CPL Theory
Aerodynamics (CADA)

CAE Oxford
Aviation Academy

CADA 7 – Taxi, Take-off and Landing

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2. Related Documents

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CAE Oxford Aviation Academy

CADA 7 – Taxi, Take-off and Landing

Amendments made to this document since the previous version are listed below. All amendments to this document have been made in accordance with CAE OAAM's document management procedure.

Slide	Changes

LANDING GEAR CONFIGURATIONS

Landing gear configurations

Tail wheel configuration:

- Main gear on the front, ahead of CoG
- Also called “tail dragger”

Nose wheel configuration:

- Main gear at the back, behind the CoG
- Also called “Tricycle configuration”

Landing gear configurations – Visibility

Tail wheel aircraft:

Compared with a tricycle undercarriage arrangement, the nose is high making visibility low

Are Yawed up to 30° while taxing

e.g., Spitfire, Mustang, Decathlon

Seat position is very important

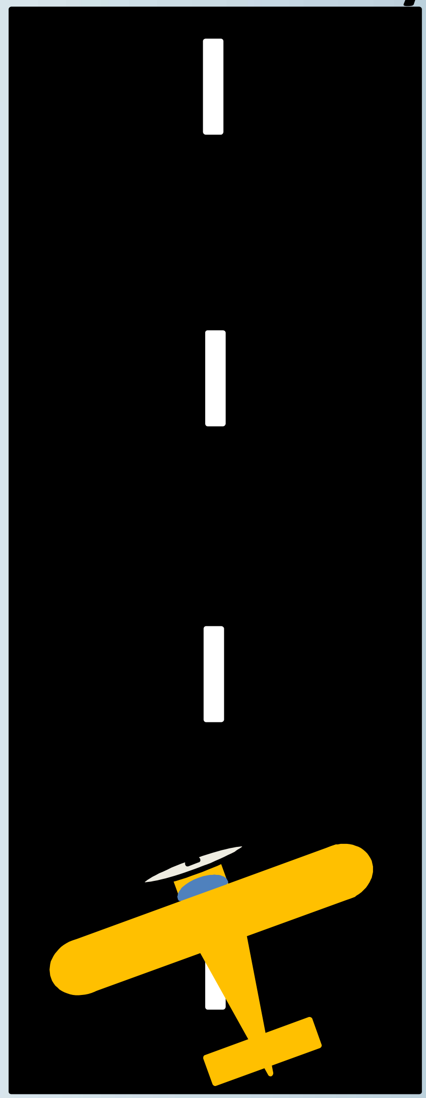
Tail wheel aircraft may be forced to continuously turn side to side while taxiing to let the pilot look out the side windows

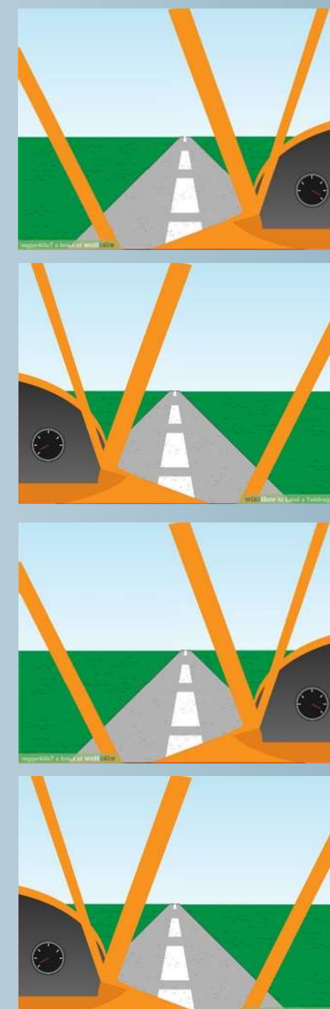
Landing gear configurations – Visibility

Tail wheel aircraft:

- Nose is high making visibility low
- Seat position is very important

Tail wheel aircraft may be forced to continuously yaw (up to 30 degrees) side to side while taxiing to let the pilot look out the side windows past the nose





Landing gear configurations – Steering

Tailwheel aircraft

- Fully or partially castoring tailwheel
- Wheel is connected to rudder via springs
- Requires a lot of rudder input
- Brakes are often required for sharp turns

Nosewheel aircraft

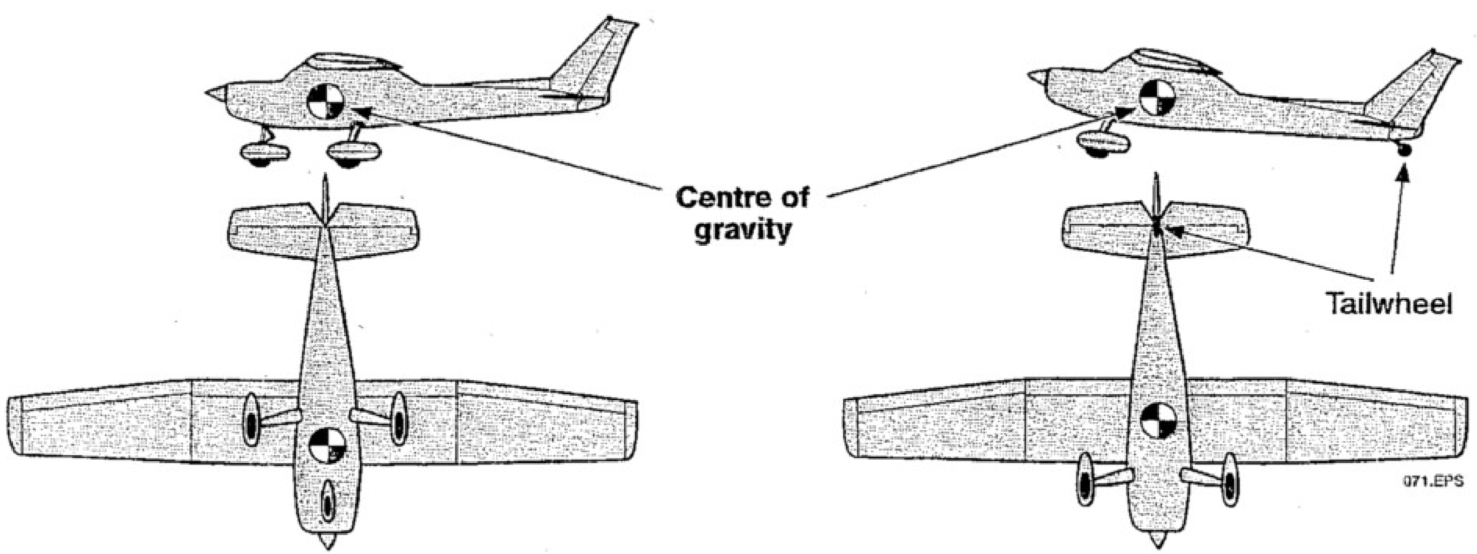
- Direct steering through nosewheel
- Directional control on the ground is good

Landing gear configurations – Stability

- Position of the CG is very important. Must lie somewhere in the area between the three wheels of the aircraft at all times.

