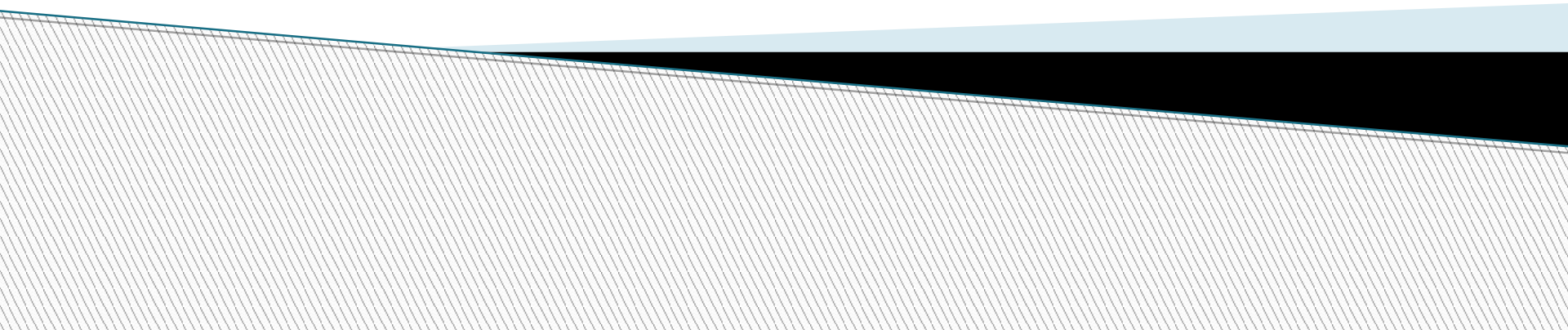


# Teaching Aerodynamics

Tom Johnson  
CFIG

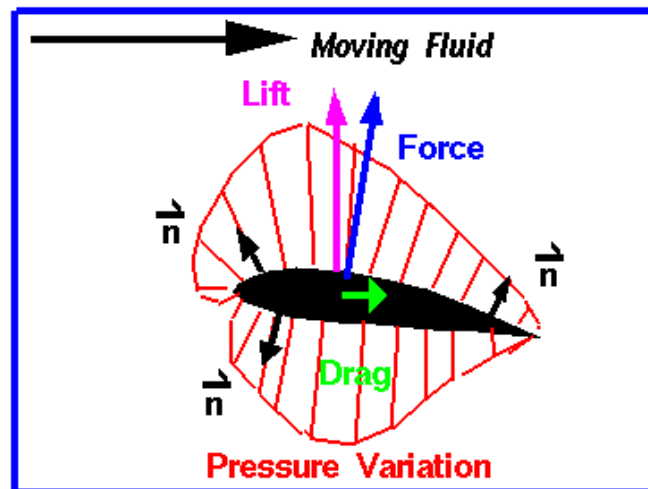


# What do we really teach?



## Aerodynamic Forces

Glenn  
Research  
Center



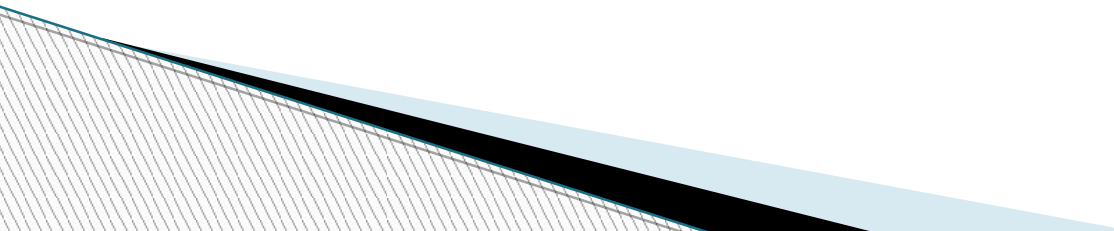
Pressure forces act normal (perpendicular) to surface.  
Force on the body is the vector sum of the pressure x area  
around the entire solid body.

$$\vec{F} = \sum_{\text{surface}} p \vec{n} A = \oint p \vec{n} dA$$

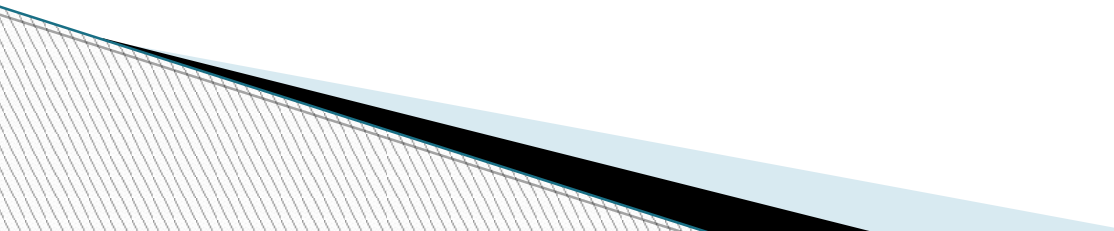
$$\text{Lift} = F_{\text{normal}}$$

$$\text{Drag} = F_{\text{stream}}$$

# Teaching Glider Aerodynamics

- ▶ Gravity is our engine
  - ▶ Lift vs Drag
  - ▶ Straight Flight
  - ▶ Turning Flight
  - ▶ Angle of Attack
  - ▶ Weight and Balance
- 

