ACTIVE FLYING

Aerodynamics theory and flying techniques

Most of the time, paragliders don’t need pilots to fly and land them safe. Sometimes, paragliders can even take off and fly themselves, without any pilot aboard. This is because of their simple design and inherent pendulum stability.

From the other side, the light paragliders fly slowly and react vigorously when air moves up and down or wind is strong and gusty. Random paraglider’s movements cause discomfort and anxiety within pilots. Turbulence can lead to abnormal flying modes, like stalls and collapses, some of which self-recover, some may need a pilot input, and some might be unrecoverable and require the use of a rescue parachute. Extreme flying modes can also happen in calm air, as a result of intentional but inadequate piloting.

SkyNomad’s Active Flying course gives the basics of how to deal with turbulence and extreme situations, which often happen in cross-country paragliding. First, learn to fly safe and then chase new horizons!

Active flying is:

- understanding the nature of paraglider’s movements and their limits;
- understanding how paraglider’s controls work and their limits;
- awareness of dangers - what outside conditions, like wind gradient, gusts, vortexes and turbulence, can cause to paragliders;
- preventing abnormal flying modes, like stalls and collapses, and when they still happen help the paraglider recover quicker;
- flying efficiently.

Let's see what is behind the beginner's mantra when flying in turbulence:

- **KEEP THE GLIDER ABOVE YOUR HEAD**
- **LET IT FLY**
- **KEEP DIRECTION**

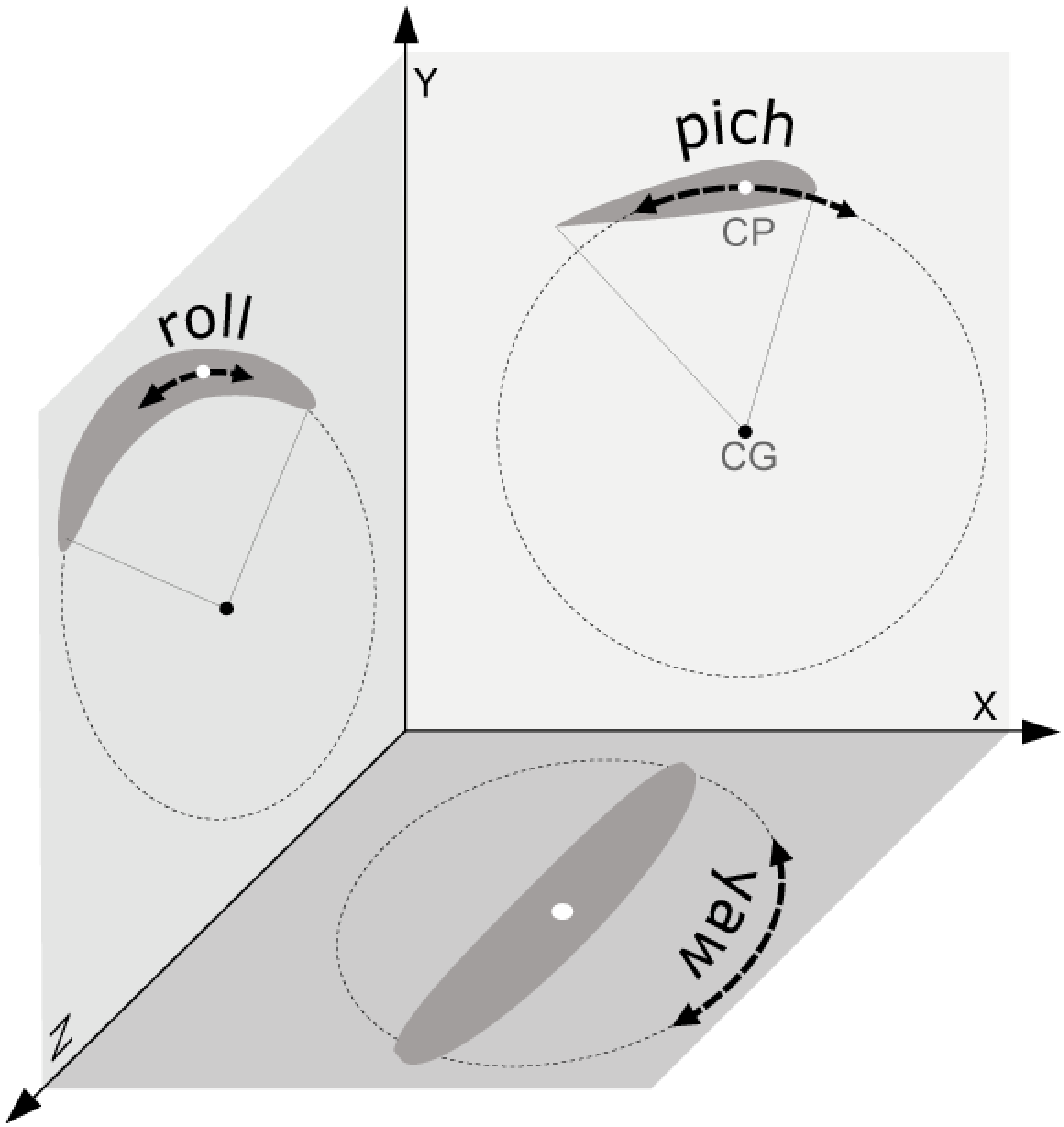
First, when we examine something complex, we need to choose our view point of reference. There are two main rectangular coordinate systems:

- **Earth-axis system** OXYZ, where OY axis is vertical and perpendicular to Earth's surface, OX and OY lay in the horizontal plane and OX points towards a chosen direction;

- **body-axis system** $OX_1Y_1Z_1$, where OX_1 points out from the central wing's profile, along the main chord line; OY_1 is perpendicular to OX_1 and both lay in paraglider's plane of symmetry. OZ_1 is perpendicular to this plane, pointing sideways. Point O is paraglider's Center of Pressure (CP).

The complex paraglider's movement can be broken into 6 basic motions:

- 3 linear motions along OX, OY, OZ axes;
- 3 rotations around OX_1, OY_1, OZ_1 axes:
  - **Pitch** - rotation around the lateral OZ_1 axis;
  - **Roll** - rotation around the longitudinal OX_1 axis;
  - **Yaw** - rotation around the vertical OY_1 axis.



The soft wing made of textile can be seen as a solid body, holding a pilot in his harness via risers and lines. The paraglider has two important points:

- **Center of pressure** (**CP**). It lies at 25% behind the beginning of main chord line (*the line connecting outer-front and outer-rear points of wing's profile*)

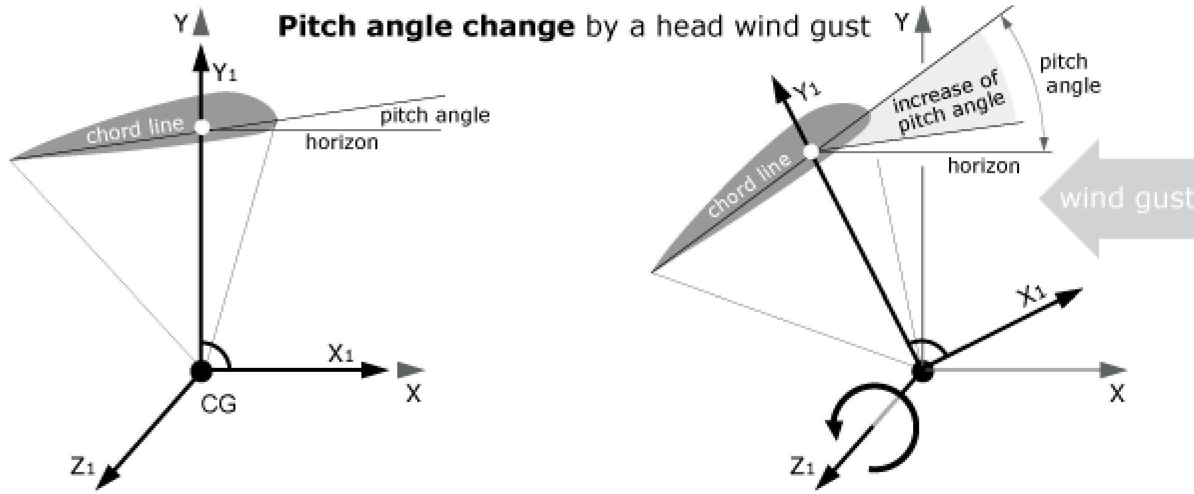
- **Center of gravity** (**CG**). This is the center of mass of the whole system – wing, risers and lines, pilot's body and harness. It depends on the body's position and is somewhere around the stomach.

The full aerodynamic force (R) and wind gusts are applied at the center of pressure (CP), while gravity weight force (G) and inertial force (Fi) are applied at the center of gravity (CG). Paragliders can be seen as a simple pendulum body (CG) with a moving pivot point (CP).

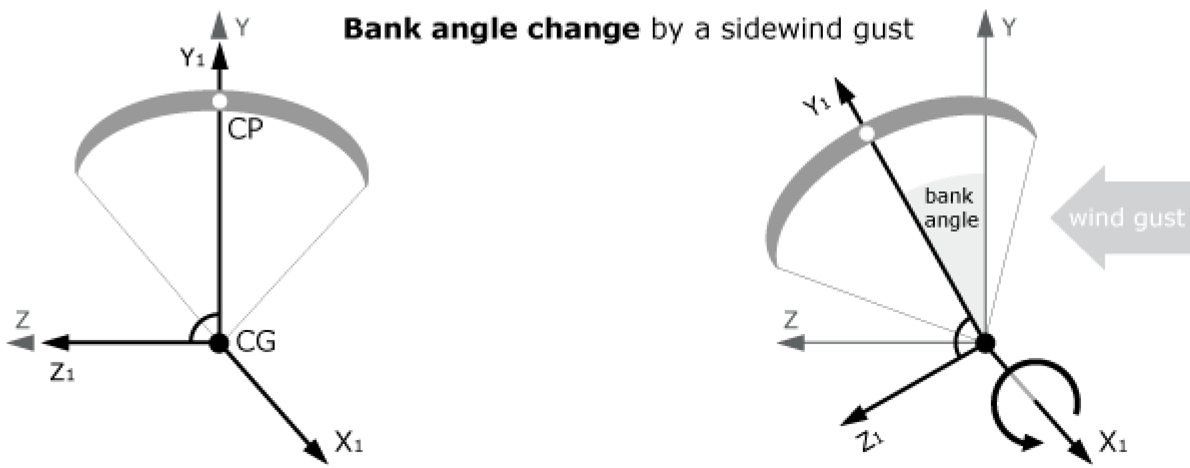
Environmental disturbances, like wind gusts, gradients, and vortexes and pilot's inputs with brakes or weight shift, change the tilt and size of the full aerodynamic force - R. This force's change accelerates the center of pressure (CP) in one direction or another and is called **upper pendulousness**.

Backward or forward CP accelerations cause **pitch motion** and it rotates the wing around its lateral OZ_1 axis, changing paraglider's **pitch angle** - the angle between wing's surface and horizon. *Pitch angle* is different than *angle of attack* – the angle between wing's surface and airflow/airspeed direction.

Sideways CP accelerations cause **roll motion**, which rotates the wing around its longitudinal OX_1 axis, changing paraglider's **bank angle** – the angle between the paraglider's plane of symmetry (OX_1Y_1) and the vertical Earth's axis (OY).

