DOCUMENT
GSM-G-CPL.002

DOCUMENT TITLE

AERODYNAMICS 1

CHAPTER 1 – SYMBOLS AND DEFINITIONS

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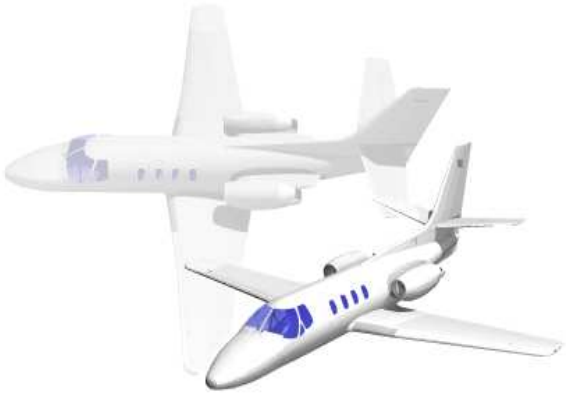
SYMBOLS AND DEFINITIONS



Introduction

In Aerodynamics, as in most subjects, a number of conventional symbols are used.

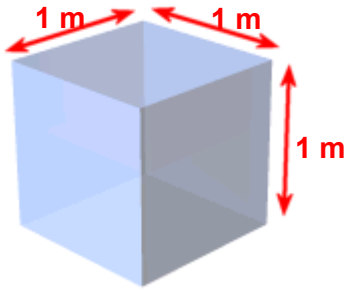
In addition, certain definitions are applicable to the subject, which could also possibly be found when studying other aspects of Aviation.

Obviously, a good understanding of these various symbols and definitions will enable a person to grasp subsequent (and more complex) aspects easier.

GENERAL SYMBOLS

DENSITY

Density (ρ) is mass per unit volume. The unit of density used is kg per m^3.



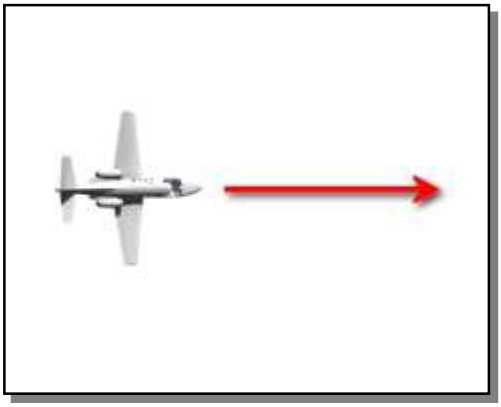
- Density at any unspecified point: - ρ **(Rho)**
- Density at MSL (International Standard Atmosphere): - ρ_o

  This value is 1.225 kg/m3
- Relative Density: - σ **(Sigma)**

Note: $\sigma = \frac{\rho}{\rho_o}$

VELOCITY

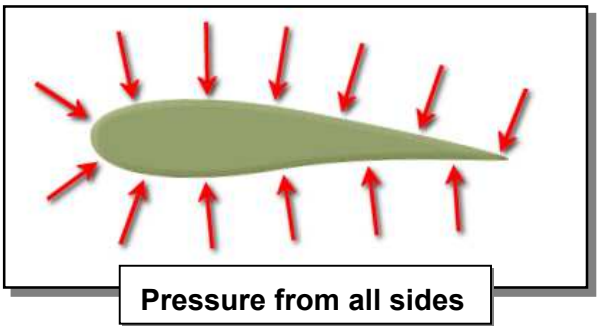
Velocity refers to a body in uniform motion in a straight line.



- Equivalent Airspeed (EAS) = $\mathbf{V_1}$
- True Airspeed (TAS) = **V**

PRESSURE

Pressure in general refers to various forces that exist around an aerofoil.