# Glider Aerodynamics Terms

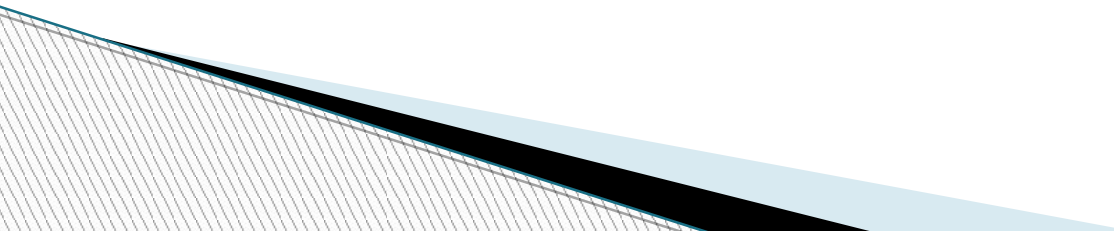
- Chamber
  - Chord
  - Relative Wind
  - Angle of Attack
  - Angle of Incidence
  - Center of Pressure (Lift) and Center of Gravity
  - Aspect Ratio (Span/Chord)
  - Aileron, Elevator and Rudder controls
  - Elevator Trim
  - Bernoulli's Principle
- 

# Glider Forces and Axes

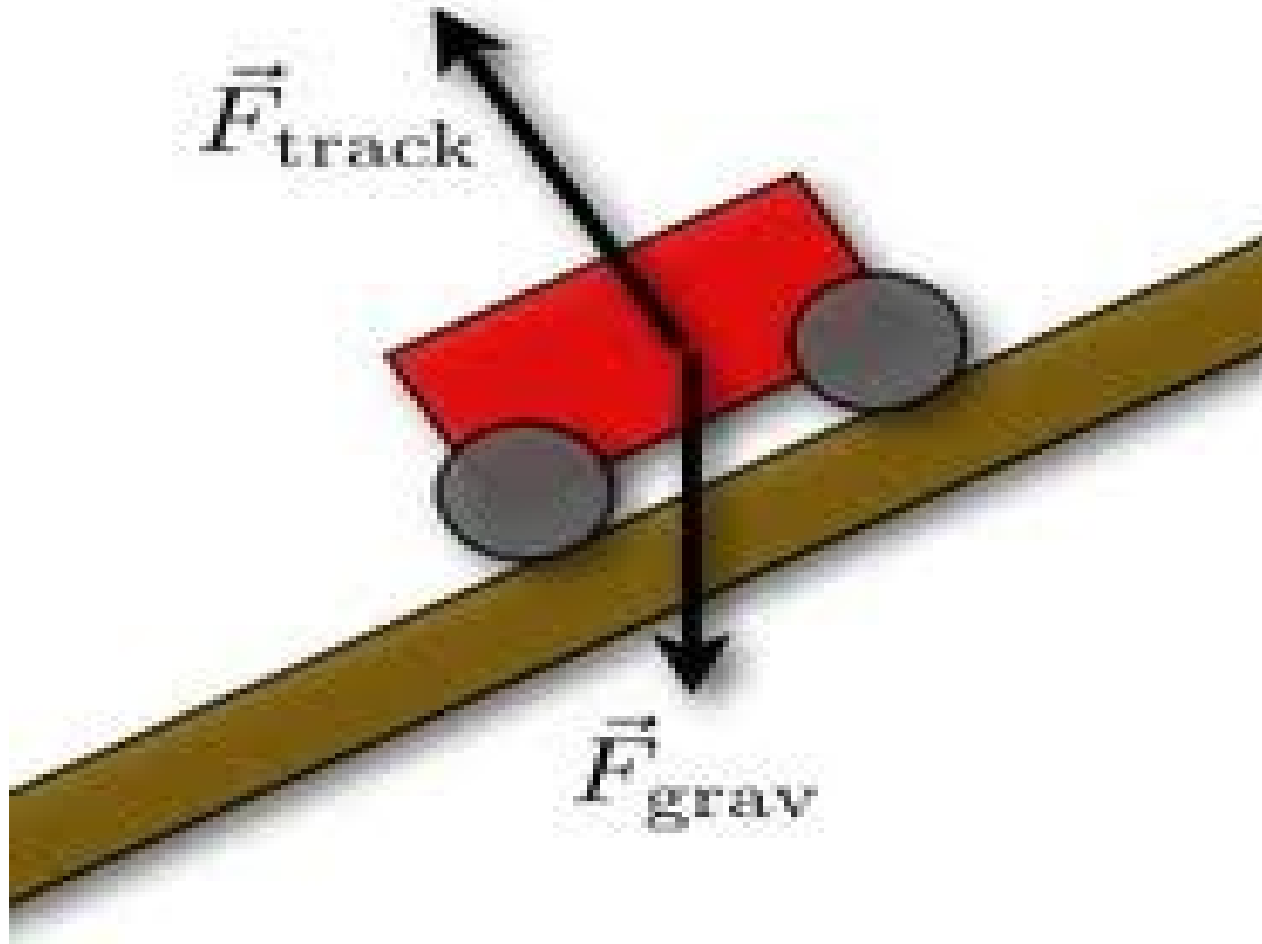
## Four Forces

- Lift
- Weight
- Drag
- Thrust

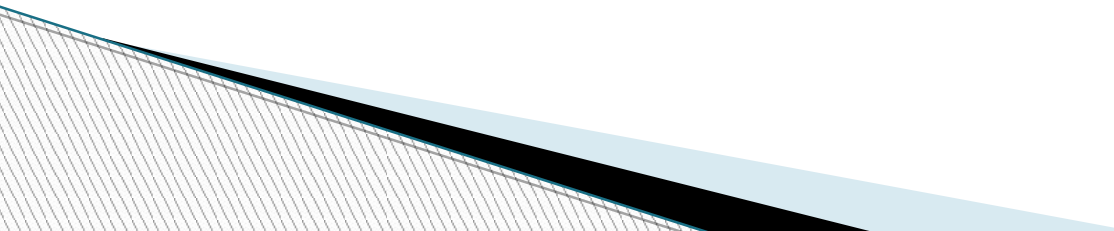
## Three Axes

- Longitudinal - Roll
  - Lateral - Pitch
  - Vertical - Yaw
- 

