Type Training

Fixed Wing Operational Training

Student Manual

FPV Australia
Fly • Photograph • Video

Version 2.2

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CHAPTER 1 – RPA COMPONENTS

1.1 Typical Components found on the Fuselage of the RPA

1.1.1 Hatch

This is a small door in an aircraft. It may be where the battery is held or possibly where the camera is mounted. A Remote Pilot needs to ensure that this hatch is secure prior to any flight and that there is no possibility of anything falling from it, should it open.

1.1.2 Vents

Vents are areas that are left open in the aircraft to allow airflow to the ESCs and LiPo battery while allowing hot air to escape.

1.1.3 Drains

Aircraft that operate to or from the water may have drains to allow water to escape from the fuselage. It is important to make sure these drains are not blocked, or the aircraft may become very unbalanced should water ingress into the fuselage.

1.1.4 Aerials

Generally, the aircraft will have aerials or antennas (sometimes more than one) to enable a signal to be transmitted or received from the ground station or controller. If these antennas are removable, the remote pilot should ensure they are attached prior to take off, or signal could be lost resulting in a crash.

1.1.5 Catapult and Airdrop Attachment

This is a device used for launching the aircraft from the ground. This is usually a system of rails and bungee cords that propel the aircraft at speed into the air. It requires a hook to be attached securely to the underside of the aircraft.

Some aircraft also have the ability to drop items on the fly. This is a specialty area and caution must be taken to ensure any release systems do not interfere with the aircraft itself, or upset the Centre of Gravity etc.

1.1.6 Fail Safe Equipment

This is equipment attached the aircraft in case of motor failure. It may be a parachute, or some other device designed to safely land the aircraft in case of equipment failure. Most modern flight controllers have a return to home function that will bring the aircraft back should control link be lost.

1.2 Typical Features of the Wings of the RPA

A wing is a type of fin that produces lift while moving through air. As such, wings have streamlined cross-sections that are subject to aerodynamic forces and act as airfoils. A wing's aerodynamic efficiency is expressed as its lift-to-drag ratio. The lift a wing generates at a given speed and angle of attack can be one to two orders of magnitude greater than the total drag on the wing. A high lift-to-drag ratio requires a significantly smaller thrust to propel the wings through the air at sufficient lift.

1.2.2 Leading and Trailing Edges

The leading edge of an airfoil surface, such as a wing, is its foremost edge and is therefore the part which first meets the oncoming air. A rounded leading edge helps to maintain a smooth airflow at varying angles of incidence to the airflow.

The trailing edge of a wing is its rear edge, where the airflow separated by the leading edge meets. Essential flight control surfaces are attached here to control the direction of the departing air flow, and exert a controlling force on the aircraft. Such control surfaces include ailerons on the wings for roll control, elevators on the tailplane controlling pitch, and the rudder on the fin controlling yaw. Elevators and ailerons may be combined as elevons on tailless aircraft.

1.2.3 Ailerons

An aileron (French for "little wing" or "fin") is a hinged flight control surface usually forming part of the trailing edge of each wing of a fixed-wing aircraft. Ailerons are used in pairs to control the aircraft in roll (or movement around the aircraft's longitudinal axis), which normally results in a change in flight path due to the tilting of the lift vector. Movement around this axis is called 'rolling' or 'banking'.

1.2.4 Flaps

A flap is a high-lift device used to reduce the stalling speed of an aircraft wing at a given weight. Flaps are usually mounted on the wing trailing edges of a fixed-wing aircraft. Flaps are also used to reduce the take-off distance and the landing distance. Flaps also cause an increase in drag so they are retracted when not needed.

The flaps installed on most aircraft are partial-span flaps; spanwise from near the wing root to the inboard end of the ailerons. When partial-span flaps are extended they alter the spanwise lift distribution on the wing by causing the inboard half of the wing to supply an increased proportion of the lift, and the outboard half to supply a reduced proportion of the lift.

1.2.5 Elevons and Flaperons

Elevons are aircraft control surfaces that combine the functions of the elevator (used for pitch control) and the aileron (used for roll control), hence the name. They are frequently used on tailless aircraft such as flying wings. An elevon that is not part of the main wing, but instead is a separate tail surface, is a stabilator (but stabilators are also used for pitch control only, with no roll function, as on the Piper Cherokee series of aircraft). The word "elevon" is a portmanteau of elevator and aileron.

A flaperon (a portmanteau of flap and aileron) on an aircraft's wing is a type of control surface that combines the functions of both flaps and ailerons. Some smaller kit planes have flaperons for reasons of simplicity of manufacture, while some large commercial aircraft may have a flaperon between the flaps and aileron. They are essentially similar to an Elevon, in that they can be used for two purposes.

1.2.6 Servomechanisms (Servos)

In control engineering a servomechanism, sometimes shortened to servo, is an automatic device that is used to correct the action of a mechanism. Servos are literally the "muscles" that control every moving part of RC aeroplane. Servos actuate the control surfaces, throttle, landing gear, smoke, and anything else aboard the airplane that needs our input while in the air.

One thing to be cautions of in an eclectic RPA, is if a Servo gets jammed (stalled) it could certainly overload the electrical system and cause a catastrophic failure.