- Static Pressure at any unspecified point = **p**
- Free stream static pressure = **p_o**
- Dynamic pressure = **q**

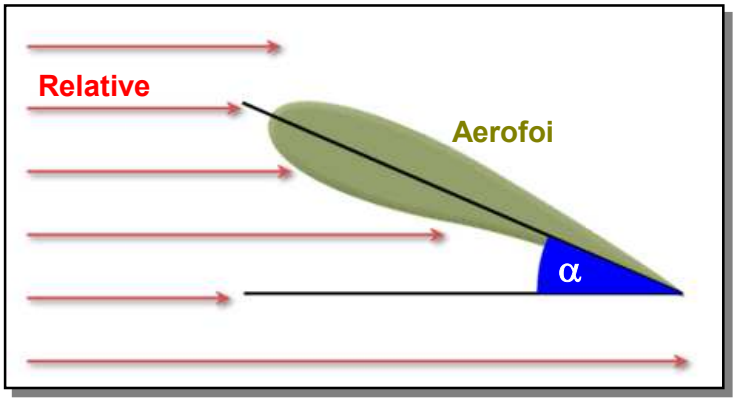
Note: Dynamic Pressure = $\frac{1}{2}\rho V^2$ or $\frac{1}{2}\rho_o V_1^2$

- Total head pressure = **H**
- Stagnation pressure = **p_s**

ANGLE OF ATTACK

Angle of Attack refers to the angular difference (α) between airflow and an aerofoil or wing.

- α = angle of attack
- α_o = alpha (applicable to two dimensional flow)
- α_{lo} = zero lift incidence (applicable to two dimensional flow)



COEFFICIENTS

In order to express certain mathematical relationships, it is necessary to make use of dimensionless values called coefficients.

Coefficients		
Lift	Aerofoil	Wing
	$C_l = \frac{\text{Lift / Span}}{q \times c}$	$C_L = \frac{\text{Lift}}{q \times S}$
Drag	Aerofoil	Wing
	$C_d = \frac{\text{Drag / Span}}{q \times c}$	$C_D = \frac{\text{Drag}}{q \times S}$
Pressure	$\frac{p - p_o}{q}$ $\quad$ $\frac{p - p_o}{q}$	
Note: S = Wing area c = chord $p - p_o$ = Pressure differential		

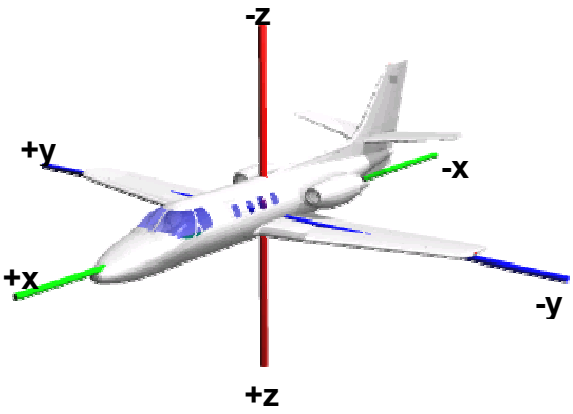
AIRCRAFT BODY AXES

AXES

An aircraft has three imaginary axes about which movement takes place.

The different symbols are indicated about each axis:

- Longitudinal (**x**)
- Lateral (**y**)
- Normal (**z**)



These axes have negative (-) and positive (+) values.

FORCES

A force is described in terms of:

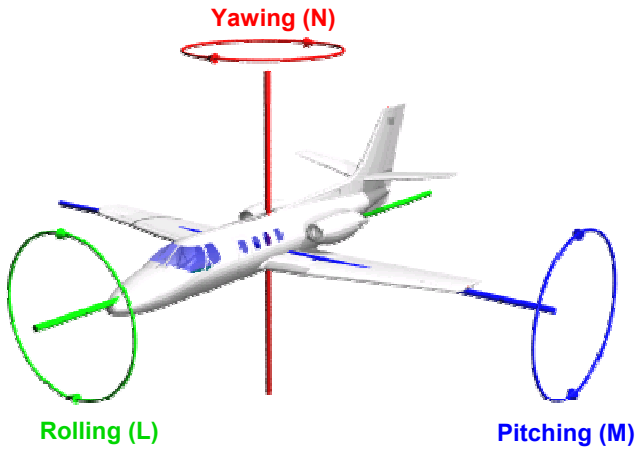
- its point of application
- its size
- its direction

These forces act along the different axes along an aircraft.