# Soap Box Derby Car on Incline Plane



# Lift or Weight? Drag or Thrust?

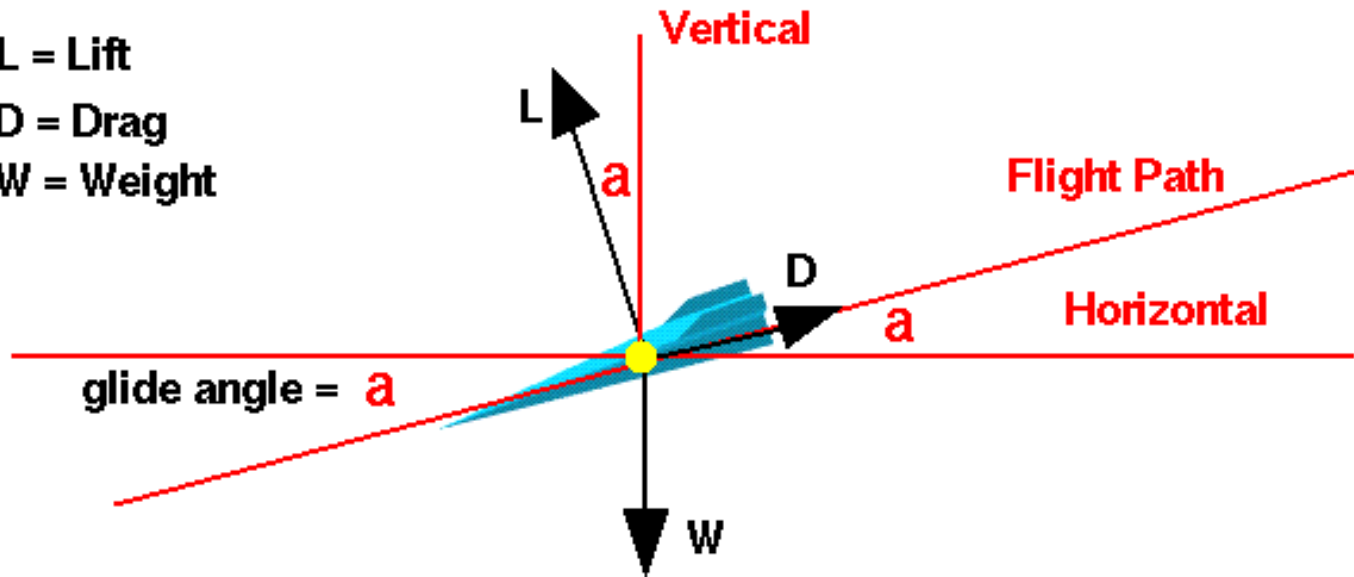
- ▶ What powers the glider thru the air?
  - ▶ What causes the glider to speed up?
  - ▶ What causes the glider to slow down?
  - ▶ How are Lift, Drag and Weight related?
- 



# Vector Balance of Forces for a Glider

Glenn  
Research  
Center

L = Lift  
D = Drag  
W = Weight



Equations:      Vertical:  $L \cos(a) + D \sin(a) - W = 0$

Horizontal:  $L \sin(a) - D \cos(a) = 0$

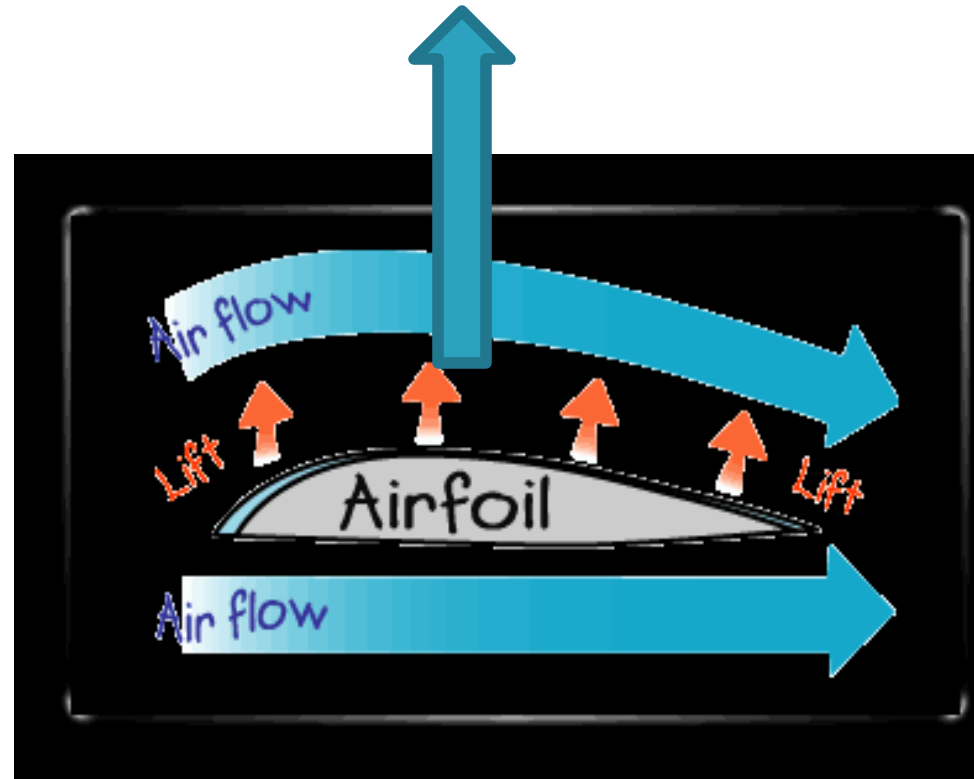
From the Horizontal equation:  $\frac{L}{D} = \frac{\cos(a)}{\sin(a)} = \frac{1}{\tan(a)}$

