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Stability and Control

Rotational Motion

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Basic Object Motion

Translation and Rotation

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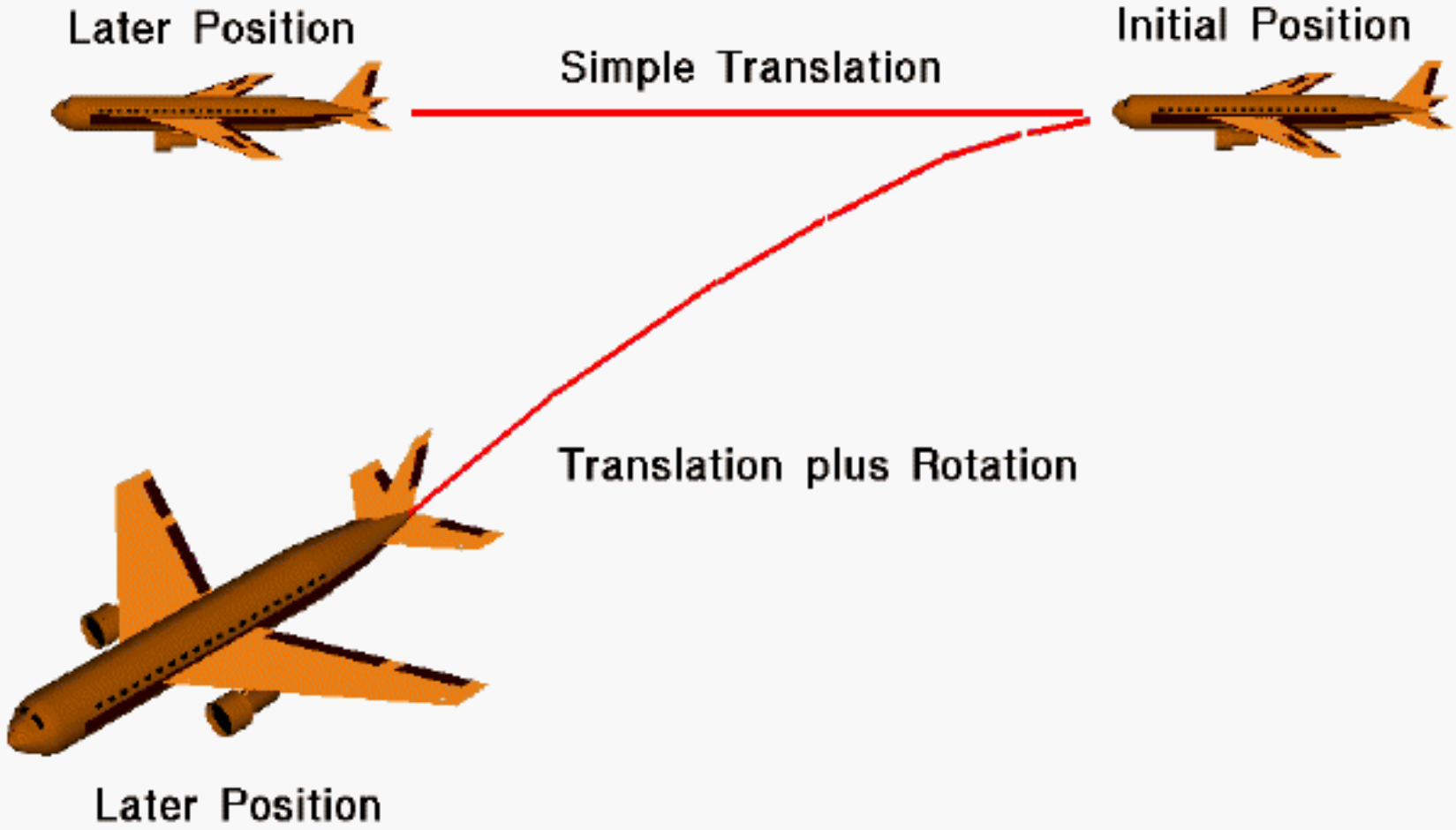

Four Forces on an Airplane

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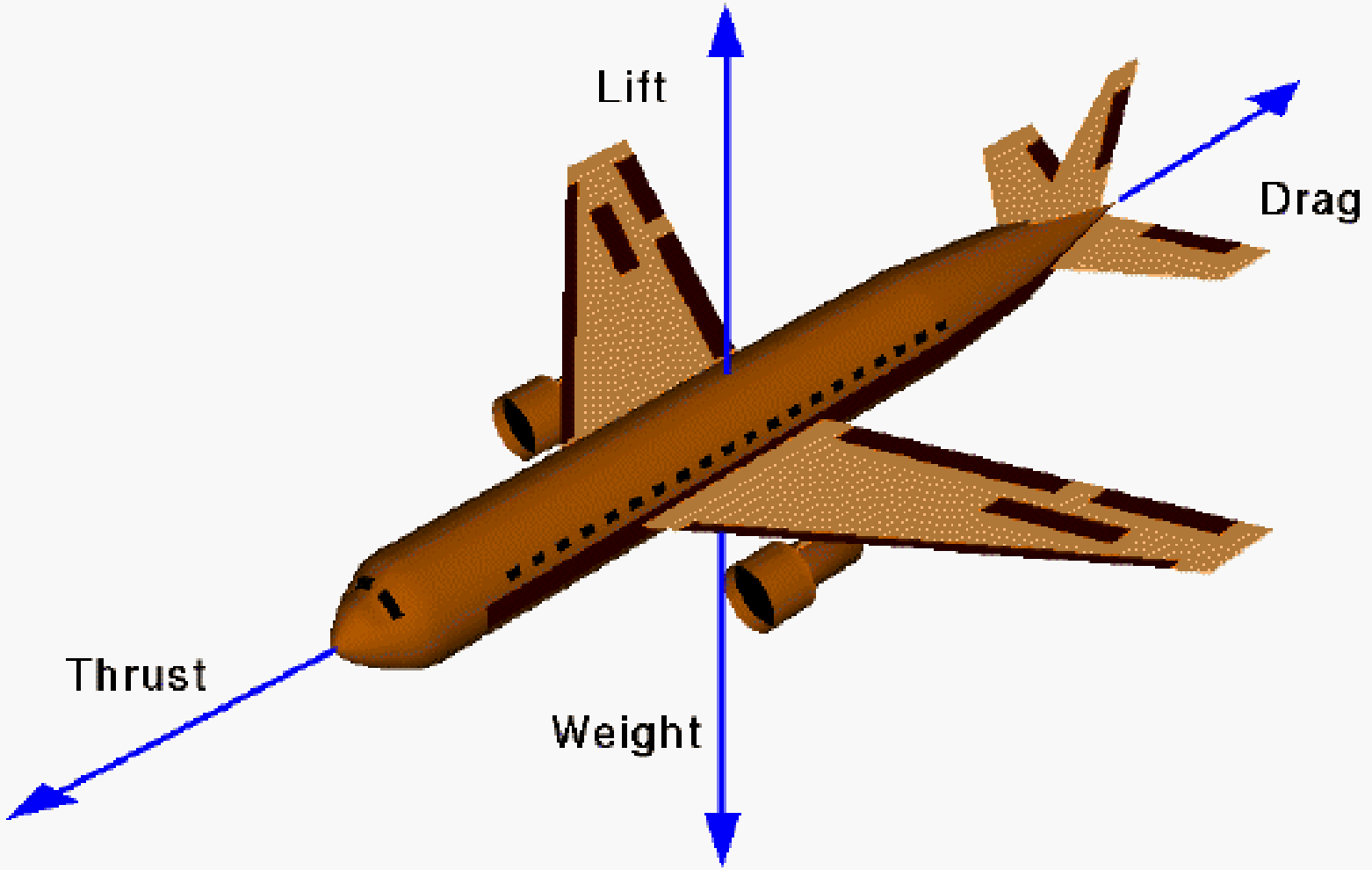

