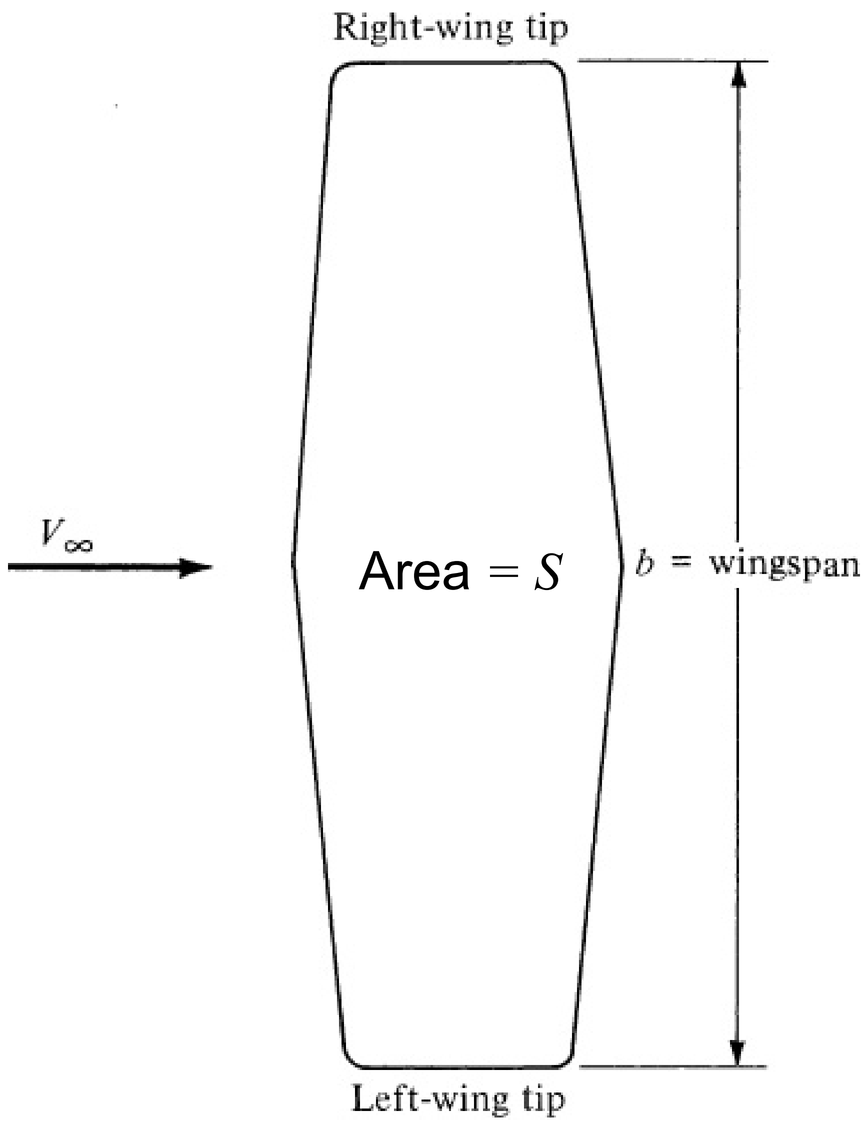
Introduction to Wings

AE 1350

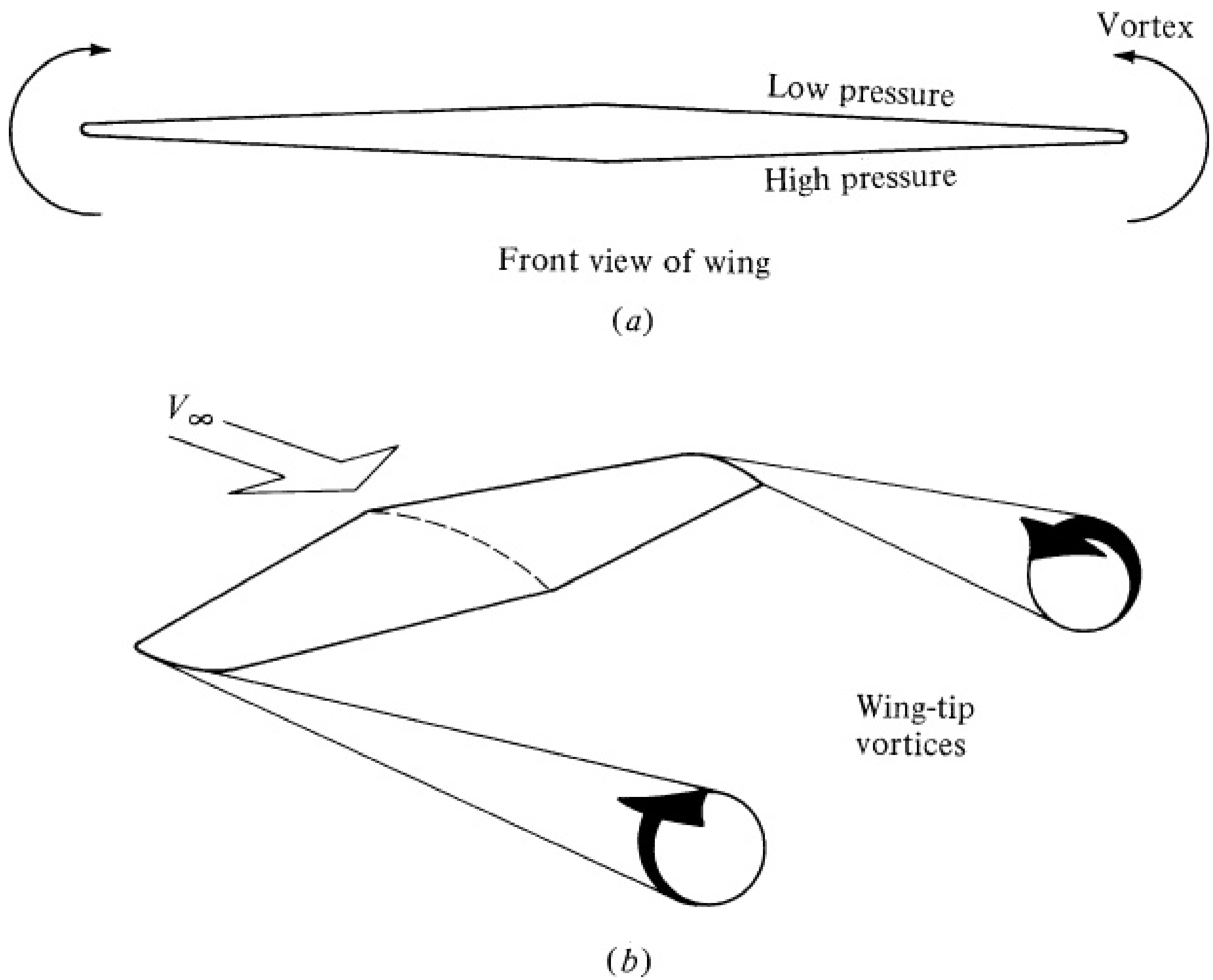
Anatomy of a Wing



Aspect Ratio

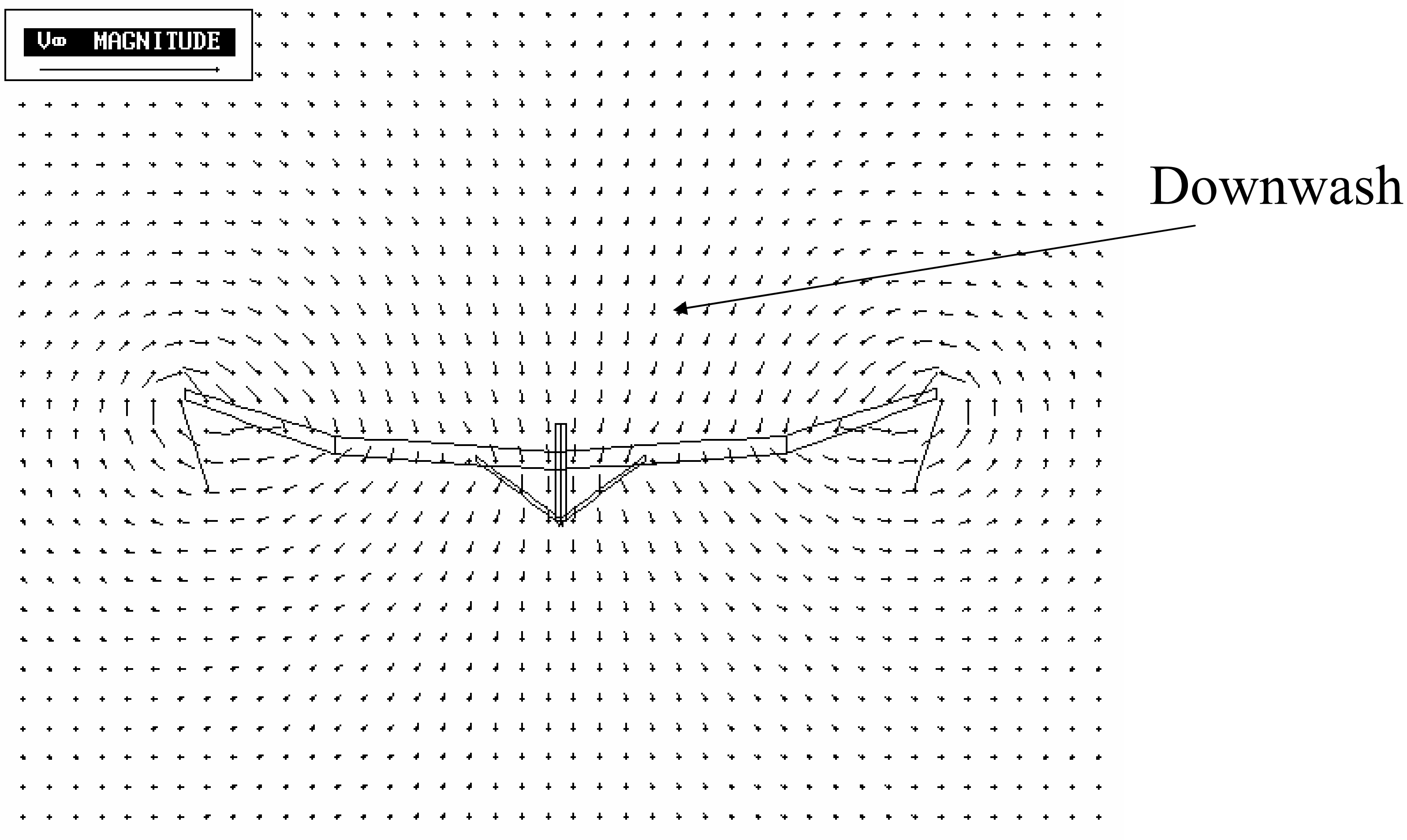
$$AR = \frac{b^2}{S}$$

Trailing Vortices



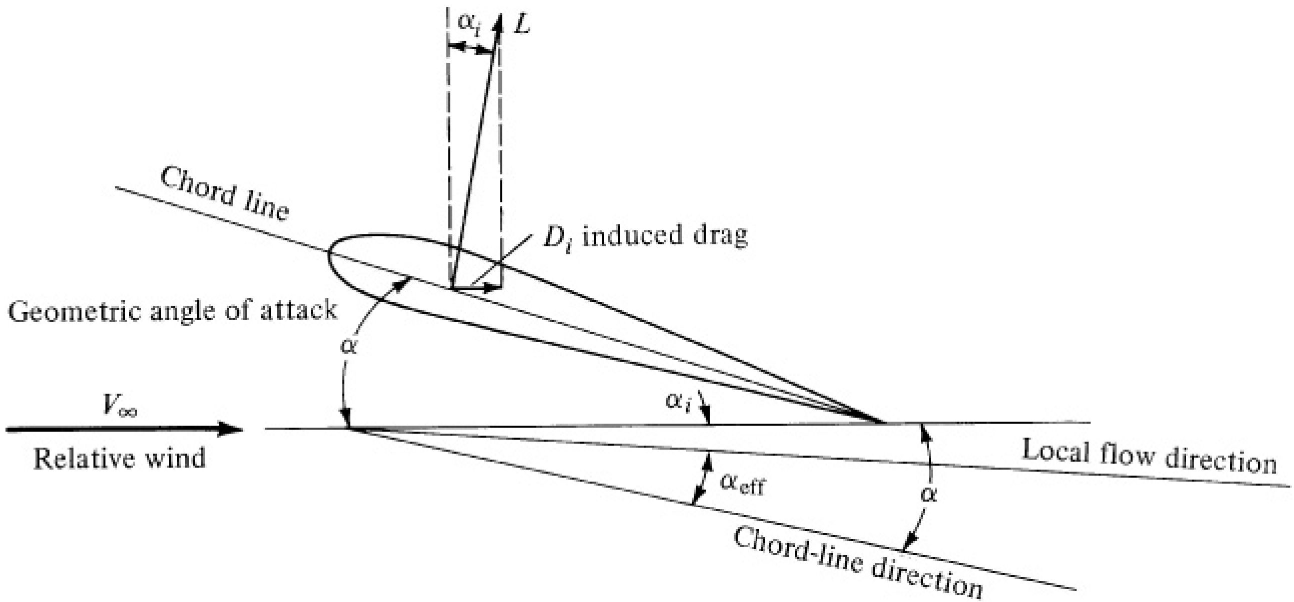