For small angles,  $\tan(a) = a$  (in radians!):  $\frac{L}{D} = \frac{1}{a}$



# What is lift?

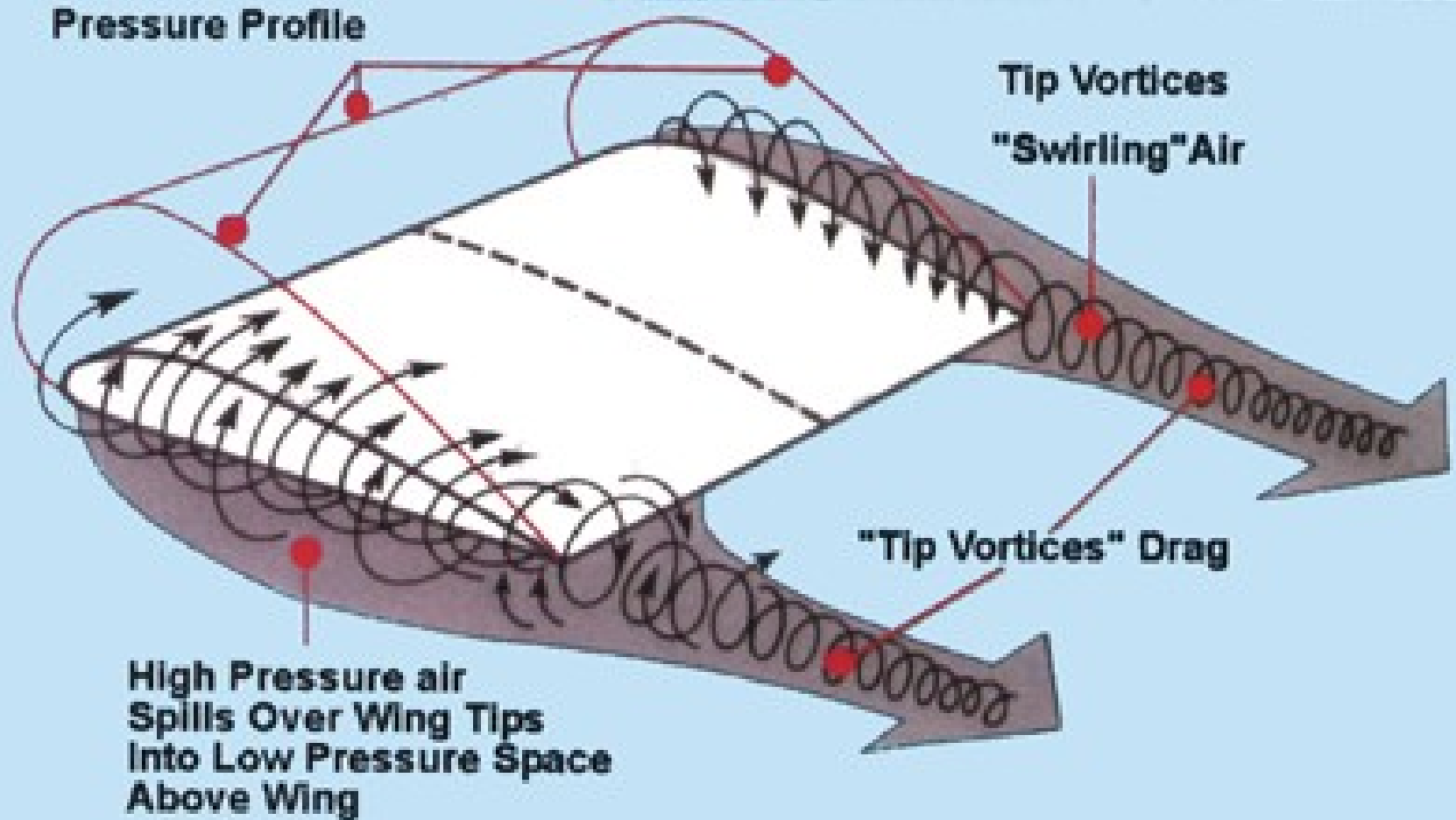
Lift is the mechanical force generated by the interaction of the wing through the air and acts perpendicular to the chord line of the wing.



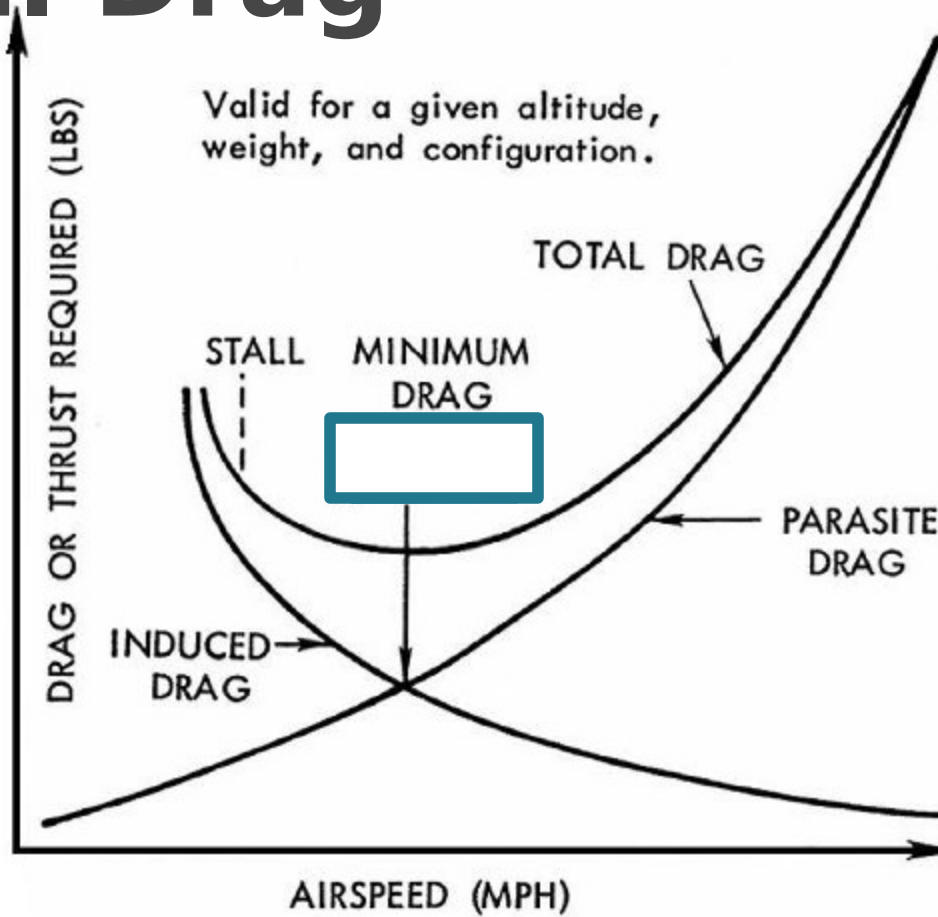
# What is drag?

