INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

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CONCEPTUAL DESIGN OF FLIGHT VEHICLES

B.Tech III-II Sem (R15)

DEPARTMENT OF AERONAUTICAL ENGINEERING

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UNIT-I

OVERVIEW OF THE DESIGN PROCESS, SIZING FROM A CONCEPTUAL SKETCH AIRFOIL AND GEOMETRY SELECTION, THRUST TO WEIGHT RATIO, WING LOADING

WHAT IS DESIGN ?

- Aircraft design is a separate discipline in Aeronautical engineering. An aircraft designer need to well versed in Aerodynamics, structures, flight control and stability, propulsion.
- Design looks like a “drafting” (now a days – Computer Aided Drafting)

Fig 1: Conceptual Sketch

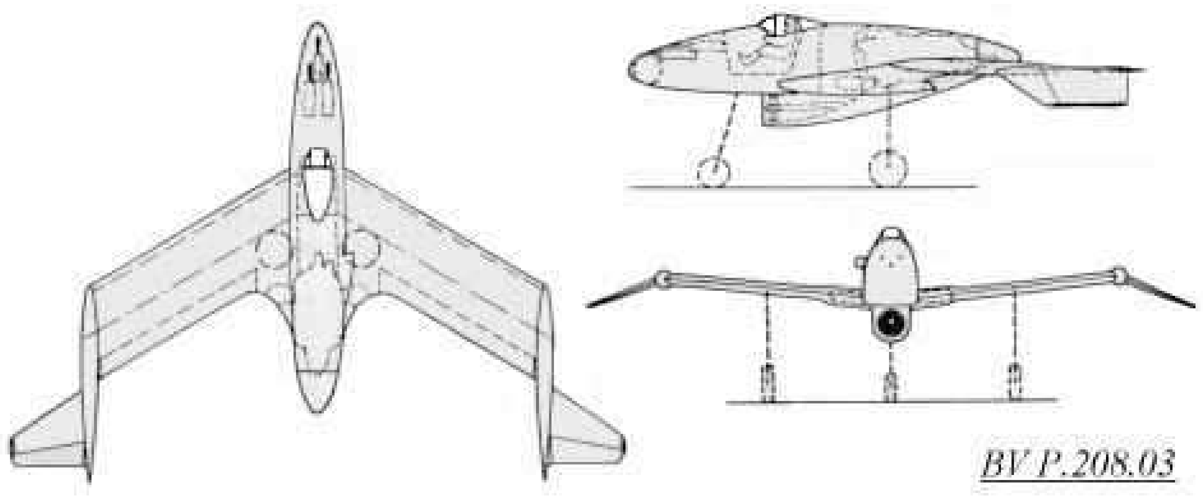
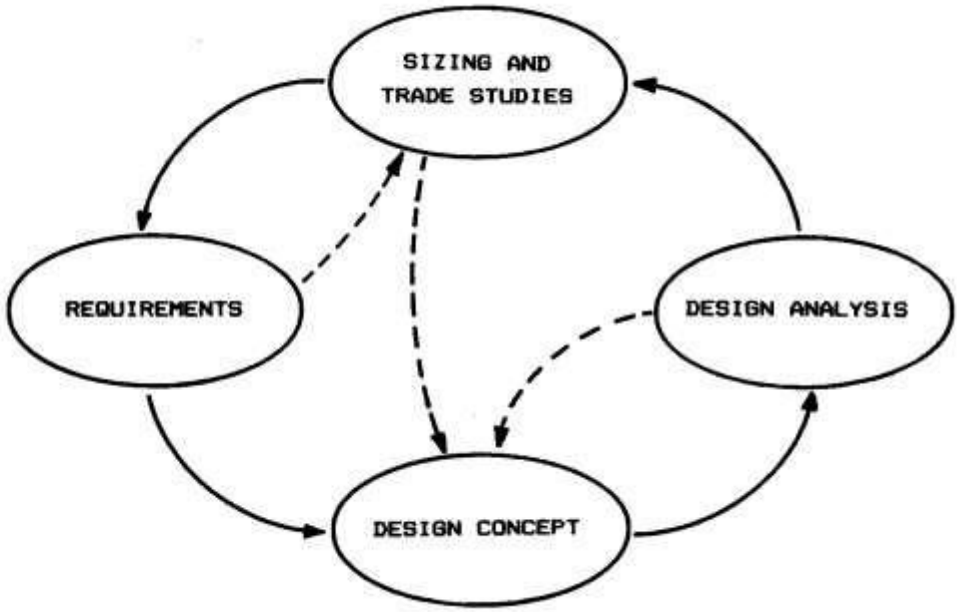


Fig 2: Design Wheel

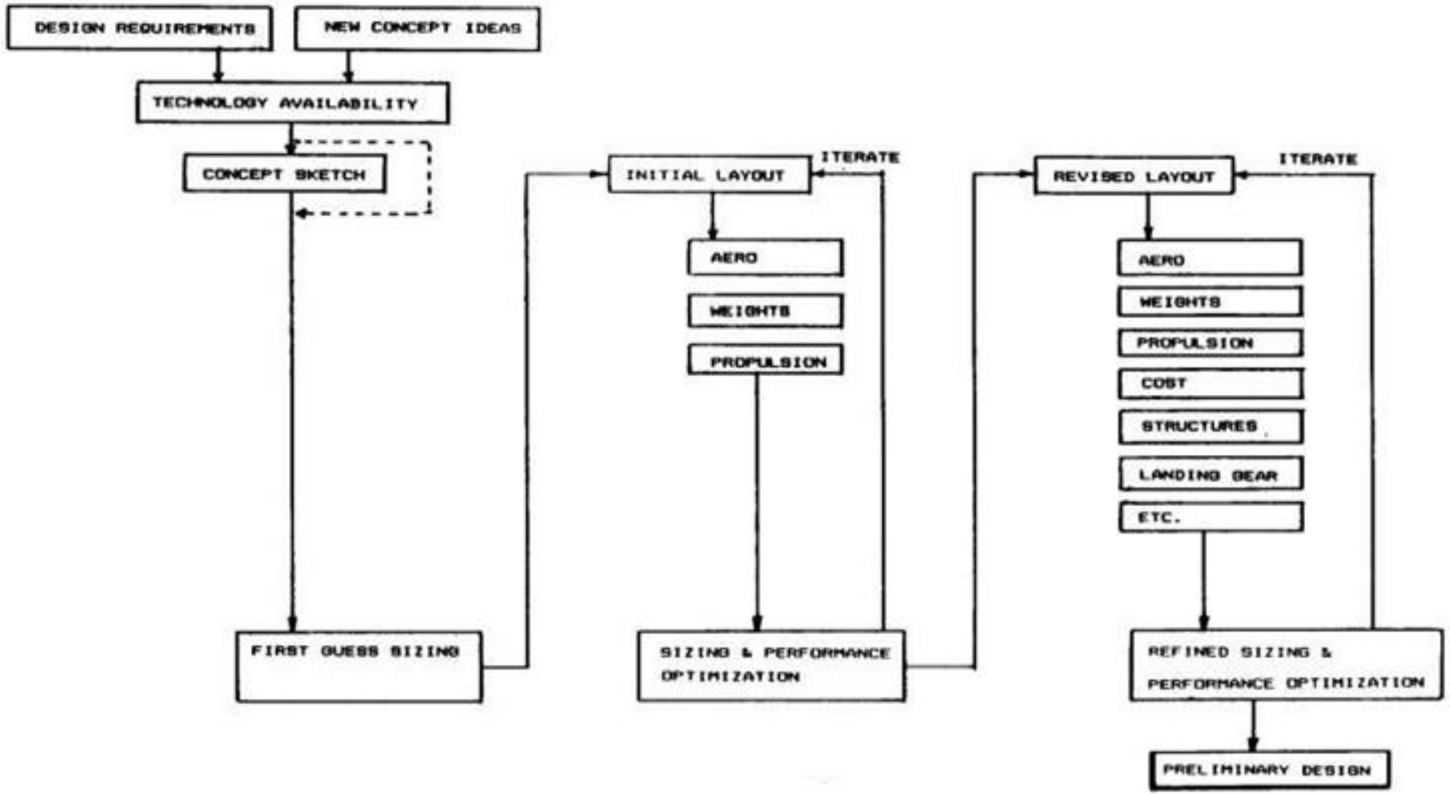


Phases of Aircraft design

1. Conceptual
2. Preliminary
3. Detailed

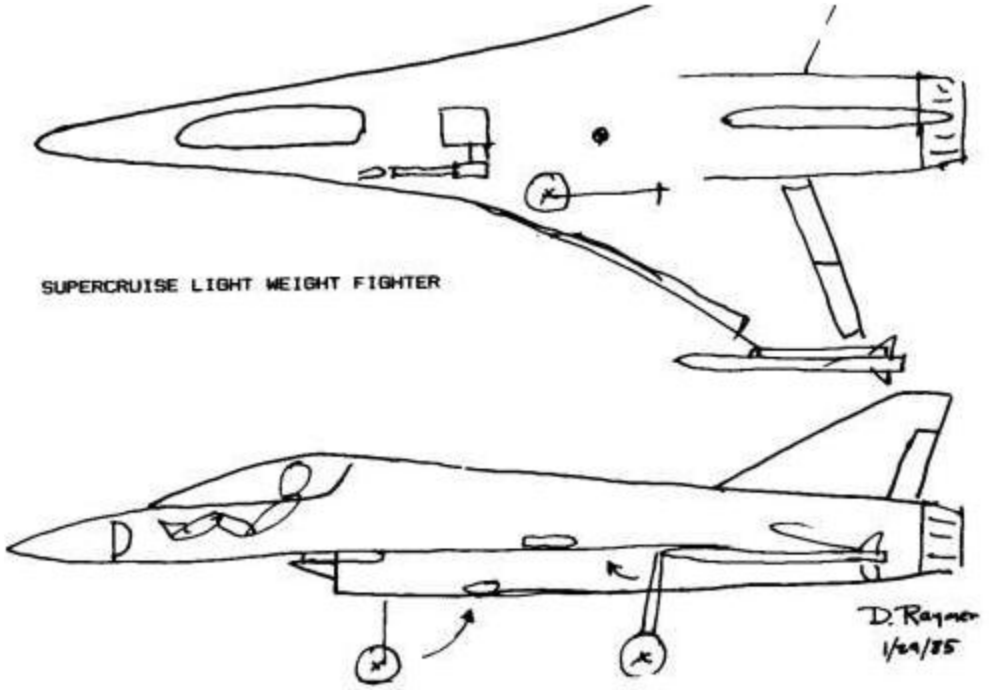
- Aircraft conceptual design process begins with a specific set of design requirements established by the customer.
- Design requirements include parameters like aircraft range, payload, takeoff, landing distances, maneuverability, speed requirements.

Fig 3: Aircraft Conceptual Design Process



The initial sketch of conceptual design

Fig 4: Initial Sketch



TAKE OFF-WEIGHT BUILDUP, EMPTY-WEIGHT ESTIMATION

- “Design take off gross weight” is the total weight of the aircraft.

$$W_0 = W_{crew} + W_{payload} + W_{fuel} + W_{empty}$$

$$W_0 = \frac{W_{crew} + W_{payload}}{1 - (W_f/W_0) - (W_e/W_0)}$$

Fig 5: Empty Weight Fraction Trends

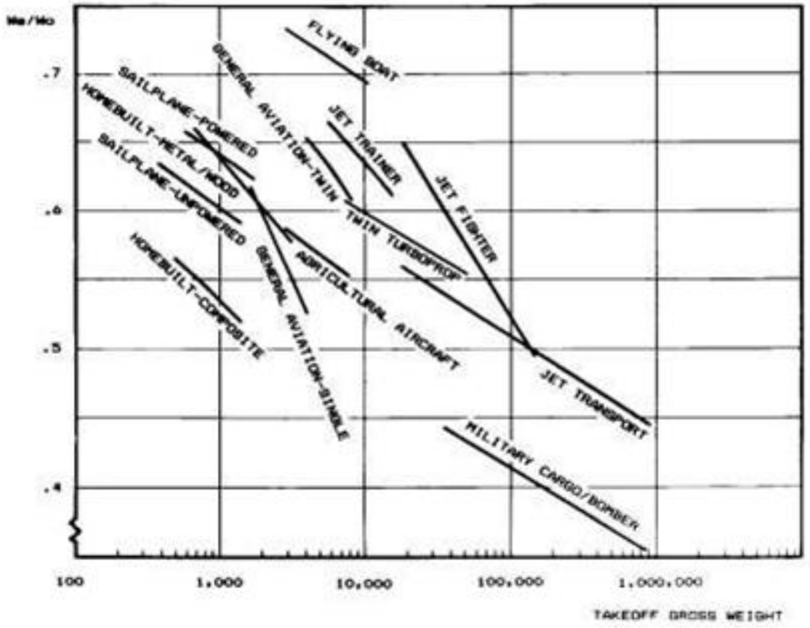


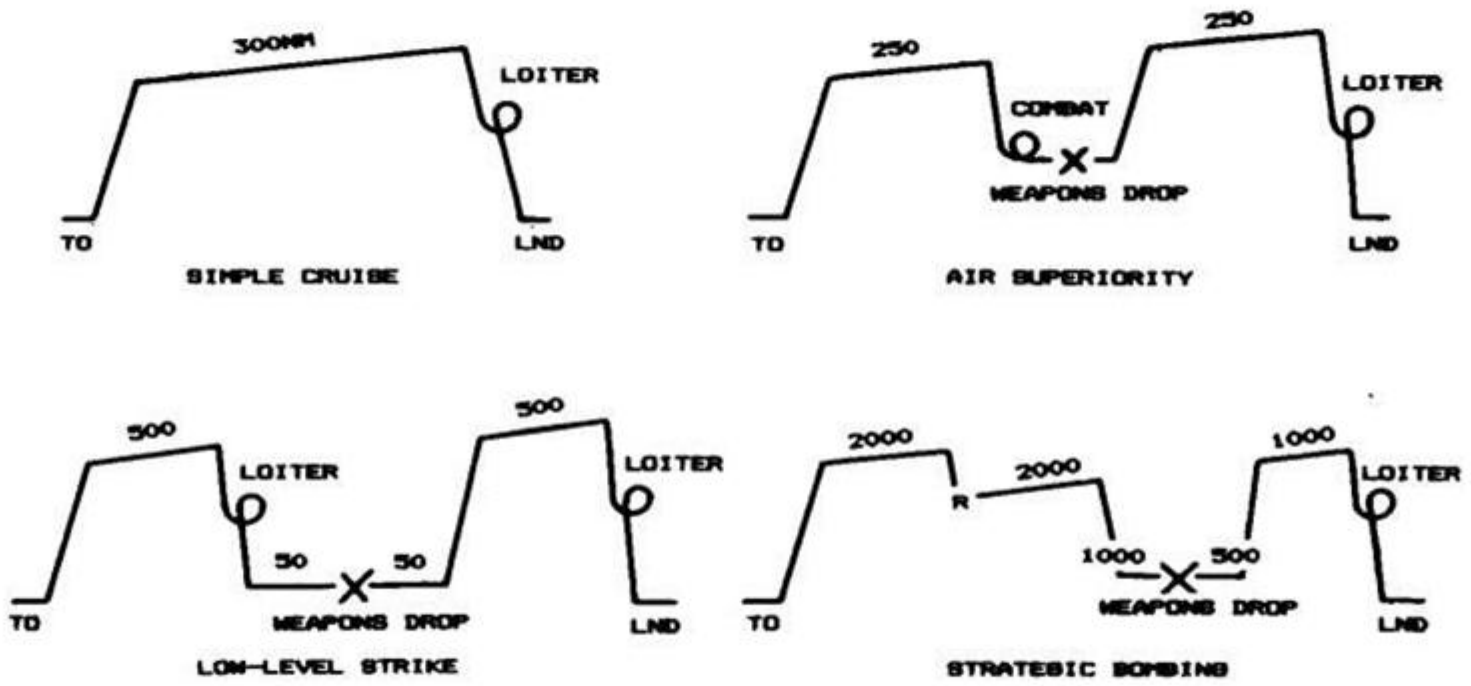
Table 1: Empty Weight Fraction Vs W0

$W_e/W_0 = A W_0^C K_{vs}$	A	C
Sailplane—unpowered	0.86	−0.05
Sailplane—powered	0.91	−0.05
Homebuilt—metal/wood	1.19	−0.09
Homebuilt—composite	0.99	−0.09
General aviation—single engine	2.36	−0.18
General aviation—twin engine	1.51	−0.10
Agricultural aircraft	0.74	−0.03
Twin turboprop	0.96	−0.05
Flying boat	1.09	−0.05
Jet trainer	1.59	−0.10
Jet fighter	2.34	−0.13
Military cargo/bomber	0.93	−0.07
Jet transport	1.02	−0.06

K_{vs} = variable sweep constant = 1.04 if variable sweep
= 1.00 if fixed sweep

MISSION PROFILES

Fig 6: Mission Profiles of Typical Aircrafts for Sizing



DESIGN OF ANTISUBMARINE WARFARE AIRCRAFT

Fig 7: ASW Concept Sketches

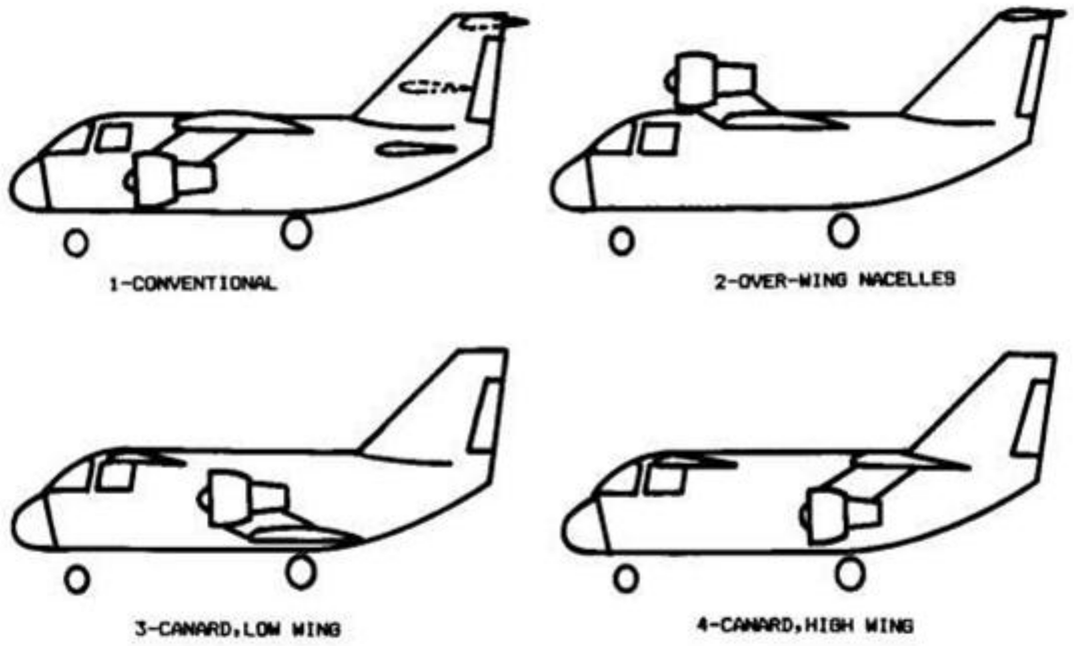
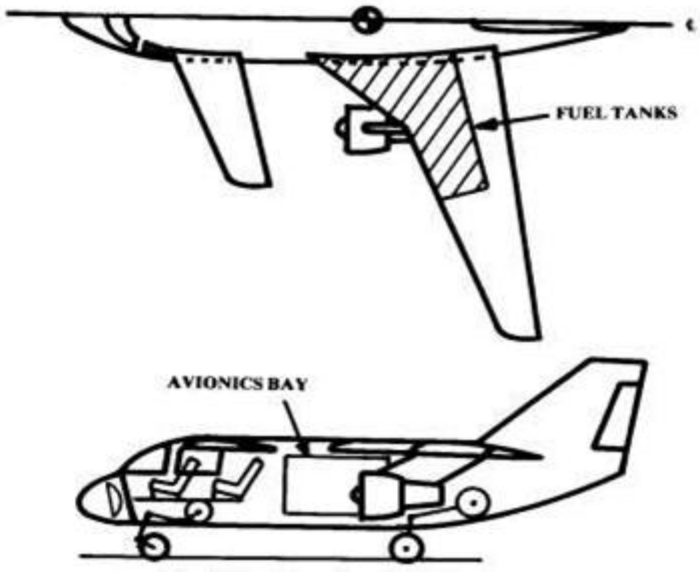


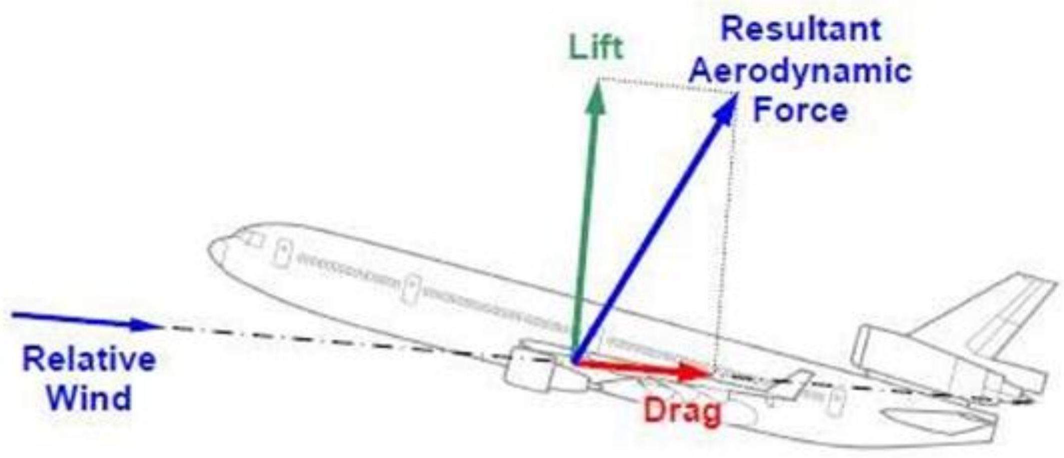
Fig 8: Completed ASW Sketch



AERODYNAMIC CHARACTERISTICS OF AIRFOILS AND WINGS

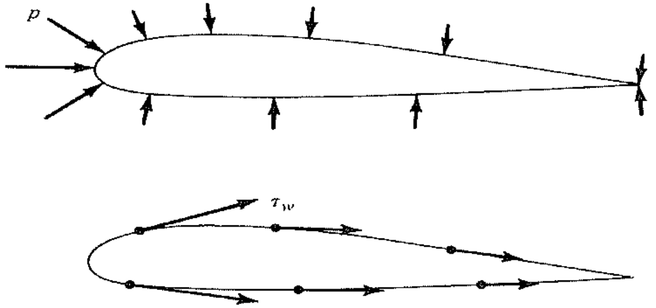
- Aerodynamic forces and Moments coefficients

Fig 9: Aerodynamic Forces acting on an Aircraft



AERODYNAMIC FORCES

Fig 10: Airfoil Geometry



- Aerodynamic forces exerted by airflow comes from only two sources
- Pressure, p, distribution on surface

  Acts normal to surface
- Shear stress, tw, (friction) on surface

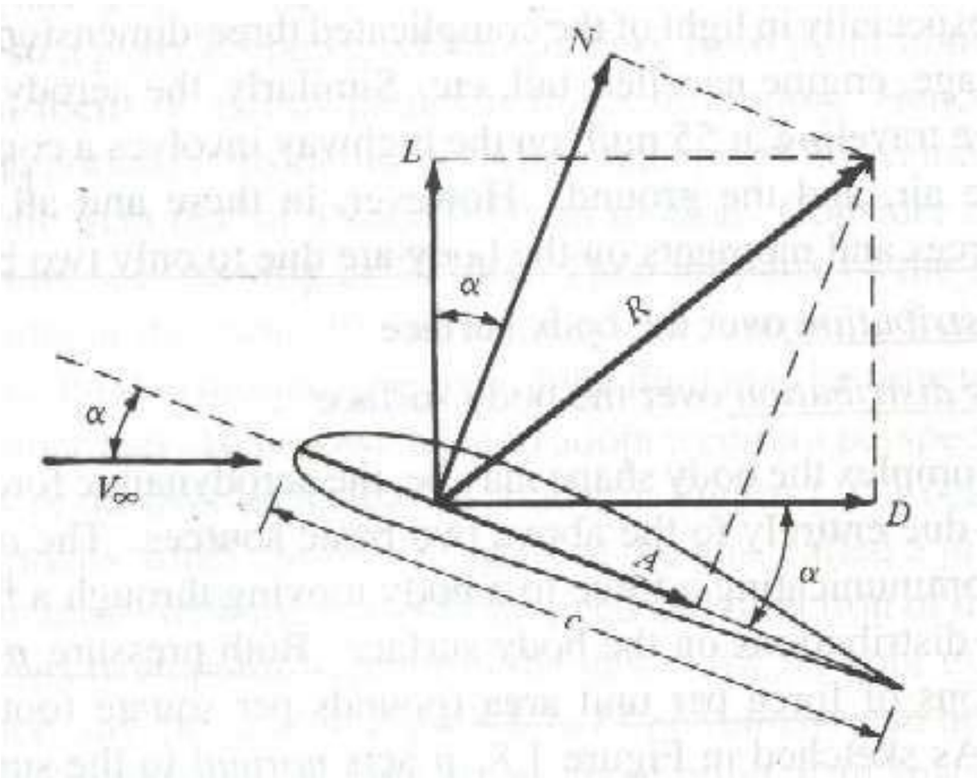
  Acts tangentially to surface
- Pressure and shear are in units of force per unit area (N/m2)
- Net unbalance creates an aerodynamic force
- No matter how complex the flow field, and no matter how complex the shape of the body, the only way nature has of communicating an aerodynamic force to a solid object or surface is through the pressure and shear stress distributions that exist on the surface.
- The pressure and shear stress distributions are the two hands of nature that reach out and grab the body, exerting a force on the body – the aerodynamic force.

- Aerodynamic forces and moments are due to
  - Pressure distribution
  - Shear stress distribution
- Nomenclature
  - R = Resultant force
  - L = Lift
  - D = Drag
  - N = Normal force
  - A = Axial force

$$L = N\cos\alpha - A\sin\alpha$$

$$D = N\sin\alpha + A\cos\alpha$$

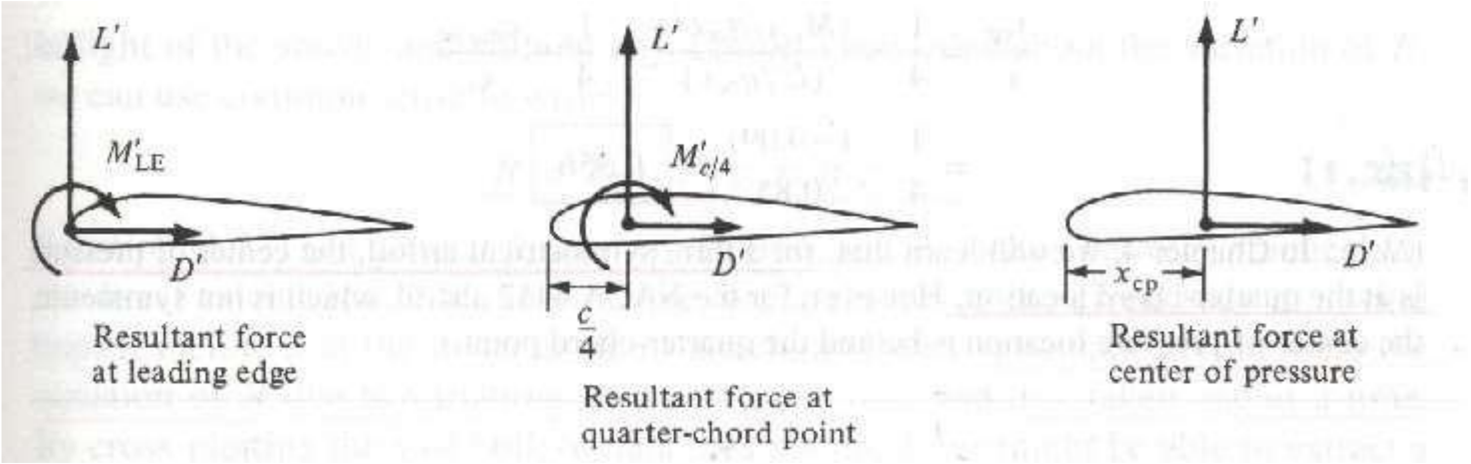
Fig 11: Aerodynamic Forces generated on an Airfoil Section



- Relative Wind: Direction of V_∞
  - We used subscript ∞ to indicate far upstream conditions
- Angle of Attack, a: Angle between relative wind (V_∞) and chord line
- Total aerodynamic force, **R**, can be resolved into two force components
  - Lift, **L**: Component of aerodynamic force perpendicular to relative wind
  - Drag, **D**: Component of aerodynamic force parallel to relative wind
- Center of Pressure: It is that point on an airfoil (or body) about which the aerodynamic moment is zero
- Aerodynamic Center: It is that point on an airfoil (or body) about which the aerodynamically generated moment is independent of angle of attack

MOMENTS ABOUT LEADING EDGE , QUARTER CHORD POINT AND ABOUT CENTER OF PRESSURE

Fig 12: Aerodynamic Moments generated on an Airfoil Section



- Center of Pressure: It is that point on an airfoil (or body) about which the aerodynamic moment is zero
  - Thin Airfoil Theory:

Symmetric Airfoil $x_{cp} = \frac{c}{4}$

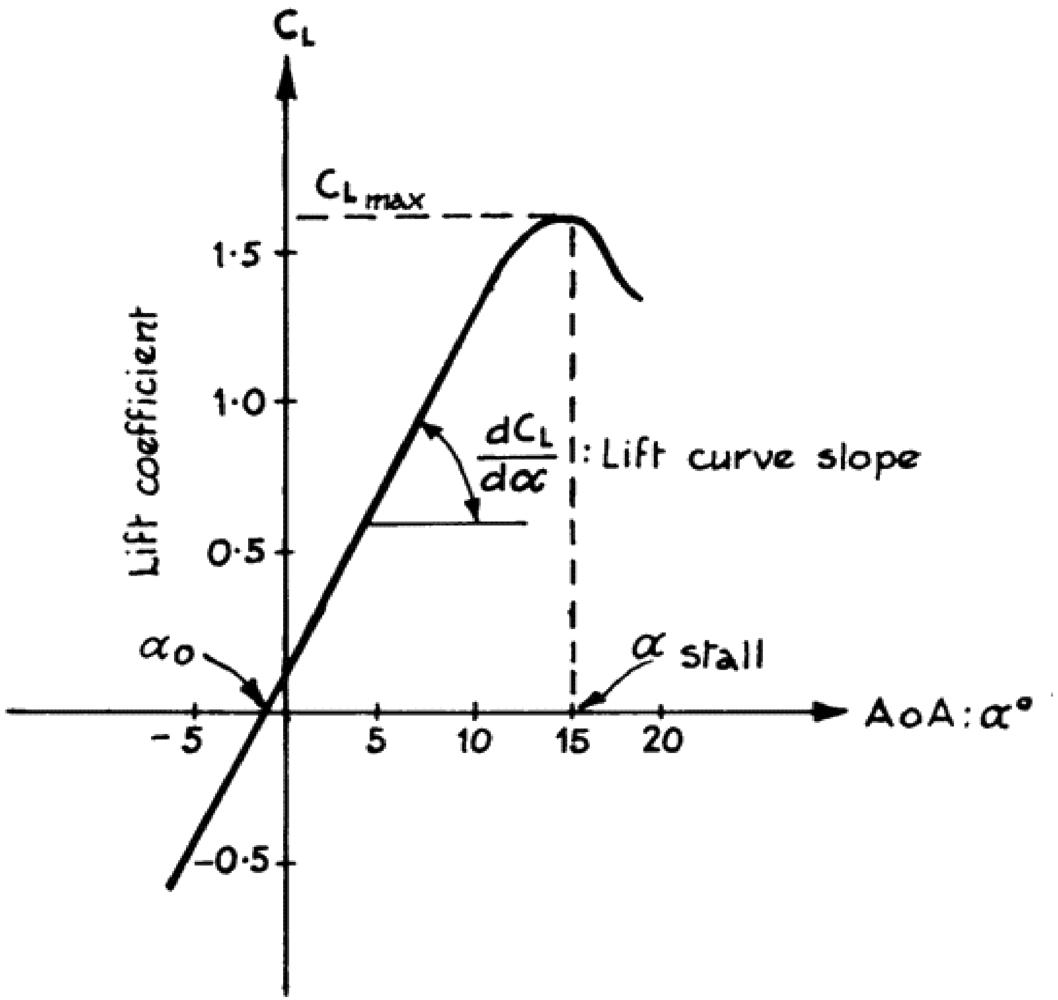
Cambered Airfoil $x_{cp} = \frac{c}{4}\left[1 + \frac{\pi}{c_l}\left(A_1 - A_2\right)\right]$

- Aerodynamic Center: It is that point on an airfoil (or body) about which the aerodynamically generated moment is independent of angle of attack
  - Thin Airfoil Theory:

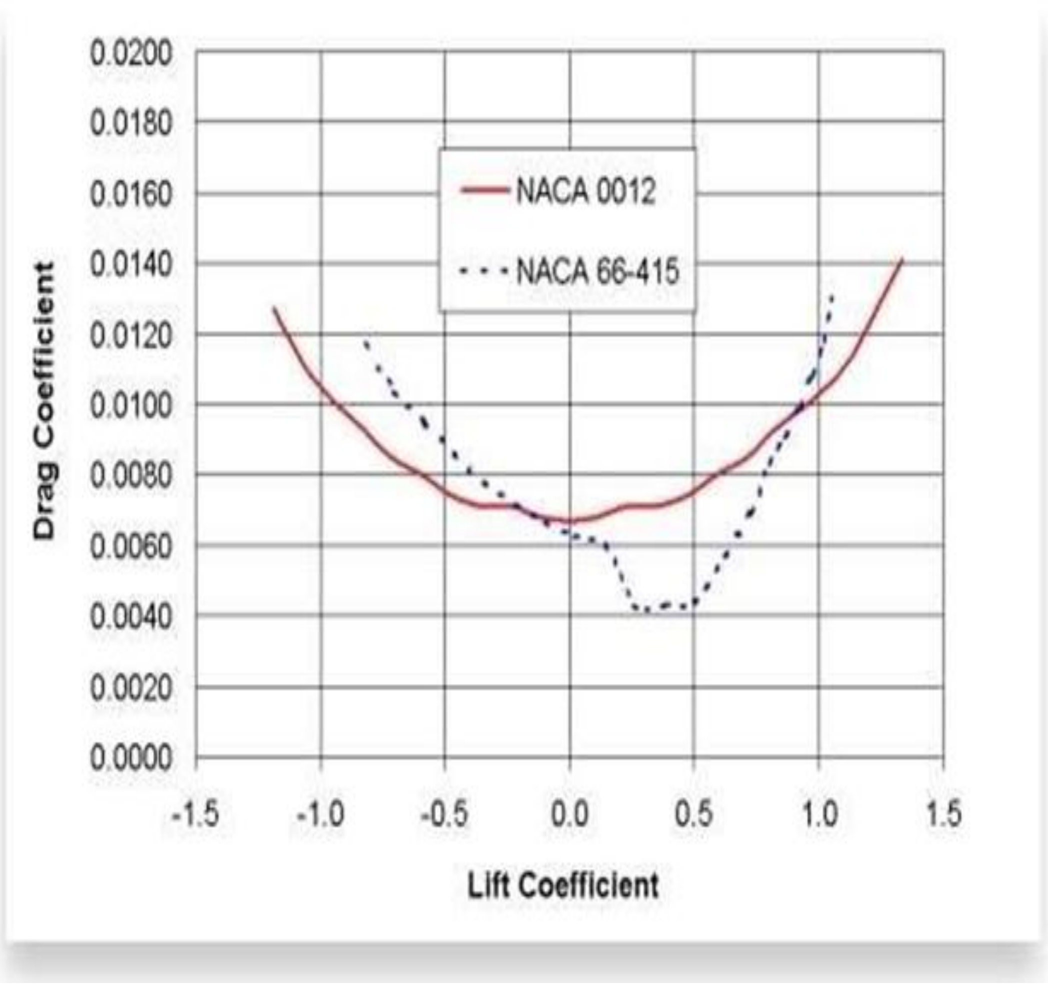
Symmetric Airfoil $x_{A.C.} = \frac{c}{4}$

Cambered Airfoil $x_{A.C.} = \frac{c}{4}$

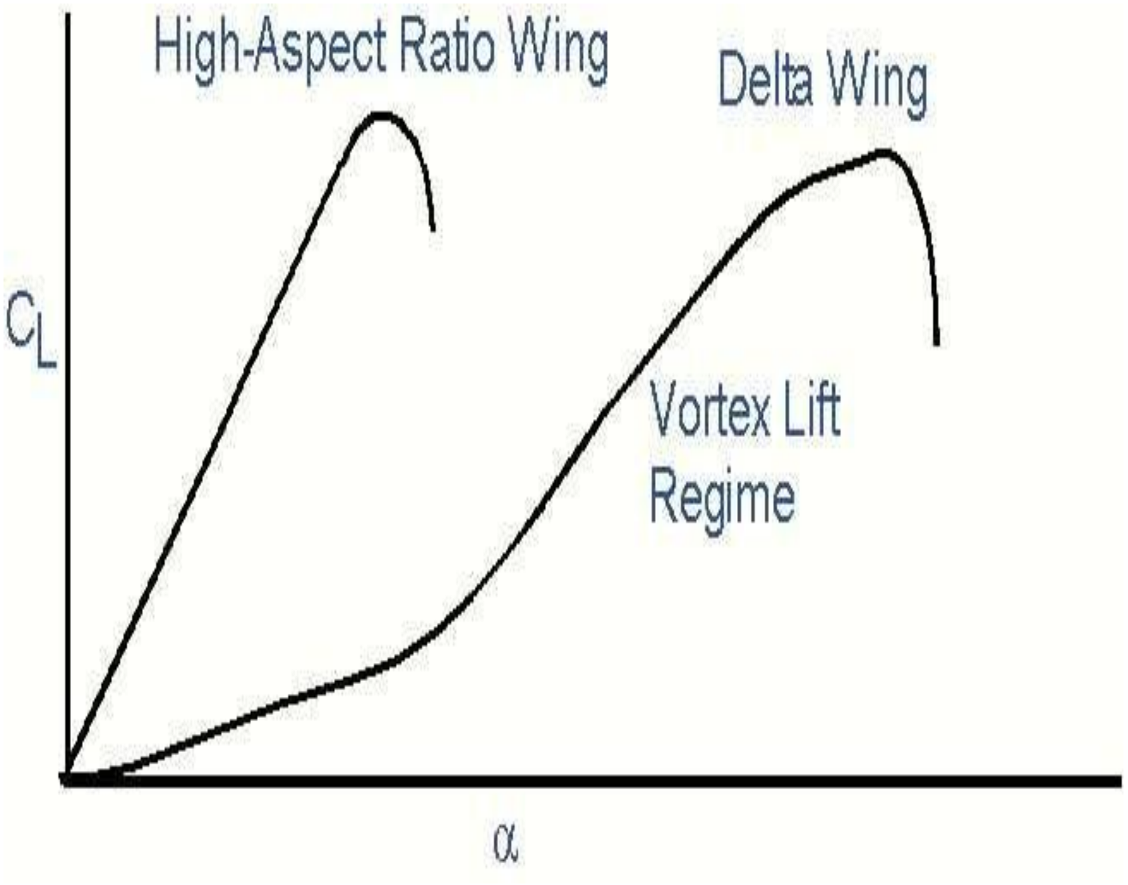
LIFT CURVE SLOPE



DRAG POLAR



Lift curve for High aspect ratio wing and Delta wing Aircraft



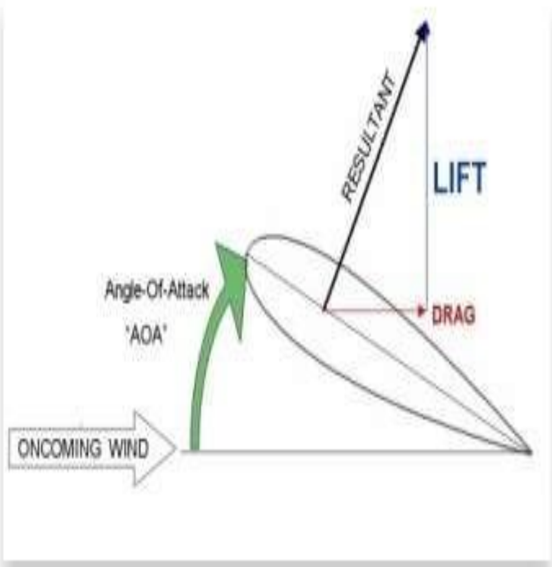


FIGURE 1

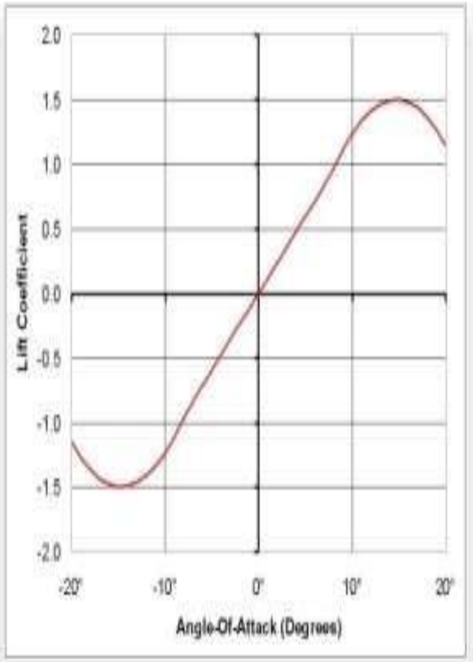
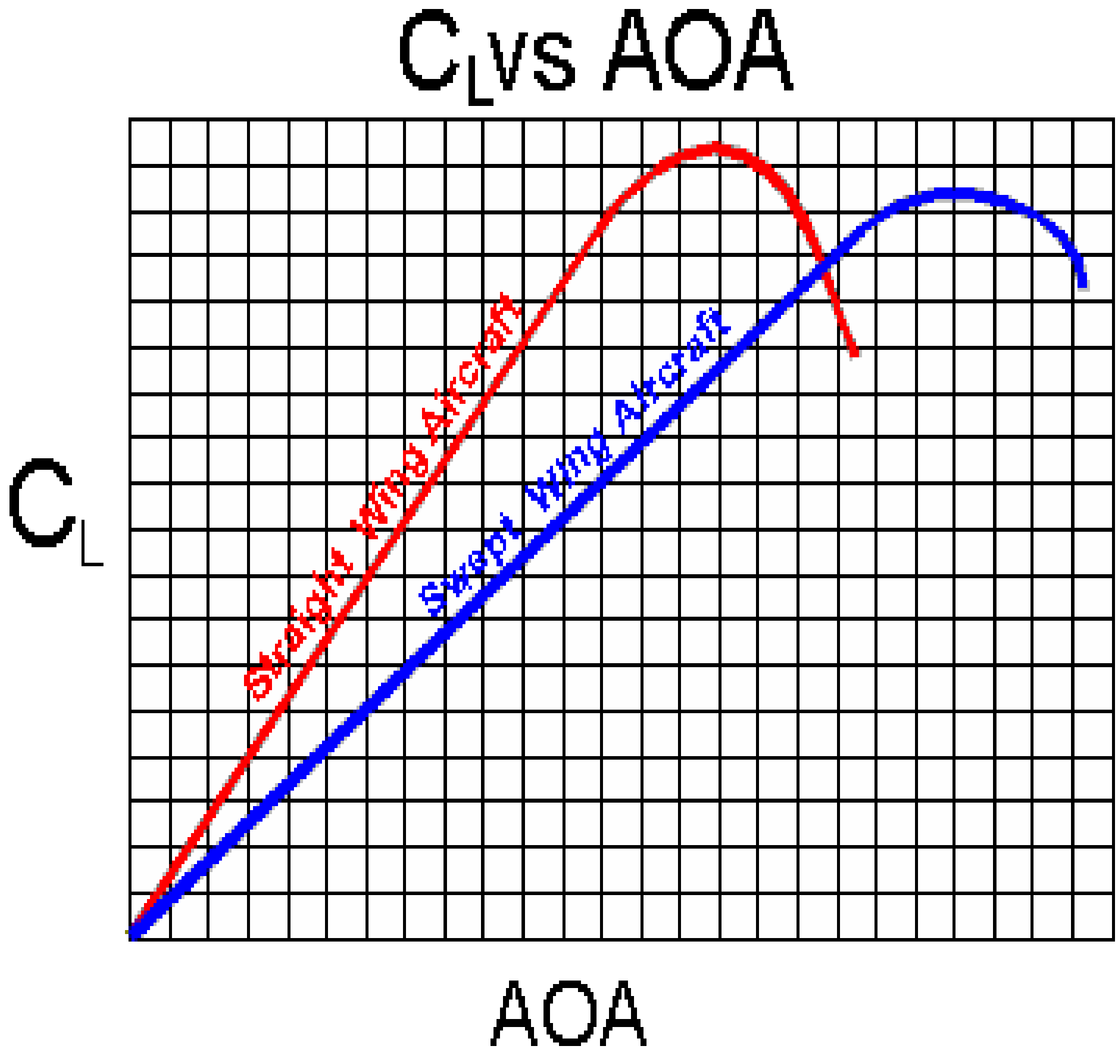
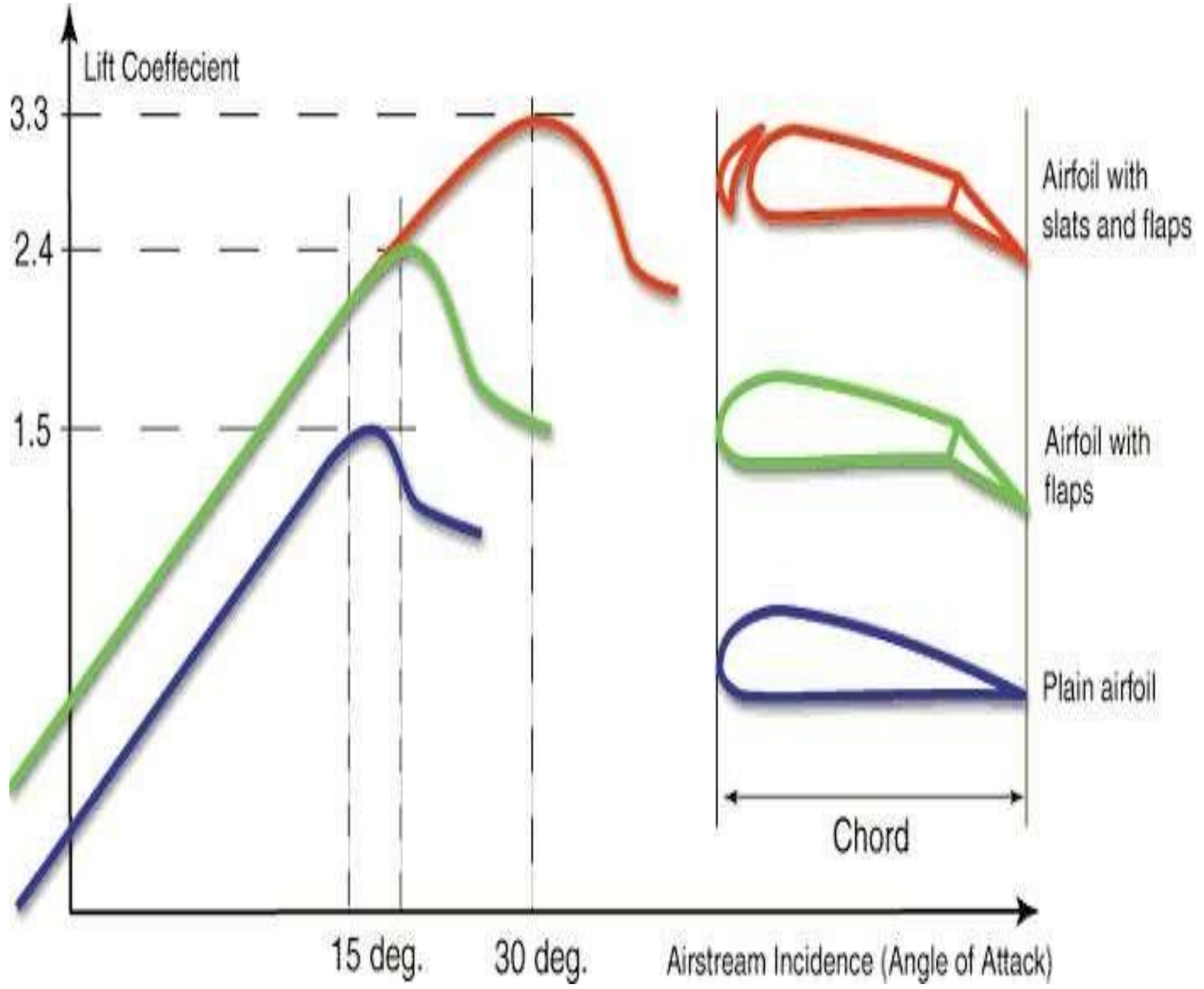


FIGURE 2: Lift coefficient for a symmetric airfoil (note that Cl is zero for zero degrees).

