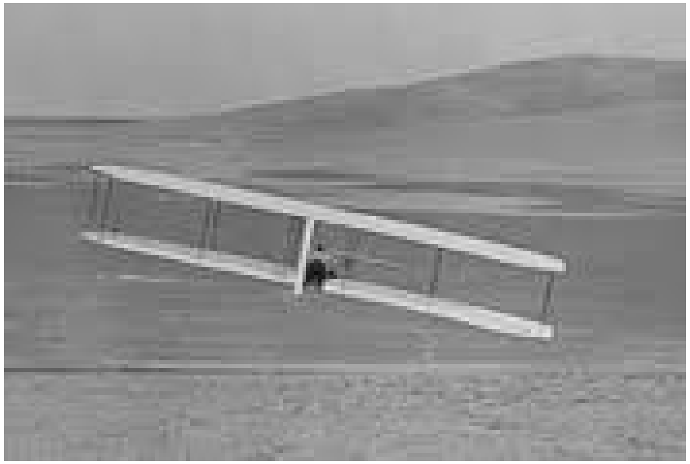
DUBLIN
GLIDING CLUB

PRINCIPLES OF FLIGHT

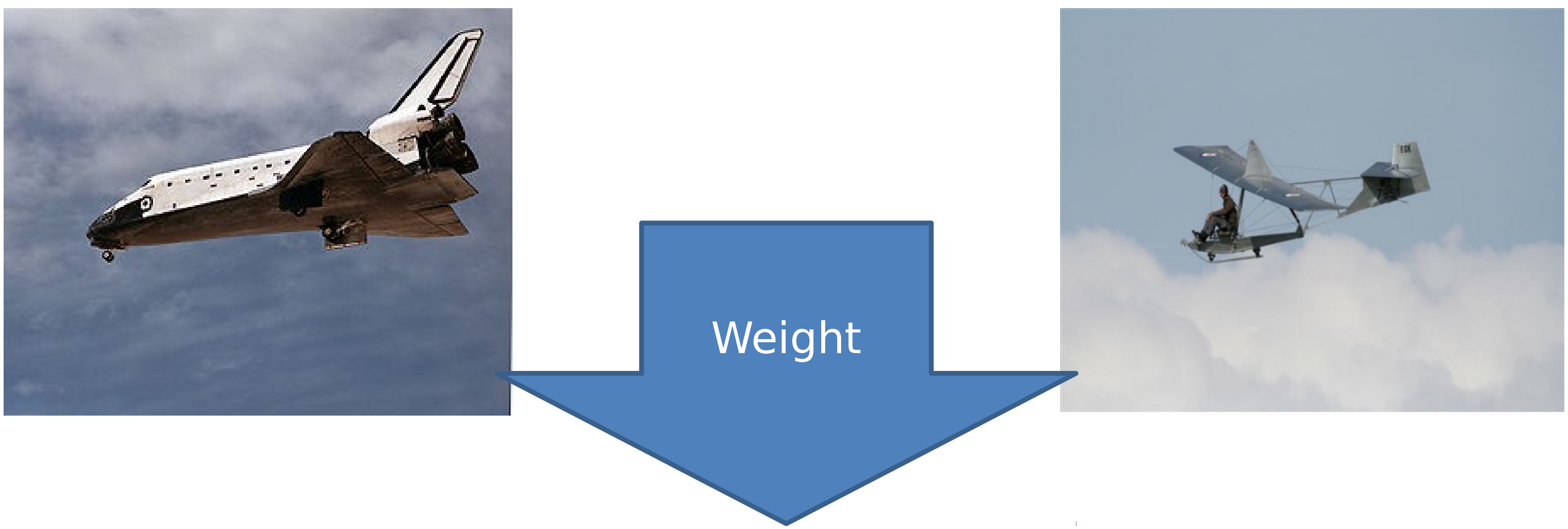


Syllabus …

- How does a Glider Stay in the Air?
- Forces Acting on a Glider
- Basics
- Lift
- Drag
- Stalling
- Spinning
- Control
- Stability
- Glider Performance
- Flight Envelope

How Does a Glider Stay in the Air?...

- A glider flies because the wings generates sufficient **Aerodynamic Force** (i.e. **Lift**) to counterbalance the **Weight** of the aircraft.



Say Again?...

“The wing keeps the airplane UP

by pushing the air DOWN”

- Wolfgang Langewiesche, Stick and Rudder (1944)

That's not flying,

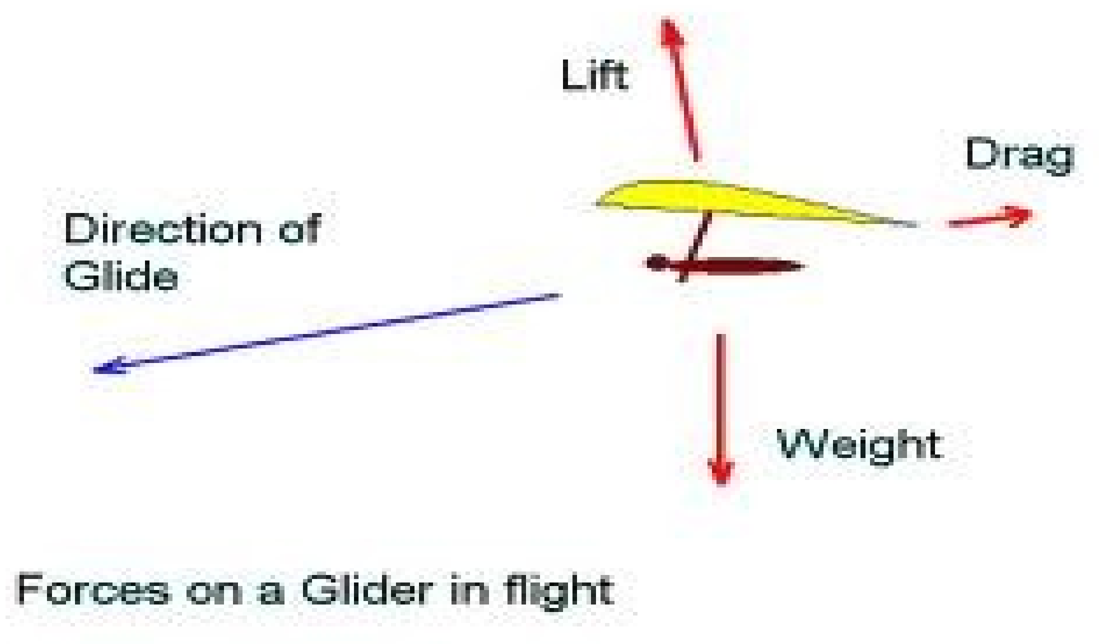
That's just falling with style!"

- Woody, regarding Buzz Lightyear,

in the 1996 movie Toy Story

Forcing Acting On A Glider …

The Aerodynamic Force is spilt into two vectors: **LIFT** and **DRAG**



Back To Basics…

Newton's Laws

1. A body at rest, or in steady motion, will remain at rest (or in steady motion) unless subject to an externally applied force,

2. The acceleration of an object depends directly on the force acting upon the object, and inversely upon the mass of the object, i.e. **F = M x A**

3. For every action, there is an equal and opposite reaction

Back To Basics…

Coanda Effect

Due to viscosity, a moving fluid will adhere to a gently curved surface.

Bernoulli's Principle

Pressure in a fluid is inversely proportional to its speed.

Air Compressibility

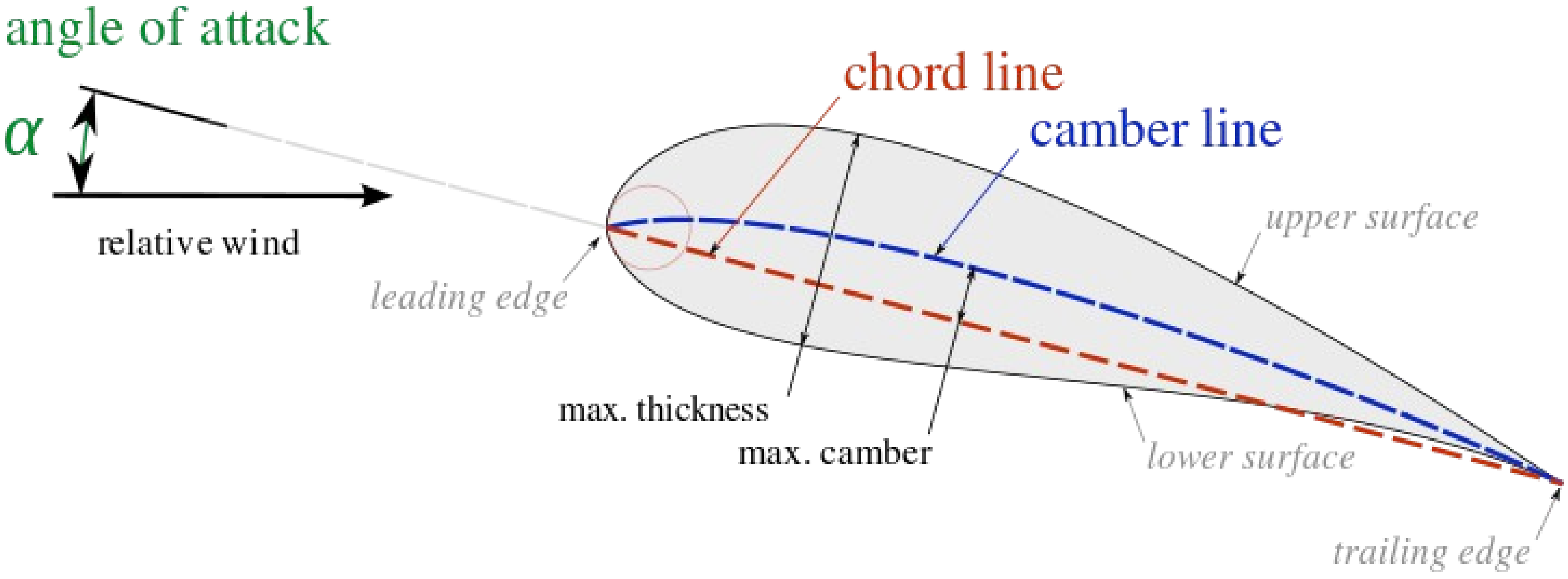
At velocities < 0.5M (~350kts), air can be regarded as an incompressible fluid.

Weight…

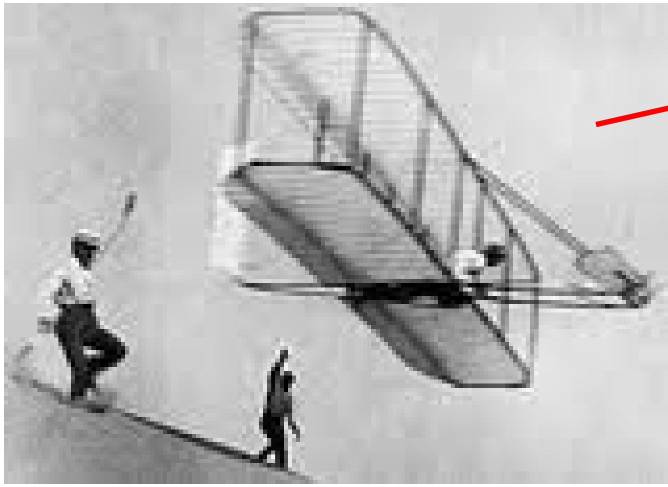
Weight: The force caused by gravitational attraction to the earth (1G = 9.81 m/s2).