Center of Gravity – cg

Aircraft Application

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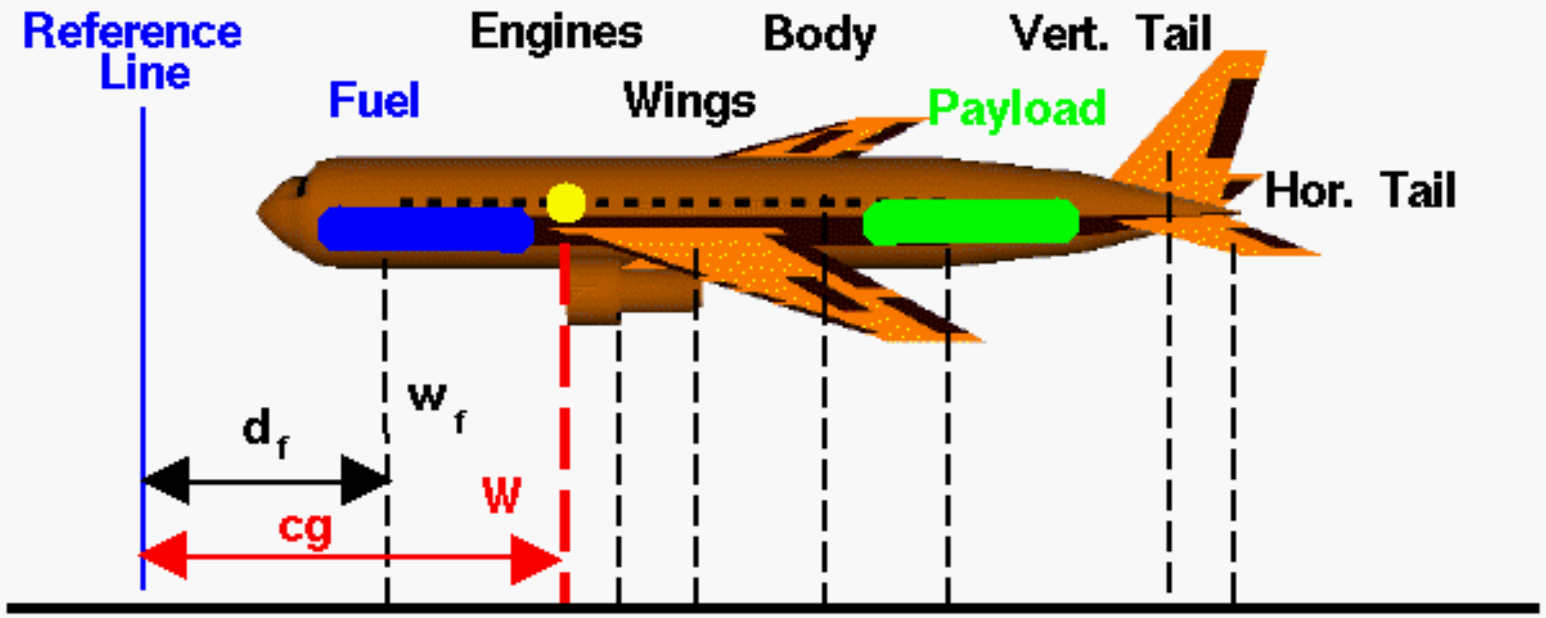

Each component has some weight w_i
located some distance d_i from reference line.

Distance cg times the weight W equals the sum of the component distance times weight.

$$cg\ W = d_f w_f + d_e w_e + d_w w_w + d_p w_p + \ldots$$

$$cg\ W = \sum_{i}^{n} (wd)_i$$

Aircraft Rotations

Body Axes

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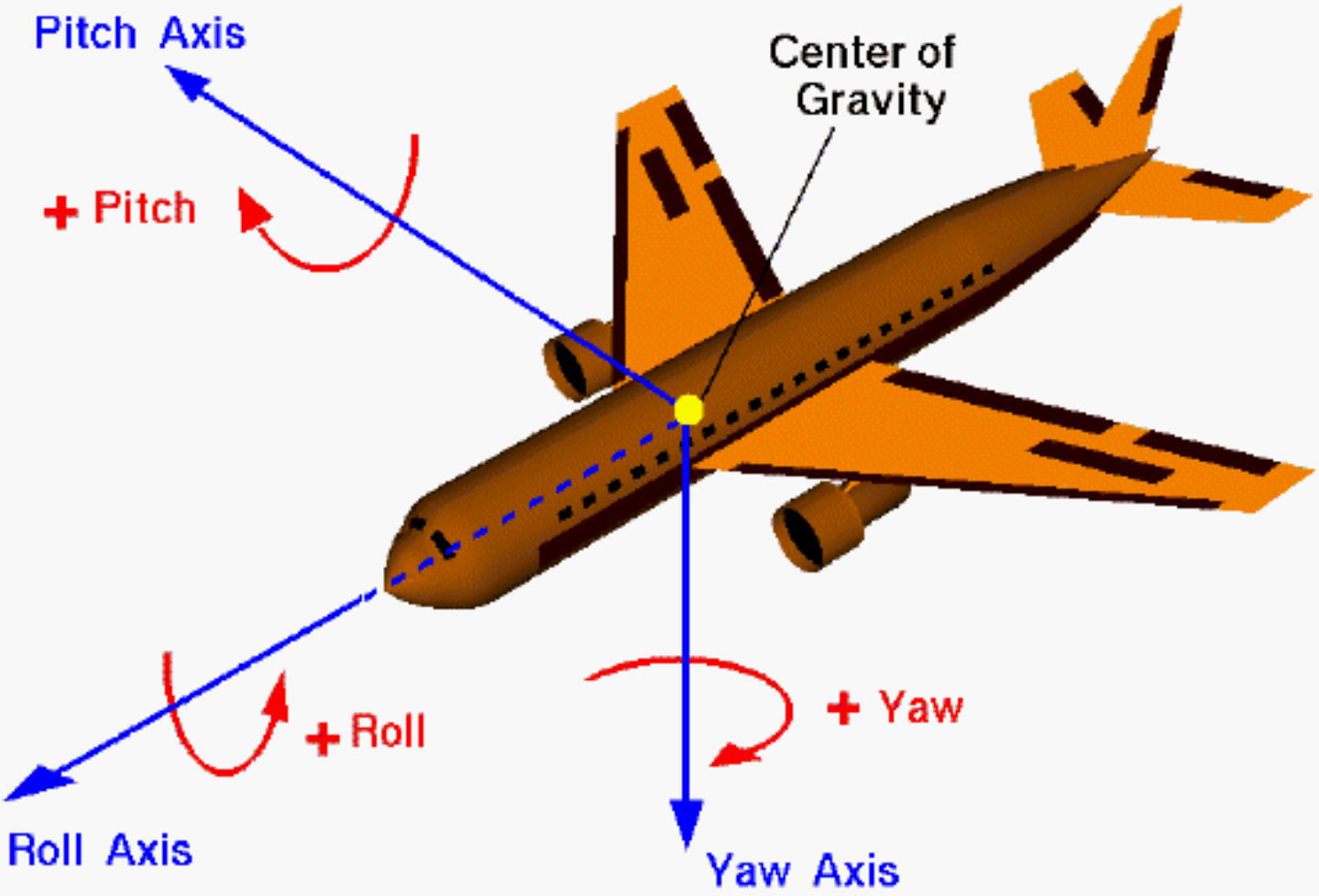