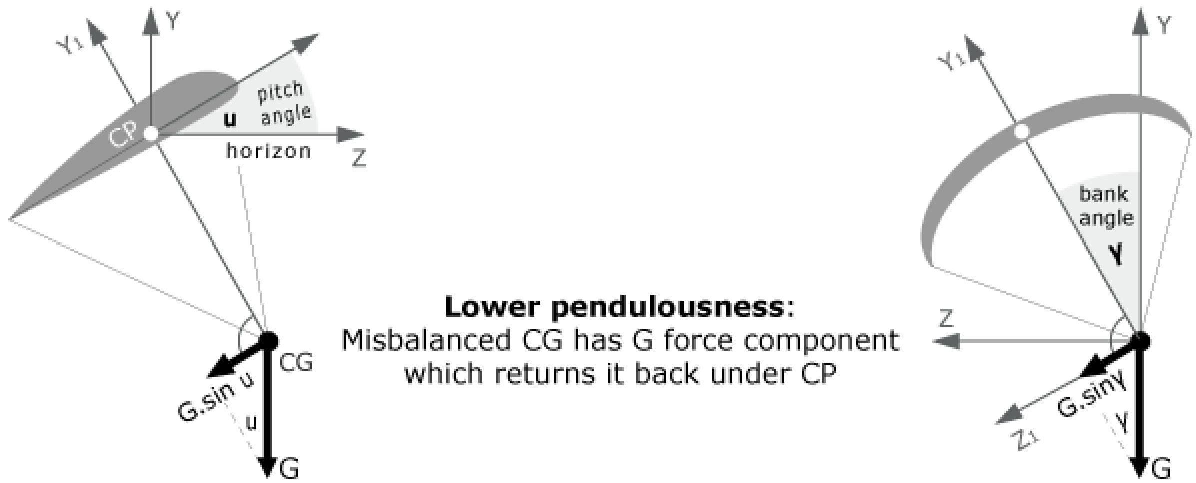


Sudden head-wind gust pushes the light wing backward, while CG continues forward by inertia.
The paraglider rotates around its OZ_1 axis increasing its pitch angle.
Similar increase of pitch angle happens when the pilots pulls the brakes and slows down the wing.



Sideways wind gust pushes and tilts the light wing to one side.
The paraglider rotates around its longitudinal OX_1 axis which creates a bank angle between its vertical axis OY_1 and Earth vertical axis OY.
Similar roll, tilt and bank angle happens when pilot weightshifts and moves his body to one side.

When a paraglider is misbalanced by outside disturbances or pilot's input, its CP is no longer aligned with its CG and an imbalanced component of G force appears, returning CG back under CP. This is called **lower pendulousness**.



CP and CG movements are interconnected! Every CP motion (upper pendulousness) misbalances the paraglider, causing immediate CG reaction (lower pendulousness). Every CG motion changes the angles of pitch or roll. This directly changes the angle of attack and the aerodynamic force R. The change of aerodynamic force accelerates the whole wing in one direction or another and this is how CP moves because of CG motion.

Of course, at the end, the great distance between CP and CG makes *lower pendulousness* prevail over *upper pendulousness*. After few oscillations, CG reaches a balanced position under CP.

PARAGLIDING PITCH CONTROL

The purpose of this exercise is:

- To make the pilot comfortable with wide range of pitch motions;
- To teach the pilot how to control pitch motions and dampen oscillations;

Pitch motions are easily noticed when the pilot looks forward, towards the horizon. Human eye is poor about measuring distances, but sensitive about angles and comparisons. If the pilot looks forward without moving, then he can detect even 2-3° pitch angle changes in relative to the horizon. The balance apparatus in pilot's inner ear also registers pitch movements and sooner or later pilots have to get used to them as they are pretty normal for each flight. Another way to register all kind of paraglider's motions is to feel our body's acceleration through its contact with the harness, reading the *specific paraglider behaviour*. A good homework exercise is to close your eyes when travelling in a car as a passenger, trying to guess if it is turning, loading, unloading, accelerating or decelerating i.e. trying to feel the normal, longitudinal and lateral accelerations.

It is quite normal for beginner's pilots to feel uncomfortable when they look forward and see sky or ground increasing or decreasing; or when they feel their body surging forward or falling backward. Paraglider's pitch motions are like kid's swing. Never refuse to swing a child! It develops senses of rhythm, dance, playing with G-force, acceleration and inertia; weightlessness and urge to fly.

Step by step, swing by swing, beginner's pilots need to become comfortable with big pitch motions, to expand their range and learn their limits. Too high angle of pitch and attack means being close to stall; too low angle of pitch and attack means being close to collapse. What is the point to panic during a big swing, if you are still far from a stall or a collapse point?

Pitch-control exercise consists of two parts:

- Simulation of pitch motions;
- Stopping a pitch motion and dampening oscillations.

The most difficult part is the simulation of pitch motions, because simple brake inputs are not enough to overcome the big *lower pendulousness* and achieve wide range of pitch motions.

The precise timing of brake inputs is more important than the amount of brake pull for an effective pitch-motion simulation, which relies on paraglider's **inductive ability** (*see Forward Motion in SkyNomad Beginner's Aerodynamics article*). Pitch-motion oscillations are easy for natural pilots with a sense of rhythm – it is an entire uninterrupted play, like in a kid's swing. Still, there are several distinct stages:

First, the pitch-motion simulation starts with a single pull of brakes, up to carabineers' level. This increases the angle of pitch and attack, the glider opens its bottom surface to the airflow and slows down by the increasing drag. The body of the pilot continues further forward by inertia, until it is also stopped by the wing. The paraglider is misbalanced – CP is well behind CG, fully activating the *lower pendulousness* which tries to restore CG under CP.

Second stage is when the pilot keeps holding brakes. This further kills both airspeed and lift force; the paraglider falls down in a momentary parachute stall. The airflow now comes from underneath, with almost 90º angle of attack to wing's surface. This activates the *inductive ability*, which would accelerate wing forward, making it to fly again, but it is still weak and cannot overcome the brakes, still kept down by the pilot.

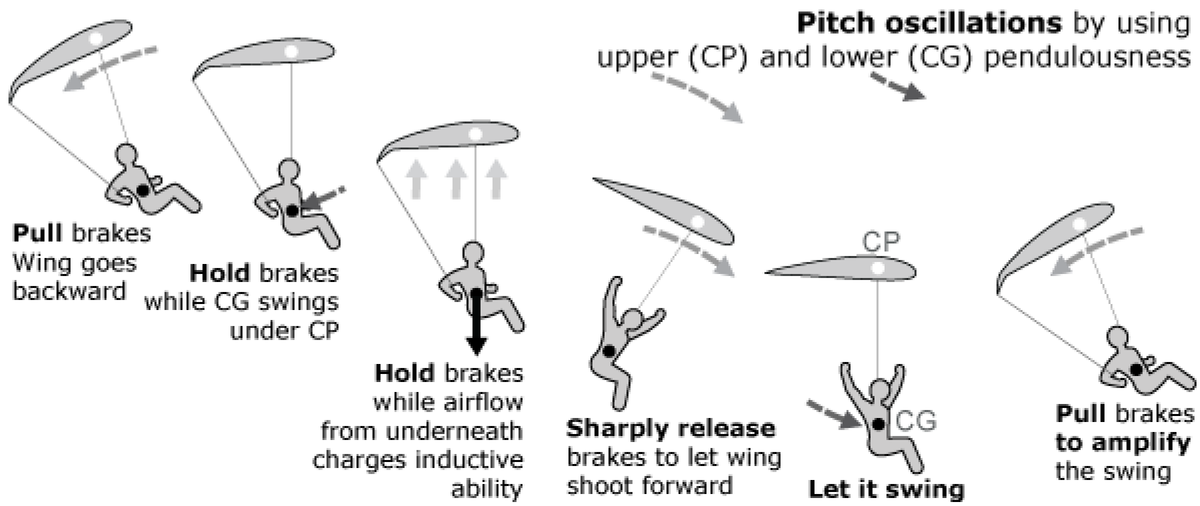
The paraglider continues dropping, increasing its airspeed from below, and then, the pilot suddenly releases brakes, fully unleashing the mighty *inductive ability*.

This third stage of a sudden, sharp release of brakes requires good timing of the moment when the pilot vigorously throws his hands up. The pull of brakes during the previous two stages lasts 2-3 seconds. If the pilot releases too early, then there will not be enough drop and airflow from below, which to create a strong *inductive ability* and forward self-acceleration of the wing. If the pilot releases brakes too late or not sharp enough, then he will miss to harvest the initial wing's self-recovery impulse from its *inductive ability* and the exit from the parachute stall will be dampened. The timing of sharp-brake-release moment requires the pilot to concentrate on inductive ability's peak, which feels like letting off the leash of an aggressive dog, or breaking the chain of a hard pulling horse. Of course, if the pilot holds brakes too long too deep, then he may cause a proper full stall. That is why pitch motion simulation starts with a shallow pull of brakes. Step by step.

Fourth stage is when the unleashed wing shoots forward. Enjoy it. It is a sign that the wing is healthy and wants to fly. If you feel that the self-acceleration is too aggressive or the wing will go too much forward and cause a collapse, then be ready to stop it with brakes. Normally, wing does not shoot fast after the first pull and with each next pull and release of brakes it builds up speed and swings further ahead, closer and closer to collapse point.

The final fifth stage is when the wing reaches the maximum of its forward motion and stops. The CP is well in front of CG. The *lower pendulousness* swings the pilot forward, catching up with the wing ahead of him. The whole paraglider system travels forward, but for the pilot the CG's swing following CP seems like wing goes backward, so he amplifies this motion by pulling both brakes when wing comes above his head.

Again, the moment of brake's pull requires a good timing in order to harvest fully the *lower pendulum* swing. If the pilot wants to increase pitch motion oscillation, then next brake pull might be slightly stronger than the previous one, but again - good pitch oscillations are more a result of good timing, not so much of harder pulling. At some point, oscillations may increase and reach the *collapse point*, even without further increase of next brake pull.



The pitch motions might be halted by a wind gust or a thermal bubble because these disturb the consequence of processes and because the glider is sensitive to angle of attack changes. Also, the lifting air clears pendulum misbalances quicker, sinking air prolongs them. In case of wind or thermal disturbance, the pilot should not continue with pitch motion simulation by pulling brakes harder as this may cause stall or too aggressive self-acceleration of the wing. Better wait for calm air and start again.

Stopping pitch motion, when wing shoots forward, is done simply by pulling both brakes. How much the brakes should be pulled depends on how aggressive the forward surge is – the more aggressive it is, the faster and deeper the pull should be. In extreme cases, the brakes are pulled completely below carabineers, like stalling for landing. In all cases, the brake pull should be fast and very importantly – after the pull release brakes, not so fast, but release them. Hands up. **LET IT FLY**. Let the wing regain airspeed and start flying again itself. A classic cause of accidents is pilot's overreaction from panic. Inexperienced pilots might be so overwhelmed by an aggressive forward surge, with or without a collapse, that they freeze holding the brakes for too long and stall the wing. The inductive's ability forward motion is limited by the inertia of pilot's body mass and at the end of the overshooting there is a loss of airspeed, so the wing may stall with less brakes pull than during a normal flight. That is why, it is important on each overshooting to find the corresponding amount and duration of brakes' pull. No more, no less. It should be a **dosed brake pull**.

A very useful exercise is to practice pitch-control oscillations by increasing their amplitude and then decreasing it, without stopping, without reaching the collapse point. Increase and decrease, fast and slow, like a dance, like a jazz. And those who still keep the child inside will remember the fun of learning by playing.

There are two major reason collapses.

The first one is when the wing suddenly enters sinking air. The push of airflow from above collapses the wing and the pilot cannot do anything about it.

