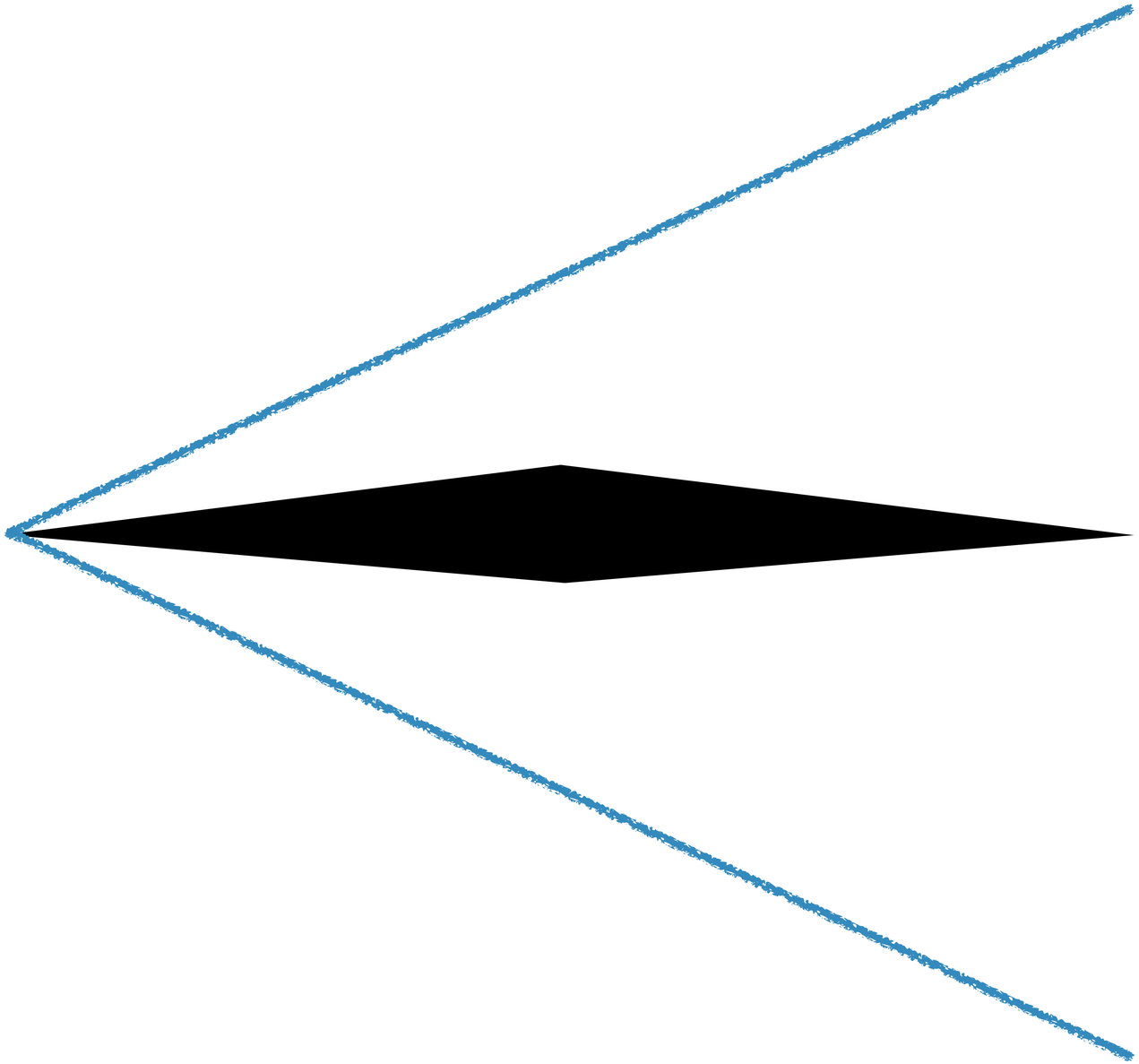
Crest critical Mach number

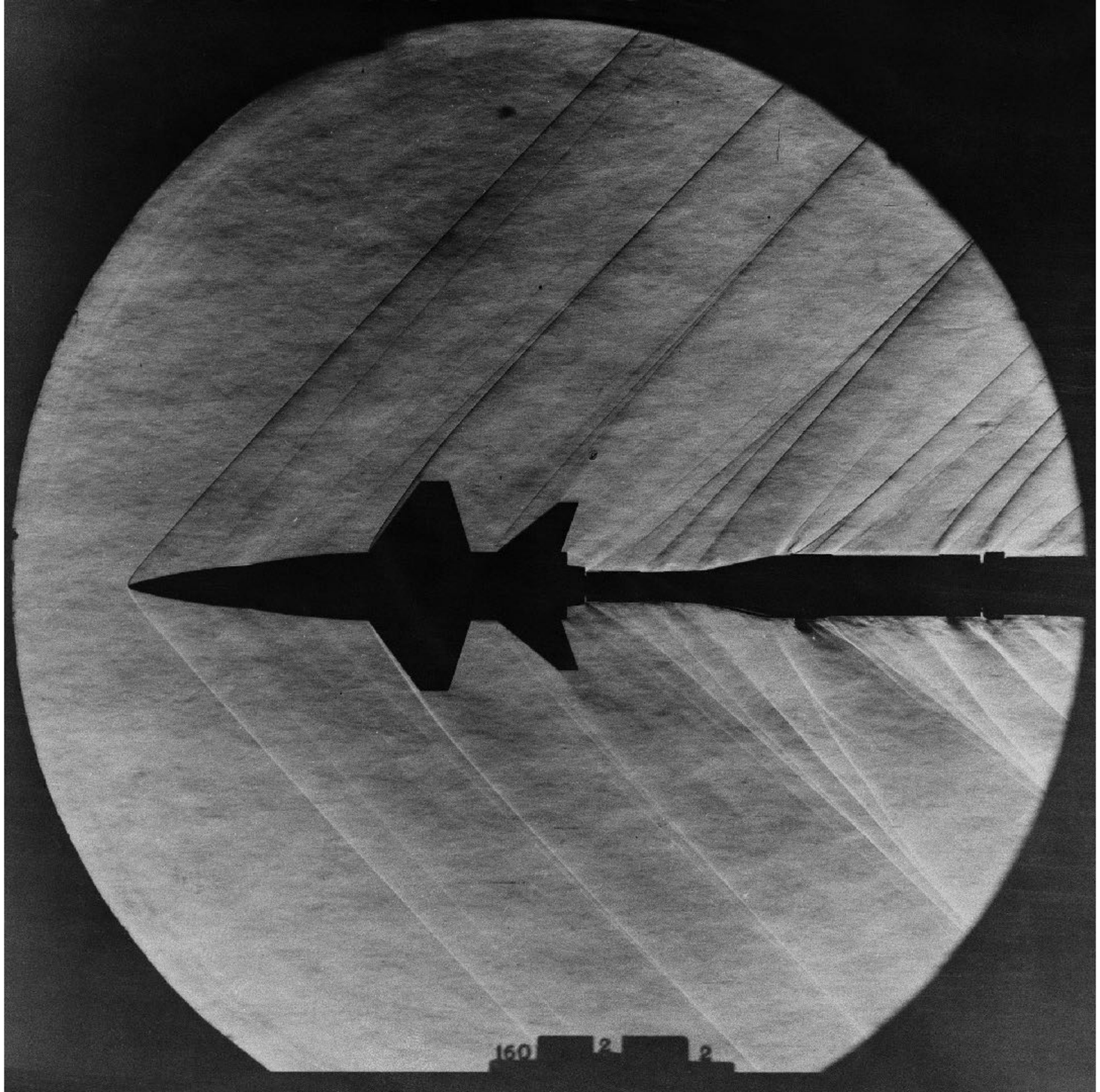
$$M_{cc} = M_{DD} - 0.1$$

Wave drag

$$C_{Dc} = \begin{cases} 0 & M < M_{cc} \\ 20(M - M_{cc})^4 & M_{cc} < M < 1 \end{cases}$$