1.3 Typical Components found on the Tail of the RPA

1.3.1 The Rudder/Vertical Stabiliser

The rudder is a hinged control surface attached to the vertical stabiliser at the tail of the aircraft. It is connected to the rudder control so that when the left rudder stick is moved left, the rudder is deflected to the left. The airflow passing over the deflected rudder is also deflected to the left producing a reaction that pushes the tail of the aircraft to the right. This causes the aircraft to yaw about its normal axis. (Refer to Figs 1.1 and 1.2)

Fig 1.1

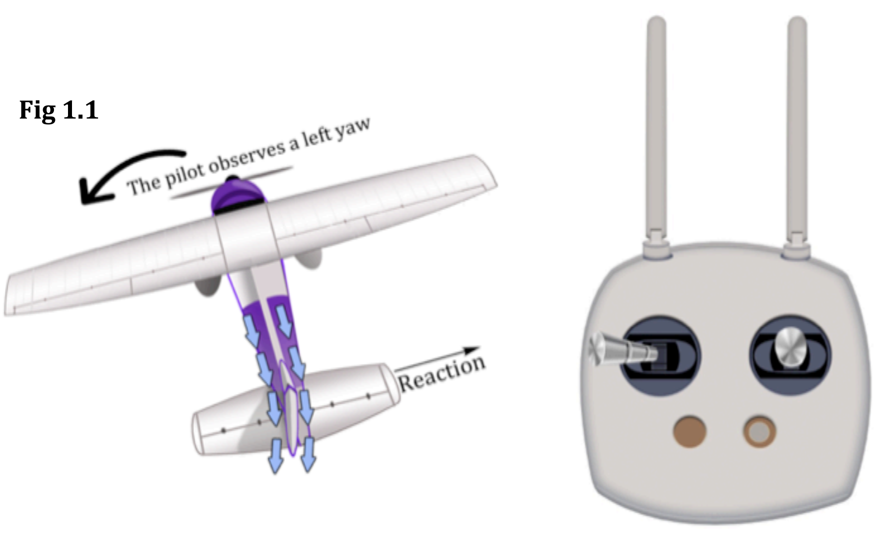
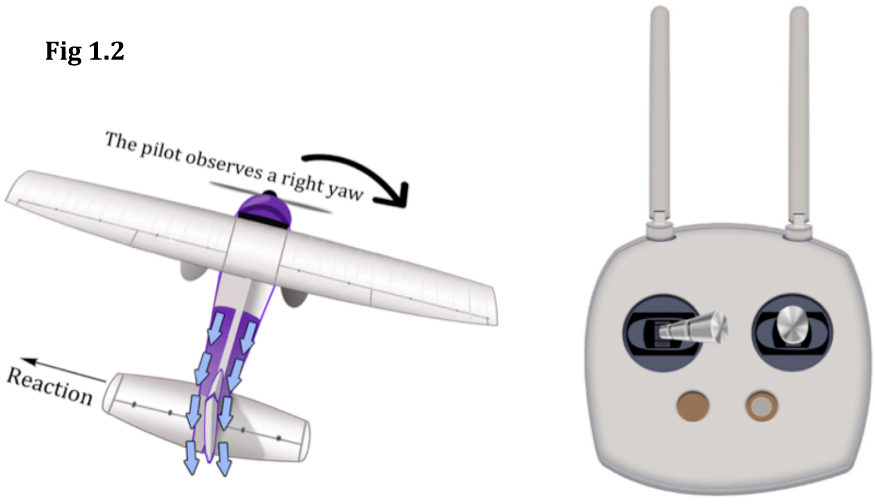


Fig 1.2



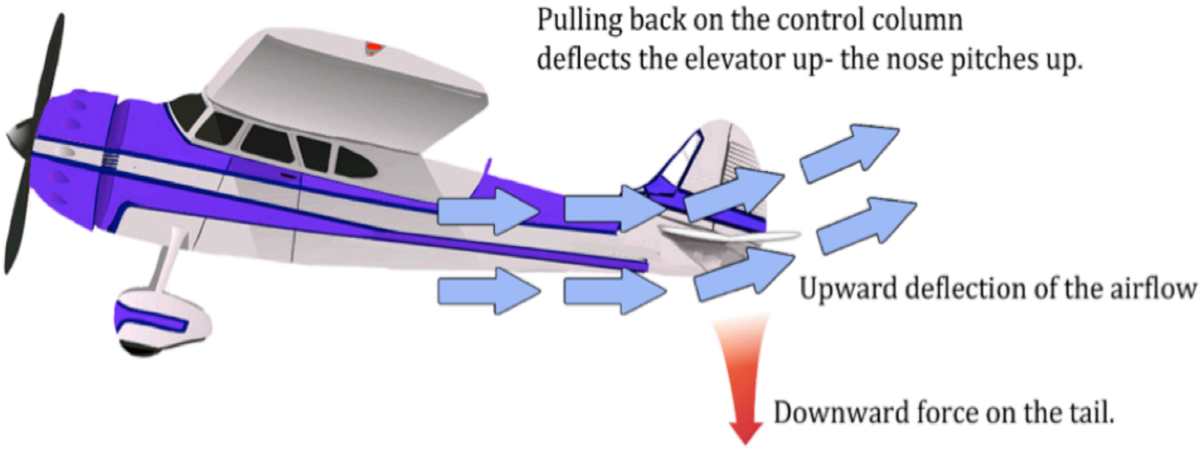
Even though the force is actually pushing the tail to the right, the nose of the aircraft yaws in the opposite direction. The motion as known as a yaw to the left.

1.3.2 The Elevator/Horizontal Stabiliser

The elevator is the main control surface used to affect a climb. It is a hinged control surface on the tail of the aeroplane and deflects air according to the control input. If the elevator is held in a neutral position, there is no deflection of the airflow passing over it and therefore, no resulting force acting on the tail. (Refer to Fig 1.3)

- Pulling back on the elevator control causes the elevator to deflect upwards.
- As the passing airflow follows the line of the deflected elevator it is also deflected upwards imposing a downward force on the tail. The resulting motion is a pitch up to a *higher nose attitude*
- Pushing forward on the elevator control deflects the elevator downwards. The resulting downward deflection of the airflow imposes an upward force on the tail. This is seen as a pitch down to a *lower nose attitude*.

