



Aircraft Simulation and Control
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Translational Kinematic Equations:

- Displacement of an object with constant velocity
 $x_2 = x_1 + v * t$
- Velocity change for an object with constant acceleration
 $v_2 = v_1 + a * t$
- Displacement of an object due to changing velocity, i.e. acceleration
 $x_2 = x_1 + v_1 * t + \frac{1}{2} * a * t^2$

Angular Kinematic Equations:

- Angular Displacement for constant angular velocity
 $\theta_2 = \theta_1 + \omega * t$
- Angular Velocity (Body Rate)
 $\omega_2 = \omega_1 + \alpha * t$
- Angular Displacement due to changing angular velocity, i.e., angular acceleration
 $\theta_2 = \theta_1 + \omega_1 * t + \frac{1}{2} * \alpha * t^2$

Forces:

- Newton's Second law of physics gives us the equation:
 $F = m * a \Leftrightarrow a = \frac{F}{m}$
- F = force, m = mass, a = acceleration

Moments:

- Newton's Second law applied to rotation
 $M = I * \alpha \Leftrightarrow \alpha = \frac{M}{I}$
- M = Moment, α = angular acceleration, I = moment of Inertia

Mass and Moment of Inertia Properties:

- Mass and moment of inertia are known properties
- Center of gravity (CG) is the center point where gravity acts on the aircraft
- CG is the center location where all Force, Moment, velocity and acceleration is determined

Where Do the Forces and Moments Come From?

- Depends on flight condition

Example flight conditions:

- Steady level flight
 - Forces – Lift, Drag, Weight, Thrust
 - Moments – caused by displacement of Forces from CG
- Takeoff
 - Forces – Lift, Drag, Weight, Thrust, and Friction
 - Moments – Caused by displacement of Forces from CG

Force and Moment Equations:

- Lift: $L = \frac{1}{2} * \rho * V^2 * S * C_L$
- Drag: $D = \frac{1}{2} * \rho * V^2 * S * C_D$
- Moment Aero: $M = \frac{1}{2} * \rho * V^2 * S * c * C_M$
- Thrust: $T = \rho * n^2 * D^2 * C_T$
- Weight: $W = m * g$
- Friction: $F_{Friction} = \mu * F_{Normal}$
- Moment: $M = F * dx_{cg}$

Terms:

$\rho = \text{Air Density}$

$V = \text{Velocity}$

$S = \text{Wing Area}$

$c = \text{Wing Chord}$

$C_L = \text{Lift Coefficient}$

$C_D = \text{Drag Coefficient}$

$C_M = \text{Moment Coefficient}$

$C_T = \text{Thrust Coefficient}$

$D = \text{Propeller Diameter}$

$n = \text{Propeller rev/sec}$

$m = \text{Mass}$

$g = \text{Gravitational Acceleration}$

$\mu = \text{Friction Coefficient}$

$dx_{cg} = \text{Force Displacement from CG}$