The second reason for collapses is when the wing develops strong inductive ability and shoots aggressively forward, beyond the collapse point. These self-accelerations might be sudden for the pilot, his reaction with the brakes might not be fast enough, but if he knows how the inductive ability works, then he should not be surprised, he should be able to stop them all. The inductive ability is driven by an airflow coming from underneath the wing, perpendicular to its bottom surface – for example when entering a thermal or dropping after a stall or collapse. So, the prevention is simple - **after every vertical drop or push expect the wing to overshoot**, to bite like a snake and be ready to stop it. The faster the drop, the stronger the airflow from underneath, the more aggressive is the inductive ability and the wing's self-acceleration.

In real world, acrobatics or strong thermals and turbulence can cause asymmetric overshooting which can lead to a huge asymmetric collapse. This may require an asymmetric work with brakes - the side which overshoots more should be stopped more. Another useful pitch-control exercise is to practice nonstop oscillations with asymmetric use of brakes, so to make a full 360 º circle to one side and then to the other. If you manage to combine it with the previous exercise of increasing and decreasing oscillations, then you will become a pitch control master :-)

PARAGLIDING ROLL CONTROL

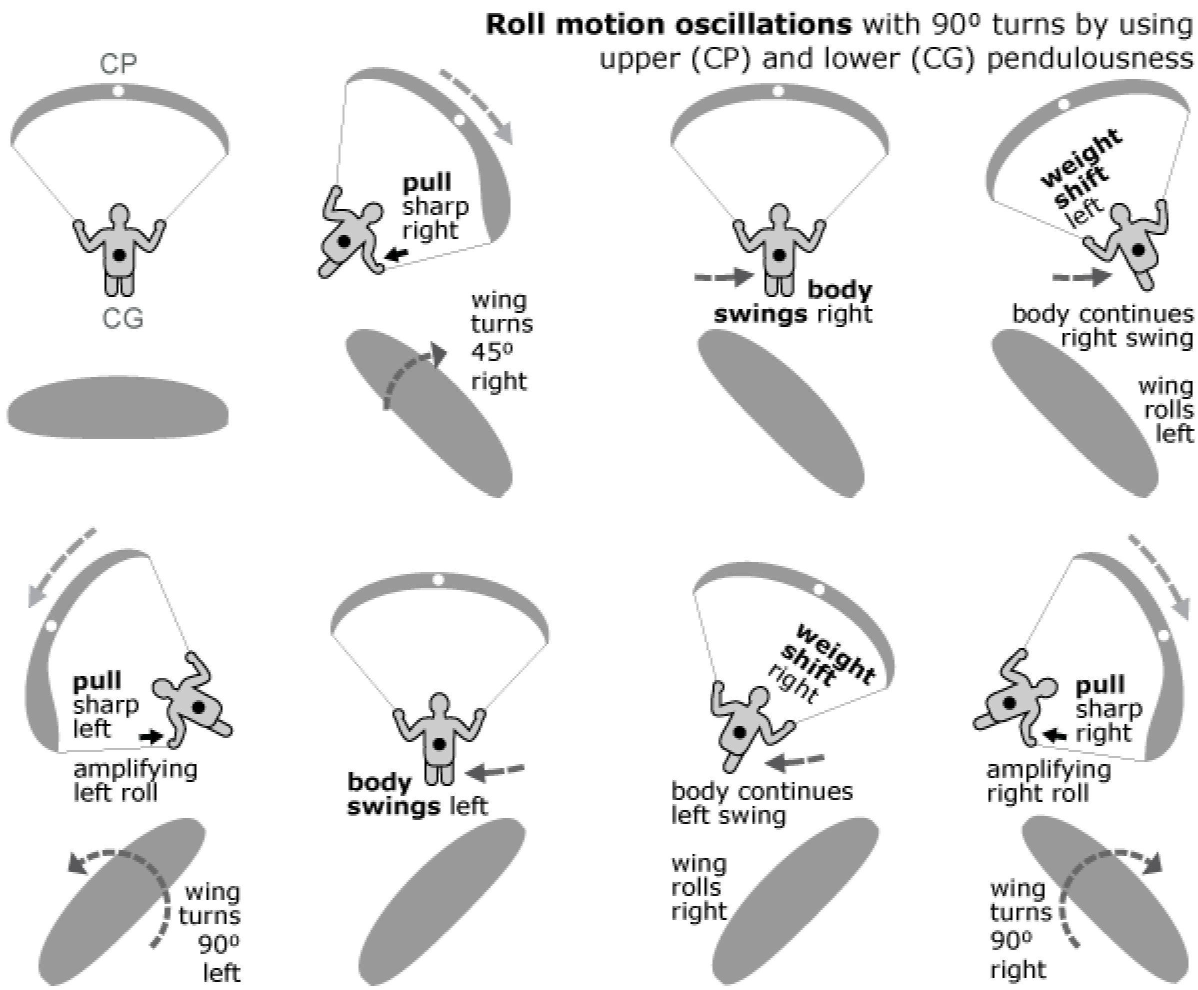
Roll-control exercise makes the pilot comfortable with a wide range of roll motions and teaches him how to manage them. Again, it consists of two parts – simulation of roll motions and stopping roll motions and dampening oscillations.

Unlike the clean and symmetrical pitch motion, the roll motion is not isolated and causes additional pitch and yaw motions. Still, the pilot should focus on the roll part of this complex movement. Again, the simulation is more difficult than the stopping part.

The roll motion simulation starts with a sharp brake pull and weight shift to one side, let's say to the right. The wing turns to the right, changing its course at about 45º from its original direction. At the same time, the wing tilts to the right and rolls away from vertical position, misbalancing the CP-CG pendulum. It cannot go too far right as it is attached to the pilot. The heavy body of the pilot (CG) swings to the right, following the wing (CP). CG inertia makes it overpass the vertical position under CP like a classic pendulum. It continues a little further to the right and if nothing else is done, after 2-3 oscillations, CG would return back itself under CP. But for the roll control simulation purpose, the pilot needs to switch direction and roll the wing properly to the other side.

The **switch-of-direction turn** starts in advance, during this overpassing motion, somewhere between the lowest CG position and the highest point of pendulum swing, where pilot's body loses speed and swings back. Again, the moment of sharp turning to the other side requires good timing. If it is too early, before or around the lowest CG position, then the pilot cannot harvest fully the lower pendulum swing, the CG motion. If it is too late, around the highest CG pendulum position, where speed is lost, then the paraglider feels weightless, loses maneuverability and cannot produce an energetic turn, no matter how hard the pilot tries.

The *switch-of-direction* turn, between lowest and highest pendulum CG positions, starts with an energetic weight shift to the left. The pilot uses the increased g-force and wing loading around the lowest CG position as a support to throw his heavy bum further along the initial swing to the right. This is a preparatory weight shift for the switch-of-direction turn. Despite being in opposite weight shift to the left, the pilot's body continues by inertia further along the original swing to the right. Then, before the *loss of speed* high point, the pilot pulls sharp the left brake to turn the wing 90º left, amplifying the left roll. The pilot's body continues by inertia slightly more to the right, while the wing is already engaged with a left roll and turn.



Break pulls, weight shifts, pendulum swings and roll motions cause an overall loss of speed and lift force. The paraglider sinks more and the increased airflow from underneath allows for extra use of our favorite *inductive ability* and for accelerating the wing further, in one direction or another.

For example, during roll control exercise, after each *switch-of-direction* brake pull, there might be a **secondary brake pull**, which additionally turns the wing further 45º; or 90º from the original course line. The sharp and short *switch-of-direction* brake pull enhances the next roll motion but also creates a period of increased sink. The additional break pull turns the wing further and lets it dive downward with its leading edge symmetrical to the airflow from below. The wing builds up extra speed which can be converted into more powerful turn. This is how **wingover** maneuvers are achieved. They are an extreme version of roll motion simulations and they rely on **build-up-speed sideway dives**.

The *build-up-speed* dives should be as symmetrical to the airflow from below as possible. A wing is much more resistant to collapses if it meets air frontally, head on, instead of sideways. Wingover rolls are quite joyful and addictive, but they can be deceivingly stable, causing huge asymmetric collapses, if you let the wing drop or dive sideways.

The *switch-of-direction* pull and the *secondary brake* pull can be one whole pull. Especially for sensitive sporty wings, which roll pretty easy. Beginner's wings are quite stable and difficult to roll, so they require good pulling and precise timing to produce good roll swings.

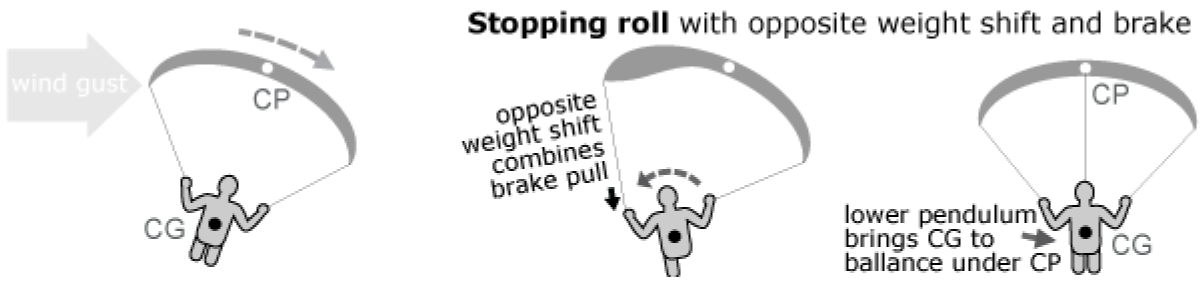
Roll motion simulations require calm air as thermals or wind gusts can stabilize or prolong paraglider's pendulum swings.

A variation of roll motion simulations is when trying to roll the wing by working only with one brake. This limits the paraglider's maneuverability and makes the pilot more focused on CG pendulum swings, trying to harvest their smallest details. AN extreme version of this exercise is *one-directional wingovers*, or also called an *asymmetric spiral*. It produces effective swings and is safer than classic wingovers, but leave it for later, after you have mastered all exercises from SkyNomad's Active Flying course.

Paraglider's roll motions are quite common when flying in lively air, when wing enters lift or sink asymmetrically, or when wing is hit by sideways wind gusts and vortexes. The big wing span self-dampens roll motions quickly, but still the pilot can accelerate the paraglider's stabilization with his controls.

Stopping of roll oscillations can be done simply by pulling and keeping both brakes at shoulder's level for a while. This slows down the wing and reduces its responsiveness; the rest is done by the lower pendulousness.

A roll motion may precede big outside disturbances and turbulence. After a roll motion starts, we do not know when it will end and how big it will be. Aggressive roll motions can make the wing dive sideways and cause a big asymmetric collapse. We should remember that the wing's horizontal projection is what creates lift force and opposes our weight force. Paraglider's wing has a distinct arc shape (dihedral) and when it rolls, its upper half is more horizontal and carries most of the weight. That is why, when wing rolls to one side, the pilot should oppose this roll by weight shifting to the other side, the higher one, the more horizontal one. Another good reason to counter any roll with opposite weight shift is that the lower half of the wing is unloaded, softer and may collapse at any moment. So, we do not want to put our body on something unreliable and worsen the situation. The countering of roll motion with opposite weight shift might be combined with opposite brake as well. This prevents potential aggressive surges and also temporarily increases canopy's internal pressure, reducing chances of collapses.