Fig 1.3



1.3 Undercarriage and Recovery Fittings of the RPA

1.3.1 Wheeled Undercarriage

Landing gear is the undercarriage of an aircraft and may be used for either takeoff or landing. For aircraft it is generally needed for both. For aircraft, the landing gear supports the craft when it is not flying, allowing it to take off, land, and taxi without damage. Wheeled landing gear is the most common and some can retract into the belly of the aircraft. Care must be taken when using RPA with wheeled undercarriage as the pilot must ensure the ground is pertinent to the size of the wheels. As in, not to lumpy for small wheels etc.

1.3.2 Floats

Similar to wheeled landing gear, floats support the aircraft during take-off and landing, but are design for water. The essentially do the same thing and allow the aircraft to float on the surface of the water, keeping the aircraft high and dry. Landing on water is a very different exercise to landing on the ground, and special techniques will need to be employed to enjoy successful take offs and landings. In the manned word, there are endorsements for this alone.

1.3.3 Brakes

Brakes are obviously used for exactly what they are! They are used to slow the aircraft down once on the ground. They will be controlled in a way similar to other components, by way of a switch or dial on the transmitter. Brakes on RPA of the size used in this course are rare. They can be found more in the larger fixed wing models etc, like jet turbine machines that need to land fast.

1.3.4 Steering Mechanism

If the RPA has landing gear, it may well have a steering mechanism. This could be similar to a servo connected to the front landing gear, and is generally controlled with the rudder control, which in turn, turns the front wheel. In the case of a tail wheeled aircraft, the steering Is simply achieved by using the rudder. The tail wheel is connected to the rudder, and swivelled around when the rudder is moved.

1.3.5 Hook/Skid

Some RPA don't have landing gear or floats, and are belly landed. Some land on the belly of the aircraft itself, and some land on skids purposefully designed to take the rough treatment of the ground. Hooks on a pole can also be utilised to "catch" the RPA at landing. Although it looks violent, it can be a very effective way to get an RPA down in a tricky environment.

Fig 1.4

CHAPTER 2 – AEROPLANE AERODYNAMICS

2.1 Characteristics of an Aerofoil

2.1.1 Chord

The straight line drawn from the leading to trailing edges of the airfoil is called the chord line. The chord line cuts the airfoil into an upper surface and a lower surface.

The wing, horizontal stabilizer, vertical stabilizer and propeller of an aircraft are all based on aerofoil sections, and the term chord or chord length is also used to describe their width. The chord of a wing is determined by measuring the distance between leading and trailing edges in the direction of the airflow.

(If a wing has a rectangular planform, rather than tapered or swept, then the chord is simply the width of the wing measured in the direction of airflow.)

The term chord is also applied to the width of wing flaps, ailerons and rudder on an aircraft.

2.1.2 Span

The wingspan (or just span) of an airplane is the distance from one wingtip to the other wingtip. For example, the Boeing 777-200 has a wingspan of 60.93 metres.

The lift from wings is proportional to their area, so the heavier the aircraft the bigger that area must be. The area is the product of the span times the width (mean chord) of the wing. So either a long, narrow wing or a shorter, broader wing will support the same mass. For efficient steady flight, the ratio of span to chord, the aspect ratio, should be as high as possible (the constraints are usually structural) because this lowers the lift-induced drag associated with the inevitable wingtip vortices.

2.1.3 Aspect Ratio

In aeronautics, the aspect ratio of a wing is the ratio of its span to its mean chord. It is equal to the square of the wingspan divided by the wing area. Thus, a long, narrow wing has a high aspect ratio, whereas a short, wide wing has a low aspect ratio.

A higher aspect ratio (given the same wing area) means more wingspan and less lift-dependent drag. At the same angle of attack, higher aspect ratio also means more lift (within limits).

Lift is produced by deflecting the oncoming stream of air downwards. The more air can be affected, the more efficient lift production becomes.

2.1.4 Camber

Camber is the curved surface of an aerofoil from the leading edge to the trailing edge.

As lift is primarily based on airspeed, angle of attack and aerofoil design, a fundamental component of aerofoil design is the camber which will vary with the intended speed and purpose of the aerofoil.

The upper surface of the aerofoil will always have a positive camber while the lower surface may have a positive (convex), zero (flat) or negative (concave) camber as appropriate for the intended use. Designers may also vary the camber over the span of the wing to improve stall and stall recovery characteristics.

2.1.5 Aerodynamic Stall

How does an aircraft stall?

There really is one answer here and that is, “the pilot stalled the aircraft!” Or at least put the aircraft into a situation that resulted in a stall. But let’s look at the aerodynamics behind a stall.

An airplane stall is an aerodynamic condition in which an aircraft exceeds its given critical angle of attack and is no longer able to produce the required lift for normal flight. When flying an airplane, a stall has nothing to do with the engine or what is propelling the aircraft. In piloting, a stall is only defined as the aerodynamic loss of lift that occurs when an aerofoil (i.e., the wing of the airplane) exceeds its critical angle of attack.

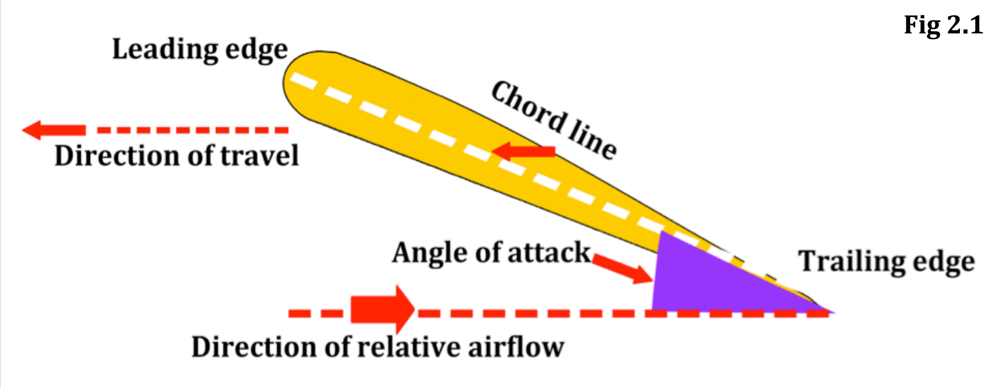


Fig 2.1

2.1.6 Wing Loading

Wing loading is the total mass of an aircraft divided by the area of its wing. The stalling speed of an aircraft in straight, level flight is partly determined by its wing loading. An aircraft with a low wing loading has a larger wing area relative to its mass, as compared to an aircraft with a high wing loading.