- The further the CG is away from any one wheel, the less the tendency for the aircraft to tip over at that wheel.

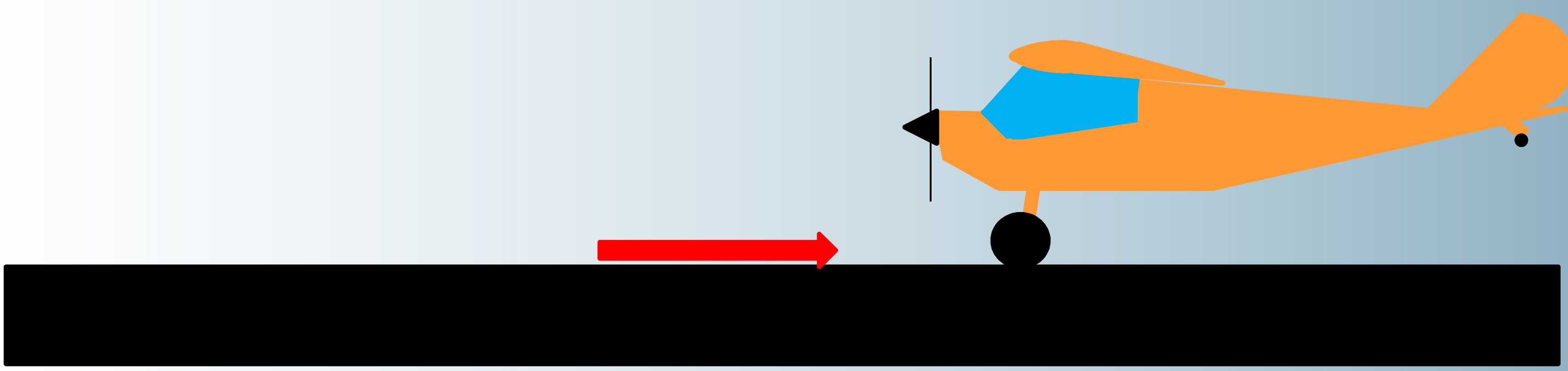
- With a trycilce undercarriage, the CoG is ahead of the main wheels
- With a tail dragger, the CoG is behind the main wheels



The CG must remain within the area bounded by the wheels

Landing gear configurations – Longitudinal Stability

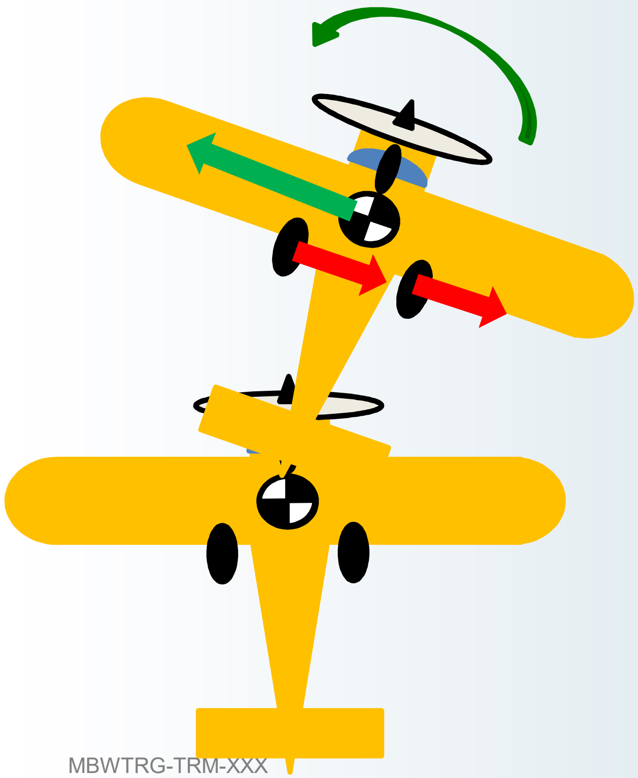
- Harsh breaking with a tail dragger undercarriage configuration may cause the aircraft to flip onto its nose



Landing gear configurations – Directional Stability

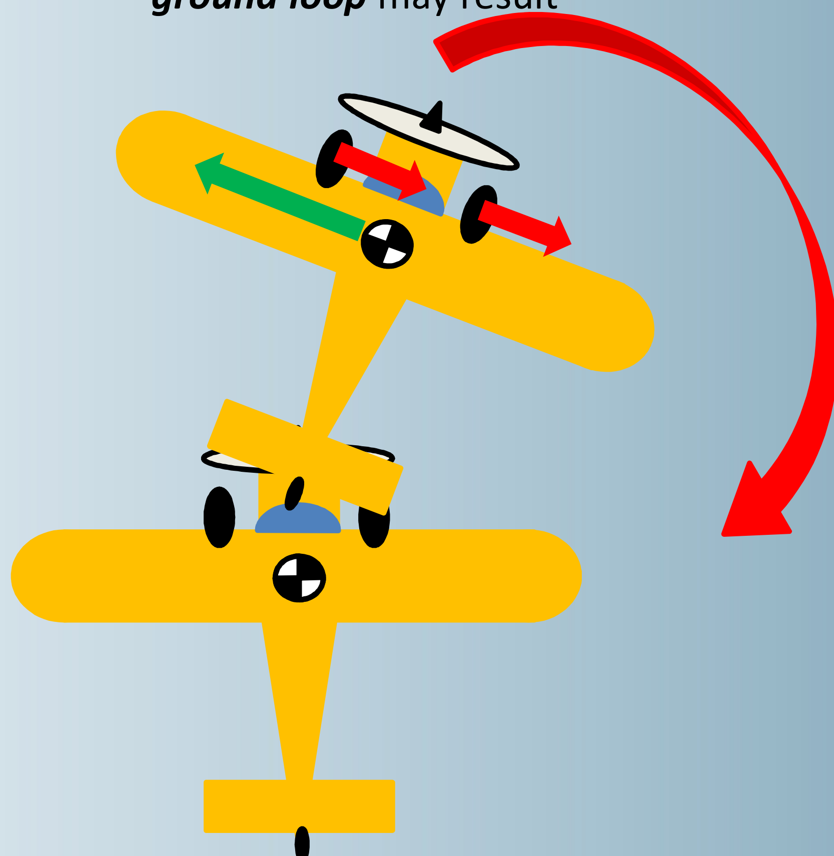
Tricycle: STABLE

- If the aircraft yaws, the CoG will try to swing out and the yaw will be resisted.
- Aircraft will want to continue in a straight line