Trailing Vortices

Effect of Tip Vortices



Most Efficient Formations Involve flying in Up-wash of Other Aircraft

Induced Drag



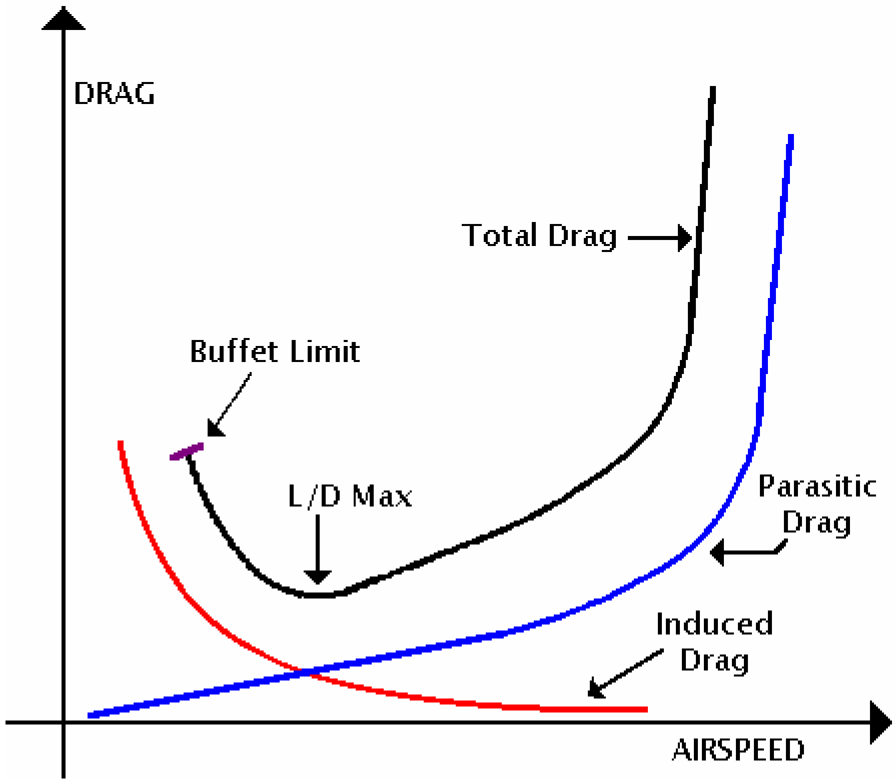
Induced drag is caused by the downward rotation of the freestream velocity, which causes a rotation of the lift force