- ▶ Parasitic Drag
  - The retarding force produced from pushing the shape through the air
- ▶ Induced Drag
  - The retarding force produced from making lift

# Wingtip vortices = Induced Drag

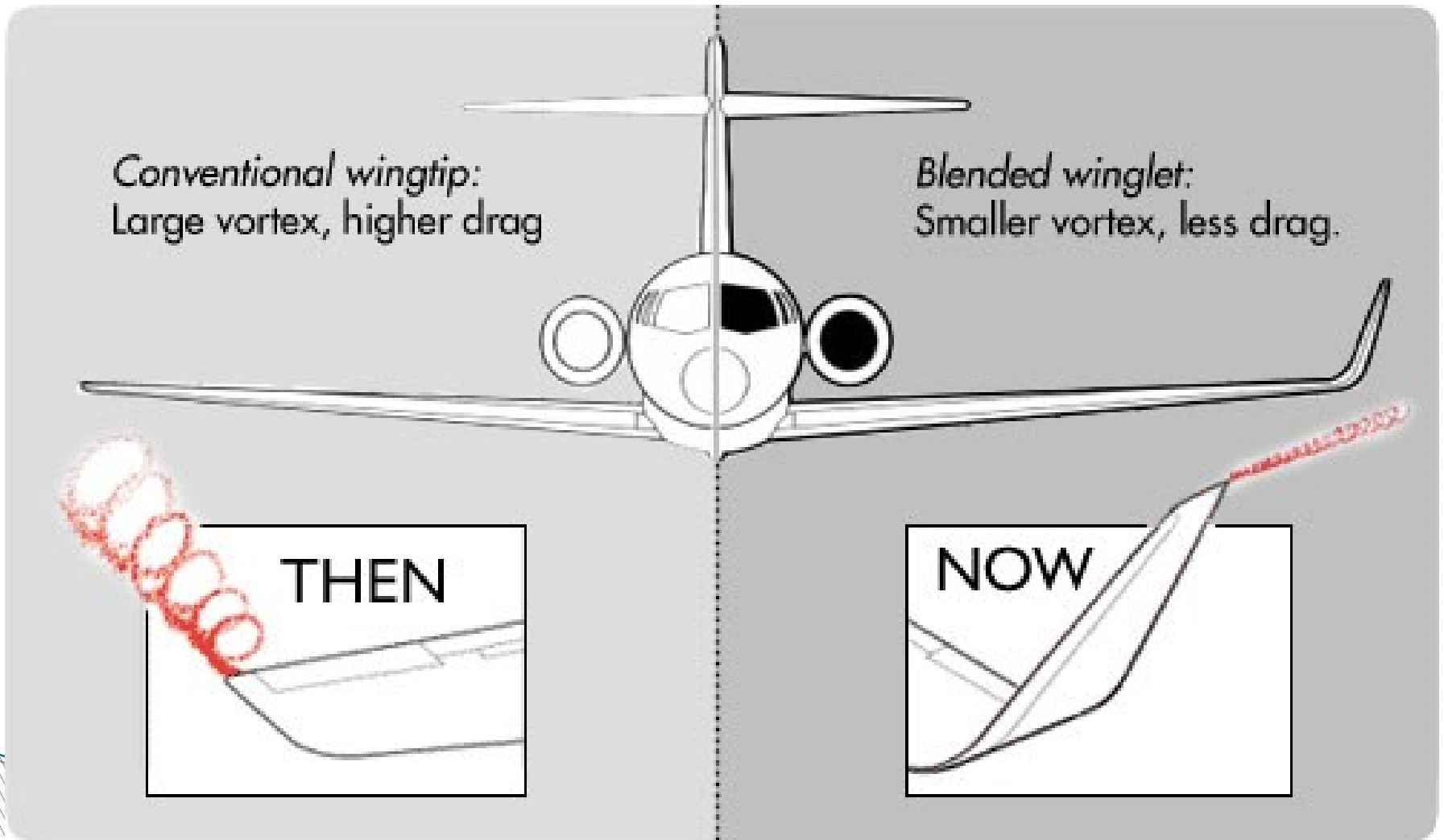


# Total Drag





# Winglets - A quick aside

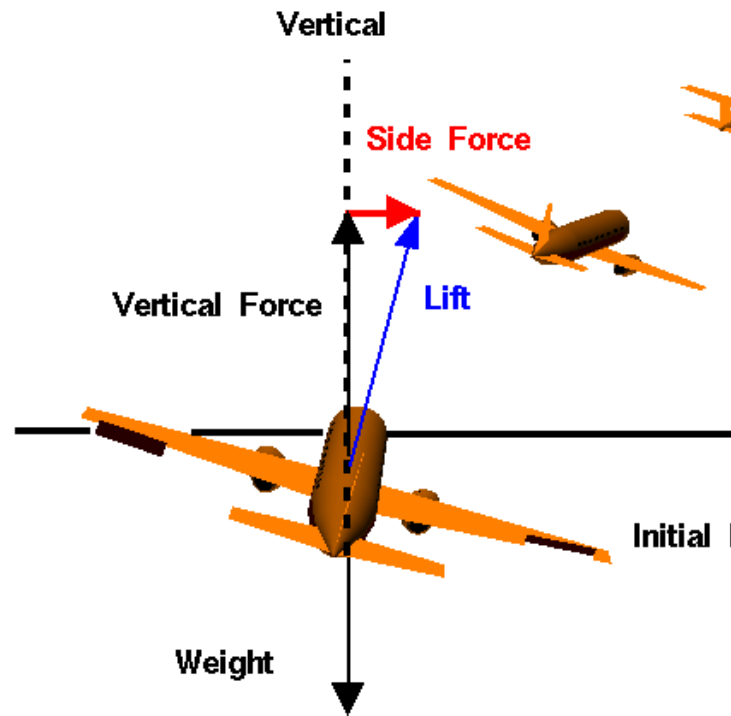


# Glider Stability

- ▶ Longitudinal Stability – Static & Dynamic
  - Positive
  - Neutral
  - Negative
- ▶ Lateral Stability
  - Dihedral
- ▶ Directional Stability
  - Vertical Stabilizer – Weather vane effect

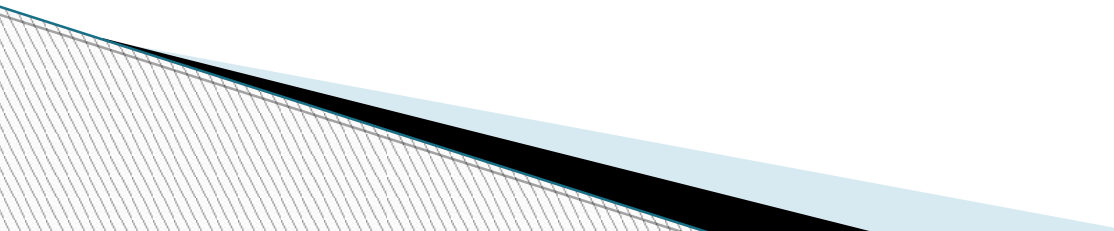
# Turning Flight

- ▶ The WING turns the glider
- ▶ Horizontal Component of Lift turns glider
- ▶ Total Lift of wing must increase or...

