Christopher Lum
lum@uw.edu

Lecture 04d
Dimensionless Aerodynamic Coefficients

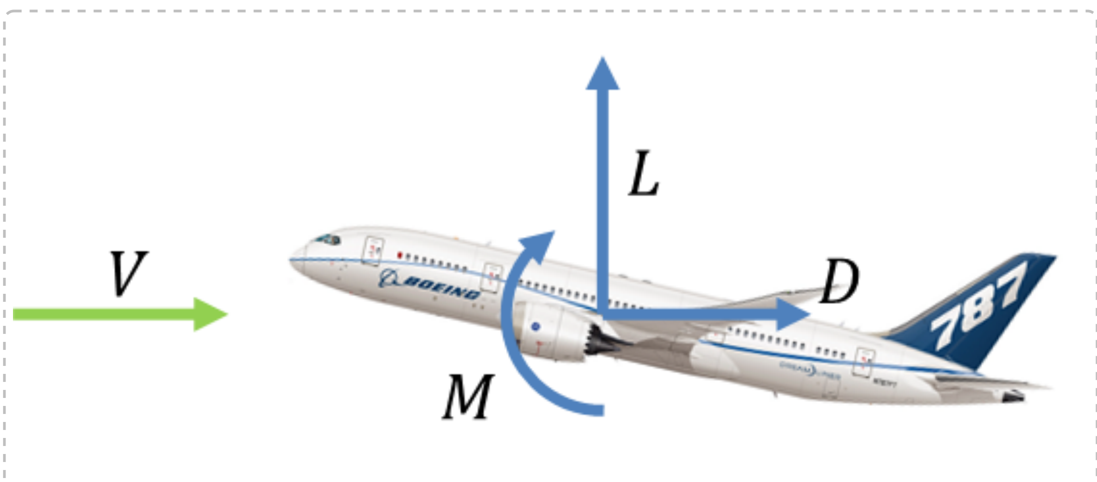
The YouTube video entitled ‘Dimensionless Aerodynamic Coefficients’ that covers this lecture is located at https://youtu.be/XO8KvIoCNbE

Outline

-Aerodynamic Forces and Moments
-Dimensionless Aerodynamic Coefficients

Aerodynamic Forces and Moments

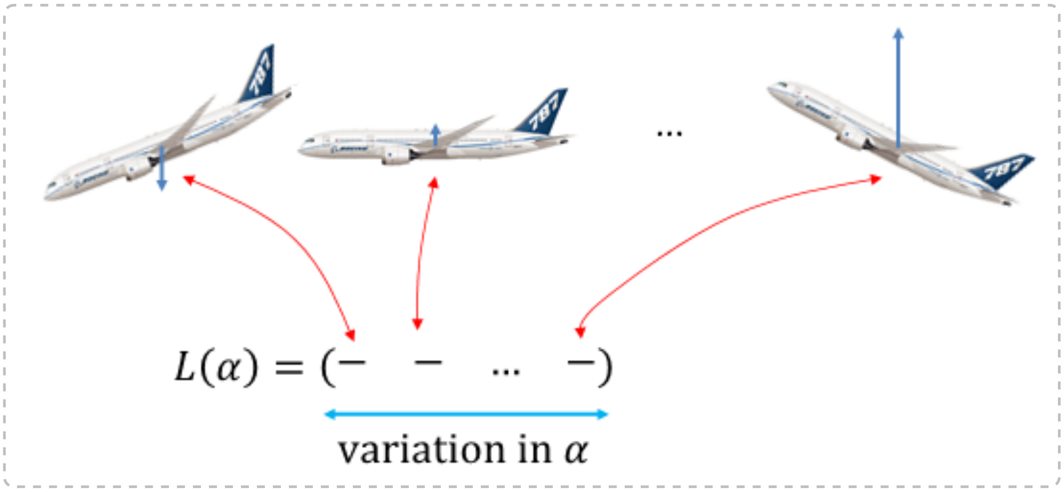
As we develop our model of an aircraft, one of the main things we need to model and understand is the aerodynamic effects (forces and moments) on the aircraft.