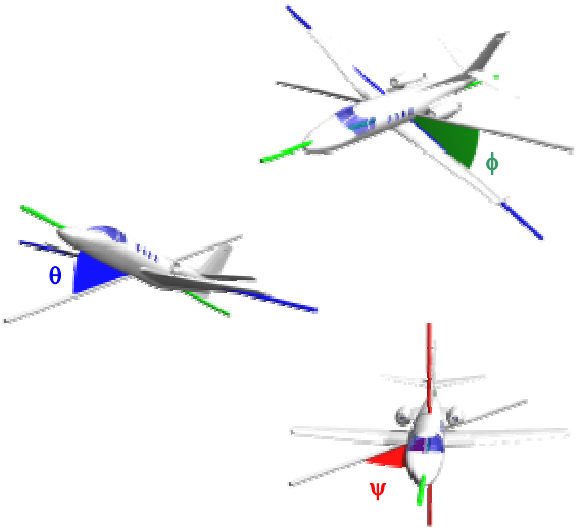
MOMENT

A rotation around any of the mentioned axes of an aircraft is expressed as a moment.

Clockwise rotation indicates a positive moment.



ANGLE OF ROTATION



This is the angle between the initial and final positions of an axis after rotation has taken place.

- The angle of rotation with reference to the **longitudinal** axis is indicated by ϕ (phi).
- The angle of rotation with reference to the **lateral** axis is indicated by θ (theta).
- The angle of rotation with reference to the **normal** axis is indicated by ψ (psi).

VELOCITY

This refers to the uniform motion, linear and angular, about each of the axes.

- Longitudinal Axis

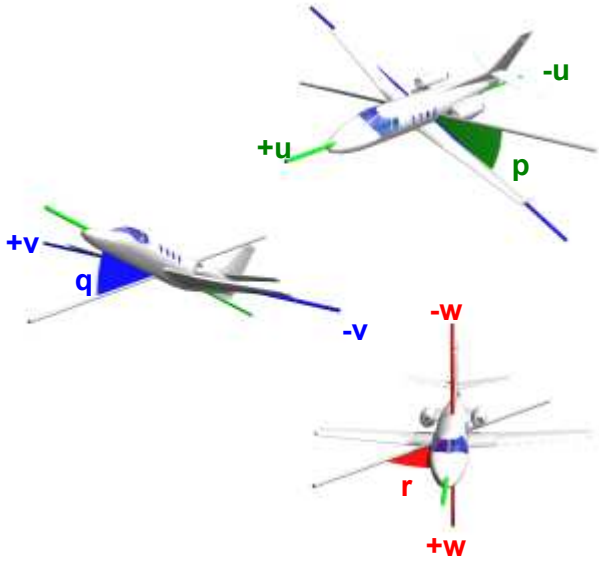
  Linear Velocity is +u or -u
  Angular Velocity (p) is the rate of change of ϕ (phi).

- Lateral Axis

  Linear Velocity is +v or -v
  Angular Velocity (q) is the rate of change of θ (theta).

- Normal Axis

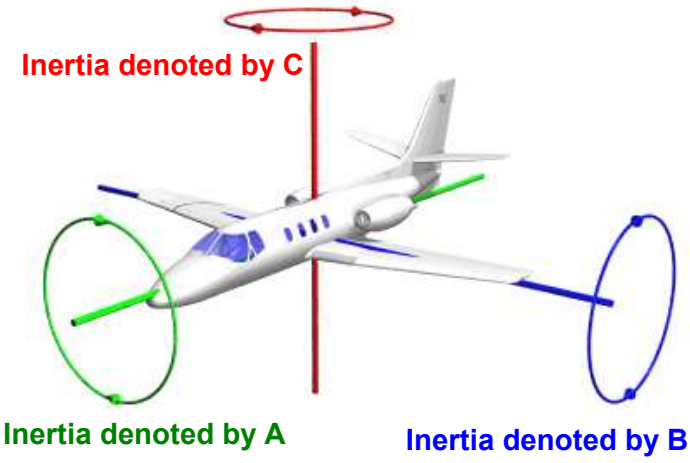
  Linear Velocity is +w or -w
  Angular Velocity (r) is the rate of change of ψ (psi).



INERTIA

This quantity expresses the amount of mass together with its distribution about the axis of rotation.

- Distribution of mass about the longitudinal axis determines the moment of inertia in the rolling plane, which is denoted by "A".
- Distribution of mass about the lateral axis determines the moment of inertia in the pitching plane, which is denoted by "B".
- Distribution of mass about the normal axis determines the moment of inertia in the yawing plane, which is denoted by "C".