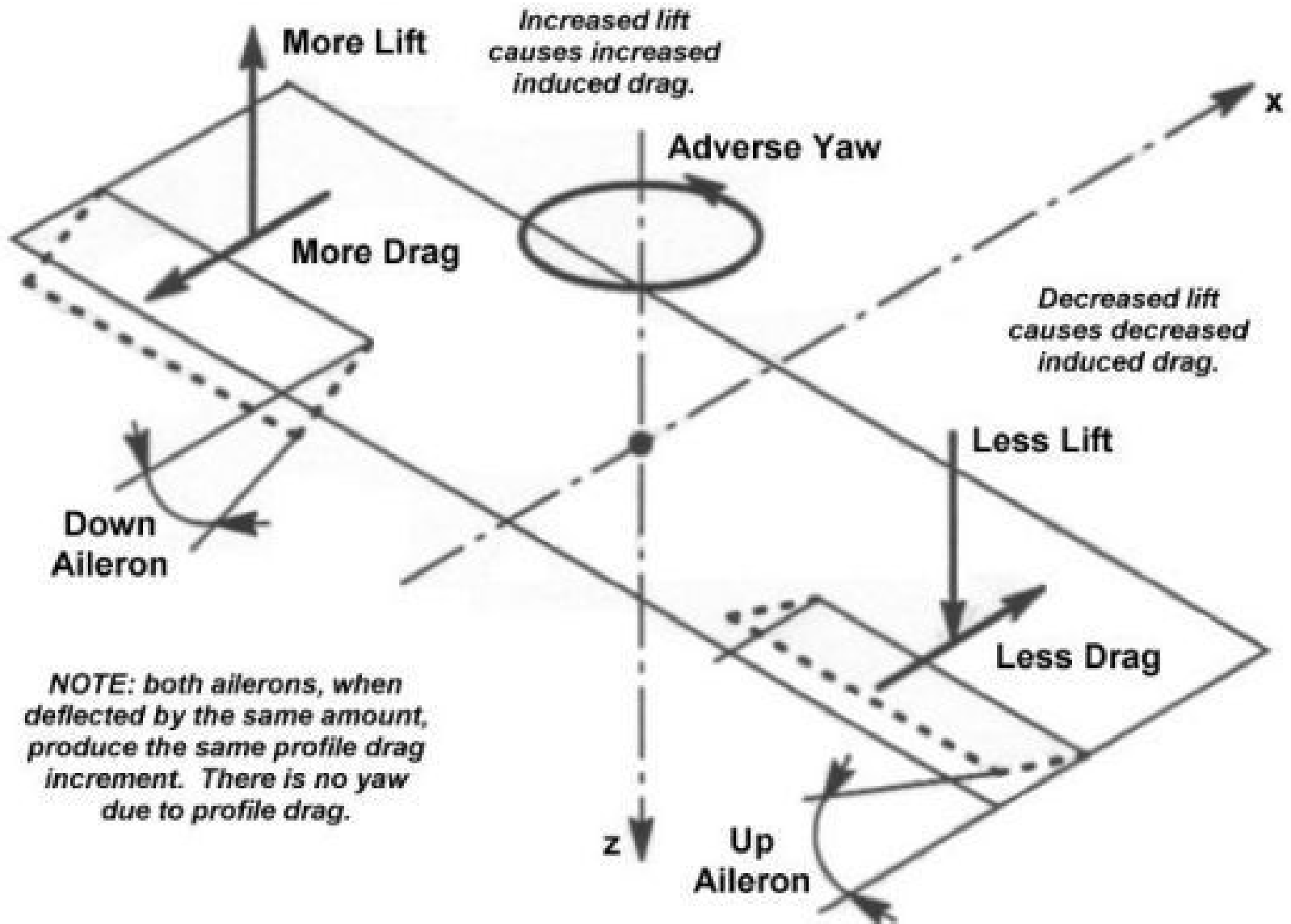




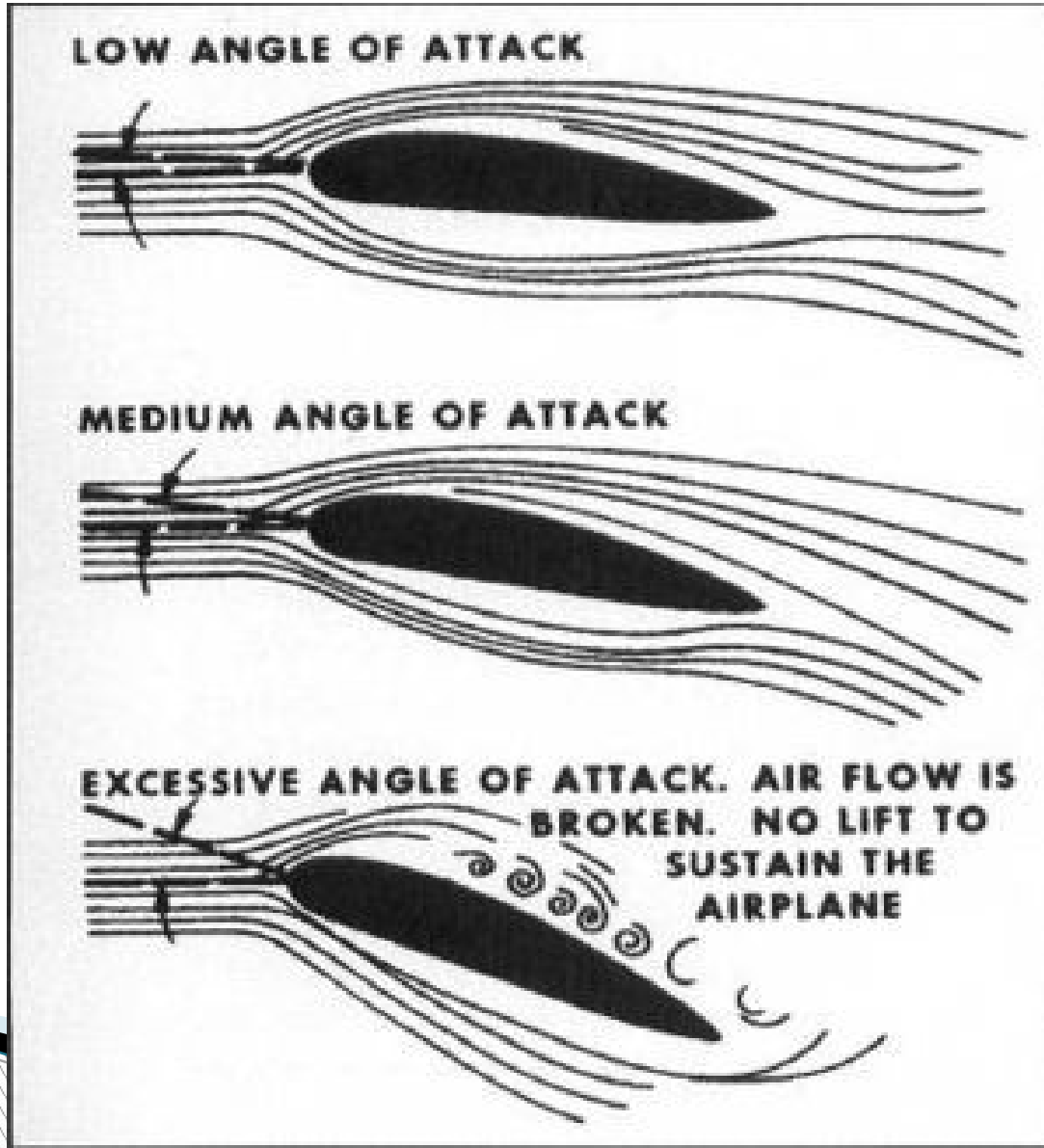
# 5 Effects of Turning Flight

- ▶ Adverse yaw
  - ▶ Diving tendency
  - ▶ Over-banking tendency