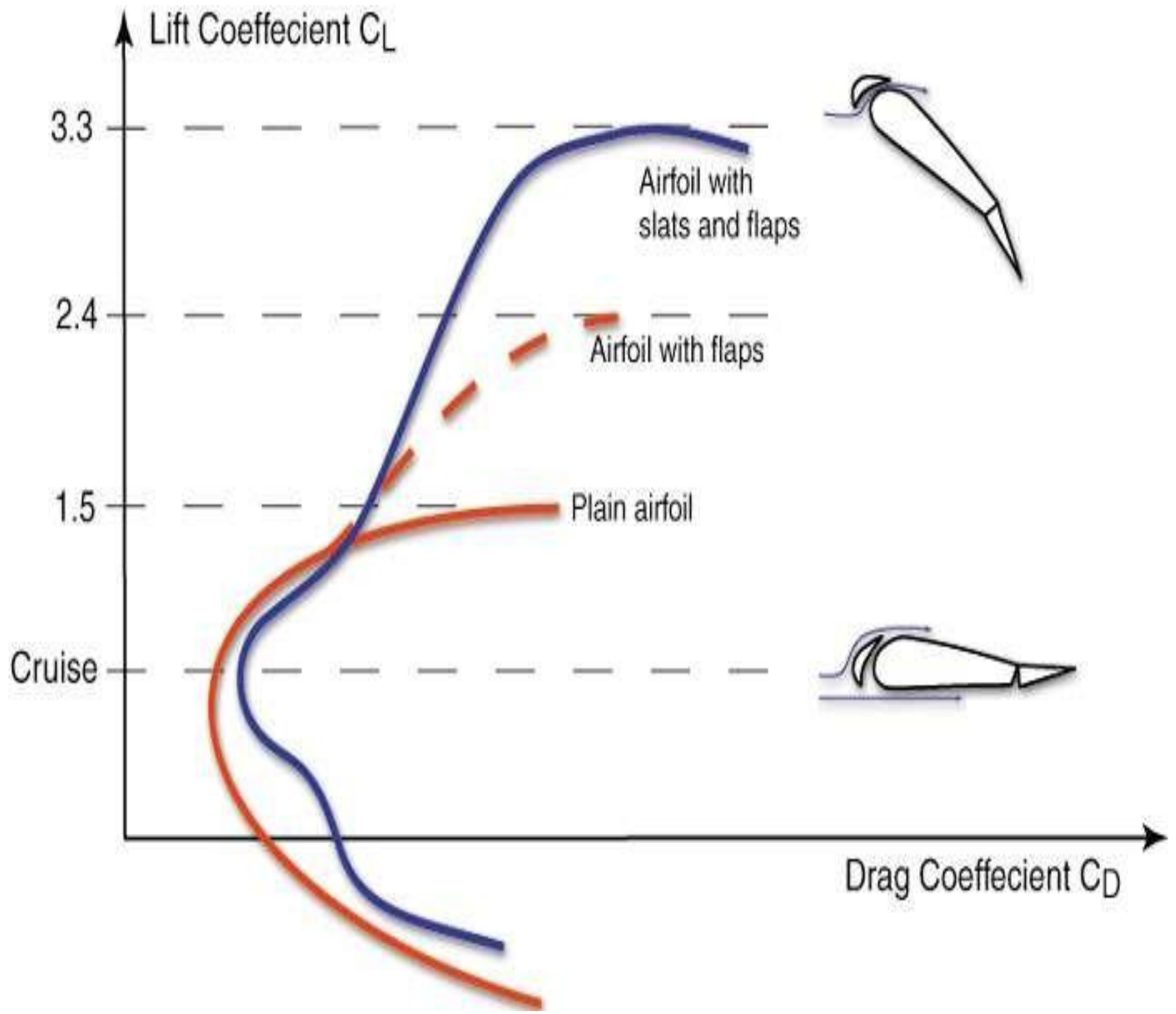
Lift curve for a straight wing and Swept wing Aircraft

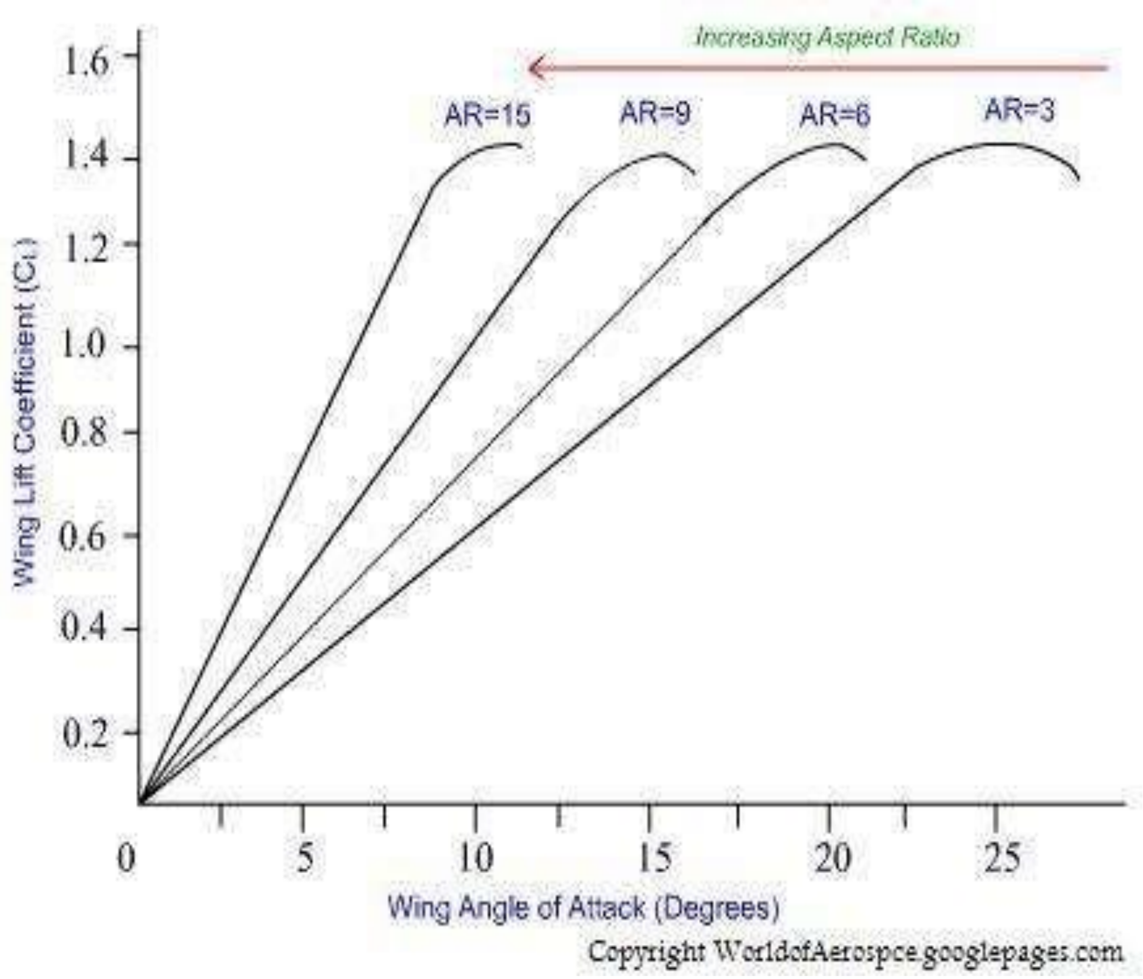


Maximum Lift Coefficient

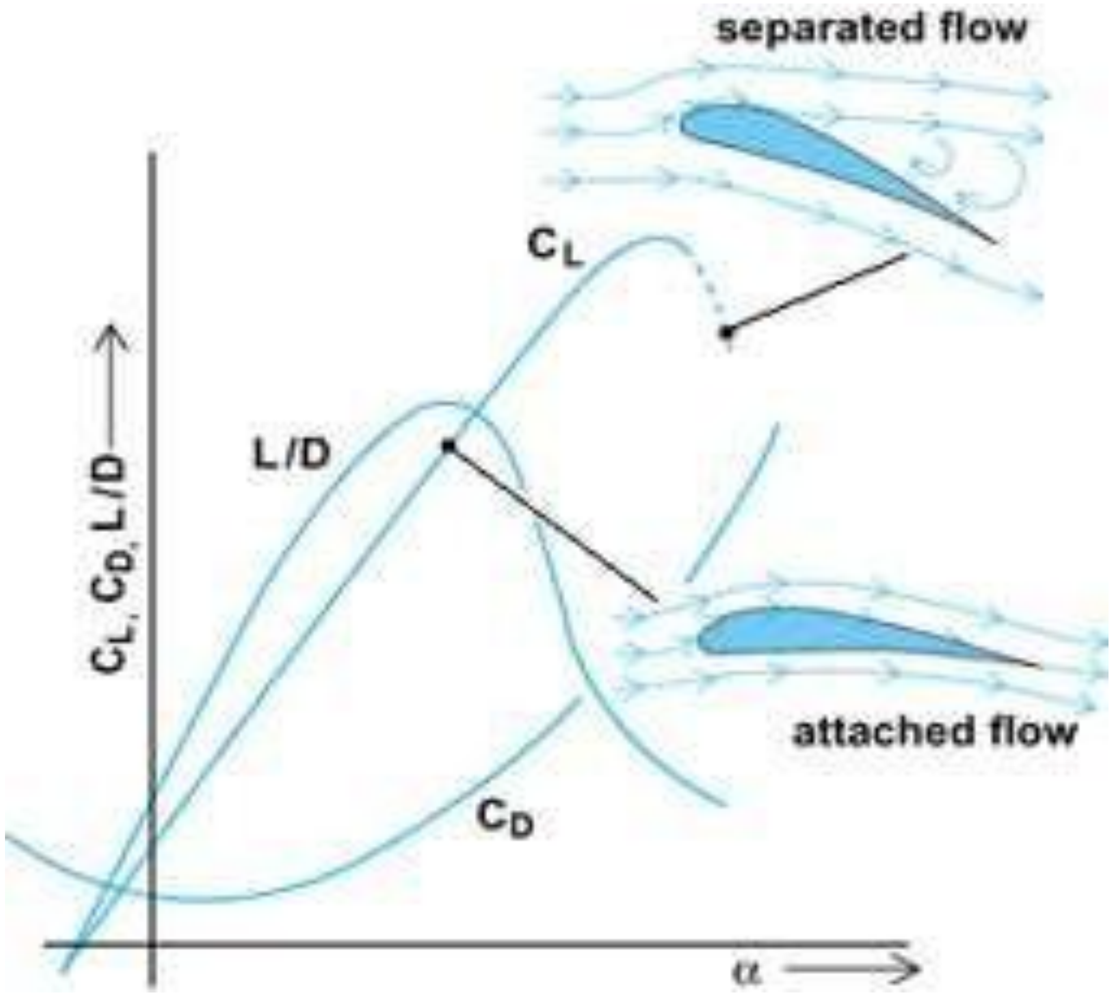


Lift coefficient changes with addition of control surfaces

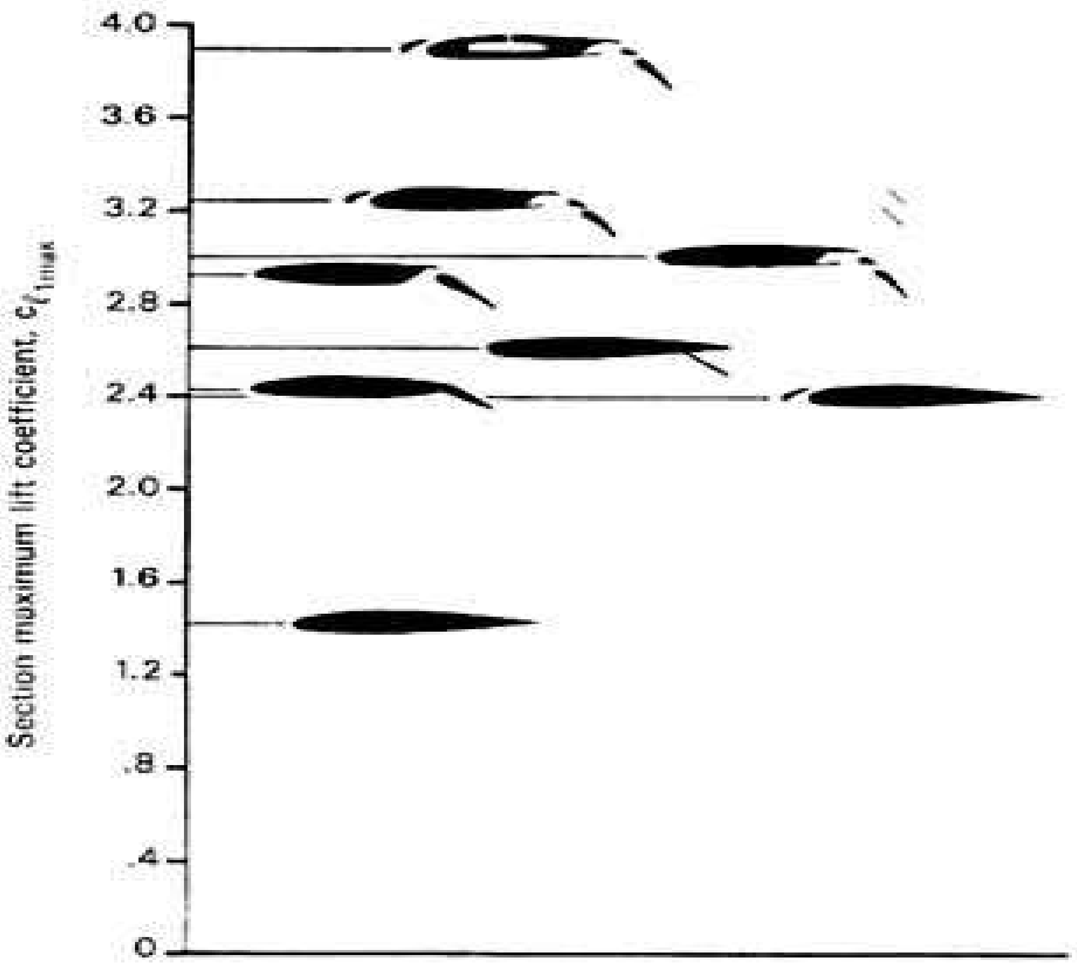




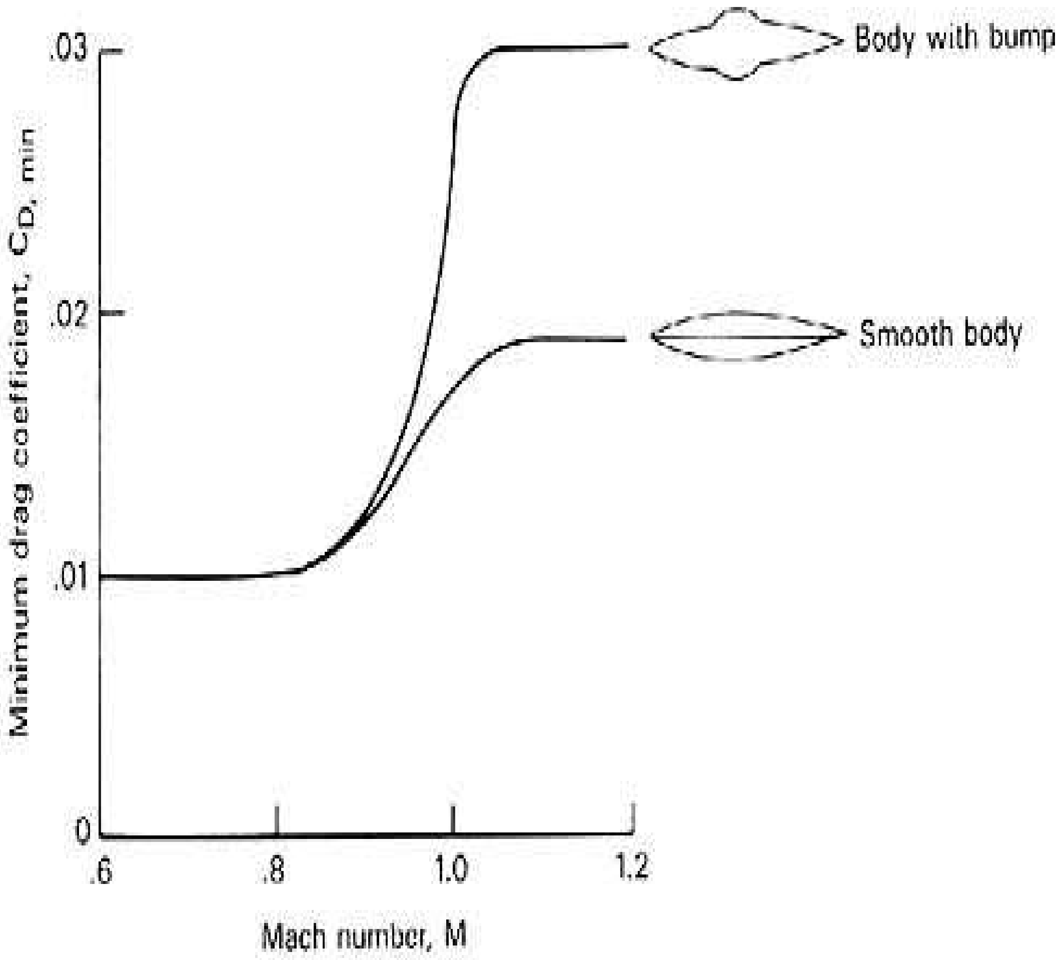
Variation of Cl, CD, L/D with AOA



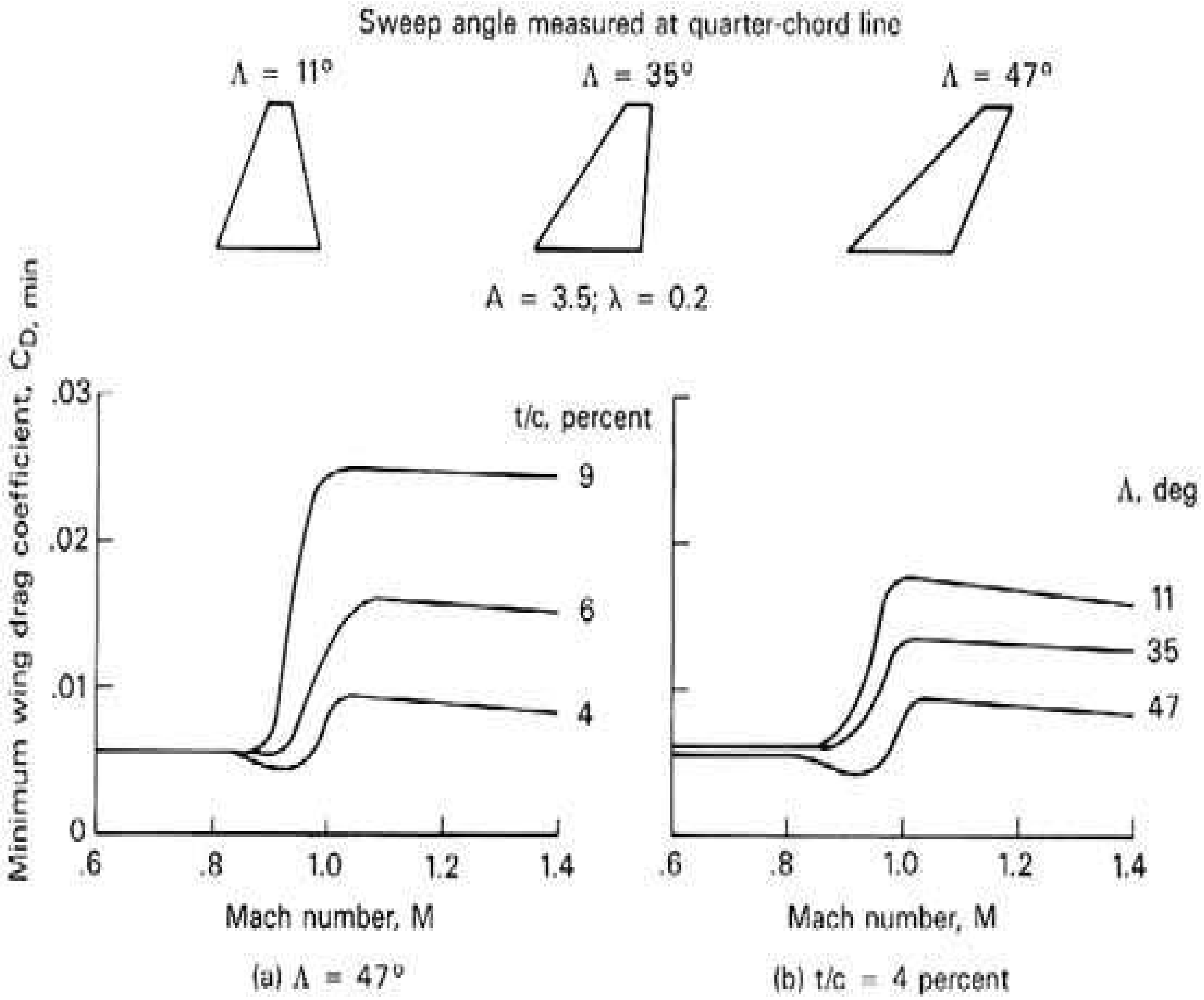
Increase in lift coefficient with different control surfaces or high lift devices



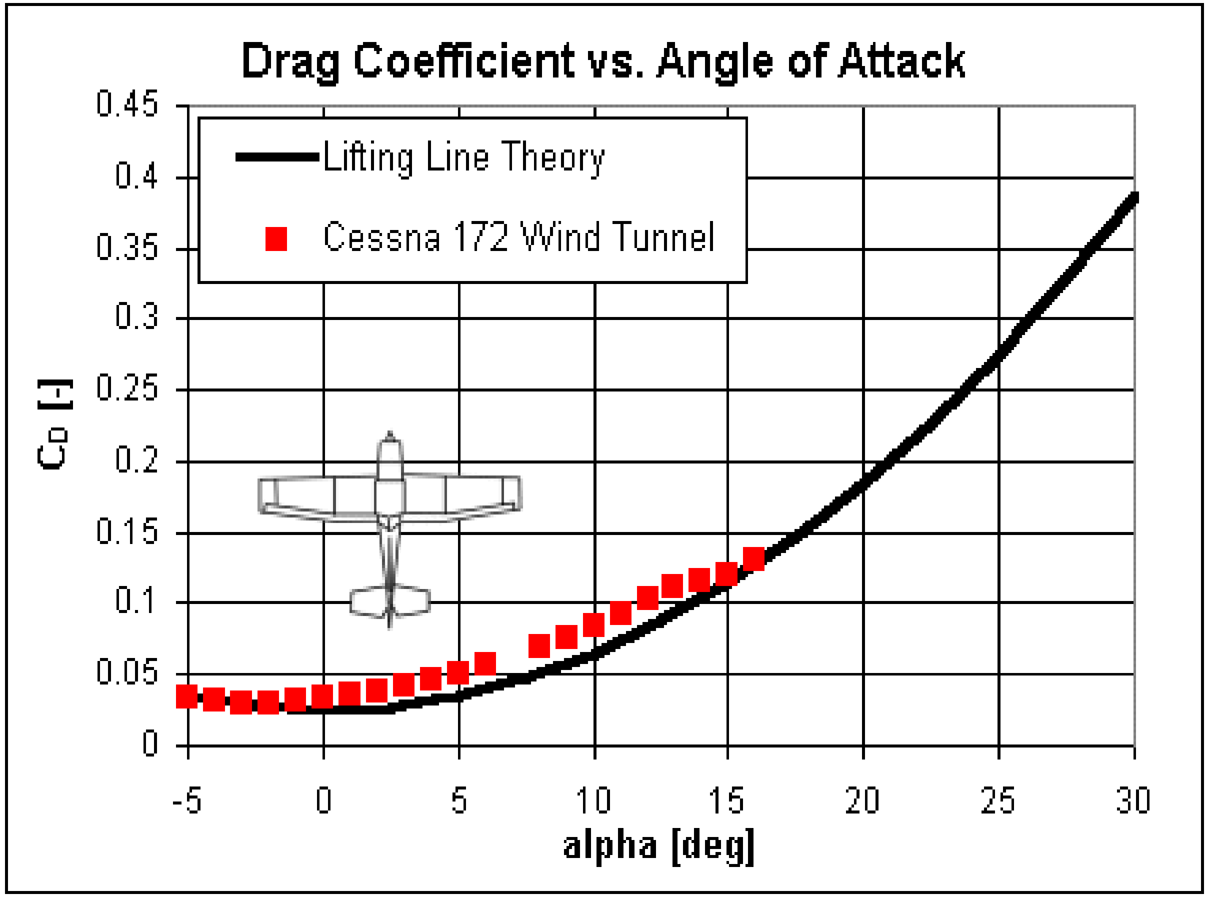
Minimum drag coefficient

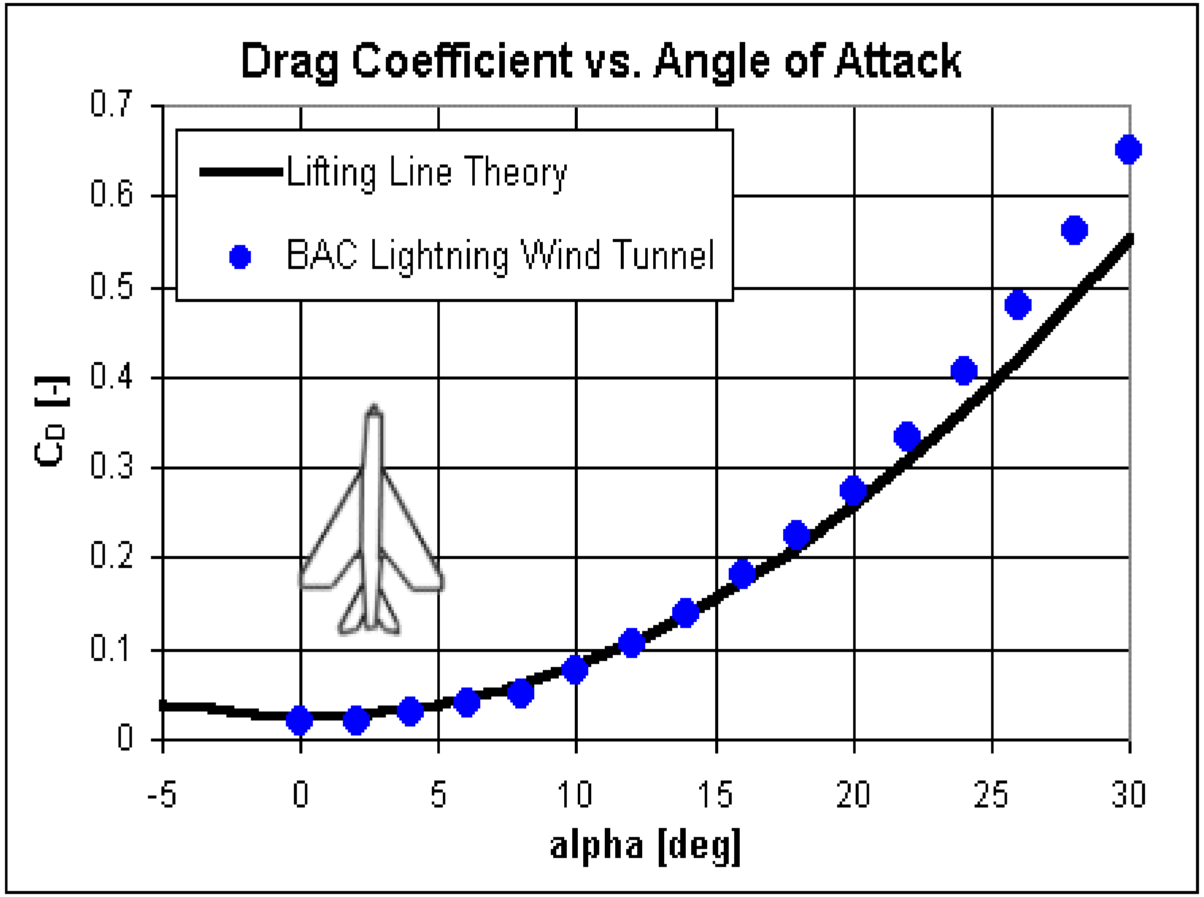


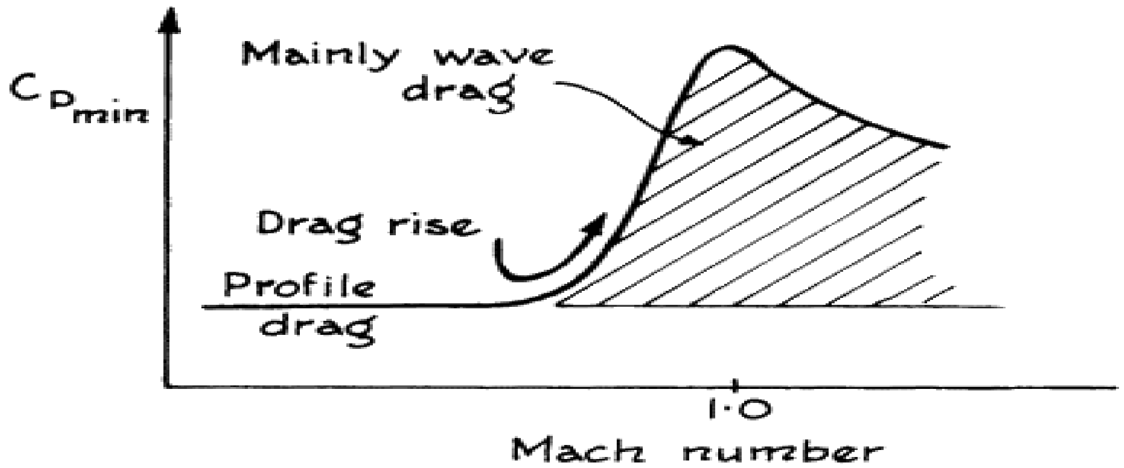
Increasing the sweep angle



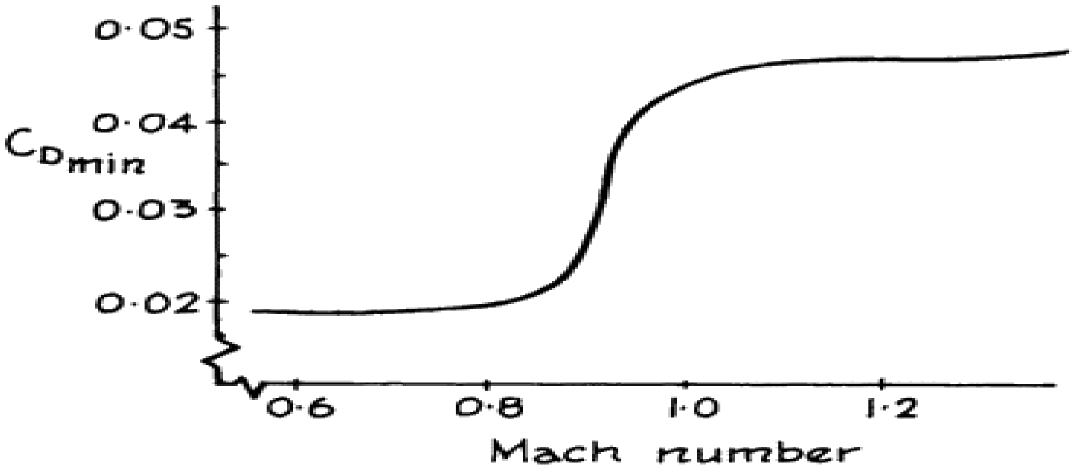
Drag coefficient data obtained for a rectangular wing and swept back wing on wing tunnel and lifting line numerical methods





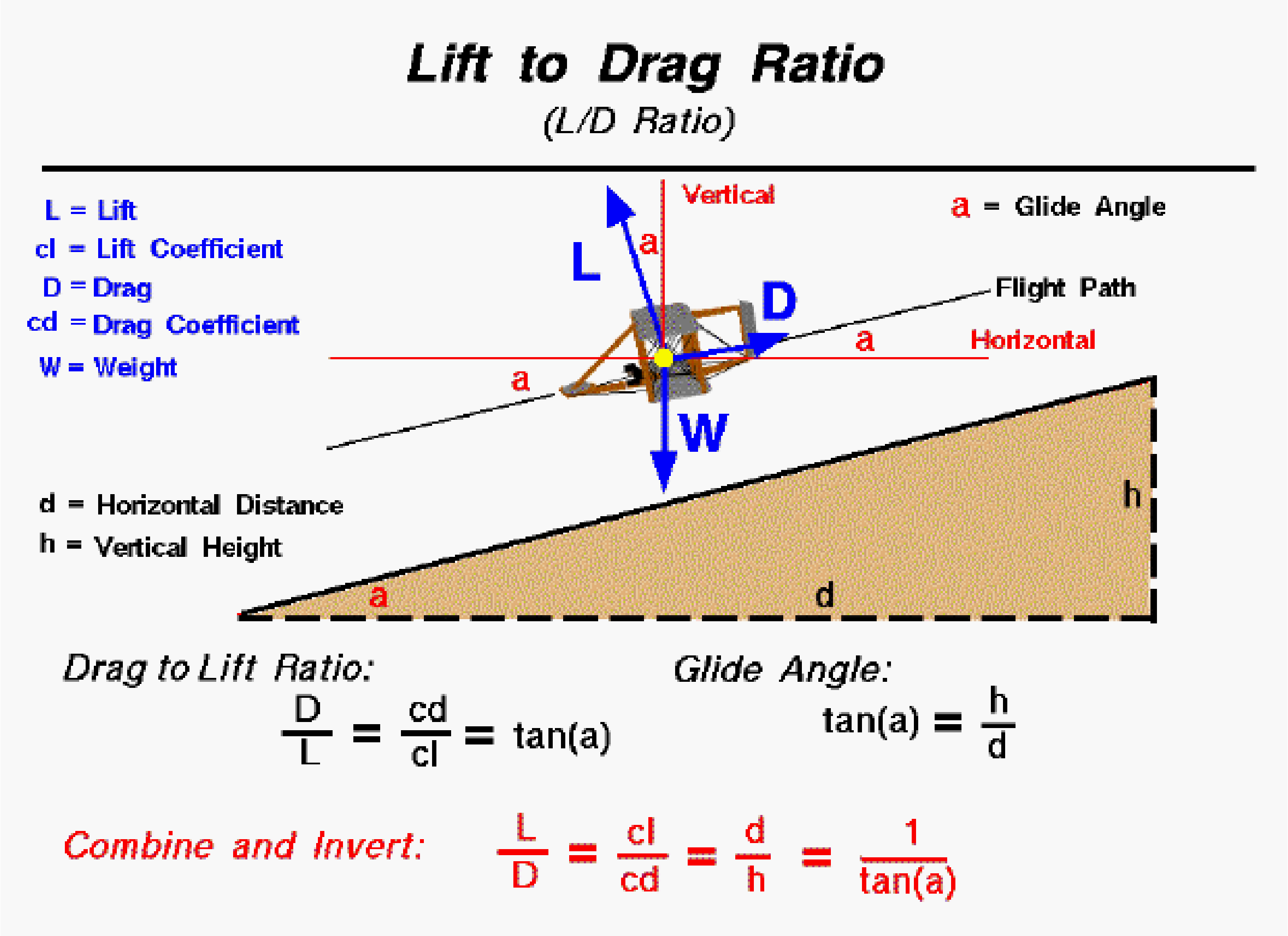


(a) Wing alone



(b) Whole aircraft (F-16) [1]

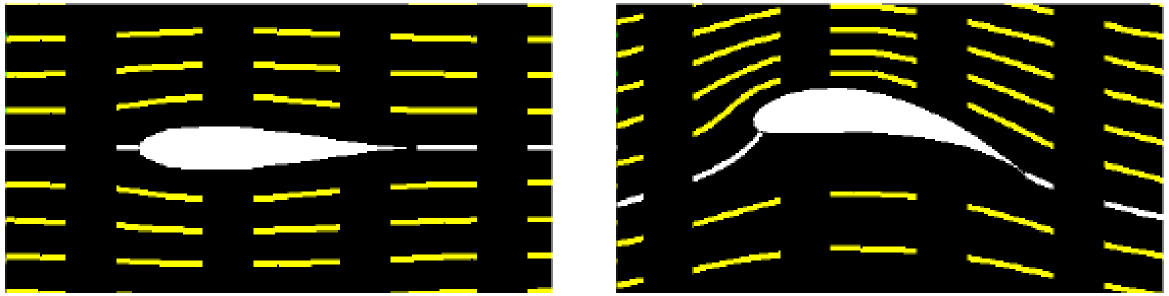
Min drag coefficient for wing section and complete airplane



It gives the maximum possible glide angle

Effect of Airfoil and wing geometry

Shape Effects on Lift



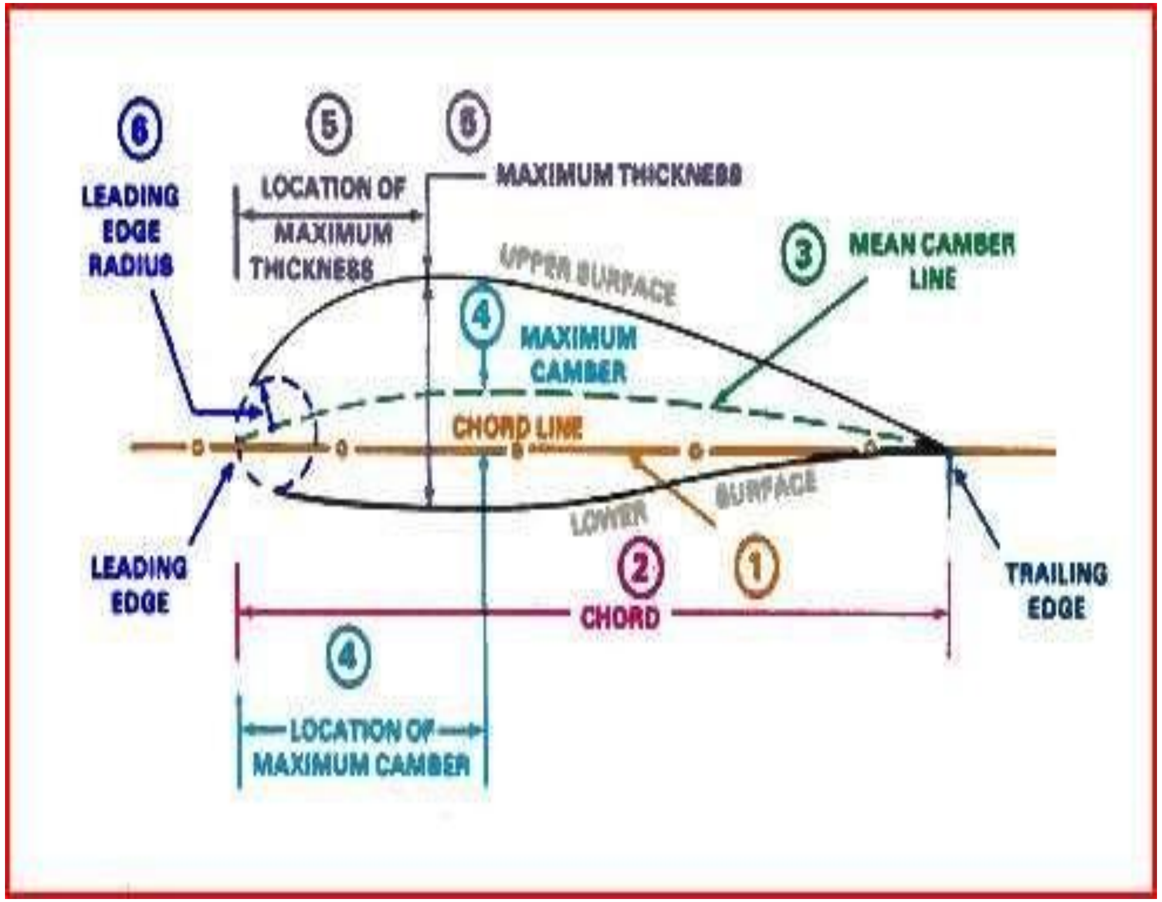
Flow turning at trailing edge is very important.