From theory,

$$C_{D,i} = \frac{C_L^2}{\pi AR\, e}$$

$e =$ span efficiency factor

Variation of Drag with Speed



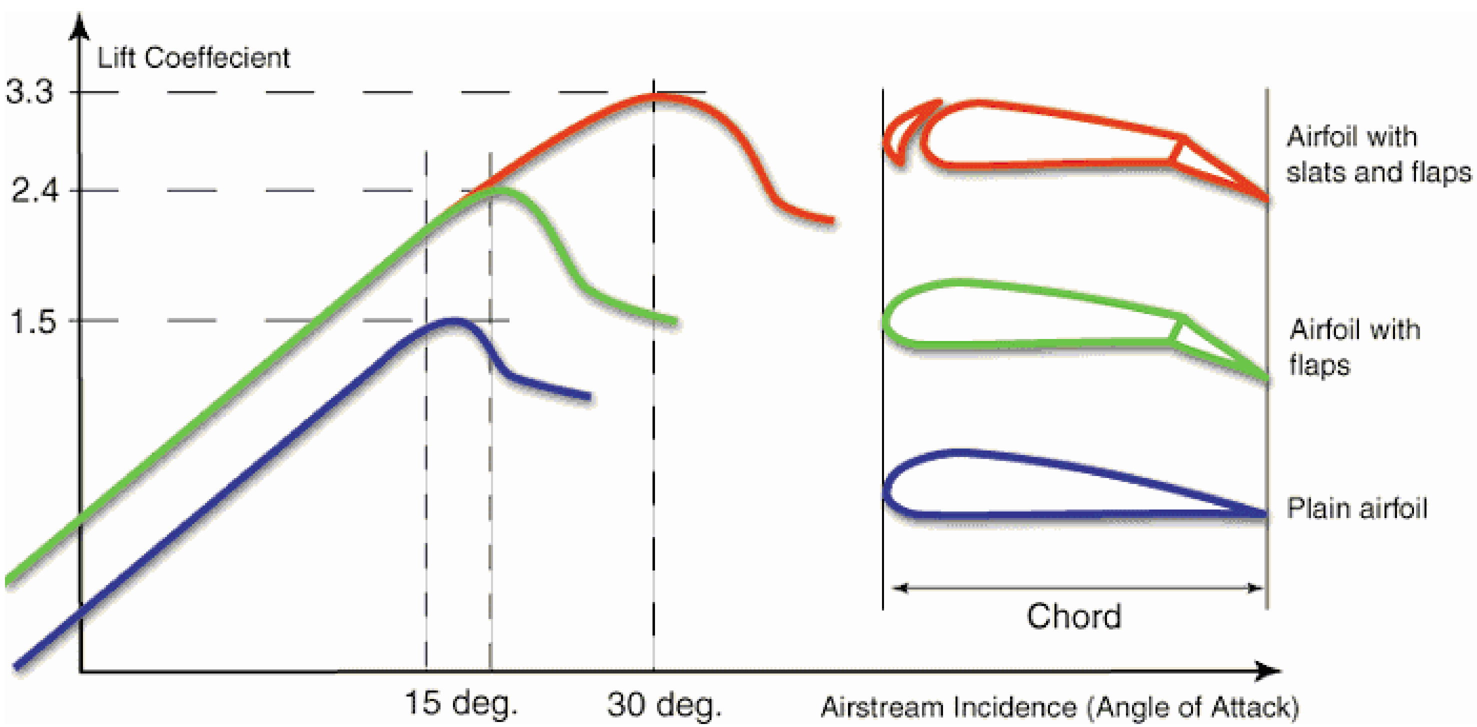
Induced drag decreases as V increases, because we need less values of C_L at high speeds

Other drag forces (form, skin friction , interference) increase

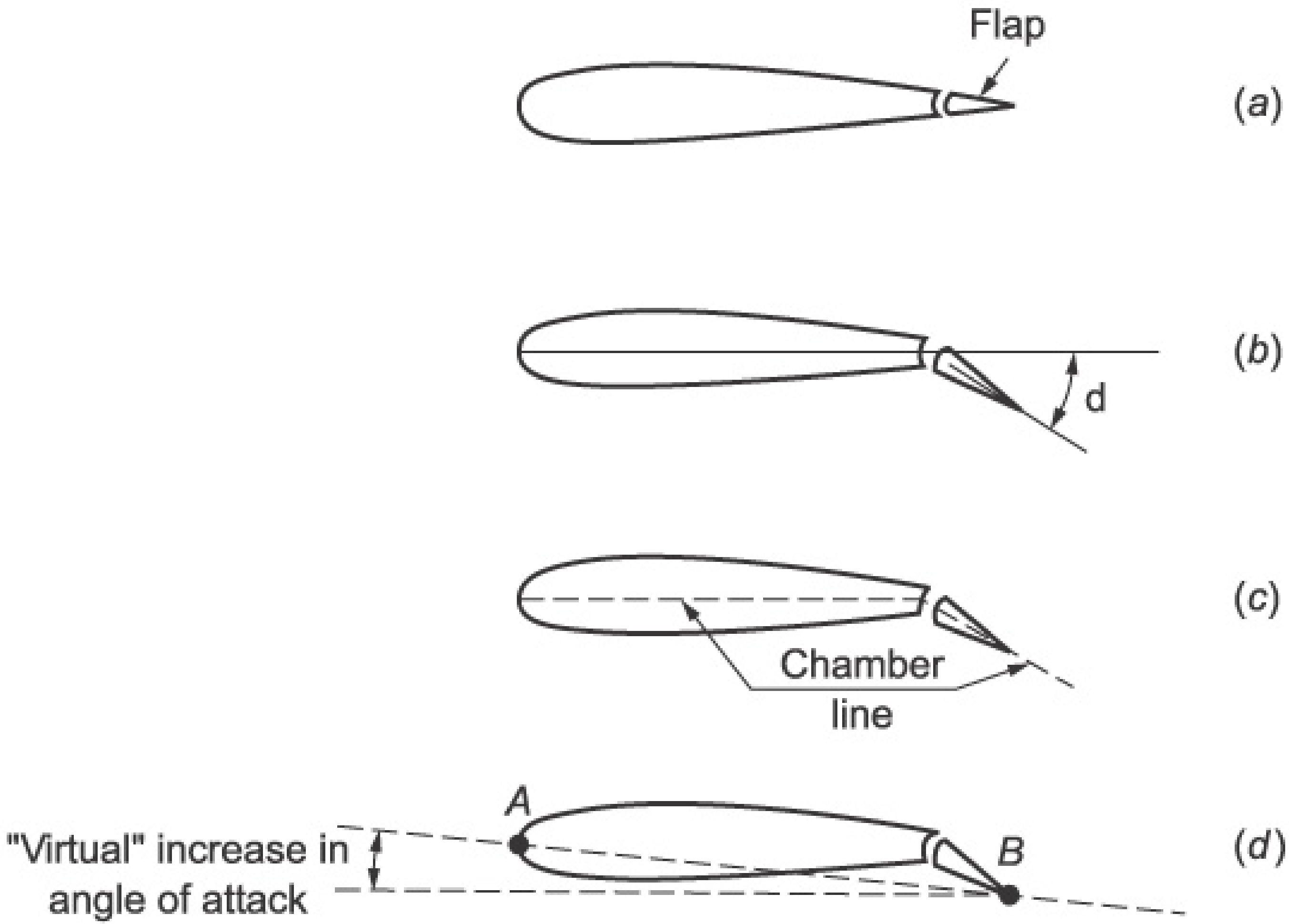
Result: Drag first drops, then rises!

