Flight Dynamics & Control

Introduction

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Objectives – What you should get from this course

- An understanding of what dynamic performance an airplane can achieve.
- An understanding of what design parameters affect the performance, and how.
- An understanding of how to change the design parameters to improve the performance of an airplane.
- An understanding of how to design an automatic controller to help improve the performance of the airplane.

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Administration

- Professor: H. Kwatny, 3-151-A, hkwatny@coe.drexel.edu
- TA: Ed Mensah, 3-174-A, edoe.fernand.mensah@drexel.edu
- Meeting time: Tues & Thurs 2-3:20 3-174
- Grading
  - Homework 20%
  - Midterm 30%
  - Final project (team) 50%

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Outline

- Introduction & Definitions
- Aircraft Equations of Motion
- Static Stability & Control
- Steady-State & Linearized Dynamics
- Longitudinal Dynamics & Flying Qualities
- Lateral Dynamics & Flying Qualities
- Automatic Control
- Stalls & Spins

Nomenclature

	Roll	**Pitch**	**Yaw**
Body Axis	x	y	z
Angular Rates	p	q	r
Velocity	u	v	w
Aerodynamic Force	X	Y	Z
Aerodynamic Moment	L	M	N

Forces & Moments

aerodynamic forces:

$X = C_x QS$ $\quad C_i \; i = x, y, z$ dimensionless coefficient

$Y = C_y QS$ $\quad Q = \frac{1}{2}\rho V^2$ dynamic pressure

$Z = C_z QS$ $\quad S$ reference or characteristic surface (e.g. wing surface), ρ air density

aerodynamic moments:

$L = C_L QS\ell$

$M = C_M QS\ell$ $\quad \ell$ reference or characteristic length (e.g., wing span or mean chord)

$N = C_N QS\ell$

coefficients,C_i, are typically functions of Mach number, Renolds number, angle of attack, sideslip angle, plus others

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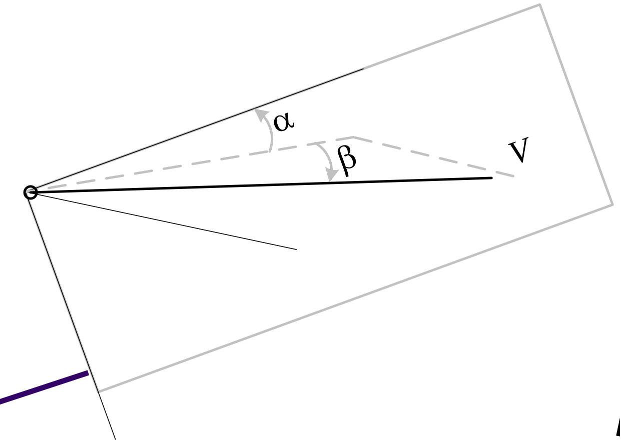
Alternate Velocity Coordinates



Wind Coordinates: $(u,v,w) \Leftrightarrow (V,\alpha,\beta)$

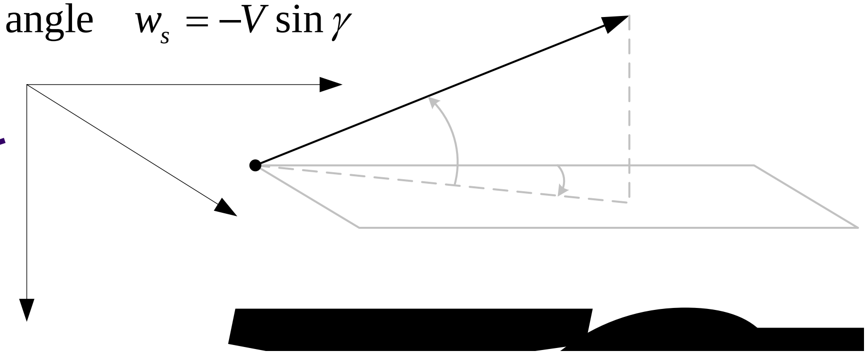
$V=\sqrt{u^2+v^2+w^2}$	speed	$u=V\cos\alpha\cos\beta$
$\alpha=\tan^{-1}\left(w/u\right)$	angle of attack	$v=V\sin\beta$
$\beta=\sin^{-1}\left(v/V\right)$	sideslip angle	$w=V\cos\beta\sin\alpha$

Body Frame

Flight Path Coordinates: $(u_s,v_s,w_s) \Leftrightarrow (V,\Psi,\gamma)$

$V=\sqrt{u_s^2+v_s^2+w_s^2}$	speed	$u_s=V\cos\gamma\cos\Psi$
$\Psi=\sin^{-1}\left(v_s/\sqrt{u_s^2+v_s^2}\right)=\tan^{-1}\left(v_s/u_s\right)$	heading	$v_s=V\cos\gamma\sin\Psi$
$\gamma=\sin^{-1}\left(-w_s/V\right)=\tan^{-1}\left(-w_s/\sqrt{u_s^2+v_s^2}\right)$	flight path angle	$w_s=-V\sin\gamma$

Space Frame



Flight Path in Body Coordinates

$$\gamma = \sin^{-1}\left(-w_s / V\right) = \tan^{-1}\left(-w_s / \sqrt{u_s^2 + v_s^2}\right)$$

$$\Psi = \sin^{-1}\left(v_s / \sqrt{u_s^2 + v_s^2}\right) = \tan^{-1}\left({}^{v_s}\!/_{u_s}\right)$$

$$\begin{bmatrix} u_s \\ v_s \\ w_s \end{bmatrix} = L \begin{bmatrix} u \\ v \\ w \end{bmatrix}$$

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