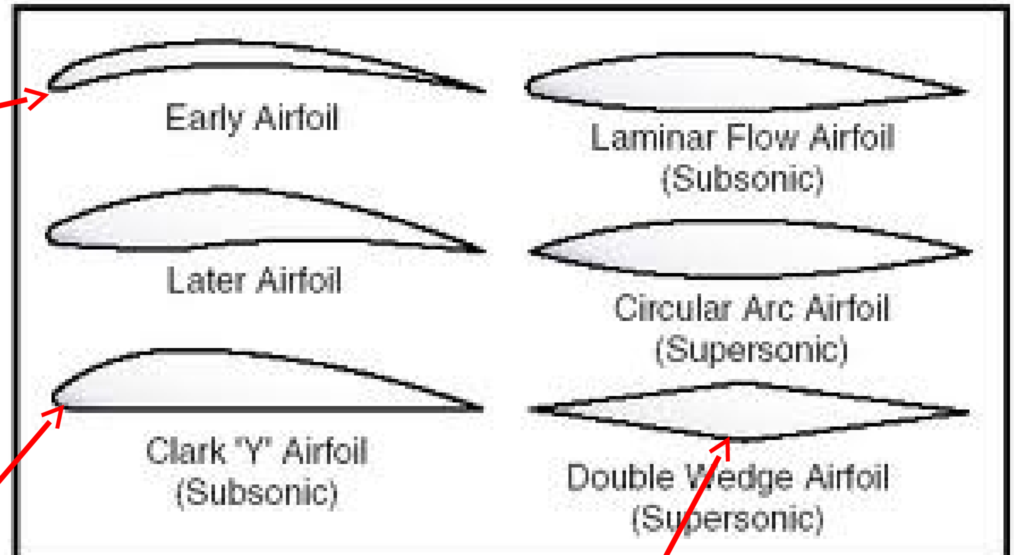
Weight depends on the mass of the airplane itself, plus its payload.

Aerofoil Section…



Aerofoil Sections …





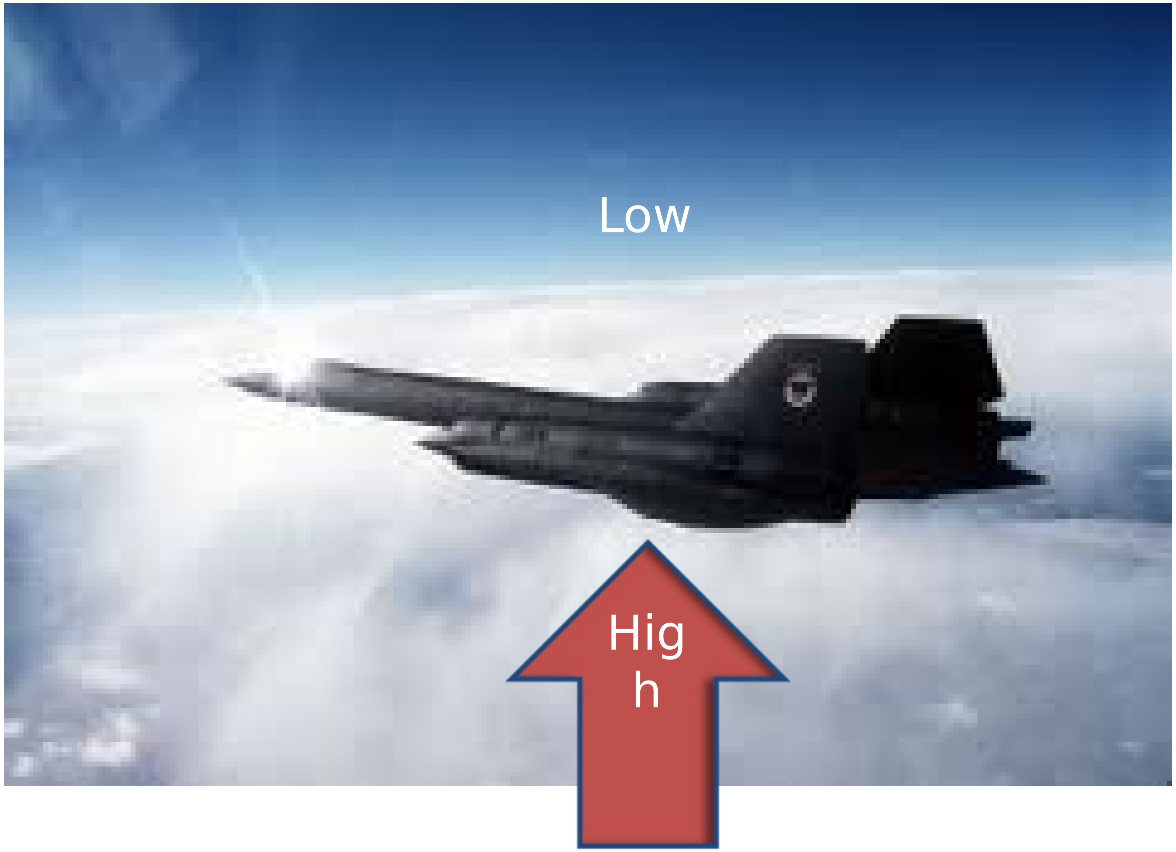
Lift…

Lift is the aerodynamic force produced by the wings which acts perpendicular to the relative airflow (i.e. that airflow flowing exactly opposite to the direction of travel of the aircraft).

Lift is created by the motion (i.e. velocity) of the aircraft through the air.

The flow of air across the wing generates an area of Low Pressure above the wing and an area of High Pressure below the wing. This pressure differential generates **Lift**.

Pressure...



Lift ...

Three Interlinking Effects:

- Deflection
- Bernoulli
- Circulation

Deflection…

Deflection: The oncoming airflow is deflected downwards by the wing (Downwash).
The airflow Reacts to this by pushing the wing upwards, thus creating Lift. (Newton's Third Law).

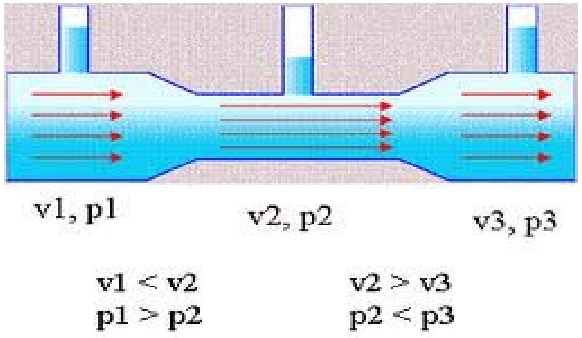
Bernoulli…

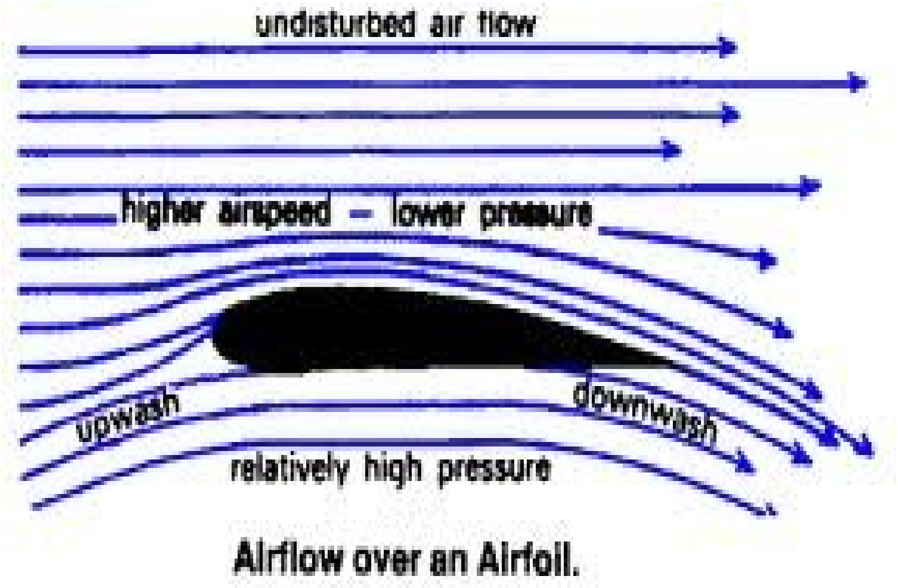
Bernoulli's Principle: P + (1/2 ρV2) = Constant