The opposite brake is dosed; a short impulse in the beginning of the roll motion. Weight shift is primary and brake is complementary. No need to pull much. The opposite weigh shift with hands at shoulder’s level, like cactus, is often enough as a brake pull. Weight shift cannot do harm, but too much brake can stall and spin the wing. Remember, after each brake input – “Hands up. Let it fly! Let the wing recover its airspeed”.

Roll oscillations often end with a pitch motion, which can be dampened by a gentle pull of both brakes.

PARAGLIDING COLLAPSES

Wing collapses when airflow pushes it from above i.e. when it experiences negative angle of attack. Collapse is different than stall, where wing reaches too high angle of attack, rupturing the airflow above, making it broken and turbulent. The collapse is a quick folding of paraglider’s leading edge; downward and backward. If it affects the entire leading edge, then it is a **frontal collapse** or **tuck**. If only part of leading edge folds and deforms, then it is an **asymmetric collapse**. Depending on how much of the leading edge is folded, it can be 30-50-80% collapse.

There are two main causes of collapses:

- The paraglider suddenly enters sinking air or a vortex. Nothing can be done to stop it. It just happens;
- The paraglider’s wing self-accelerates aggressively, surges forward and rotates around the pilot, reaching negative angles of attack. Self-accelerations are caused by boost of paraglider’s *inductive ability*, either because of outside disturbances like thermals, vortexes, wind gusts and gradients, either because of poor piloting and acrobatics.

Collapses are dangerous because:

- They happen suddenly and often without warning;
- The deformed wing stops flying and starts falling down fast;
- They can develop into an aggressive swing or spiral dive;
- There might be complications, like riser twists or cravats, when the paraglider’s lines get tangled with the canopy.

The most dangerous thing for any paragliding pilot, beginner or experienced one, is a collapse close to the ground, because its resultant swing or spiral dive can throw the pilot onto the ground, like a whip. Even if the collapse does not lead to energetic swing or spiral, even if it is only vertical fall, its speed of 7-8 m/s is still too high for safe landing. Additional problem is that in most emergency situations, the pilot does not have much support and control over his body position and the way he hits the ground.

Most of paragliding accidents happen from a collapse after takeoff. It is difficult to “see” the surrounding invisible air and to decide when it is safe to take off. At landing, the pilot has already spent some time in the air and better understands its character, so he is more prepared for surprises and can choose a safer landing field, if needed.

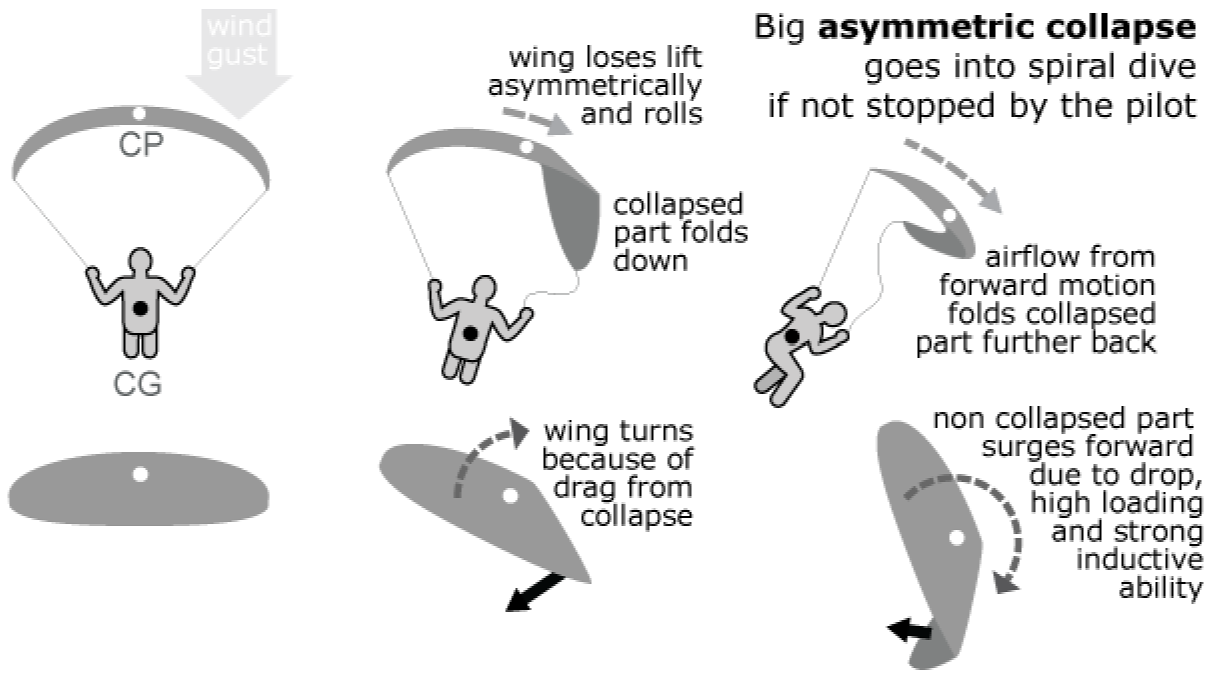
Still, despite their chaotic nature and risks, collapses can be studied and practiced in order to prepare beginners for the real world.

PARAGLIDING ASYMMETRIC COLLAPSE

Asymmetric collapse is when a part of leading edge collapses and folds down, because air pushes it from above. The collapsed side creates big drag and slows down, while the rest of the wing continues flying forward. That is how any collapse makes the wing turn toward the collapsed side.

Collapses also cause a loss of lift force and a sudden drop. The bigger the collapse, the bigger the loss, the deeper the drop. The drop creates airflow coming from underneath, which later helps to unfold the collapsed part of the canopy and restore flight. This airflow from below is very important for any collapse recovery. All collapses are different and depend on what type of air they occur within. If a paraglider collapses in sinking air, then it will take a lot of time to start falling faster than the surrounding sinking air, before creating healthy airflow from underneath. If the collapse happens in turbulent or fizzy air, then it may take surprisingly long time, until airflow becomes orderly and recovers flight.

When collapse is big, then the resultant drop will significantly affect the remaining part of wing which still flies. The strong airflow from underneath is acting on a smaller surface, creating an enormous *inductive ability*. The remaining not-collapsed part of wing will shoot aggressively forward. This, combined with the drag from the collapsed side of wing can throw the paraglider into a **violent swing** and **spiral dive**. Those can reach 100 km/h speeds and can easily harm or kill, if ground is nearby. In extreme cases, the surge of the working part of wing can be so aggressive, that wing spins, **twisting risers**, blocking brake lines and any control inputs by the pilot.



Another problem with collapses is when the collapsed side of canopy tangles with lines – **cravat**. The cravat delays collapse recovery and sometimes it might not be possible to recover at all.

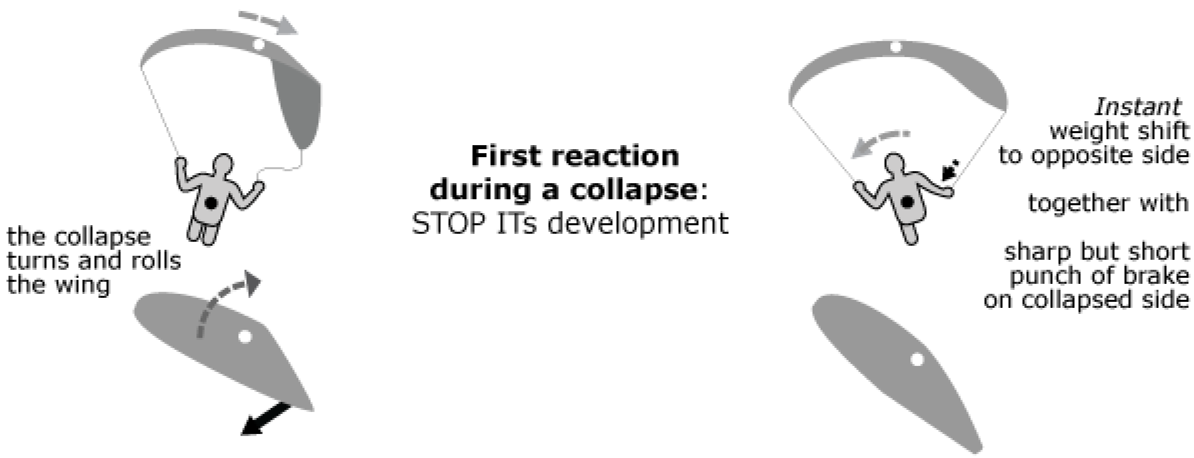
Collapses seem quite dangerous but they are an inevitable paragliding companion, so pilots should get used to them. For beginners, collapses might be freaky scary, but for experienced pilots they are something annoying, time-wasting, like the need to go to toilet in the middle of a delicious meal. Frequent and big collapses can be also a warning sign about too risky flying.

Collapses require prevention and action.

Study more micro meteorology and avoid turbulent zones early enough.

A classic example is when thermalling experienced pilots stay well inside a thermal, while beginners do not recognize its borders and constantly come in and out, crossing shear turbulence, sink and vortexes surrounding the thermal. Experienced pilots also recognize well in advance *turbulent sources* and zones. They avoid them with reasonable margins, judging well the gliding capabilities of their wings. It takes a lot of practice for beginner pilots to learn the gliding range of their wings and they often fall in this or that trap of terrain.

Experienced pilots are good at catching collapses at birth and preventing their development. They feel when a side of the wing shoots forward or gets softer and they instantly punch its brake down, without even looking at the wing:



It is difficult to move body mass quickly, without using an external force or support, but it is easy to throw your body to one side, while punching the brake at the other side. Body is heavier, but arm is faster. There is a similar use of *conservation of momentum law* in martial arts like kung foo and karate, while sports like box just rely on brutal muscle force and friction with the floor.

If the instant opposite weight shift and brake punch to collapsed side do not work and the asymmetric collapse still happens, then the pilot should **STOP THE TURNING** - by opposite to the collapse weight shift and brake.

When a collapse starts, we do not know how big it will become. Will it develop into a single violent swing or throw us directly into a proper deep spiral? Or it is just a small 30% collapse, like saying “hello, I am here”? We do not know, but in any case we should *instantly* throw our body to the opposite and still flying side of our wing. Then we pull the brake on this side and throughout the collapse we decide how long and deep we continue with the brake pull. If the collapse does not lead to significant turning, swing or spiral, then we release the brake, but keep the opposite weight shift.

Overreaction with brakes is a common pilot error, which can worsen any situation by stalling and spinning the wing, bringing it into cascades. **Too much brake is worse than too little or no brake at all**. That is why, first we use our body fully, to stop any potential turning, swing or spiral from a collapse, and then we use our brake. Don't be lazy; move your ass quickly, even it is faster and easier with brakes. **You cannot overdo weight shift, but you can overdo brakes**. If you watch the body of an experienced pilot, flying in turbulent air, you will see how energetically it moves. There are all kind of weigh shifts; big and small, fast and slow. It resembles the springy body of a boxer, who skillfully avoids punches from his opponent. It is like a dance with your wing and the turbulence around.

About 50% of pilot's control is weight shift and 50% is brake pull, and they are interconnected!

When we have a collapse we instantly move our body to the working side of the wing, which can carry our weight. This doubles the load and creates even stronger inductive ability. This is another reason to stay sharp and be ready to pull the opposite brake to stop any aggressive surge. There might be two brake pulls – a cautious, but instant one, to stop the initial turning from the drag from collapsed side and a secondary, deeper and longer brake pull, to stop any potential aggressive surge and turning from the inductive ability. Depending on the nature of collapse, the brake pull can be one – first a shallow impulse, a pause to see if there will be any big surge and then continue with the deep pull, if needed. No matter, if it is one or two brake pulls, always **release the brake after it does the job**, do not hold it even half a second longer, otherwise you may stall and spin the wing. Of course, if the collapse throws you into a proper deep spiral, then it requires quite some time and brake pull to stop it, but then there is no danger of stall or spin as the spiral goes with plenty of airspeed.