Higher Turning = Greater Lift

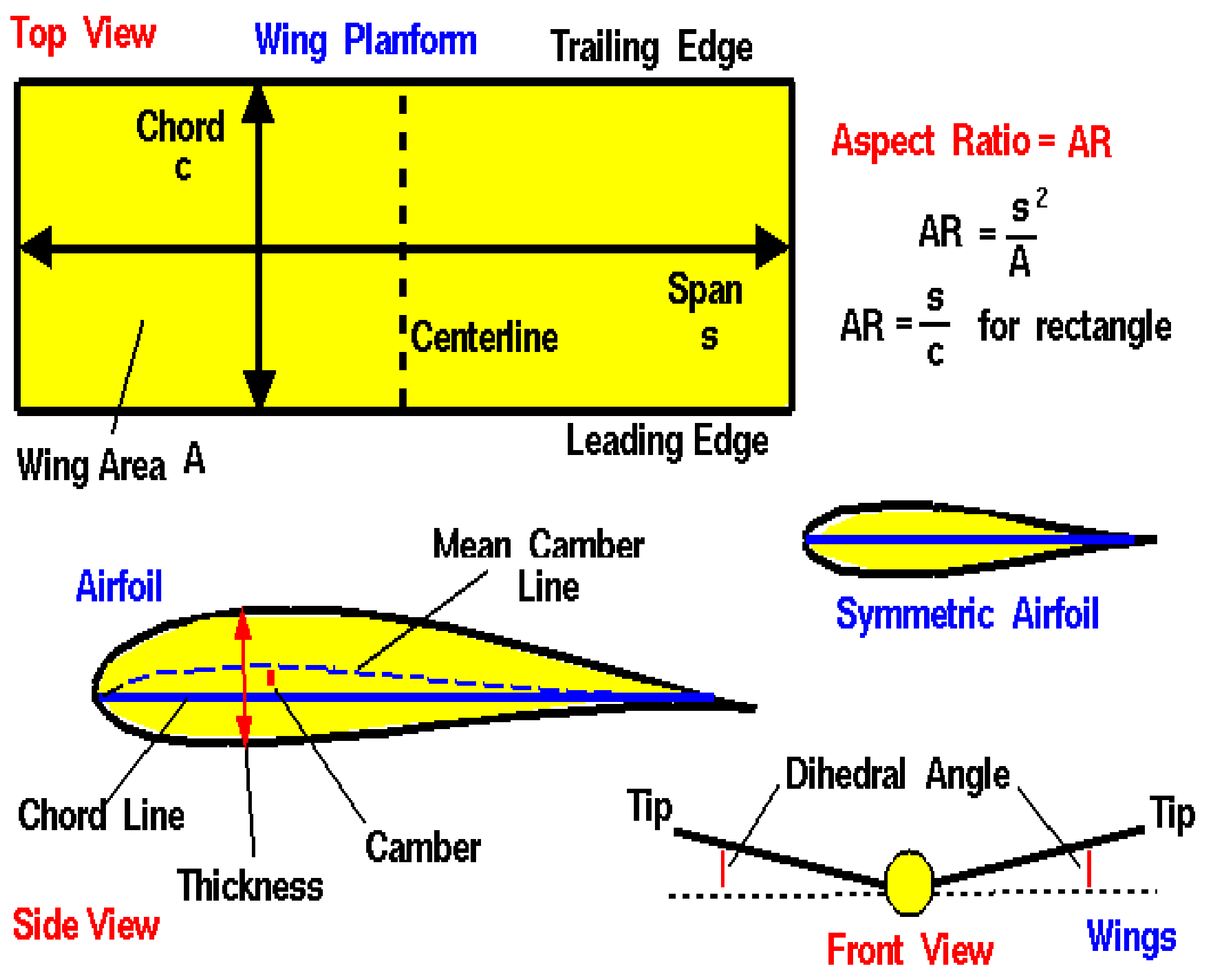
This effect is used for stability and control of the airplane.

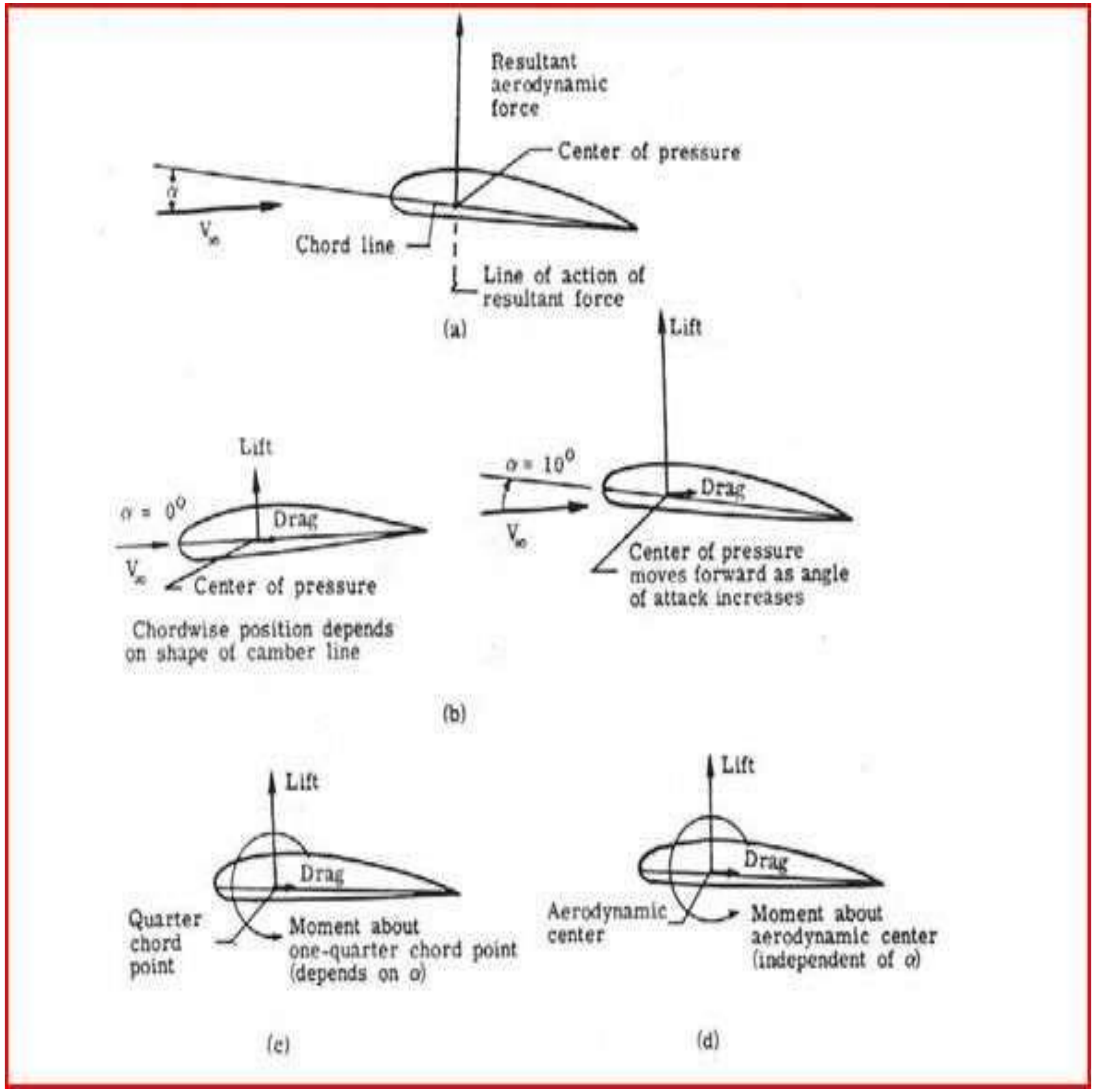
Included in Lift Coefficient

Airfoil Nomenclature

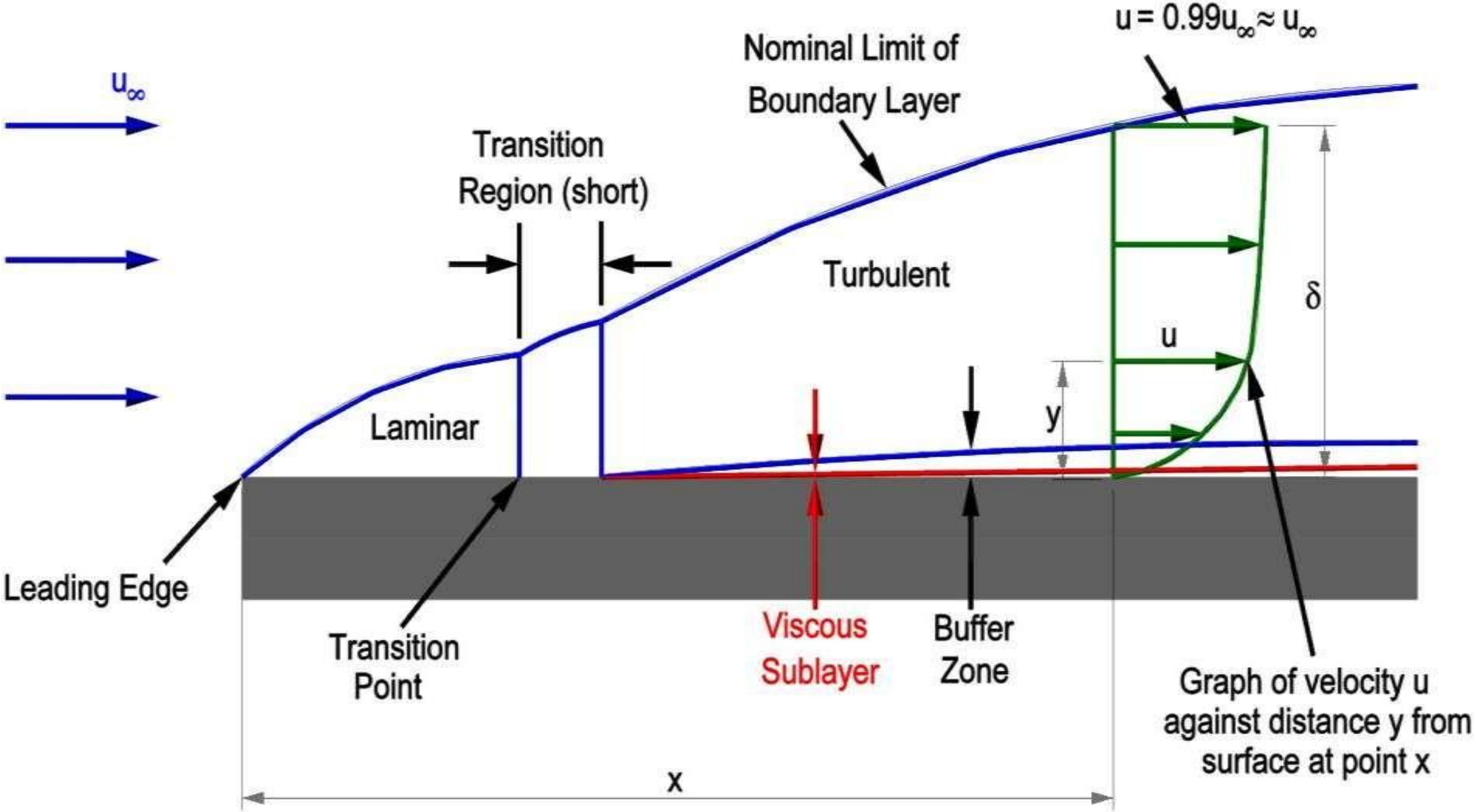


Wing Geometry Definitions



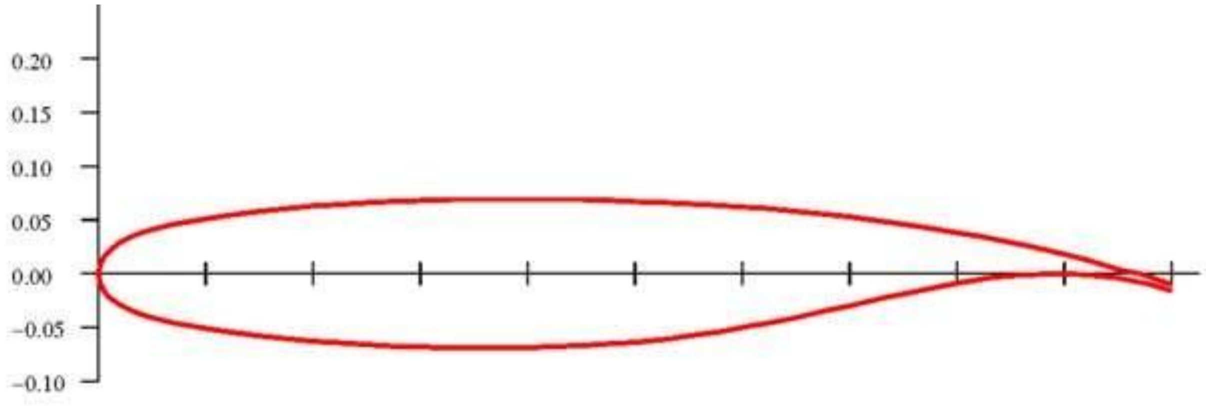


Reynolds No, Boundary Layer Transition and surface roughness



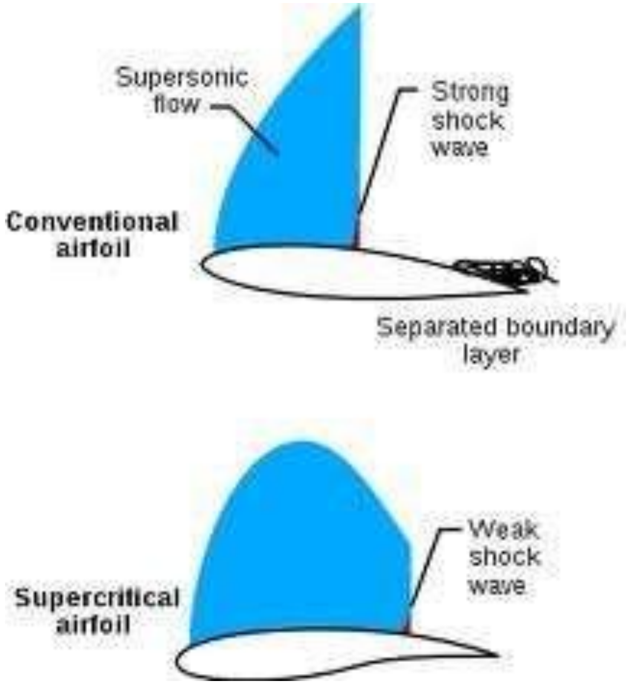
Laminar Flow Airfoils

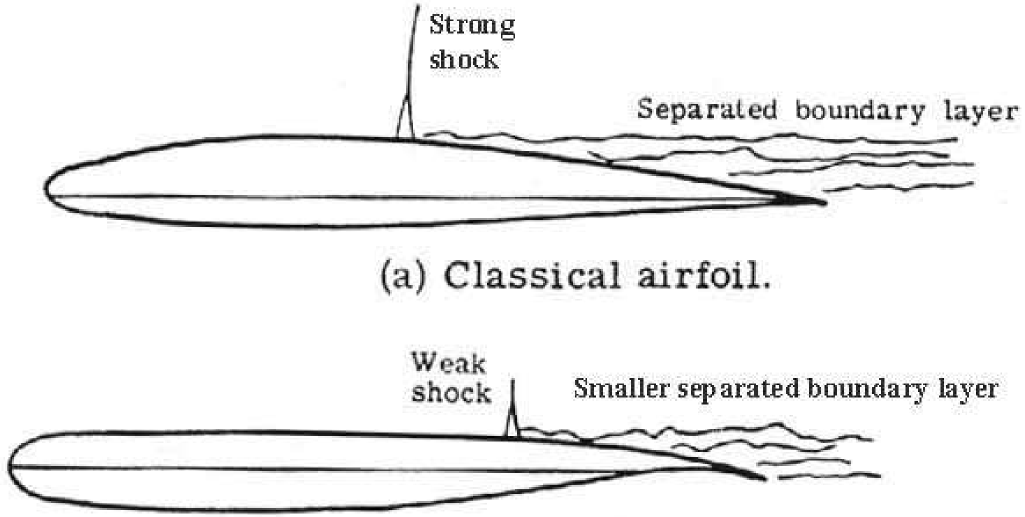
- An airfoil designed for minimum drag and uninterrupted flow of the boundary layer is called a laminar airfoil.



Supercritical Airfoils

- Designed to delay and reduce transonic drag rise, due to both strong normal shock and shock-induced boundary layer separation



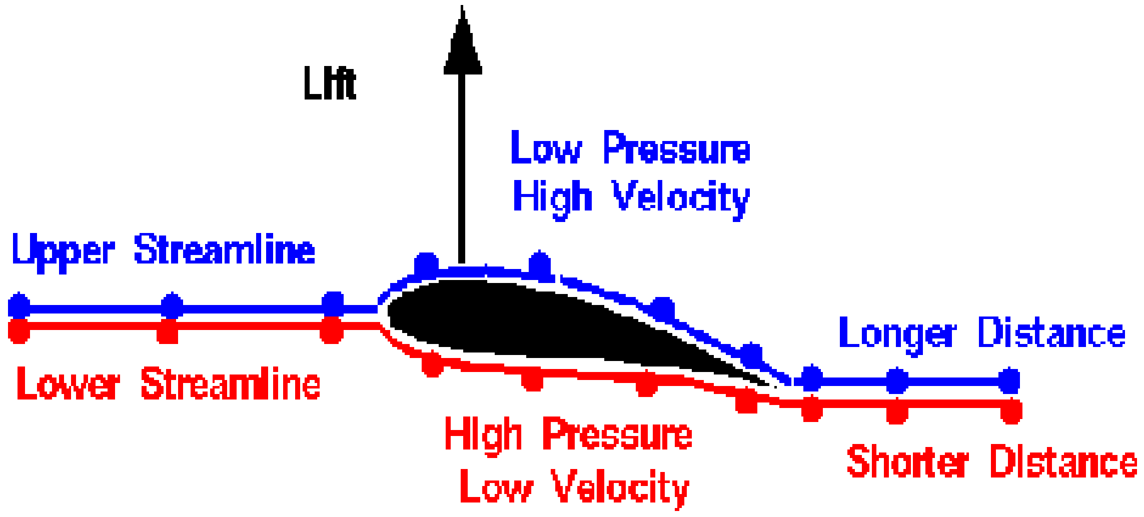


(a) Classical airfoil.

(b) Supercritical airfoil.

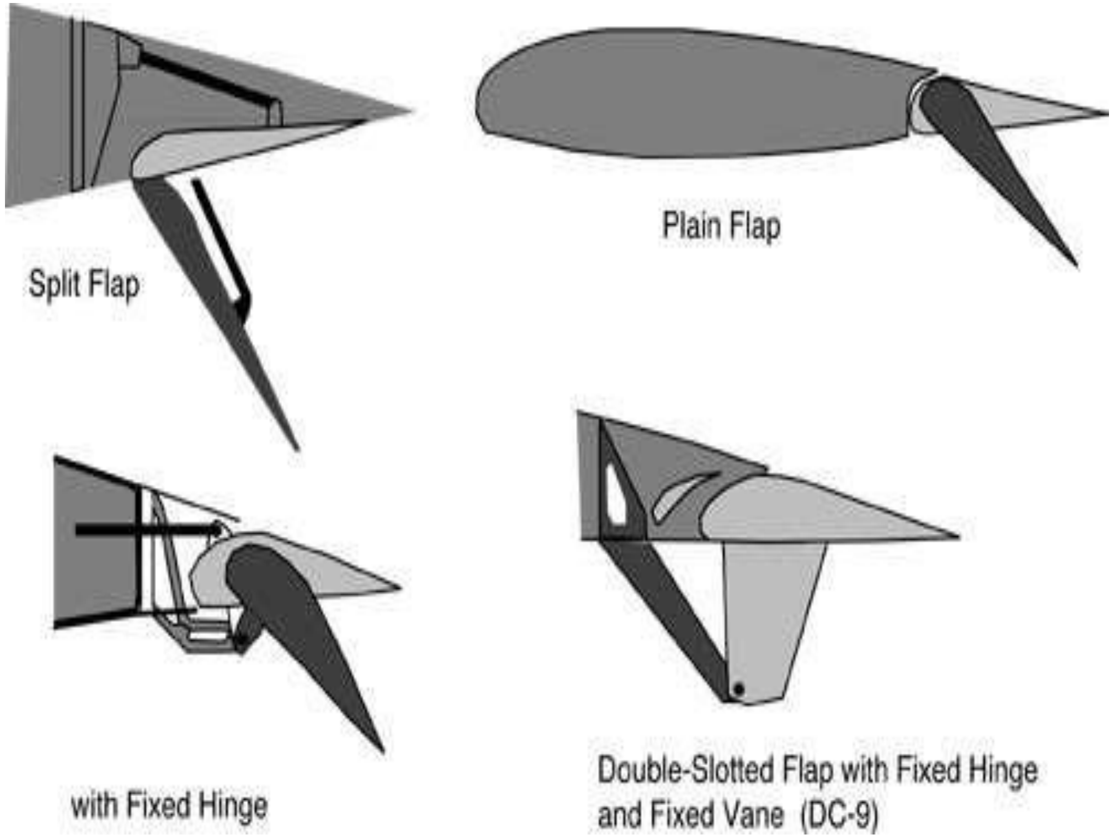
Drag Reduction And lift Augmentation Methods

- Many theories have been developed on how a wing generates lift. The most common one is the ***"Longer Path Theory"***.
- This theory describes how the shape of the aerofoil produces a pressure difference which generates lift. As the aerofoil is designed in such a way that its upper surface is longer than the bottom, and because the molecules that hit the leading edge must meet again at the trailing edge, the ones that travel on the upper surface do so with greater velocity than the lower

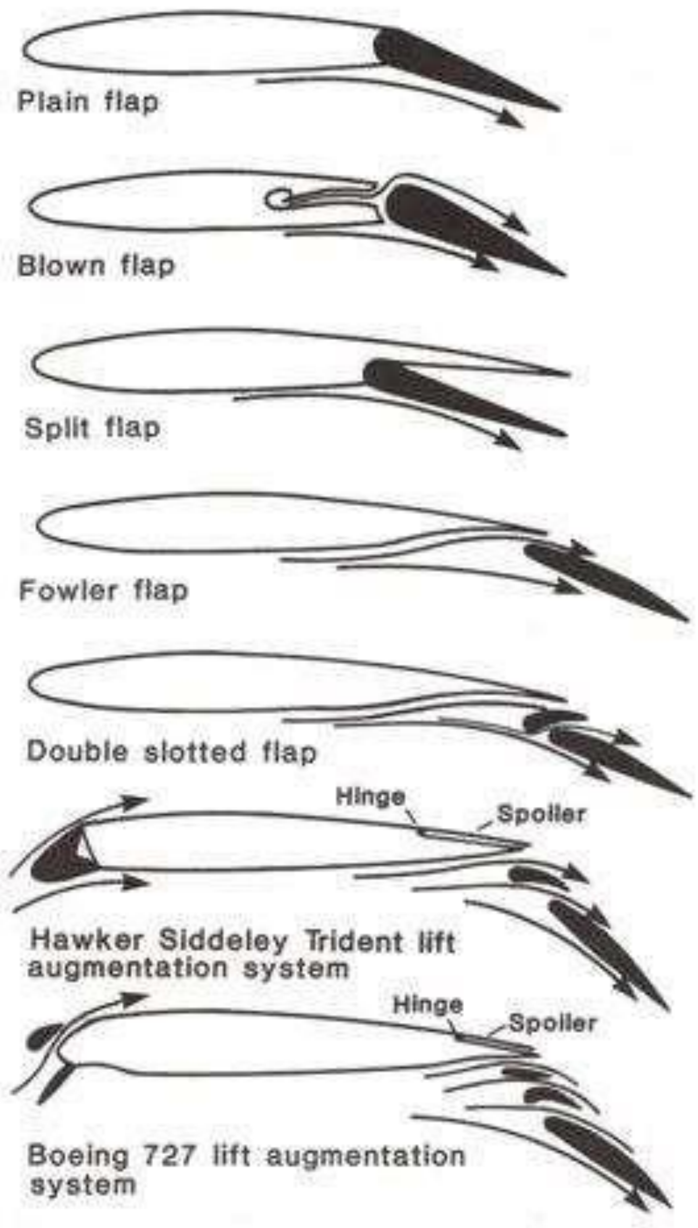


Flap systems

- Flap is an element attached to the aileron of the wing section
- It is always possible to reduce stall speed by increasing wing area



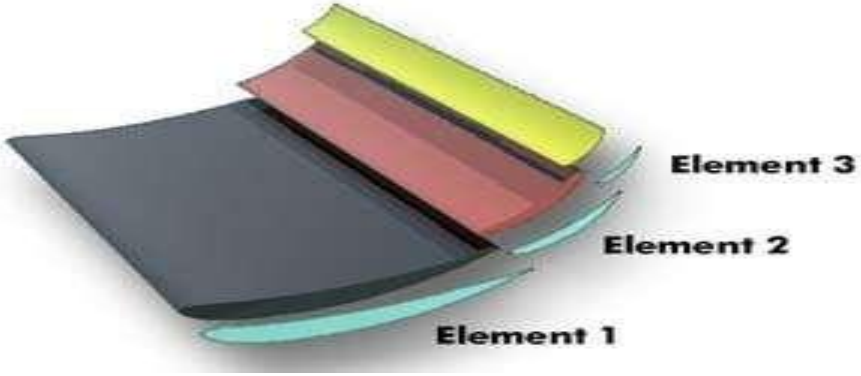
High-lift devices	Increase of maximum lift	Angle of basic aerofoil at max. lift	Remarks
Basic aerofoil	–	15°	Effects of all high-lift devices depend on shape of basic aerofoil.
Plain or camber flap	50%	12°	Increase camber. Much drag when fully lowered. Nose-down pitching moment.
Split flap	60%	14°	Increase camber. Even more drag than plain flap. Nose-down pitching moment.
Zap flap	90%	13°	Increase camber and wing area. Much drag. Nose-down pitching moment.
Slotted flap	65%	16°	Control of boundary layer. Increase camber. Stalling delayed. Not so much drag.
Double-slotted flap	70%	18°	Same as single-slotted flap only more so. Treble slots sometimes used.
Fowler flap	90%	15°	Increase camber and wing area. Best flaps for lift. Complicated mechanism. Nose-down pitching moment.



Leading Edge Devices

- Leading edge devices such as nose flaps, Kruger flaps, and slats reduce the pressure peak near the nose by changing the nose camber. Slots and slats permit a new boundary layer to start on the main wing portion, eliminating the detrimental effect of the initial adverse gradient.

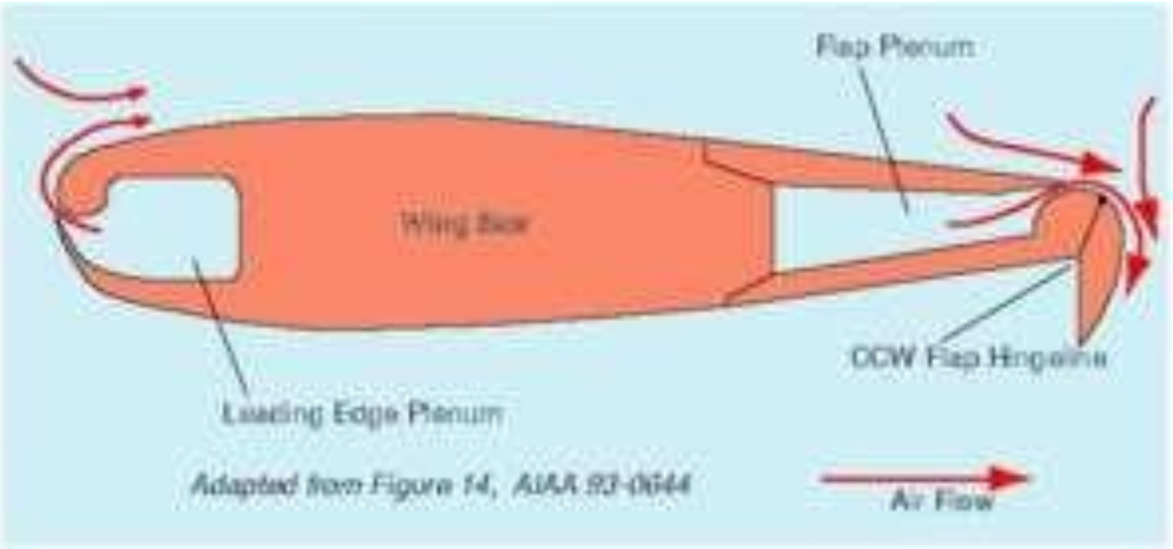
A Wing with slats and Flaps

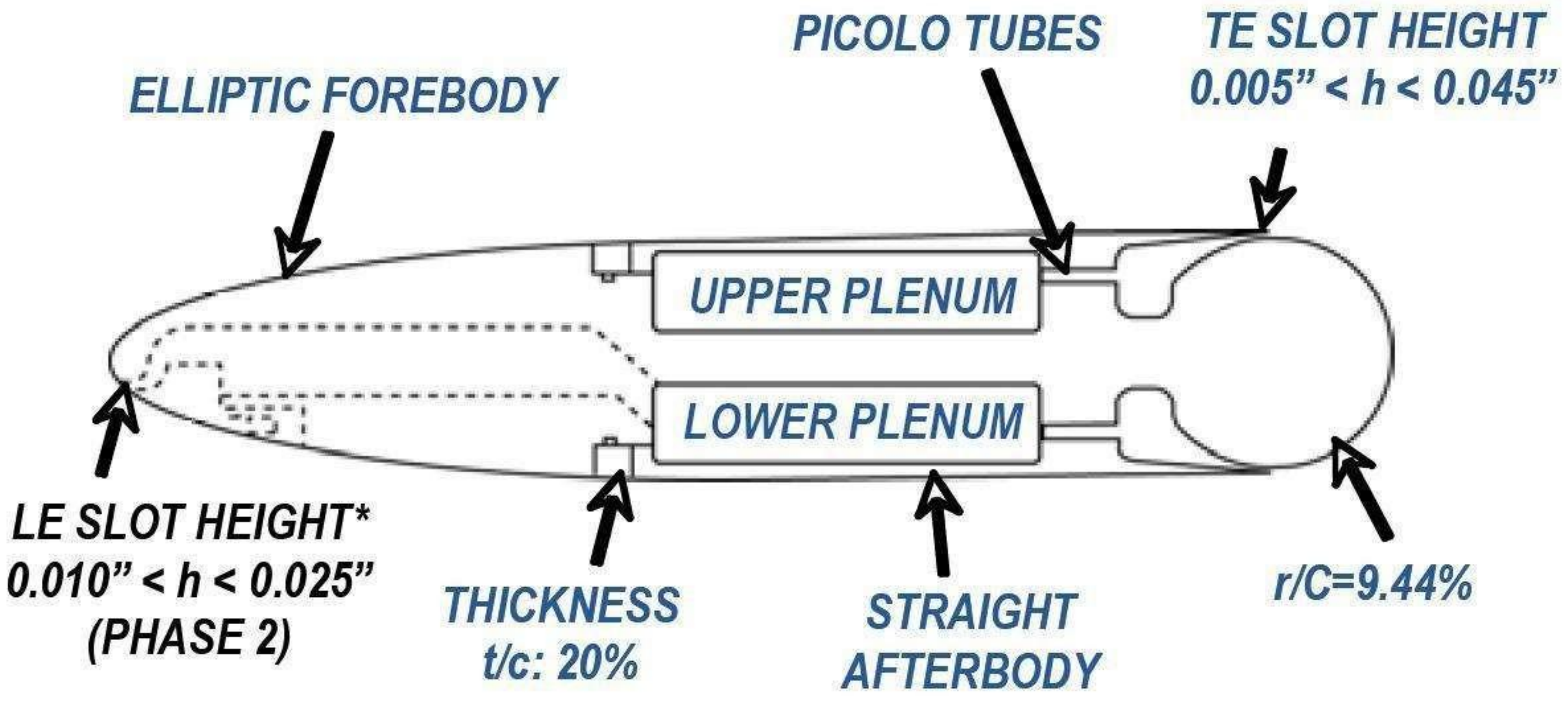


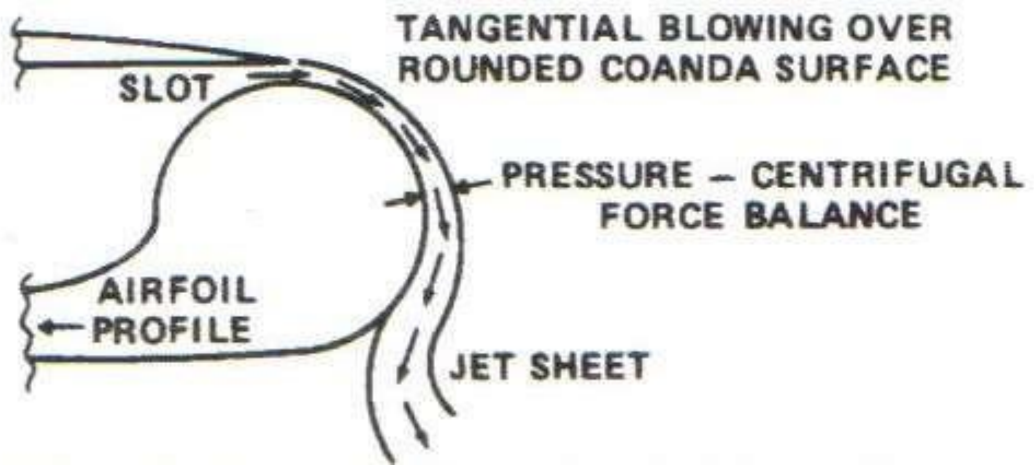
Circulation Control

- Circulation Control Wing technology is one of the most important potential applications of the Coanda Effect.

- The objective is to replace the lift devices on the leading and trailing edges of a wing by use of Coanda Surfaces and slot blowing instead.

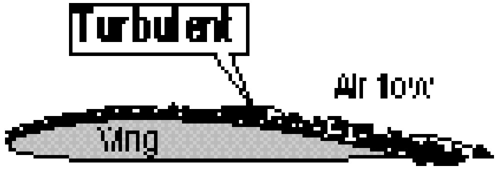



PICOLO TUBES
TE SLOT HEIGHT
0.005" < h < 0.045"
ELLIPTIC FOREBODY
UPPER PLENUM
LOWER PLENUM
LE SLOT HEIGHT*
0.010" < h < 0.025"
(PHASE 2)
THICKNESS
t/c: 20%
STRAIGHT
AFTERBODY
r/C=9.44%

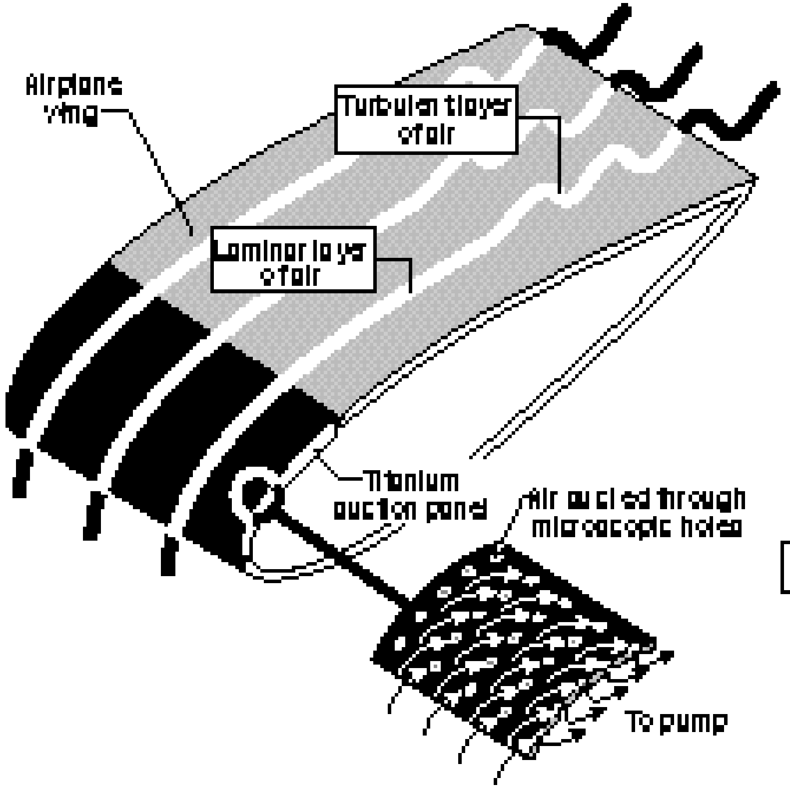

TANGENTIAL BLOWING OVER
ROUNDED COANDA SURFACE
SLOT
PRESSURE – CENTRIFUGAL
FORCE BALANCE
AIRFOIL
PROFILE
JET SHEET

The Problem: Skin Friction Drag

When air flows over an airplane wing, it breaks into swirling eddies which cause drag. Research engineers seek ways to suppress eddies and preserve laminar flow, in which the air glides over the surface in smooth layers.

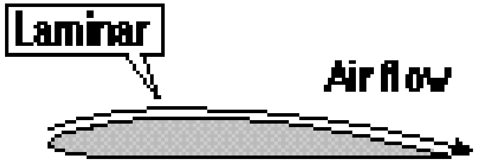


The Solution: Laminar Flow Control



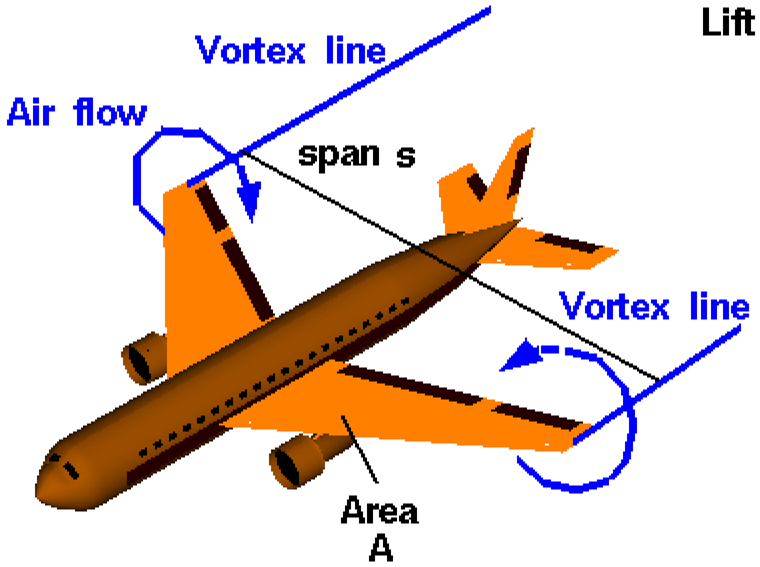
How Laminar Flow Control Works

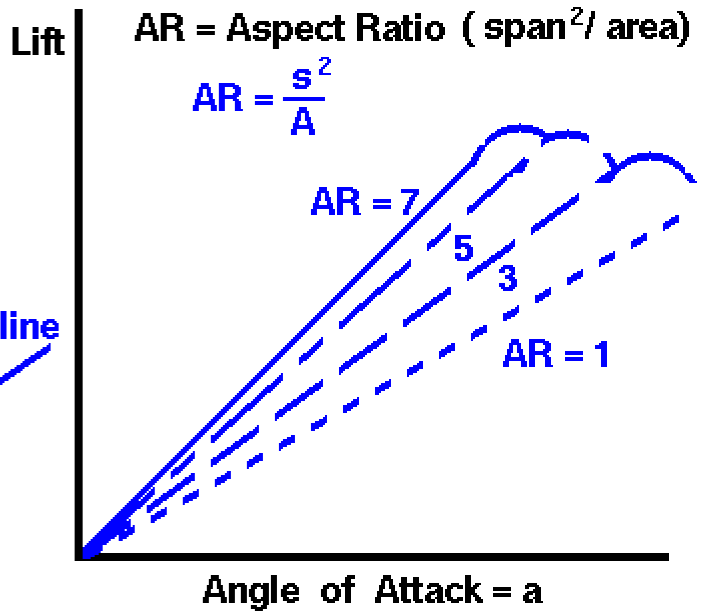
Turbulence can be prevented by actively controlling the laminar flow. Part of the layer of air nearest the wing surface is sucked into the wing by a pump inside the aircraft and later is expelled from the aircraft. The remainder of the air nearest the surface continues to move smoothly along most of the wing before becoming turbulent.