P = Pressure

ρ = Density

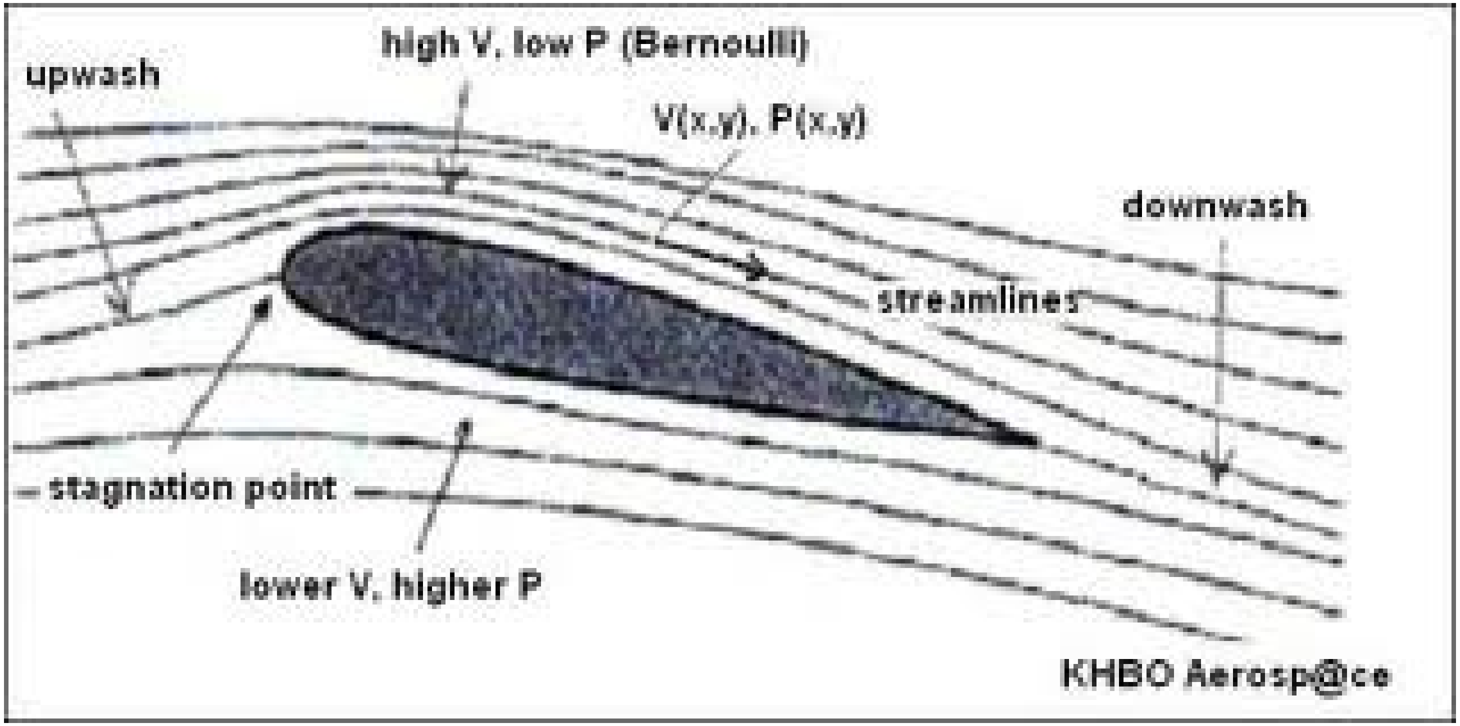
V = Velocity





Downwash & Bernoulli …

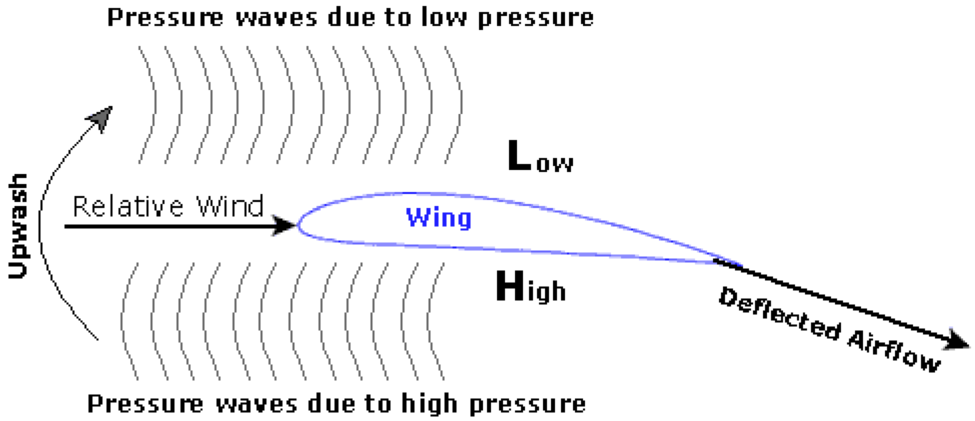
Downwash & Bernoulli



Circulation …

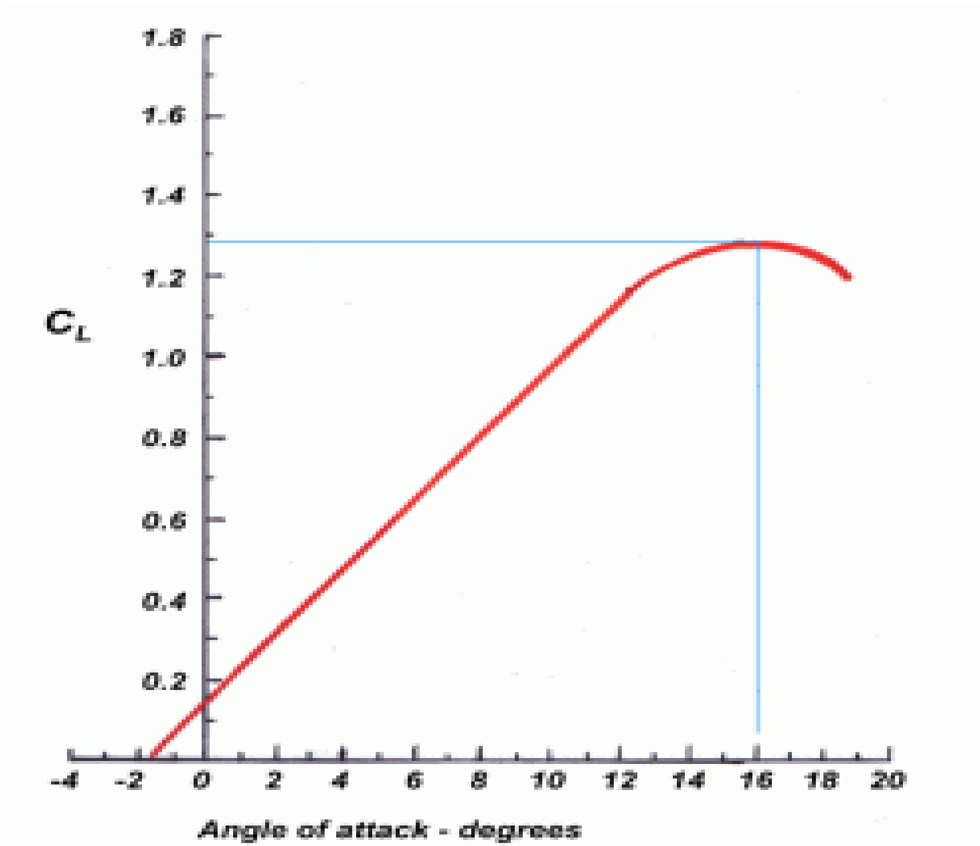
- **Circulation:**

Air flows from areas of high pressure to areas of low pressure. So, the high pressure area below the wing creates pressure waves that cause the air below the wing to start moving forward to a location where the pressure is lower (because the air ahead of the wing is at atmospheric pressure.)
At the same time the low pressure above the wing causes air ahead of and above the wing to start moving rearward, as shown.
As a result an upwash ahead of the wing is created, as shown. The process that creates the upwash is known as "circulation".



Lift Curve ….

Lift: L = ρ V2ClS/2



L = Lift

ρ = Air density

V = Velocity

Cl = Lift Co-efficient

S = Wing area

Lift Distribution….

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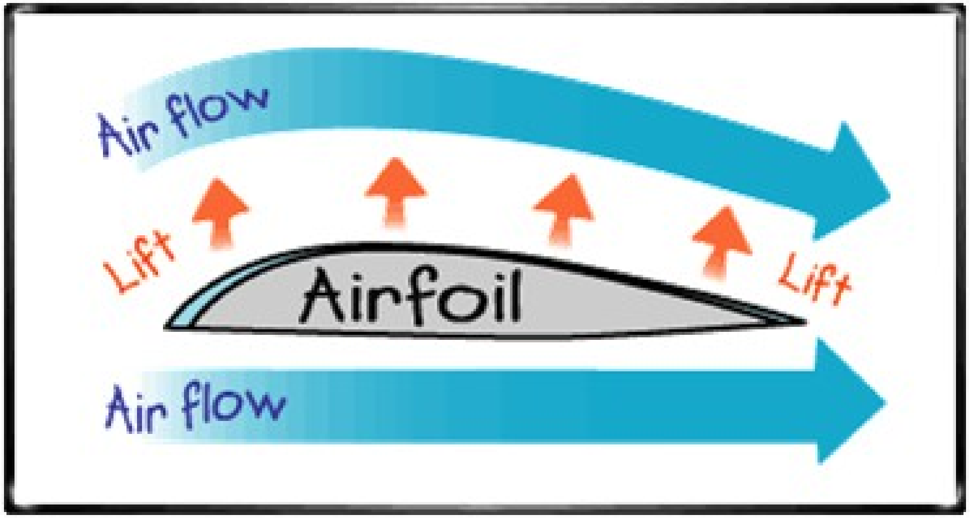


1/3

Drag…

Drag: As an aircraft moves through the air, the air opposes its motion, creating drag

Drag acts in the opposite direction of the aircraft's flight (i.e. opposite to the relative airflow)

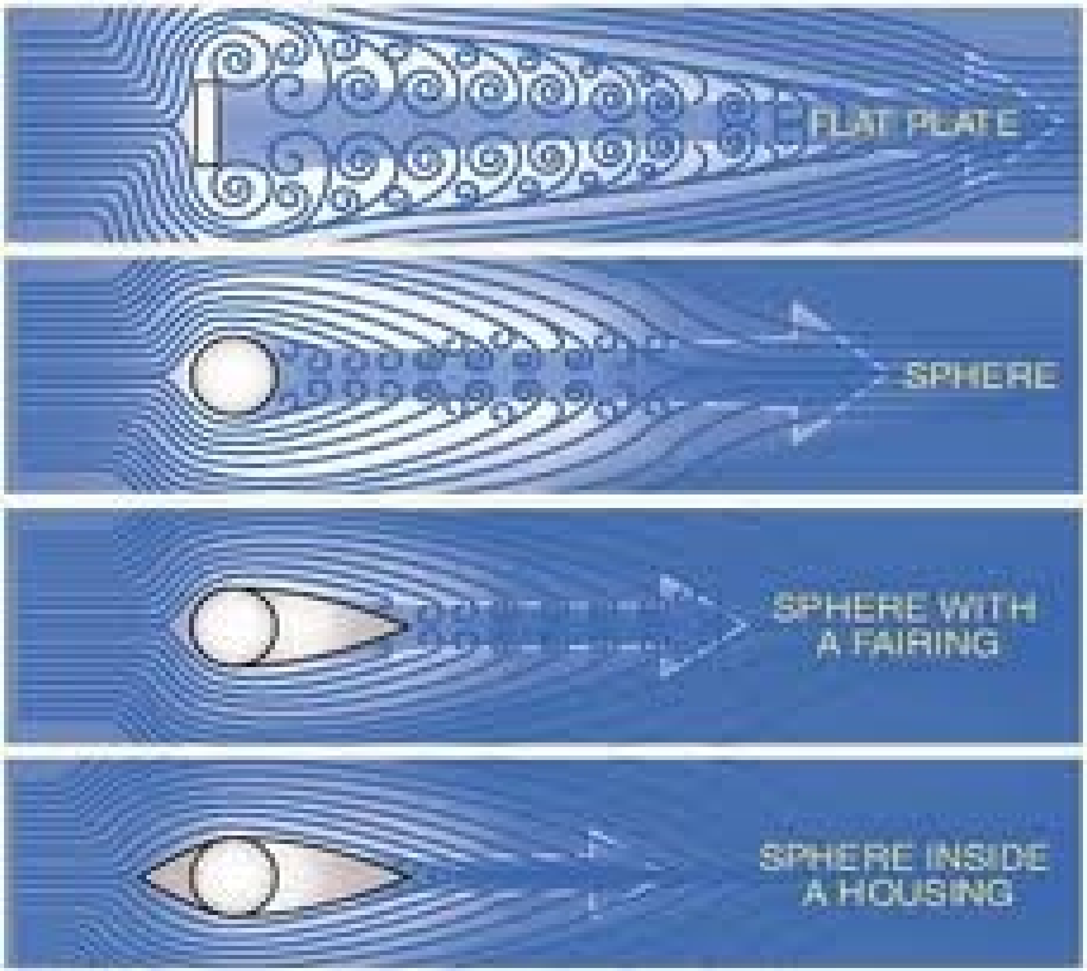
Drag...

Profile Drag

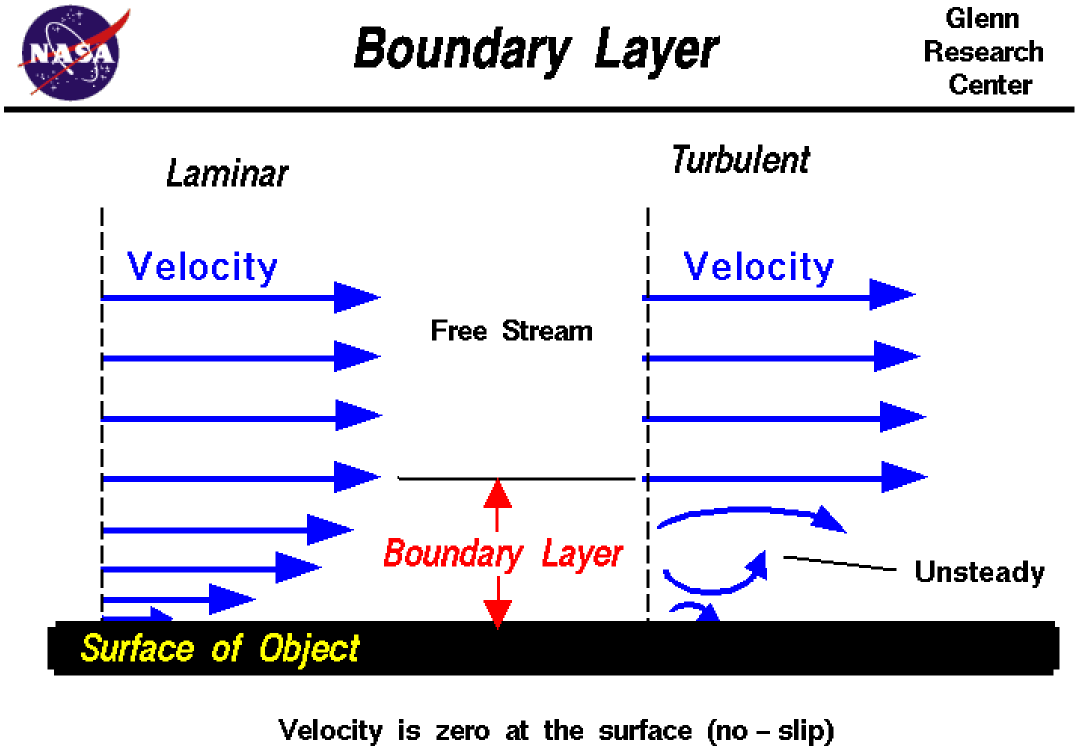
- Form Drag
- Skin Friction Drag
- Interference Drag