  - ▶ Yaw against the turn
  - ▶ Increase stall speed
- 

# Adverse Yaw



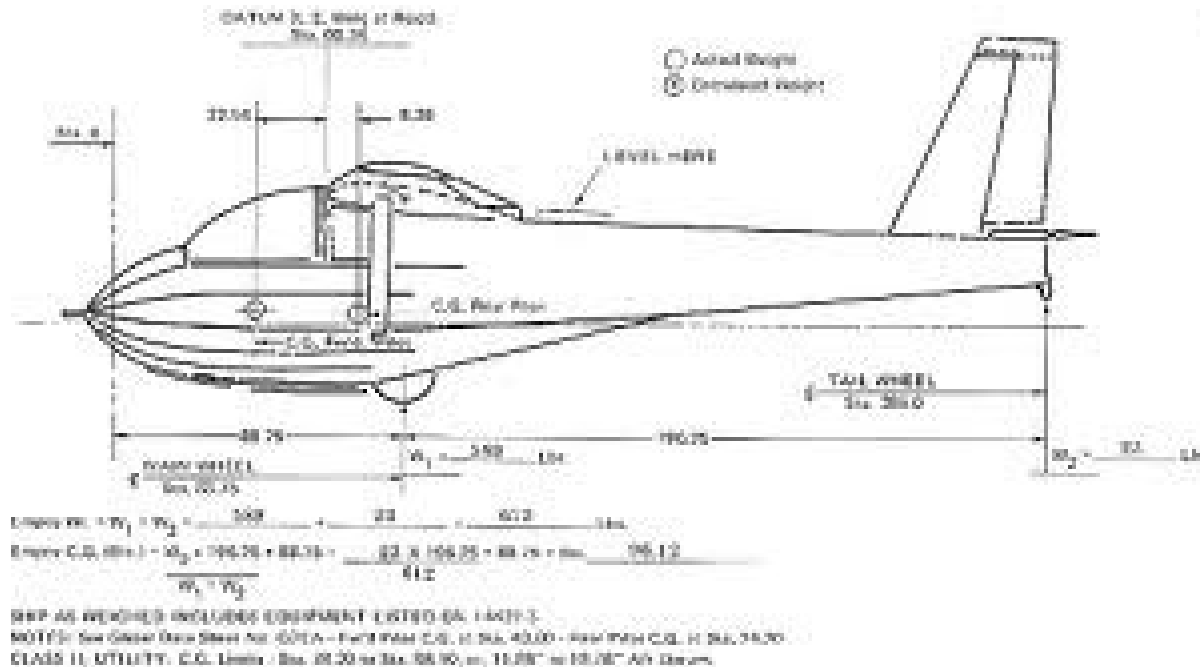
# Stalls...a stall is a loss of lift when the wing exceeds the critical Angle of Attack



