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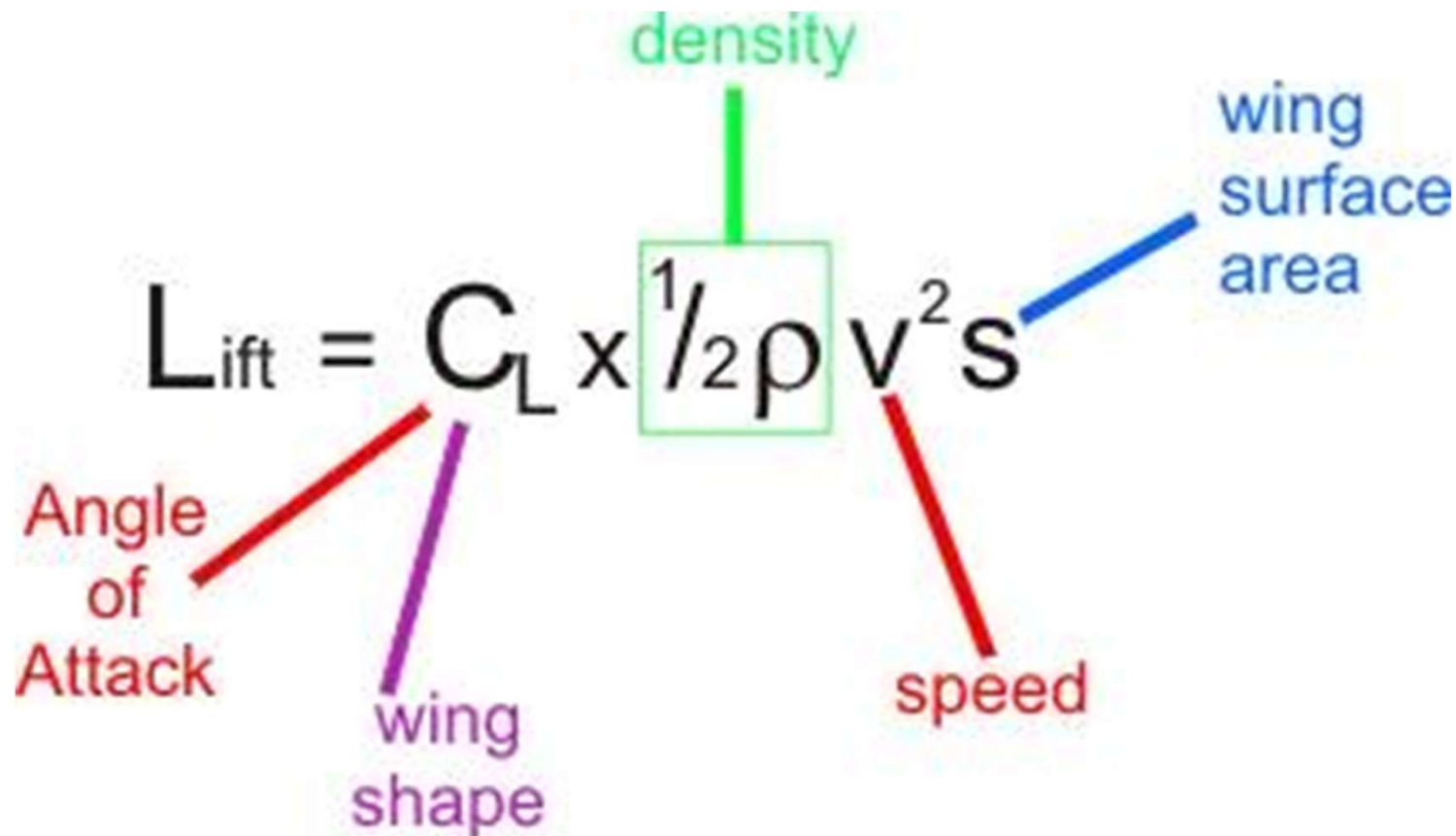
# Unmanned Airplane Design

— An overview of Designing and Constraints —

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# The Lift Equation



The diagram illustrates the Lift Equation,  $L_{\text{lift}} = C_L \times \frac{1}{2} \rho v^2 s$ , with color-coded annotations for each variable:

- $C_L$** : Lift coefficient, determined by the **Angle of Attack** (indicated by a red line).
- $\frac{1}{2} \rho$** : A term representing half the air density, where  $\rho$  is the **density** (indicated by a green line).
- $v^2$** : The square of the **speed** (indicated by a red line).
- $s$** : The **wing surface area** (indicated by a blue line).
- $C_L$**  is also associated with the **wing shape** (indicated by a purple line).