Induced Drag

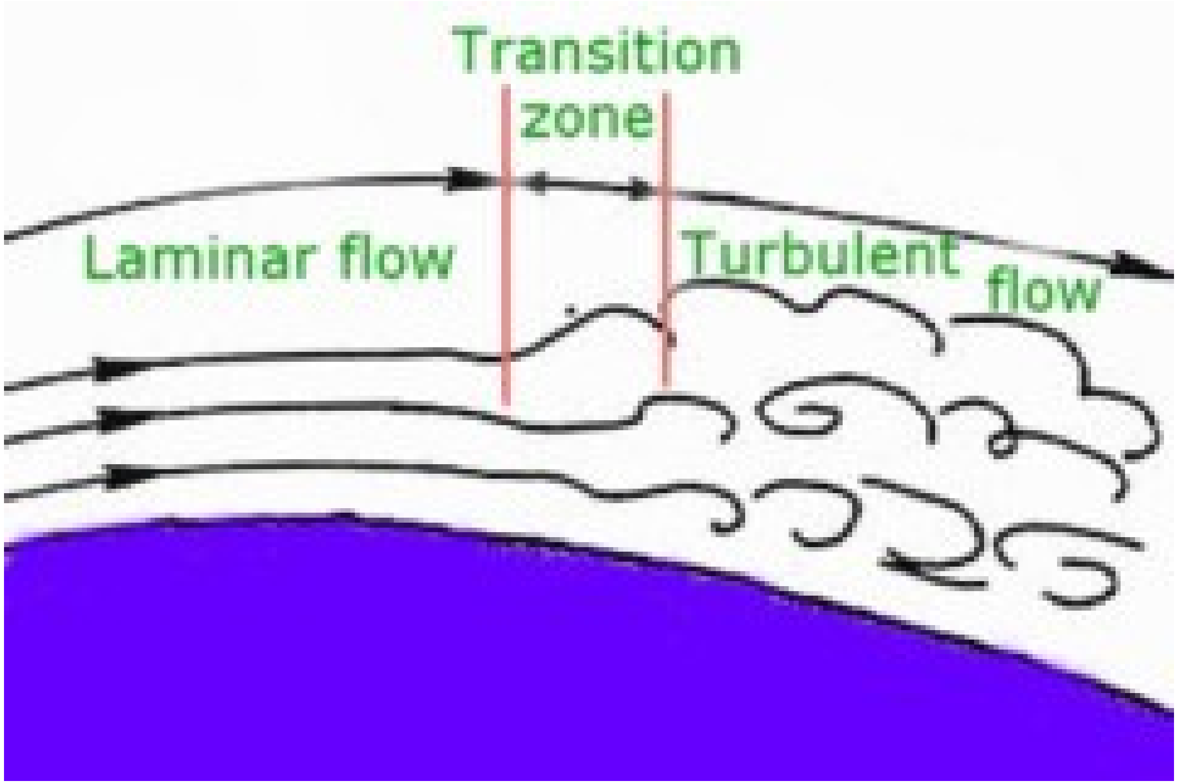
Form Drag...


FLAT PLATE
SPHERE
SPHERE WITH
A FAIRING
SPHERE INSIDE
A HOUSING

Skin Friction Drag…



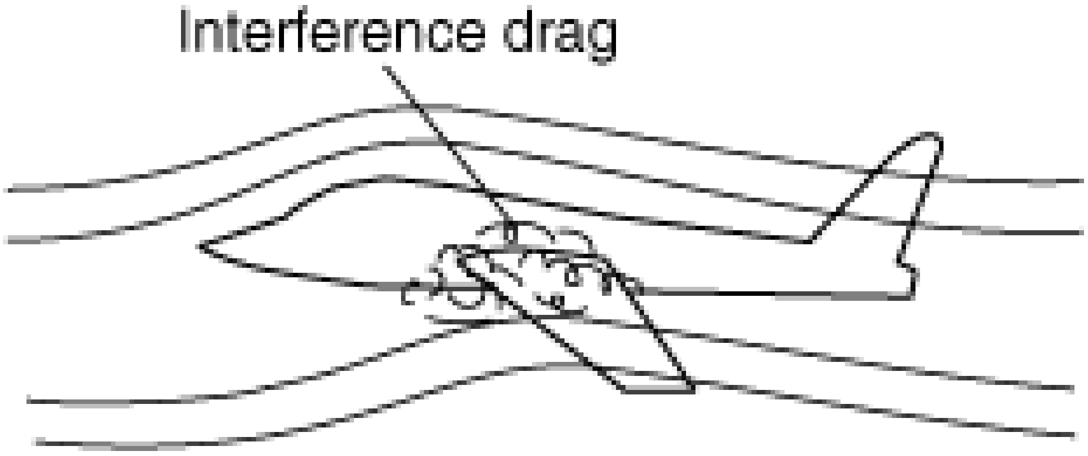
Boundary Layer …



Interference Drag…

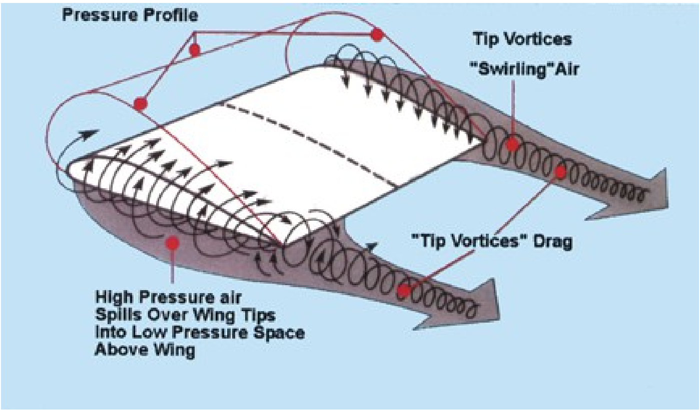
Two or more airflows flows Interacting:

- Decrease in lift
- Boundary Layer Disturbance



Induced Drag…

Induced drag is the drag created by the vortices at the tip of an aircraft's wing. The high pressure underneath the wing causes the airflow at the tips of the wings to curl around from bottom to top in a circular motion. This results in a trailing vortex.
The circular motion creates a change in the angle of attack near the wing tip which causes an increase in drag. The greater the angle of attack up to the critical angle (where a stall takes place), the greater the amount of lift developed and the greater the induced drag.



Induced Drag...

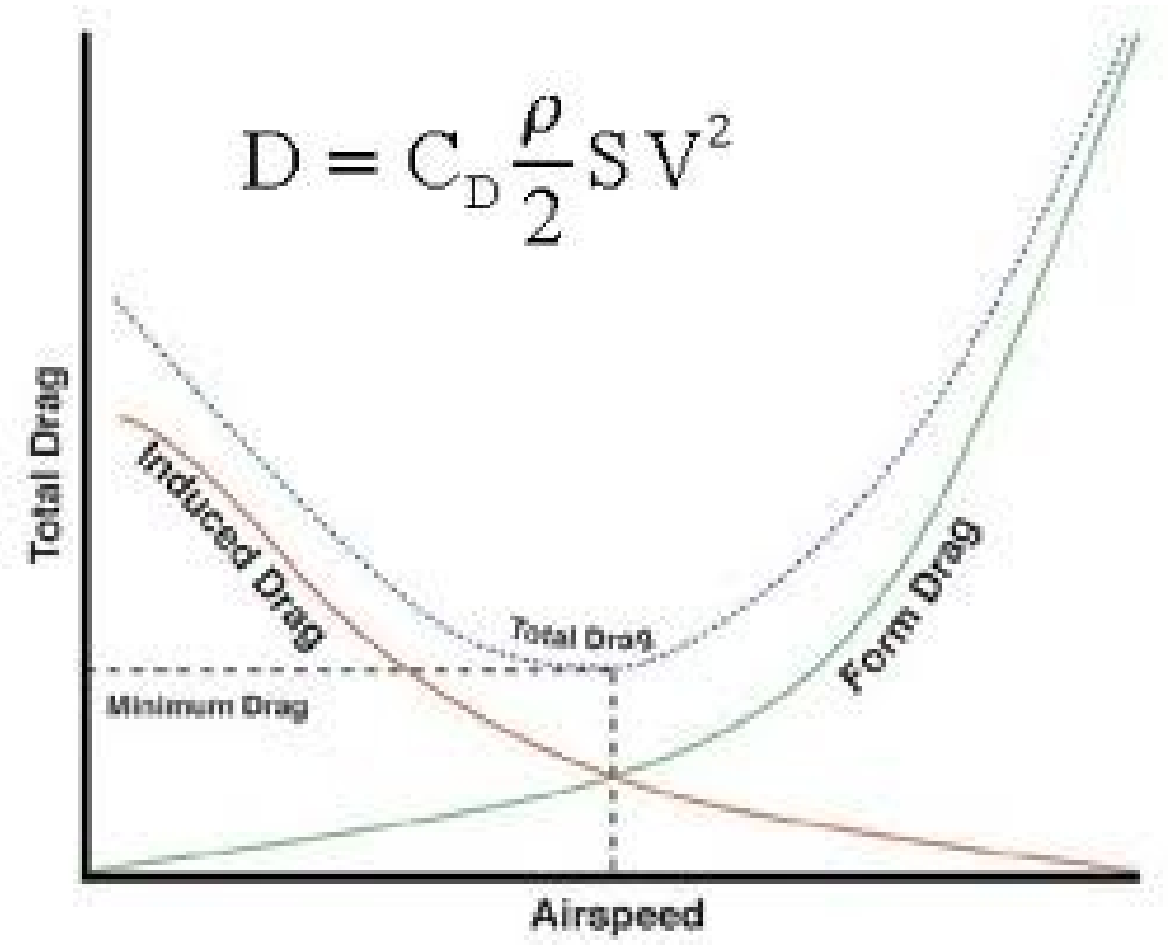
Induced Drag…

Aspect Ratio…

-
- The Aspect Ratio of a wing is the ratio of it's length (known as wingspan) to it's chord.
- As chord is usually non-linear, Aspect Ratio = (Wingspan)2/Wing Area

Aspect Ratio…

Drag Curve . . .



D = Drag

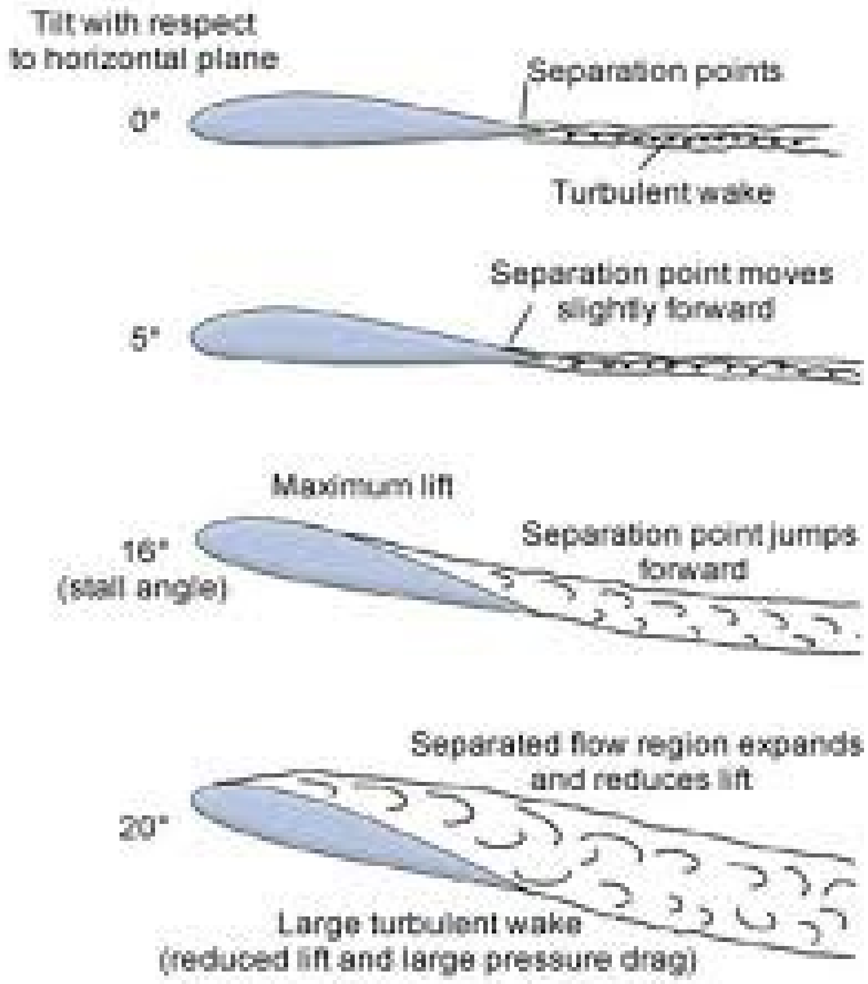
Cd = Coefficient of drag

ρ = Air density

V = Velocity

S = Wing Area

Stalling …



Tilt with respect
to horizontal plane
Separation points
0°
Turbulent wake
Separation point moves
slightly forward
5°
Maximum lift
Separation point jumps
forward
16°
(stall angle)
Separated flow region expands
and reduces lift
20°
Large turbulent wake
(reduced lift and large pressure drag)