Experienced pilots quickly recognize which collapse is violent and which is easy to control, so they do not bother to stop the easy one too quickly, but let it turn the paraglider a little, perhaps 45º, in order to regain the vital airspeed. Remember, airspeed means more maneuverability and effectiveness for brakes, as they are aerodynamic type of controls, which depend on V^2. Good airspeed also means higher internal pressure for the canopy and quicker collapse recovery.

The post-collapse surprises come when it gets calm for a while, when you lose airspeed. Too much opposition and confrontation is not good for anyone. You have to quickly let the wing know about your intentions, but do not be a stubborn dictator, requiring a full submission. The wing is just a tool in experienced hands … and in the hands of turbulence too :-)

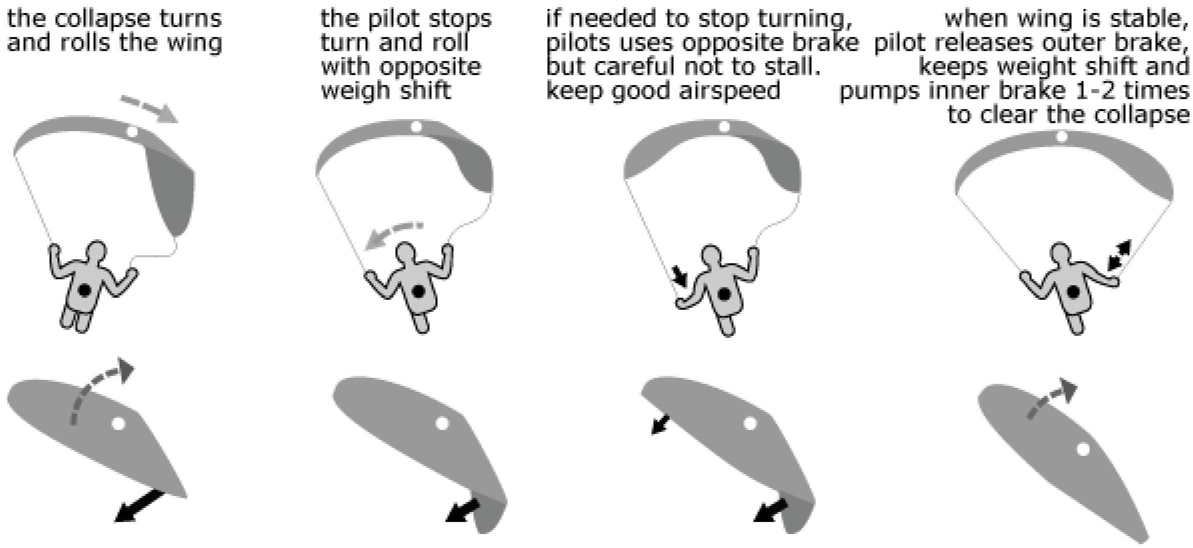
After we control the turning, after we are sure that there is a sufficient airspeed and that the collapsed wing is kind of stable, and then we can continue with **clearing the collapse**.

Often, the collapse clears itself – because the airflow from underneath pushes it out, unfolds it.

If the collapse still stays, than 1-2 brake pulls from the collapsed side usually open it quickly. Again, make sure you have sufficient airspeed before any pull of brakes. The body still might be weight shifted to the opposite side of collapse to counter any turning.

If the *collapsed-induced-turning* is stronger, weight shift might not be enough to keep the wing stable and it may require a certain amount of a constant opposite brake pull. In this case, in order to clear the collapse, the pilot should release the outside brake and let the wing turn for a while, then use this moment to pump the inner brake 1-

2 times, before the turn intensifies. If the collapse still does not clear and the wing starts turning faster, like entering a spiral, then the pilot should cancel the pumping with inner brake and stop the turning with opposite outer brake. After the wing is stabilized for a while, then the pilot can try again with inner brake pumps to open the collapsed side of wing.



Stopping and **clearing** an asymmetric collapse

Often, the reason for a collapse to stay is a *cravat* – the canopy is being tangled with the lines. In such case, the pilot should localize the **stabilo line** – a line which usually starts from “B” or “C” risers, has a distinct color and ends at wing tip. It should not be mistaken with “*Big Ears*” line, which starts from “A” risers and ends with outermost “A” lines. When an asymmetric collapse happens, the wing tip folds first and goes in between the lines. So, pulling the stabilo line is an efficient way to clear cravats. Some more complicated cravats may require pulling of other neighboring lines. Again, make sure you have sufficient airspeed during collapse recovery attempts.

Some cravats might be quite stubborn; the thin paraglider lines might be stuck by the plastic rods, shaping the leading edge from inside. The last option to clear a cravat is to stall the paraglider. It is like a reset, providing a lot of airflow from underneath and also a vigorous motion of wing tips. Of course, stalls for clearing cravats should be done with sufficient altitude and by experts only. Luckily, nasty collapses and stubborn cravats happen mostly to high aspect ratio sporty wings and are rare for beginner and intermediate paragliders.

If a collapse and its resultant cravat are too big and about half of the wing stays collapsed, then this might be unstable situation with a narrow margin between spin and spiral. The use of rescue parachute is the best solution. Especially, if surrounding air is not calm enough for further recovery attempts.

Do not forget to **watch your height** when you are busy with your wing. Give yourself enough time, speed and space for using your rescue parachute: for finding the handle, for pulling it out and throwing the rescue parachute in a clear direction, for its opening, for collecting the paraglider wing in order not to mess up with the rescue, and for preparing your legs and body for Parachute Landing Fall during the hard landing.

Sounds scary, ah?

That is why, pilots should **exercise collapses** and be prepared. During SkyNomad beginner's paragliding course, students learn to make "Big Ears", which is already a 30% collapse on each wing tip. Essential part of paragliding testing and EN certification is simulating 50% collapses. For example, an EN A paraglider completely self-recovers, within 90º turning, without significant loss of height. During SkyNomad's Active Flying course we do the same - simulate 50% collapse by pulling down "A" riser on one side. It is done with an EN A paraglider, 500 meters over a forest, in calm air, through radio supervision by an instructor on the ground.

When the student comes above the designated area, he grabs "A" risers on one side of the wing and pulls it sharp and hard down. Half of the wing collapses and within 90º turn it self-recovers as in its certification test.

The “A” riser grab, let’s say to the right, includes the “Big Ear” “A” riser, which is often a separate “A” riser on most beginner’s wings. The grab is as high as possible, where lines start; the right brake handle stays in the right hand. The pilot checks visually that he really holds the risers connecting all “A” lines, the most frontal and closest to the right half of the leading edge. The grip must be strong. The downward pull is sharp and hard, like you want to hammer someone you hate. Most of the wing loading is around “A” lines, so the pull really needs to be strong, to overcome the 20 kg aerodynamic force there. At the end of the pull, at the lowest possible hand position, the pilot releases all “A” risers and returns his hand up to a normal position, still holding the right brake in his hand. The collapsed wing turns about 45º to the right, losing about 50 meters and self recovers.

The next exercise is simulating a 50% collapse but to stop its turning with opposite weight shift, to see how it works.

Next exercise is to simulate a 50% collapse and stop its turning with dosed opposite brake pull and neutral body. The opposite brake pull is cautious, just enough to stop the turning. If the paraglider turns in opposite to the collapse direction, this means that you are pulling too much brake.

The easiest exercise is what we do in reality - stopping the turning with both opposite weight shift and brake.

Next series of exercises is to simulate a 50% collapse and keep it by holding “A” risers down, after the sharp initial pull. Weigh shift to the opposite direction to stop the turning from the collapse. This is actually a simulation of a 50% cravat, where wing stays collapsed. Return body to a neutral position, so see how it goes. Try it even with “wrong” weight shift to the collapsed side, but be ready to release the collapse and stop the turning with opposite brake if wing goes into a spiral. There were fatal accidents with inexperienced pilots, who flew with big harness when a sudden asymmetric collapse threw their body to the collapsed side of the harness. This “wrong” weigh shift caused the collapse to develop and lock the wing into an aggressive spiral dive, freezing the pilot in panic and possibly leading to unconsciousness, due to high g-forces.

The collapse simulation exercises with sharp pull and release of “A” risers at lowest hand position can be extended further by using the speed system. This lowers the angle of attack and makes the collapses more likely. The higher speed also makes the collapses more aggressive. Again, it is also part of EN certification and real life.

Asymmetric collapse simulation should be done with sufficient height, minimum 200 meters above ground for the safest exercises and higher for the riskier one. The best is to do them during paragliding SIV training course over water, but over a dense forest is a good option too. It is recommended that the pilot repeats the above exercises with every new wing he acquires.

There are some old model competition wings with very aggressive response to collapses, especially 70-80% big collapses. The not-collapsed side may shoot and turn surprisingly fast, spinning the wing, **twisting the risers** several times and completely blocking any possibility for weight shift and brake inputs, or blocking them in wrong position. The biggest pilot’s dilemma in such cases is whether to pull the outer brake super-fast to stop the shooting of the flying part of the wing, or to grab and push both sets of risers, apart from each other, in an attempt to prevent their twist. In any case, during any collapse, the pilot should shrink his body and bend his legs, especially if they are flying with a laying pod harness. Upright body position has a smaller inertia moment than a laying one and it helps the body follow the spin of the wing, reducing the chance of line twist. If the line twist happens at low altitude and if it is combined with a cravat or spiral dive, then the use of rescue parachute could be the only solution. If the line twist happens at higher altitude but the wing continues to fly normally, then the pilot can grab the risers and push them hard and apart from each other. Even slowly, this can clear the twist.

Line twists also happen when taking off with reverse launch in strong lifty wind.

New model wings with less reactive profiles, like “shark nose”, are less sensitive to the inductive ability and usually do not shoot that aggressively forward and do not cause such violent swings, spirals or line twists. After a collapse they may fall down longer with bigger height loss and may take more time to recover.

There are many cases, when pilots experience a big asymmetric collapse which brings them into an aggressive swing, spiral, line twist or cravat. They hurry to throw their rescue parachute and then surprisingly the wing self recovers before, during or after the opening of rescue parachute. This does not mean that they made a wrong decision. Sometimes, the self-recovery might be due to the stabilization effect from the rescue parachute, which drag force opposes and dampens any fast rotations and motions. But sometimes, the situation is not as bad as it seems in the beginning. Often, it worsens up to a certain level and stays bad but stable, giving the pilot opportunity to interfere. Paragliding is full of miraculous self-recoveries of wings, just before hitting the ground. Do not rely on them, but also do not panic, especially if you have time to try this or that.