The faster an aircraft flies, the more lift can be produced by each unit of wing area, so a smaller wing can carry the same mass in level flight. Consequently, faster aircraft generally have higher wing loadings than slower aircraft. This increased wing loading also increases takeoff and landing distances. A higher wing loading also decreases maneuverability.

CHAPTER 3 – LAUNCH

3.1 Launch

Wind direction is critical when it comes to the launch of a fixed wing aircraft. The aircraft must (where possible) be launched directly into a headwind. This allows the aircraft to gain airspeed quickly, as the air is already moving over the wings, prior to launch.

3.1.1 Effects of Cross-Wind on High- and Low-Wing Aeroplanes During Launch And Control Technique

Cross wind launching also brings similar problems to the pilot. As soon as the RPA is launched, it will want to "weather cock" into the direction of the wind. This may result in a change in the direction of climb, which may result in the impact with an object such as a tree etc. The key to control here is to maintain good rudder control on the ground (if the RPA has landing gear) to keep a straight line. Once the aircraft has lifted, allow it to weather cock into the wind and continue to maintain control straight in line with the runway. Resist the urge to want to fight the wind with ailerons, and allow the aircraft to fly.

High wing aircraft differ in their reaction to crosswinds than that of say a delta wing aircraft (such as the Parrot Disco). The delta wing aircraft do not suffer anywhere near the crosswind problems of other traditional type aircraft and is one of the reasons they are favored for RPA flight.

3.1.3 Effects of Cross-Wind on Tail-Wheel Equipped Aeroplanes and Control Techniques

On an aircraft with a tailwheel, the centre of gravity is behind the main wheels which means that on the ground it is inherently unstable directionally as the tail wants to overtake the nose. Here in a crosswind landing the initial approach is crabbed until just prior to rounding out. Crosswind management will be required by independently using rudder to point straight and simultaneously opposite aileron to control ground track.

3.1.4 Advantages of Launching into Wind

Launching with a tail wind is not recommended at all, as the aircraft will need a lot more room and power in order to commence flight at the time of launch. Launching with a strong tail wind is downright dangerous. The aircraft needs "air over the wings" to fly. So let's look at what is happening during tailwind take off, and we can look at this in a simplistic but informative way.

Let's say the wind is blowing 10kts from the south, and you wish to launch the aircraft to the north. You would have 10kts of tailwind. Now, if your aircraft has a stall speed of

40kts, then you need 40kts of air rushing over the wings in order for the aircraft to fly. The problem is you have 10kts of tailwind, so you essentially need the aircraft travelling at 50kts on the ground, before it can even begin to fly.

However, if on the other hand, that 10kts of wind is a headwind, then the aircraft need only reach 30kts on the ground to achieve the 40kts of air over the wing!

In this simplistic explanation, you could use the following equations;

Stall Speed + Tailwind Speed = Roll speed. (40kts + 10kts = 50kts)

Stall Speed – Headwind Speed = Roll speed (40kts – 10kts = 30kts)

The other problems that come with tailwind is during landing. Again, if the aircraft is going to stall at 40kts and you have a 10kt tailwind, it means the aircraft will be touching down with a 50kt ground speed – AND – will take longer to roll and out stop.

CHAPTER 4 – CLIMBING

4.1 Effect on Climb Rate

Once the aircraft has left the ground and a constant speed climb established, then climb performance can be simply calculated using a balance of the forces acting on the climbing aircraft. Your best climb angle and climb rate is different for every aircraft type, and most modern RPA flight controllers will take care of that anyway.

4.1.1 Weight

Weight and balance must be considered during the climb, along with wind direction. A heavy aircraft that is say, underpowered, will have a longer and lower climb out, than a lighter more powerful aircraft. The remote pilot must ensure the is ample distance between the take off point and the first obstacle to allow enough room for the aircraft to climb over the obstacle.

4.1.2 Power

Power here is also important. The initial take off and climb out phase is where the aircraft is usually at maximum power. If climb cannot be established, then other factors will need to be considered. If power is reduced during the climb, the climb rate and the climb angle will change. Power should not be adjusted at all until such time as the aircraft is at an altitude that is safe to do so.

4.1.3 Airspeed (Changed from recommended)

Every aircraft be it an RPA, or a manned aircraft, has recommended airspeeds. These include maximum airspeed and stall speed etc. All aircraft will also have an optimum speed and power to climb. This will be different on every aircraft, but it is important to understand how your aircraft climbs efficiently, at what power and at what speed.

That said, most RPA in this category are very overpowered when scaled up to meet their full sized cousins. The climb performance on most RPA models will way outstrip any need for the pilot to be concerned. That said, you should make sure your aircraft operates as described by the manufacturer, and understand it completely, so you can recognise when things are wrong.

4.1.4 Flap Deflection

As mentioned previously flaps are deployed during take and landing to assist the aircraft when flying at slower speeds. However once the aircraft has successfully departed, the laps should be retracted to allow speed to increase. If flaps are left deployed and the speed of the aircraft is increased, damage can occur to the airframe. The ability of the aircraft to climb will be significant impacted with flaps deployed. They are not designed to allow the aircraft to climb, more they are to assist in the take-off portion of the departure.

4.1.5 Headwind/Tailwind Component, Windshear

As we discussed earlier, a headwind is favoured over tail wind. A tailwind climb may result in an extended climb out, dependant on the speed of the aircraft. Whereas a headwind may increase the climb angle.