Tail dragger: UNSTABLE

- If the aircraft yaws, the CoG will try to swing out and the yaw will continue.
- If yaw is allowed to continue unchecked, a ***ground loop*** may result



Landing gear configurations – Ground Loop

- Ground loops can occur of tail wheel aircraft when the pilot is lazy with the rudder
- It is an unstable situation which can result in the aircraft violently yawing around on the ground
- They can cause substantial damage to the aircraft
- Ground loops in a tricycle undercarriage aircraft are most likely following a wheelbarrow

https://www.youtube.com/watch?v=aActGWgfUDo

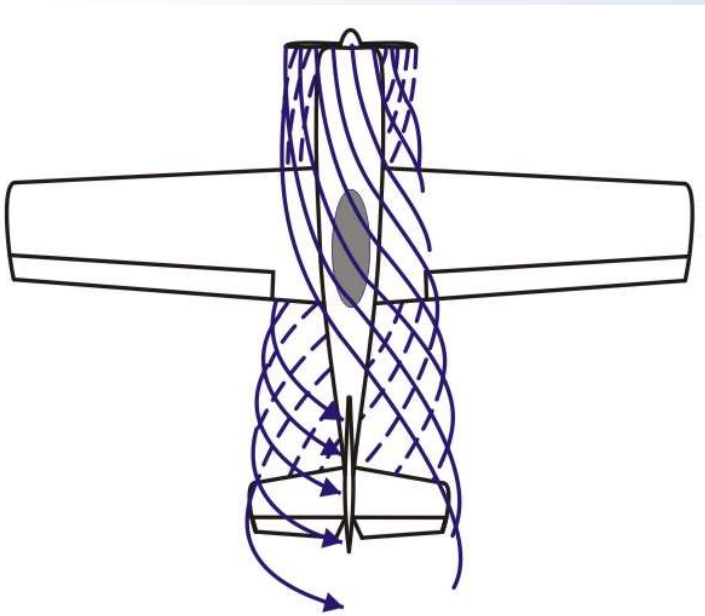
Landing gear configurations - Wheelbarrow

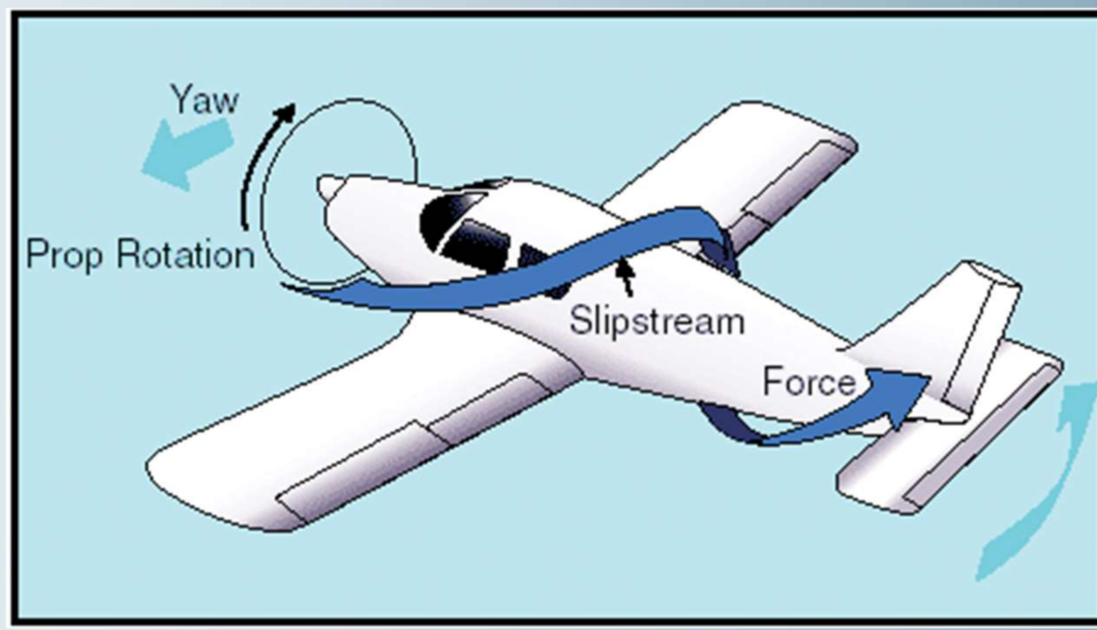
A wheelbarrow occurs on tricycle undercarriage aircraft when too much forward pressure is applied during takeoff or landing, typically when the aircraft is held on the ground at high airspeed

The nose wheel will remain in contact with the ground, this risks damaging the gear, propeller or could even result in a ground loop because the nose wheel is ahead of the CoG