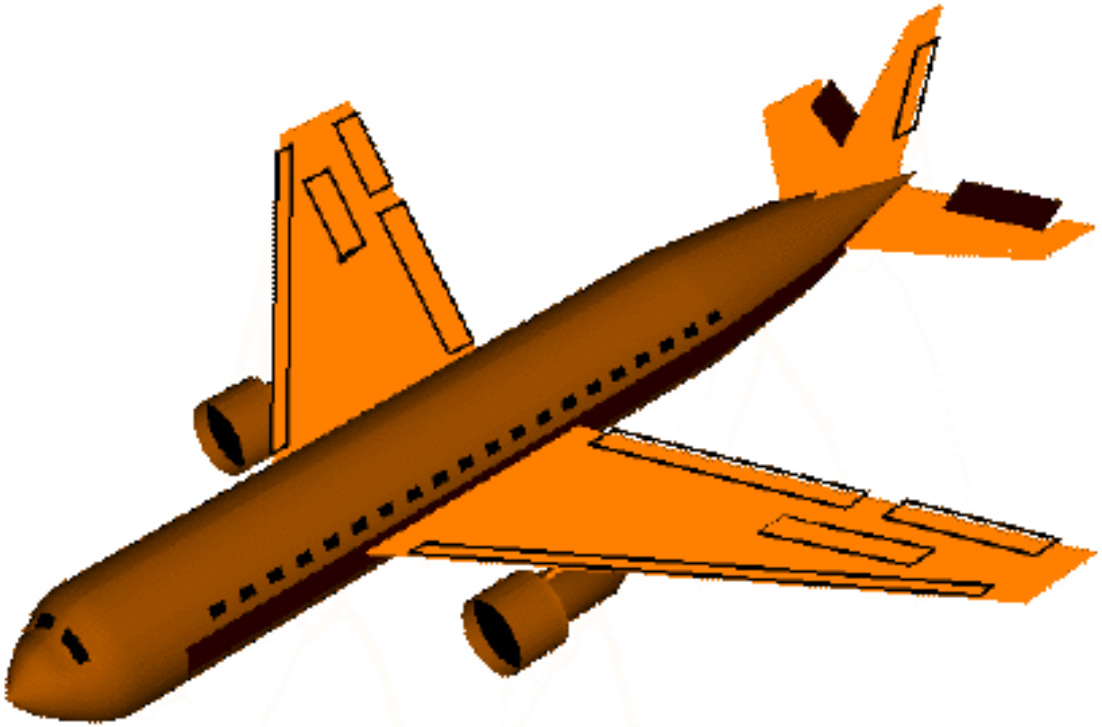

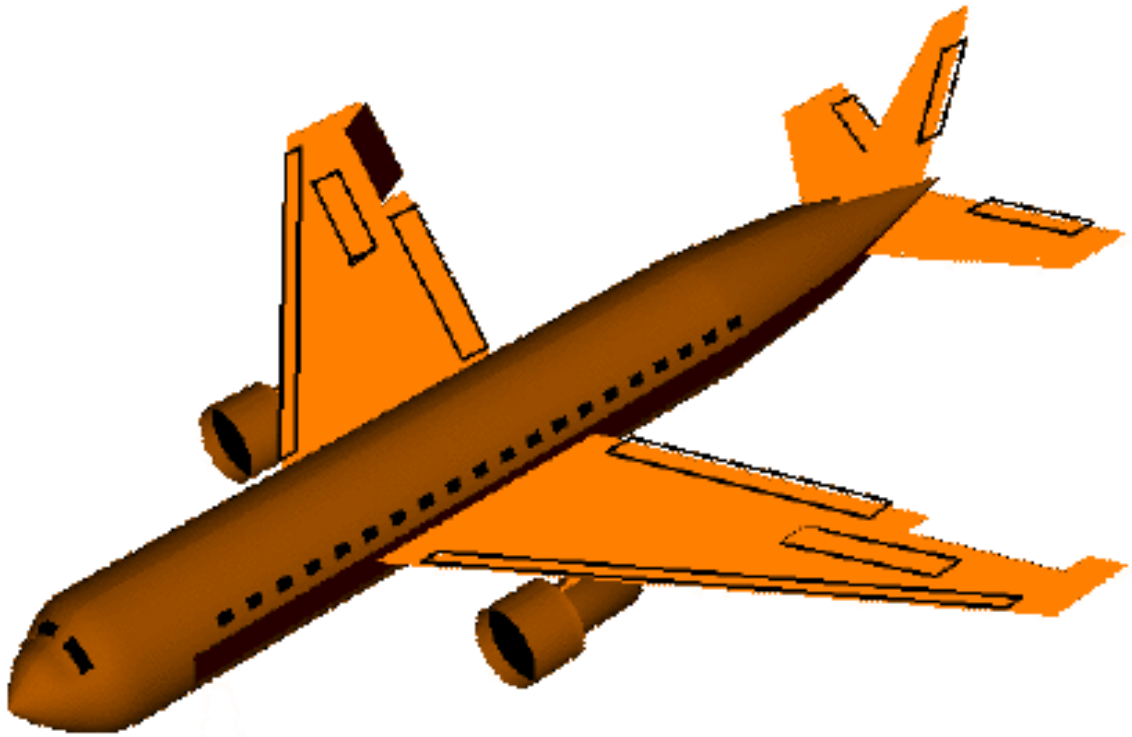

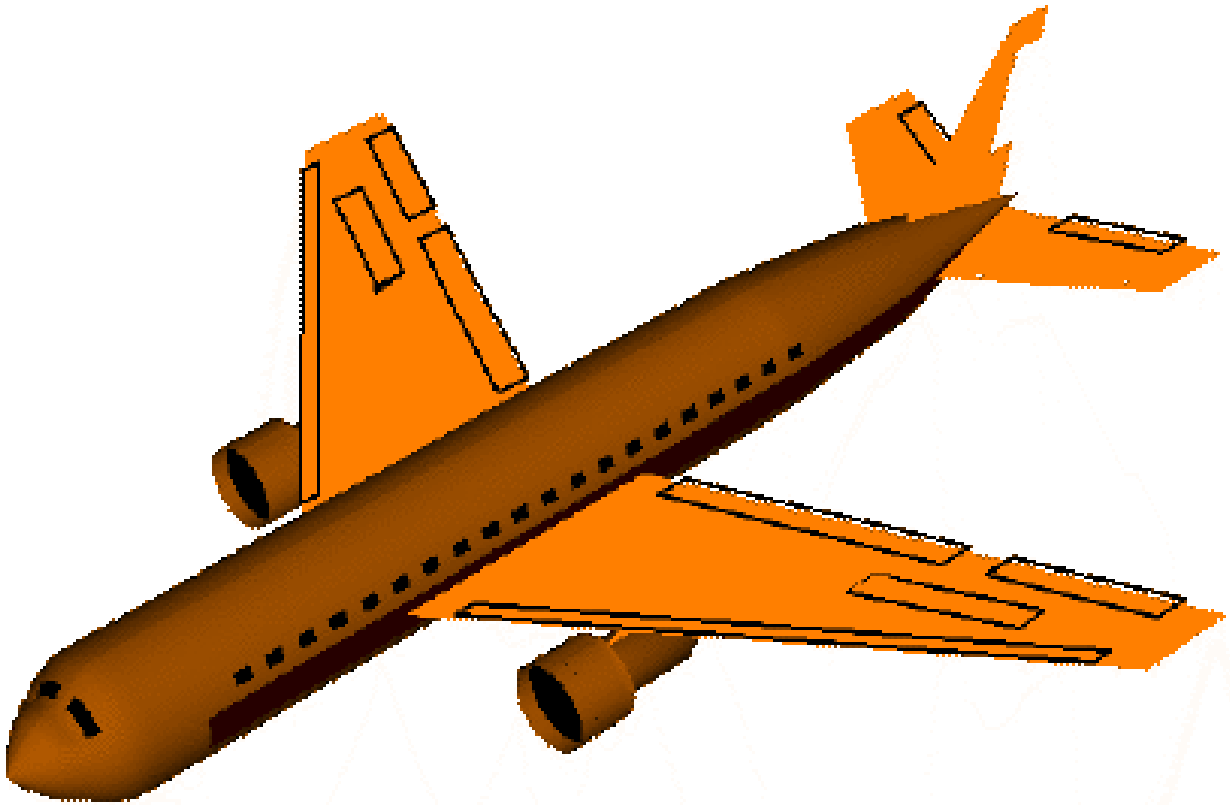

Stability and Control

An aircraft is stable if it returns to its initial equilibrium flight conditions when it is perturbed. There are two main types of aircraft instability:

An aircraft with static instability uniformly departs from an equilibrium condition

An aircraft with dynamic instability oscillates about the equilibrium condition with increasing amplitude.

There are two modes of aircraft control: one moves the aircraft between equilibrium states, the other takes the aircraft into a non-equilibrium (accelerating) state.

Control is directly opposed to stability.

Center of Pressure – cp

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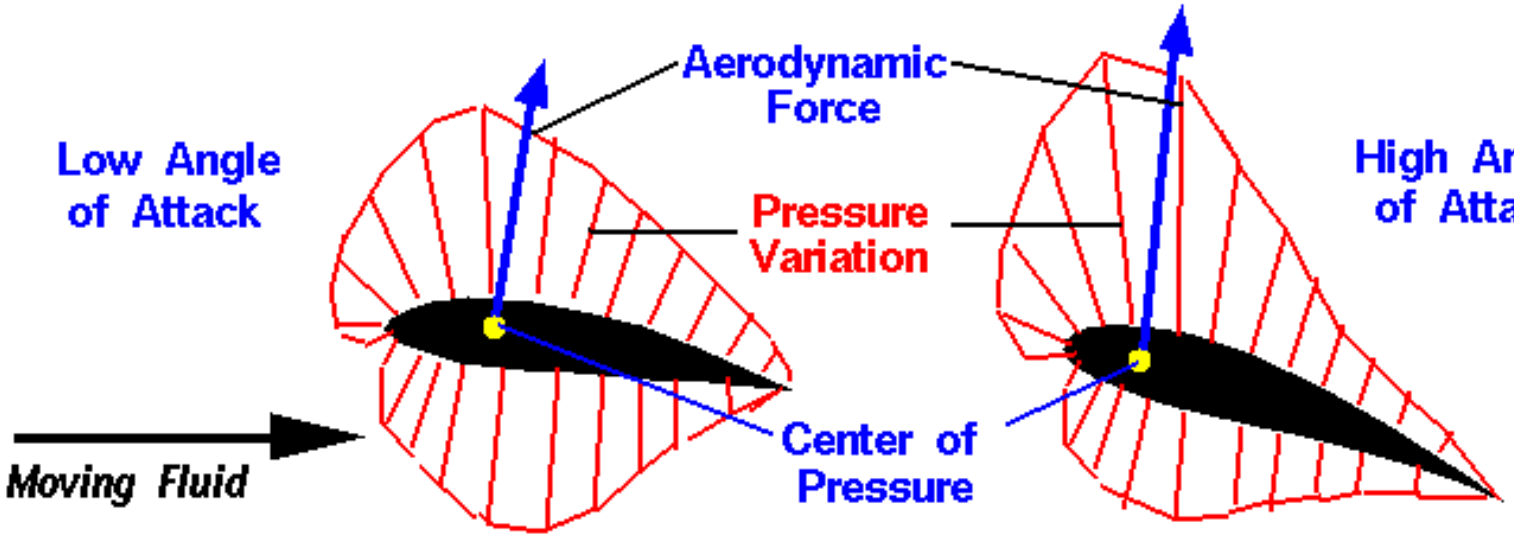

Center of Pressure is the average location of the pressure.

Pressure varies around the surface of an object. $P = P(x)$

$$cp = \frac{\int x\ p(x)\ dx}{\int p(x)\ dx}$$

Aerodynamic force acts through the center of pressure.

Center of pressure moves with angle of attack.