Basically, a good head wind (or tail wind) will not affect your climb rate, but will affect your climb angle. This means your aircraft will sill reach a specific altitude in the same time frame, but the difference covered across the ground will be affected.

Windshear is nasty stuff. Horizontal and/or vertical Wind Shear on take-off can result in sudden loss of airspeed and/or reduction in climb rate, with potentially disastrous consequences. It is vital that such conditions should be quickly recognised if they are encountered, and that pilot response should be immediate and correct.

Before launch, it is a good idea to monitor and observe the conditions for some time, so that you have a good understanding of wind directions, gusts and possible windshear.

4.1.6 Bank Angle

An aircraft can turn during a climb, and this will have an effect on the aircraft's performance. During a turn, the lift vector is pointing partly up and partly to the side. This causes more drag, which tends to make the aircraft slow down. However, when climbing, the aircraft is probably already going quite slowly, so the pilot does not want to slow down too much, or a stall may follow. For this reason the pilot will make only very shallow turns (not much bank angle) during a climb.

If the bank angle is changed too much during a climb, either the aircraft slows down or it stops climbing. Slowing down is potentially dangerous and aircraft have crashed for this reason. Stopping the climb is possible, but great care is necessary in case there is an obstacle in front of you that you must climb over. Usually it is best to turn only with small angles of bank to avoid this problem, and only do so when the desired altitude is reached.

4.1.7 Altitude and Density Altitude

The density altitude is the altitude relative to standard atmospheric conditions at which the air density would be equal to the indicated air density at the place of observation. In other words, the density altitude is the air density given as a height above mean sea level. The density altitude can also be considered to be the pressure altitude adjusted for a non-standard temperature.

What does all this technical jargon mean? In simple terms, when the air is thinner, an aircraft performs less than if the air was thick. At high altitudes the air is thinner, and therefore the aircraft will not perform as if it was say, down at sea level.

Both an increase in the temperature and a decrease in the atmospheric pressure, and, to a much lesser degree, an increase in the humidity, will cause an increase in the density altitude. In hot and humid conditions, the density altitude at a particular location may be significantly higher than the true altitude. This basically means that even though on that particular day, you were at say, 3000ft up a mountain, the air up there might be as if you were at 5000ft!

What does all this mean? It means that care must be taken when operating at high altitudes, and especially in hot, low pressure. In the manned world, density altitude issues have resulted in crashes, and loss of life.

Remember, air density will affect the performance of the aircraft. A lower air density (known as high density altitude) will result in poorer performance. The wings produce less lift, and the prop will produce less thrust. An internal combustion engine will also perform less. This will result in a longer take off run, poor climb performance and longer landing distances.

High density altitude is never a good thing for your aircraft's performance. An increase in density altitude adversely affects your aircraft's performance by increasing take-off distance, reducing rate of climb, increasing true air speed on approach, landing and increasing landing roll distance.

CHAPTER 5 – STRAIGHT AND LEVEL

Straight and level flight is achieved by keeping the wings level and maintaining power for the cruise. Any deflection of the ailerons at this point, will change the bank angle of the aircraft, resulting in the beginning of a turn in the direction of the lower wing.

A decrease in power will result in less speed, and if continued, without changing the angle of attack, the aircraft will begin to lose altitude and enter a decent phase.

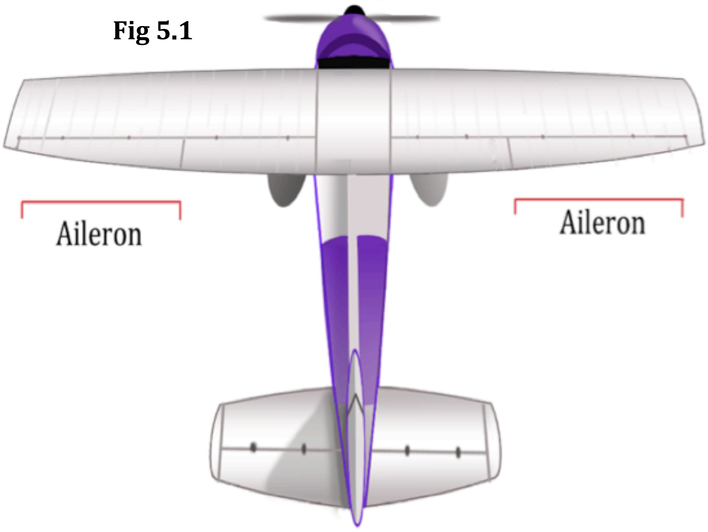
An increase in power will result in more speed, and if continued without changing the angle of attack, the aircraft will begin to gain altitude and enter a climbing phase.

To change the airspeed in level flight, we must consider the effect of the change of power. In order to gain airspeed in level flight, power must be applied, and then a slight forward pitch must be applied to prevent the aircraft from climbing – lessening the angle of attack.

To decrease airspeed and maintain level flight, power must be reduced, and a slight backward pitch pressure must be applied to prevent the aircraft from descending – increasing the angle of attack.

Basically, an increase in airspeed will require you to lower the nose. A decrease in airspeed will require you to raise the nose.