PARAGLIDING FRONTAL COLLAPSE (TUCK)

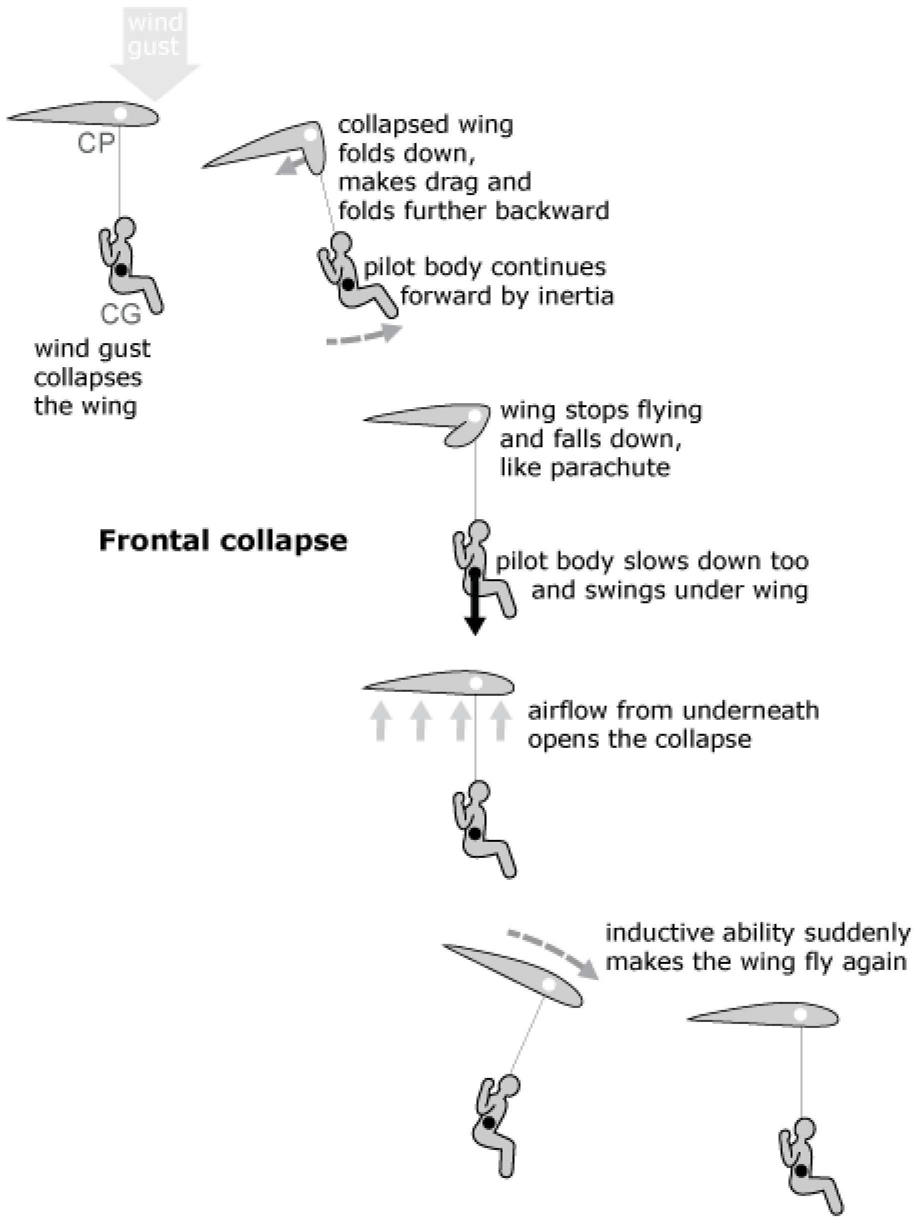
Frontal collapse, also called tuck, is a symmetric collapse of the entire leading edge. Like asymmetric collapse, it happens when the wing suddenly enters a vast zone of sinking air or when the wing surges aggressively forward, self-accelerated by its inductive ability, either due to outside conditions or poor piloting.

The idea of simulating a frontal collapse is scarier for the beginner pilots, who think that collapsing the entire wing is worse, than collapsing half of the wing. However, frontal collapse is safer than asymmetric collapse, which can throw the pilot in violent swing or deep spiral dive. The frontal collapse recovers completely by itself, while a 50% asymmetric collapse usually requires pilot's participation with opposite weight shift and brake.

Frontal collapse is a part of EN certification, where the test pilot pulls all "A" risers sharp and hard down and releases them at the lowest possible hand position, checking how quickly the paraglider self recovers, with how much height loss, are there any side effects or complications, etc.

Regardless, if the frontal collapse is simulated by the pilot or caused by outside turbulence, it goes through the following interconnected processes:

- The leading edge folds down by air push from above or by the “A” riser pull from below;
- As the paraglider still flies with 38 km/h speed, the collapsed leading edge is hit by this airflow and folds backward;
- The collapse creates an enormous drag and the whole wing goes backward, while the body of pilot continues forward by inertia;
- The lower pendulousness brings the pilot back under the wing;
- From the very beginning of the collapse, the deformed wing profile ceases the entire lift force production and the paraglider falls down;
- Even deformed, the wing works like a drag parachute, slowing down the fall;
- The airflow from underneath pushes out the folded leading edge and eventually opens it;
- The parachute-like fall still creates plenty of airflow from underneath and when the leading edge opens, this suddenly activates the inductive ability, surging the wing forward;
- After few fading oscillations, the lower pendulousness recovers normal gliding flight.



Like with asymmetric collapse, the frontal collapse development can be reduced by an *instant* brake pull. This deforms the trailing edge, pushing its air towards the leading edge, increasing pressure there. If the frontal collapse is caused by a sudden entry in sinking air, the collapse happens super-fast, like a cobra bite, so the pilot's reaction should be fast too, regardless of its amount. The speed of reaction has priority over the amount of brake pull. If the collapse is caused by an aggressive forward surge of the wing, then there is more time for pilot's reaction and he can dose more precisely the amount of brakes. Too little brake lets the collapse develop more; too much brake stalls the wing and both lead to bigger height loss. The right amount of brake gives the minimum height and time loss with minimum side effects.

Frontal collapses can come with some complications.

The classic one is a **horseshoe frontal collapse**. The central part of wing is designed with lower angle of attack than the wingtips, which create sideways forces to keep the wing open along its span. When a frontal collapse happens, wingtips may stay intact, still flying, while the central part massively tucks down and folds backward, creating a horseshoe shape of the wing. The overall fall and airflow from underneath charge the wingtips' inductive ability, shooting them forward. As this rarely happens symmetrically, the more active wingtip may rotate inward and mess up with the rest of the wing. A prompt pull of both brakes usually prevents the wing tips' surge. If wingtips surge and rotate inward symmetrically, they will hit each other in front of the central part of the wing, creating the classic horseshoe shape. Horseshoe frontal collapses may seem innocent, even funny, but they should not be underestimated as they may lead to massive cravats, especially for high-aspect-ratio sporty wings in turbulent air.

Some frontal collapses may not just tuck and fold the leading edge, but even roll it backwards like a cigarette. A prompt pull of brakes prevents this and unrolls the leading edge.

Another variation is when leading edge folds backward and stays there, pressed by the otherwise useful airflow from underneath. Again, a sharp brake pull disrupts the equilibrium, allowing airflow to separate the folded leading edge from the wing's bottom surface.

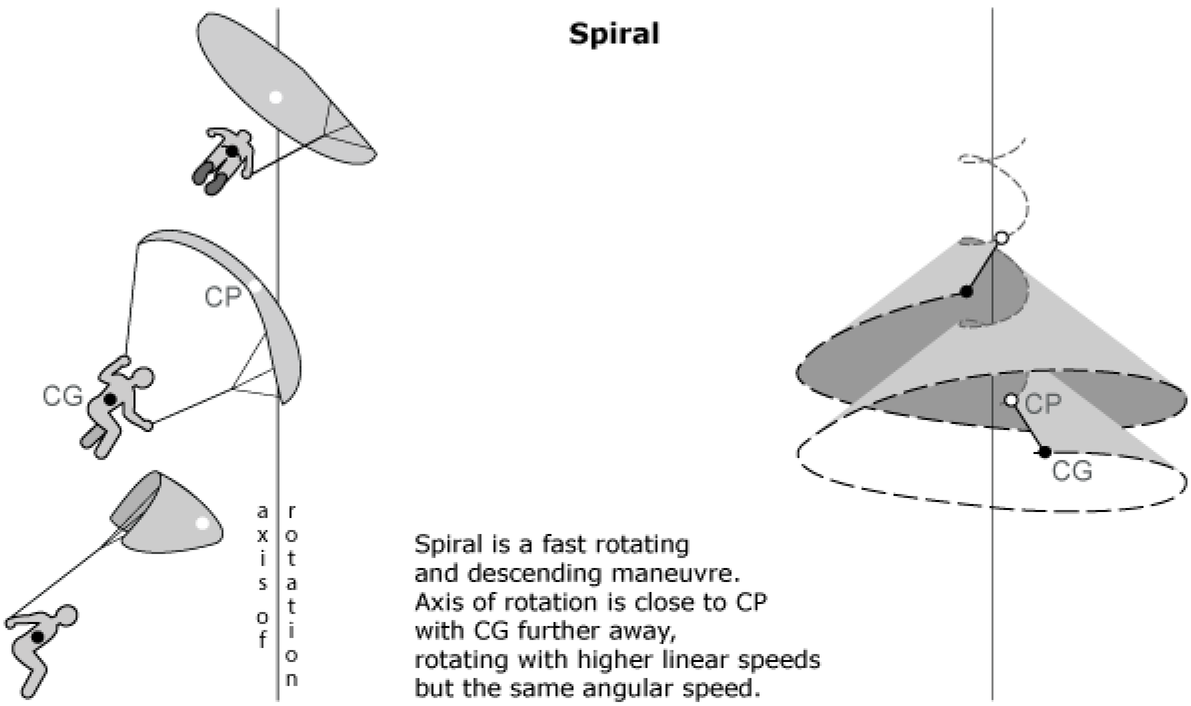
The recovery process of a frontal collapse goes through a temporary stall, which may turn into permanent parachute stall, with perfectly opened wing above the pilot. It happened even with beginner’s EN A paragliders, but it is more probable with sharp leading edge sporty wings with modern shark nose profiles. Other factors which play role are: wet wing surface from rain, prolonged recovery, and sinking surrounding air. A push of speed system or “A” risers usually help the wing to bite the flow, but they still take time and significant height loss. Another cure, when wing goes into a stable parachute stall, is to pull both brakes sharp. This pulls the wing back, like in a full stall, and swings the pilot’s body back too. Then the pilot uses this pendulum swing and releases both brakes, like in a pitch control exercise, to let the wing go maximum forward. There, the wing hopefully reaches its working range of angle of attack, “bites the flow” and starts flying forward again. Paraglider’s inductive ability starts working beyond a certain angle of attack and also has a specific range of angles of attack, where it works best.

Some frontal collapse recoveries might be quite aggressive, due to strong inductive ability, causing a secondary frontal collapse, if the initial one is not stopped in time with brakes. Such strong inductive ability conditions often happen from a thermal entry shortly followed by a thermal exit. The strong airflow from underneath charges the inductive ability and shoots the wing forward, rotating it around the pilot. If this shooting coincides with a thermal exit, then the sinking air on the other side, wind gradient, or perhaps a vortex may boost the surge. It may go fast and far, beyond the usual motion we have practiced during pitch-control simulations. The wing may shoot forward, even below the horizon, requiring a full brake pull, which may stall the wing in the classic backward horseshoe shape. If brake pull and release are done well, then the pilot swings and comes under the wing, which meanwhile starts flying like nothing has happened.

Sometimes, these massive surges forward are slightly asymmetrical and require correspondingly asymmetrical pull of brakes, in order to **recover symmetry** of motion. For example, left brake should be pulled 90% and kept for 1.5 seconds while the right one 70% and kept for 1 second. The pitch control exercise with constant oscillations while performing a 360º turn is particularly useful for this scenario.