Aerodynamic Center – ac

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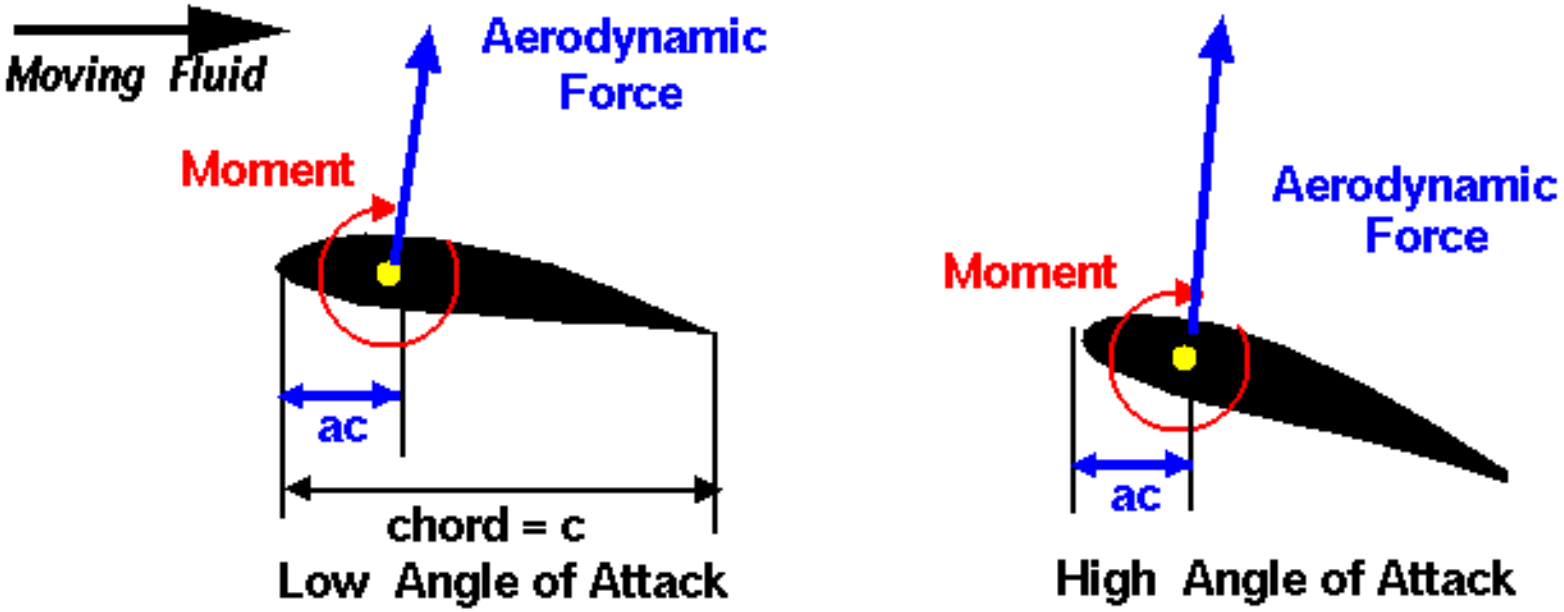

Aerodynamic Center

For low speed, thin airfoils (flat plate) :

$$ac = \frac{c}{4}$$

Moment about the aerodynamic center is constant with angle.

Aerodynamic center does not move with angle.

Trimmed Aircraft

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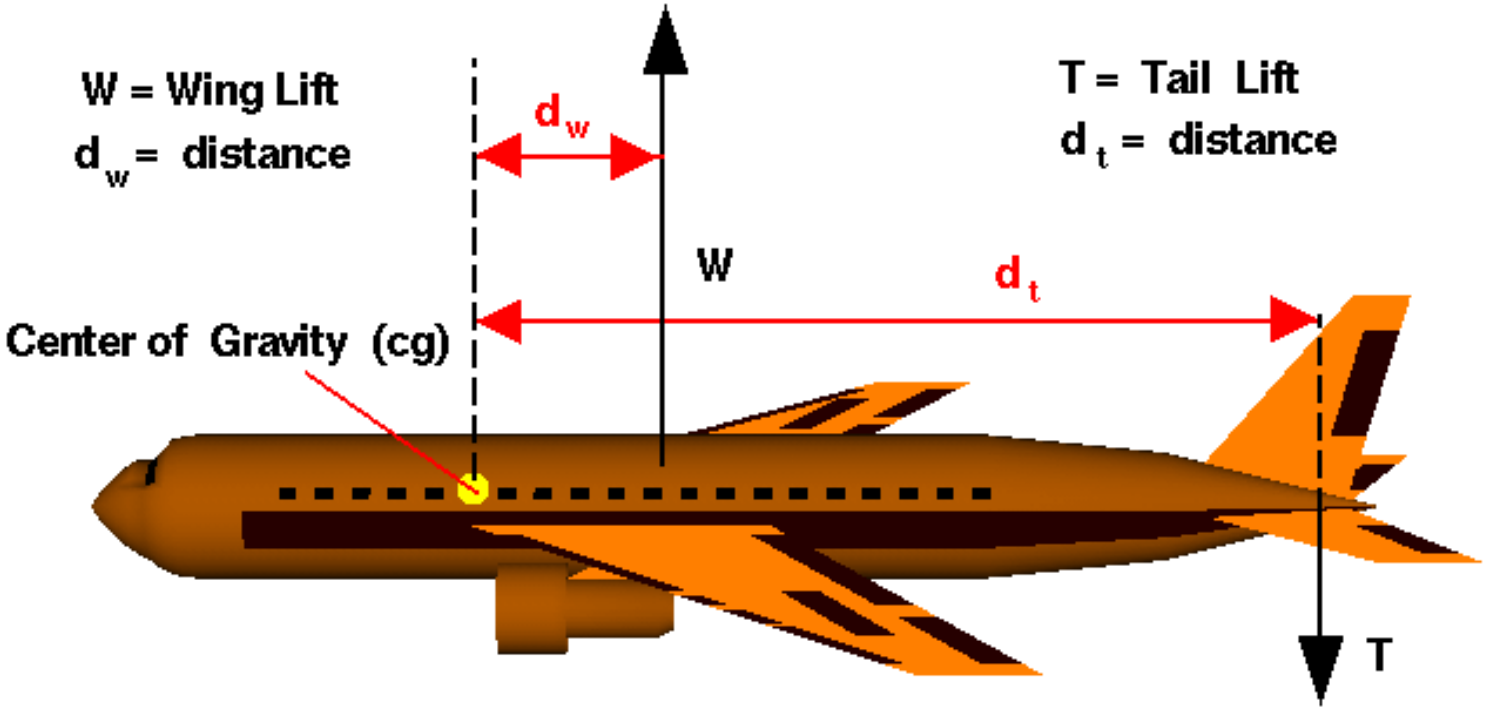

For trimmed flight, no rotation about cg.

Equation: $(\overleftarrow{W} \times \overleftarrow{d_w}) + (\overleftarrow{T} \times \overleftarrow{d_t}) = 0$

(Lift of Wing x distance from cg) + (Lift of Tail x distance from cg) = 0

Inclination Effects on Lift

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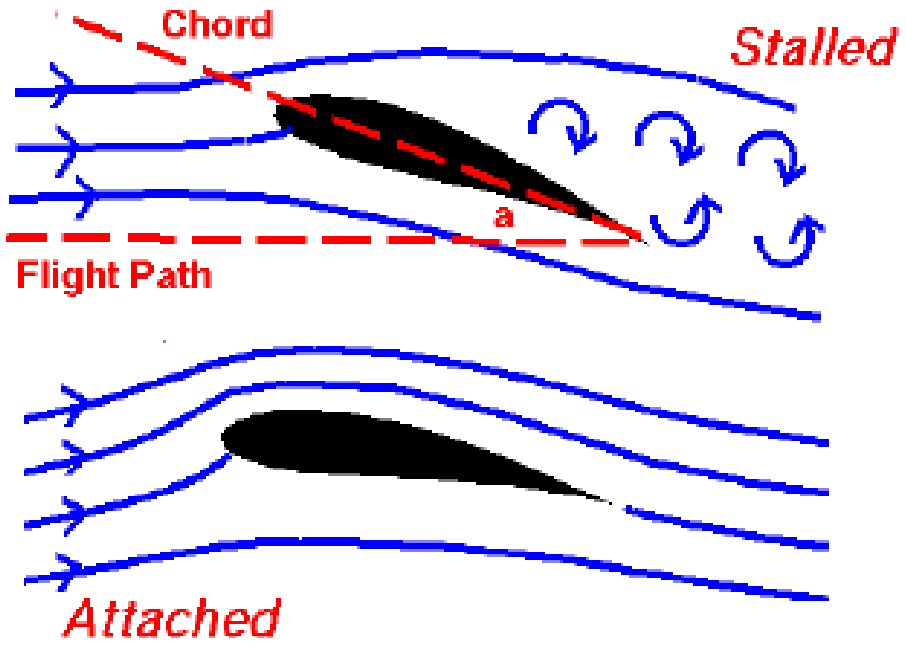
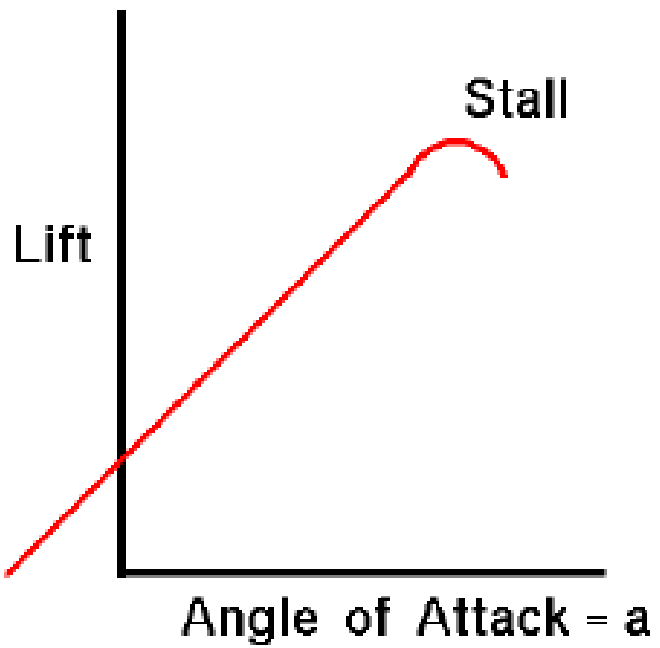