Fig 5.1



CHAPTER 6 – TURNING

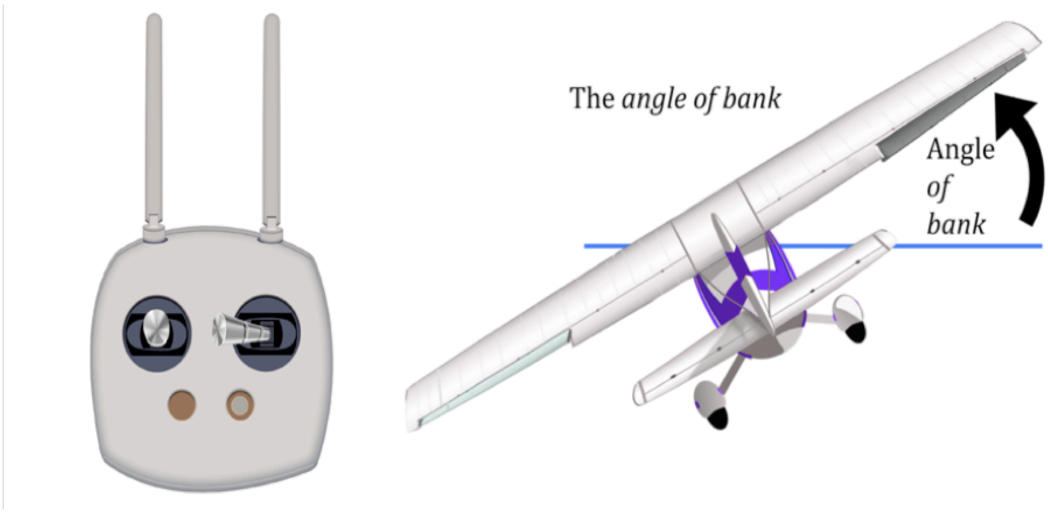
6.1 Concept of Balanced Turns

The ailerons are hinged control surfaces situated on the outboard trailing edge of each wing. They are controlled by the aileron control stick and move in such a way that left or right movement of the control causes the ailerons to operate. When the aileron control is turned to the left, the left aileron deflects upwards while the right aileron deflects downwards. The airflow imparts a downward force to the left wing and an upward force to the right wing. The aircraft rolls to the left and adopts a banked attitude.

The angle formed between the aircraft's lateral axis (wing tip to wing tip) and the horizon is called the *angle of bank* (refer to Fig 6.1).

When the aileron control is turned to the right the right aileron deflects upwards while the left aileron deflects downwards. The aircraft rolls to the right. Depending on the type of aircraft, rudder input maybe required to perfect the turn, along with elevator input. This is called a coordinated or balanced turn. In the manned world the pilot will have an instrument on the dash that will show if the turn is not balanced, indicating a slip or skidding turn. Balancing the turn will prevent slip or skid, but the reality is an RPA's flight controller will generally control all of this during critical phases of the flight.

Fig 6.1



6.1.2 Steep Turns – Effect of Increasing or Decreasing Bank Angle

Let's look at a climbing turn. In order to climb and turn, more power will be required, as the angle of attack will be increased. Without increasing power in a climbing turn, airspeed will be lost, and if this is allowed to continue, a stall can be induced. This is a critical moment for the aircraft. If a stall occurs in a climbing turn, a flat spin may result, which may or may not be recoverable.

The opposite is true for a descending turn. Less power will be required or an increase in airspeed will occur. If left to continue, the airspeed may exceed the VNE – Velocity Never Exceed. This is the airspeed in which structural damage may result.

There are a number of things to consider in steep turn. One the angle of bank starts to increase, you will need to apply back pressure to the elevator in order to maintain altitude. If not, a loss of altitude will occur. An increase in power here may be required. If the aircraft has a rudder, it may also need to be applied in order to keep the turn balanced and counteract any adverse yaw.

The elevator must be used in order to maintain the aircrafts correct attitude in the turn. – REMEMBER – Too much elevator in the turn can result in the turn being too tight, and the aircraft will stall. This may result in the aircraft flipping over and entering a spin.

Load factors must also be considered here. The tighter the turn, the higher the load factors on the aircraft. Never exceed your aircrafts maximum load – structural damage may occur resulting in the aircraft breaking up in flight.

Never attempt a steep turn with slow airspeed!! A stall will most likely be induced and may result in a crash. The slower the airspeed, the more gentle the turn should be. Remember tight turns increase the aircrafts stall speed. In the manned world, this has resulted in many crashes, many, sadly, fatal.

6.1.3 Turning Downwind and Visual Illusions

The remote pilot needs to understand slight differences in what he will see of the aircraft during flight. Unlike a manned pilot, the remote pilot gets to visually see the aircraft at work from outside the cockpit. These produces some phenomena that the RPA pilot needs to be aware of.

When flight "upwind" the aircraft will be moving slower than downwind at the same power. This is due to the now tailwind that will allow the aircraft to have a greater ground speed. Resist the want to slow the aircraft down! If the aircraft slows down too much, the airspeed over the wings may drop to a critical level and the aircraft may stall. Airspeed is the critical factor here – NOT ground speed.

The other thing to consider here is orientation. It can be quite deceiving and to some remote pilots the aircraft may appear to be turning in the opposite direction to what it is. The trick here is experience, and to trust your aircraft. If you have given the aircraft a command to turn left, and it appears to be turning right, wait! Don't react immediately. Let the aircraft fly, as you may be experiencing some orientational illusions which should correct itself shortly thereafter.