Wash-Out …

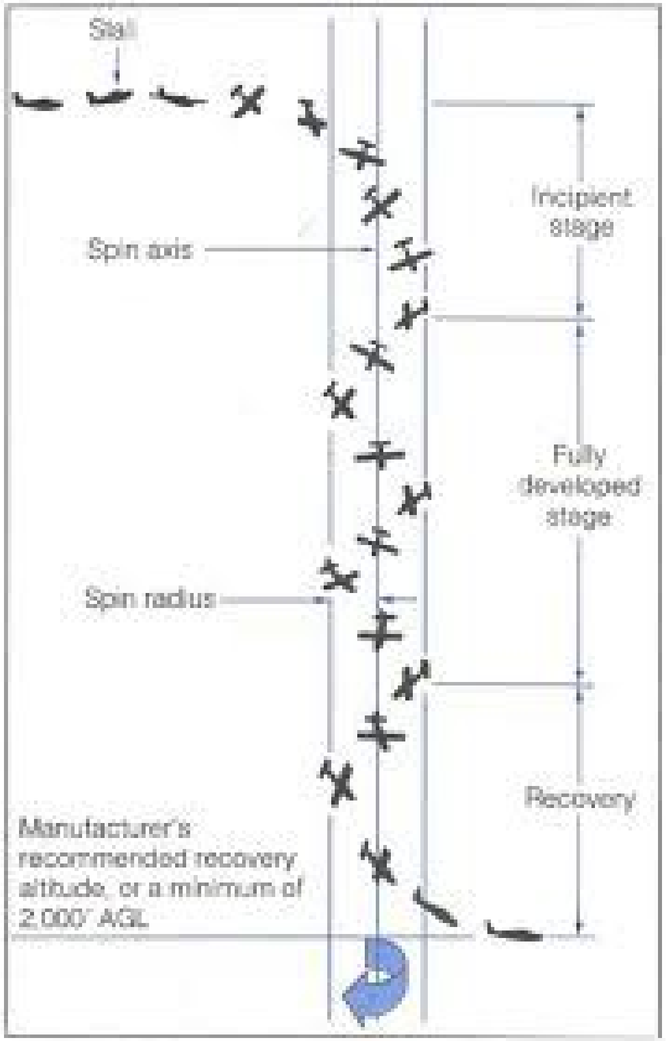
Washout: The aerofoil at the wingtip is at a lower angle of attack than that at the root. The stall starts at the root and spreads gradually outwards.

Spinning …

Spinning: An aircraft will spin when it is stalled and yawed.

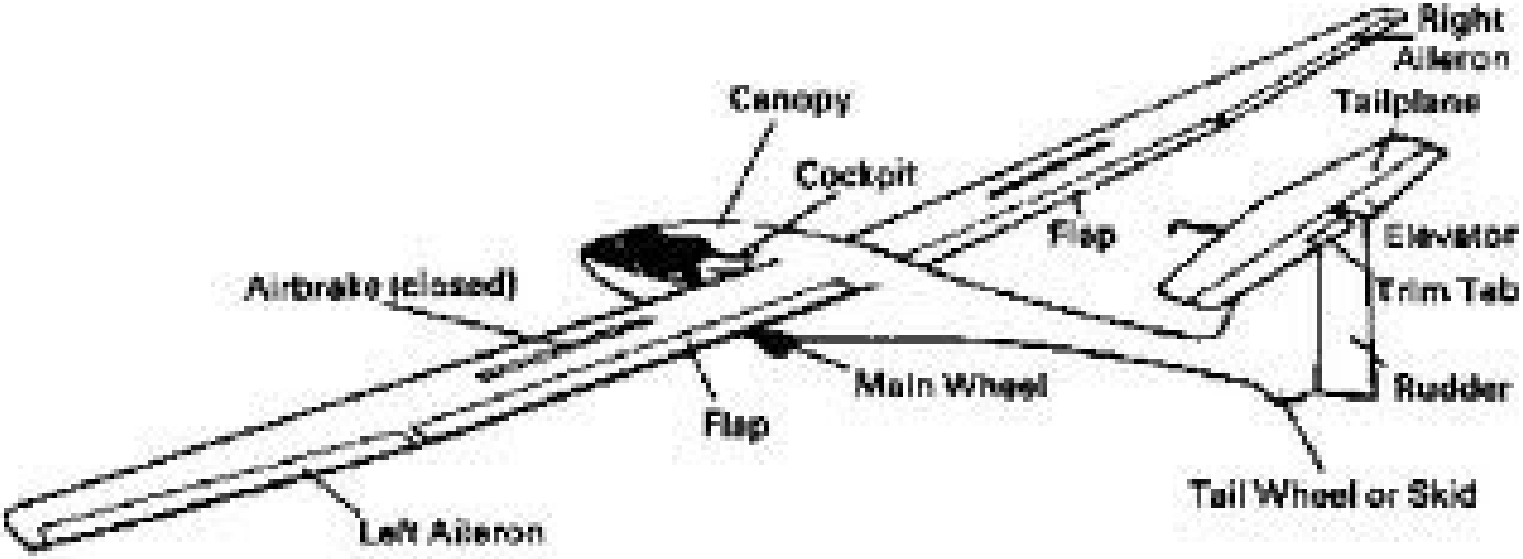
Dependent on CG Position.

Some aircraft more prone to spin than others.

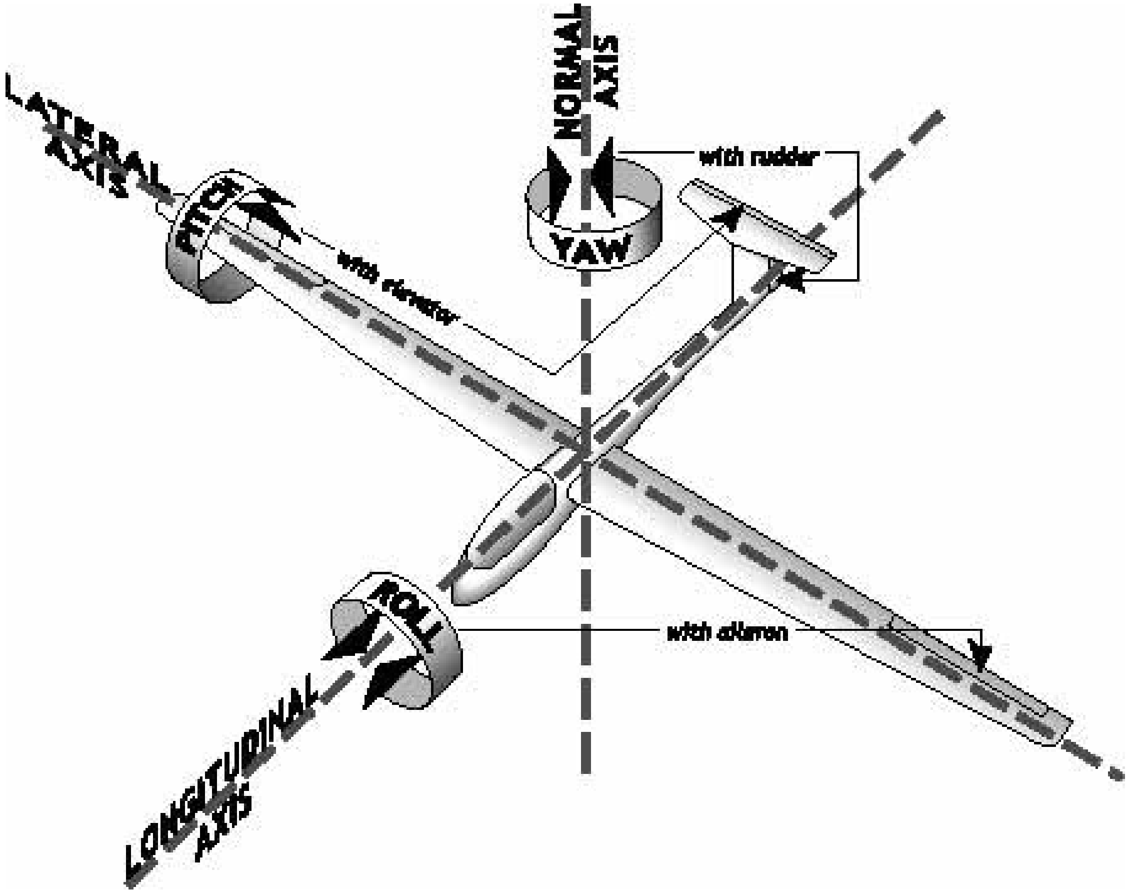


Spinning …

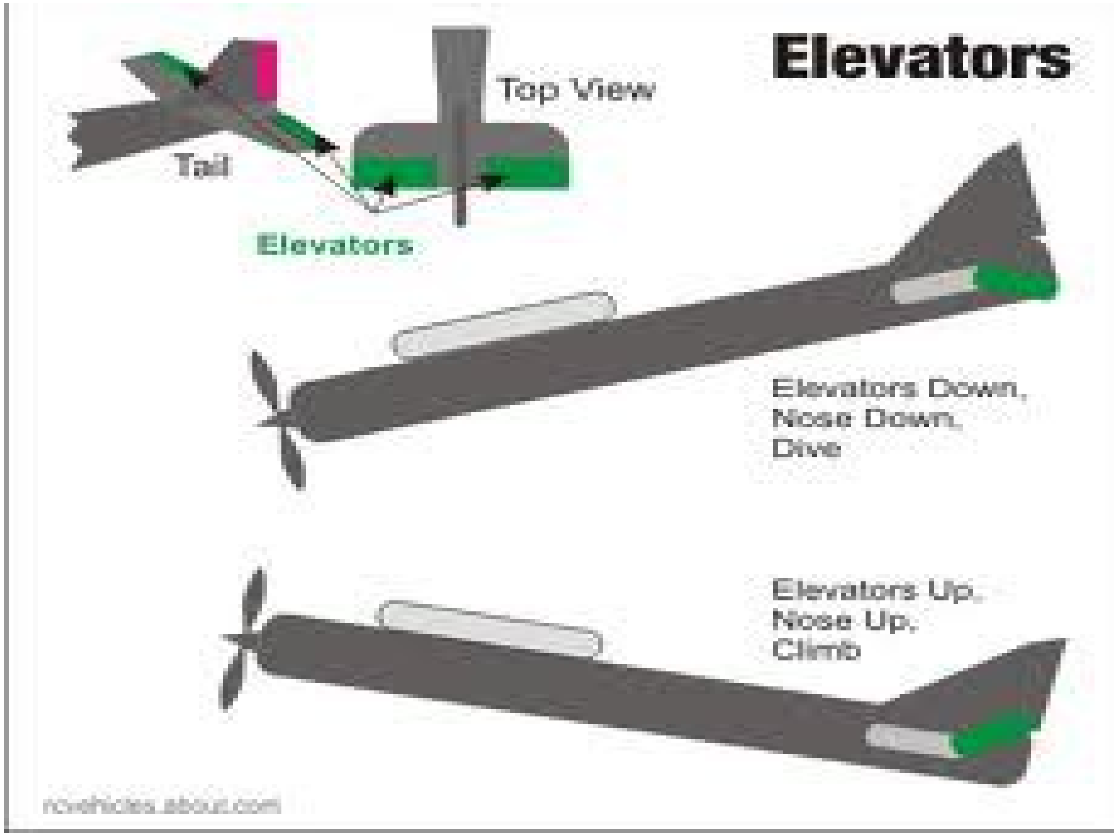
Control…


Right
Aileron
Canopy
Tailplane
Cockpit
Flap
Elevator
Airbrake (closed)
Trim Tab
Main Wheel
Rudder
Flap
Tail Wheel or Skid
Left Aileron