# Weight and Balance



# Weight and Balance



Why is it important?

Too far forward, what can happen?

Too far aft?

# Slips, Skids and Crabbing

## ▶ Forward Slip

- Controlling Glide Path
- With and Without Dive Brakes
- Longitudinal Axis alignment

## ▶ Side Slip

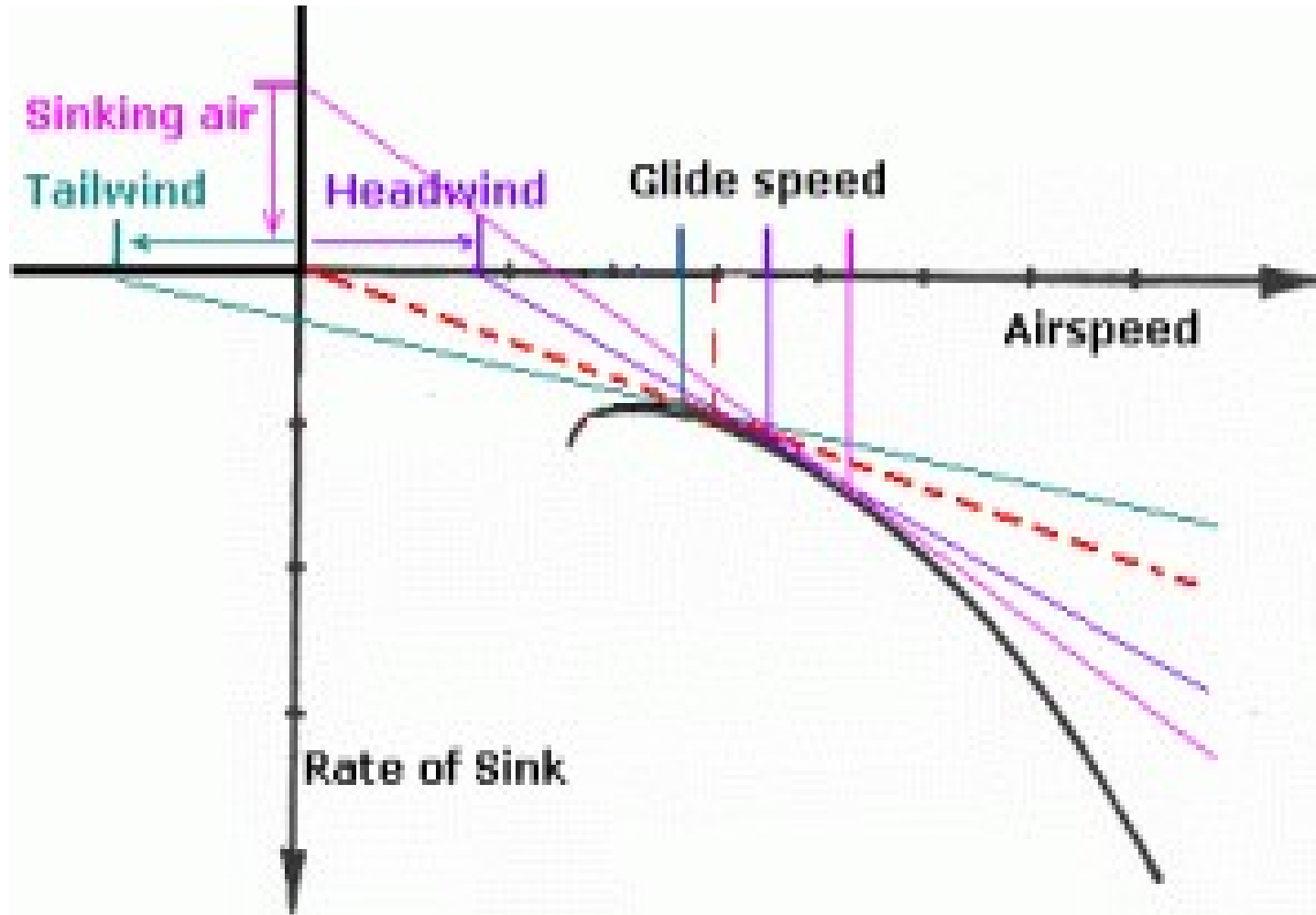
- Landing in a Crosswind
- Cross-wind Takeoff technique
- Longitudinal Axis alignment

## ▶ Turning Slips & Skids

## ▶ Crabbing Flight - coordinated turn into wind

- Cross-wind Correction in the Pattern
  - Cross-wind Takeoff technique
- 

# Speed to Fly



# More on Stalls & Spins Tomorrow



TJ over the Med  
1989