CHAPTER 7 – THE STALL, THE SPIN AND THE SPIRAL DIVE

7.1 The Characteristics of a Stall

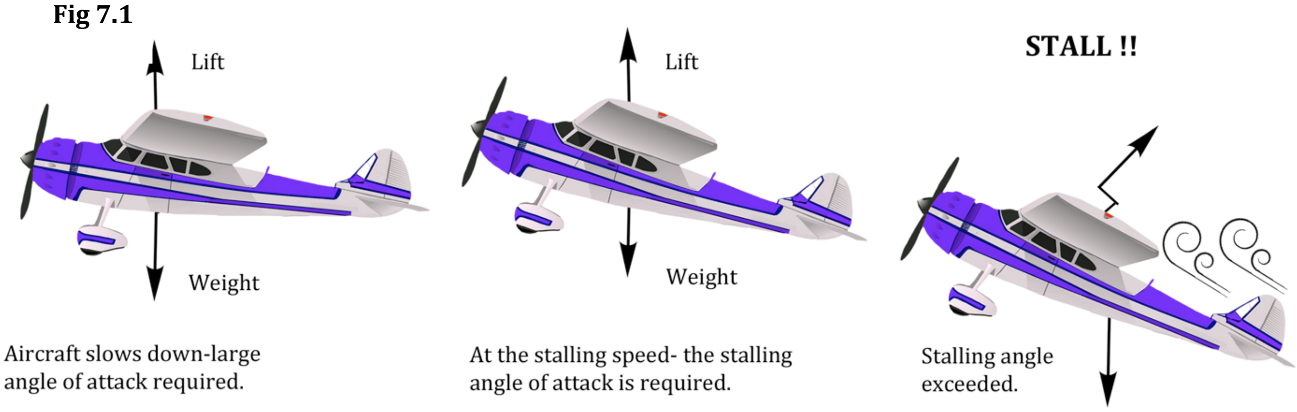
Visual signs of a stall of an RPA from the ground may be quite difficult to detect, as the conditions on the ground can vary somewhat than the conditions up high. One sign may be the "belly wash". This is where the aircraft appears to be wallowing around its belly, in a side to side motion. It means there is not enough lift being generated, and the aircraft is battling to stay aloft. A decrease in control effectiveness is also another sign.

Recovering from a stall is actually quite simple! We need to get the aircraft flying again, and all we need is air over the wings.

When you realize you have entered a stall, the first, most important step to begin recovering is to reduce your angle of attack. Most airplanes require at least 4 steps to fully recover from a stall.

1. Pitch nose-down to decrease the angle of attack.
2. Reduce the bank by levelling the wings.
3. Add power as needed.
4. Return to the desired flight path.

Fig 7.1



Aircraft slows down-large angle of attack required.

At the stalling speed- the stalling angle of attack is required.

Stalling angle exceeded.

Ailerons can cause the wingtip to stall early

If a wing starts to drop and you lower the aileron on that wing to raise it, you increase the wing's angle of attack. You can quickly push the wing over the critical angle of attack - stalling and dropping the wing. Avoid using any ailerons approaching or at the stall. Get the aircraft flying first.

7.1.2 Why the RPA may Stall at Different Speeds

A fixed-wing aircraft can be made to stall in any pitch attitude or bank angle or at any airspeed, but deliberate stalling is commonly practiced by reducing the speed to the unaccelerated stall speed, at a safe altitude.

Unaccelerated stall speed varies on different fixed-wing aircraft. As the plane flies at its unaccelerated stall speed, the angle of attack must be increased to prevent any loss of altitude or gain in airspeed (which corresponds to the stall angle described above).

The pilot will notice the flight controls have become less responsive and may also notice some buffeting, a result of the turbulent air separated from the wing hitting the tail of the aircraft.

Stalls depend only on angle of attack, not airspeed. However, the slower an aircraft flies, the greater the angle of attack it needs to produce lift equal to the aircraft's weight.

As the speed decreases further, at some point this angle will be equal to the critical (stall) angle of attack. This speed is called the "stall speed".

An aircraft flying at its stall speed cannot climb, and an aircraft flying below its stall speed cannot stop descending. Any attempt to do so by increasing angle of attack, without first increasing airspeed, will result in a stall.

The actual stall speed will vary depending on the airplane's weight, altitude, configuration, and vertical and lateral acceleration.

Here are a few things to consider about stalling.

7.1.2.1 Power

If the aeroplane could climb vertically there would be no requirement for lift at all. So when thrust is inclined upwards, it decreases the requirement for lift and reduces the stalling speed. In addition, the slipstream generated by having power on increases the speed of the airflow and modifies the angle of attack (generally decreasing it) over the inboard sections of the wing.

7.1.2.2 Flap

Flap increases lift and therefore the stalling speed is reduced. However, flap also changes the shape of the wing, and this results in a lower nose attitude at the stall.

The effect of flap on the lift/drag ratio should be revised, with particular emphasis on the reason the flap is raised gradually during stall recovery.

7.1.2.3 Manoeuvres

If at the stall the aeroplane starts a slight roll, using aileron to stop the roll (a natural tendency) will increase the angle of attack on the down-going wing. This decreases the lift even further and increases the drag, continuing the roll not stopping it.

This is the reason for maintaining ailerons neutral in the initial stall recovery and using rudder to keep the aeroplane straight on the reference point. You really should avoid using ailerons once the aircraft has stalled, until such time as stall recovery has occurred.

7.1.2.4 Weight

An increase in weight will require an increase in lift, resulting in an increase in the stalling speed. If the aircraft is loaded above its MTOW, then the advised stall speed will be incorrect, and the stall speed will be higher.

7.1.2.5 Frost or Ice

If ice forms on the wing, or the wing is damaged, the smooth airflow over that part of the wing will be disturbed, allowing the airflow to break away earlier. This increases the requirement for lift and therefore the stall speed. The effect of ice is twofold in that it also increases the aeroplane's weight.

7.1.2.6 Air Density

At higher altitudes, the air density is lower than at sea level. Because of the progressive reduction in air density, as the aircraft's altitude increases its true airspeed is progressively greater than its indicated airspeed. For example, the indicated airspeed at which an aircraft stalls can be considered constant, but the true airspeed at which it stalls increases with altitude.

As air density decreases with increasing altitude, more lift must be generated by an aerofoil to sustain flight and so the true air speed at which an aerofoil will stall will increase.

7.1.3 Differences between a Spin and a Spiral Dive

A Spin is basically a stall resulting in autorotation (uncommanded roll) about the aircraft longitudinal axis and can be entered intentionally or unintentionally. In a normal spin, the wing on the inside of the turn stalls while the outside wing remains flying.

Spins are characterized by high angle of attack, an airspeed below the stall on at least one wing and a shallow descent. Recovery and avoiding a crash may require a specific and counter-intuitive set of actions.

A spin differs from a spiral dive in which neither wing is stalled, and which is characterized by a low angle of attack and high airspeed. This can occur when an aircraft in flight is allowed to roll with no further control inputs by the pilot. The sideslip resulting from the inclined lift produces a yaw in the direction of bank.