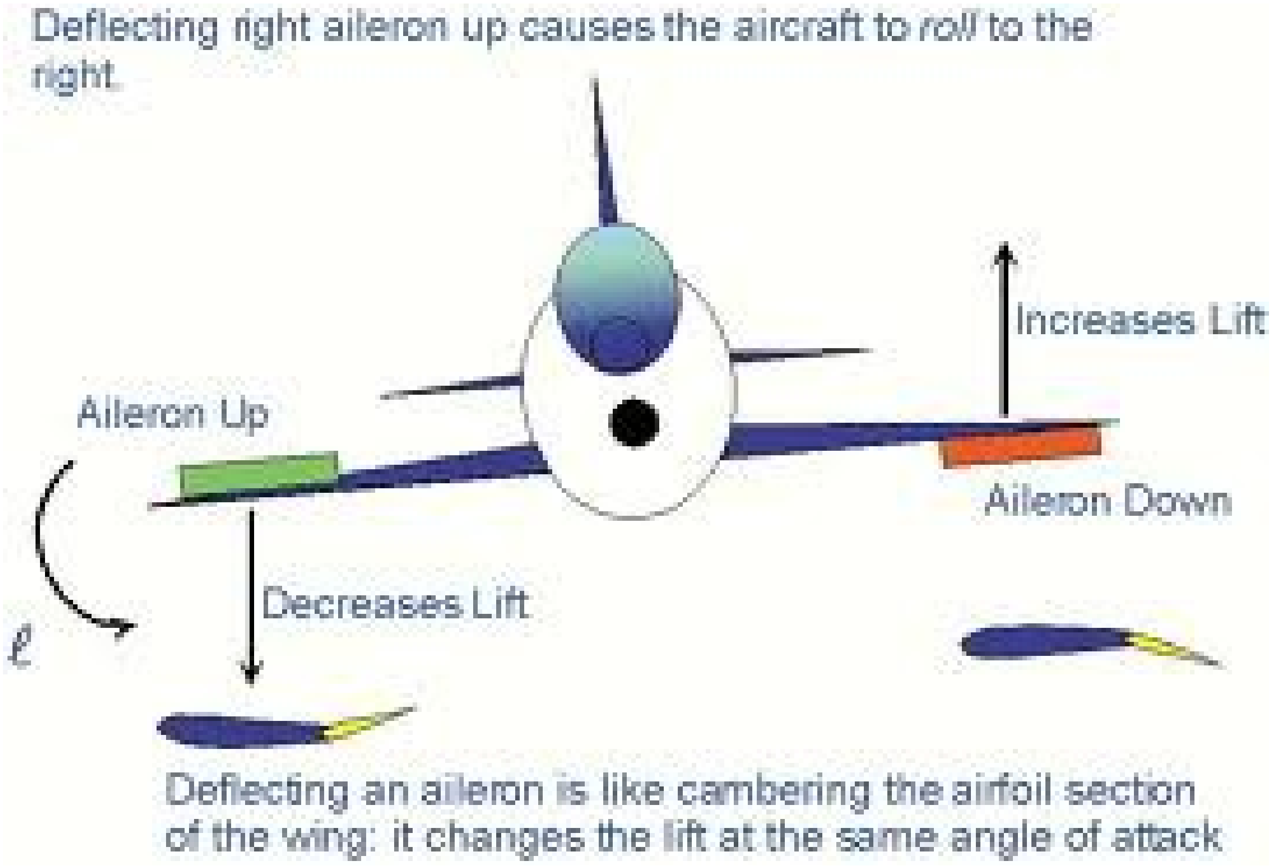
Control Axes…



Control Surfaces… Elevator



Control Surfaces… Ailerons



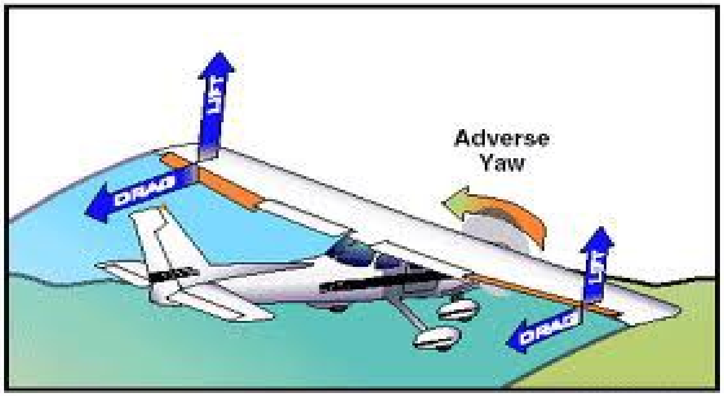
Control Surfaces… Ailerons

The Primary Effect of the ailerons is to roll the aircraft

A Secondary Effect of the ailerons is to yaw the aircraft.

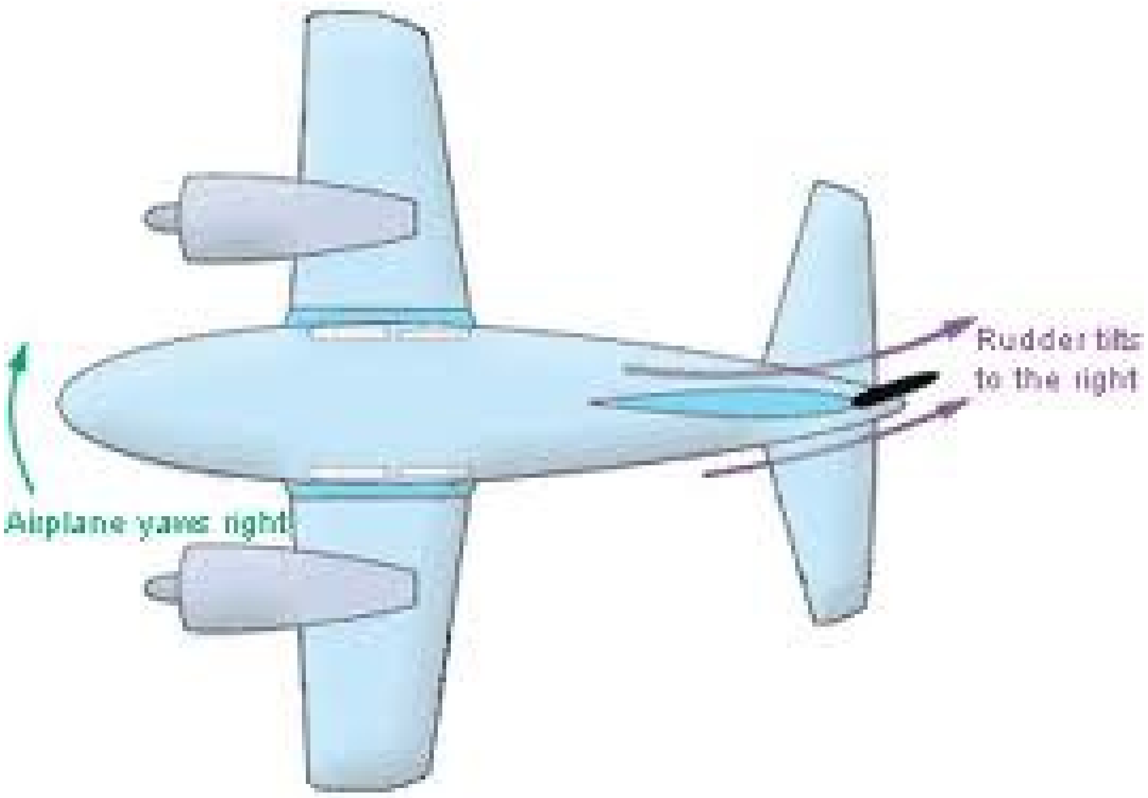
As the aircraft rolls, the downgoing aileron develops lift.

Because it generates lift, it also generates drag, which tends to pull that wing rearwards, thus yawing the aircraft to the same side.



This is called **Adverse Yaw**, and is why we need to use rudder in conjunction with the ailerons when turning the glider.

Control Surfaces … Rudder



Control Surfaces … Rudder

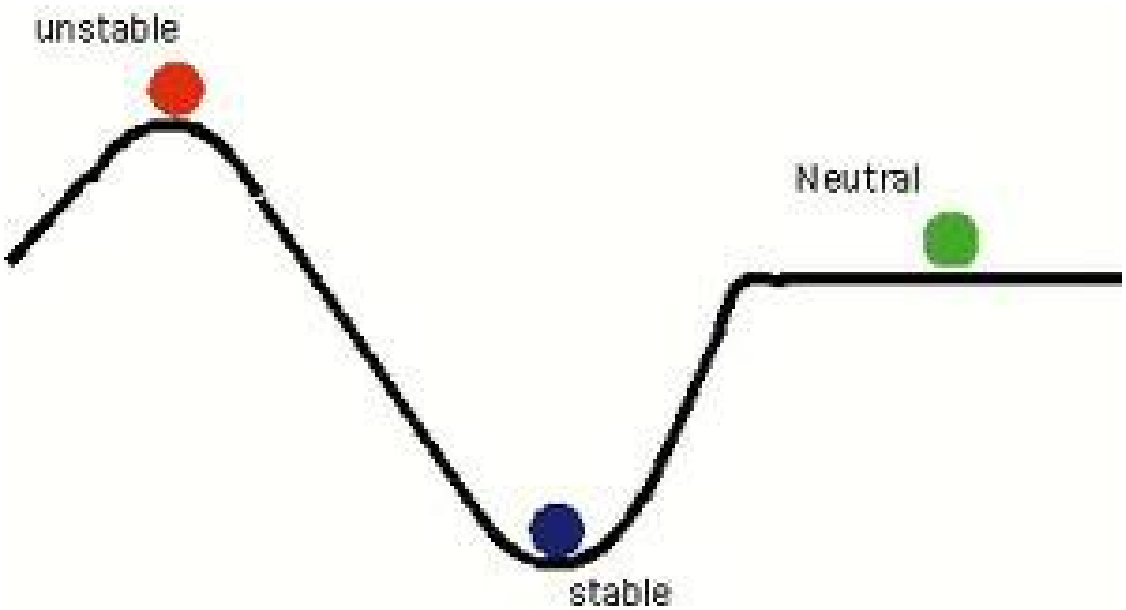
The Primary Effect of the rudder is to yaw the aircraft

A Secondary Effect of the rudder is to roll the aircraft.

As the aircraft yaws, the outside wing travels faster than the inner wing, and therefore generates more lift.

This additional lift causes the aircraft to bank and therefore turn.

Stability…



Static and Dynamic Stability …

Static Stability:

Refers to the aircraft's initial response to a disturbance.
A statically unstable aircraft will depart uniformly from an initial disturbance.

Static stability is proportional to the tailplane area and moment (i.e. its distance from the CG)

Dynamic Stability:

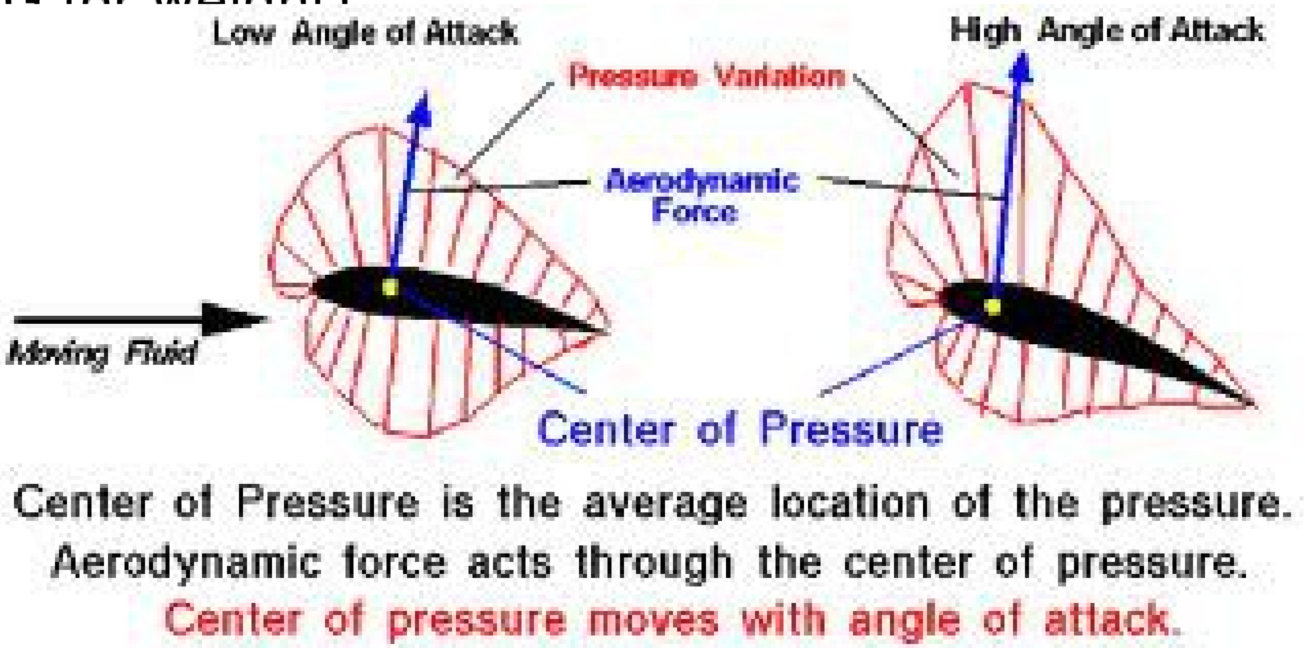
Refers to the aircraft's ability to damp out oscillations.
A dynamically unstable aircraft will [after a disturbance], start oscillating with increasing amplitude.