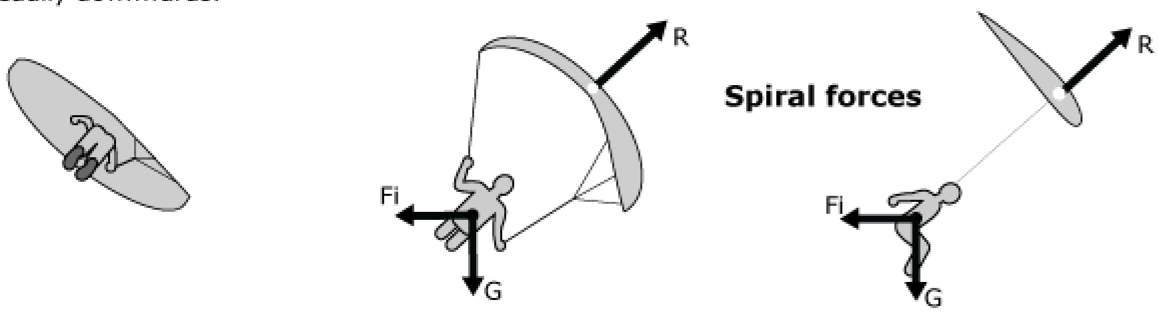
PARAGLIDING SPIRAL DIVE

Spiral dive is a fast circling and descending maneuver with high g-force loading and constant pitch and roll angles. If seen from above, in perspective, the paraglider's trajectory looks like a spiral.



Unlike simple turns, spiral dive reaches much higher speeds, because its inductive ability employs not only the weight of pilot's body but also its inertia. The centripetal force in this rotation is the aerodynamic lift force component, applied at CP, while the centrifugal force is the pilot's body inertia force applied at CG. The faster the wing flies and turns, the faster the lift force changes its direction, the more the pilot's body inertia opposes this change, the higher the g-force and wing loading. The higher the g-force and wing loading, the stronger the airflow from underneath, the stronger the inductive ability, the faster the wing flies. This does not mean that the speed of rotation will increase infinitively. It means that the pilot's body inertia creates conditions for the spiral to self-increase and then self-maintain its fast rotation and descent.

Wing's rotation constantly changes aerodynamic force R, every time pulling pilot's body in a new direction. Body mass opposes spiral's circular motion with its inertial force Fi.
Weight force G and inertial force Fi equilize the aerodynamic force R and the paraglider spirals steadily downwards.



The addition of inertial force Fi ncreases g-force and paraglider's inductive ability, which makes the wing fly faster, compared to when its driven only by its weigh force G, like in straight flight. This allows the rotation to self-increase, during a spiral entry, and then self-maintain when the wing settles in a spiral.

It is important to understand and exercise spirals because any big collapse can throw us into a spiral dive, which we need to control and exit. A spiral dive can reach descent rates of 15-20 m/s, faster than a full stall with its 8 m/s; linear speeds of pilot's body can reach 100 km/h; g-forces of 2-3g can cause a blackout.

Spiral dive can be also a friend – it is a reliable escape maneuver, which saves us from the suction of a thunderstorm cloud. The high wing loading during a spiral dive makes the wing solid and resistant to turbulence.

Spiral dive exercise consists of three stages – entry, spiral, and exit.

Spiral entry is achieved by *progressive* tightening of a turn, until the paraglider enters this self-perpetual rotation from its inductive ability. The turn starts with full weight shift to one side, followed by a *progressive* pull of same side brake.

The key word for **spiral entry is *progressive***, as there are cases when students pull the brake indecisively, reducing the overall airspeed of entire wing, and suddenly stalling and spinning the wing, bringing it into cascades. This happens even with beginner's EN A paragliders.

In order to achieve *progressive* turning and smoother entry after the initial weight shift, the brake can be pulled incrementally: pull 10 cm and wait the wing to speed up, pull 10 more and wait for more speed to come, then 5 cm more, 5 more and at some point the wing enters a spiral. If, after each break pull step, the pilot does not feel an increase of airspeed in his face, then he should abort the spiral entry by *immediate* release of the brake and return his body to a neutral position, letting the paraglider restore normal flight and recover airspeed. Then try spiral entry again. Sometimes, a thermal bubble or a wind gust may stabilize the paraglider, opposing any control attempts and decreasing airspeed.

Spiral aerodynamics is complex as pitch, roll and yaw motions are interconnected. There are static but also dynamic cross (spiral) torques. The most important thing to remember, in order to avoid spin during a **spiral entry**, is that it **requires** a **well pronounced *initial roll motion impulse***. This means well pronounced weight shift to one side combined with a sharp initial same side brake pull, then the brake pull deepens progressively further down. Another technique is first to roll the wing to the other side, let's say left, create a good body swing and use it to roll to the right, for the spiral entry. Roll motions or wingovers for spiral entry are used by tandem pilots whom passengers jump off with parachute and leave the pilot alone on a very low-loaded and slowly-flying big tandem wing.

Usually, the beginning of a spiral is easy to recognize, it feels like a gentle kick or surge. The airspeed in pilot's face self-increases without further pull of brake, rotation intensifies and g-force grows, pressing pilot's bum onto the seat. Air becomes noisy and the student may not be able to hear radio commands from his instructor. It is recommended, students to practice spirals with two radios, close to each ear.

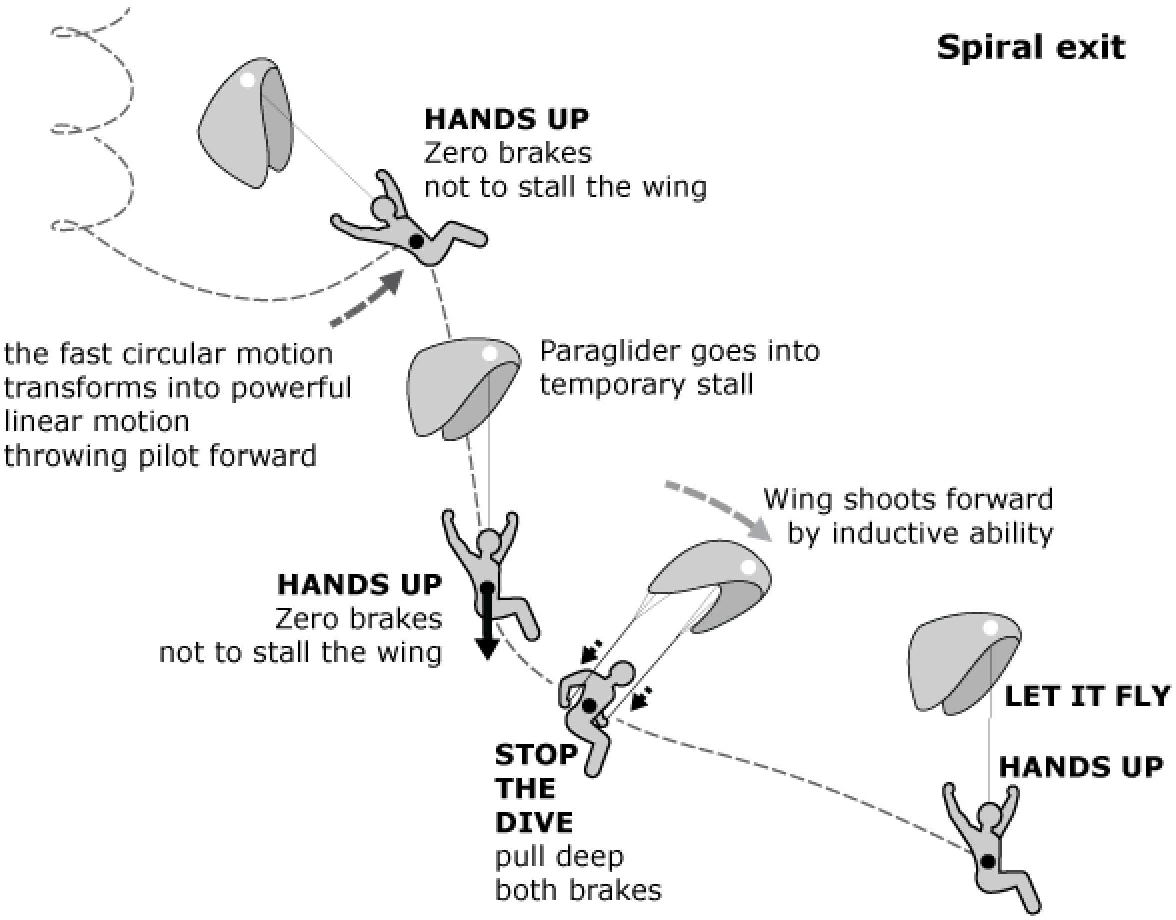
Once the pilot recognizes the spiral entry, he releases the brake a little, let's say with 10 cm, in order to make the spiral milder, but still keeps it going. It takes more efforts to initiate a maneuver than to maintain it.

Some paragliders have a very distinct and spontaneous spiral entry; others - very smooth, even unnoticeable, with perfect control all the time. Some paragliders enter a spiral easily; others need more time and efforts. Therefore, students first start practicing a spiral entry only, trying to reach and recognize the **spiral entry point** and then release the brake completely. After they are confident with the *spiral entry point*, then they can keep the spiral for 2-3 turns and exit it gently.

Once in a spiral, despite high speed and g-force, the pilot can control it with minimalistic weight shifts, inner and outer brake pulls. Most wings exit a spiral themselves, spontaneously. That is why, most spirals needs to be maintained with inner brake. Experienced pilots sense well paraglider's self-exit tendency, even before it happens, and they use minimum brake to keep the spiral going. Students are not so sensitive about spiral's entry and exit points and tendencies, they are either going in or out. They usually keep the spiral deeper, with excessive use of brake, suffering from the high g-force. Spiral dive is one of the safest and easiest to learn acrobatic maneuvers, so with some practice, students should reach full control of keeping, increasing or decreasing the spiral.

During a spiral, pilots should look at the horizon and from time to time look down to **check height** and look around to **check position in space**. Looking at wing or at blurred picture around increases chances of **vertigo** and **motion sickness**. Nailing your gaze at various objects reduces **disorientation**. The high g-force drains blood from brain towards legs; eyes may temporary **lose vision**, from the periphery toward the centre, but the brain still works, giving enough time to exit the spiral. **G-force's effect on pilot's body** has an accumulative effect and does not depend only on how strong the g-force is but also how long it lasts. There are cases when untrained pilots **blackout completely** and **lose consciousness** from too strong and too long g-force exposure. When a pilot needs to escape a thunderstorm, he may need to spiral for a long time. G-force effect on pilot's body depends also on its current conditions, how strong it is, how well rested, how much awaken. If the pilot feels a blackout coming, then one trick is to stiffen his body, like shitting hard, or giving birth. This contracts blood vessels and restricts bloody brain drain.

For a spiral exit, the pilot releases the inner brake and turns his body to a neutral position. The paraglider still continues spiraling by inertia. The release of brake reduces self-perpetual rotation and beyond **spiral exit point** it starts slowing down intensively and suddenly throwing pilot's body tangentially, away from the circle. This energetic body motion produces a **massive pitch back** – the wing goes far behind the pilot. Then pilot's body swings backward, like a pendulum, and comes under the wing. A **pronounced vertical fall** follows, because the massive pitch back ate all airspeed and lift force. The *massive pitch back* is a proper momentary stall. The long lasting vertical fall produces fast airflow from underneath, activating a powerful inductive ability, which at some moment shoots the wing aggressively forward. The pilot must stop this surge with pull of both brakes, like in pitch control exercise, to prevent a big asymmetric or frontal collapse. Then - hands up and the paraglider continues to fly normally.