Winglets

Downwash Effects on Lift



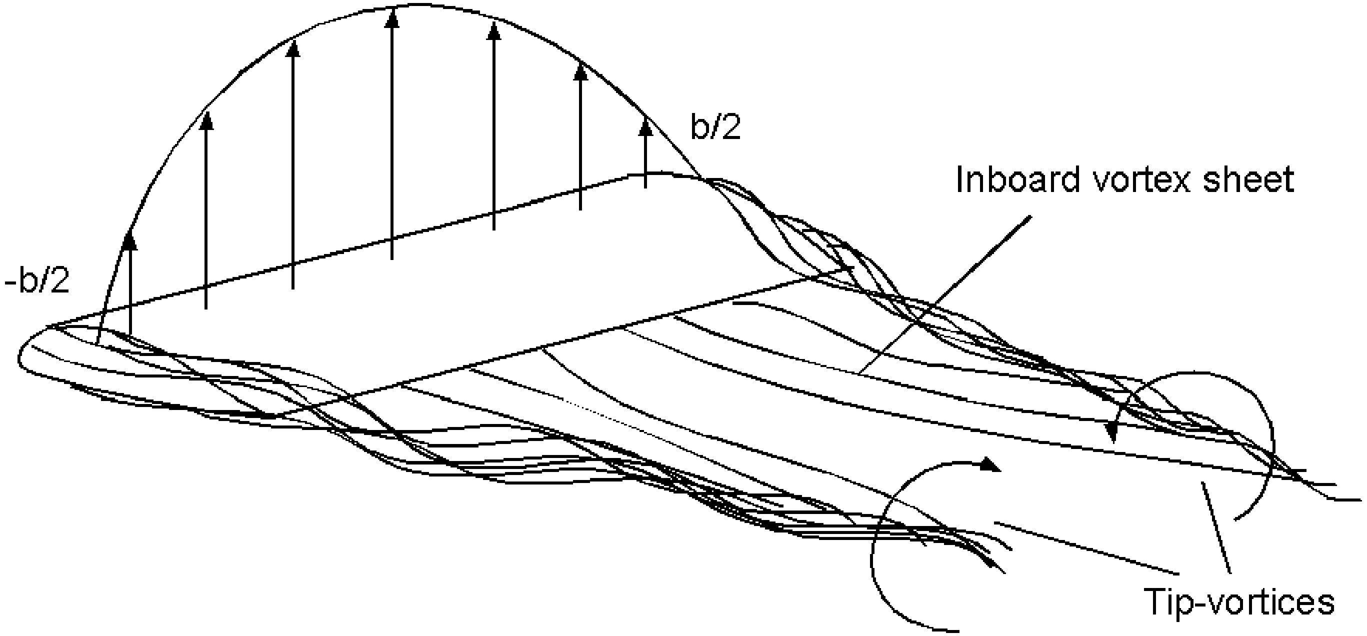


Pressure difference across wing surface causes spillage around wing tips.

Downwash causes a local induced angle of attack which reduces lift.

Lift Coefficient

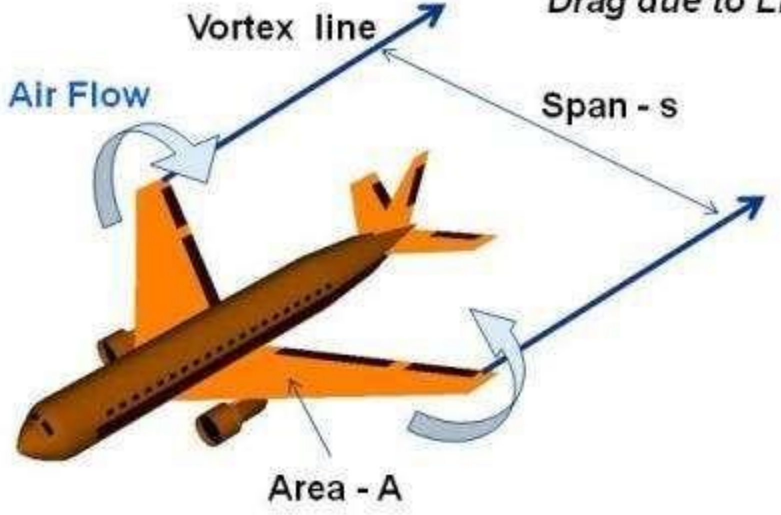
$$C_l = \frac{C_{lo}}{1 + \frac{C_{lo}}{\pi AR}}$$



Wing Vortices

Induced Drag Coefficient

Drag due to Lift



Aspect Ratio = AR

$$AR = \frac{s^2}{A}$$

$$Cd_i = \frac{Cl^2}{\pi \; AR \; e}$$

Efficiency factor = e

For an ellipse, e = 1

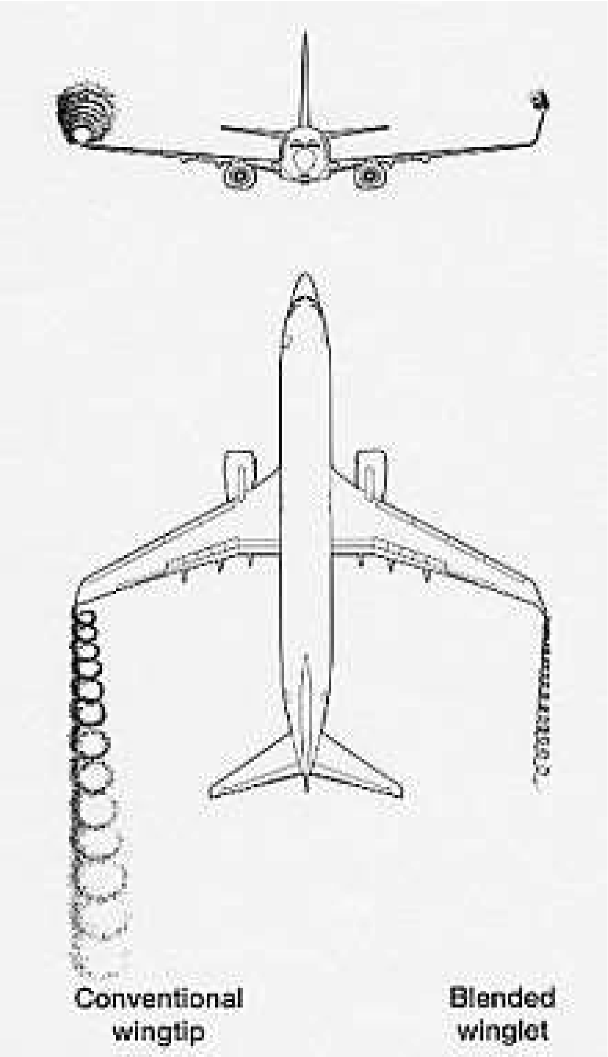
In general e < 1

Pressure difference from top to bottom of the wing causes spillage around the wing tips.

Downwash from the tips induces local angle of attack with additional drag component on a finite wing.

www.nasa.gov

Winglets



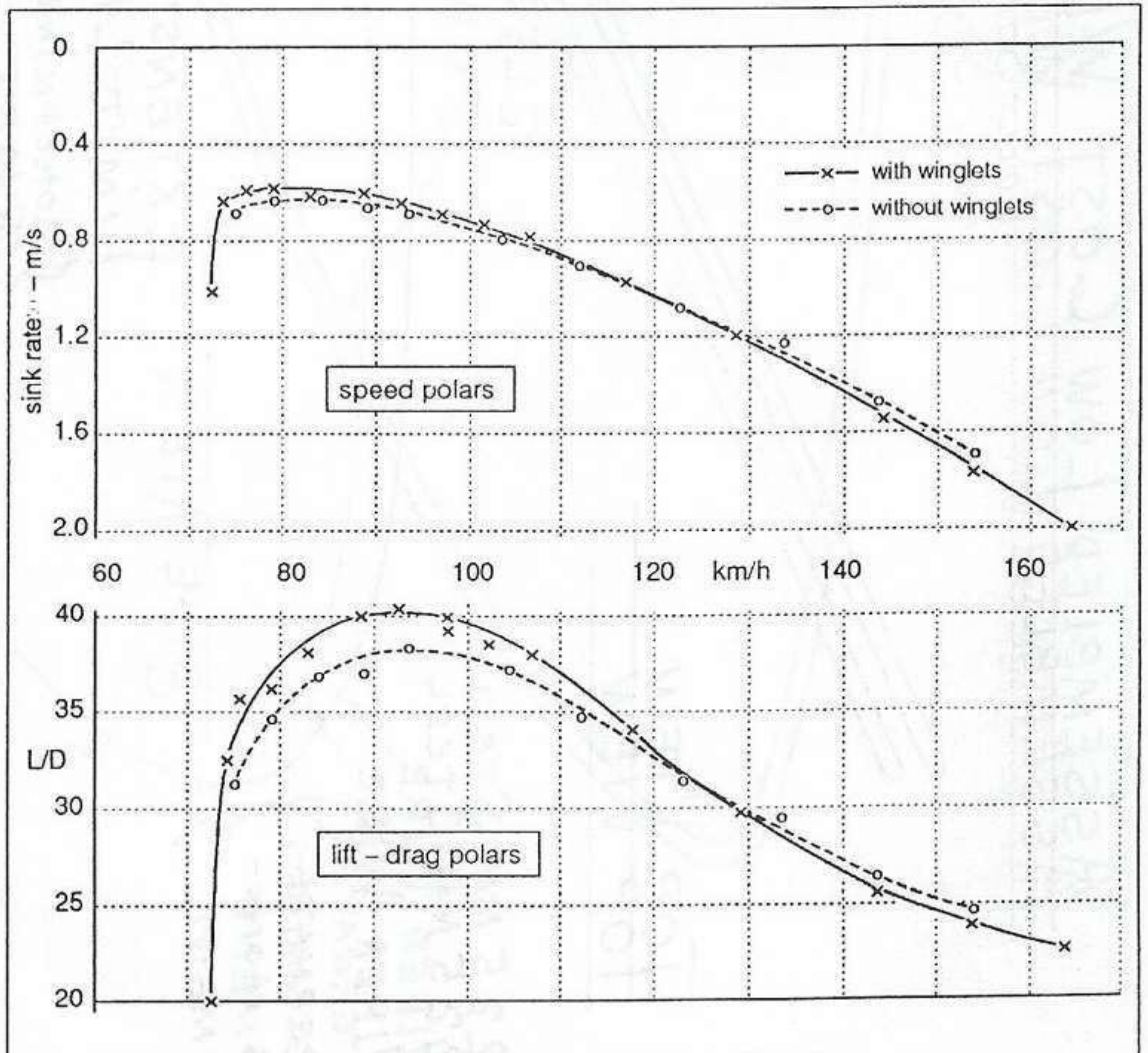
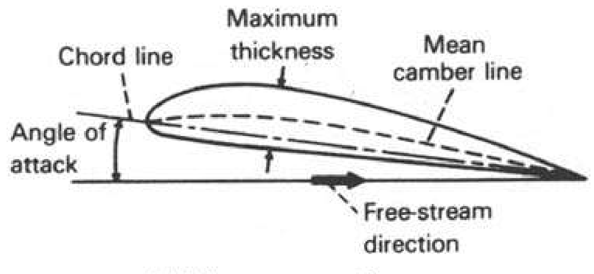


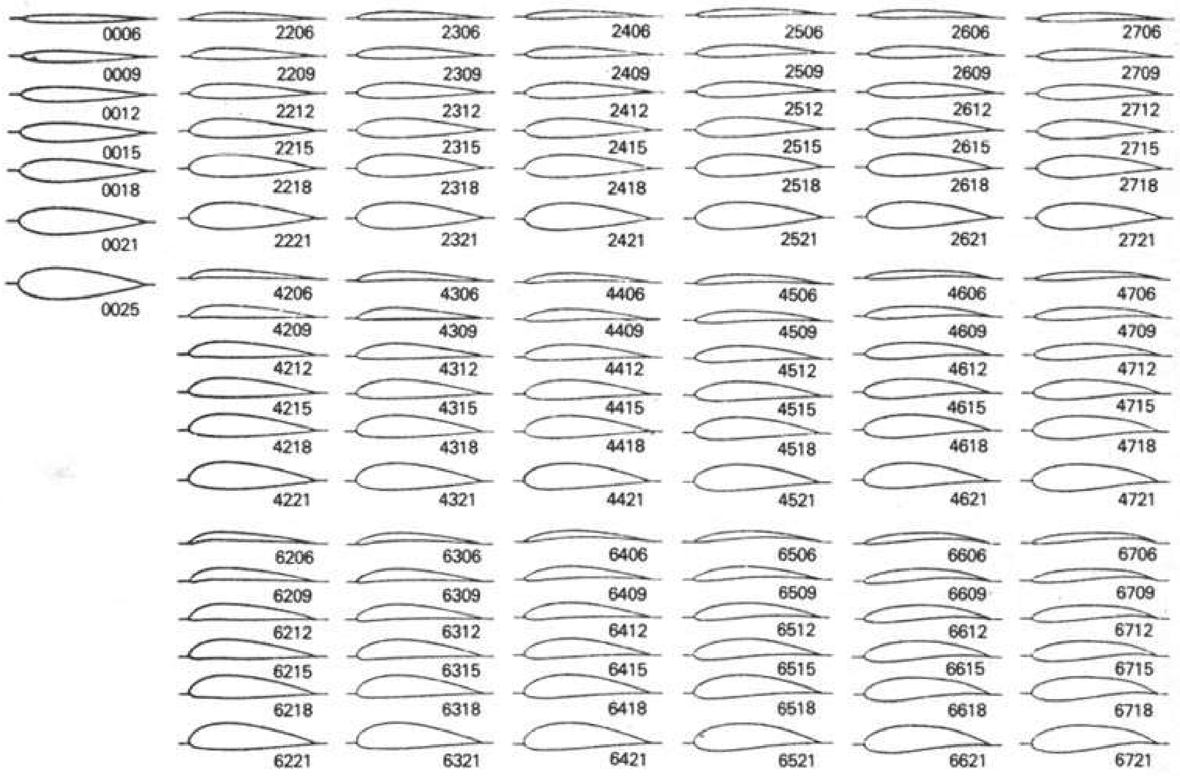
Figure 2 — Influence of winglets on the performance of an ASW–19

Airfoils



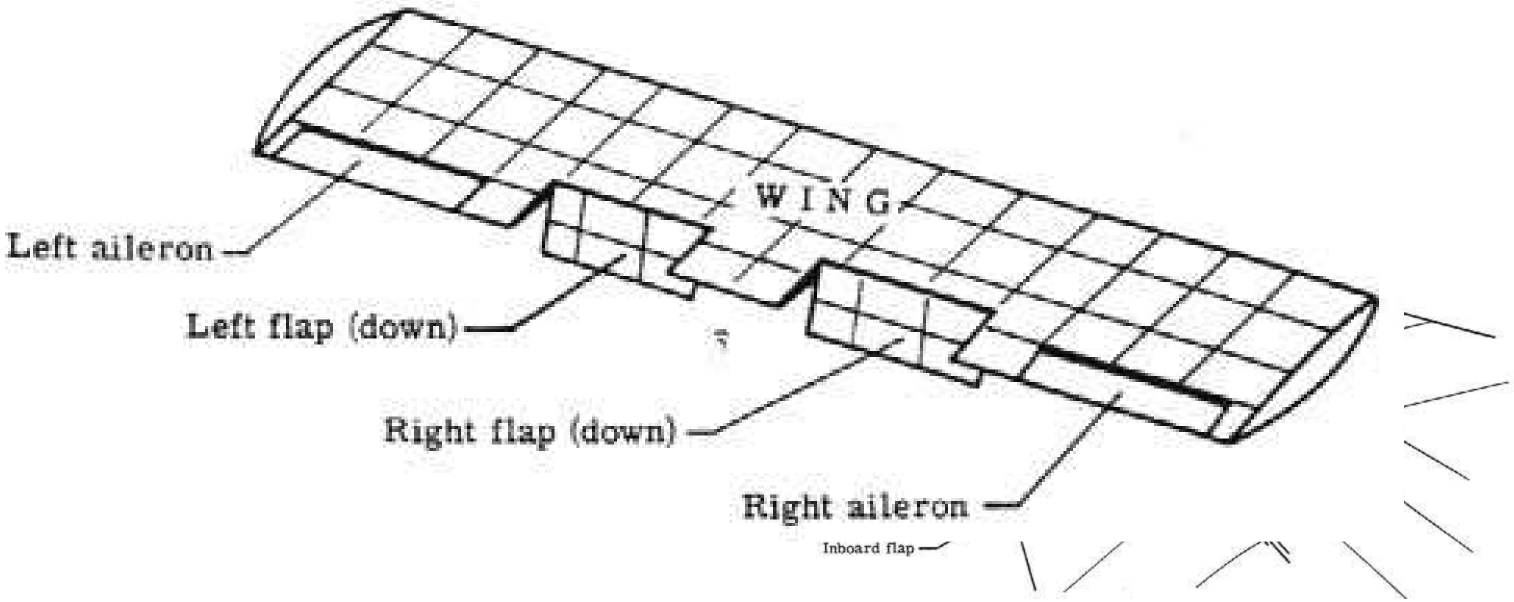
(a) Wing cross section.

The camber of an airfoil section is the curvature of the mean line relative to the chord line. (NASA EP–89, 1971, p. 100)



- **What is NACA?**
  - National Advisory Committee for Aeronautics
  - Chartered in 1915, operational from 1917-1958
  - The National Aeronautics and Space Act of 1958 created NASA from NACA

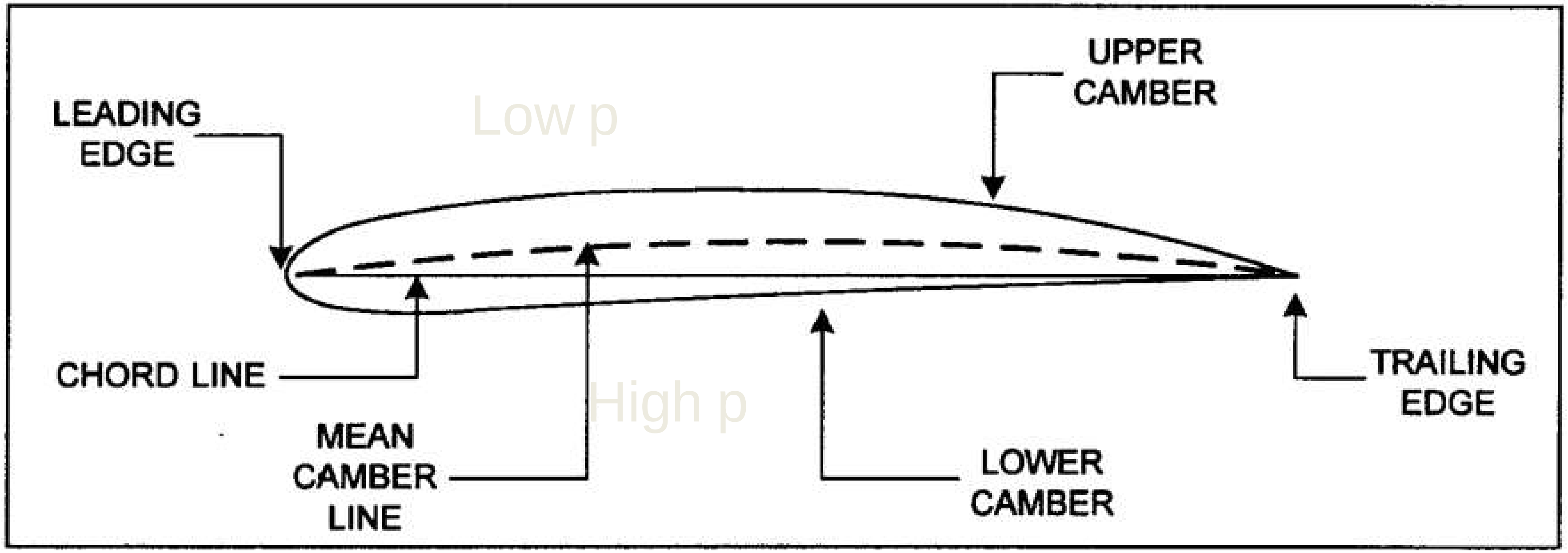
Aerodynamic Surfaces



Jet

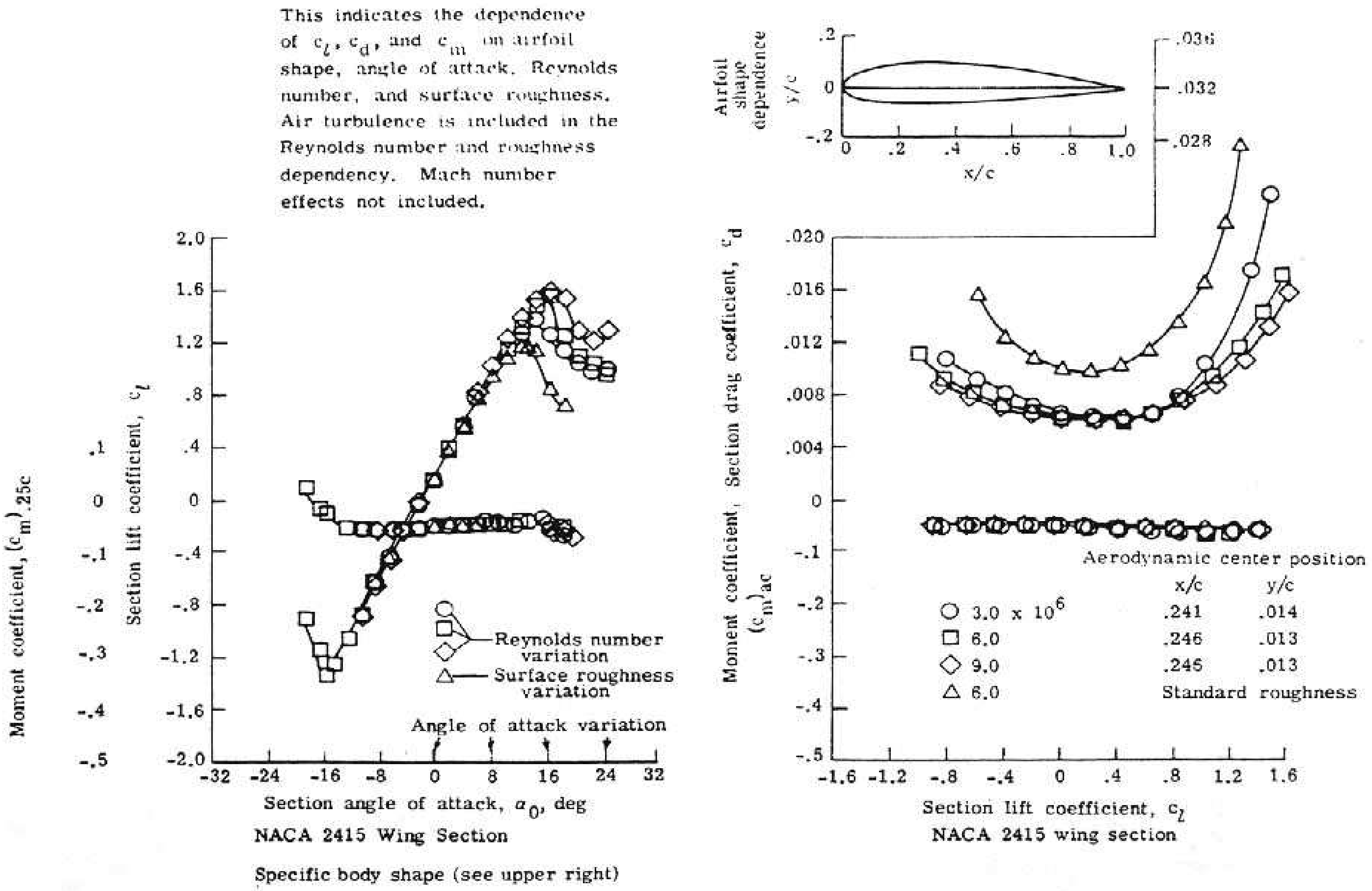
B727 Spoilers

Airfoils - Nomenclature

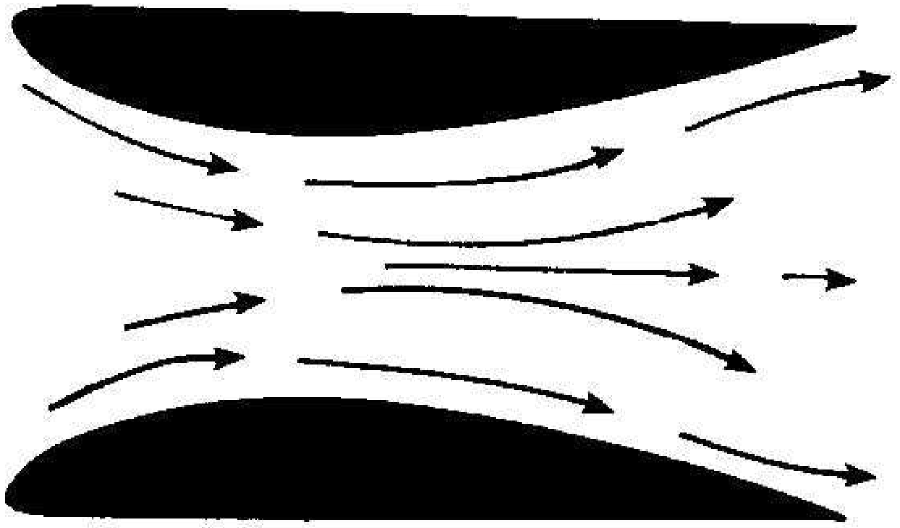


- Chord line - straight line connecting the leading and trailing edges of an airfoil
- Camber line – locus of all points equidistant from top and bottom of airfoil
- Camber – distance between chord line and camber line
- Thickness – maximum distance between top and bottom surfaces of wing
- Leading Edge
- Trailing Edge
- Wingspan (b)
- Aspect Ratio (AR = b^2/S)

Published NACA Data – NACA 2415

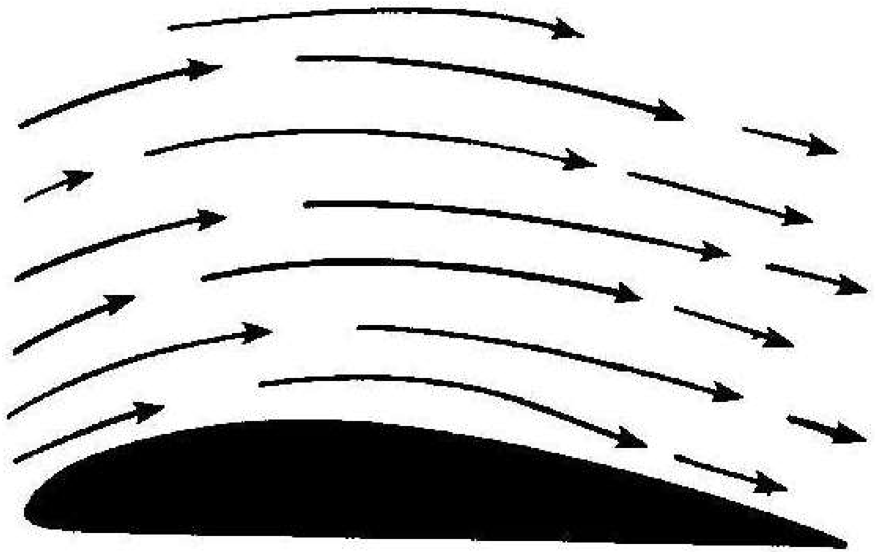


Bernoulli's Principle



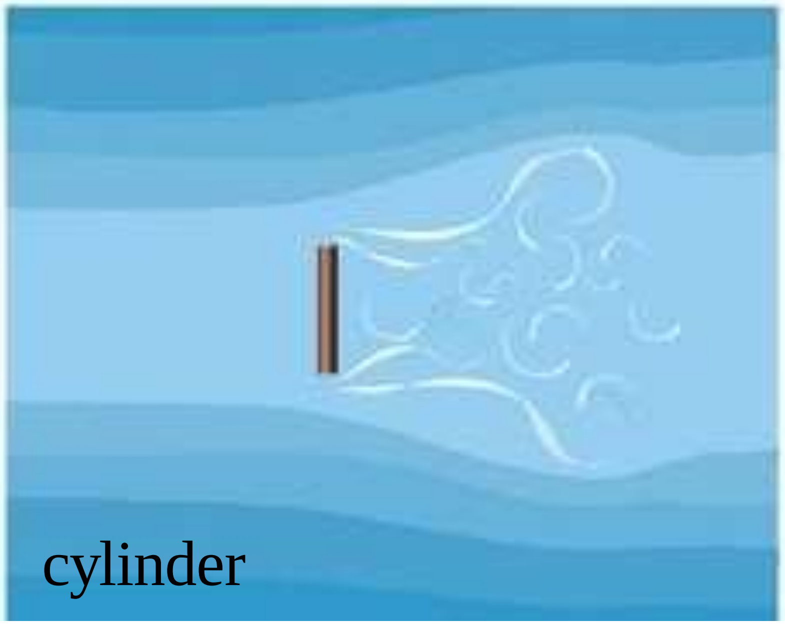
THE CONSTRICTED AIRFLOW shown here, formed by two opposed airplane wings, is analogous to the pinched-pipe situation at left: air moving between the wings accelerates, and this increase in speed results in lower pressure between the curved surfaces.

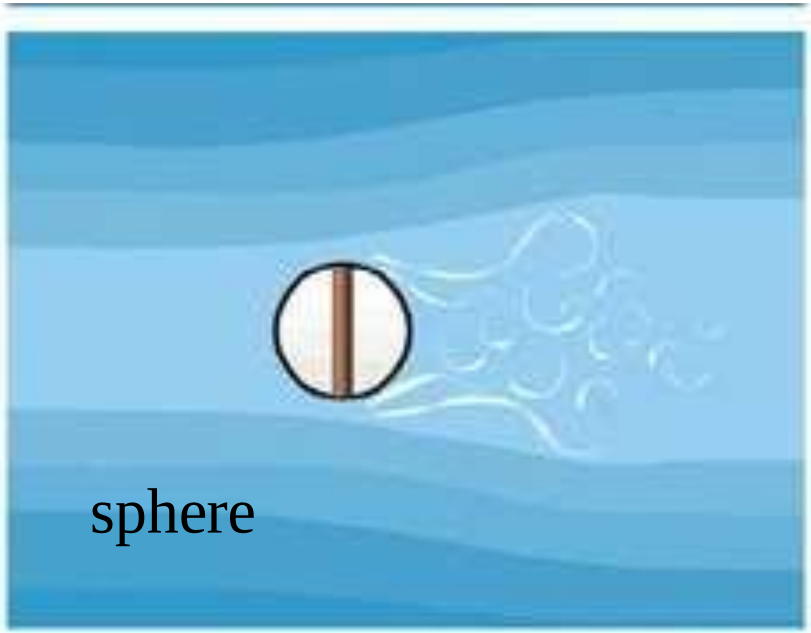
Bernoulli's Principle

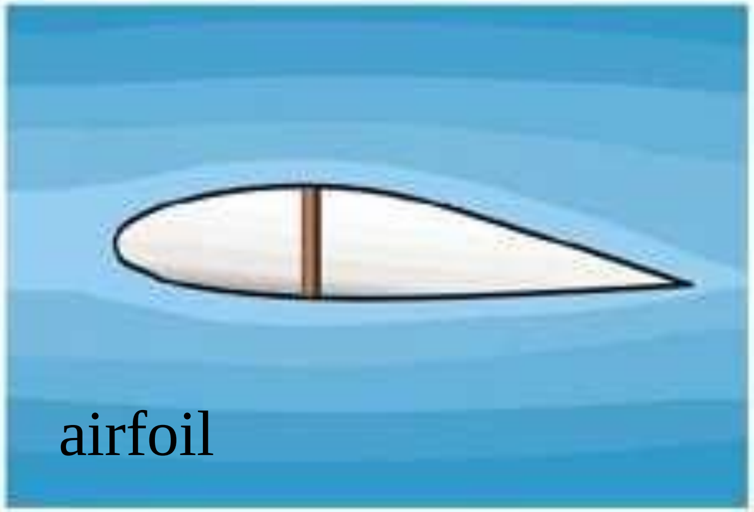


THE SAME PRINCIPLE applies when the air is distrubed by a single wing. The accelerating airflow over the top surface exerts less pressure than the airflow across the bottom. It is this continuing difference in pressure that creates and sustains lift.

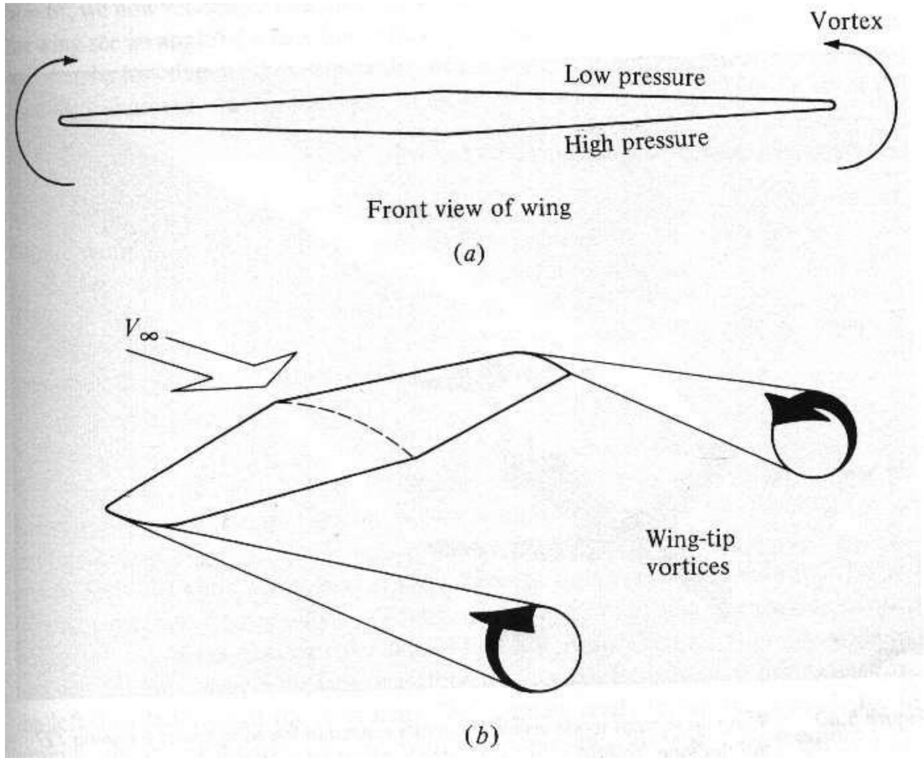
Drag – Body Comparison

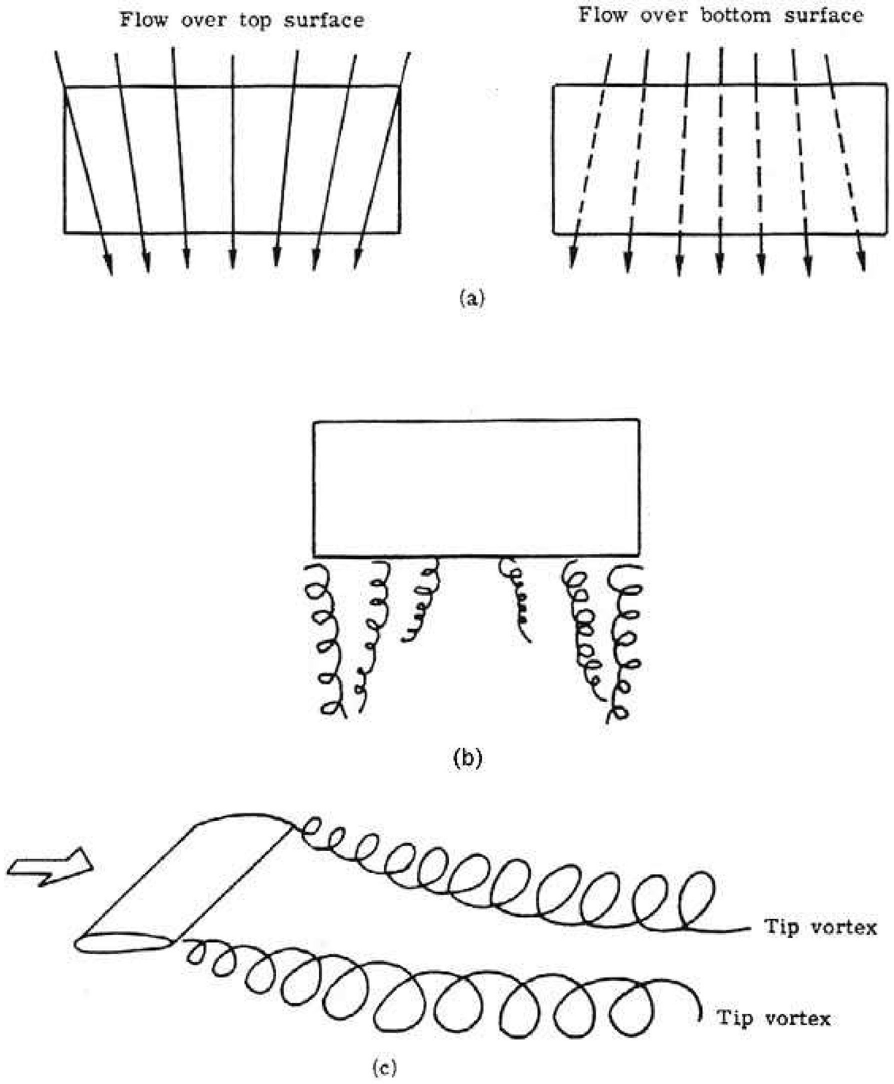






Wingtip Vortices – "Twin Tornadoes"

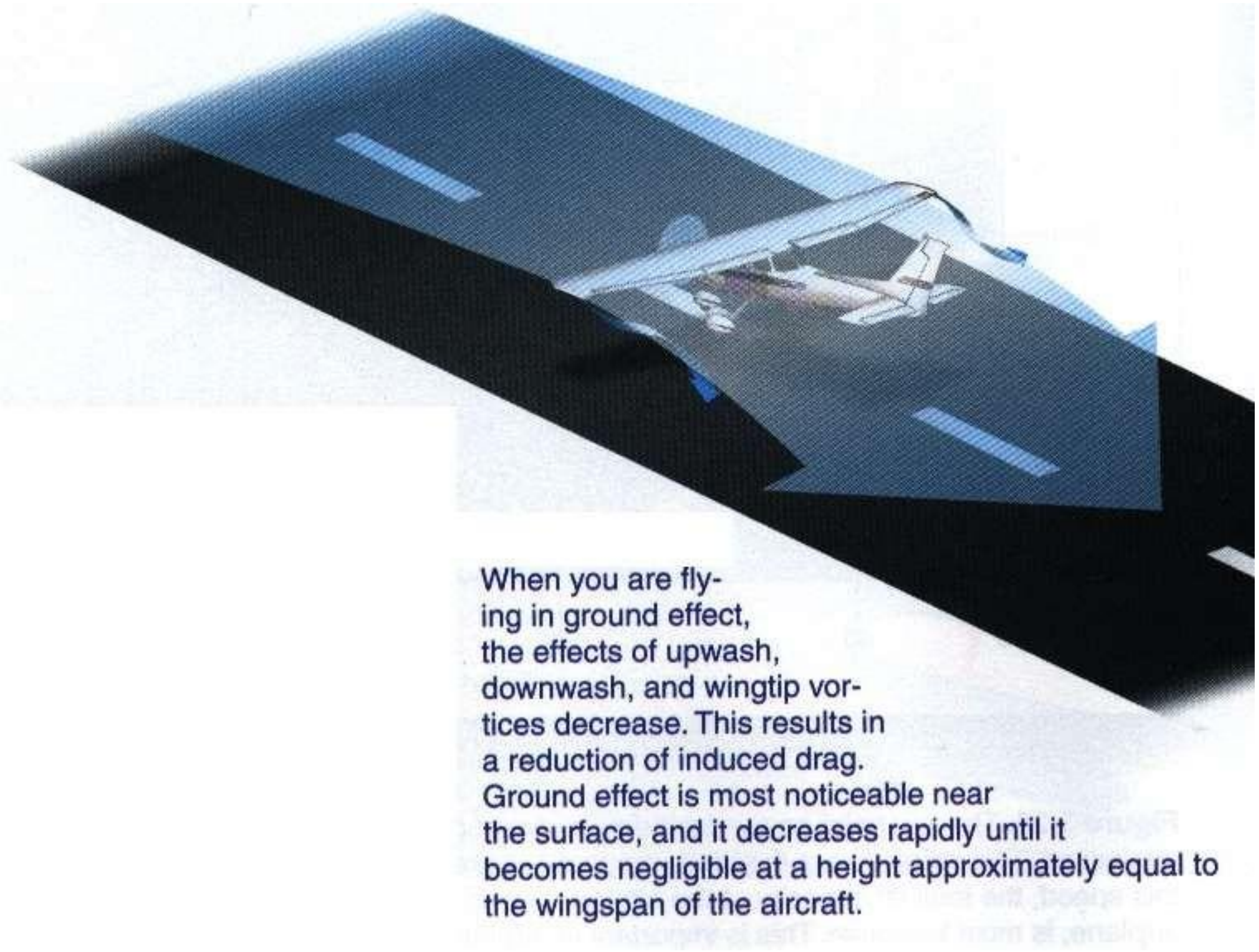




A few words on wingtip vortices:

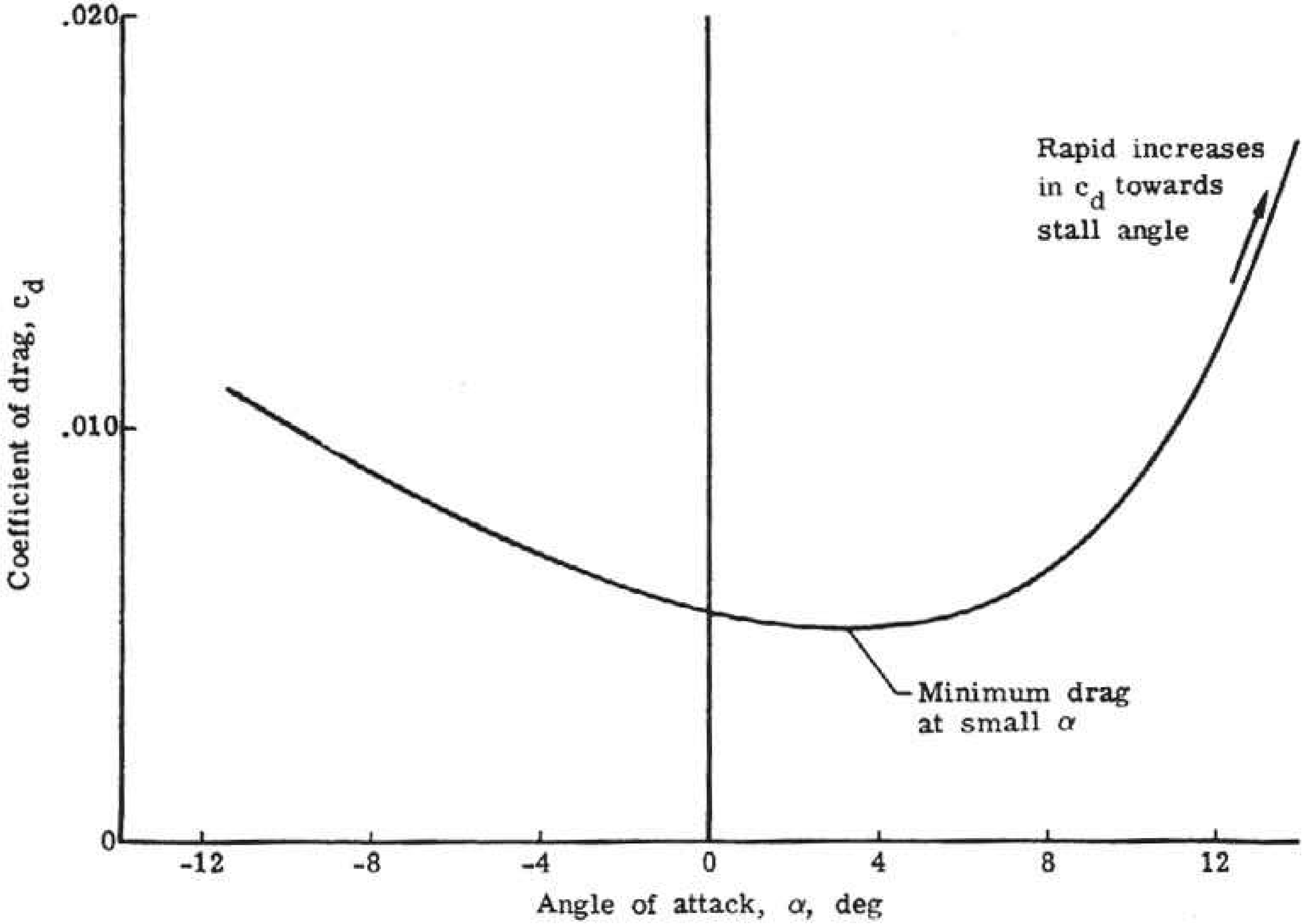
'High pressure on the lower surface creates a natural airflow that makes its way to the wingtip and curls upward around it to the area of low pressure. When flow around the wingtips streams out behind the airplane, a vortex is formed. These twisters represent an energy loss and are strong enough to flip airplanes that blunder into them.'