Supersonic Wave Drag




160
2
2

Wing Wave Drag (minimum. assumes elliptical in all directions)

$$\beta = \sqrt{M^2 - 1}$$

Volume:

$$C_{Dw,v} = 4(t/c)^2 \frac{(\beta^2 + 2r^2)}{(\beta^2 + r^2)^{1.5}} \frac{S_g}{S_{ref}}$$

$$r = \frac{\pi l^2}{4 S_g}$$

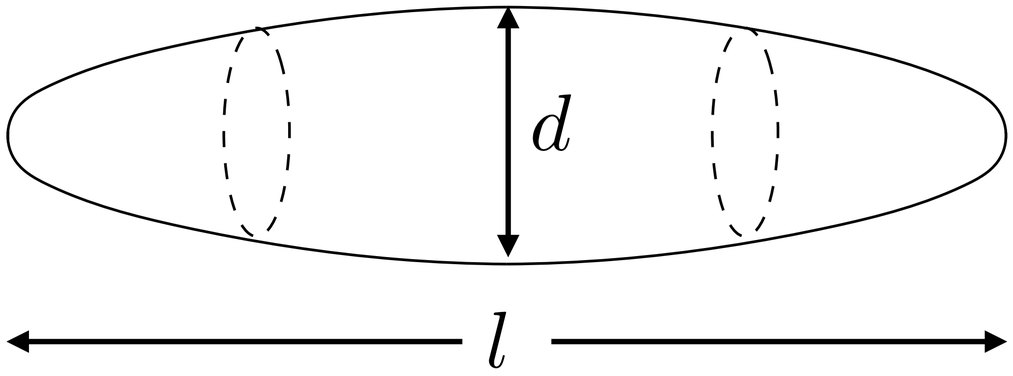
Lift:

S_g: gross area

$$C_{Dw,l} = \frac{{C_L}^2 r}{4} \left[\sqrt{1 + \frac{\beta^2}{r^2}} - 1 \right] \frac{S_{ref}}{S_g}$$