Spiral dives should be first practiced on a tandem with an instructor, because spiral exit is where students mostly have problems. Spiral entry is OK; it is fun, like flirting with motions and sensations. But once the paraglider kicks in a spiral, the high g-force and speed, the noise and vertigo overwhelm the student and he may block, going into an embryo pose grabbing risers, looking for support. Then he may hear the instructor screaming something on the radio, or at some point he may remember to release brake to exit the spiral. There is a short moment of relieve, when the paraglider starts exiting the spiral, but the student panics again when his body is spat tangentially away, transforming the energetic circular motion into a linear motion. He wants to do something, perhaps grab the risers again. The wing massively pitches back. He must do something; let's stop it with the brakes. Ops! **Do not touch the brakes when wing pitches backward**! It is a recipe for a dynamic full stall. Do not grab the risers either, as it may still affect the brakes. Look for a **zero brake position** of your arms, somewhere close to the brake's pulleys on the rear risers. Action is not over. After the massive pitch back, the wing goes into a looong fall. Still, do not touch the brakes. Resist the temptation to do something. Do not be a control freak. Wing knows better what to do. Just keep hands up to have a clean profile and let the wing work. Feel the inductive ability and be ready to catch the wing when it bites the flow i.e. pull both brakes when wing surges forward, like in pitch control exercise. **Stop the dive, hands up, let it fly.**

Some paragliders have soft and fuzzy exit point with mild **spiral-exit behaviour**. Other paragliders have a well pronounced exit point with hard spiral exit-behaviour, no matter how gentle you release brakes for the spiral exit.

Hard spiral-exit behaviour can be softened by re-pulling of inner brake, just after the exit point. The idea is not to allow pilot's body to transform entirely the enormous energy of rotation into a single linear motion. The re-pull of inner brake transforms spiral's high speed into a wide turn in the same direction as the spiral before. This engages the wing into a new turn, reducing the pitch back, the vertical fall and the forward surge. There is a narrow window for re-pulling of inner brake for **same-turn-direction softer spiral exit**. It starts at the spiral exit point, at the beginning of spiral's deceleration and ends when wing suddenly pitches backward. If you miss the window for same-turn soft spiral exit, then accept the hard spiral exit and don't pull brakes when wing pitches massively backwards.

The biggest danger of spiral dives is **locking into a spiral**, because of:

- a collapse. It reduces wing surface and changes lift force and its application point – the Center of Pressure;
- a cravat. It makes drag and maintains the turning;
- loose harness, which lets the pilot's body slide to one side and maintain the spiral;

- unintentional weight shift. A wide shouldered pilot sitting on a harness with low attachment points has higher CG and even light weight shift may have significant effect during a spiral;
- paraglider’s design. Some wings just lock themselves into a spiral and do not exit it, even if inner brake pull and weight shift are completely released.

If a paraglider locks in to a spiral, then the pilot should apply opposite weight shift or brake pull to stop it. These should be like short but sharp impulses, because as the roll impulse helps to enter a spiral, it also helps to exit it.

If wing locks into a spiral, the pilot should not panic and apply opposite weight shift and brake pull too sharp and aggressively, because this may cause a nasty spiral exit. Acrobatic pilots use spirals to build up speed and make a looping or tumbling by a sharp and aggressive opposite weight shift and brake, but there is a risk to fall into the wing, wrapped inside the canopy and its lines.

In case of a vertigo, or if a sudden collapse confuses the pilot and he does not know in which direction he turns and which brake he should pull to stop the spiral, then he can pull both brakes sharp as a **reset impulse**.

If the *reset impulse* of proper opposite brakes does not work, then the pilot should try again, pulling steadily, stronger and deeper. Some spirals require a lot of arm force to be stopped.

After establishing a spiral, the pilot can explore its limits and continue pulling inner brake until he reaches a **nose-down spiral**. At this point, the pilot cannot pull any further, because the force of the wing is enormous, g-force is the highest, perhaps 3g; the paraglider rotates steadily and falls like a stone, reaching descent rates of 20-25 m/s. Most paragliders lock into a nose-down spiral, or at least they self-recover after many turns and significant height loss. The exit from a locked nose-down spiral requires a lot of outer brake pull.

If an aggressive collapse throws the paraglider directly into a nose-down spiral, then a beginner pilot may get confused which is the spiral's turning direction? In a moderate spiral, lower wingtip is inside the turn and higher wingtip is outside. In SAT-like spiral it is the opposite – the higher wingtip is inner for the turn. In nose-down spiral wing is parallel to horizon. So, stay sharp and follow the history of events. Also, the collapsed side is always the inner side of the turn.

If, for some reason, the pilot cannot exit a spiral, then throwing the rescue parachute is the last solution. It will open very quickly because of the high airspeed. Still, keep in mind that the g-force pins pilot's body onto the seat and makes arm's movements difficult. In a 2-3g spiral, your arm can be 2-3 times heavier, than normal. Finding the rescue handle during a fast rotation is also a challenge. Pulling the parachute container out of the harness in proper direction is also hard. If possible, the rescue parachute should be thrown in clear space, in the same direction as the rotation, to reduce chances of it meeting and tangling with the wing or pilot's body.

It is useful to exercise throwing of rescue parachute on a *g-force simulator* on the ground. Body fitness is essential for standing long high g-forces, for stopping spirals or for safe opening a rescue parachute. *Mens sana in corpore sano*.

High-aspect ratio sporty wings are not good for using spirals as a rapid descent maneuver. They rotate easily, reaching high g-forces, but they simply do not descent much, because they are made to fly, to glide well. To reach their high performance, high-aspect ratio paragliders use fewer and thinner lines; their wing profiles are precisely shaped and balanced. High g-forces can easily damage their structure or at least deform it, permanently harming their performance and behaviour. That is why spirals should be combined with the use of an *anti-G parachute*, attached to one of the harness's carabineers.

During a spiral, the **anti-G parachute** creates extra drag applied to pilot's body and slows it down. It also increases forward pitch, which improves descent rate. The *anti-G parachute* decreases the overall speed of rotation, reducing the harmful for the pilot and the paraglider high g-forces.

In lack of an *anti-G parachute*, the pilot can make "big ears" first and then use the maneuverability of his high-aspect ratio wing to go into a spiral just with weigh shift. The reduced wing's surface increases the descent rate, which also reduces g-force and wing loading. A spiral with "big ears" can be controlled well, increased or decreased, with proper weight shift. Brakes cannot be used as hands are busy with holding the big ears.

Other variation of a low g-force spiral is to collapse the wing on one side and let it spiral to it.

Inexperienced pilots often panic when they encounter cloud suck from a potential thunderstorm clouds. Experienced pilots can confidently fly and exploit lift under big bad clouds, because they trust themselves, their equipment and its rapid descend abilities. Do not panic when flying in a vast area of lift and start spiraling in its strongest part as it will take too much time and efforts to descend there. It is better to search around for weaker lift and spiral there. Of course, prevention is the best.

Still, if you need to spiral hard for a long time in strong lift and you start experiencing the g-force effects like blackouts, then instead of one long and hard spiral do several shorter spirals and use their entries and exits as a rest. Change spiraling direction if needed.

PARAGLIDING CASCADES

For paragliding pilots, a cascade is a series of consecutive extreme events like:

- Collapse. Frontal or asymmetric;
- Spiral. With or without a cravat;
- Stall;
- Aggressive surge;
- Spin;
- Line twist.

A paraglider cascade is scary, even for experienced pilots, because of its unpredictability and mix of maneuvers; because pilots do not know what and when comes next, how strong it will be, how, when and how much they should react to it.

In reality, **a cascade consists of 2-3 consecutive extreme events** and rarely continues for a long time itself, unless the pilot maintains it with wrong inputs. In most cases, a cascade ends with a cravat-induced spiral dive, which is not so bad because it is a stable and predictable motion. In the worst case, a cascade may throw the pilot into the wing, entangling his body within canopy and lines, preventing the usage of a rescue parachute. In any case, the pilot should learn to deal with the chaos, finding predictable situations and be careful with his inputs. Previous experience of each separate extreme event is important as it saves time to decide which is recoverable, which is not, whether and when it is time to use the rescue parachute.

Cause and effect links, like fall/surge or collapse/turn, give predictability and time for pilot’s reaction; they are opportunities to restore the order in extreme situations.

During a cascade, the pilot can use the beginner’s pilots golden mantra when flying in turbulence: STOP THE DIVE, LET IT FLY, KEEP DIRECTION!

Stopping a dive, or wing's aggressive surge, either symmetric or asymmetric, has some key points:

- The dive should not be a surprise for the pilot if he knows that it is caused by the wing's inductive ability, that every drop is followed by a surge;
- The direction of the dive is usually predictable – the open, clear or more horizontal part of wing will shoot more, the collapsed, deformed or more vertical part of wing will shoot less or will not shoot at all. However, a symmetric stall in turbulent conditions, a slightly asymmetrical horseshoed stall, or a spin of tilted wing may shoot in surprising direction;
- The earlier the dive is recognized, the less brake inputs it needs and the lesser is the chance of overreaction and stalling;
- Some forward motion during the stopping of the dive is not that bad as it feeds the wing with a vital airspeed. Too strict stopping can cause another stall and fall;
- The above is also valid for a rotation after an asymmetric collapse. Let the wing turn a little, regain airspeed and increase its internal pressure.

Other important points are:

- A flat turning of the wing due to an asymmetric collapse or spin requires an instant decision whether to grab the risers and keep them apart to prevent line-twist or to work with outside brake for stopping the turn. It is possible to combine both – pull the outside brake and grab the riser lower, while the other hand grabs it normally. In any case, shrink your body, stay upright with legs beneath you to let your body follow the wing's spin/yaw rotation;
- If line-twist is inevitable, try to release brakes before it happens, to prevent them being blocked by the twist while pulled. There is less than a second to pull the brake for stopping wing spin, to grab and push the risers apart and to release the break to avoid it being blocked by the twist. It still can be done, if

you learn to work with short and sharp impulses, followed by immediate release of the brake – wing spins, short brake input, release and grab risers close to zero brake position. Push them apart before, during or after the potential line-twist;

- Minimum use of brakes, maximum use of paraglider's self-recovery;
- LET IT FLY, but stay sharp and be ready to work with brakes again, if needed. Usually, the secondary and third usage of brakes is less intensive than the first one;
- Scissors-type of kicking with legs, combined with push-impulses of risers apart, may help for line-twist recovery;
- A moderate oscillating spiral provides lose-knot moments for line-twist recovery;
- It is almost impossible to recover a line-twist during a deep nose-down spiral, so the decision for throwing the rescue parachute is pretty straightforward. Especially, if the line-twist is combined with a cravat and there is not much height left;
- It is possible to land safe with up to 40% cravat, providing the paraglider is stable, it has a certain degree of directional control (even with one brake), there is a plenty of clear space and air is not turbulent;
- There is always a risk of rescue parachute being tangled with the paraglider wing, its descent rate of 4-5 m/s can still break your leg or arm, if landing on a stone; the directional control is limited for avoiding power lines or obstacles. So, a stable and partially controlled paraglider could be be a better option;
- Two rescue parachutes are better than one.

Dealing with cascades and extreme situations often requires a quick choice between 2-3 bad outcomes, recognizing good moments and catching them. Let it fly!

Active flying is to understand your wing and air around, take control and responsibility in all kind of situations. Not to panic or freeze like a passive victim. Active flying is also prevention and not doing something stupid, against the laws of Nature. We become better and safer pilots from various experiences, but various experiences come with risks, so take them step by step. Risk wisely and efficiently as luck is limited. And when you become a good pilot, still be careful. Routine kills so stay sharp!