Drag – Ground Effect



TIP:
On a soft-field runway, you can takeoff at a lower speed and then accelerate while in "Ground Effect."

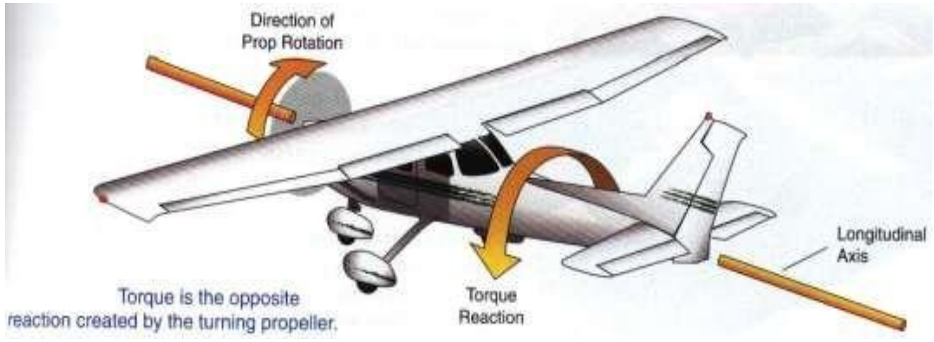
Drag vs Angle of Attack

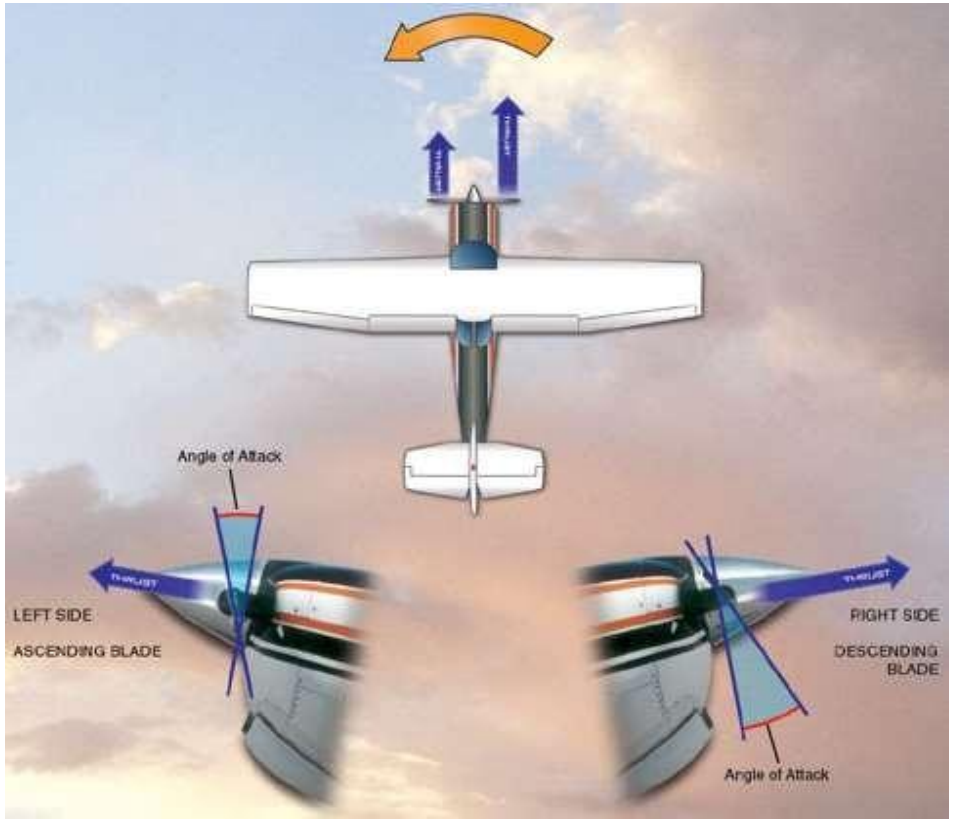


Relationship between drag and angle of attack

Torque / P-factor (Left-Turning Tendencies)

- Newton's 3rd law: "For every action there is an equal and opposite reaction."
  - Propeller rotates CW when viewed from pilot's seat.
  - Torque reaction rotates the airplane CCW about longitudinal axis
- P-factor (asymmetrical thrust) caused by descending blade taking a greater "bite" of air than ascending blade at **high angle of attack**





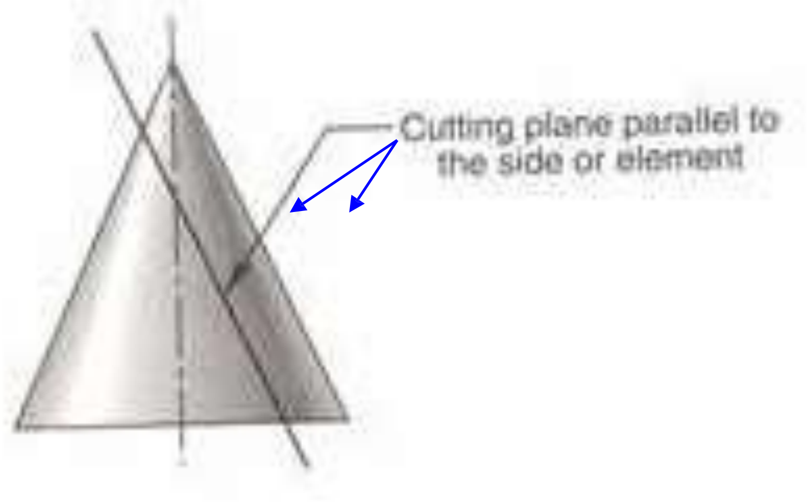
UNIT- II

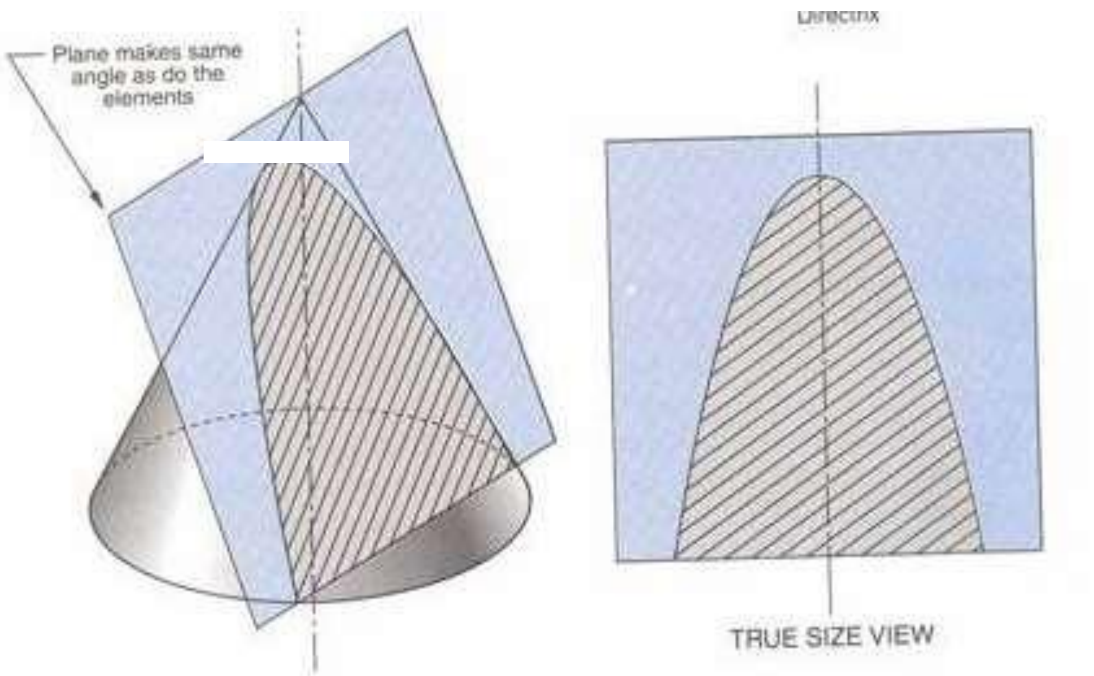
INITIAL SIZING & CONFIGURATION LAYOUT

Conic Curves - Parabolas

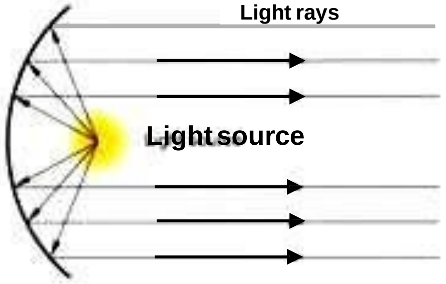
- Conic curves or conics are the curves formed by the intersection of a plane with a right circular cone (parabola, hyperbola and sphere).

- A *parabola* is the curve created when a plane intersects a right circular cone parallel to the side (elements) of the cone

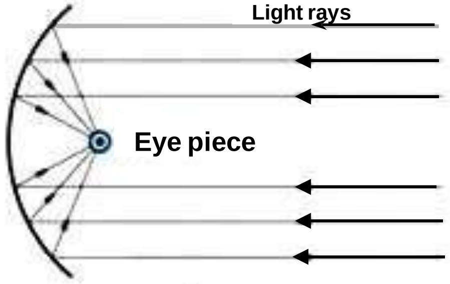




Conic Curves - Parabolas

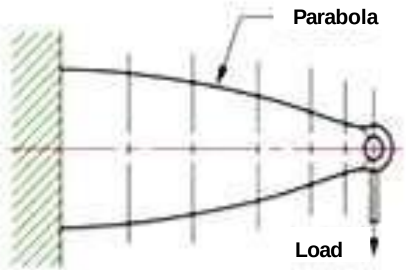


Searchlight mirror

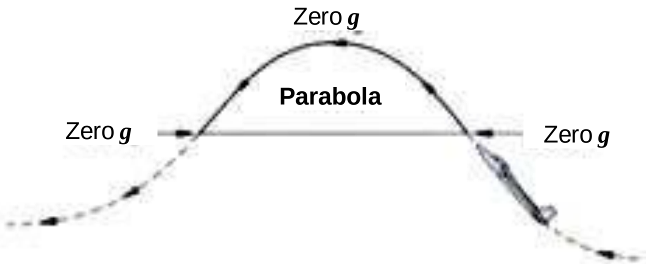


Telescope mirror

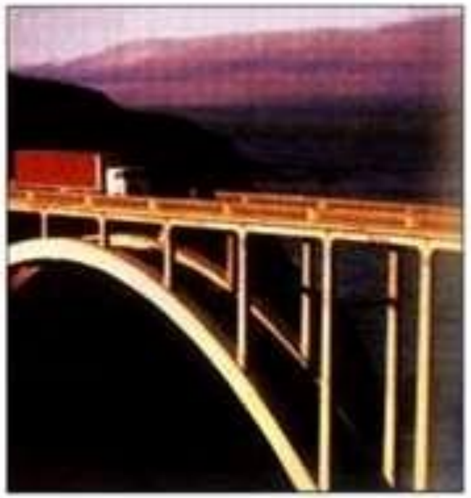
Applications of ***parabola***



Beam of uniform strength



Weightless flight trajectory



A parabola revolved about its axis creates a surface called paraboloid. An auditorium ceiling in shape of paraboloid reduces reverberations if the speaker stands near the focus

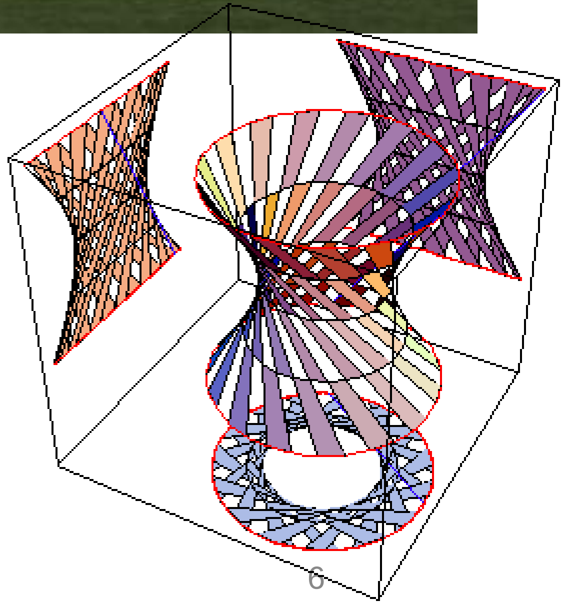
Conic Curves - Hyperbolas

Cooling Towers of Nuclear Reactors

The hyperboloid is the design standard for all nuclear cooling towers. It is structurally sound and can be built with straight steel beams.

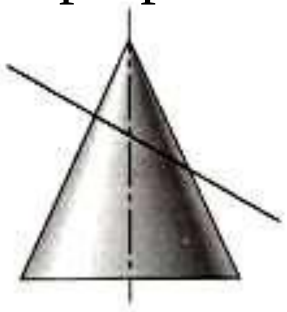
For a given diameter and height of a tower and a given strength, this shape requires less material than any other form.

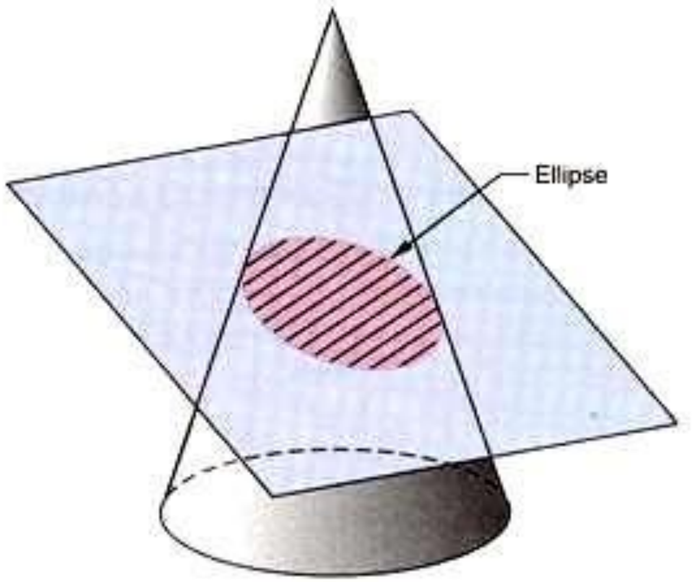
Dulles Airport, designed by Eero Saarinen, is in the shape of a hyperbolic paraboloid



Conic Curves - Ellipse

An ***ellipse*** is the curve created when a plane cuts all the elements (sides) of the cone but its not perpendicular to the axis.



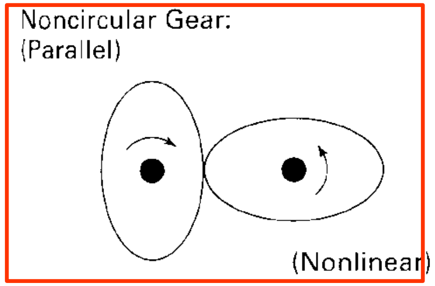


Conic Curves - Ellipse

Some tanks are in fact elliptical (not circular) in cross section. This gives them a high capacity, but with a lower center-of-gravity. They're shorter, so that they can pass under a low bridge. You might see these tanks transporting heating oil or gasoline on the highway

On a bicycle, you might find a chainwheel (the gear that is connected to the pedal cranks) that is approximately elliptical in shape. Here the difference between the major and minor axes of the ellipse is used to account for differences in the speed and force applied

Elliptical gears are used for certain applications



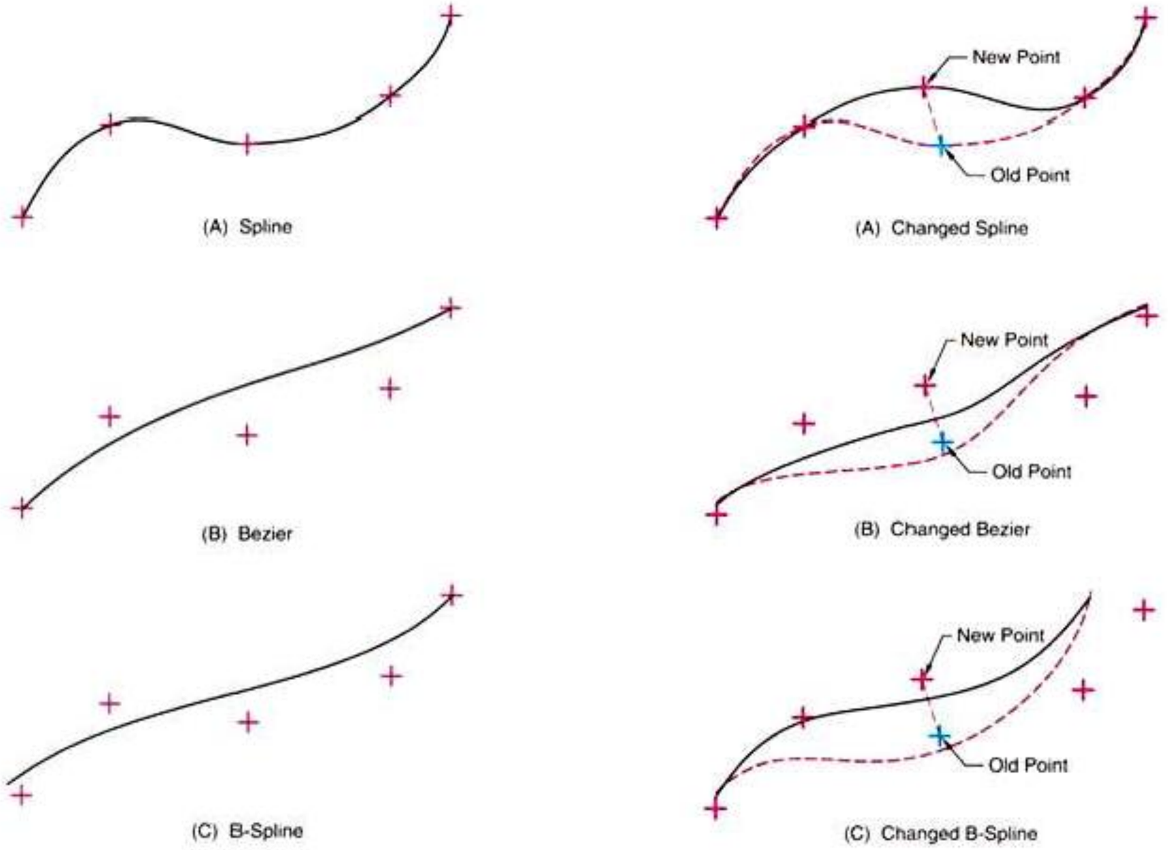
Synthetic Curves – Freeform Curves

For CAD systems, three types of freeform curves have been developed,

Cubic spline

Bezier curve

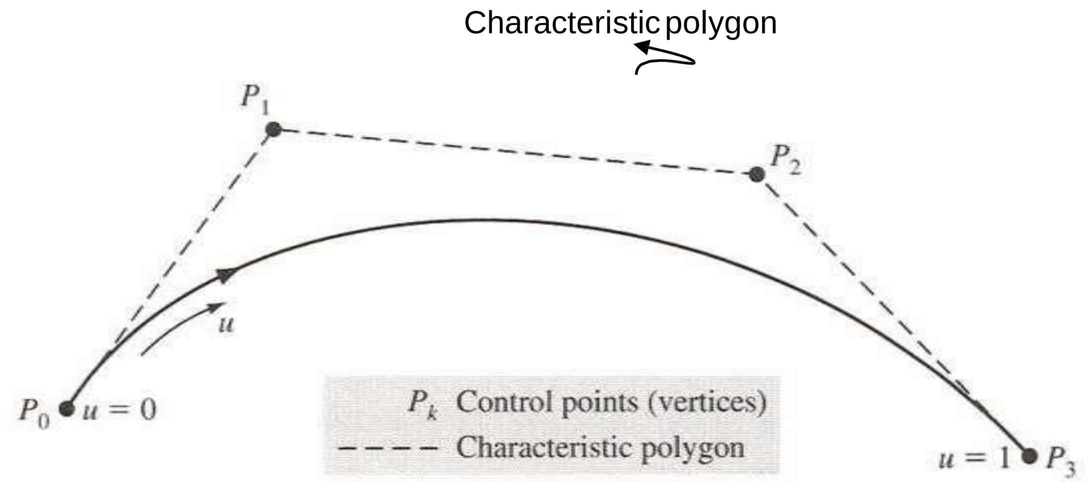
B-spline curve



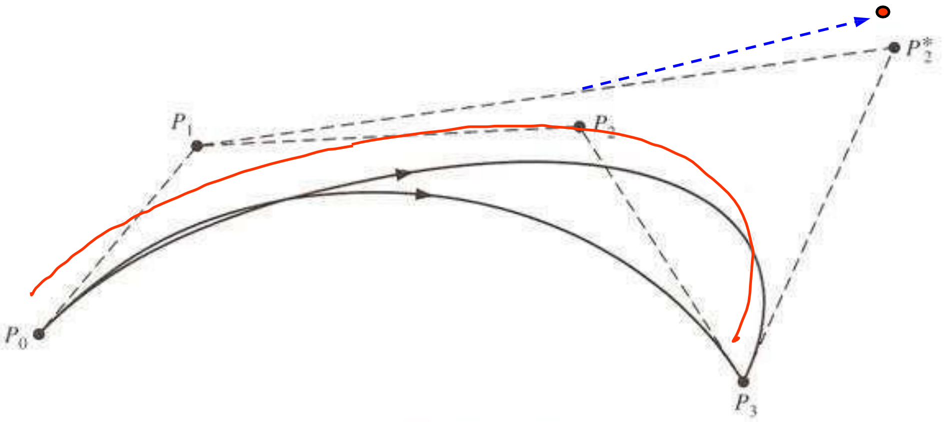
Synthetic Curves – Bezier Curve

- The data points of the Bezier curve are called control points. Only the first and the last control points lie on the curve. The other points define the shape of the curve.

- The curve is always tangent to the first and the last polygon segment. The curve shape tends to follow the polygon shape.



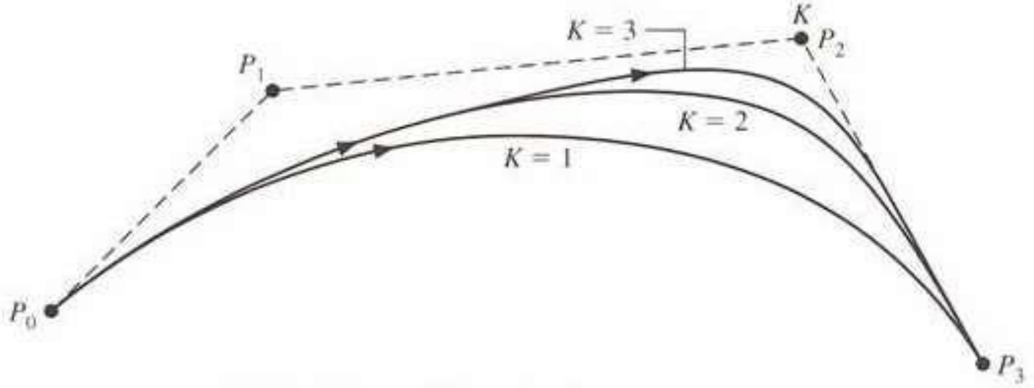
Synthetic Curves – Bezier Curve



(a) Changing a vertex

Modifying the curve by changing one or more vertices of its polygon (control points).

Modifying the curve by keeping the polygon fixed and specifying multiple coincident points at a vertex (control point)

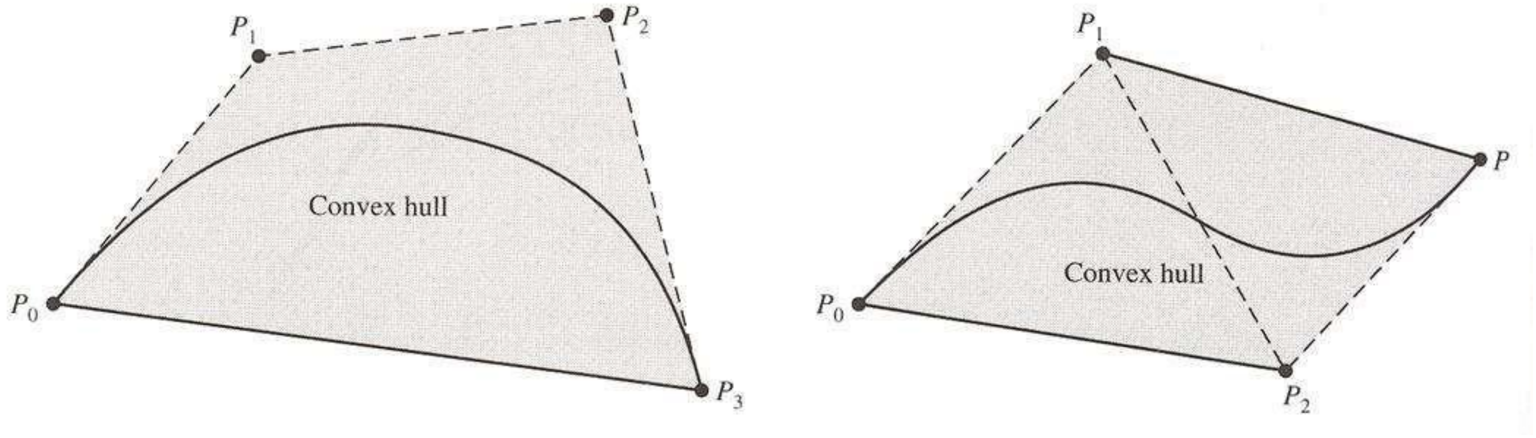


(b) Specifying multiple coincident points at a vertex

Synthetic Curves – Bezier Curve

A desired feature of the Bezier curve or any curve defined by a polygon is the convex ***hull*** property. This property guarantees that curve lies in the convex hull regardless of changes made in control points.

- The curve never oscillates wildly away its defining control points
- The size of the convex hull is the upper bound on the size of the curve itself.



Synthetic Curves – B-Spline Curve

B-spline curves are powerful generalization of Bezier curve.

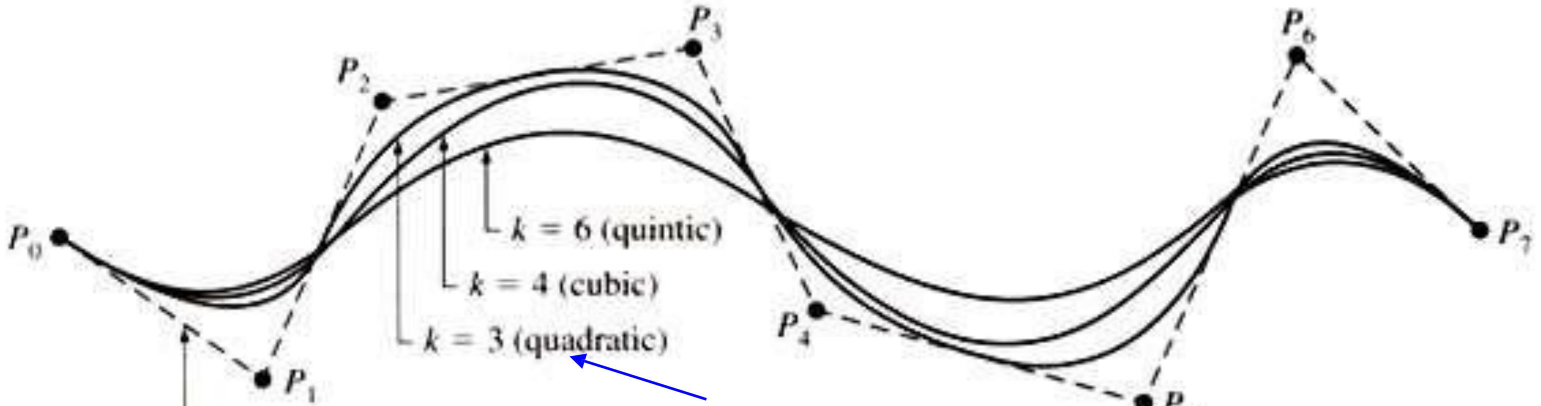
- The curves have the same characteristics as Bezier curves

- They provide local control as opposed to the global control of the curve by using blending functions which provides local influence.

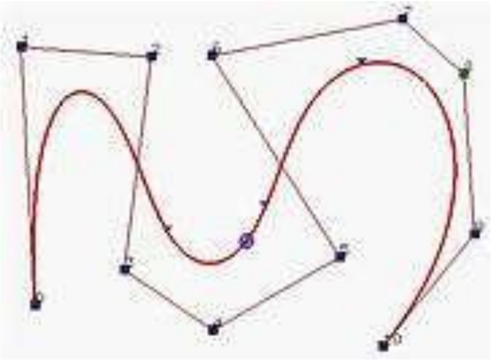
- The B-spline curves also provide the ability to separate the curve degree from the number of data points.

Synthetic Curves – B-Spline Curve

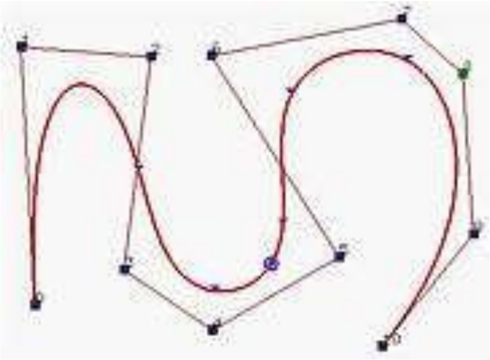
Effect of the degree of B-spline curve on the shape



Tangent to the curve at the midpoints of all the internal polygon segments



7 degree

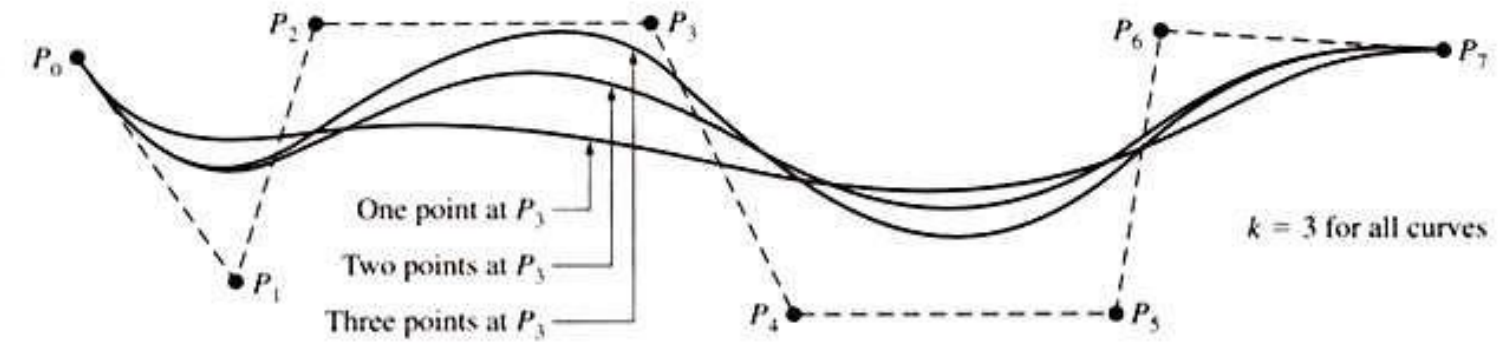


5 degree

3 degree

Synthetic Curves – B-Spline Curve

Effect of point multiplicity of B-spline curve on the shape



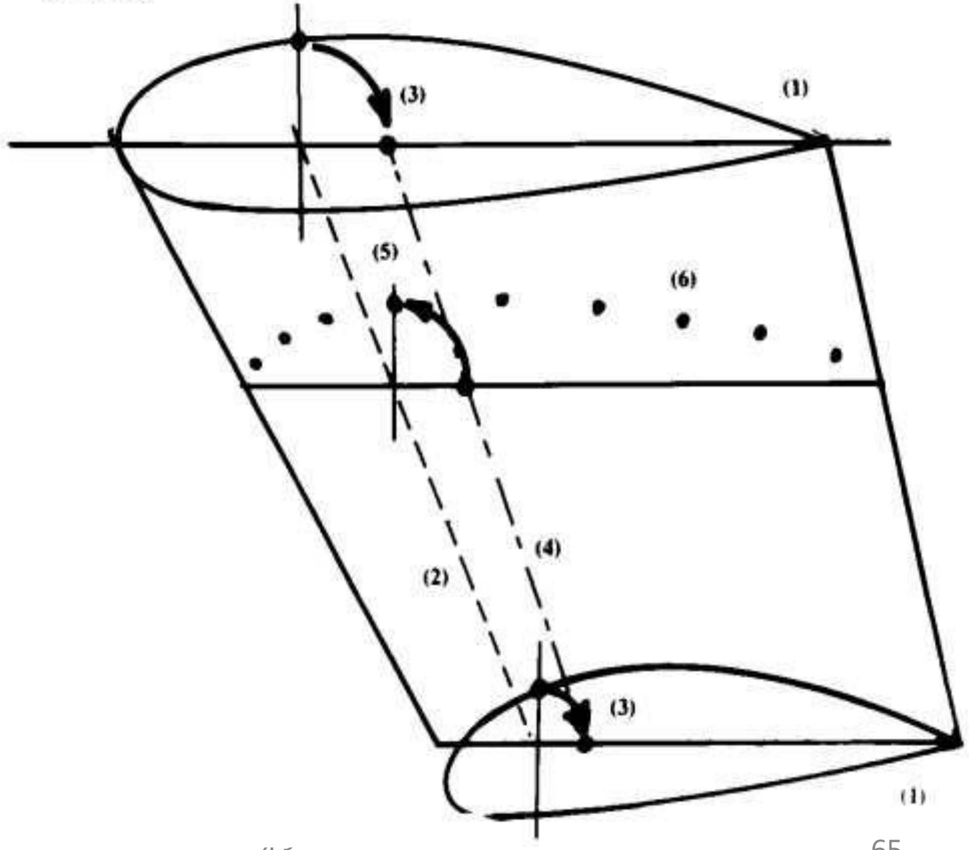
Multiple control points induce regions of high curvature, increase the number of multiplicity to pull the curve towards the control point (3 points at P_3)

- Linear interpolated airfoils have section properties that are approximately the interpolation of the section properties of the root and tip airfoils

Airfoil linear interpolation

1 - SUPERIMPOSE ROOT AND TIP AIRFOILS ON PLANFORM
2 - DRAW LINE AT SOME CONSTANT PERCENT OF CHORD
3 - SWING AIRFOIL POINT DOWN ONTO CHORD REFERENCE LINE
4 - CONNECT ROOT AND TIP POINTS FROM 3
5 - SWING POINT UP TO NEW AIRFOIL LOCATION
6 - REPEAT FOR OTHER PERCENT CHORD LINES

GRAPHIC INTERPOLATION BETWEEN DIFFERING ROOT AND TIP AIRFOILS

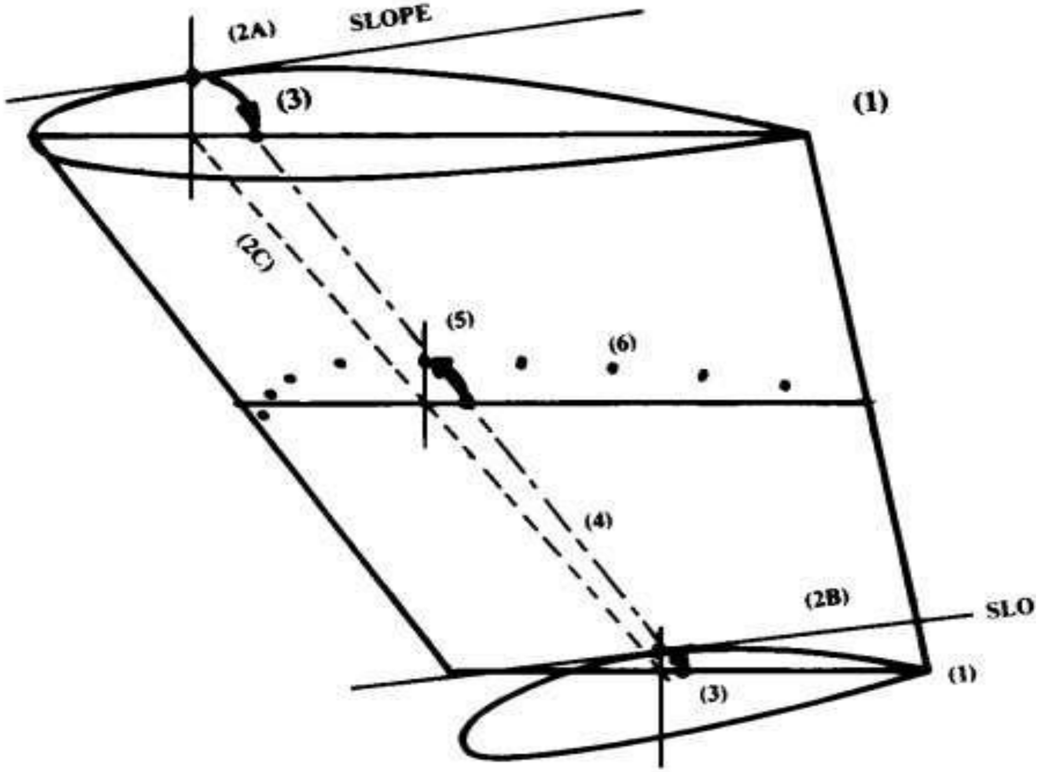


Airfoil flat wrap interpolation

- The linear interpolation method doesn’t provide a flat wrap surface.
- It is necessary to hold a same tangent angle for the conics in the different cross-section of a fuselage/wing to have a flat-wrap
- To provide flat-wrap wing, interpolate between airfoil co-ordinate with same slope(tangent angle)
- If the wing is twisted or uses different airfoils, the surface slopes may be different for airfoils at same percent of chord line.