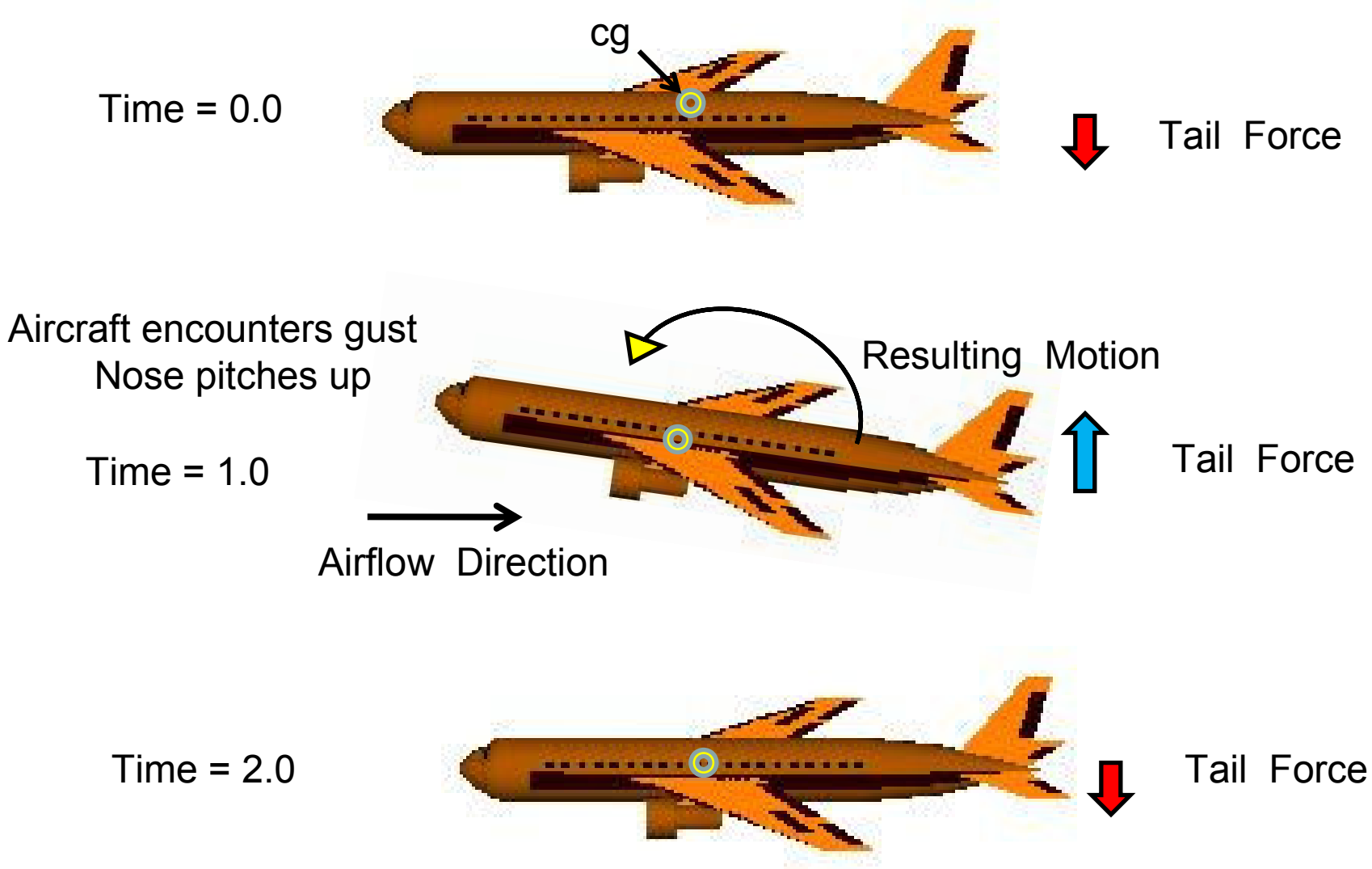
For small angles, lift is related to angle.

Greater Angle = Greater Lift

For larger angles, the lift relation is complex.

Included in Lift Coefficient

Longitudinal Static Stability



Horizontal Stabilizer – Elevator

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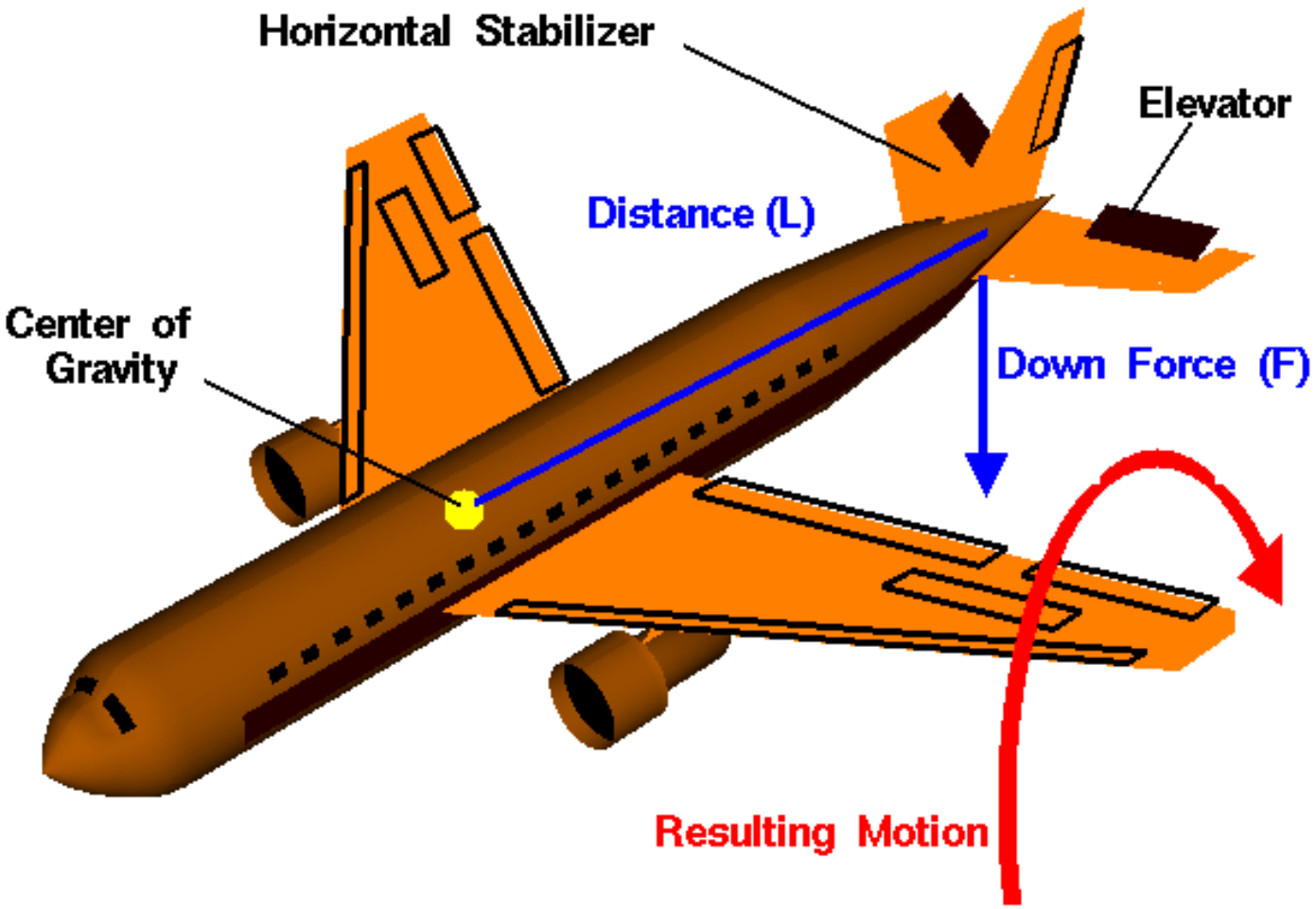