However, the yaw causes the outside wing to accelerate producing extra lift on that side. This causes the angle of bank to increase still further increasing the sideslipping tendency. The increased sideslip produces further yaw which produces further roll, which produces further yaw and so on. An unstable condition of flight results with the ever-increasing bank yawing the nose to a lower and lower attitude. Airspeed rapidly increases imposing dangerously high forces on the airframe.

This is a spiral dive. Recovery is simple - just level the wings, and pull out of the dive. It's that simple.

- Remove power
- Wings Level
- Pull out of the dive (Gently)

CHAPTER 8 – DESCENT

8.1 Angle of Descent and Attitude

If, whilst in level flight, the power is removed there will be no force balancing the drag and the result will be a reduction in speed, and a reduction in altitude. To maintain the airspeed, the nose must be lowered to decrease the angle of attack. This is achieved with forward pitch. With the nose lowered, the aircraft will begin to descend. If power is not reduced and the nose lowered, then the airspeed will increase, and if this is not a desired result, the airframe may reach Velocity Not Exceed (VNE), and damage may occur to the airframe.

As discussed earlier, the use of flaps can be employed on landing to assist.

Descending into a headwind may require more power in order for the aircraft to travel the desired distance – especially at landing. We should also always be paying attention to airspeed, as a strong tail wind may result in a loss of adequate lift, inducing a stall. Headwinds and tailwinds also affect the decent rate.

A sudden encounter with a headwind during descent will result in the aircraft generating more lift, thus angle of descent decreases. When flying into a steady headwind the ground speed will be lower at the same airspeed. But the descent rate will be the same. So if the RPA is descending at the same rate, but moving forward at a slower rate than the angle will be steeper.

CHAPTER 9 – LANDING & RECOVERY

9.1 Achieving a Smooth Landing

The process of landing an aircraft is probable the most critical part of the aircraft's operation, and where most things go wrong! However, if you get the setup right, the rest should follow through. The biggest mistake is getting the approach all wrong, which may lead to things like a higher than normal approach angle, a faster than normal approach speed, or even a slower than normal approach speed. All of these can lead to undesirable aircraft states.

9.2 Effects of a Crosswind

As we have discussed earlier, crosswinds are most problematic during take-off and landing. The same technique can be used here (as we discussed earlier) but in reverse. Earlier we discussed allowing the aircraft to weathercock after take-off, well we can do the same here during the approach to land. Let the aircraft weather cock and using aileron control guide the aircraft toward the runway. Avoid using rudder here to straighten the nose, as you will simple allow the aircraft to drift sideways away from the runway.

One disadvantage with landing a low wing aircraft in a crosswind, as opposed to a high winged aircraft is the distance between the ground and the wingtip. During the final stages of approach, and just before touching down, a slight "lean in" to the wind is required when the nose is straightened. This is to prevent the aircraft from drifting sideways. Having a high winged aircraft certainly gives a bit more room.

9.3 Advantages of Landing into the Wind

We have already discussed this previously, and the same rules apply with taking off into the wind and landing into the wind. Landing into the wind has the same advantages: It uses less runway, and ground speed is lower at touchdown.

The ground speed at touchdown will be greater than usual and any float tendency will result in a long landing. The stopping distance will be significantly increased due to the higher groundspeed and, in combination with a long landing, could easily result in a runway excursion. Easy fix - land into the wind.

9.4 Flapless Approach

With flap up, the stalling speed is greater than with flap extended. To retain the same margin of airspeed over the stall speed, the approach and threshold speeds are increased by about the difference in the aeroplane's stall speed clean.

This increase in threshold speed will result in a longer landing distance, and therefore the suitability of the runway should be considered.

Without the increased drag provided by flap, the power setting required to control the descent will be lower and the descent angle will be shallower.

9.5 Deep Stall Landings

Some RPA manufacturers have gone down the path of enabling their aircraft to land in a configuration that is called Deep Stall.

Deep stall landing is one of the landing methods by which airplanes can decrease flight speed while maintaining a deep glide path angle. This is because the wing can generate large air drag in the deep stall state. Therefore, the method is suitable for small unmanned aerial vehicles to land within narrow areas surrounded by tall obstacles.

Deep stall is the state in which the angle of attack is much higher than the stall angle. Even though the flow is unstable around the stall angle, it is stable in post-stall. Therefore, the wing can generate constant lift and drag forces when the angle of attack exceeds the stall angle by a certain value.

Adopting deep stall landing method, the plane can decrease the flight speed effectively and maintain a certain path angle, steep enough to land in a confined area. However, please ensure the aircraft is capable of such manoeuvrers, as a crash may result if this technique is performed on aircraft not capable of performing deep stalls. Please refer to the manufacturer of the RPA.

9.6 Use of a Recovery Net

There are many ways to recover a RPA to the ground depending on the type of the aircraft. A multirotor or a VTOL fixed wing (vertical take-off and landing) for example can take off and land vertically so it will not need much space to execute these manoeuvres, and as we have seen above, a deep stall technique could also be used.

A fixed wing RPA generally will need a runway to take off and land, that in many cases will be very long depending on the size, weight and power of the aircraft to get the minimum speed needed to take off, and the same regarding the minimum space to land breaking the RPA until it is completely stopped. The problem comes when we need all the capabilities and performances of a fixed wing (for example its endurance) but there is no runway or we don’t have enough space to land in the area that we are working in. In those cases, a RPA recovery net is the perfect solution to make sure that our RPA lands safely and quickly in the minimum space possible.

Nets come in all shapes and sizes, and we won't go into specifics here. The main point is to ensure your aircraft is capable of being recovered in a net. Check with your manufacturer, and don't attempt the use of a recovery net without their approval, or the aircraft is likely to sustain damage.

Fig 9.1

9.7 Circuit Diagram