1 – SUPERIMPOSE ROOT AND TIP AIRFOILS ON PLANFORM
2A – FOR A POINT ON THE ROOT AIRFOIL, FIND THE SLOPE
2B – FIND THE POINT ON THE TIP AIRFOIL WITH THE SAME SLOPE
2C – CONNECT THE PERCENT CHORD POINTS FROM (2A) AND (2B)
3 – AT ROOT AND TIP, SWING POINTS DOWN ONTO CHORD REFERENCE LINE
4 – CONNECT THE POINTS FROM (3)

5 – SWING POINT UP TO NEW AIRFOIL LOCATION
6 – REPEAT FOR OTHER POINTS



Wetted area determination

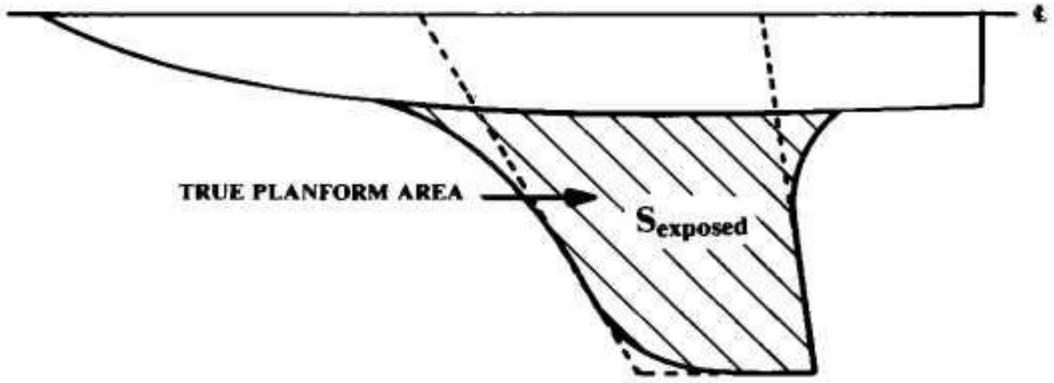
- Aircraft wetted area is the total exposed surface area.
- If a wing/tail were paper thin, the witted area would be twice

If $t/c < .05$

$$S_{wet} = 2.003\ S_{exposed}$$

If $t/c > .05$

$$S_{wet} = S_{exposed}[1.977 + 0.52(t/c)]$$



- The wetted area of the fuselage can be estimated using projected side and top views of the aircraft

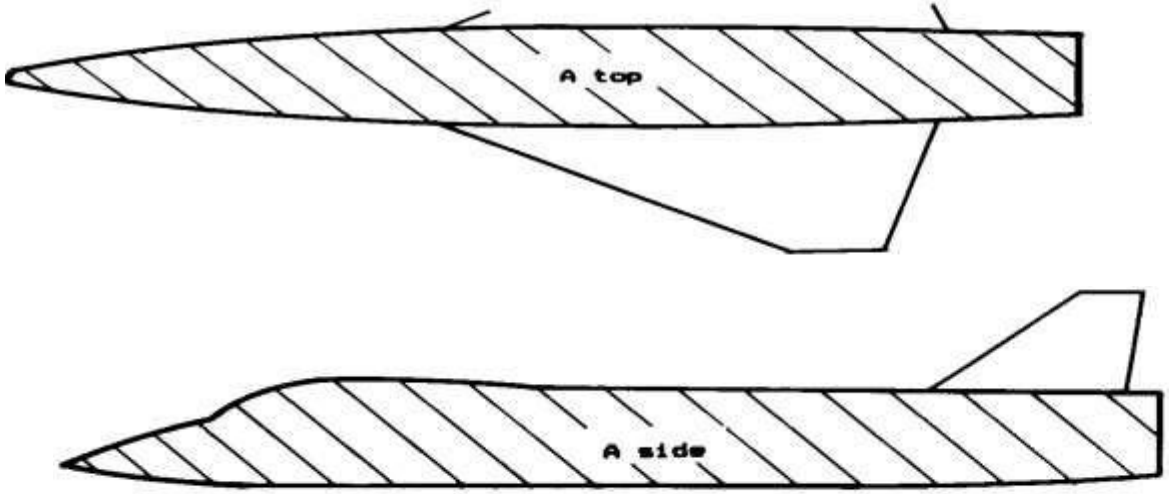
S wet = K (A top + A side)/2

K = π FOR ELLIPTIC CROSS SECTION

K = 4 FOR SQUARE CROSS SECTION

TYPICALLY USE K = 3.4

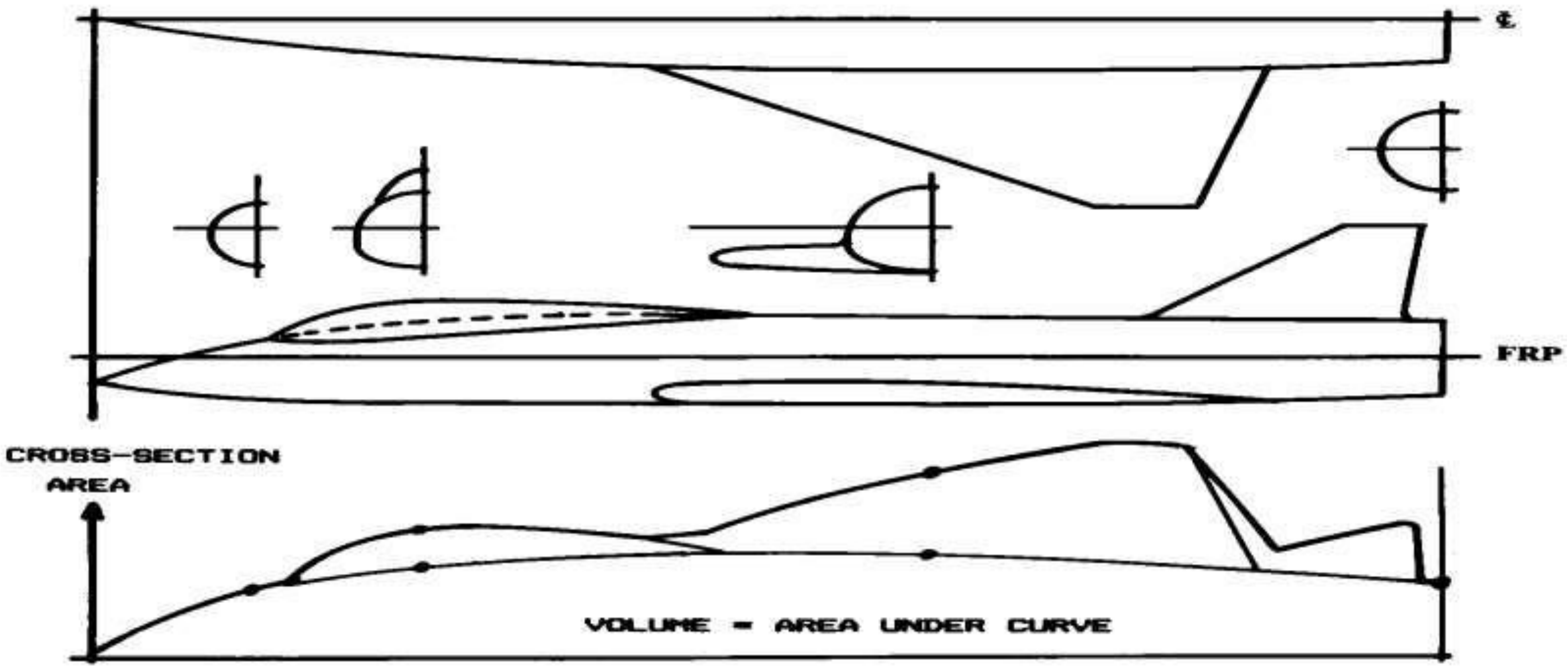
$$S_{wet} \cong 3.4\left(\frac{A_{top} + A_{side}}{2}\right)$$



Volume determination

- Aircraft volume can be estimated same as wetted area estimation.
- L – length of the fuselage
- use of Volume distribution plot is to predict and minimize supersonic wave drag and transonic drag rise

$$\text{Vol} \cong 3.4 \frac{(A_{\text{top}})(A_{\text{side}})}{4L}$$



Special consideration in configuration layout

- Aerodynamic considerations:

i)Design arrangement

ii)Isobar tailoring

iii)Supersonic area rule

iv)Compression lift

v)Design fixes

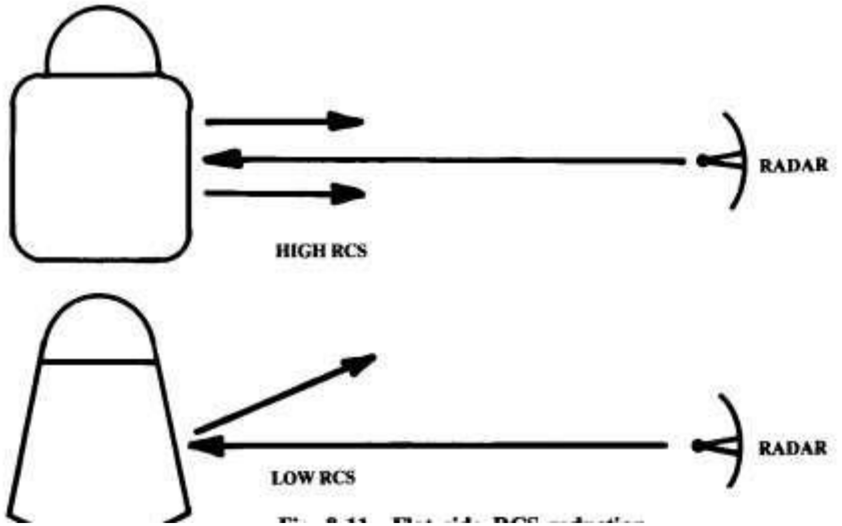
- Structural considerations

i) Load path

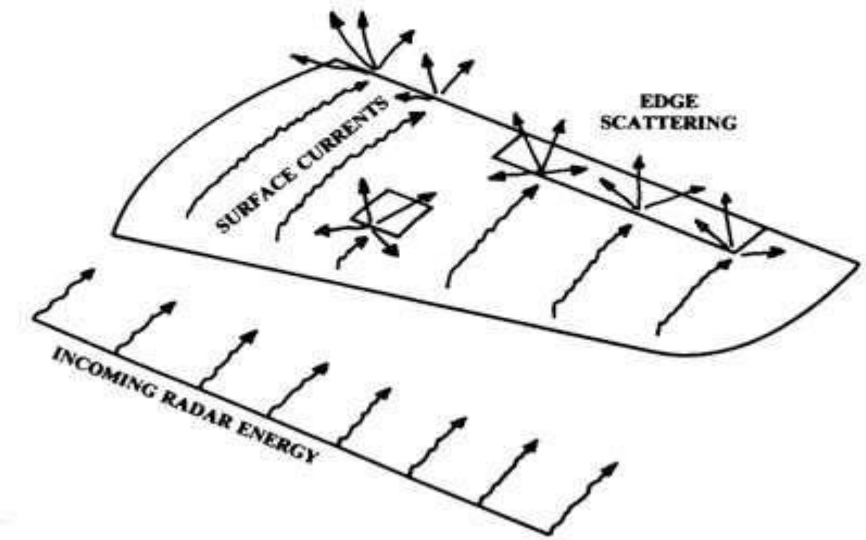
ii) Structural carry

Radar Detectability

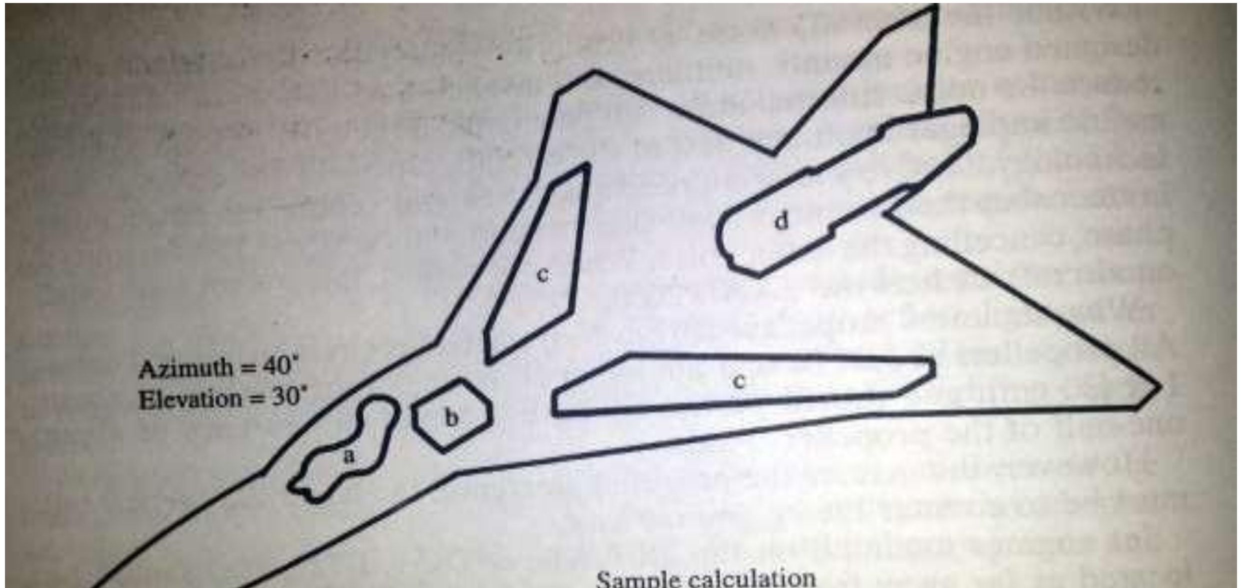
- Flat side RCS reduction (RCS-Radar cross-section)



- Surface current scatterings



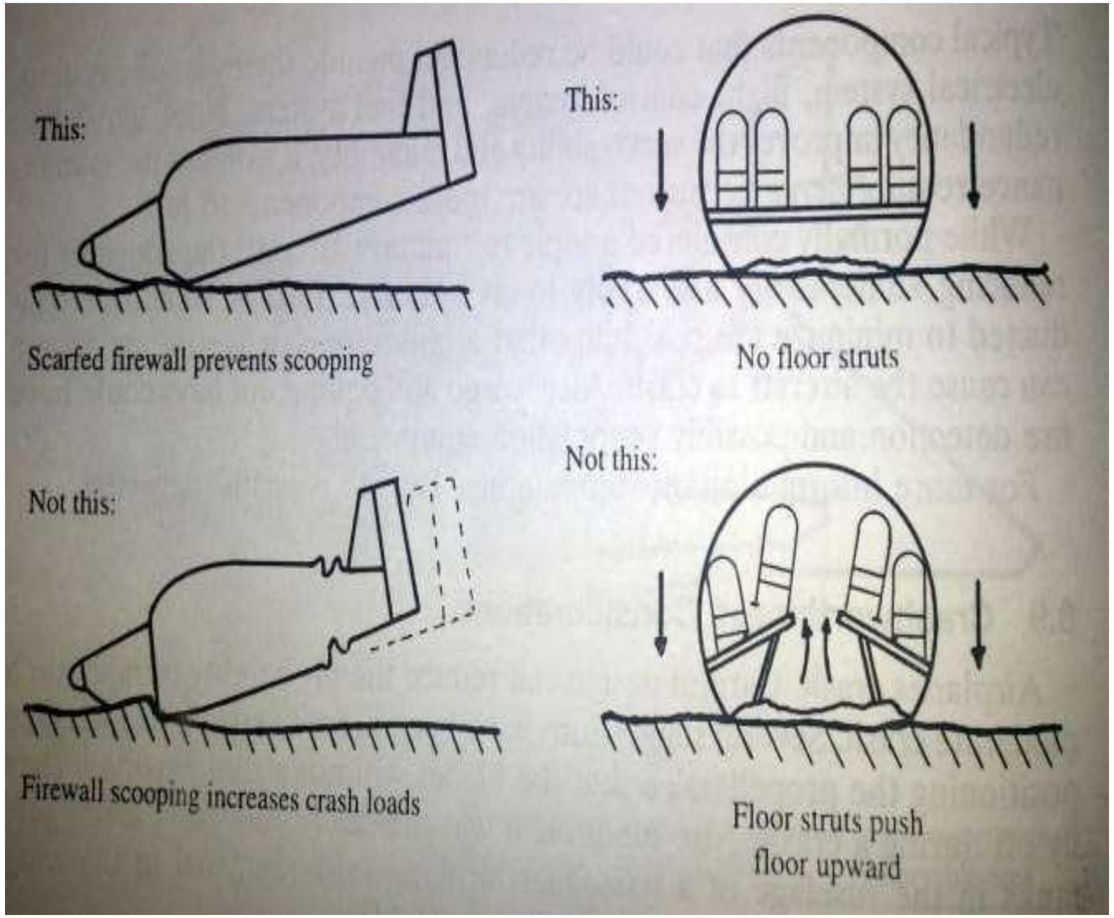
Vulnerable considerations



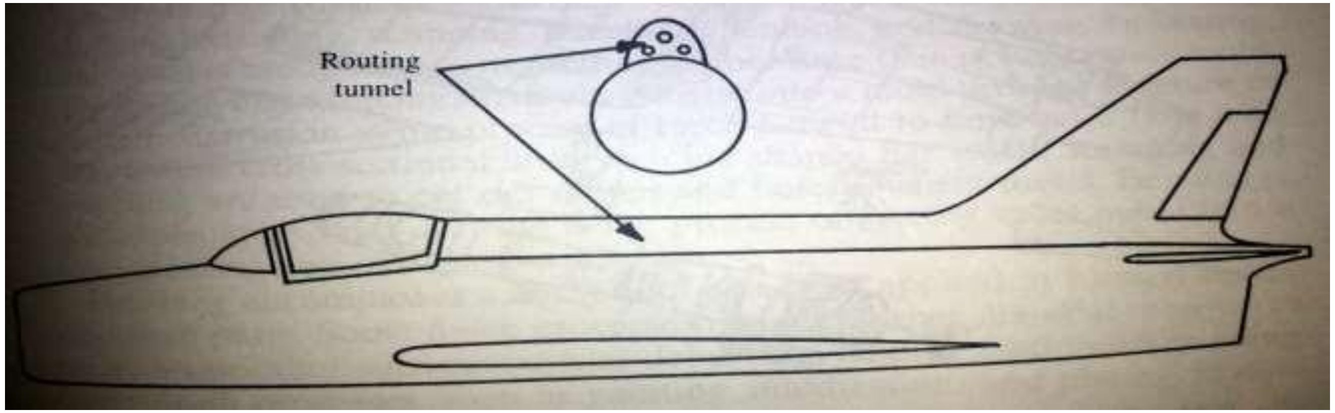
Sample calculation

Component	Presented area	P_k given hit	Vulnerable area
Pilot (a)	5 ft^2	1.0	5 ft^2
Computer (b)	4 ft^2	0.5	2 ft^2
Fuel (c)	80 ft^2	0.3	24 ft^2
Engine (d)	50 ft^2	0.4	20 ft^2
		Total vulnerable area	51 ft^2

Crash worthiness considerations

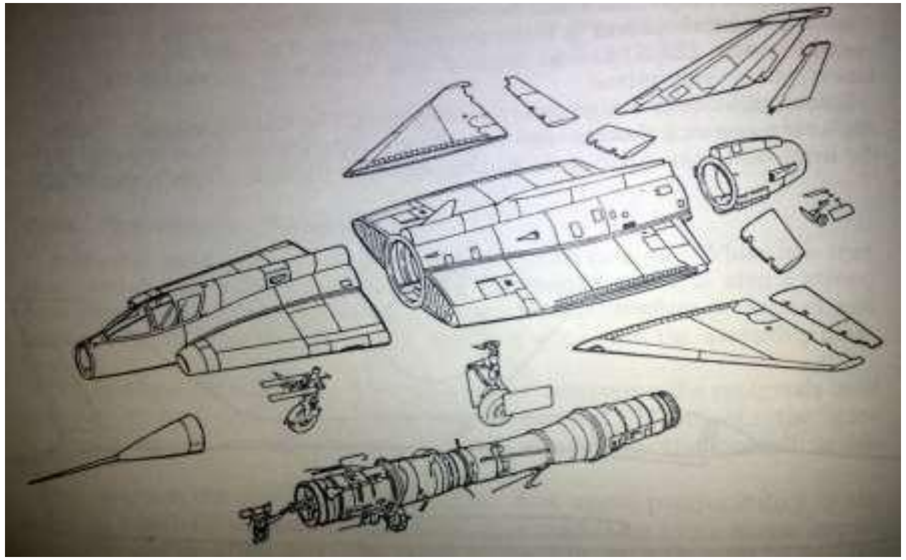


Producibility considerations

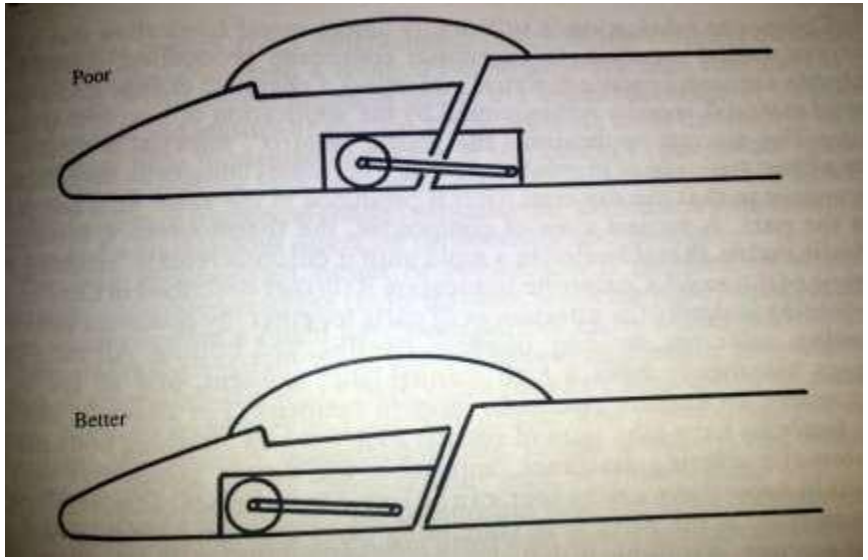


- External routing tunnel

- Material selection, manufacturing, tooling, fabrication, assembling.

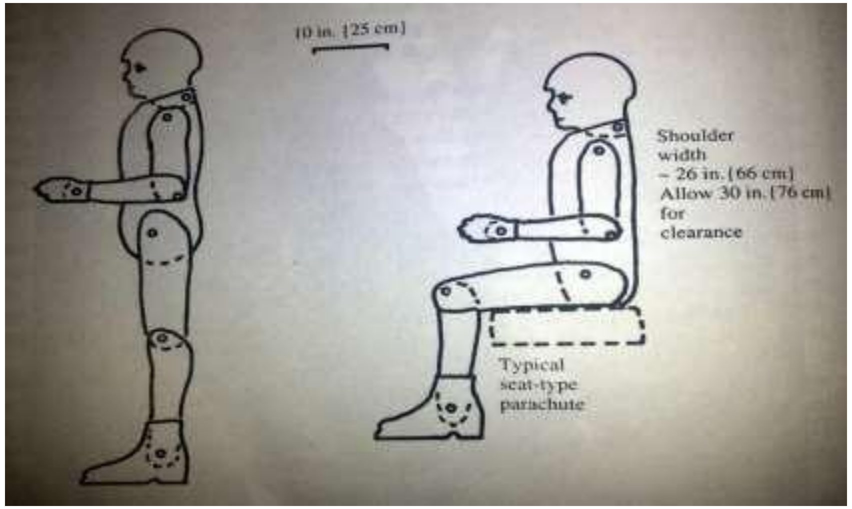


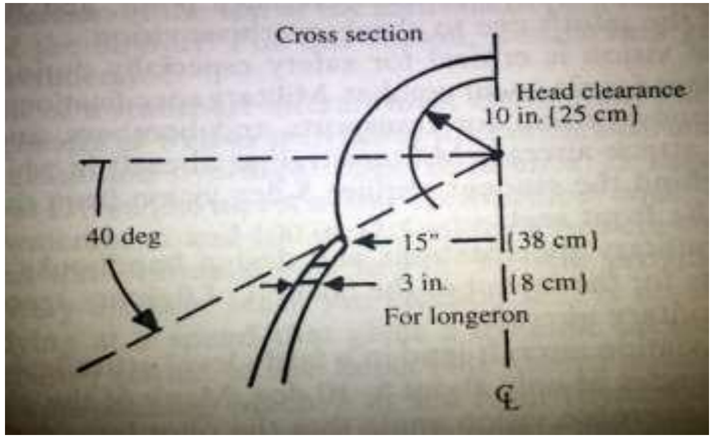
Production subassembly of SAAB aircraft



production breaks

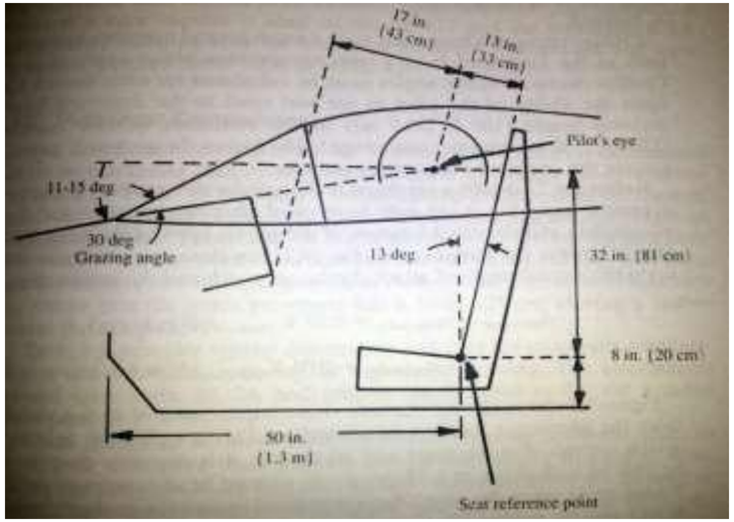
Crew station, passengers and payload



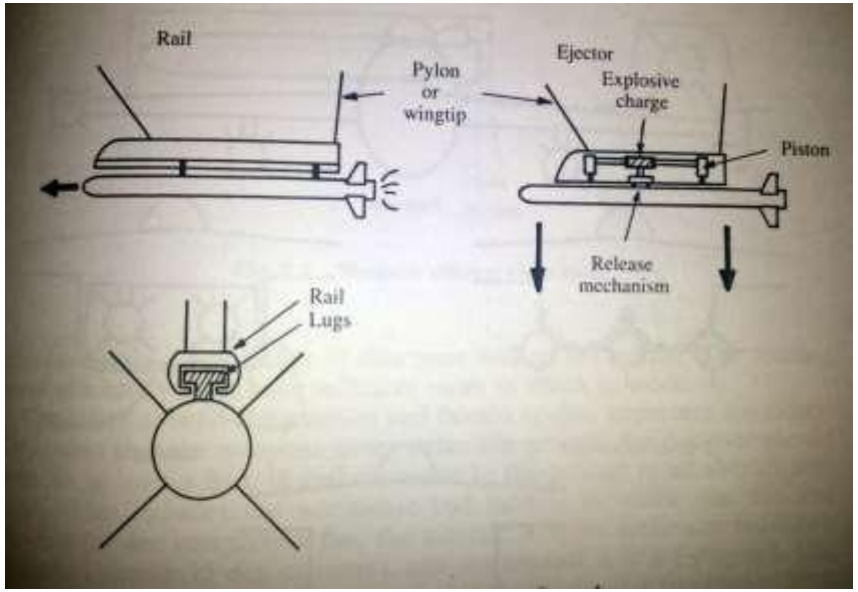


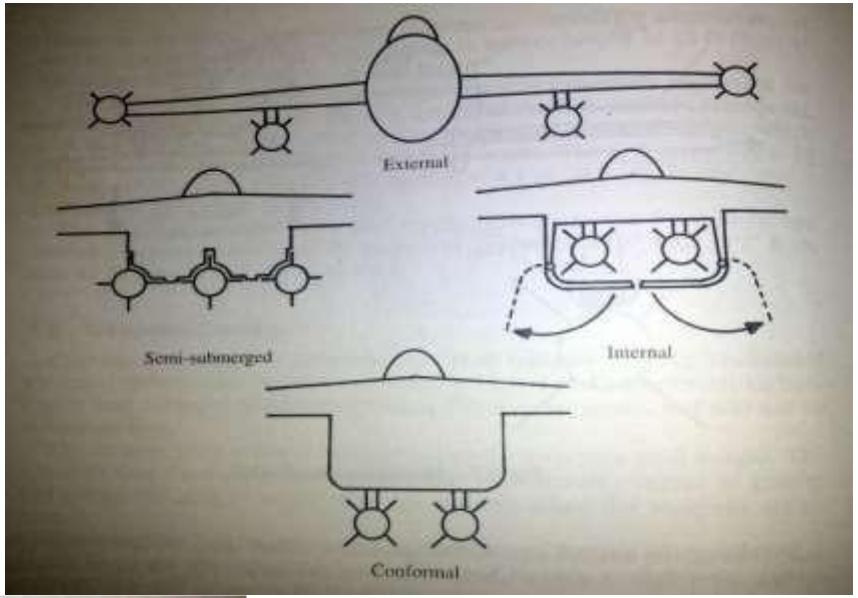
- Average 95th percentile pilot

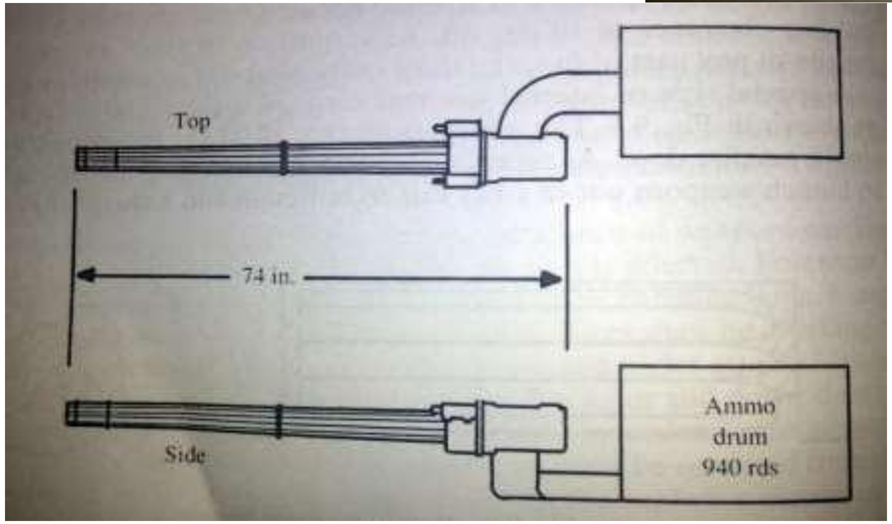
Typical fighter cockpit



Weapon carraige







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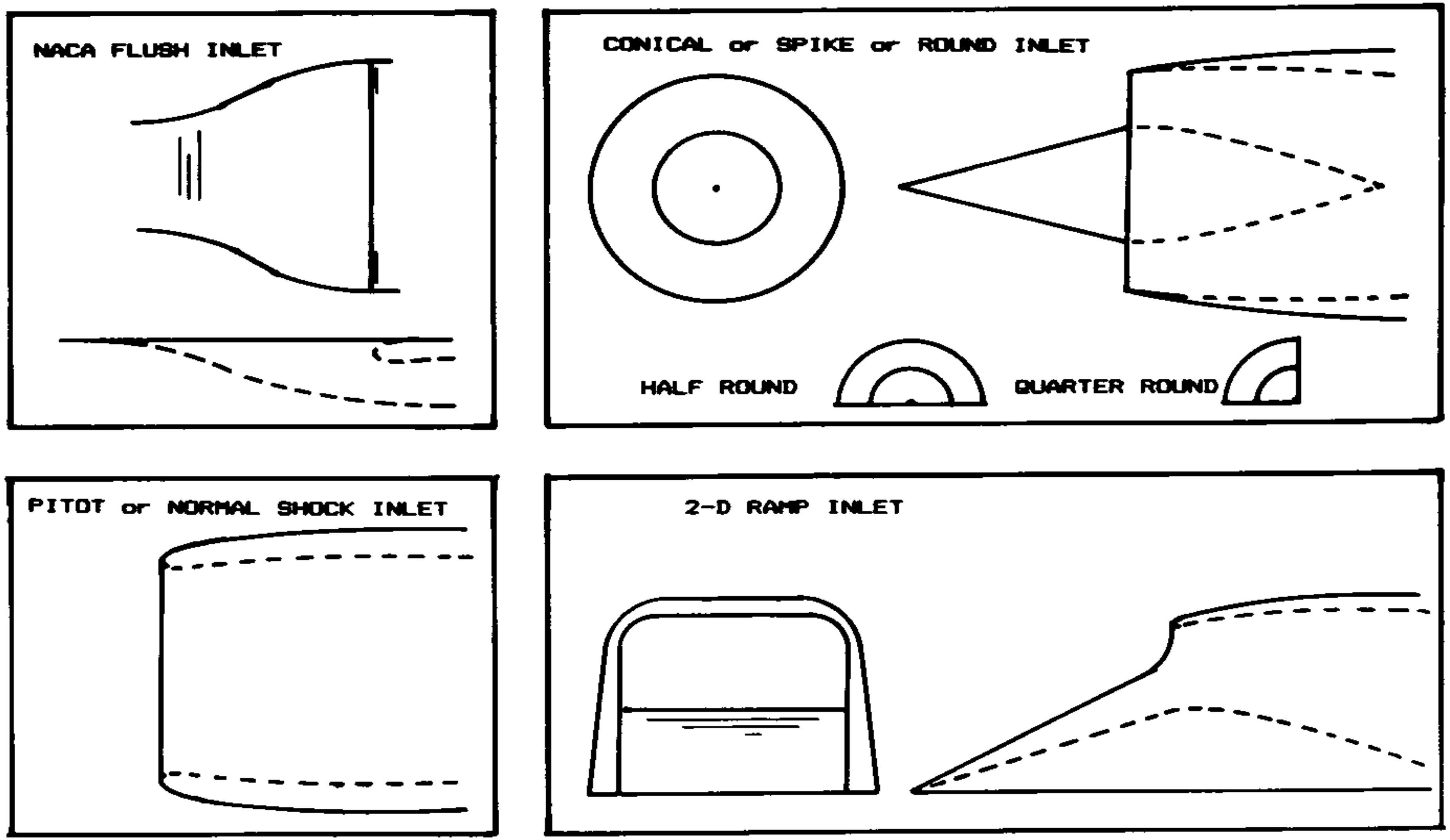
UNIT - III

PROPULSION & FUEL SYSTEM INTEGRATION, LANDING GEAR & SUBSYSTEMS

Inlet Geometry



- NACA Flush Inlet: Poor Pressure recovery. Conformal design used in Cooling air intakes.
- Pitot Type: Works good for Subsonic as well as Supersonic.

  Cowl lip Radius will be different according to missionprofile.
- Conical or Spike or Round Inlet: Used mainly in Supersonic a/c.Exploits the Shock pattern created over the cone. Optimum performance over Mach 2. Drag will be more lower speeds.
- Ramp Inlet: For speeds up to Mach 2.

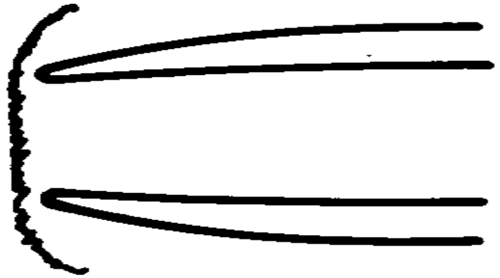
  At greater speeds the Pressure recovery will be poor.

J-5 – Multi role Fighter.

- Inlet: 2-D Ramp Type
- Splitter type boundary Layer diverter
- Canards – Horizontal control surfaces