Stabilators

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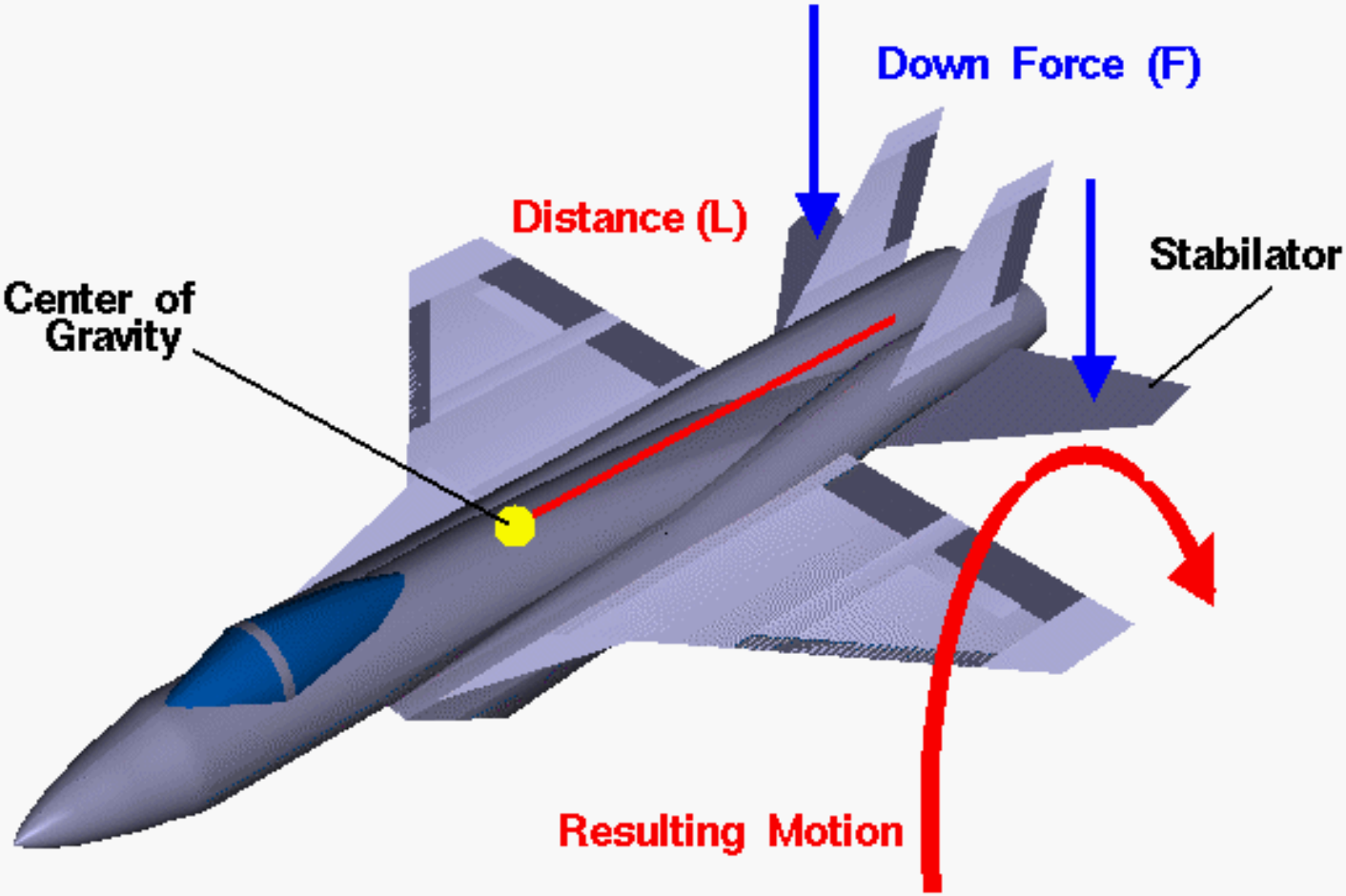

Vectored Thrust

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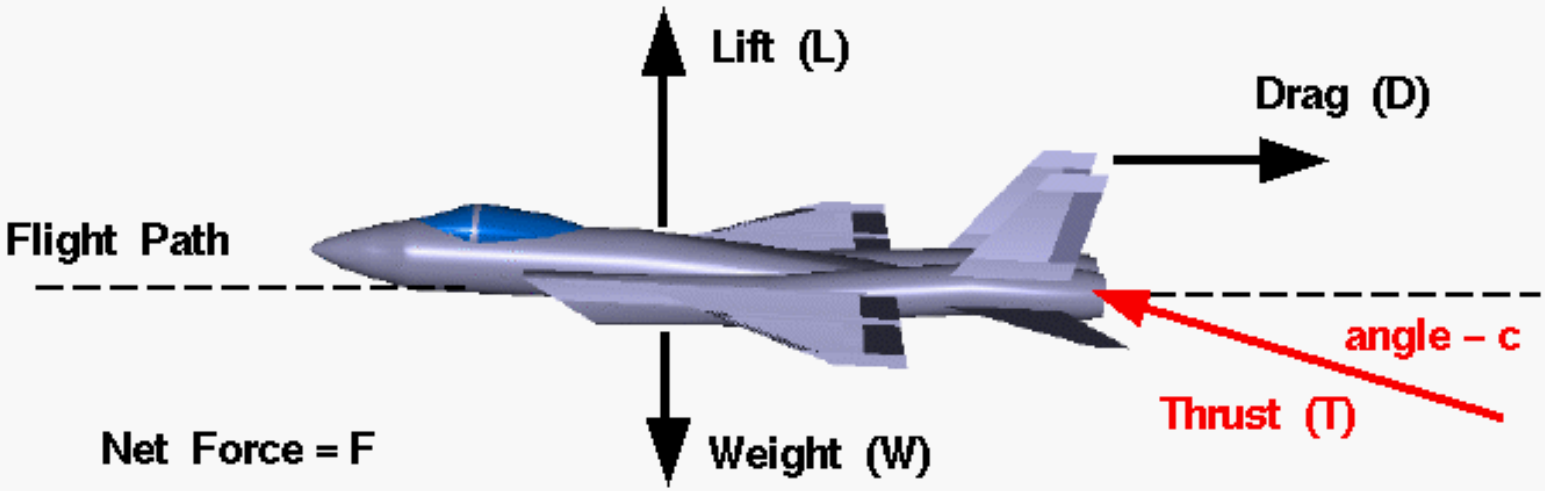