EFFECTS ON TAKE-OFF

Slipstream Effect



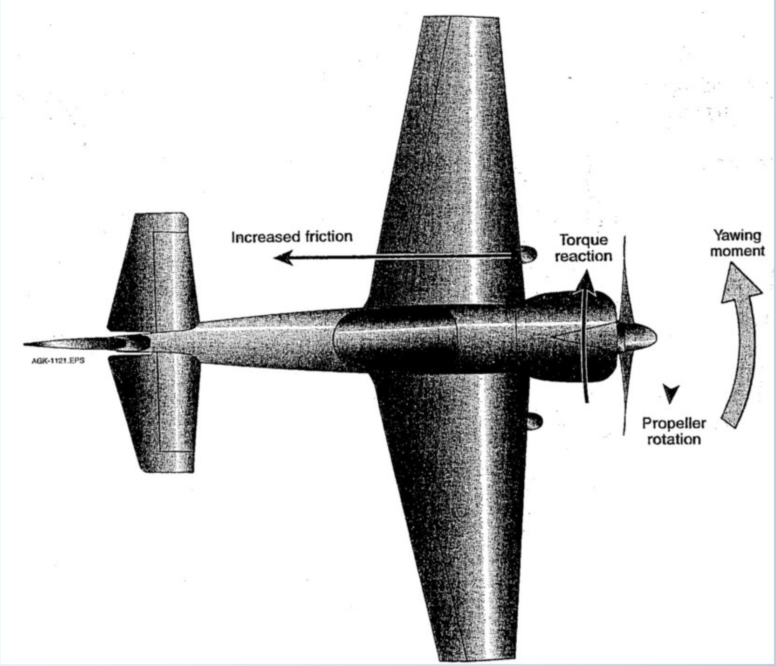


- Most pronounced at low airspeed and high power settings e.g. take-off
- If the propeller rotates clockwise when viewed from the cockpit, the aircraft will **yaw to the left**

Torque Effect

- If the propeller rotates clockwise when viewed from the cockpit, the torque reaction will try and rotate the aircraft anti-clockwise i.e. **a roll to the left**

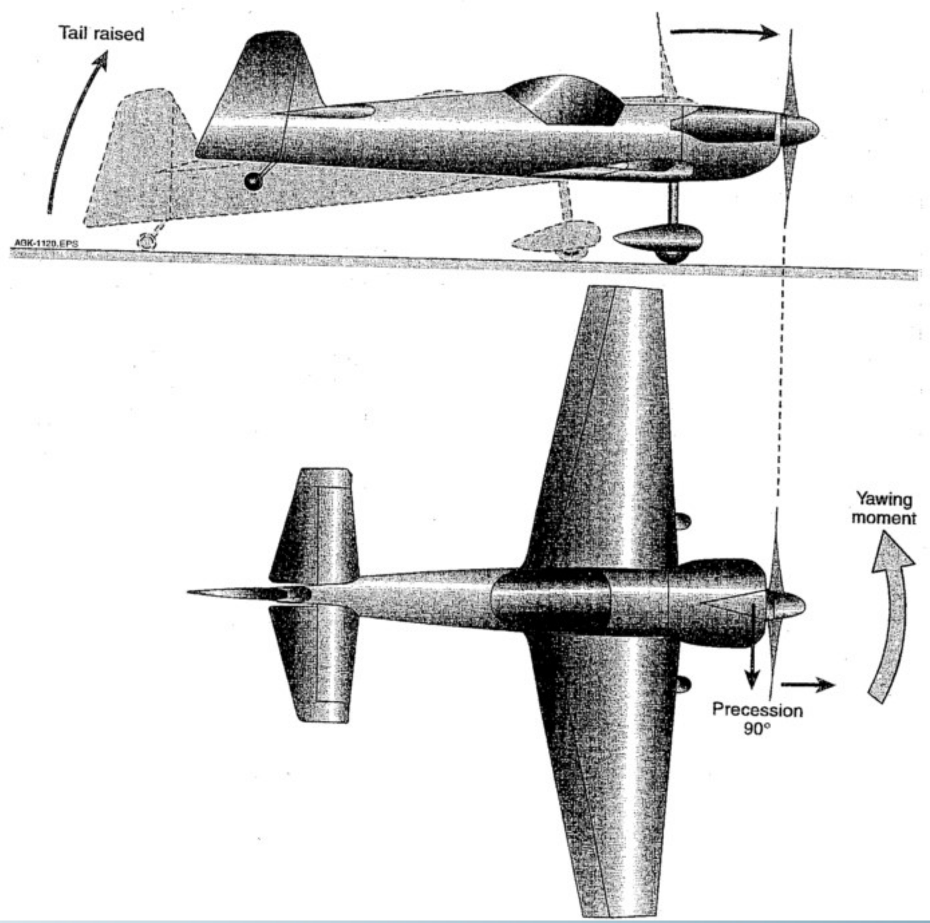
- Torque effect is felt most during high RPM settings e.g. take-off



- Note that whilst the aeroplane is on the ground, the torque reaction cannot roll the aircraft. Instead, the left wheel will simply "dig in" and the result will be a **yaw to the left**

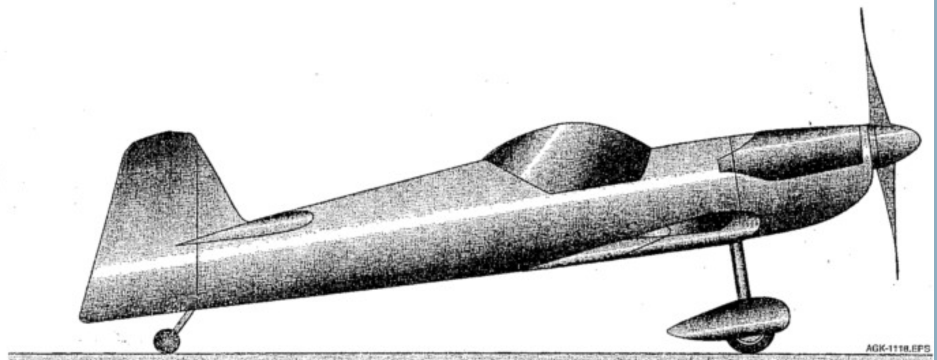
Gyroscopic Effect

- A spinning propeller rotating at high velocity adopts the properties of a gyroscope
- One such property is known as **“precession”**
- When a force is applied to a gyroscope, precession moves that force 90° in the direction of rotation
- Gyroscopic effect occurs in **tail-wheel aircraft** only and is seen during the take-off run **when the tailwheel is raised**
- If the propeller rotates clockwise when viewed from the cockpit, the aircraft will **yaw to the left**