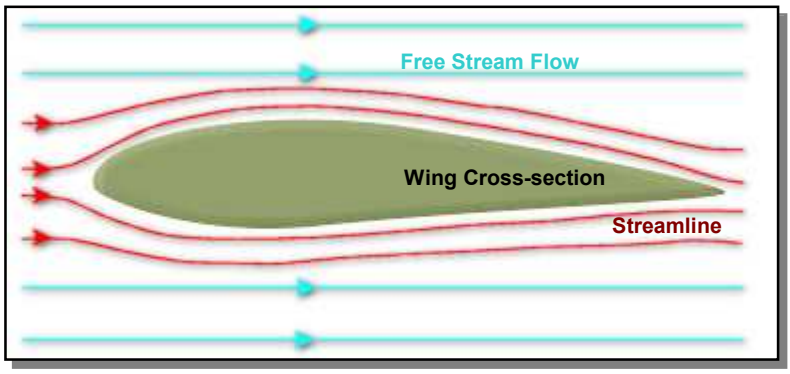
SUMMARY TABLE OF BODY AXES

	Axis		Force	Moment		Angle of Rotation	Velocity		Moment of Inertia
	Symbol	Positive Direction	Symbol	Symbol	Designation	Symbol	Linear	Angular	Symbol
Longitudinal Axis	x	Forward	X	L	Rolling	ϕ (phi)	u	p	A
Lateral Axis	y	Right	Y	M	Pitching	θ (theta)	v	q	B
Normal Axis	z	Down	Z	N	Yawing	ψ (psi)	w	r	C

AIRFLOW RELATED DEFINITIONS

FREE STREAM FLOW

Air in a region where pressure, temperature and relative velocity are unaffected by the passage of the aircraft through it, also known as relative airflow (RAF).

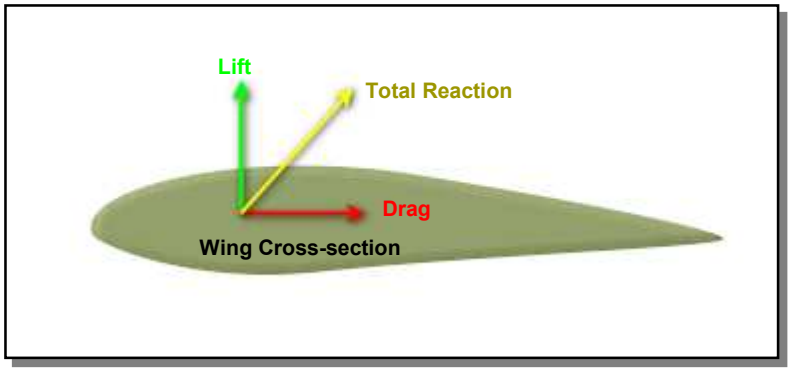


STREAMLINE

The path traced by a particle in a steady fluid flow.

TOTAL REACTION

The resultant of all the aerodynamic forces acting on the wing or aerofoil section.



LIFT

That component of the total reaction that is perpendicular to the flight path or relative airflow (RAF).

DRAG

The component of the total reaction that is tangential to the flight path; i.e. parallel to the relative airflow RAF.

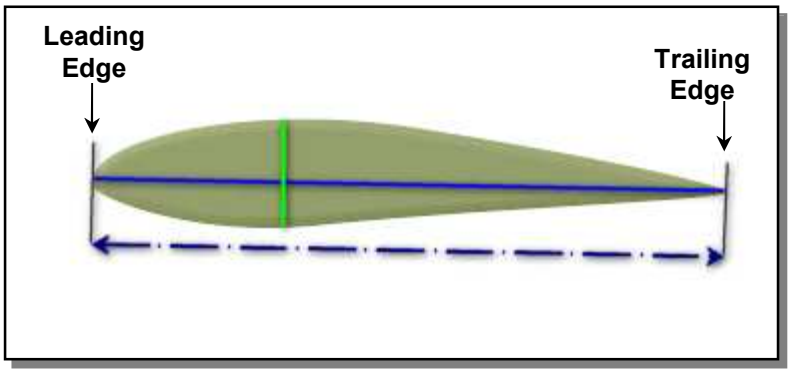
WING CROSS-SECTION DEFINITIONS

CHORD LINE

A **straight line** joining the centres of curvature of the leading and trailing edges of an aerofoil.