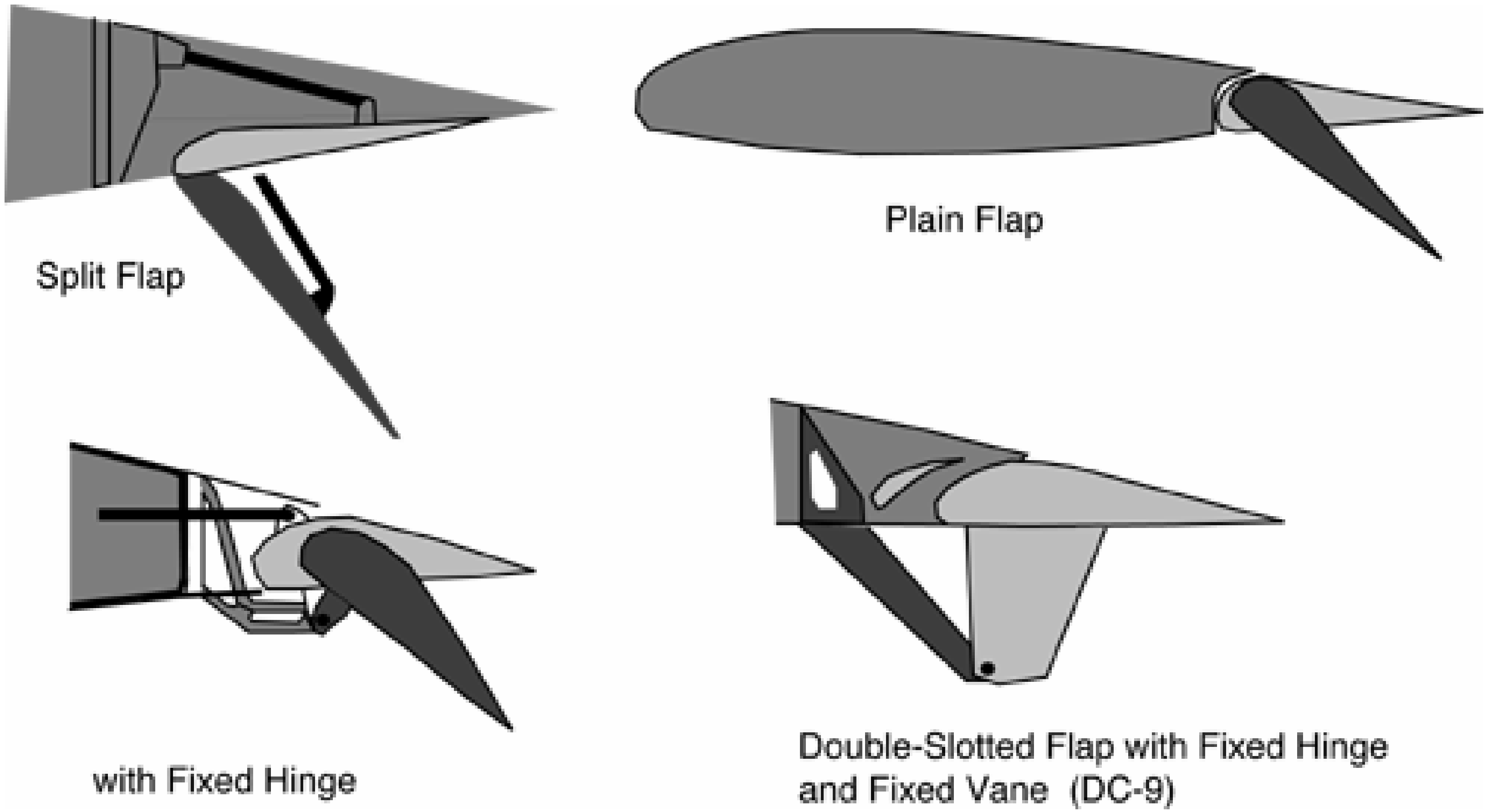
Achieving High Lift: Flaps

- When you need to go slow (takeoff/landing), need high lift coefficient so lift can still equal weight
- The higher the maximum C_L, the slower you can fly

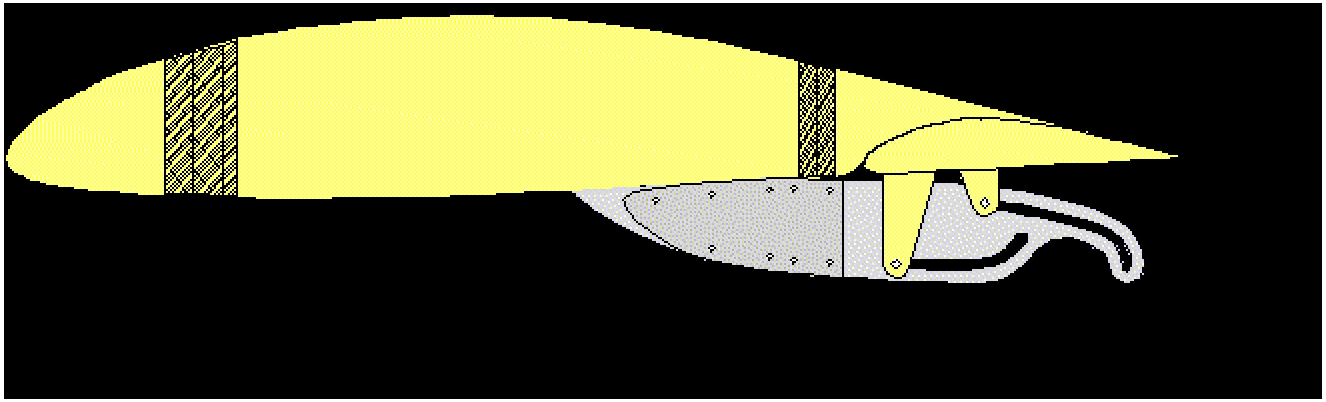


Flaps Increase Camber, Angle of Attack, and Sometimes Area

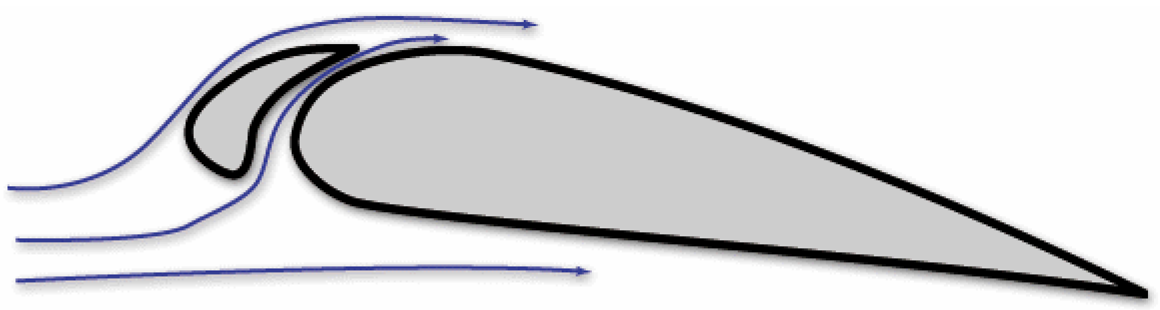



Split Flap
Plain Flap
with Fixed Hinge
Double-Slotted Flap with Fixed Hinge
and Fixed Vane (DC-9)

One form of flaps, called Fowler flaps increase the chord length as the flap is deployed.