Consider only the lift force, L. To start, we can attempt to characterize how this varies as a function of the angle of attack, α

$$L = L(\alpha)$$

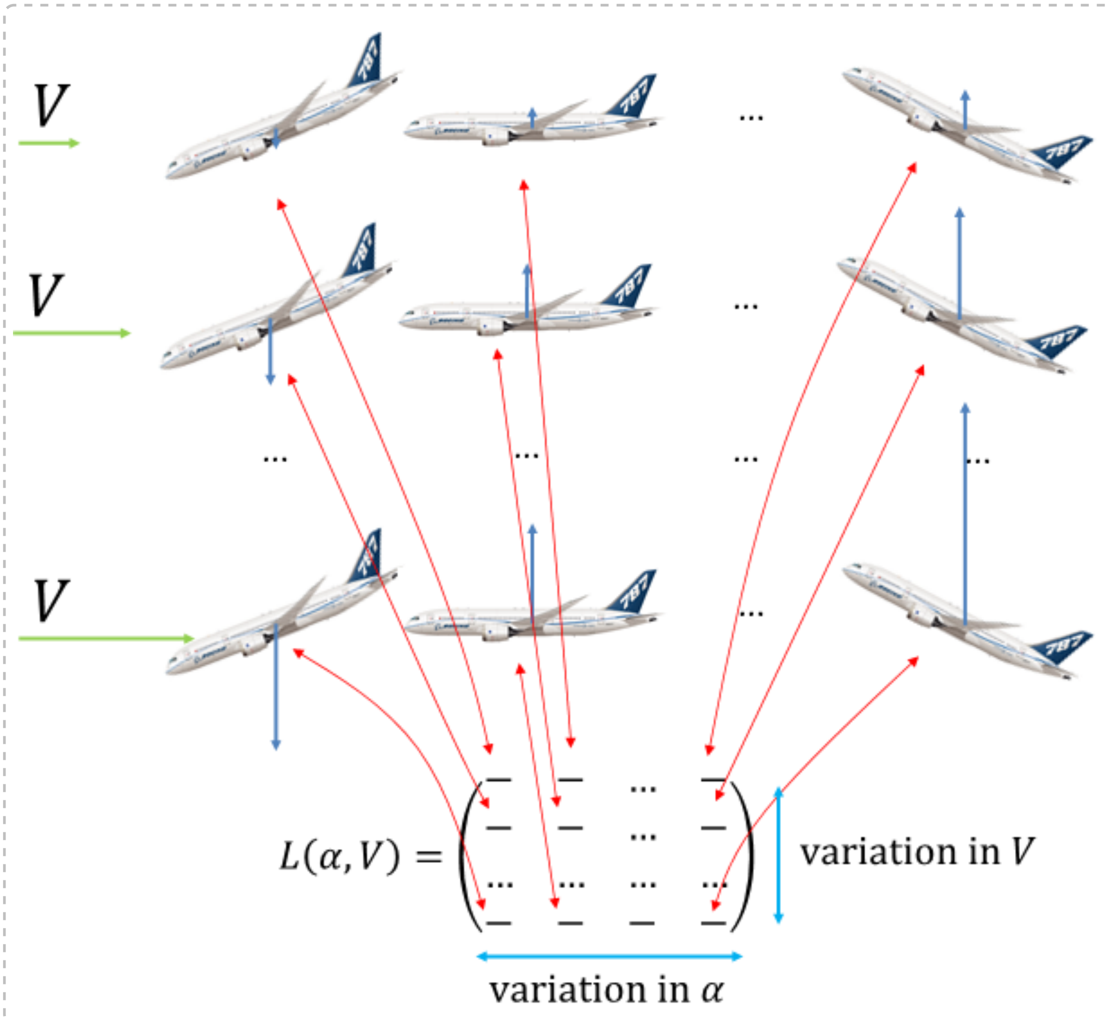
To characterize this, we can experimentally test (for example in a wind tunnel) and vary the angle of attack over several values