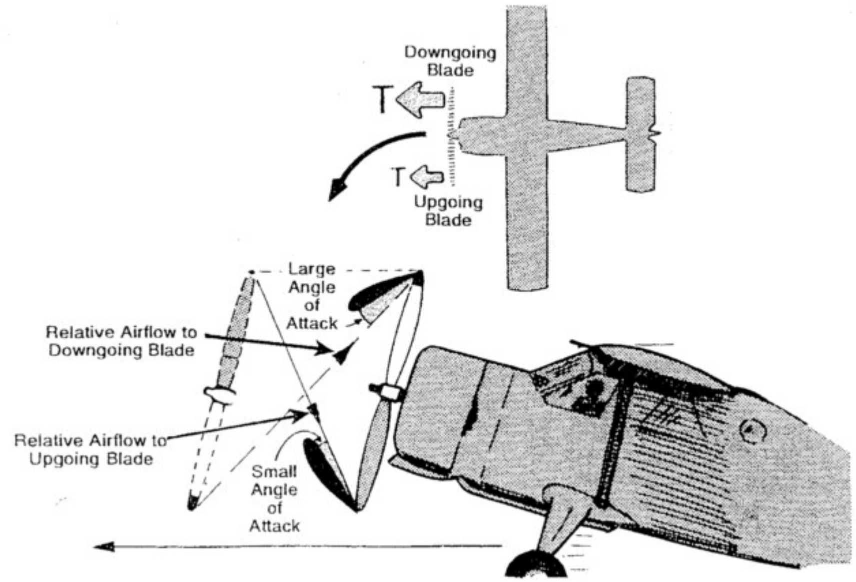


Asymmetric Blade Effect

- In tailwheel aircraft, the propeller is not perpendicular to the ground
- Therefore, during the take-off roll, the up-going and down-going blades are presented at different angles to the relative airflow
- **The down-going blade actually produces more thrust** and if the propeller rotates clockwise when viewed from the cockpit, the aircraft will **yaw to the left**



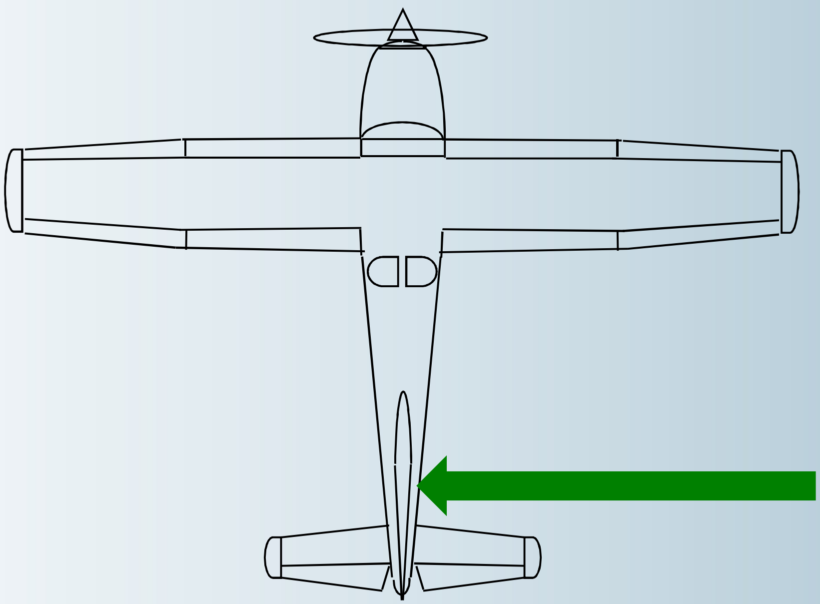
Different angle of attack due to attitude



Downgoing prop blade produces more thrust with the tail on the ground.

Crosswind

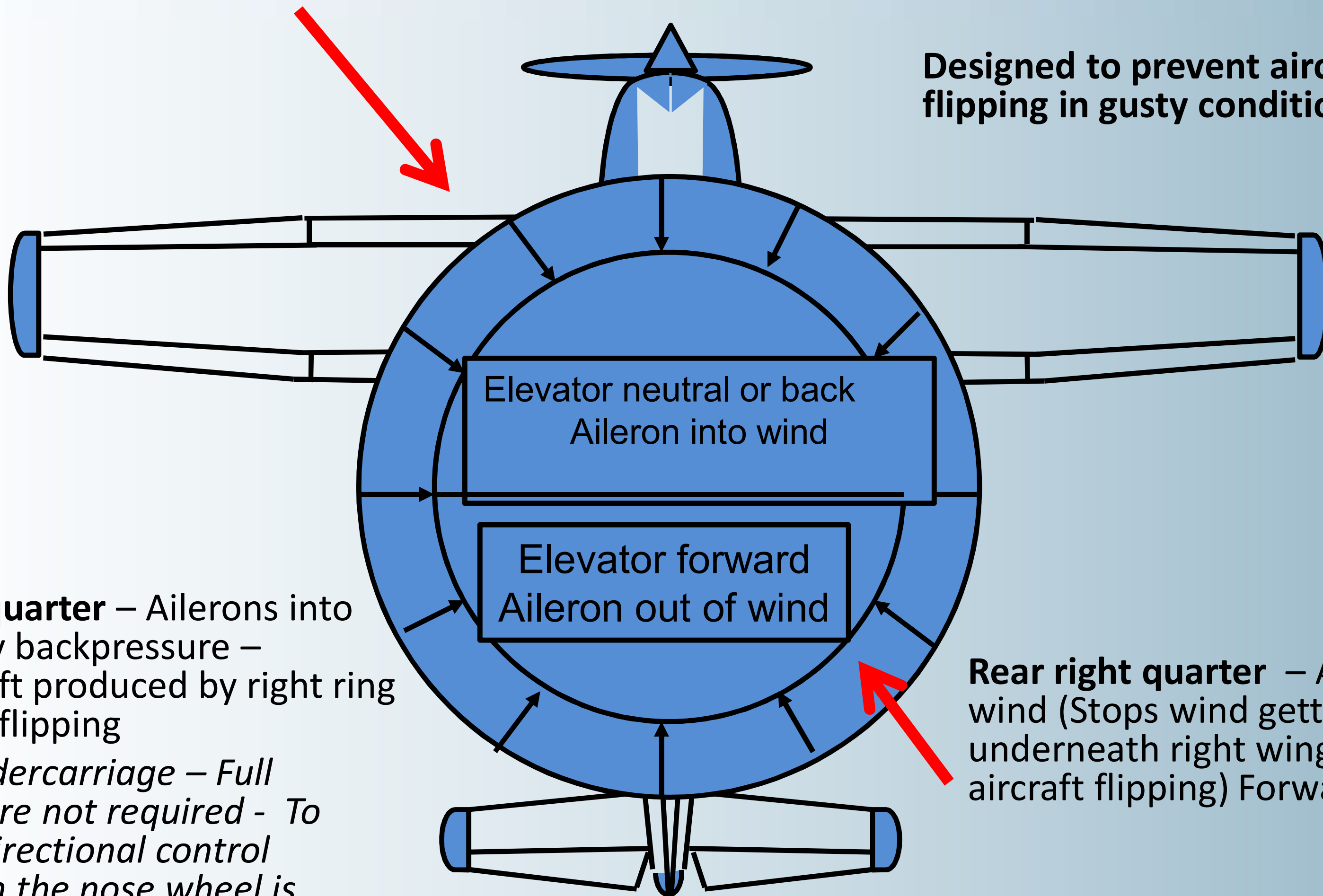
- So far, all take-off effects we have looked at have caused a **yaw to the left**
- If the propeller rotates clockwise when viewed from the cockpit, the only situation in which an aircraft will **yaw to the right** during take-off will be a **crosswind from the right**