Force Equations

Vertical

$L - W + T\sin(c) = F_v$

$a_v = F_v / m$

Horizontal

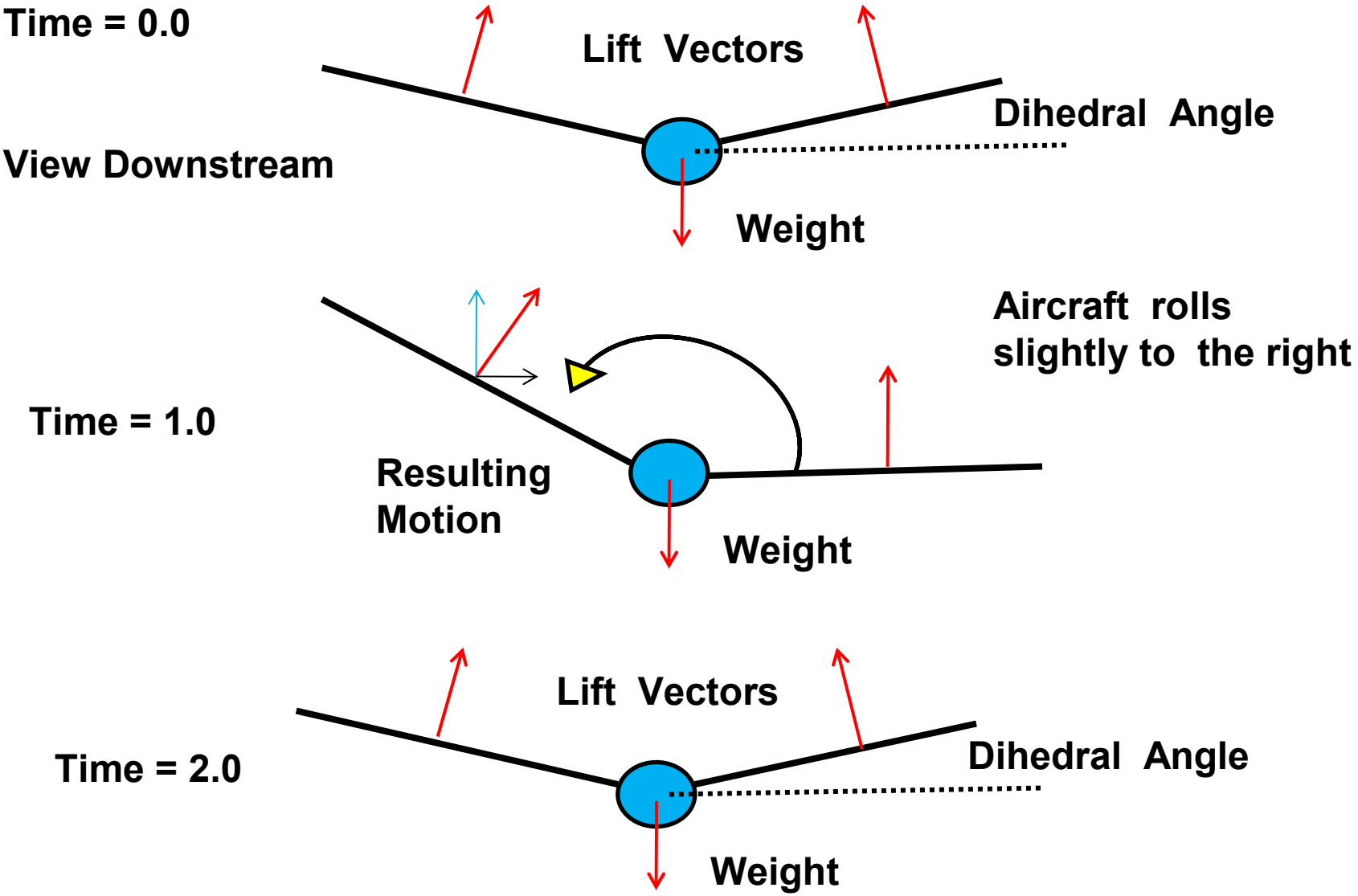
$T\cos(c) - D = F_h$

$a_h = F_h / m$

a = acceleration of aircraft

m = mass of aircraft

Lateral Static Stability



Ailerons

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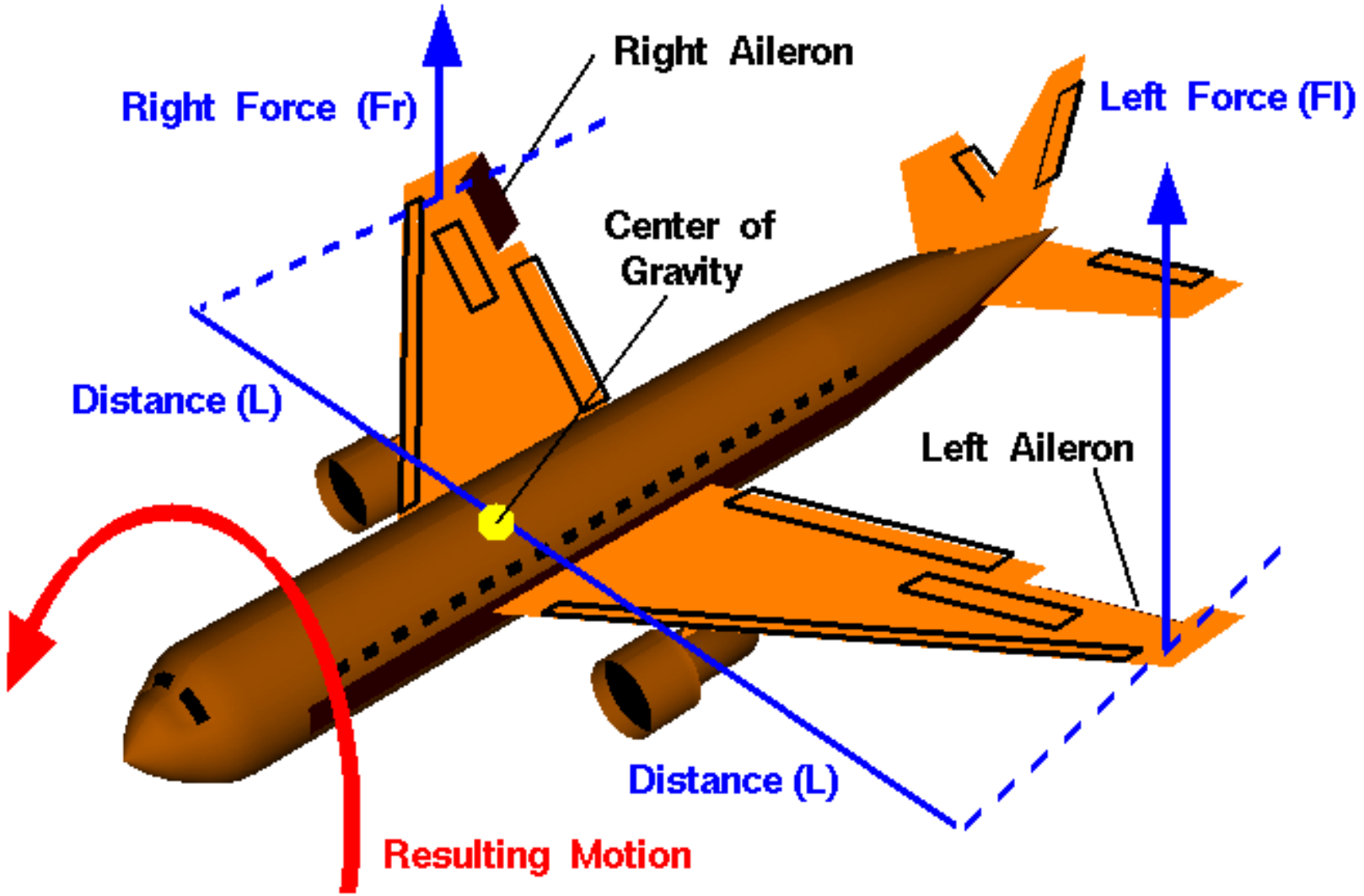

Spoilers

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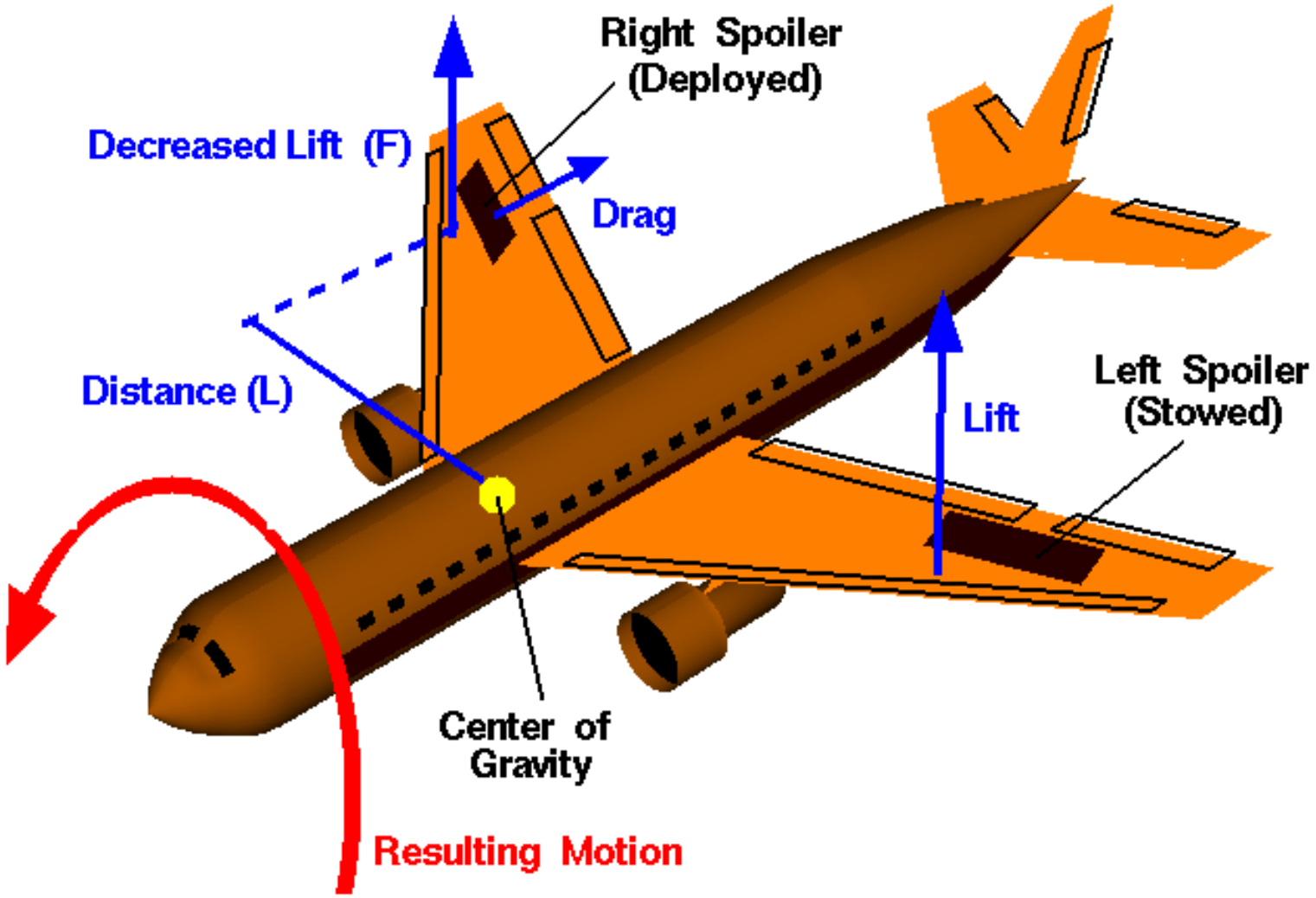

Vertical Stabilizer – Rudder

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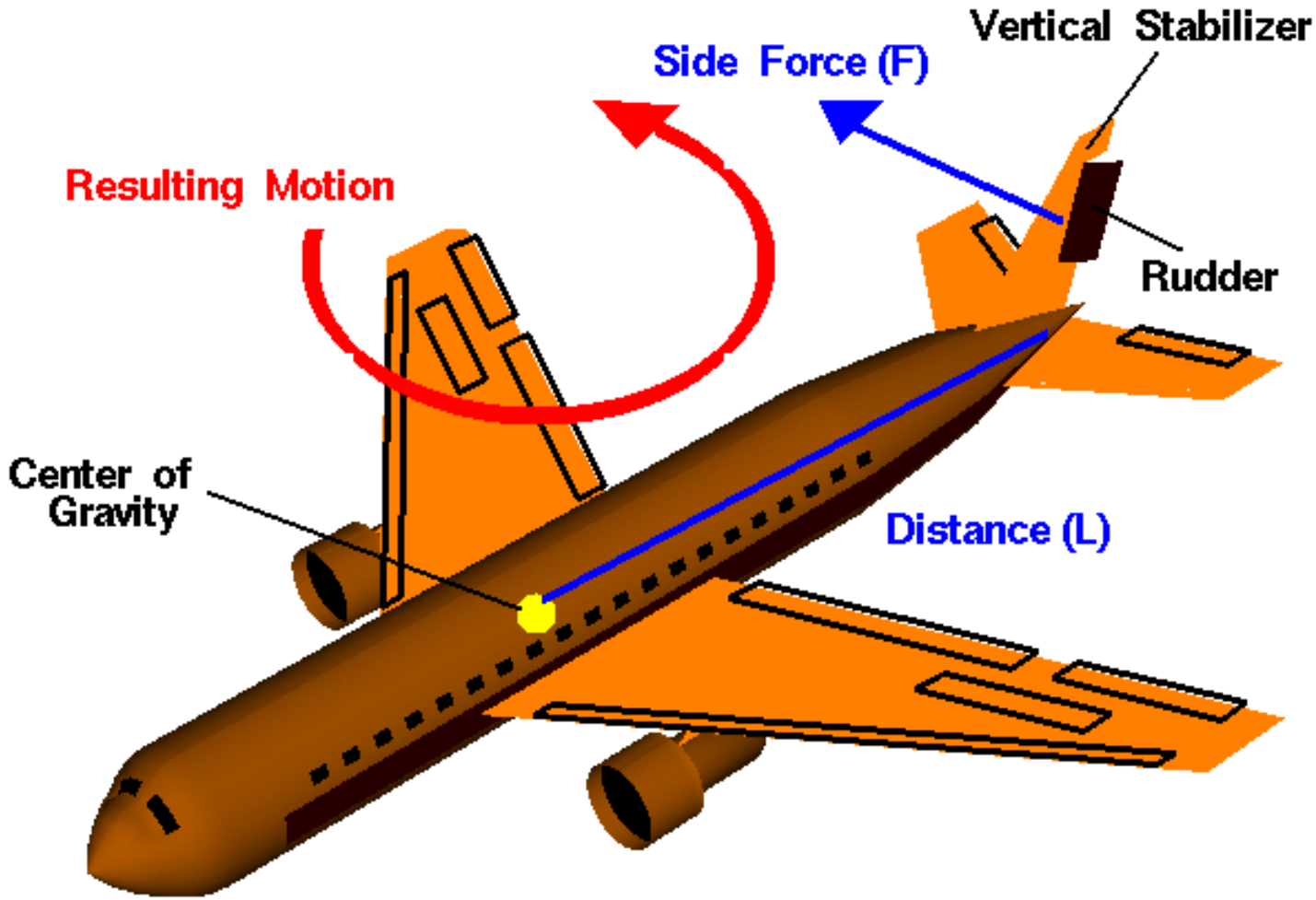