We also know that the lift is a function of the velocity (if you go faster, there is more lift).

$$L = L(\alpha, V)$$

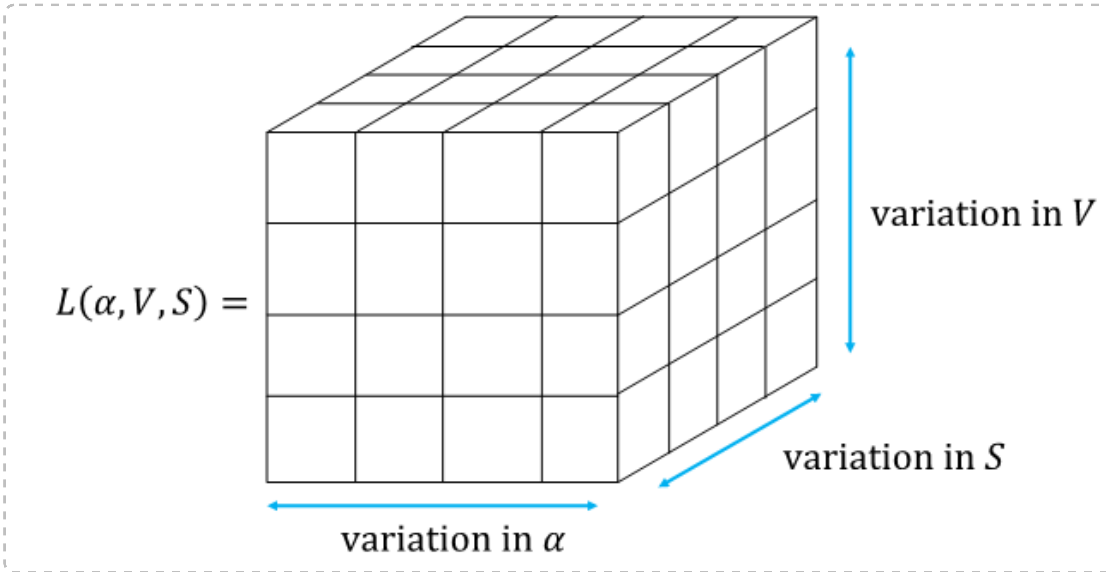
As such, we can increase the dimensionality of our test and also vary the velocity in addition to the angle of attack



We also know that the lift is a function of the size (if you have a larger aircraft/wing there is more lift).

$$L = L(\alpha, V, S)$$

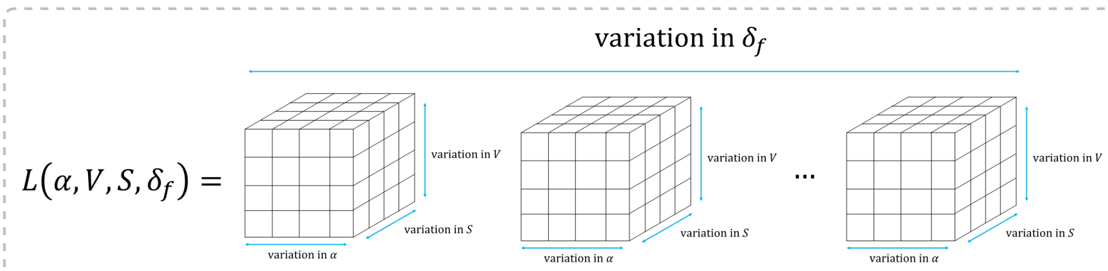
As such, we can increase the dimensionality of our test and also vary the aircraft size in addition to the angle of attack and velocity. And we start to see the problem with this approach as every increased dimension greatly increases the number of data points we need to collect