Compensating for wind

“Climb INTO wind, Dive OUT OF wind”

Designed to prevent aircraft flipping in gusty conditions

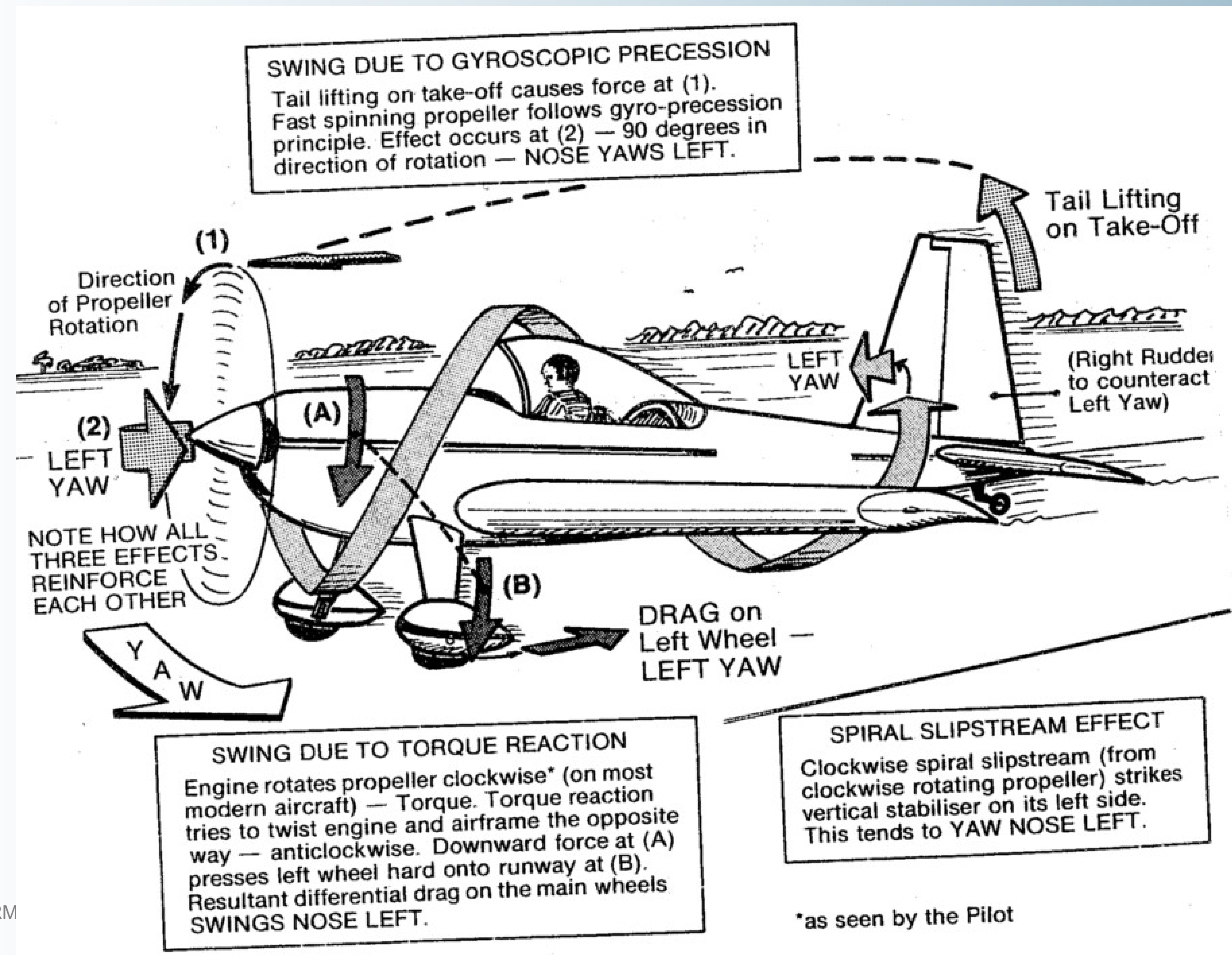


Front left quarter – Ailerons into wind, apply backpressure – Increases lift produced by right ring – prevents flipping