Shock Patterns over the Inlets

NORMAL SHOCK



ISENTROPIC

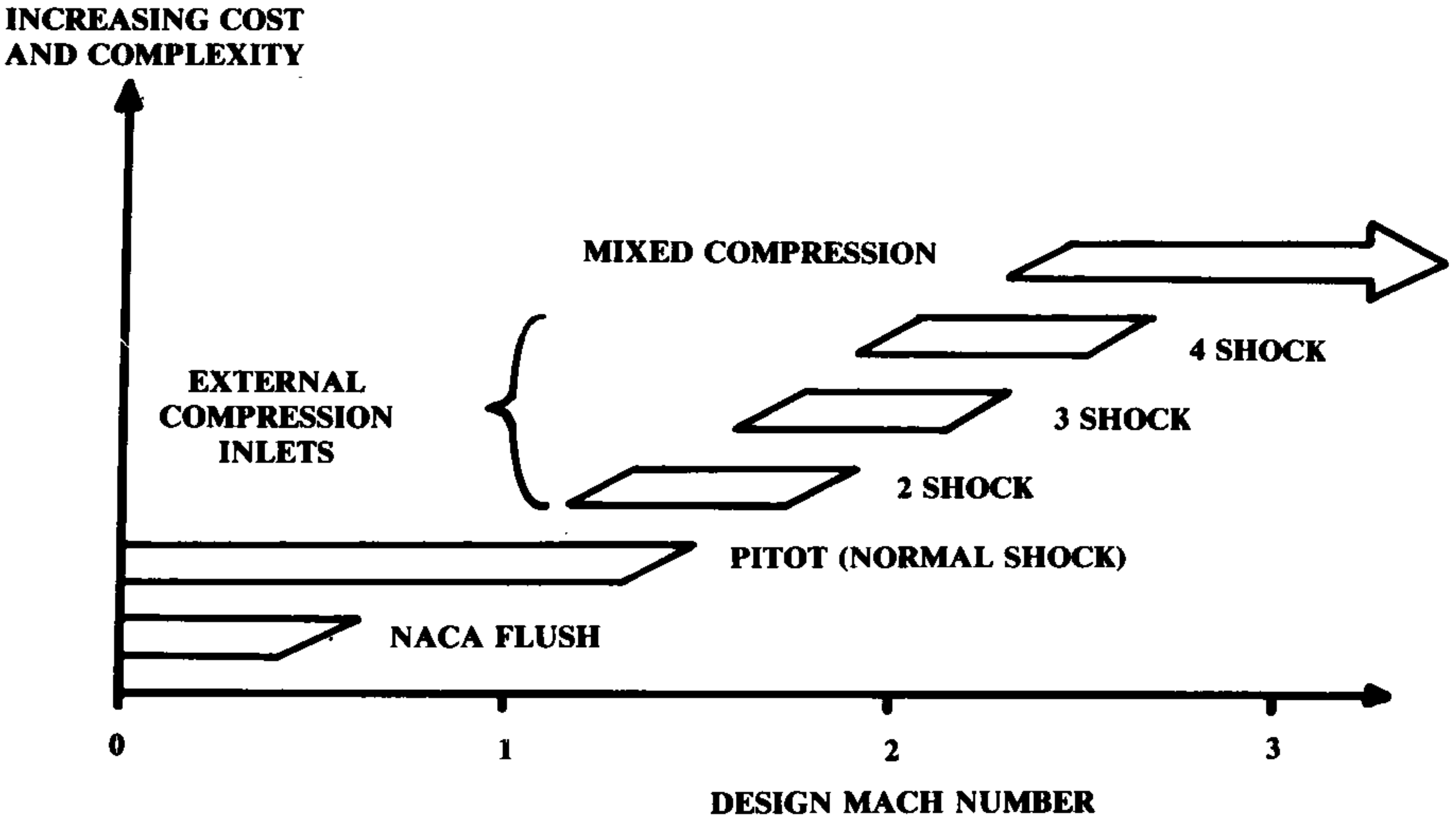
EXTERNAL COMPRESSION

2 SHOCK

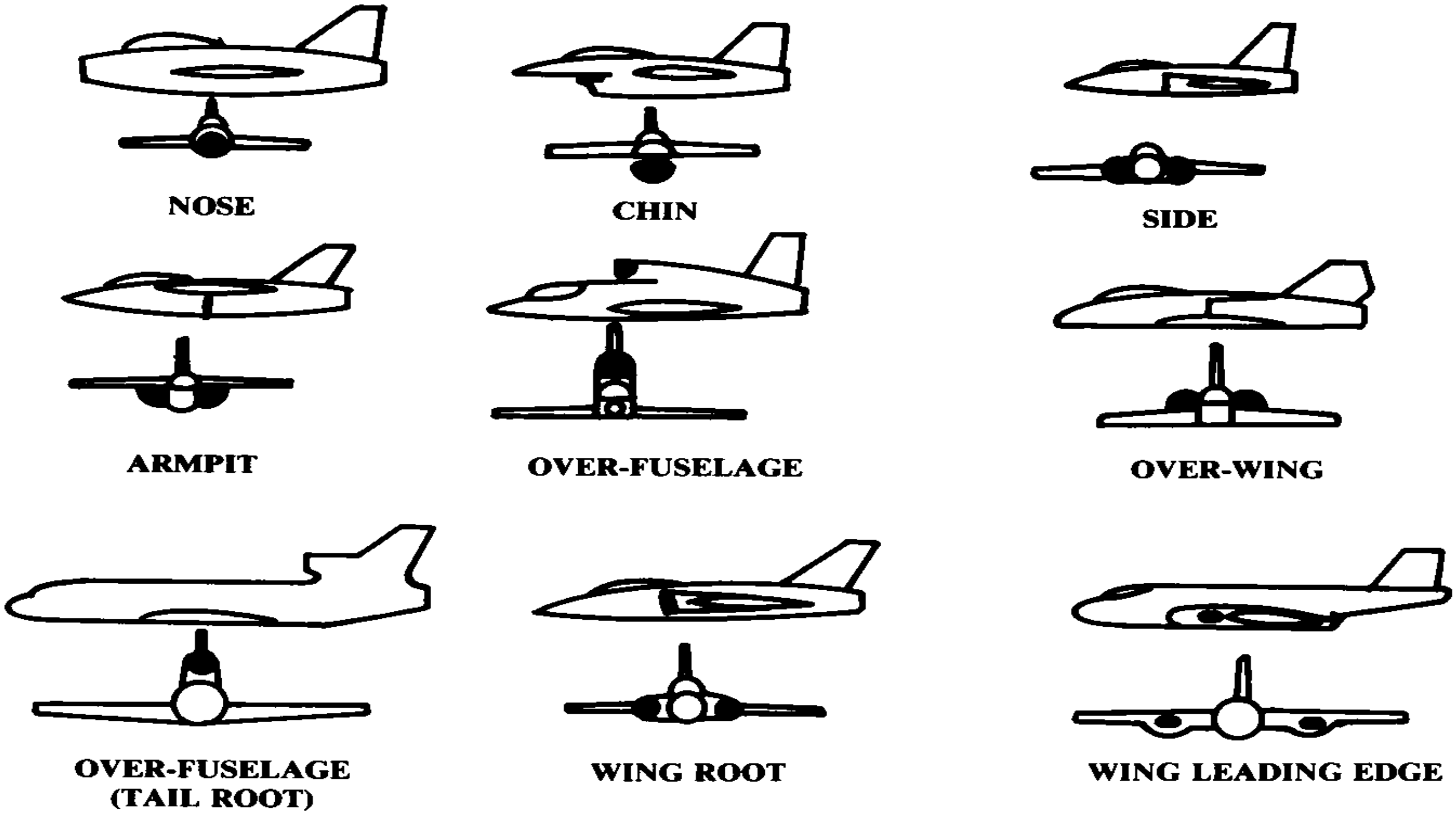
3 SHOCK

4 SHOCK

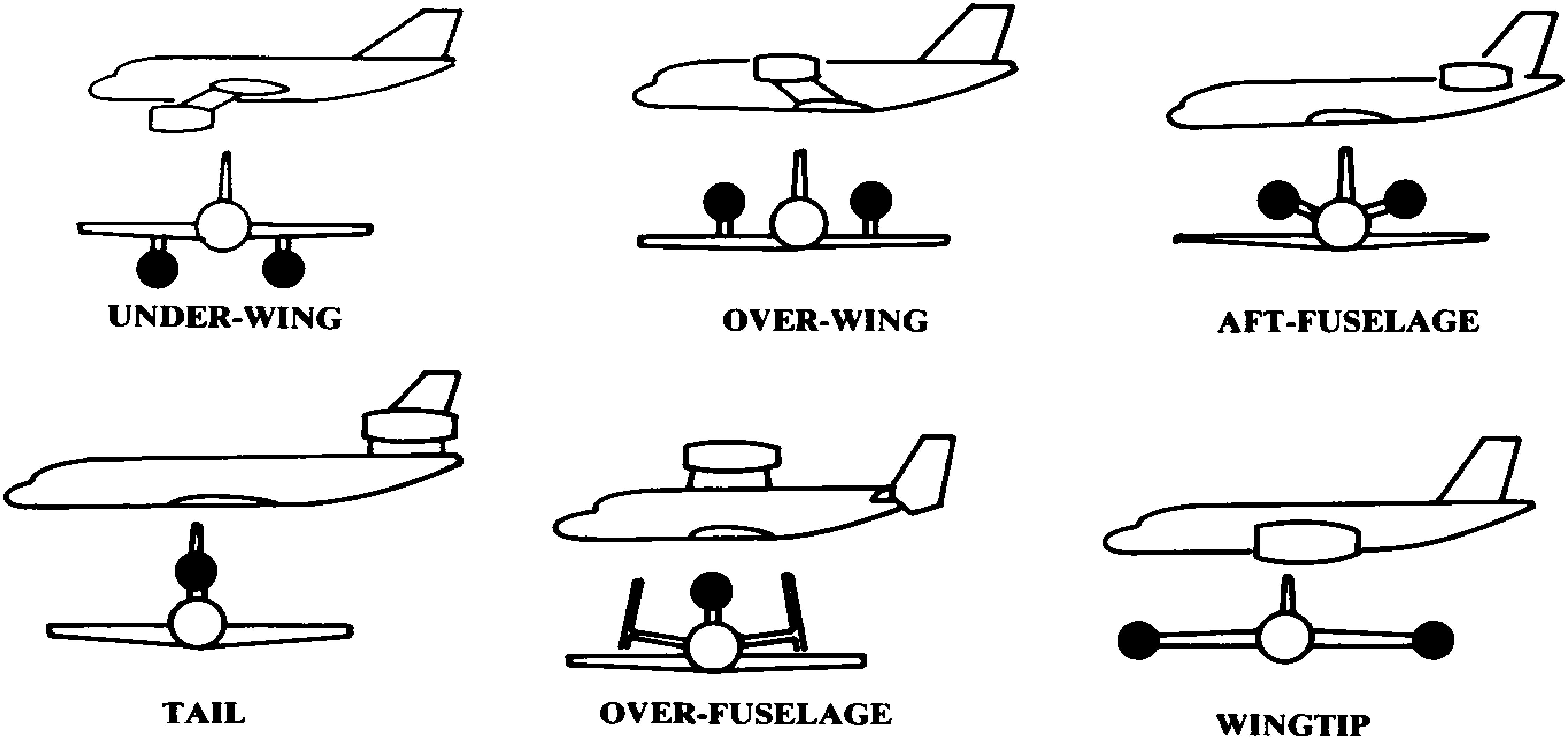
Inlet Operational Characteristics



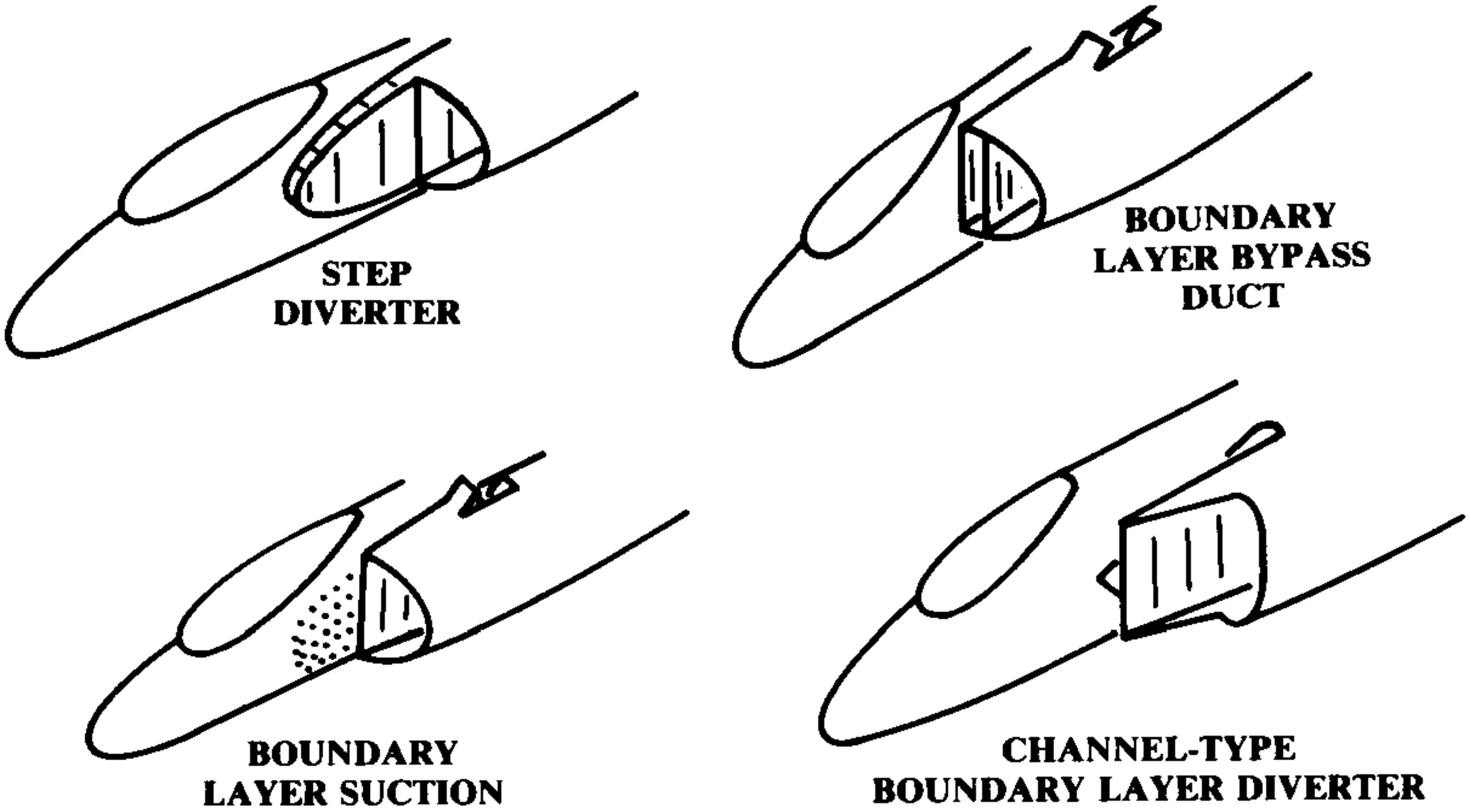
Inlet Locations – Buried Engines



Inlet Locations – Podded Engines



Boundary Layer Diverters

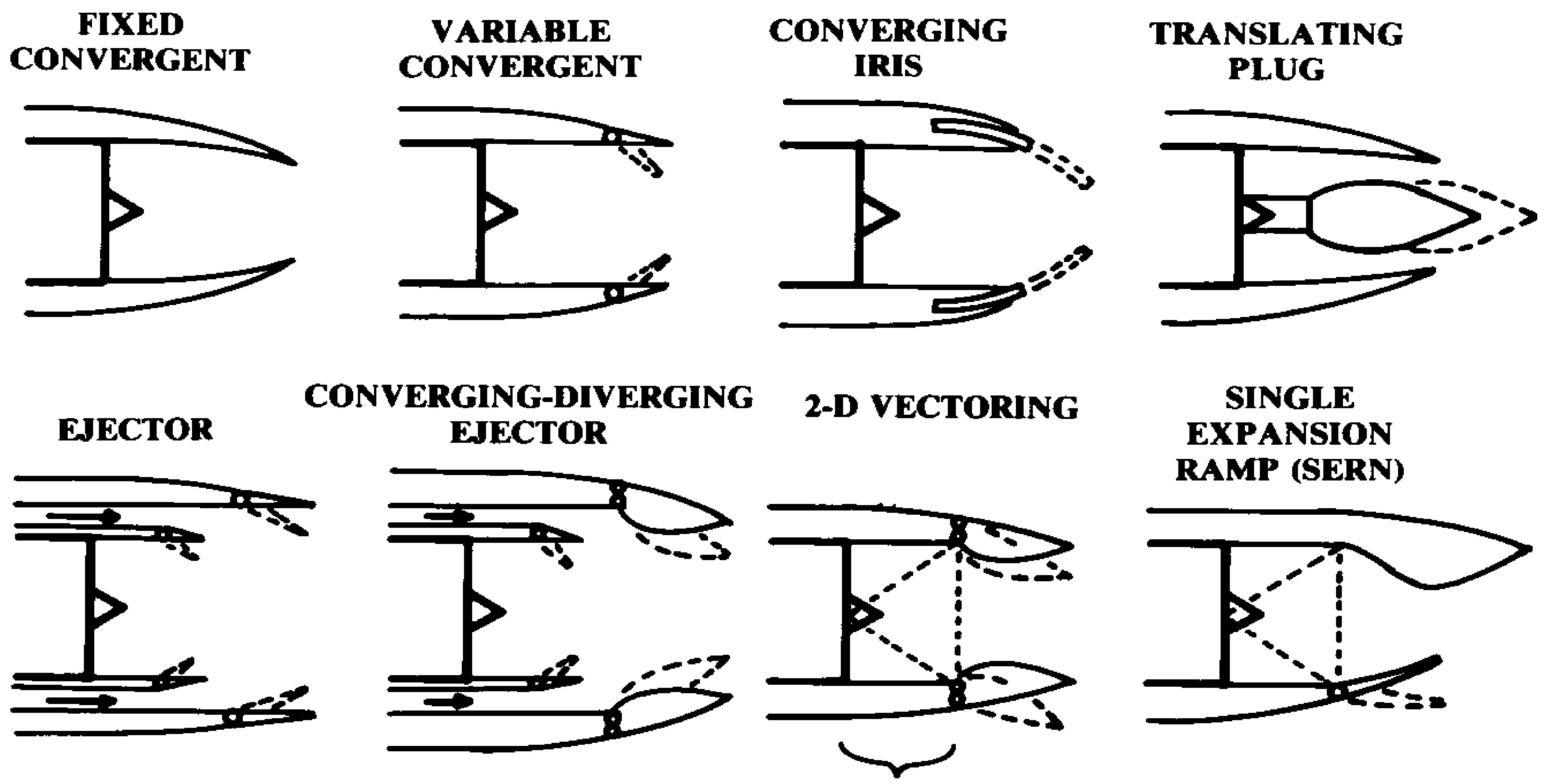


Nozzle Integration

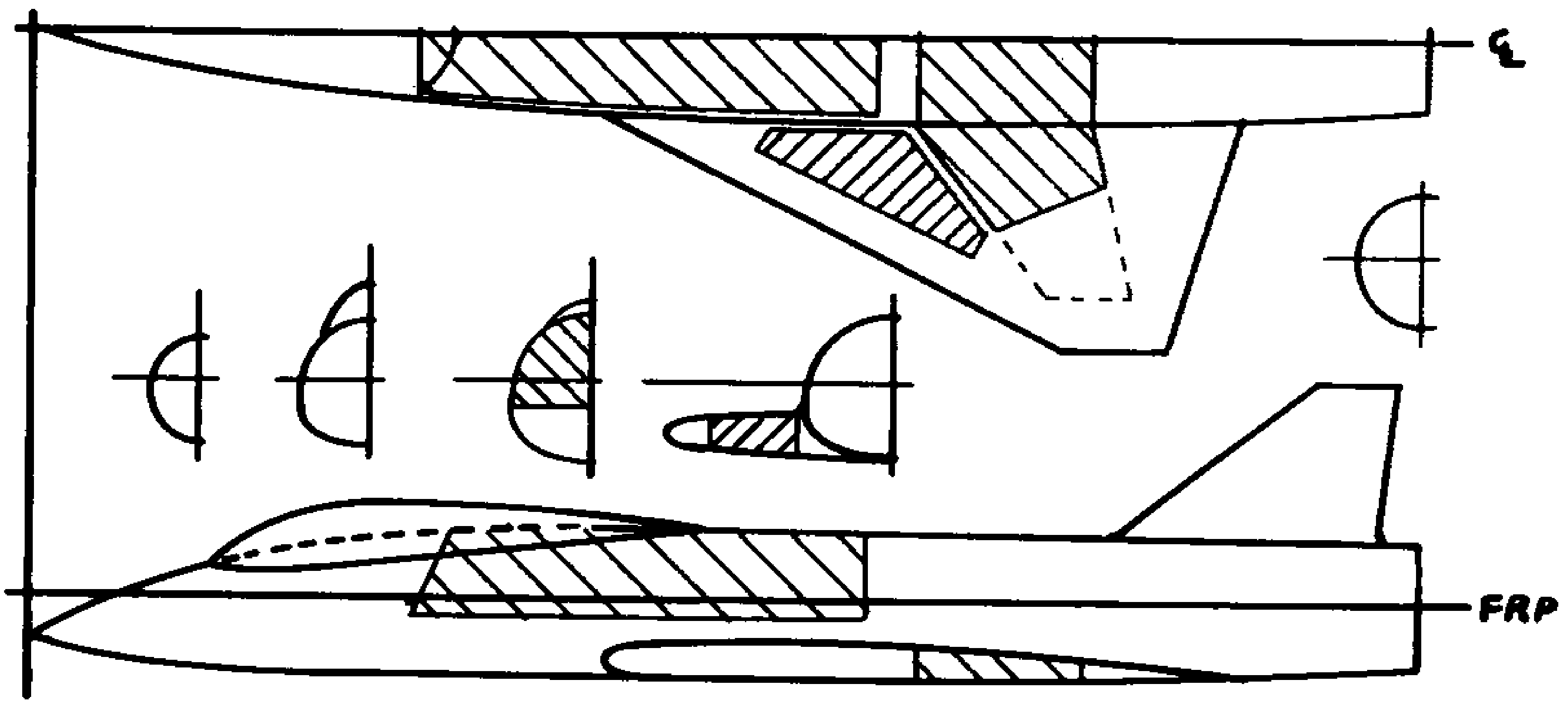
- Nozzle: Accelerate the high pressure Hot Exhaust from the Engine.
- Either Fixed or Variable area type
- Fixed Area: Subsonic - Convergent Lighter Nozzle is optimized for cruise performance Efficiency looses in lower speeds

•Variable Area: Mostly preferred for supersonic Aircrafts Convergent: higher subsonic to lower supersonic speeds Convergent-Divergent: High supersonic aircrafts.

Nozzle Integration – cont..



Fuel System (Integral) Layout



Aircraft landing Gear

- The landing gear in aviation is the structure that supports an aircraft on the ground and allows it to taxi, takeoff and to land.

- Single Main

  Mostly used in seaplanes/Gliders.

  Less Control.

- Bicycle
  - Two main gears –fore and aft of CG with small outriggers under the wings
- Quadricycle
  - Similar to Bicycle type but two individual struts at fore and aft locations.
  - Used mostly in heavy lift or Cargo aircrafts – The A/c floor will be much lower to the ground

Tail Draggers / Conventional

Two main wheels foreward of CG + one auxiliary wheel at the tail.Popular kind of Landing gears at from the early stage of flights Mostly unstable, CG location is behind the main wheels

Tricycle

- Two main gears at the aft location to CG + one nose wheel.
- Widely used for lighter aircrafts.
- Stable and have good controllability during crosswinds.

Multi Bogey

- Multiple wheels are used in each struts.
- The wheels are attached to the “struts ” through a “Bogey”

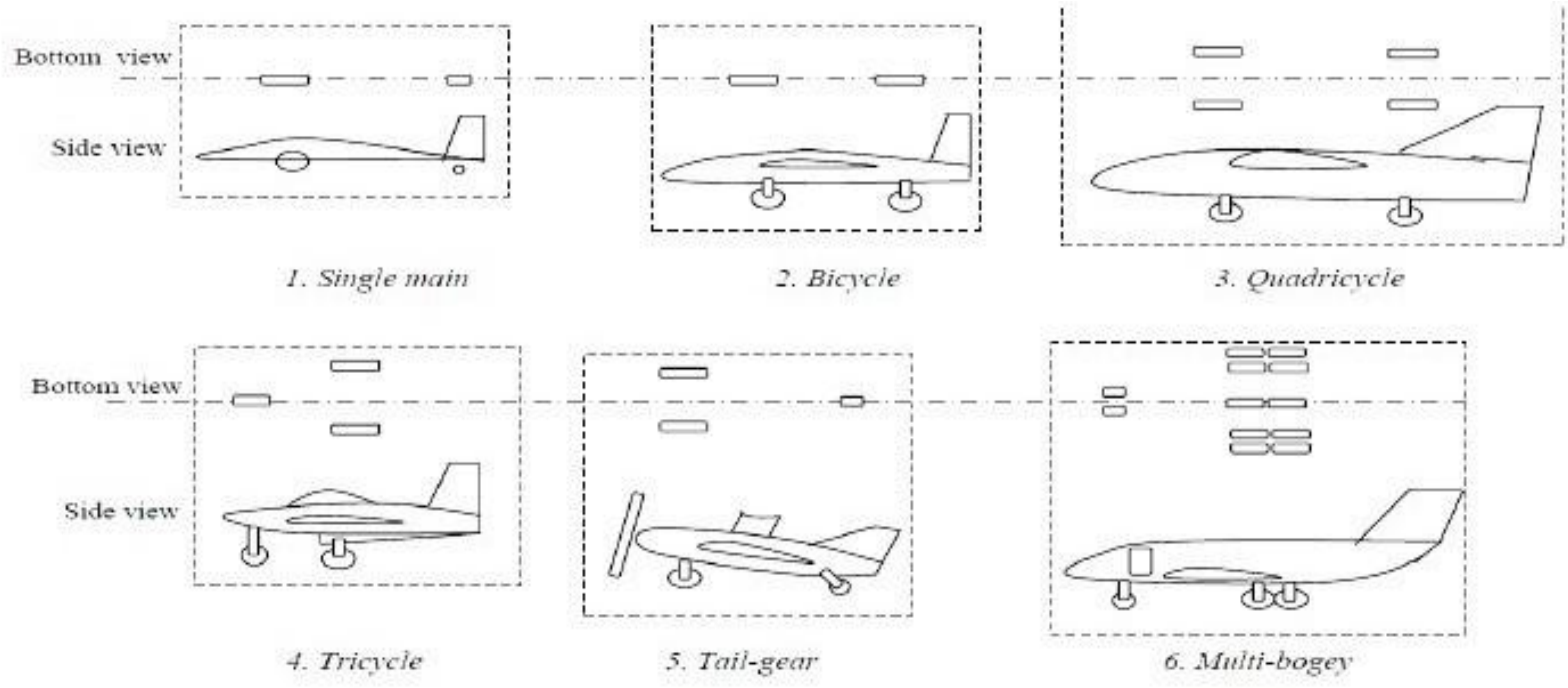
Taxiing and Braking Techniques

- CIRRUS aircraft requires a combination of rudder and differential braking for directional control on the ground.
- Use the least amount of brake pressure to maintain directional control during the taxi.
- Use power to control speed during the taxi.
  - Reduce power to slow down and then apply brakes as necessary.
- Avoid taxiing at high power settings and speeds.

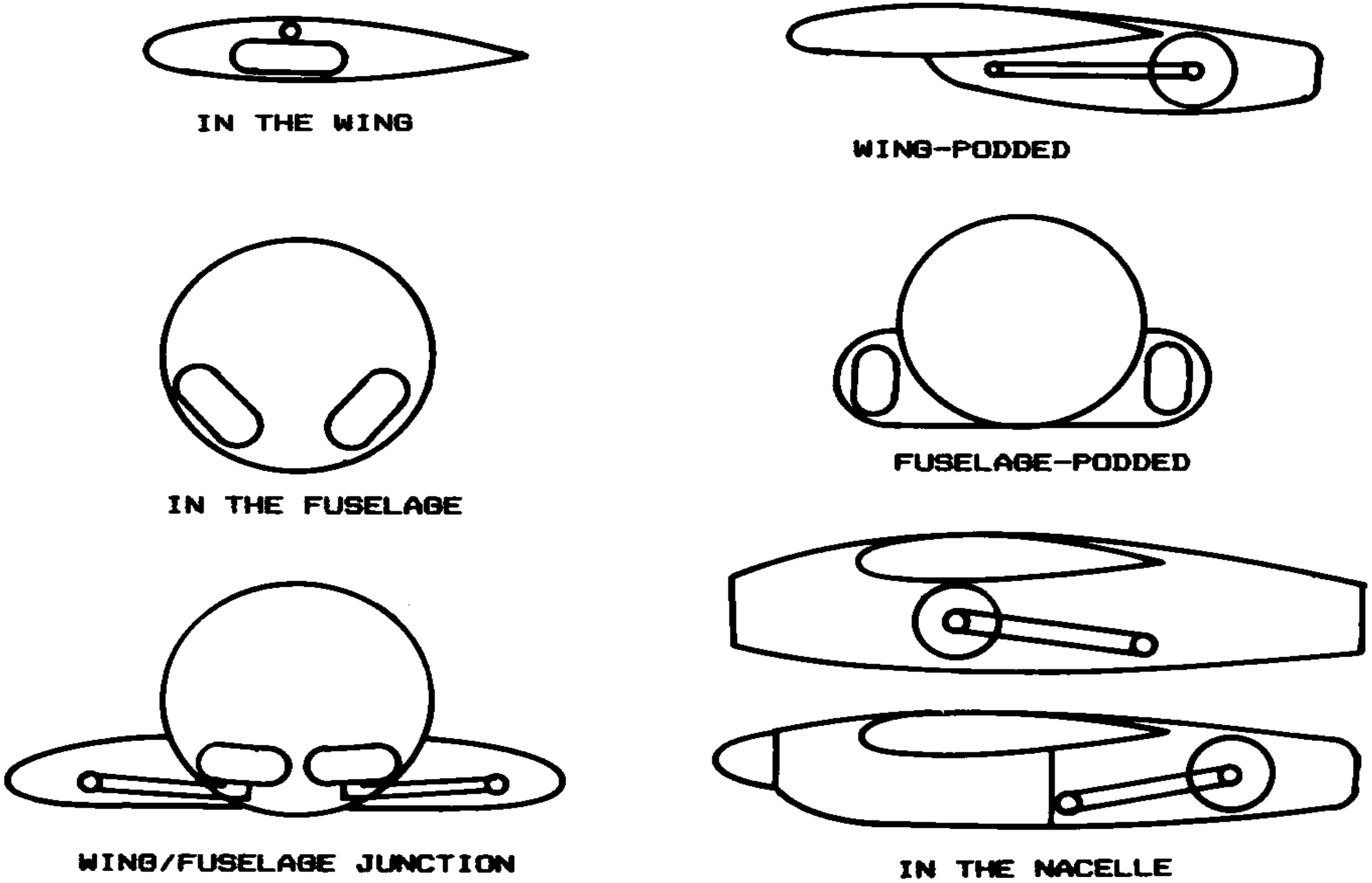
Takeoff and Landing Techniques

- Takeoff
  - At low airspeeds and power settings differential braking is required for directional control.
  - At higher airspeeds and power setting rudder control is sufficient to provide directional control on the takeoff roll.
- Landing
  - Upon touchdown the rudder is initially use to maintain directional control.
  - Once the aircraft stabilized on the runway apply even pressure to both brakes for directional control and brake as necessary.

Landing Gear Arrangements



Landing gear Retraction – Geometry



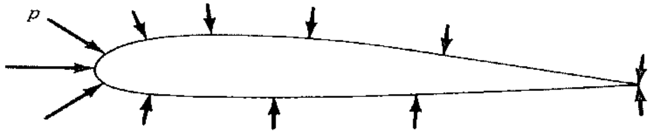
UNIT-IV

BASELINE DESIGN ANALYSIS- AERODYNAMICS AND PROPULSION, STRUCTURES AND WEIGHT AND BALANCE

Aerodynamic forces

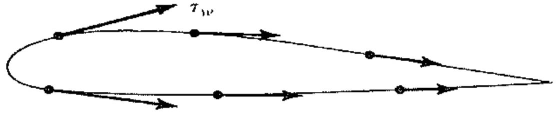
Aerodynamic forces exerted by airflow comes from only two sources Pressure, p, distribution on surface

- Acts normal to surface



Shear stress, tw, (friction) on surface

- Acts tangentially to surface



Pressure and shear are in units of force per unit area (N/m2)

Net unbalance creates an aerodynamic force

“No matter how complex the flow field, and no matter how complex the shape of the body, the only way nature has of communicating an aerodynamic force to a solid object or surface is through the pressure and shear stress distributions that exist on the surface.”

“The pressure and shear stress distributions are the two hands of nature that reach out and grab the body, exerting a force on the body – the aerodynamic force”

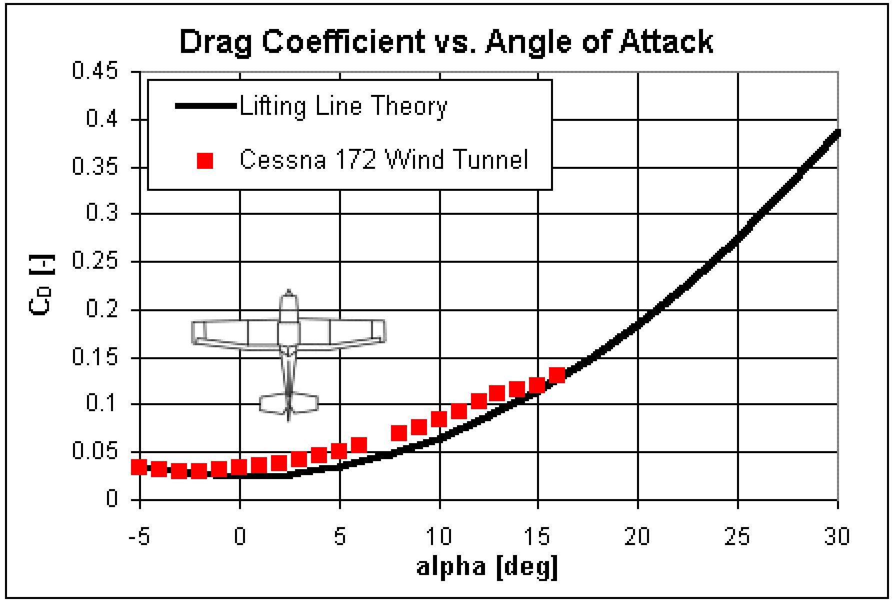
- Relative Wind: Direction of $V\infty$
- We used subscript ∞ to indicate far upstream conditions
- Angle of Attack, a: Angle between relative wind ($V\infty$) and chord line

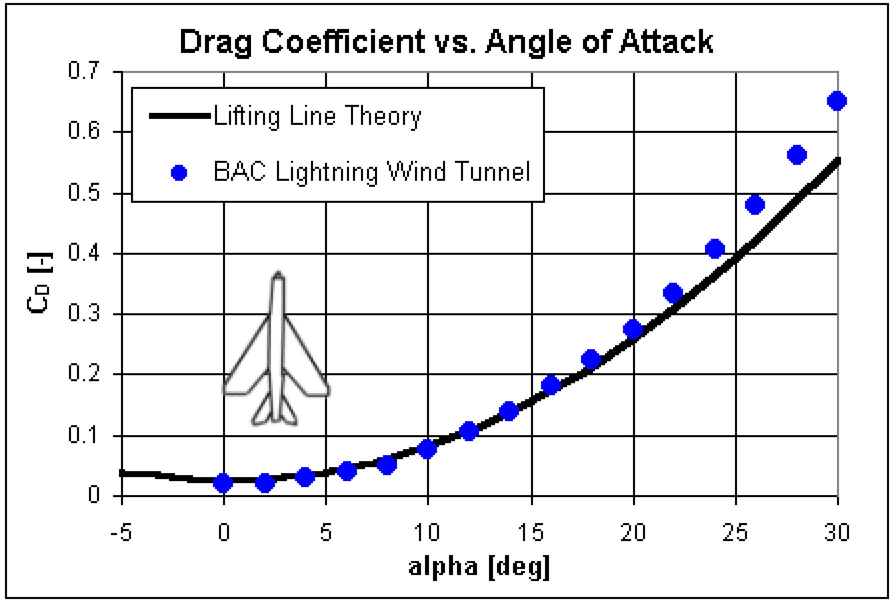
- Total aerodynamic force, **R**, can be resolved into two force components
  - Lift, **L**: Component of aerodynamic force perpendicular to relative wind
  - Drag, **D**: Component of aerodynamic force parallel to relative wind

- Center of Pressure: It is that point on an airfoil (or body) about which the aerodynamic moment is zero

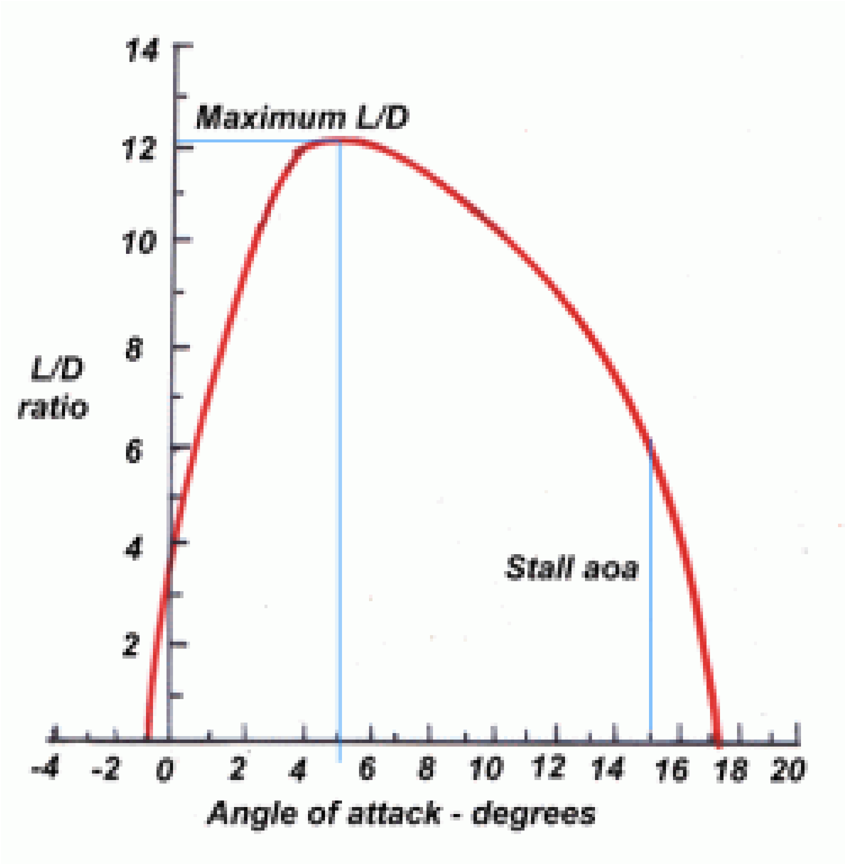
- Aerodynamic Center: It is that point on an airfoil (or body) about which the aerodynamically generated moment is independent of angle of attack

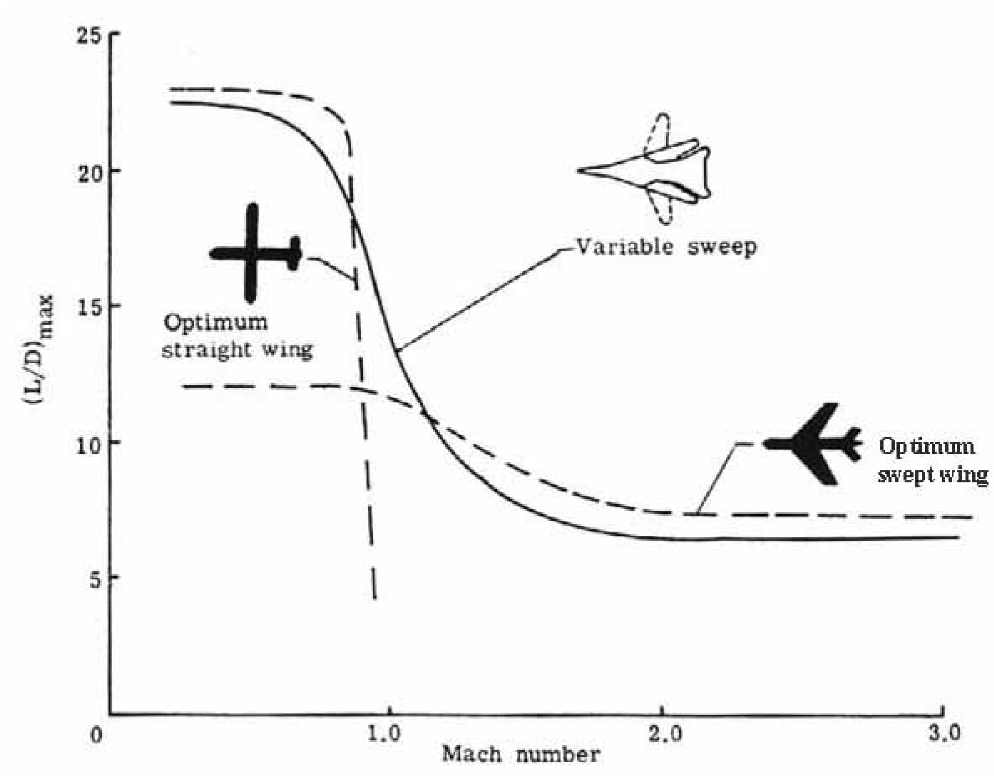
Drag coefficient data obtained for a rectangular wing and swept back wing on wing tunnel and lifting line numerical methods



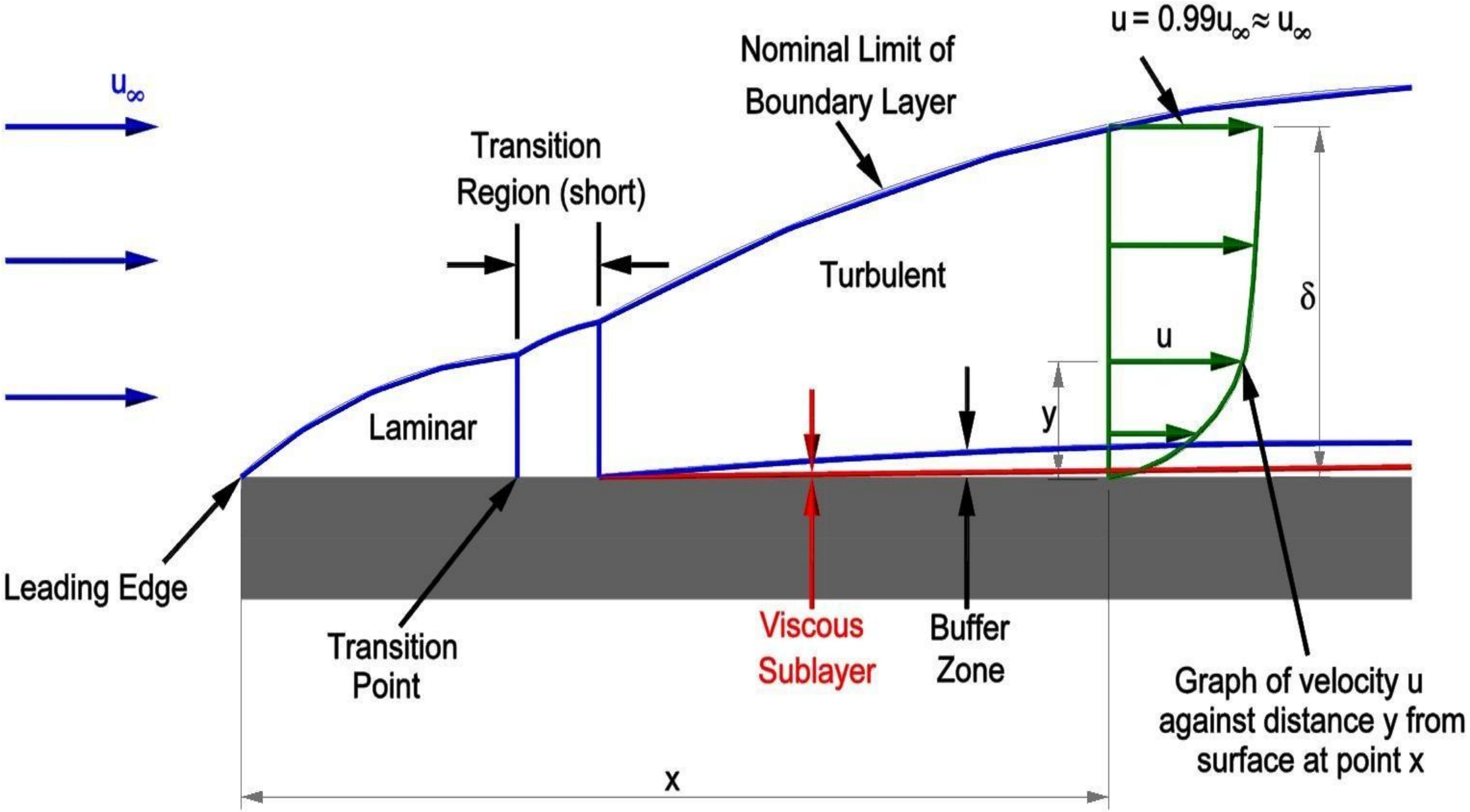


Max values of L/D ratios



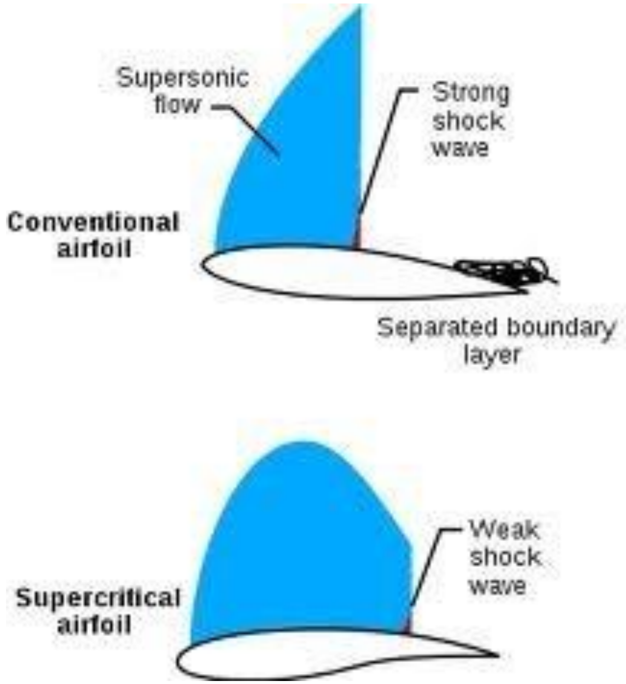


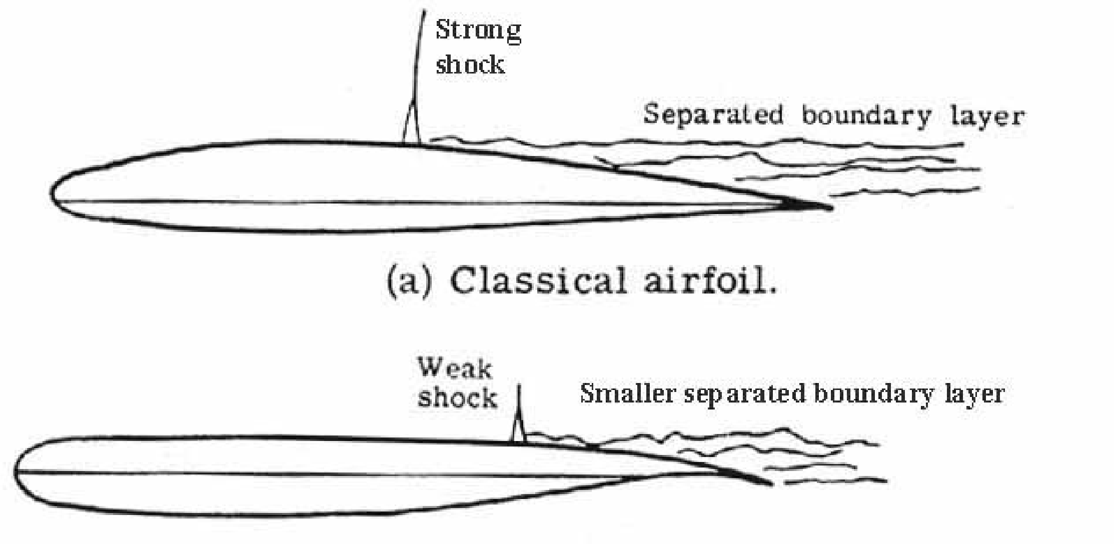
Reynolds No, Boundary Layer Transition and surface roughness



Supercritical Airfoils

- Designed to delay and reduce transonic drag rise, due to both strong normal shock and shock-induced boundary layer separation

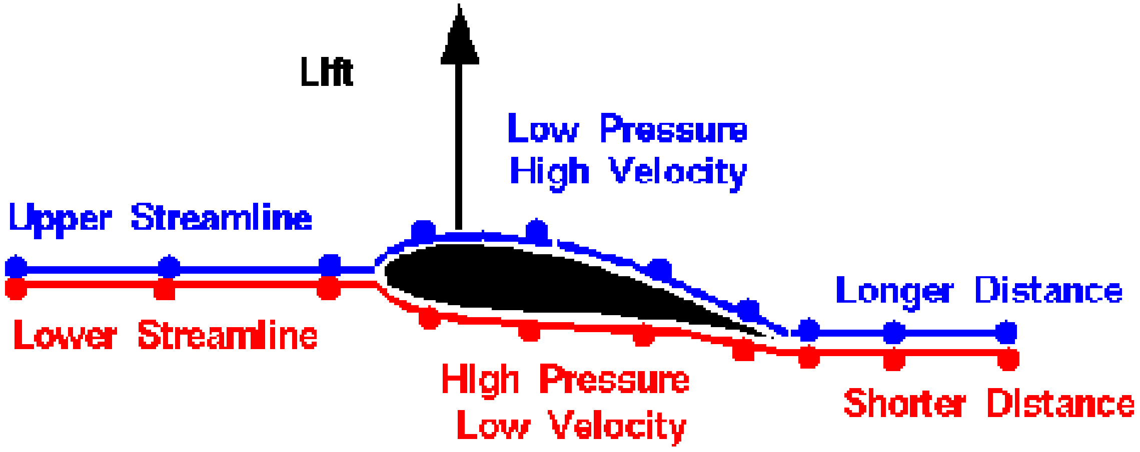




(a) Classical airfoil.
(b) Supercritical airfoil.

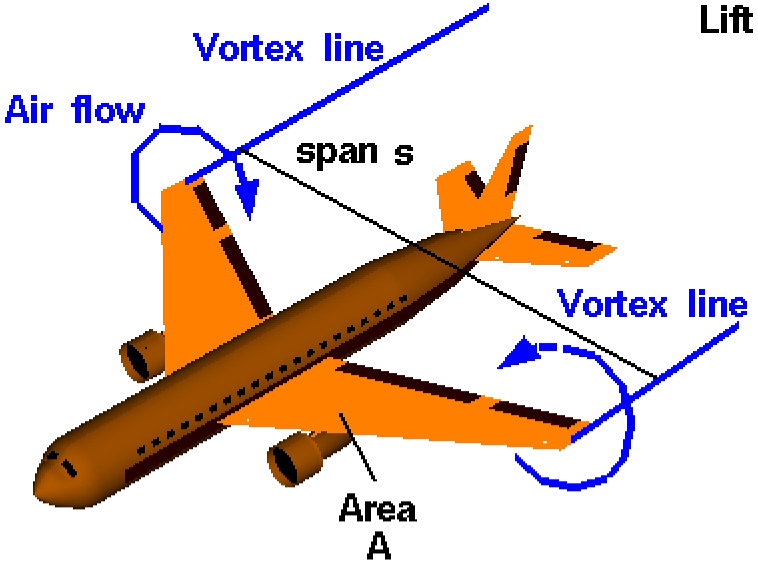
Drag Reduction And lift Augmentation Methods

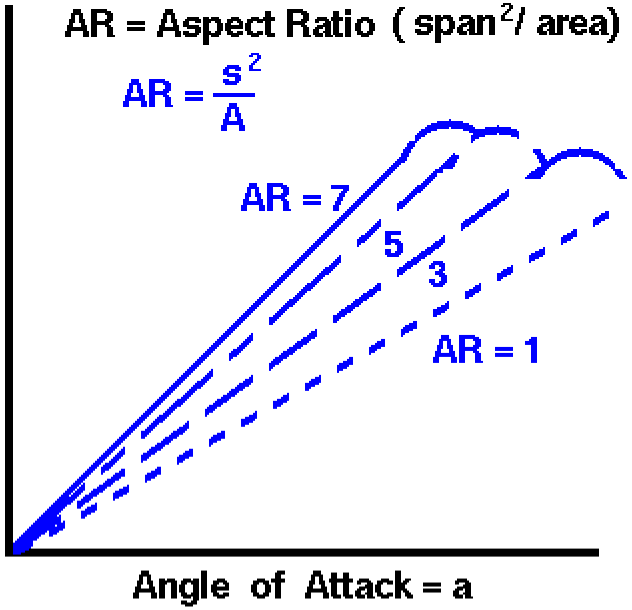
- Many theories have been developed on how a wing generates lift. The most common one is the *"Longer Path Theory"*.
- This theory describes how the shape of the aerofoil produces a pressure difference which generates lift. As the aerofoil is designed in such a way that its upper surface is longer than the bottom, and because the molecules that hit the leading edge must meet again at the trailing edge, the ones that travel on the upper surface do so with greater velocity than the lower



Winglets

Downwash Effects on Lift



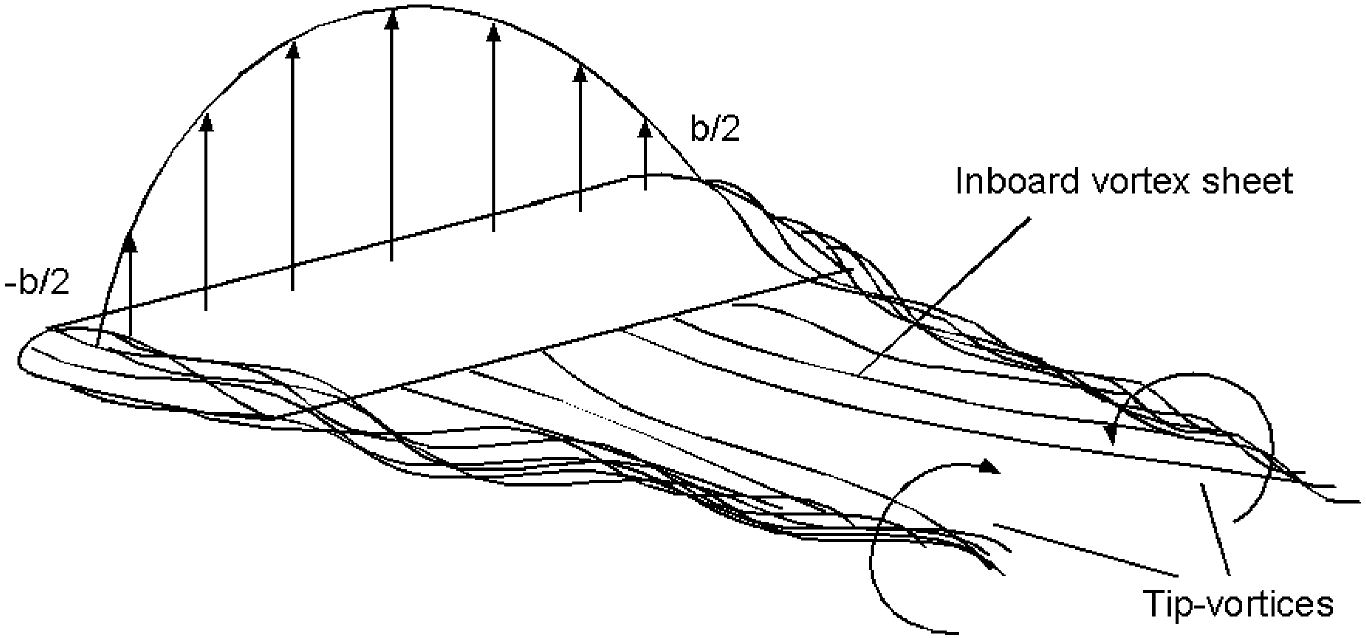


Pressure difference across wing surface causes spillage around wing tips.