We also know that the lift is a function of the control surface deflections, such as the flaps (if deflect the flaps you change the lift).

$$L = L(\alpha,\ V,\ S,\ \delta_f)$$

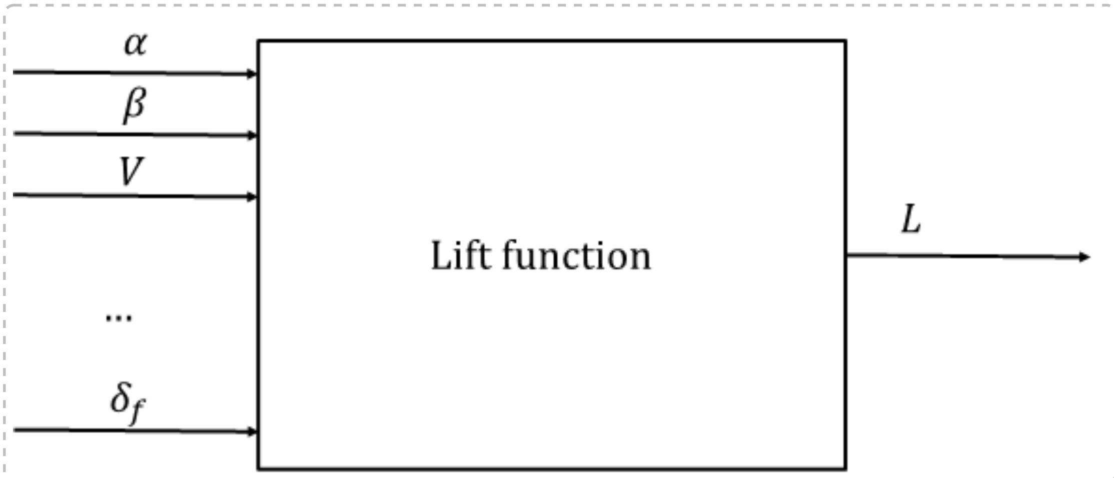
As such, we can increase the dimensionality of our test and also vary the aircraft size in addition to the angle of attack and velocity. And we start to see the problem with this approach as every increased dimension greatly increases the number of data points we need to collect



Dimensionless Aerodynamic Coefficients

We see that this is not a scalable approach because in reality, the lift is a function of many more variables such as

$L = L(\alpha,\ \beta,\ V,\ \rho,\ S,\ \delta_e,\ \delta_a,\ \delta_r,\ \ldots)$ (measured quantity so could include more effects that those listed)



We want to reduce the dimensionality of the problem thereby reducing the amount of time needed to obtain , we typically look at dimensionless aerodynamic coefficients.

$C_L \equiv \frac{L}{q\,S}$ (lift)

$C_D \equiv \frac{D}{q\,S}$ (drag)

$C_Y \equiv \frac{\text{SF}}{q\,S}$ (side force)

where $q = \frac{1}{2}\,\rho\,V^2$ (dynamic pressure)

S = normalizing area (typically the areas of the wing)

This dimensionless coefficient can be used to scale up effects to larger aircraft or to aircraft at different flight conditions (within reason).

Similarly for moment coefficients

$C_M \equiv \frac{M}{q\,S\,\bar{c}}$ (pitch) (note that the characteristic length is $\bar{c}$)

$C_R \equiv \frac{R}{q\,S\,b}$ (roll) (to be confusing, sometimes this is C_l (little L))

$C_N \equiv \frac{Y}{q\,S\,b}$ (yaw)

where $\bar{c}$ = mean aerodynamic chord

b = reference span

It is worth mentioning that some applications use $\bar{c}$ as the reference length to normalize all the moment forces (such as the RCAM model we will study later) however it is more traditional to normalize pitching moment using $\bar{c}$ and normalize roll and yaw using b.

Note that this is related to the Buckingham π Theorem (https://en.wikipedia.org/wiki/Buckingham_%CF%80_theorem) that we will cover in a separate video.