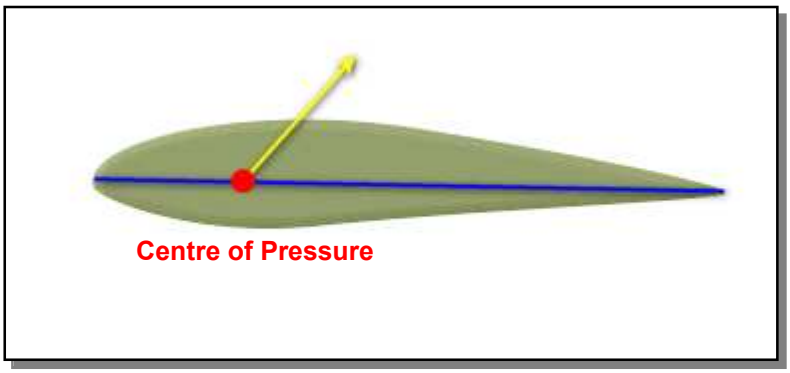
CHORD (C)

The **distance** between the leading and trailing edge measured along the Chord Line.



THICKNESS / CHORD RATIO (T/C)

The **maximum thickness** or depth of an aerofoil section expressed as a percentage of chord length.

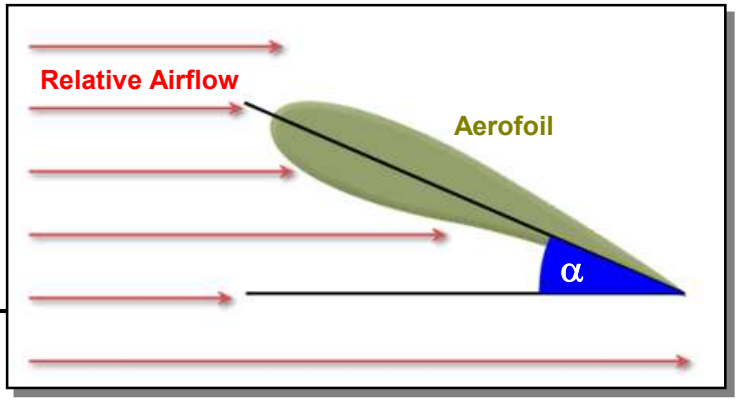


CENTRE OF PRESSURE (CP)

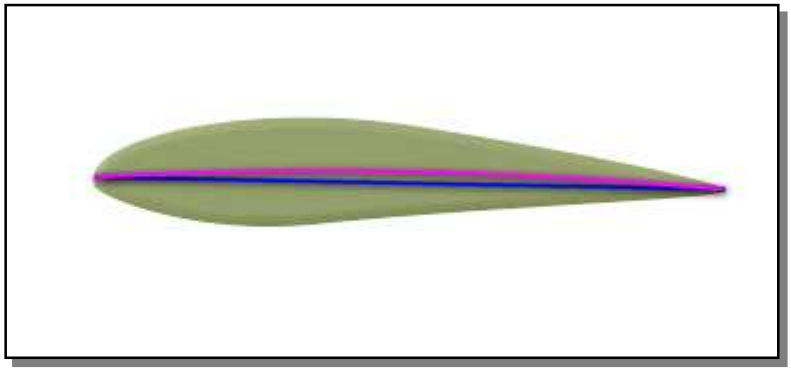
The point, usually on the **Chord Line**, through which the **Total Reaction** (TR) may be considered to act.

ANGLE OF ATTACK (α)

The angle between the Chord Line and the flight path or **Relative Air-flow** (RAF).



MEAN LINE OR CAMBER LINE



A line joining the leading and trailing edges of an aerofoil, which is equidistant from the upper and lower surfaces.

Maximum camber is usually expressed as:

A ratio of the maximum distance between the camber line and chord line, to chord length.