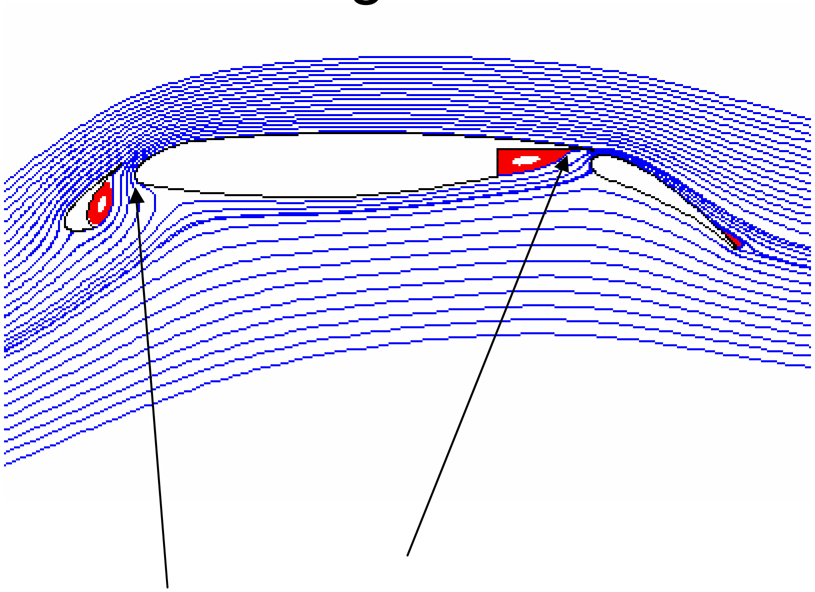


Leading Edge Slats
Help avoid stall near the leading edge

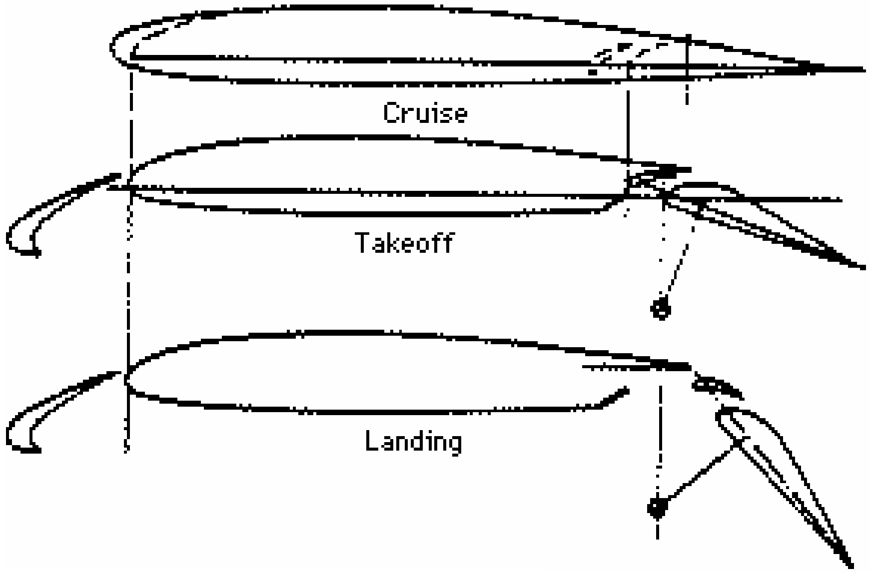


Why do slats and slotted flaps help?

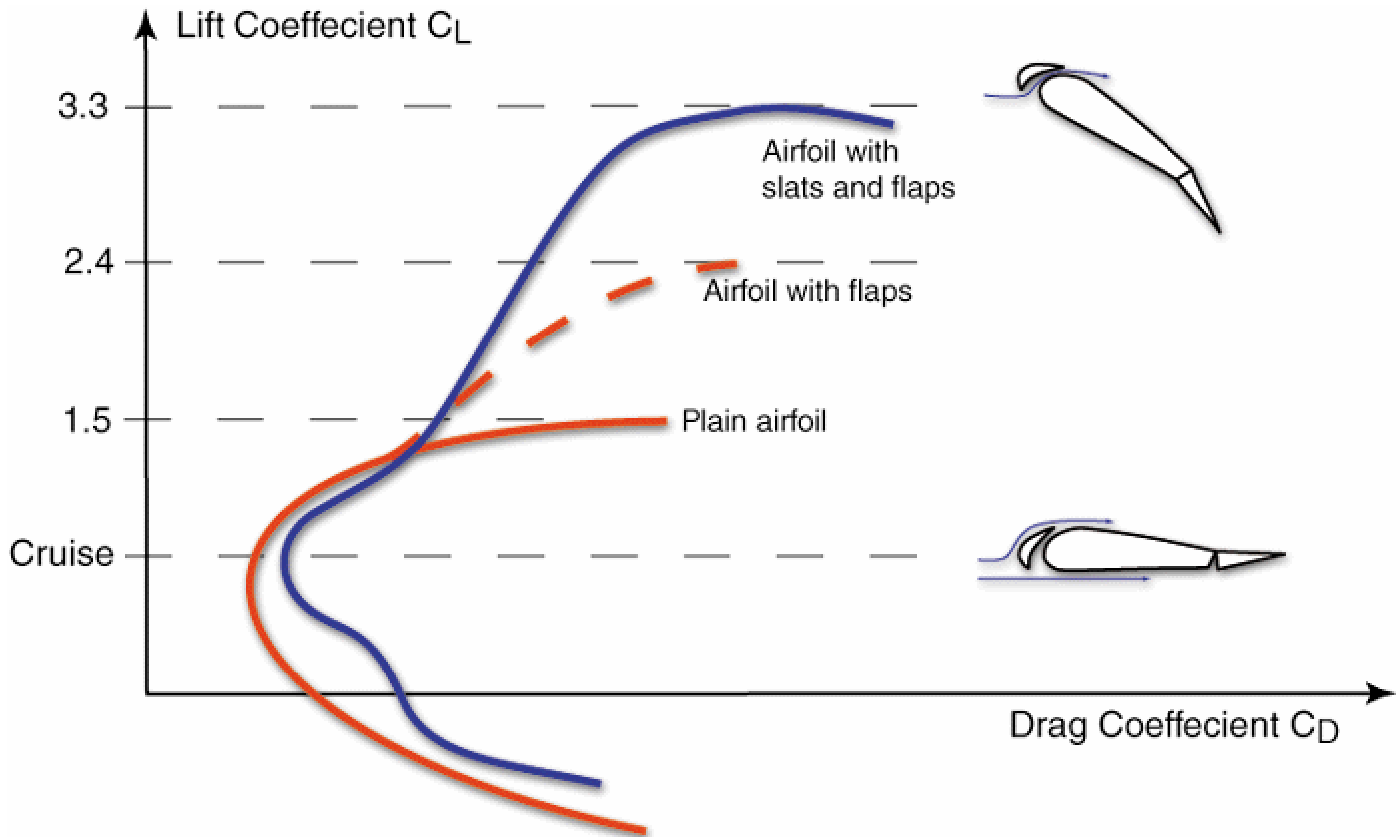
1. They increase the camber and area when needed: during take-off and landing