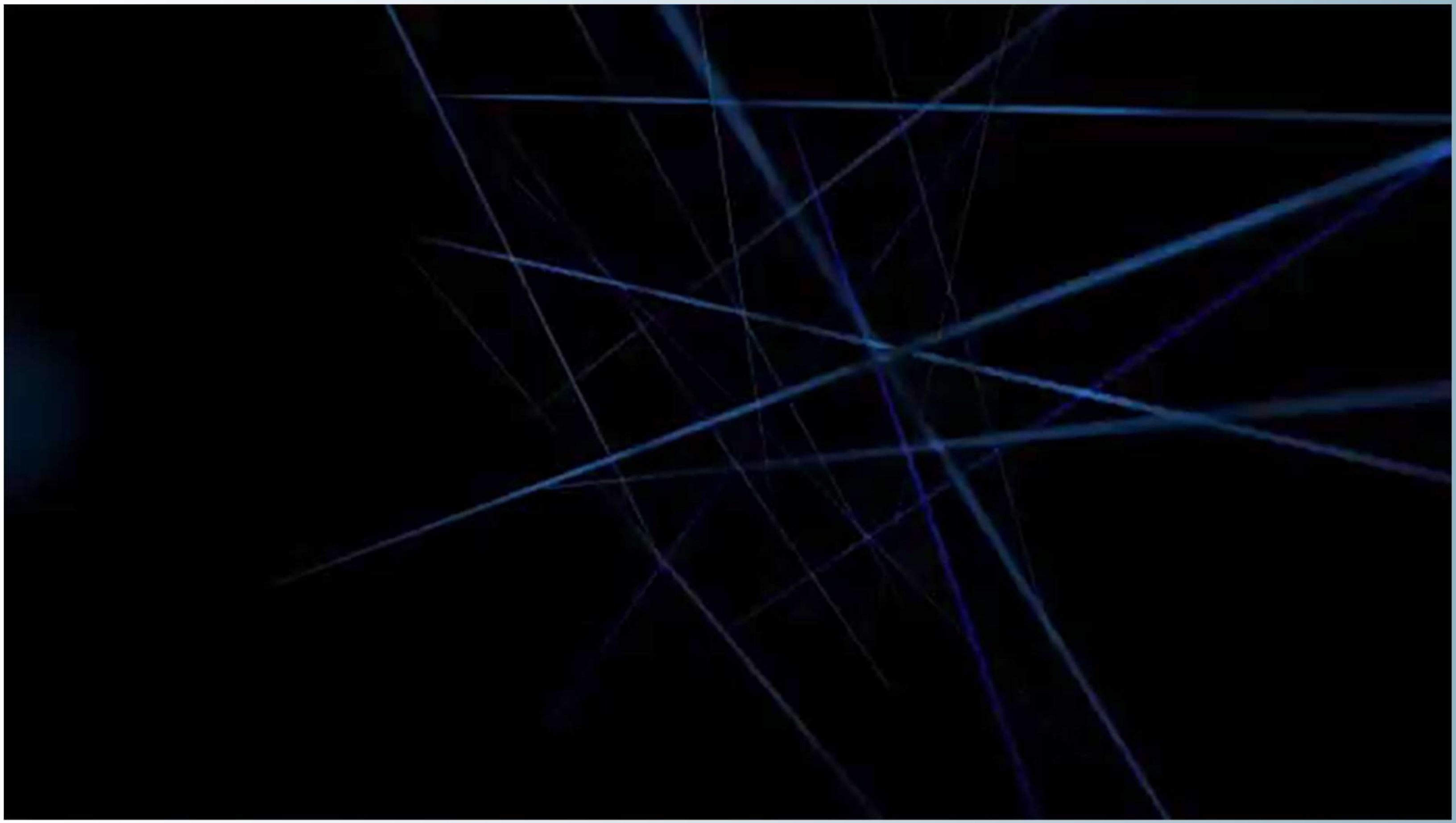
Tricycle undercarriage – Full backpressure not required - To maintain directional control pressure on the nose wheel is required

Rear right quarter – Ailerons out of wind (Stops wind getting underneath right wing – prevents aircraft flipping) Forward pressure

Summary of factors on take off



Windshear



PERFORMANCE CONSIDERATIONS

Taking Off & Landing Into Wind

- **On Take-Off:** Results in better climb performance (i.e. a better Angle of Climb)
- **On Landing:** Allows us to fly a steeper approach angle (better forward visibility)
- **If our engine fails:**

  Consider a forced landing in a 1000kg aeroplane. Touchdown speed 50KIAS and a wind speed of 30 knots.

Landing with Headwind:

Kinetic Energy = ½ mv^2
Kinetic Energy = 0.5 x mass of aeroplane x $(\text{groundspeed})^2$
Kinetic Energy = 0.5 x 1000 x 20^2

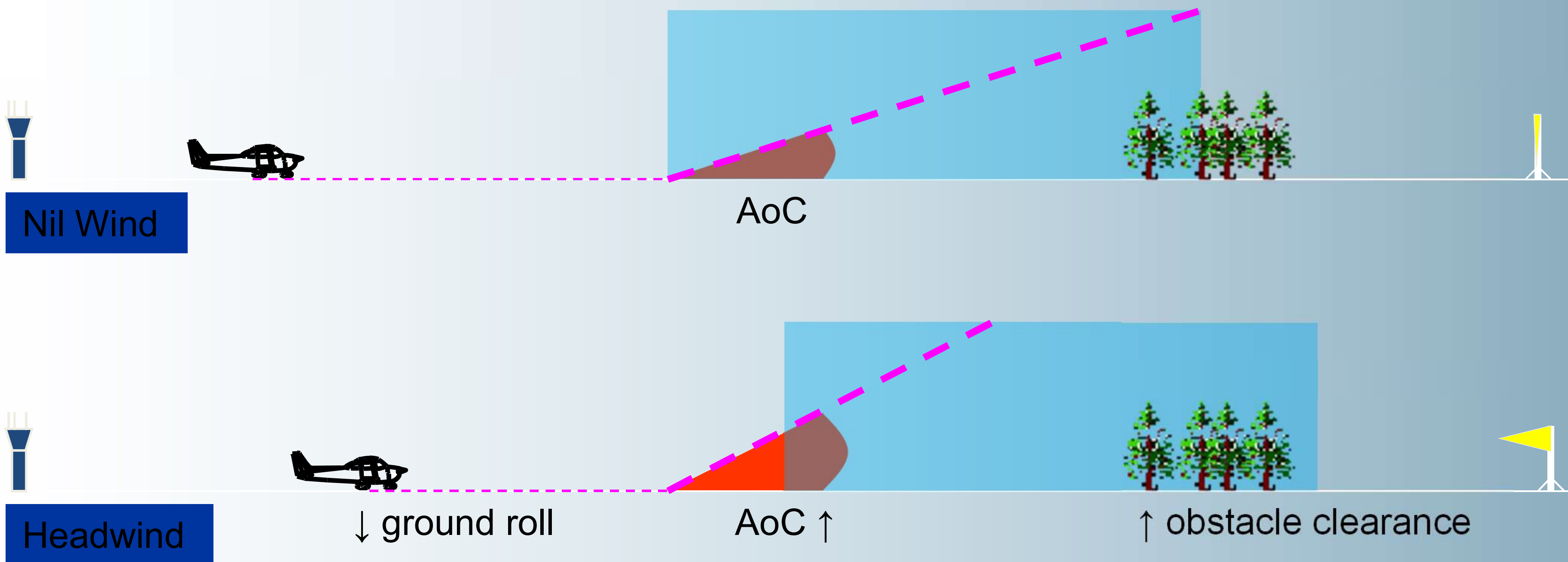
The resultant kinetic energy or impact energy will be 200,000J

Landing with Tailwind:

Kinetic Energy = ½ mv^2
Kinetic Energy = 0.5 x mass of aeroplane x $(\text{groundspeed})^2$
Kinetic Energy = 0.5 x 1000 x 80^2

The resultant kinetic energy or impact energy will be 3,200,000J

Taking Off & Landing Into Wind



Take off into wind provides:

- Shortest ground run
- Lowest ground speed
- Best directional control
- Best obstacle clearance

Land into wind provides:

- Shortest ground run
- Lowest ground speed
- Steeper approach possible

Pressure & Density Height

Pressure Height

- “Our height above or below MSL ISA (1013 hPa)
- Also referred to as QNE or Flight Level
- We need Pressure Height in order to calculate Density Height, a key factor in determining aircraft performance
- Often, you will be required to determine the Pressure Height for your take-off and landing distance calculations

Pressure & Density Height

Density Height

- Pressure Height corrected for non-ISA temperatures
- If you were sitting in an aeroplane at MSL but your Density Height was 4000,' your aircraft would **perform** as though it were at 4000'
- Air Density & Pressure decreases with altitude, therefore, a higher Density or Pressure Height will mean **worse** aircraft performance

1. **High temperature, low pressure → BAD for performance**
2. **Low temperature, high pressure → GOOD for performance**

Pressure & Density Height

How does this actually work?

- A decrease in air density has the following effects on an aircraft:

1. **Less air is flowing over the surface area of the wings, meaning that less lift will be generated**

2. **The propeller blades are rotating through less air, meaning that less thrust will be generated**

3. **There will be less air taken into the engine, meaning that less power will be generated**

Factors affecting Take-off & Landing Performance

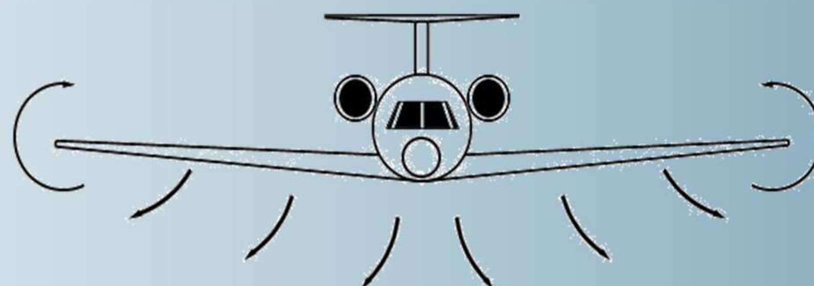
Factor	TODR	LDR
Headwind ↑	↓	↓
Tailwind ↑	↑	↑
Air temperature ↑	↑	↑
QNH ↑	↓	↓
Density Height ↑	↑	↑
Airfield elevation ↑	↑	↑
Runway slope	Upslope = BAD Downslope = GOOD	Upslope = GOOD Downslope = BAD
Runway surface	Long, wet grass = BAD Sealed = GOOD	Depends on other factors e.g. damp/wet
Ground Effect/Wind Shear	↑	↑
Frost on an aircraft	↑	↑

GROUND EFFECT

Ground Effect

- Induced Drag can be seen as wingtip vortices

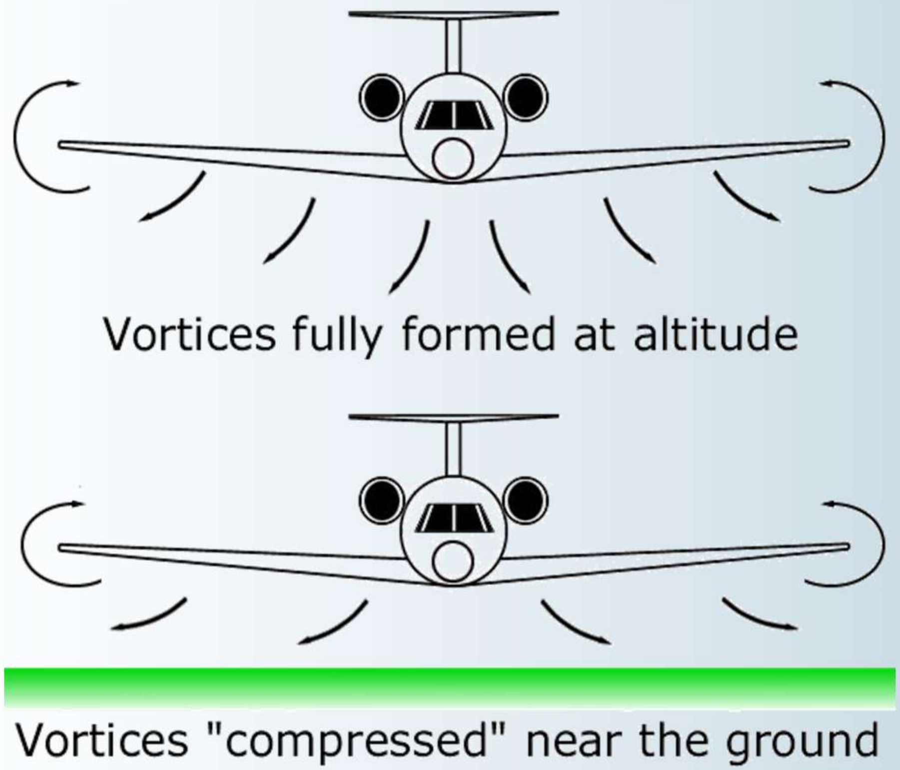
- These vortices usually move outwards and downwards, increasing in size as they move away from the aircraft



Vortices fully formed at altitude

Ground Effect

- However, when the aircraft is being operated within one wingspan of the ground, these vortices cannot fully develop (they become squashed)



- The creates an artificial "cushion" of air that artificially reduces drag by up to 41%
- The aircraft appears to perform better than it should when close to the ground
- Ground Effect is most pronounced at ½ wingspan from the ground

Ground Effect

Hazard on Take-Off

- The artificial reduction in drag allows an aircraft to become airborne at a speed below that which would normally be acceptable

- If the aircraft tries to continue the climb, once it reaches a height greater than one wingspan, the drag will increase by as much as 41% and the aircraft will crash back to the ground

- It is important to ensure that the correct speed is reached on take-off!

Hazard on Landing

- If the approach is too fast, the aircraft will enter Ground Effect and appear to ‘float’ and fail to decelerate

- The tendency is to lower the nose, yet this can lead to wheelbarrowing and a prop strike!

- The only smart thing to do is go-around

Ground Effect