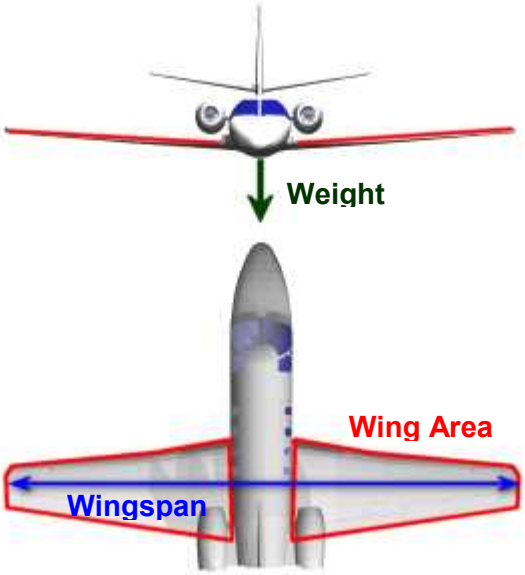
Where the camber line lies above the chord line, the aerofoil is said to have positive camber.

$$\frac{\text{Maximum distance between the camber line and chord line}}{\text{Chord length}}$$

WING AREA AND LOADING

WING AREA (S)

Area of the wing projected on a plane perpendicular to the Normal Axis.



WING LOADING

The **weight** per unit area of the wing.

$$\text{Wing Loading} = \frac{\text{WEIGH}}{\text{Wing Area}} = \frac{W}{S}$$

ASPECT RATIO

The relationship between the length and width of a wing, and is found by dividing the square of the **wingspan** by the **area of the wing**.

$$A = \frac{\text{Span}^2}{\text{Area}}$$

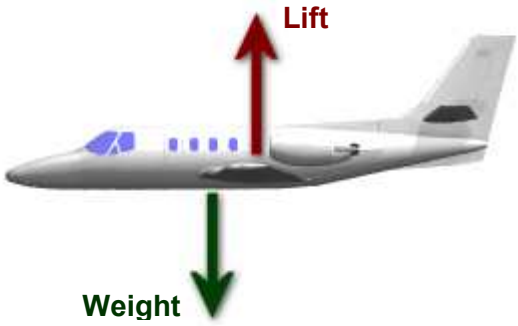
$$A = \frac{\text{Span}}{\text{Average Chord}}$$

Aspect ratio can also be calculated by the span by the average chord.

LOAD FACTOR

The ratio of the load supported by an aircraft's wings, to the actual weight of the aircraft.

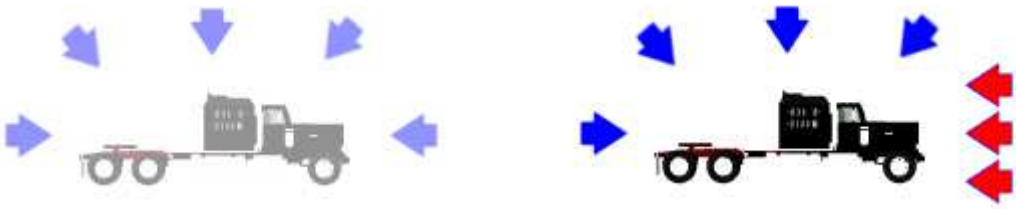
$$n = \frac{\text{Total Lift (L)}}{\text{Weight (W)}}$$



DYNAMIC PRESSURE

Any stationary object possesses **Potential Energy**. If the object is set in motion, the Potential Energy is converted into **Kinetic Energy**.

Consider a truck standing still on a road. While the truck is stationary, it will experience pressure exerted by the Atmosphere. This is known as Atmospheric Pressure (**Static Pressure**).



Dynamic Pressure due to motion

As soon as the truck starts moving, it experiences an additional pressure. As air has Density and therefore Mass, the truck has to push its way through the air.

The additional pressure experienced by the bus as it moves through the Atmosphere is known as Dynamic Pressure.

MEASUREMENT OF AIRSPEED

It is essential that an aircraft have some means of measuring the speed at which it is passing through the air.

This is displayed on an instrument known as the Airspeed Indicator (ASI).

The ASI can be calibrated to read correctly for only one Density/Altitude, and this displayed value is calculated as follows:

Total Pressure - Static Pressure = Indicated Airspeed (**Dynamic Pressure**).

RELATIONSHIPS BETWEEN AIRSPEEDS

In Aerodynamics, Indicated Air Speed (IAS) is important when considering aircraft performance.

Of equally great importance is the calculation of True Air Speed (TAS) from Indicated Air Speed for navigational purposes.

This section defines all the relevant air speeds and their relationship with each other:

IAS - Indicated Airspeed

RAS - Rectified Airspeed

EAS - Equivalent Airspeed

TAS - True Airspeed