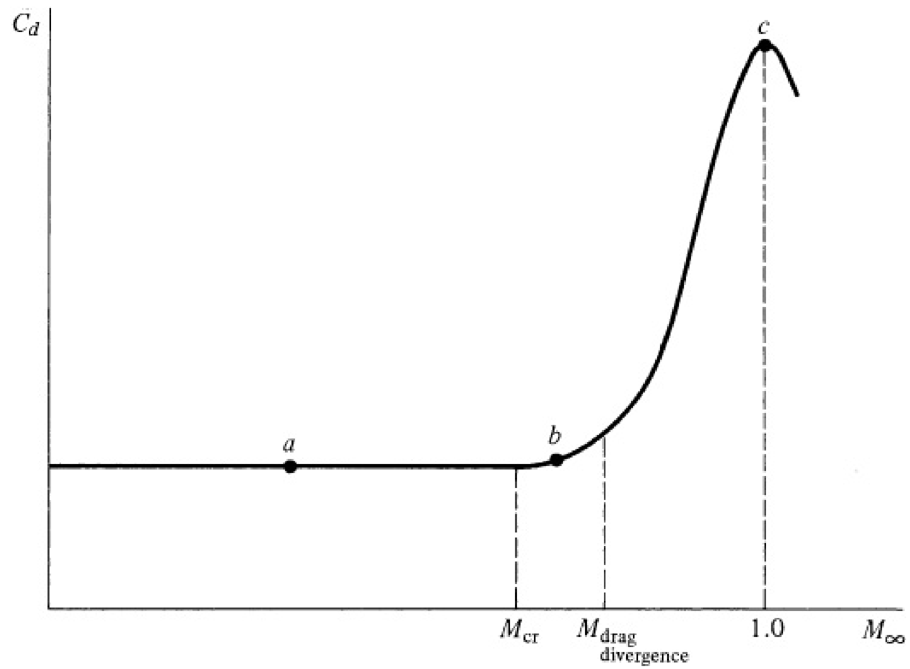
2. High energy air from the bottom side of the airfoil flows through the gap to the upper side, energizes slow speed molecules, and keeps the flow from stalling


Cruise
Takeoff
Landing

High Lift also Causes High Drag



Supersonic wave Drag



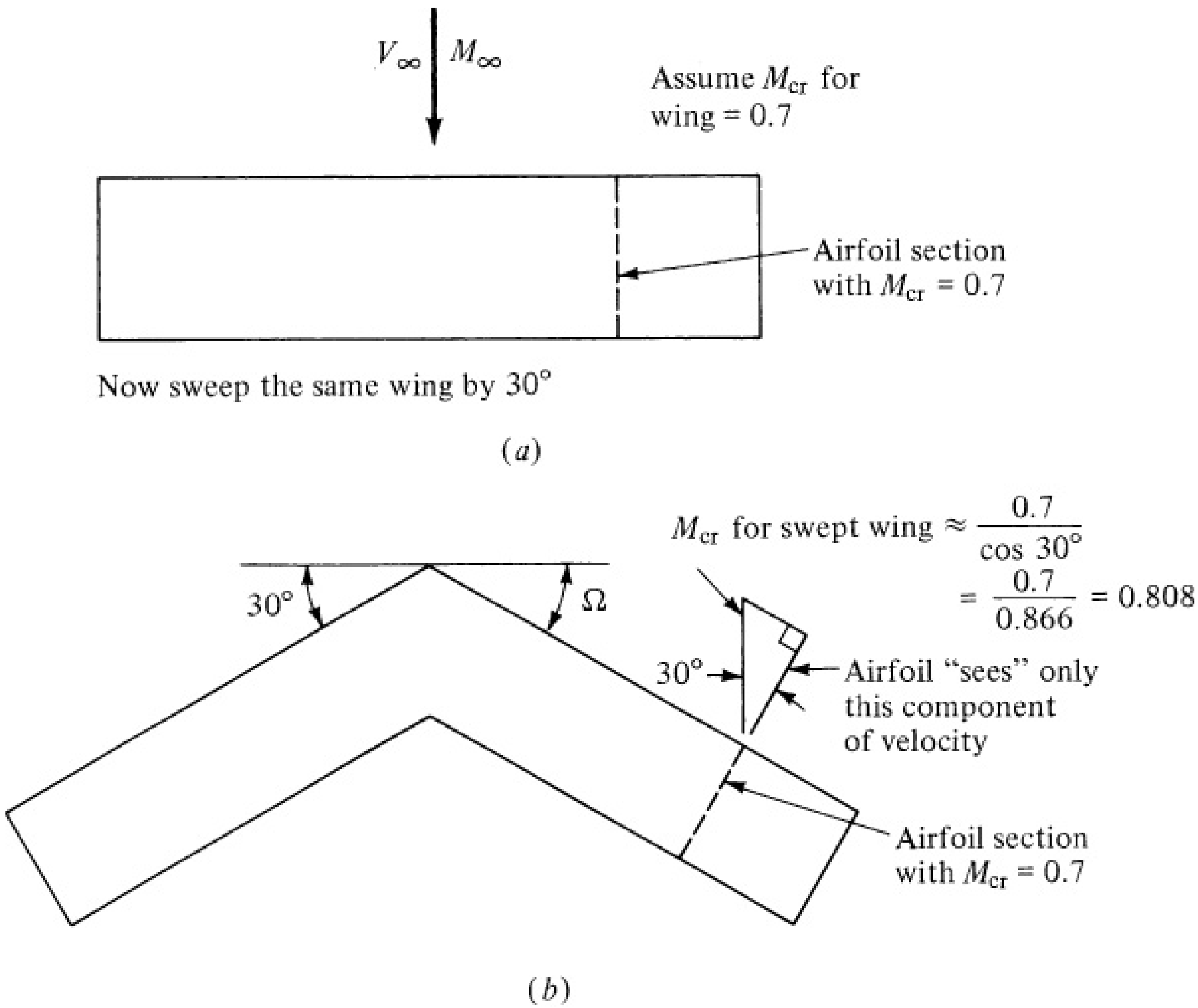
For a given airfoil or wing or aircraft, as the Mach number is increased, the drag begins to increase above a freestream Mach number of 0.8 or so due to shock waves that form around the airfoil