Dynamic Stability is proportional to the even distribution of weight around the aircraft, the location of the CG, and the tail moment.

Stability In Pitch …

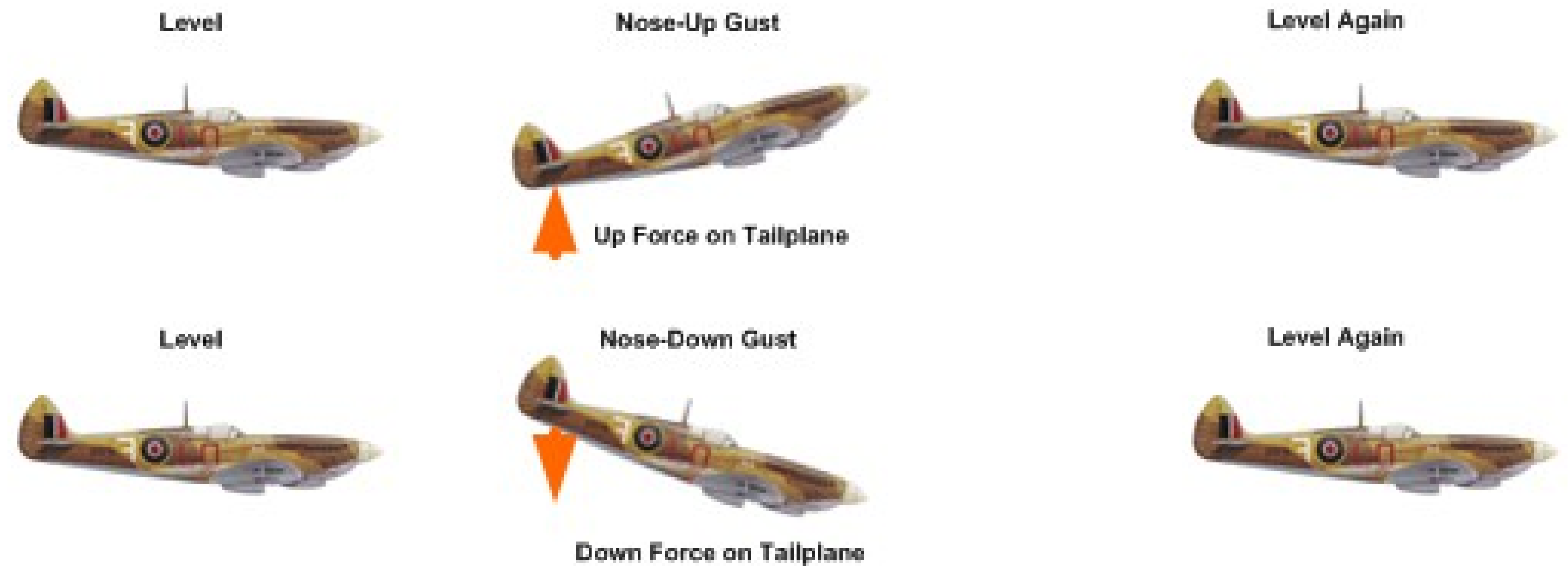
Centre of Pressure:

The **Centre Of Pressure** is that point through which the overall **LIFT** and the overall **DRAG** forces act (analogous to CG for weight)



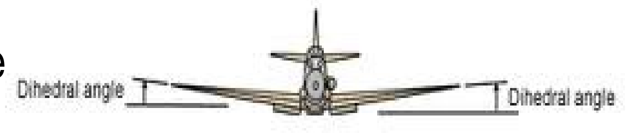
Stability In Pitch…

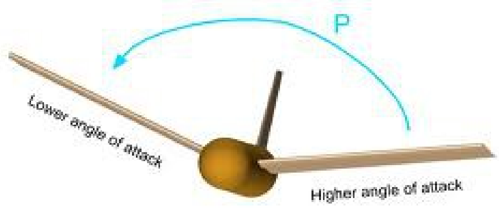
Longitudinal Stability depends on the CG location, the size of the tailplane and its distance from the CG.



Stability In Roll …

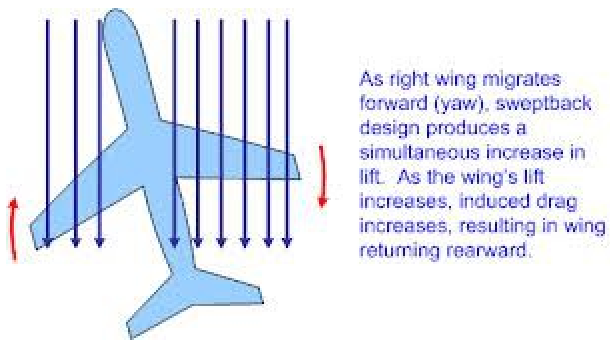
Dihedral is the angle the wings m
with respect to the horizon in leve
flight.





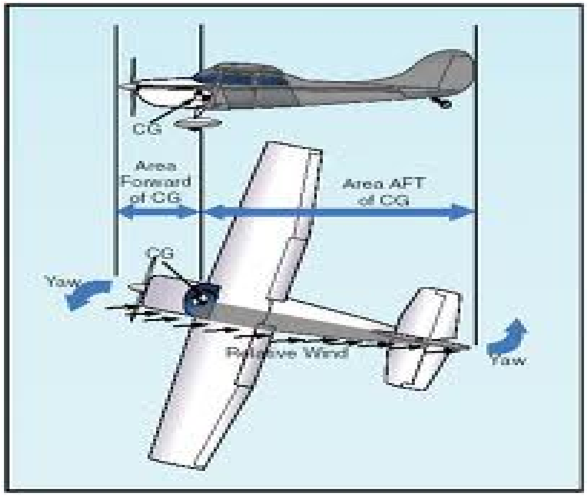
Damping: More obvious on long wings.

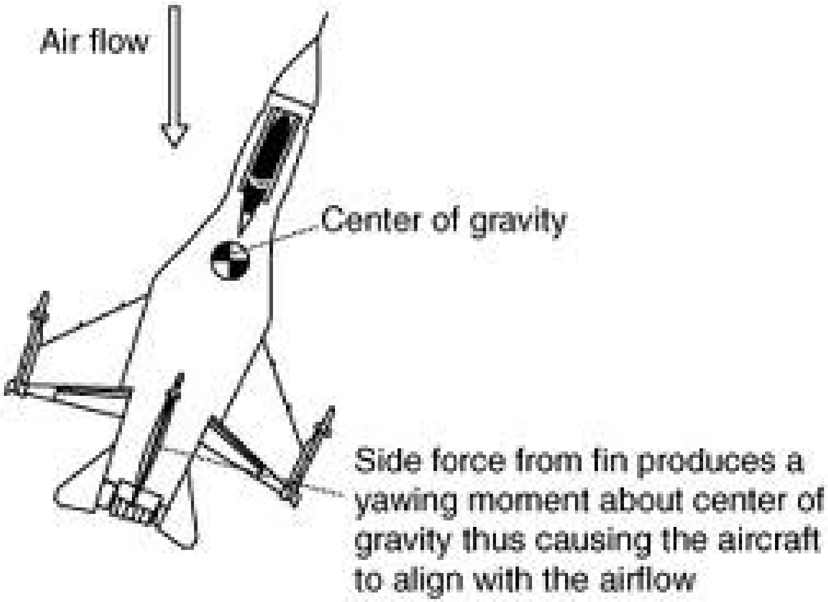
Swept-Aft wings make an aircraft more stable in roll and yaw. Any slippage towards a lower wing results in the airflow meeting that wing at a more efficient angle, thus increasing the lift and tending to level the wings.



Yaw Stability …

Yaw Stability is related to the size and moment of the fin and the shape of the fuselage aft of the CG.





Glider Performance…

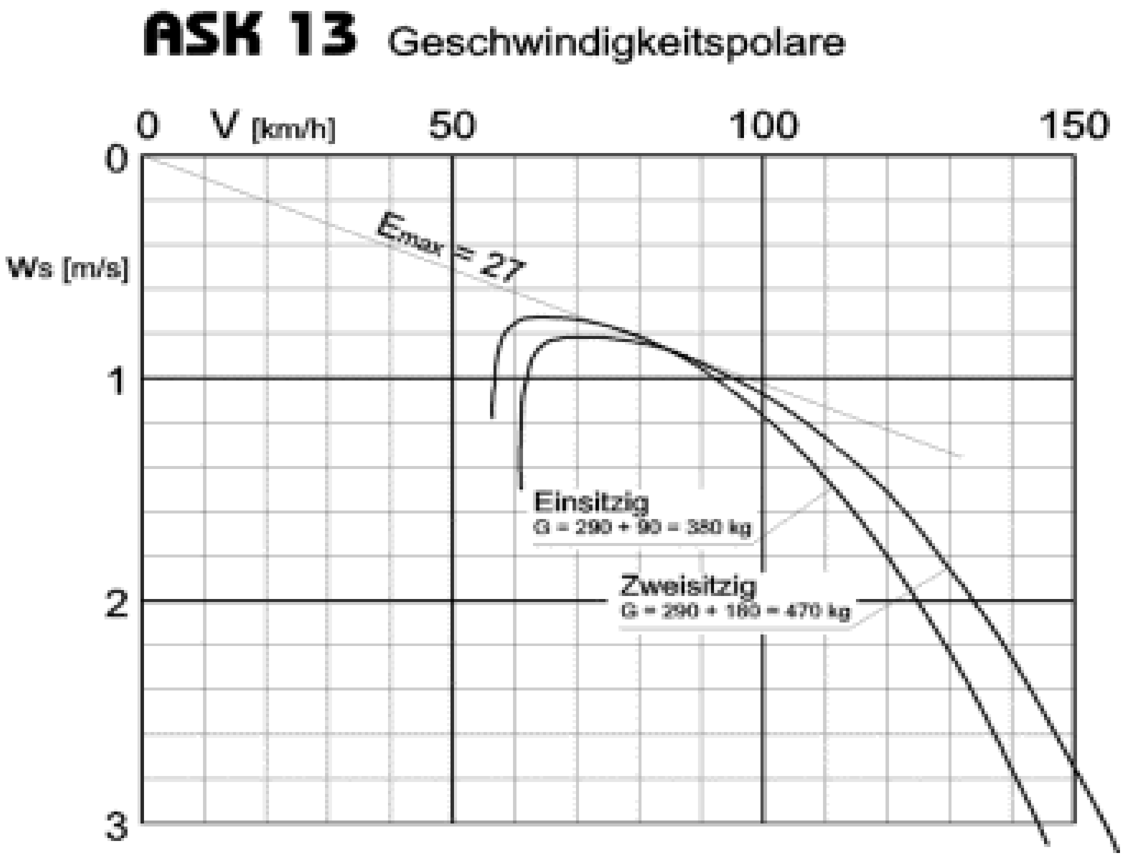
Polar Curve

A Glider’s Polar Curve is used to determine the best speed to fly at:

- **Min. Sink**
- **Best Glide**
- **Into wind**
- **Down Wind**
- **Between Thermals**

Glider Performance…

ASK-13 Polar Curve:



Mc Cready - Scala		
	einsitzig	zweisitzig
km/h	m/s	m/s
70	0,26	
80	0,90	0,41
90	1,67	0,98
100	2,55	1,70
110	3,53	2,47
120	4,81	3,55
130	6,08	4,67
140		6,13

Flight Envelope…

"If you want to grow old as a pilot, you have to know when to push it and when to back off"

- General Chuck Yeager (1923-), USAF,

1st pilot to break the sound barrier.