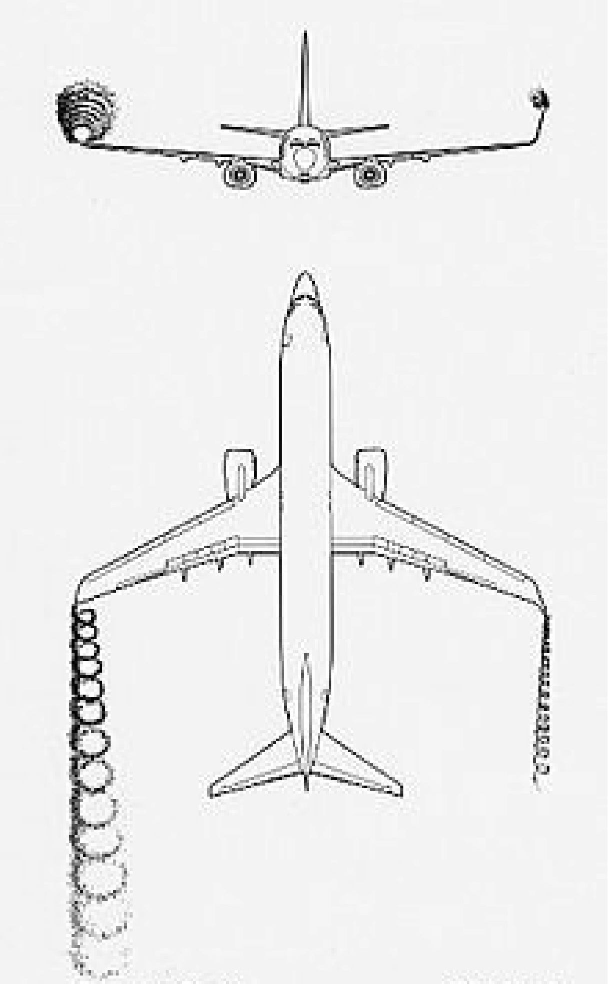
Downwash causes a local induced angle of attack which reduces lift.

Lift Coefficient

$$C_l = \frac{C_{lo}}{1 + \frac{C_{lo}}{\pi AR}}$$


b/2
Inboard vortex sheet
-b/2
Tip-vortices

Winglets



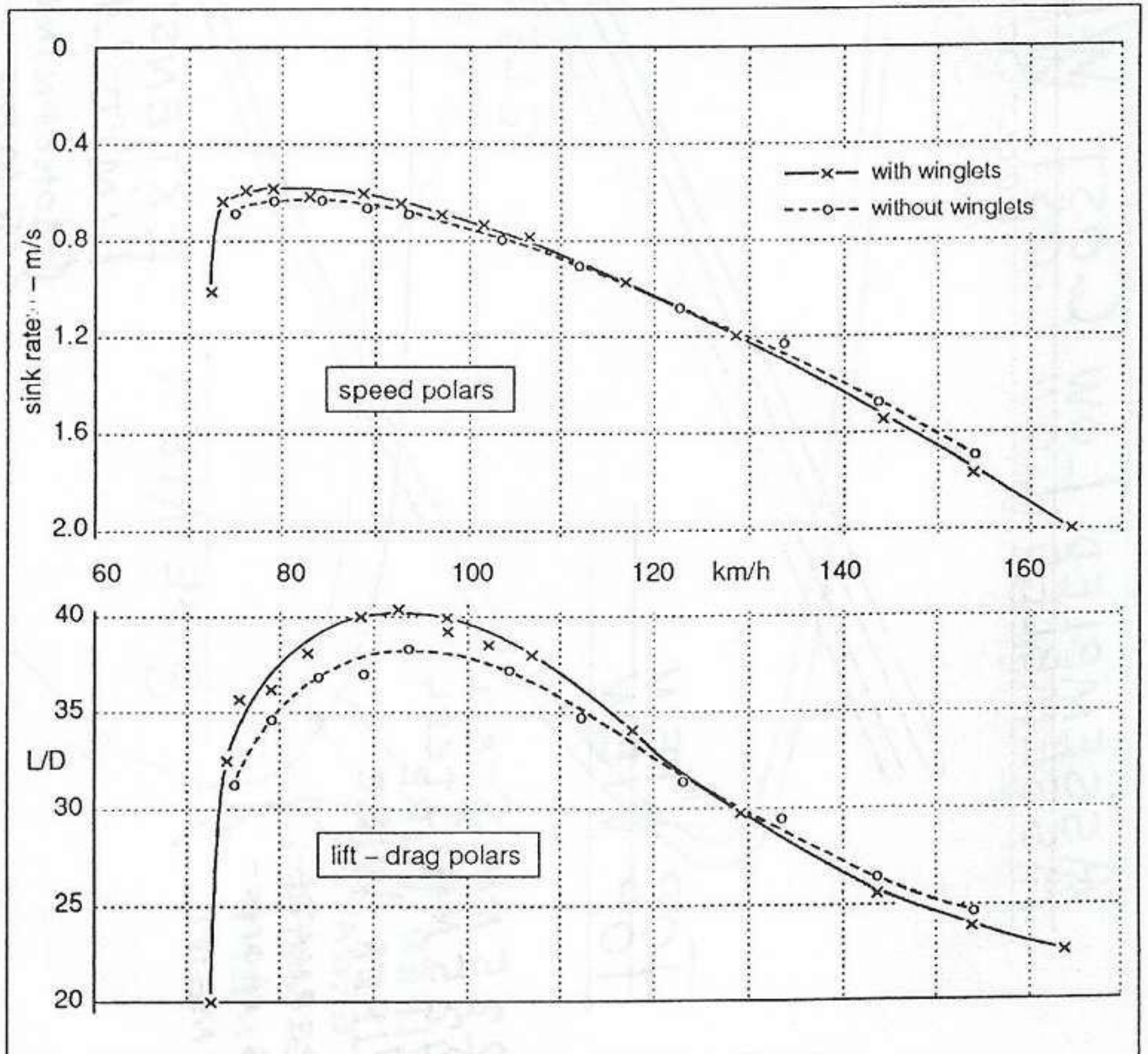


Figure 2 — Influence of winglets on the performance of an ASW–19

UNIT - V

BASELINE DESIGN– STABILITY & CONTROL, PERFORMANCE AND CONSTRAINT ANALYSIS

Stability – Three Axes

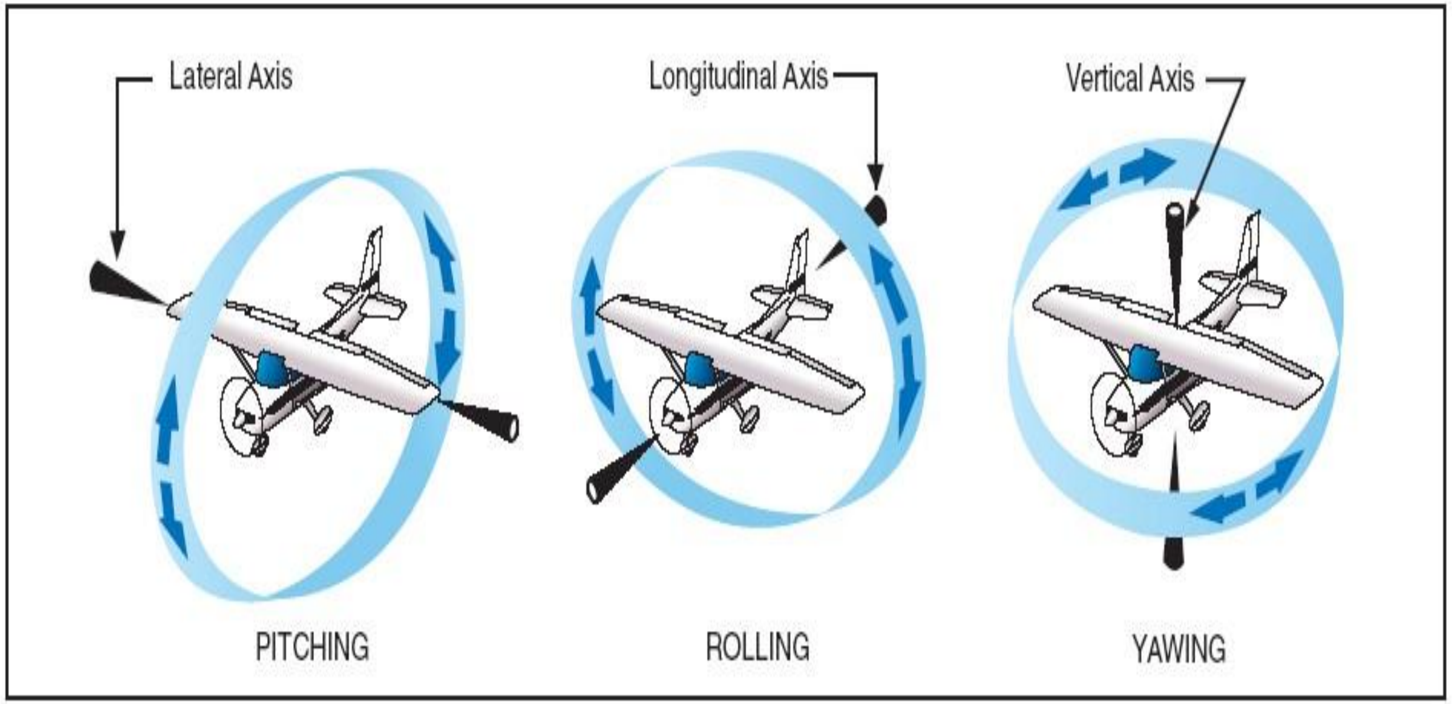


Figure 3-9. Axes of an airplane.

Stability

Terminology:

- Stability
- Maneuverability
- Controllability

Stability

- Static stability – initial tendency

– Positive– initially returns to position before displacement

– Neutral– tendency to remain in displaced position

– Negative (bad thing) – tends to continue away from displaced position in same direction

Stability

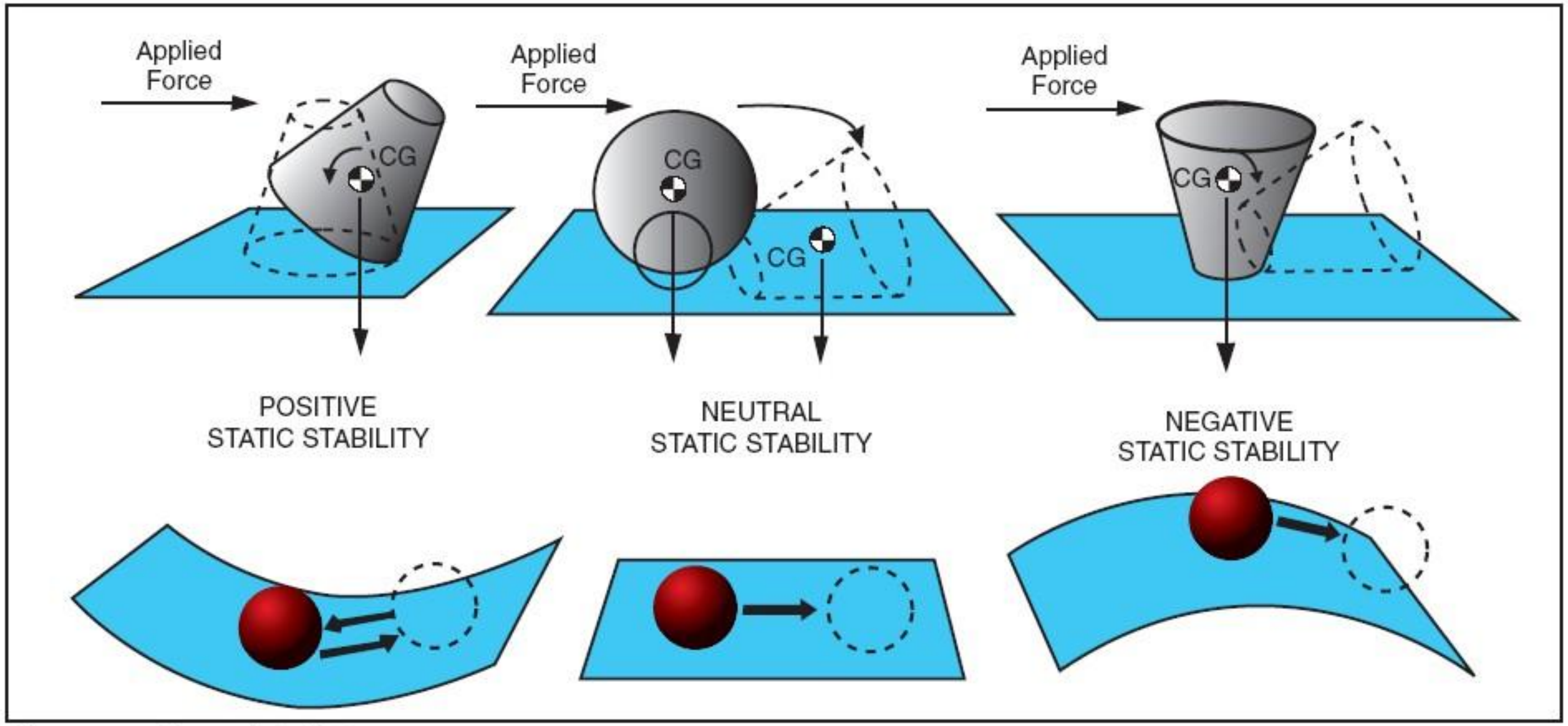


Figure 3-10. Types of stability.

3-10

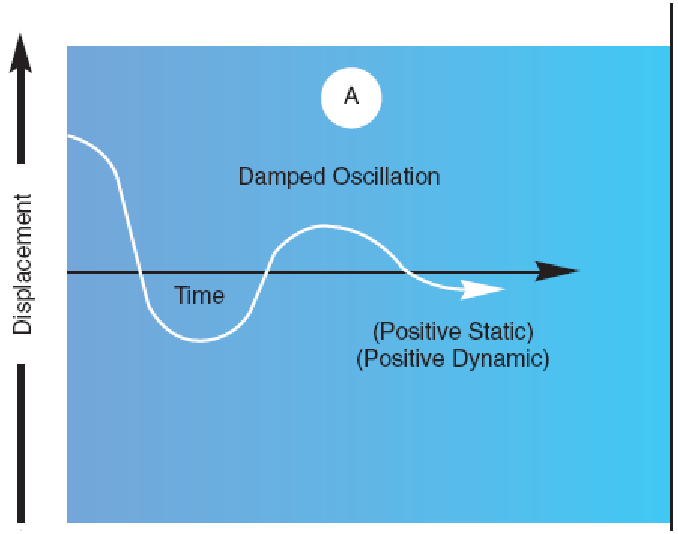
Stability

Dynamic stability

– long-term characteristics of the airplane

– Positive dynamic stability:

– Damped oscillations

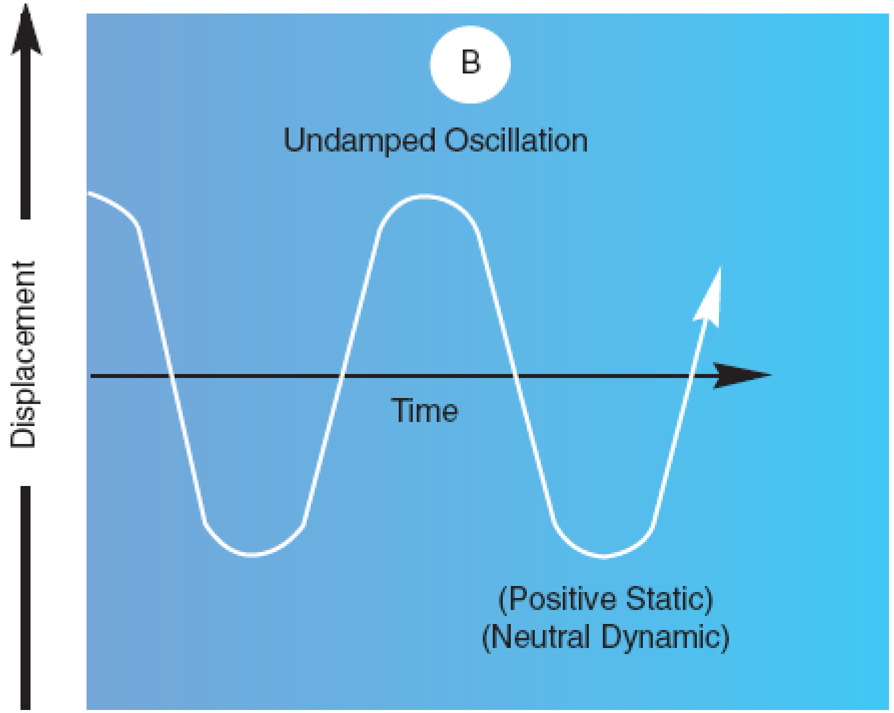


Stability

- Neutral dynamic stability
  - Persistent

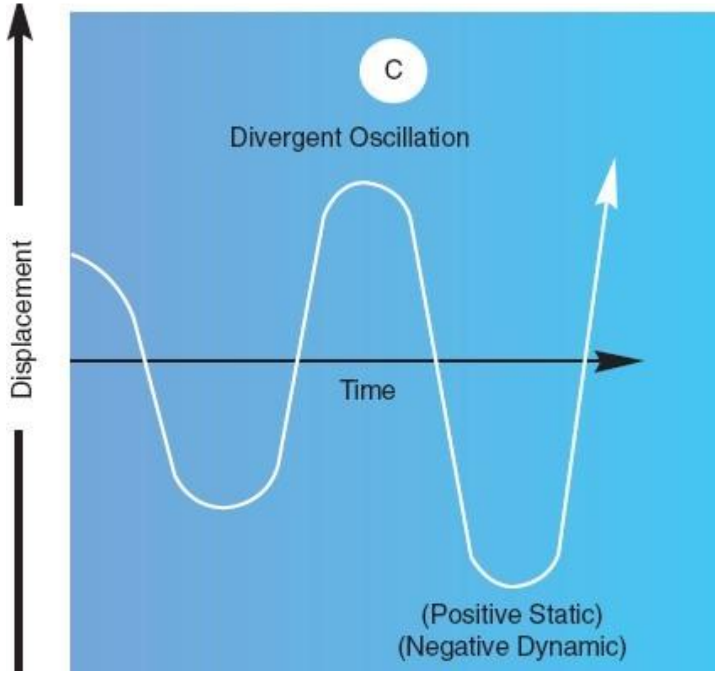
    (phugoid)

     oscillations



Stability

- Negative dynamic stability
  - Increasing (divergent!) oscillations
  - Avoid at all costs.



Stability – how do we get it?

- Longitudinal (Pitch) Stability

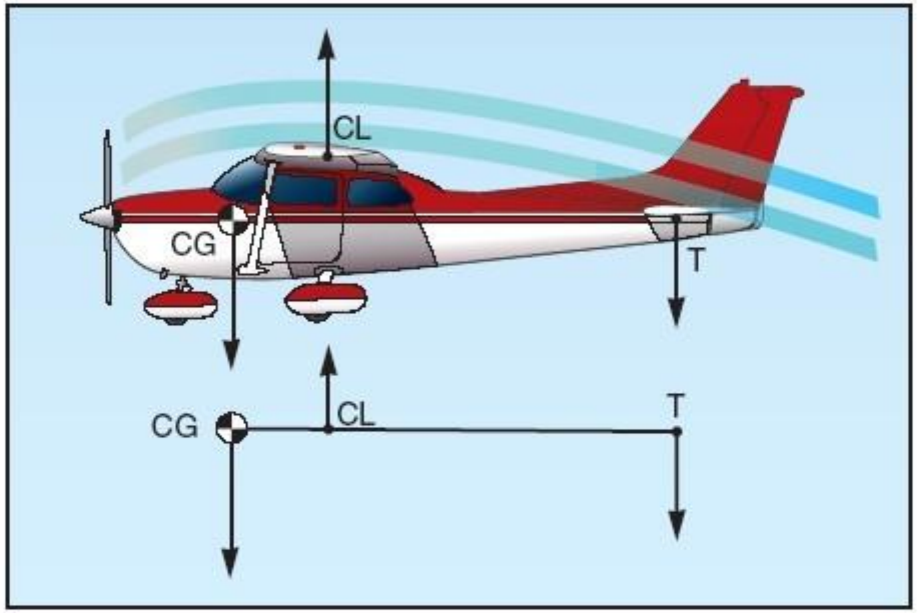


Figure 3-12. Longitudinal stability.

Stability – how do we get it?

- Lateral (roll) stability
- Dihedral
- “When the airplane is banked without turning, it tends to sideslip or slide downward toward the lowered wing. Since the wings have dihedral, the air strikes the low wing at much greater angle of attack than the high wing.”

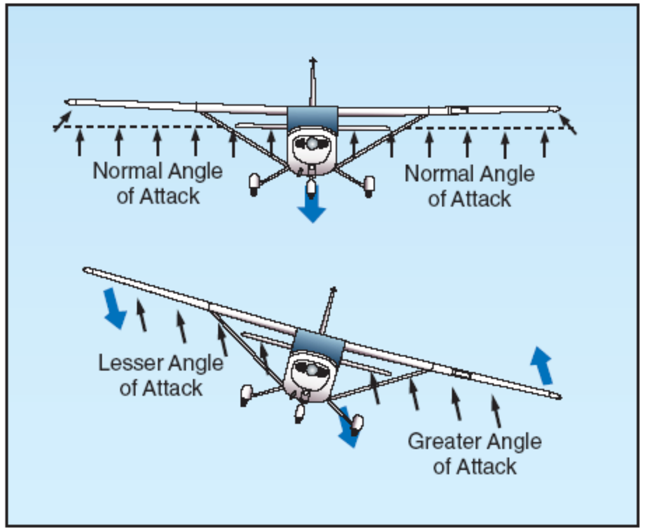
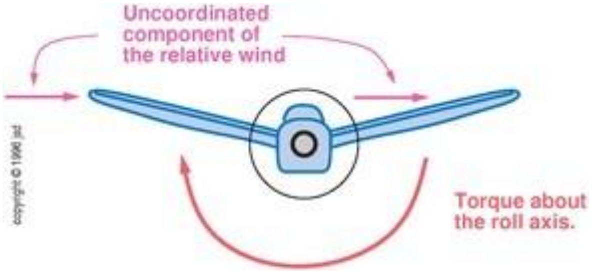


Figure 3-17. Dihedral for lateral stability.



Stability - how do we get it?

- Lateral (roll stability)
  - Keel effect

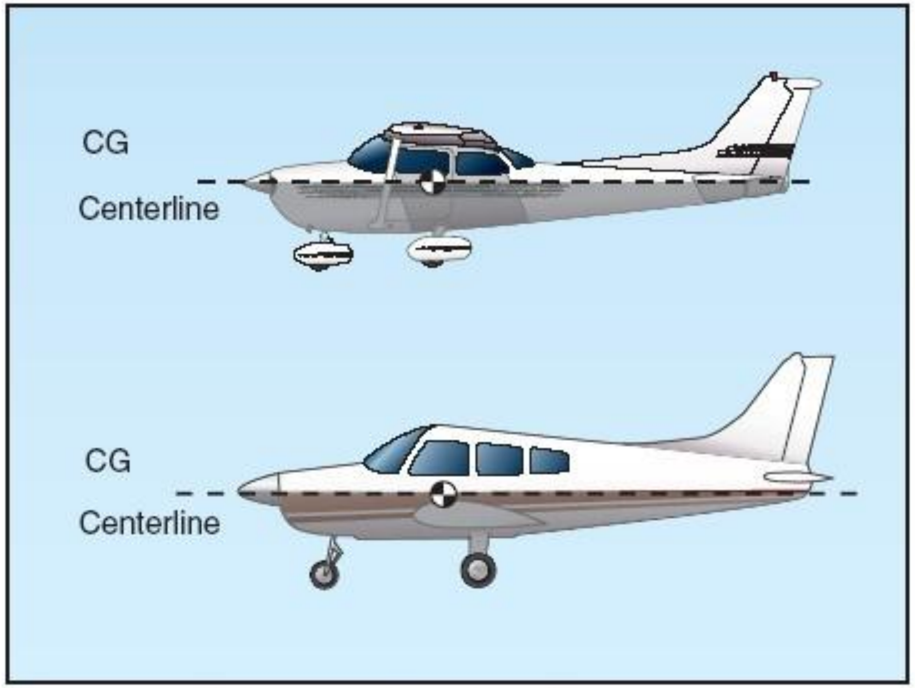


Figure 3-18. Keel area for lateral stability.

Stability - how do we get it?

- Yaw stability
  – Vertical stabilizer.

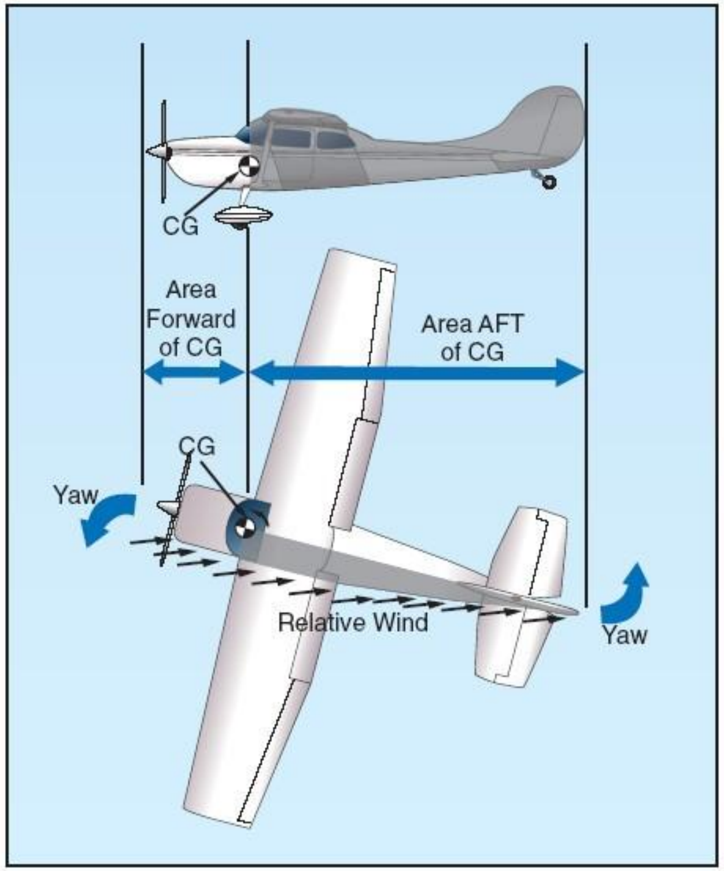


Figure 3-19. Fuselage and fin for vertical stability.

The Turn

- Airplanes turn by creating a horizontal component of lift.
- Airplanes must be banked to turn.

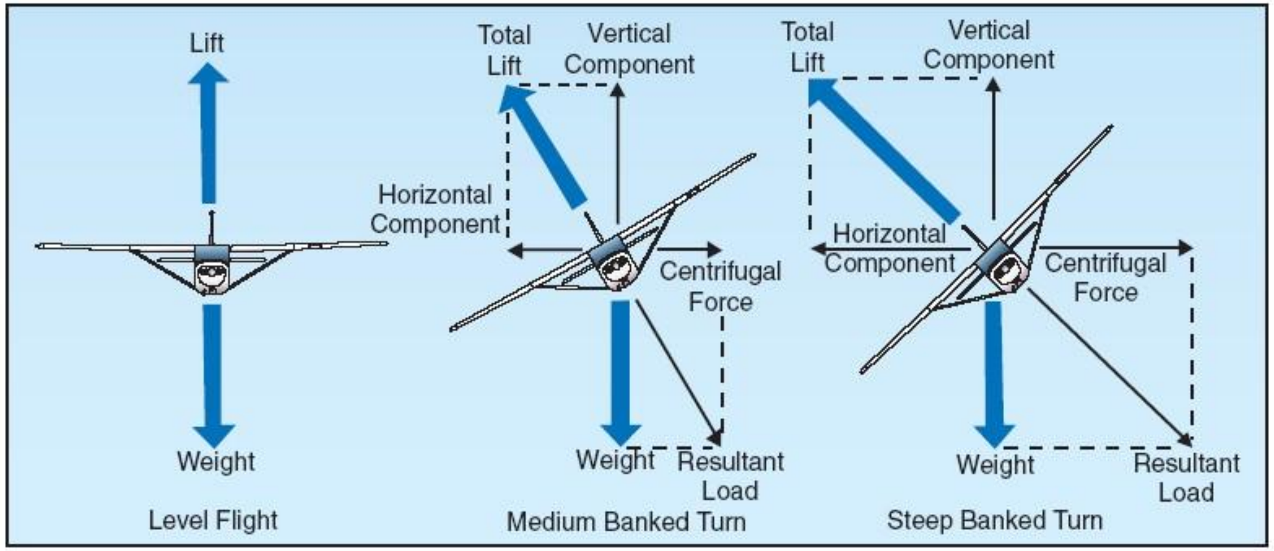


Figure 3-20. Forces during normal coordinated turn.

The Turn

- Total lift must be increased.
- Increase back pressure during a turn
- More bank = more back pressure required

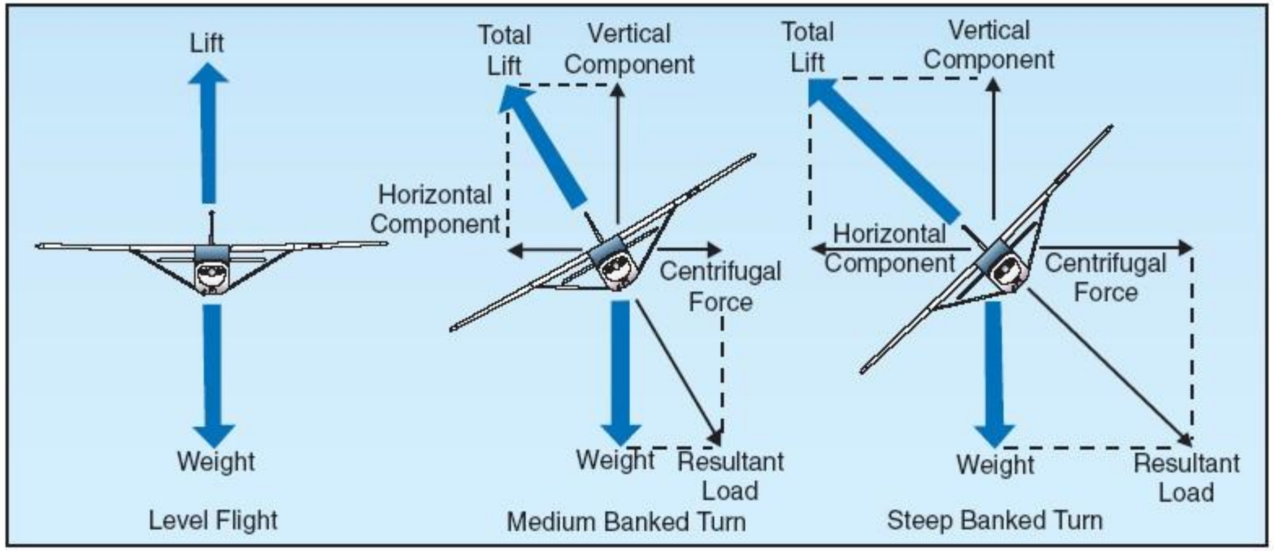


Figure 3-20. Forces during normal coordinated turn.

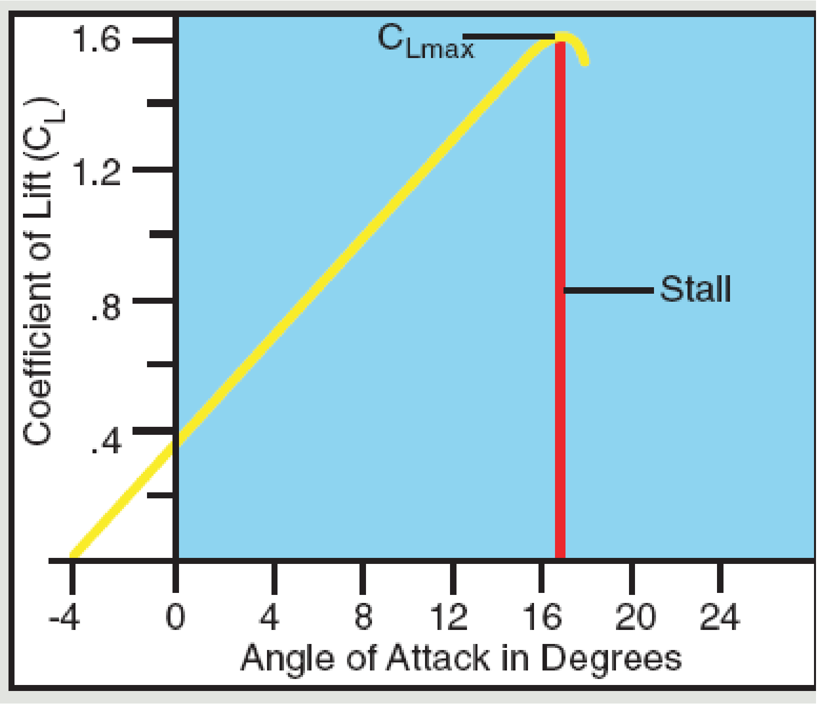
The stall

- Stalls occur by exceeding the critical angle of attack
- Stalls can occur at any attitude and any airspeed
- “Stall speed” of an aircraft refers to straight-and-level, unaccelerated flight

The spin

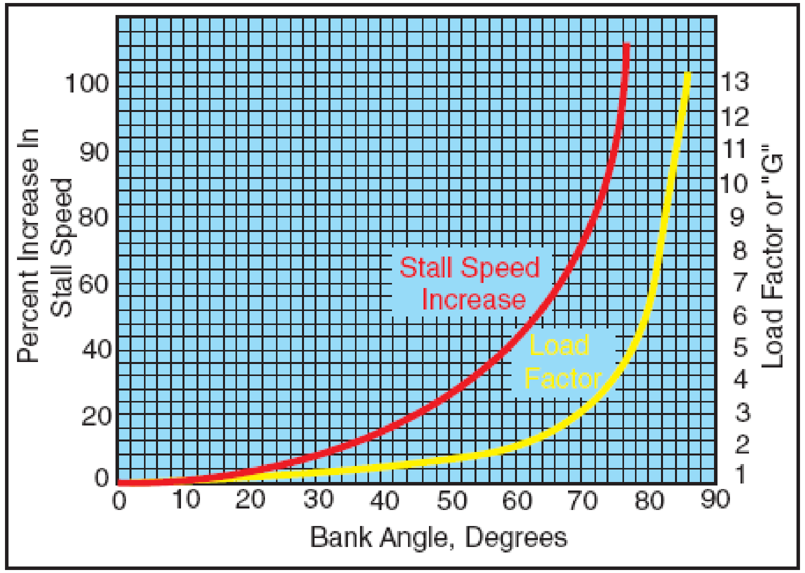
The spin is the result of stalling in "uncoordinated" flight. (more later)

Both wings are stalled…one wing is "more stalled" than the other:



Load Factor

- Ratio of “weight” of the airplane (e.g., on the ground) to lift
- Load factor is 1 in S&L
- Any acceleration affects load factor



Maneuvering Speed (VA)

- Fastest speed an aircraft can travel when a full deflection of the controls is possible.
- Increases with increased weight.

Turning tendencies

- Torque reaction
- Corkscrewing effect of slipstream
- P-factor (asymmetric disc loading)
- Gyroscopic action of propeller

Corkscrew effect (spiraling slipstream)

- Propwash tends to spiral around fuselage
- Vertical stabilizer is on the top of the airplane, not the bottom
- A left-yawing tendency

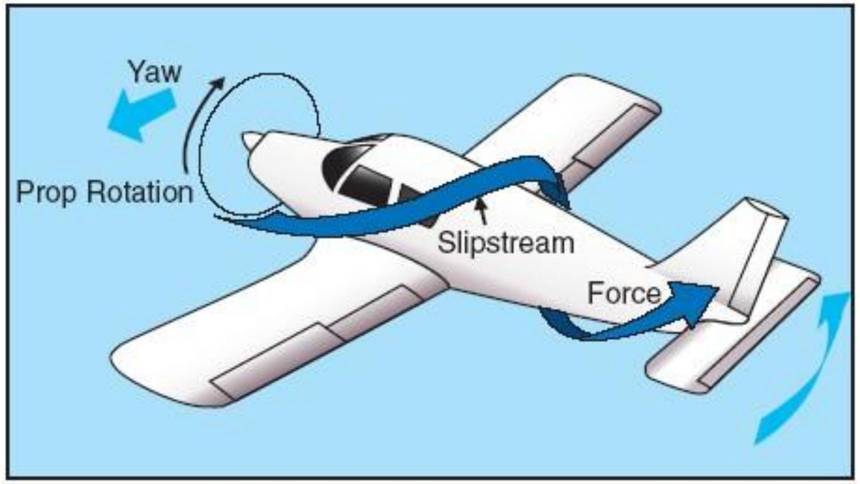
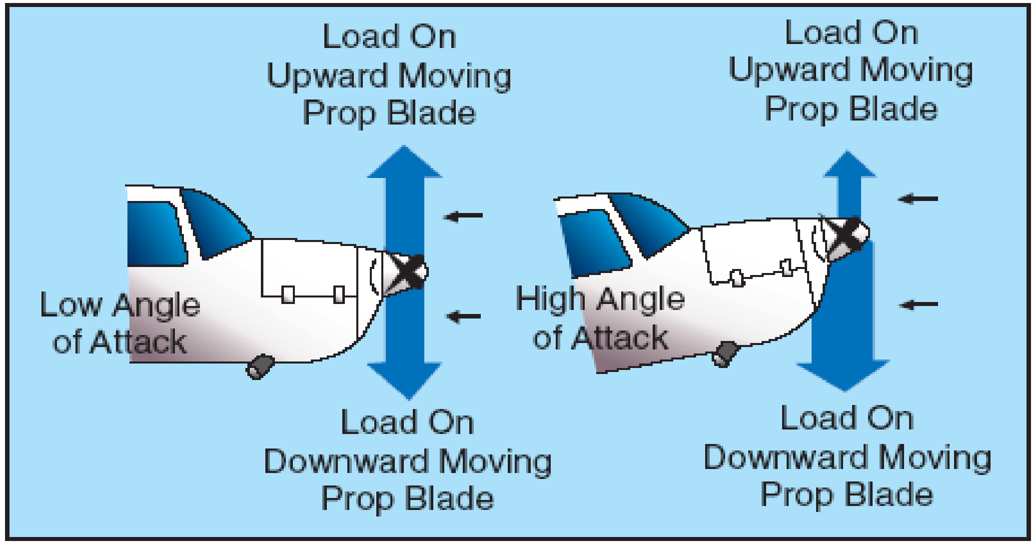


Figure 3-31. Corkscrewing slipstream.

P-factor

- Downward moving blade takes a bigger “bite” of air than upward moving blade



Gyroscopic precession

- "90 degrees ahead in the direction of rotation"
- Occurs during pitching (e.g. rotation about the lateral axis)
- Right-yaw tendency when the nose is rising
- Left-yaw tendency when the nose is falling

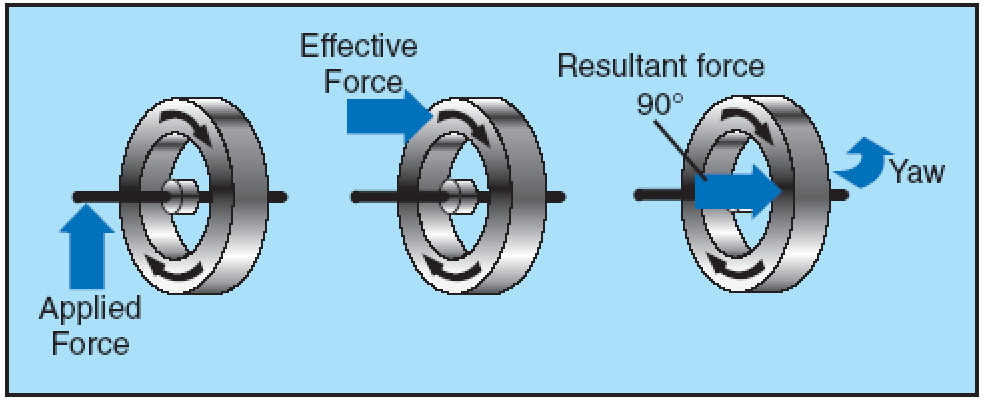


Figure 3-32. Gyroscopic precession.

Gyroscopic precession

- A left-turning tendency during takeoff in taildragger aircraft only.

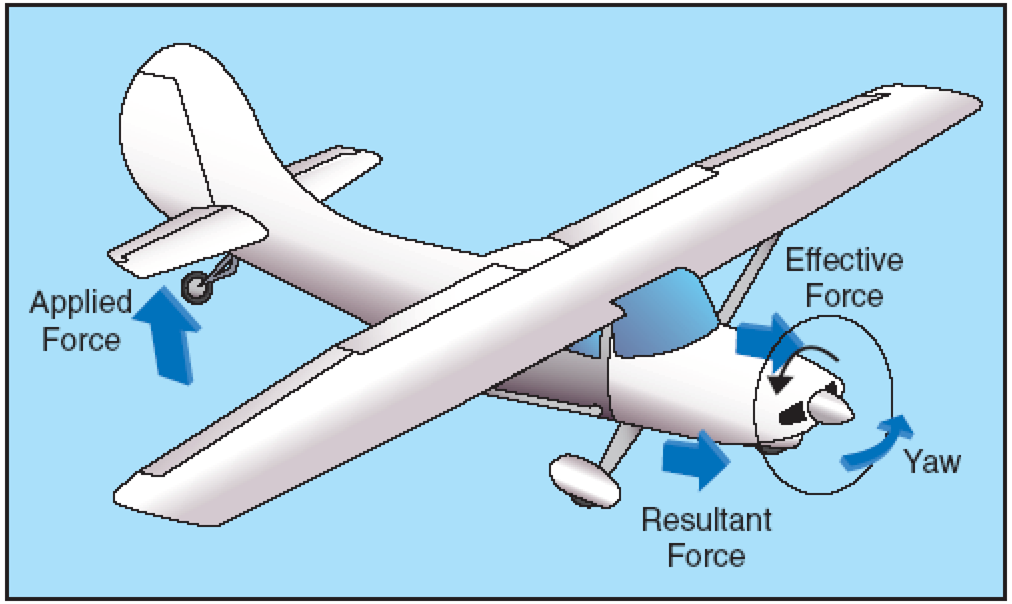
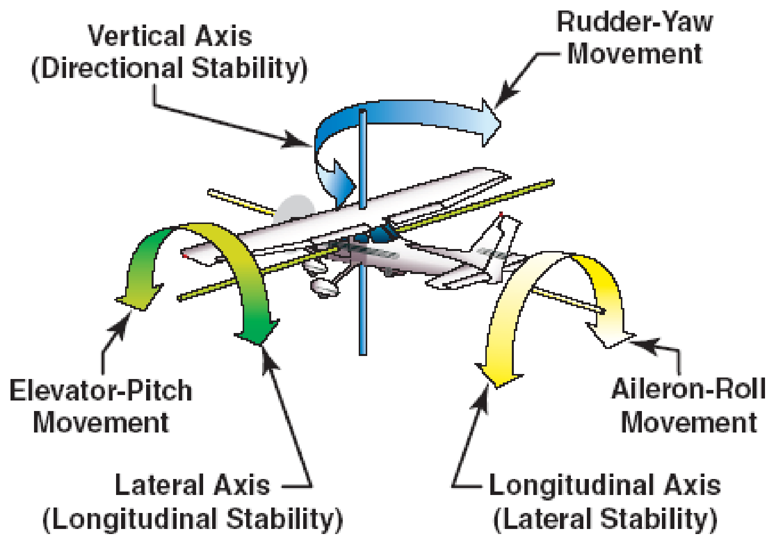


Figure 3-33. Raising tail produces gyroscopic precession.

Primary Flight Controls

- Aileron
- Elevator
- Rudder



PRIMARY CONTROL SURFACE	AIRPLANE MOVEMENT	AXES OF ROTATION	TYPE OF STABILITY
Aileron	Roll	Longitudinal	Lateral
Elevator/ Stabilator	Pitch	Lateral	Longitudinal
Rudder	Yaw	Vertical	Directional

Adverse Yaw

What happens when an airplane banks?

- Left-bank: left aileron up, left wing down. Right wing has more lift more drag.
- Airplane tends to yaw in opposite direction of desired turn.
- Primary function of the rudder is to control yaw.
- Use rudder in the direction of the deflection of the ailerons.