Banking Turn

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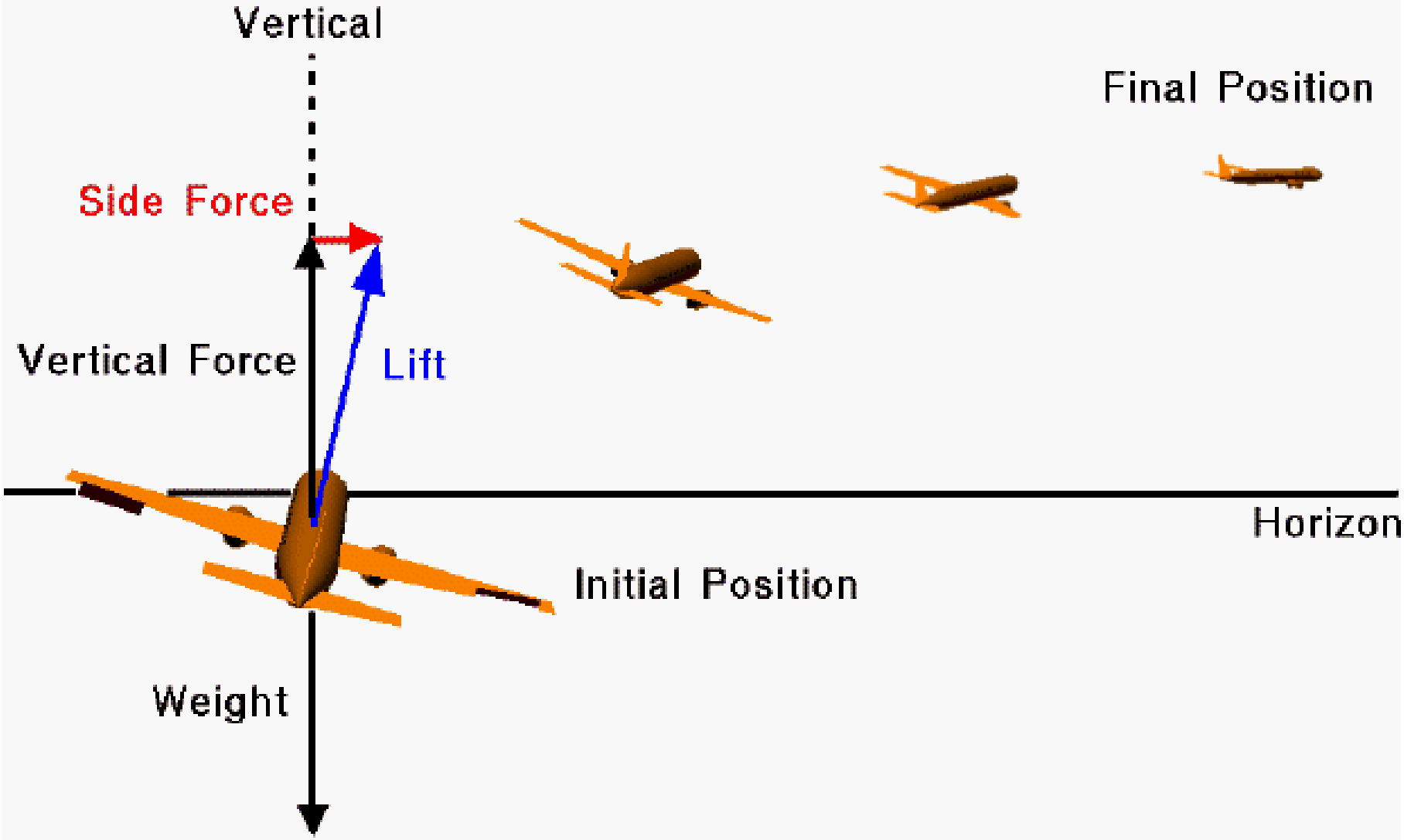

Object Motion with a Side Force

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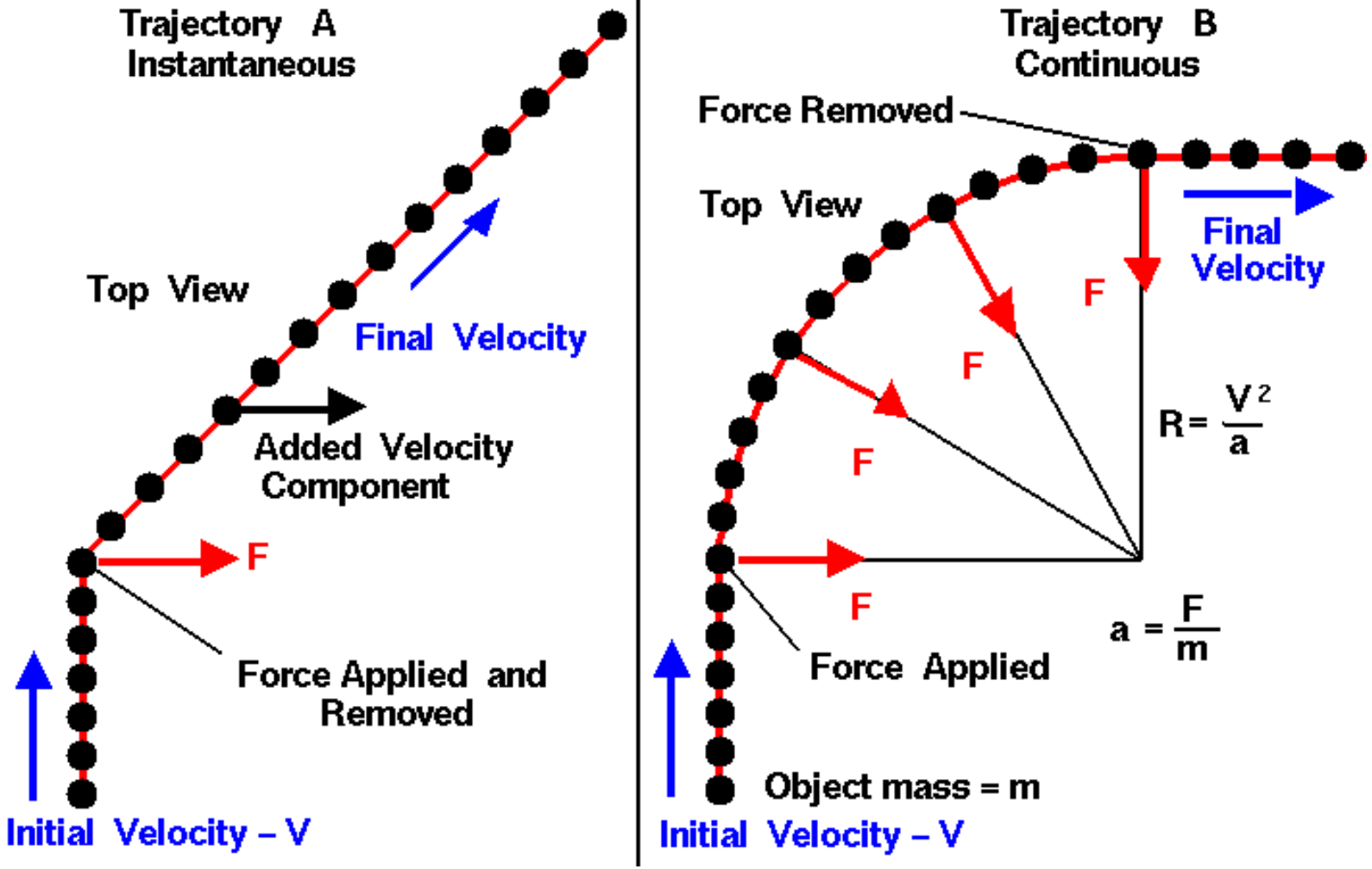

On-Line Educational Resources

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Aerodynamics:

http://www.grc.nasa.gov/WWW/K-12/airplane

Wright Brothers:

http://wright.nasa.gov/

Aero Activities:

http://www.grc.nasa.gov/WWW/K-12/aerores.htm

Help:

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