## *The Drag Equation*

Glenn  
Research  
Center



$$D = C_d \times r \times \frac{V^2}{2} \times A$$

Drag = coefficient x density x velocity squared x reference area  
two

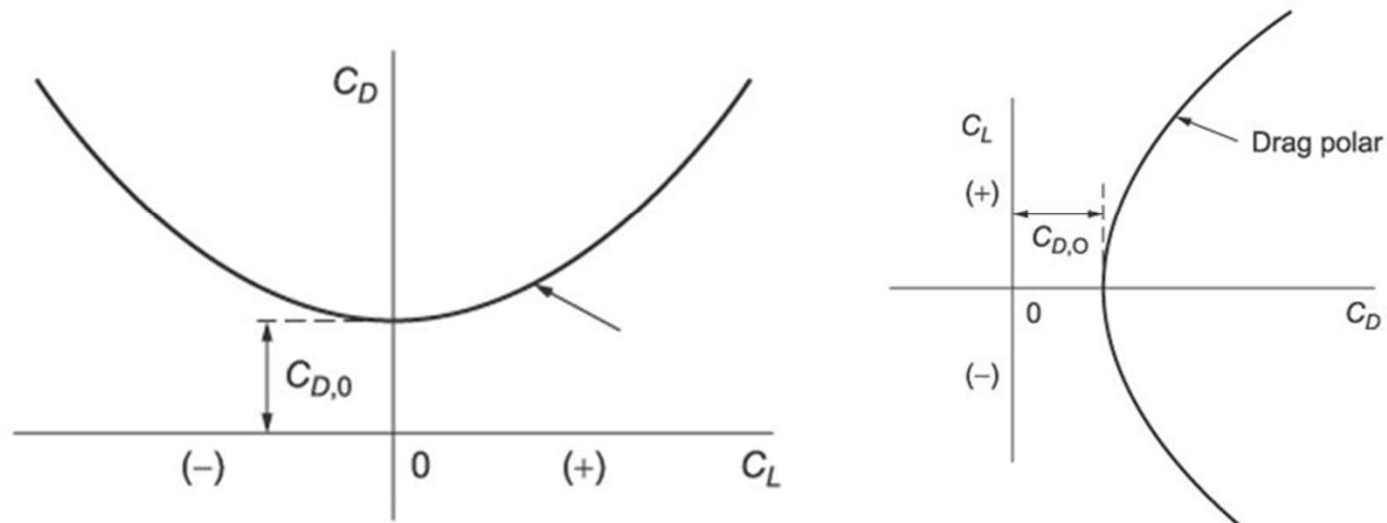
Coefficient **C<sub>d</sub>** contains all the complex dependencies  
and is usually determined experimentally.

Choice of reference area **A** affects the value of **C<sub>d</sub>**.

## DRAG POLAR

- $C_{D,0}$  is parasite drag coefficient at zero lift ( $\alpha_L=0$ )
- $C_{D,i}$  drag coefficient due to lift (induced drag)
- Oswald efficiency factor,  $e$ , includes all effects from airplane
- $C_{D,0}$  and  $e$  are known aerodynamics quantities of airplane

$$C_D = C_{D,0} + \frac{C_L^2}{\pi e AR} = C_{D,0} + C_{D,i}$$



Example of Drag Polar for complete airplane

Coefficient of lift	$\alpha$
0.3	-2
0.45	0
0.54	1
0.62	2
0.79	4
0.96	6
1.12	8
1.28	10
1.33	12
1.20	15

# Find:

- Maximum rate of climb, velocity for maximum rate of climb and corresponding angle of attack.
- Angle of attack during cruise for which aerodynamic efficiency is maximum.
- Minimum turn radius and its corresponding velocity and angle of attack.
- Maximum turn rate and its respective velocity and angle of attack.
- Minimum glide angle and respective velocity and angle of attack.
- Minimum sink rate and velocity and angle of attack to maintain that sink rate.