Shock waves

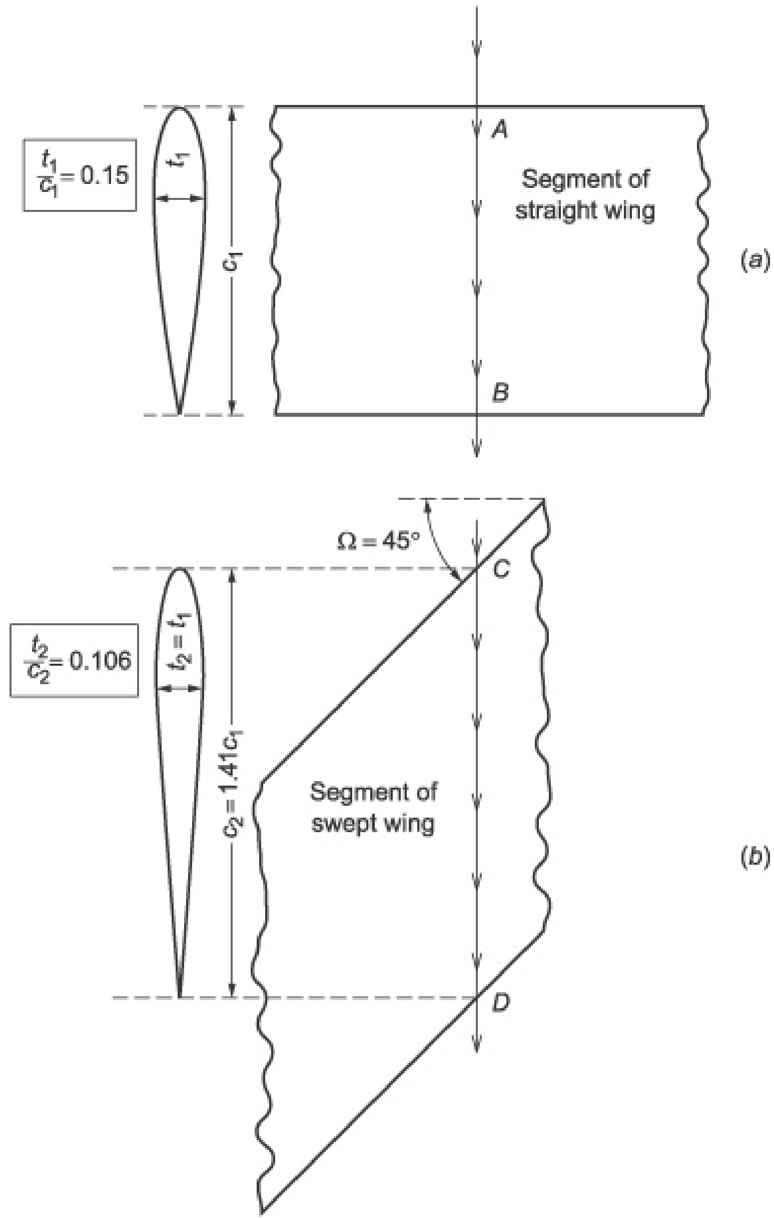
How can shock waves be minimized?

- Use thin airfoils
- Use wing sweep
- Use supercritical airfoils, which keep the flow velocity over the airfoil and the local Mach number from exceeding Mach 1.1 or so
- Use area rule- the practice of making the aircraft cross section area (from nose to tail, including the wing) vary as smoothly as possible

Wing Sweep

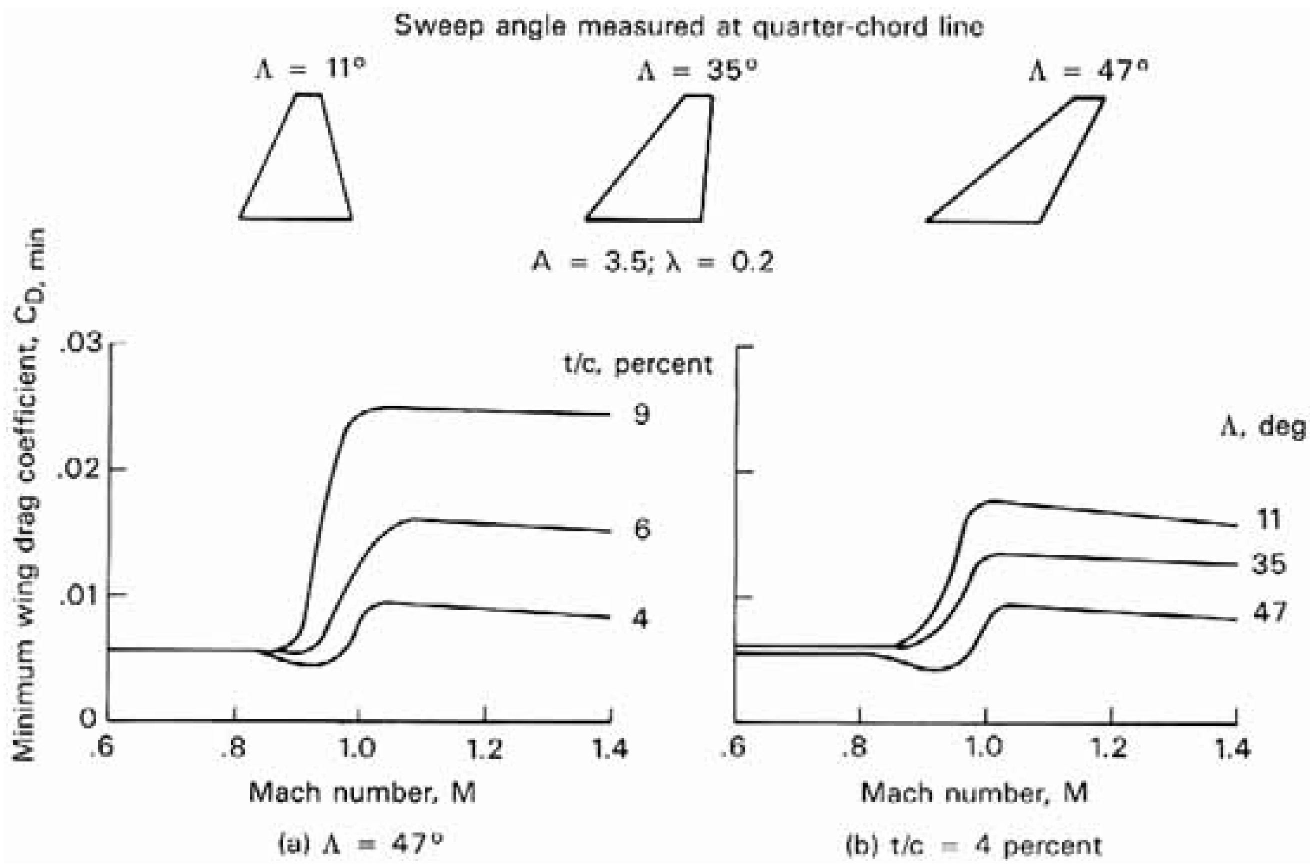

V_∞
M_∞
Assume M_{cr} for wing = 0.7
Airfoil section with M_{cr} = 0.7
Now sweep the same wing by 30°
(a)
M_{cr} for swept wing $\approx \frac{0.7}{\cos 30°} = \frac{0.7}{0.866} = 0.808$
30°
Ω
30°
Airfoil "sees" only this component of velocity
Airfoil section with M_{cr} = 0.7
(b)

Wing Sweep



$\frac{t_1}{c_1} = 0.15$
t_1
c_1
A
Segment of straight wing
B
(a)
$\Omega = 45°$
C
$\frac{t_2}{c_2} = 0.106$
$t_2 = t_1$
$c_2 = 1.41c_1$
Segment of swept wing
D
(b)