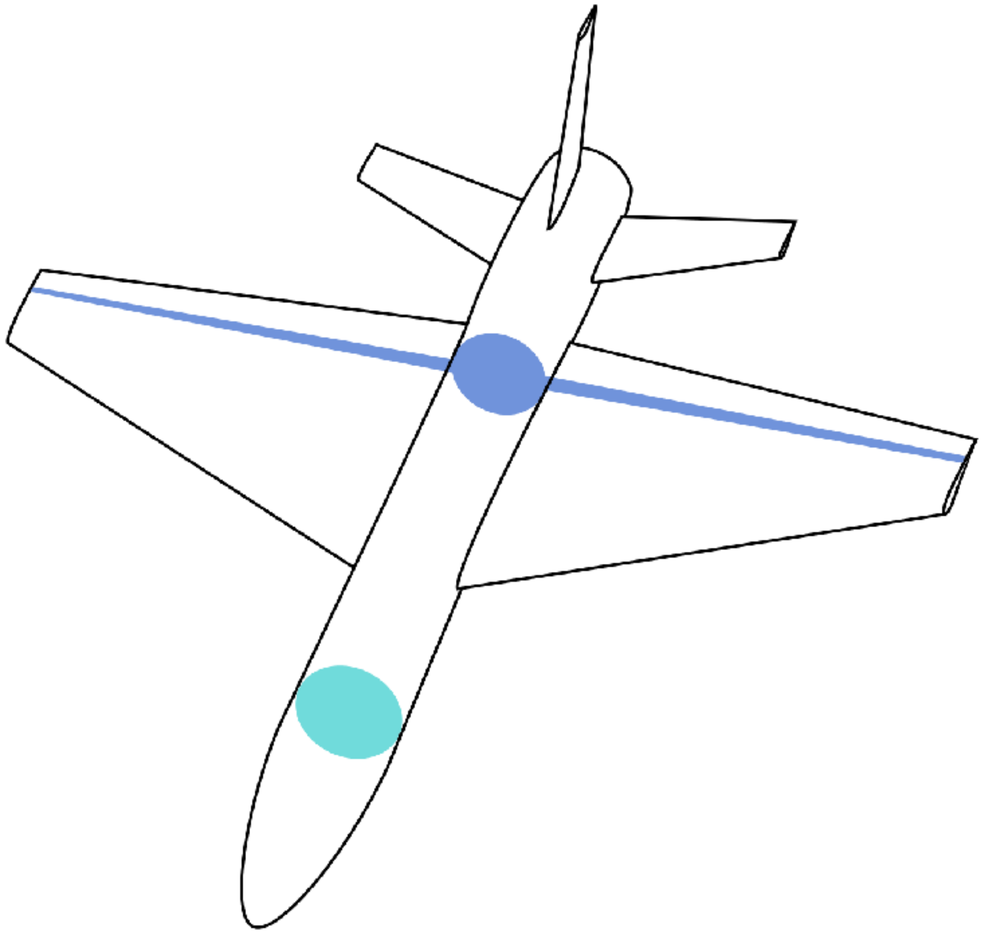
Fuselage Volume Wave Drag

$$C_{Dw,v} = \frac{\pi^3}{4} \frac{d^2}{(l/d)^2 S_{ref}}$$



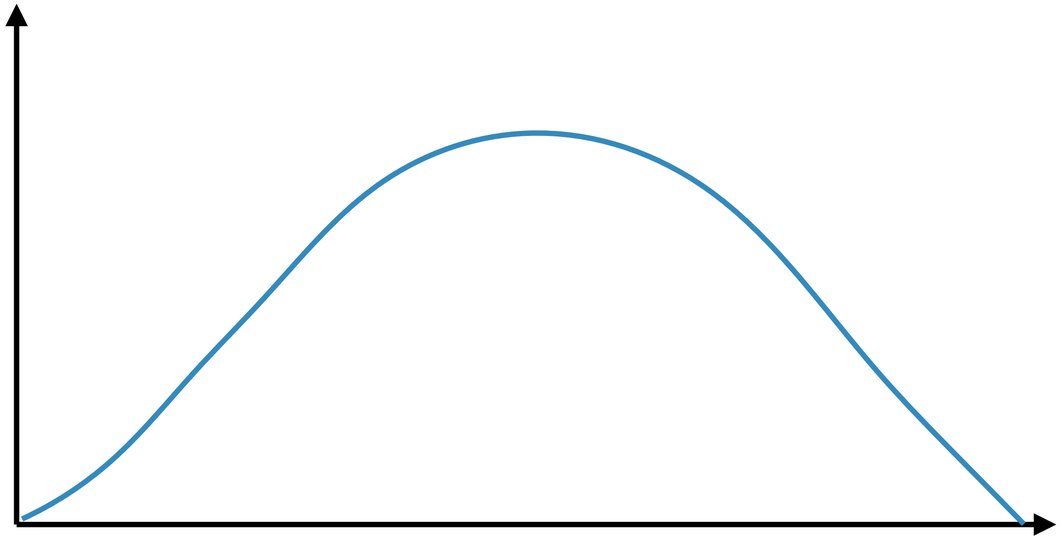
$$D \sim \frac{V^2}{l^4} \quad \text{volume}$$

Supersonic Area Rule



Sears-Haack

cross-sectional area



Ballistic or Blunt Body

bow
shock