Flight Envelope…

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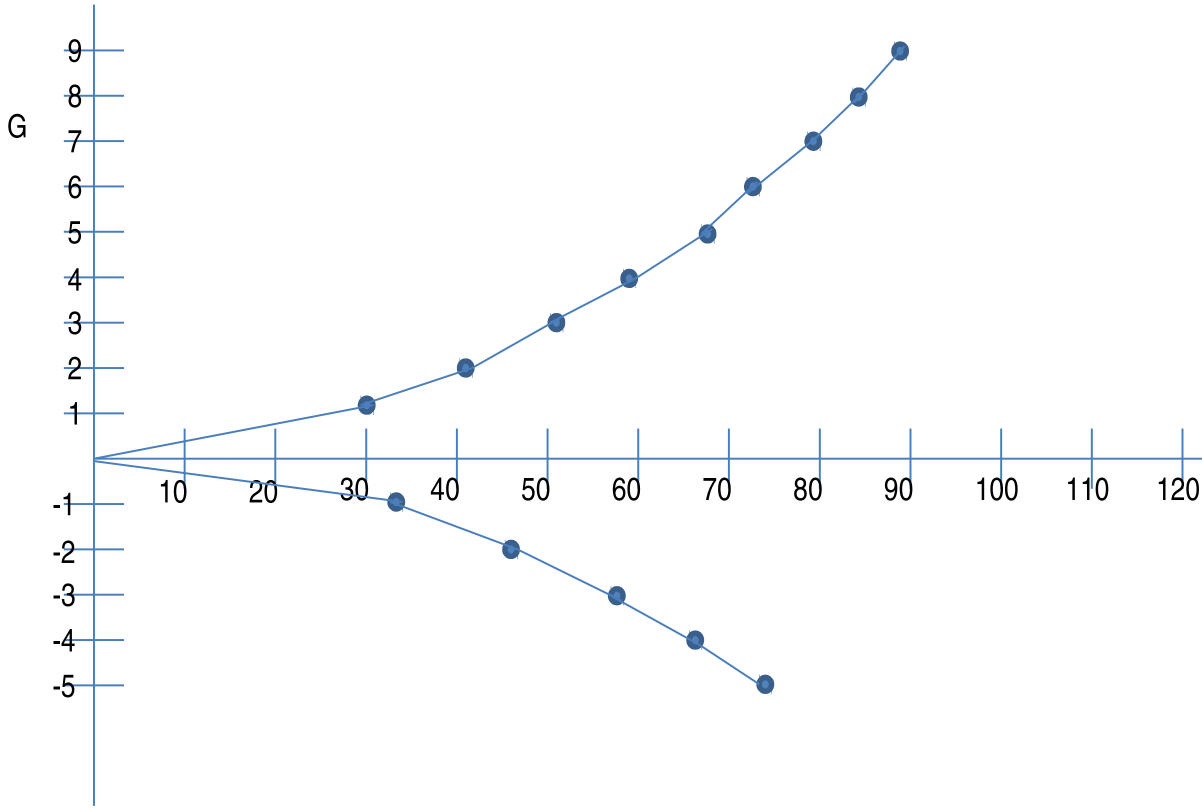
G vs Airspeed Graph



G	Stall
1.00	30
2.00	42
3.00	52
4.00	60
5.00	67
6.00	73
7.00	79
8.00	85
9.00	90

Flight Envelope...

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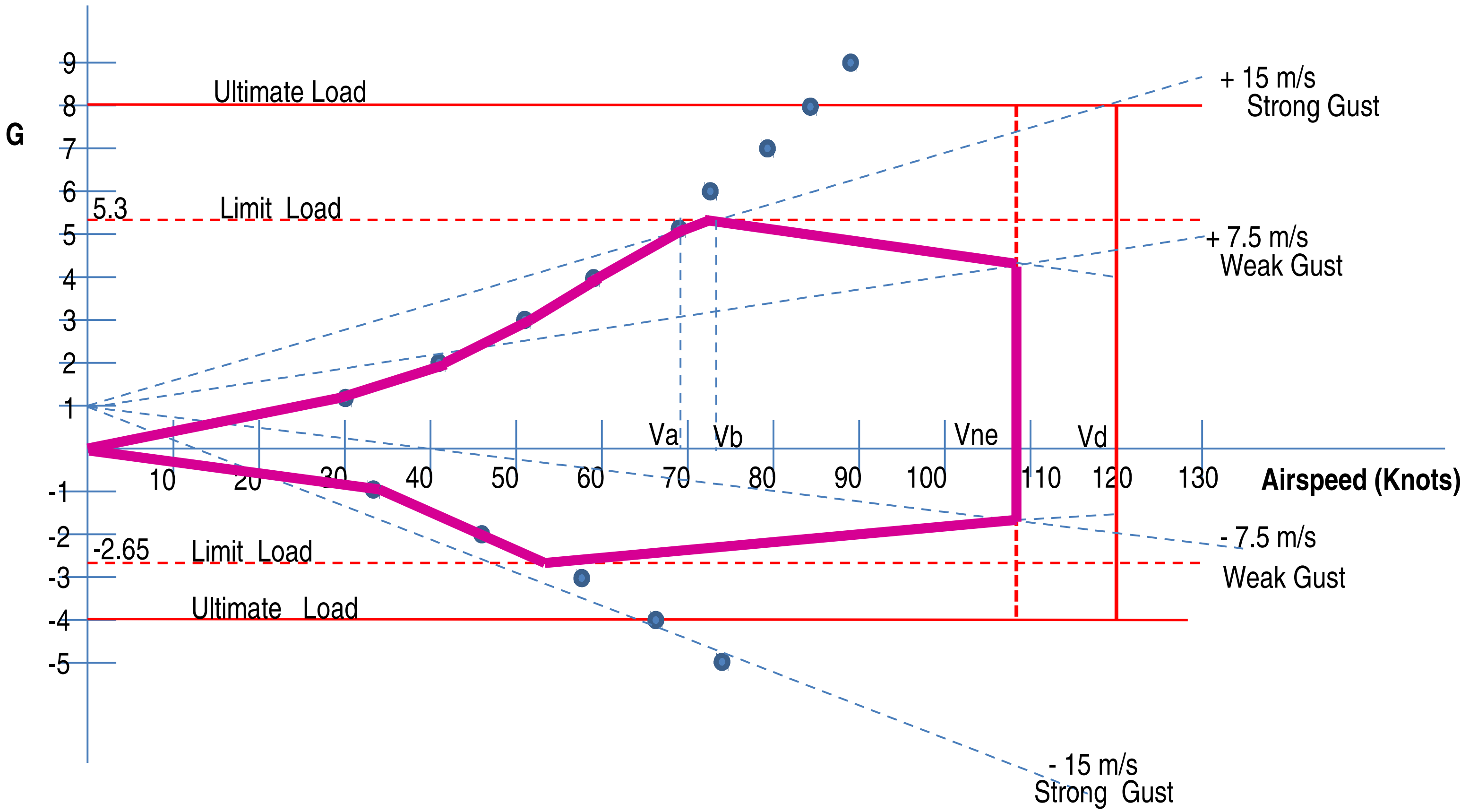
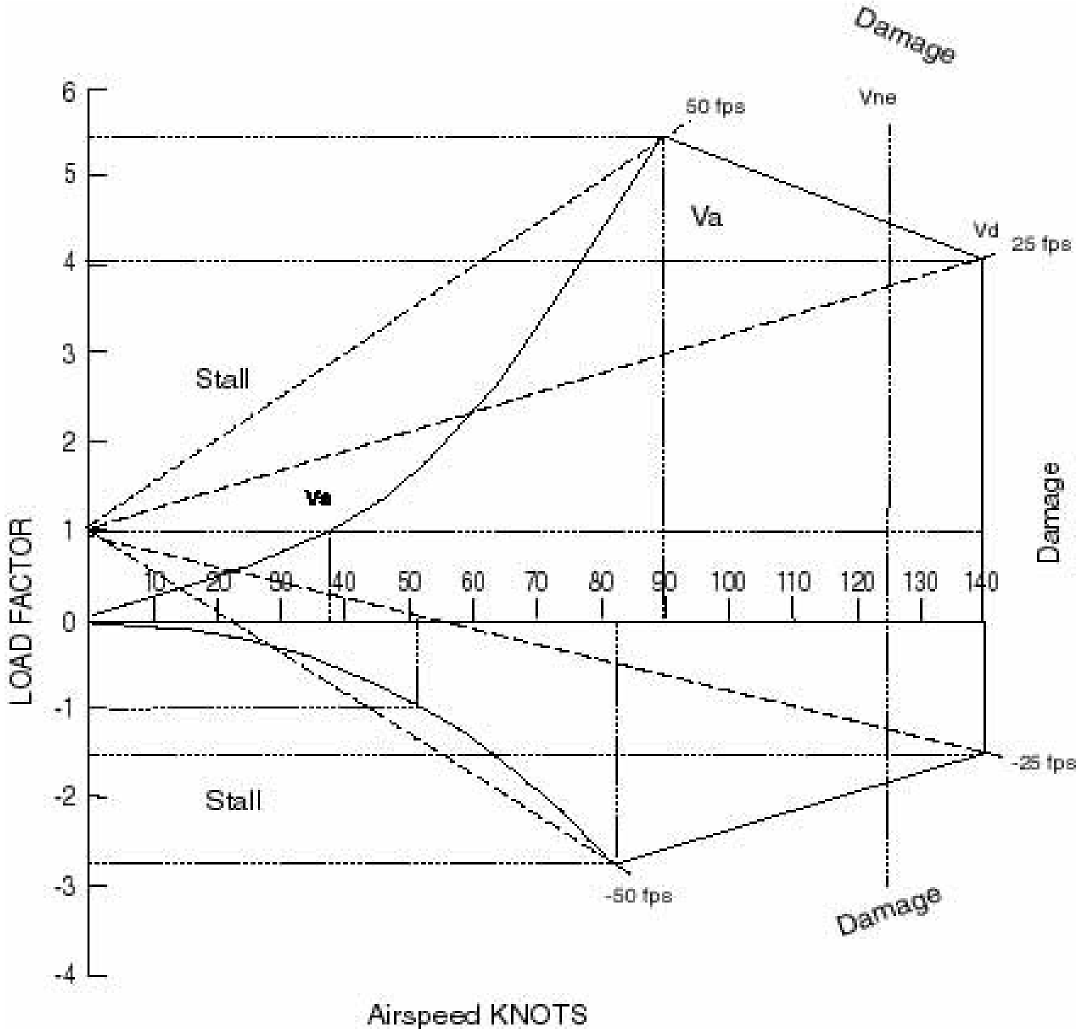


Flight Envelope…



Flight Limitations Placard…

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Irish Gliding & Soaring Association
Glider Limitations Placard

Type Schleicher ASK21
Reg. No. EI-GLA

Maximum Speeds Knots / ~~M.P.H./ K.P.H.~~

Never Exceed (Vne)	151
Auto/Winch	81
Aerotow	97
Manoeuvring (Va)	97
Rough Air	108
Flaps Extended	N/A

Limitations in Flight (delete as per C. of A.)
Fully Aerobatic (Wt. not exceeding 1,323 lbs)
Loops - Spins - Chandelles - Tight Turns 6.5g.- Stall Turn -Immelmann – Steep Climbing Turns- Lazy Eight – Split ‘S’ -
Inverted Flight - Rolling Manoeuvres –
Outside Loops - Tailslide
Cloud Flying with T.&S. fitted **Yes ~~/ No~~**

Date of Issue 24th April 2011

Weight & Balance Placard…

Glider Limitations Placard
Type Schleicher ASK21

Reg. No. EI-GLA

Weight and Balance Limitations

Max.Cockpit Load	212 Kg
Max. Weight Dry	600 Kg.
Min. Cockpit Load	70 Kg
With Water	N/A
Max Front Load	110 Kg
Max. Water	N/A
Max Rear Load	110 Kg
Empty Weight	388 Kg
Max. Landing Wt.	600 Kg
Max. breaking load of weak link:	1,400Kg

Date of Issue: 24th April 2011

References …

- Understanding Gliding Derek Piggott
- Mechanics Of Flight A.C. Kermode
- Theory of Flight BGA
- Flightwise Chris Carpenter
- Understanding Flight Anderson, Eberhardt