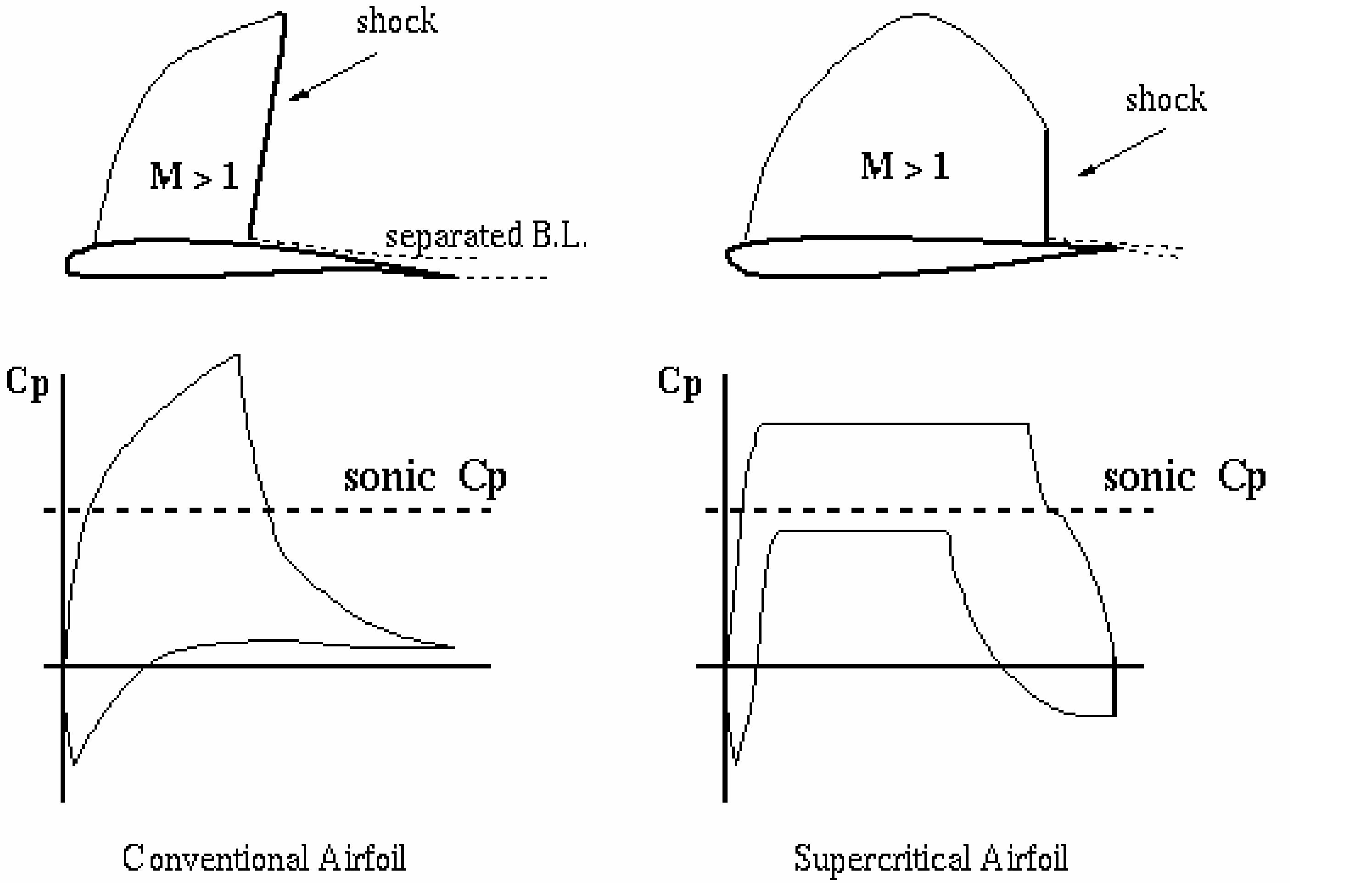
Effect of Thickness and Sweep on Wave Drag



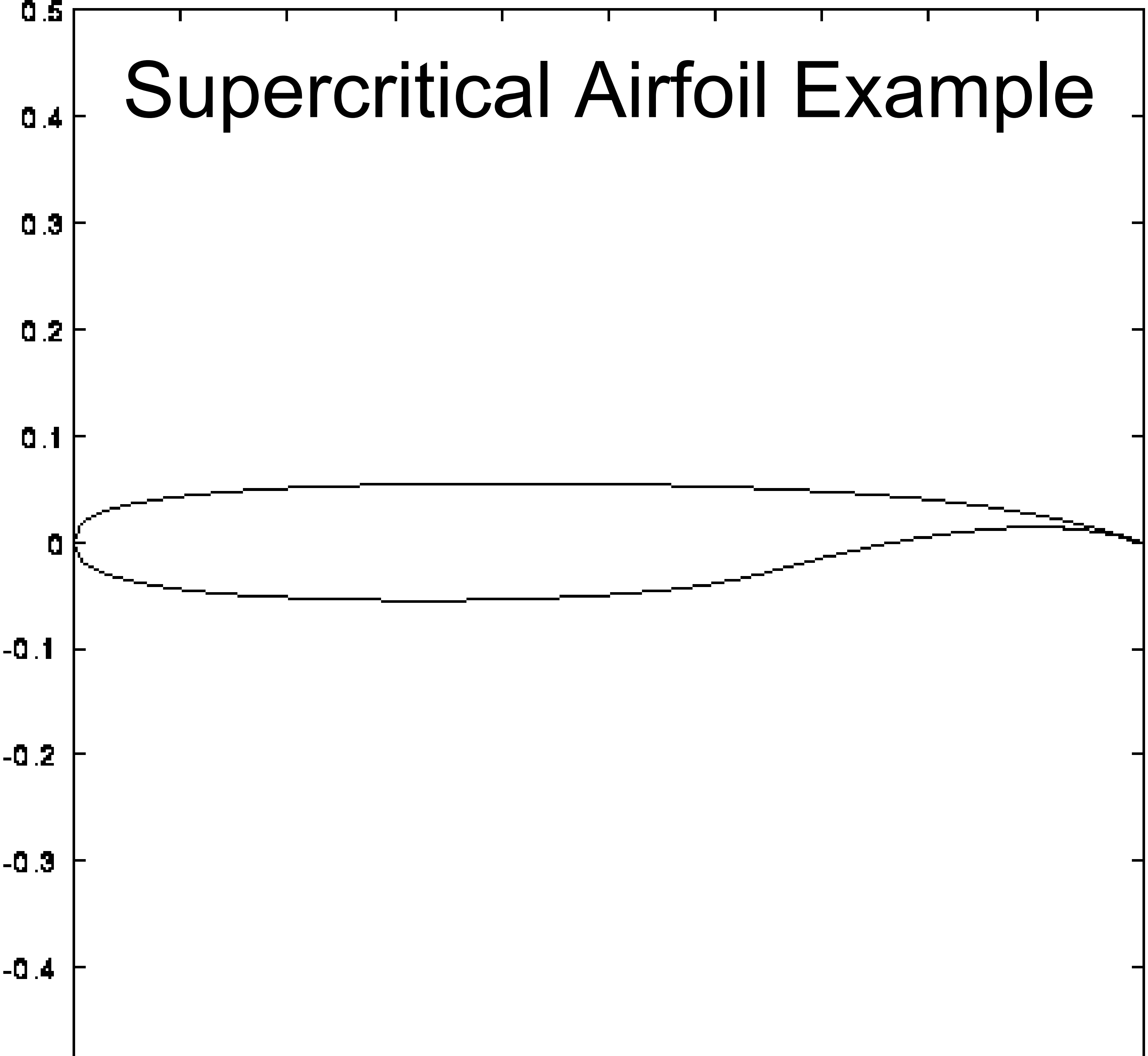
Source:
http://www.hq.nasa.gov/office/pao/History/SP-468/ch10-4.htm

Conventional vs. Supercritical Airfoils

$$C_p = \frac{p - p_\infty}{\frac{1}{2}\rho V_\infty^2}$$



Supercritical Airfoil Example



Area Ruling

- Keep changes in cross sectional area along aircraft smooth (main result: pinch fuselage at wing)

F-106

Dryden Flight Research Center EC97-43932-16 Photographed 1997
F-106 in flight from tanker (NASA/Jim Ross)

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