Spin Avoidance
and Recovery

GOOD AVIATION PRACTICE

CIVIL AVIATION AUTHORITY OF NEW ZEALAND
Te Mana Rererangi Tūmatanui o Aotearoa

The majority of unintentional spins occur at altitudes too low for recovery. They generally have only one outcome…

This booklet explains the conditions that will encourage an aircraft to spin, and what you can do about them. But nothing can help you if you enter a spin at low altitude. The best line of defence is to avoid the spin in the first place.

This booklet discusses unintentional spins. It is not a substitute for intentional spin training. Under no circumstances should pilots deliberately enter a stall in the turn, an incipient spin or a fully developed spin unless they have received appropriate training from a qualified instructor in a suitable aircraft type, and at a safe height in a suitable location.

There is no universal spin-recovery technique that will work for all aircraft. This booklet outlines one of the most widely-used techniques. You must consult the Pilot Operating Handbook/Flight Manual for the aircraft you fly.

Some aircraft simply cannot be recovered from spins.

Photo: Neil Gorrie

The pilot was killed in this 1976 spin-related accident at Motueka.

Contents

Acknowledgement:

The CAA gratefully acknowledges the work of the Tiger Moth Club of New Zealand Inc, on which this booklet is heavily based.

References:

DeLacerda F.G. (1989). *Surviving Spins.* Ames : Iowa State University Press.

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CAA Web Site

Current Civil Aviation Rules are on the CAA web site.

www.caa.govt.nz

What is a **spin?**

When an aircraft spins, a stall occurs together with yaw, and self-perpetuating rotating forces develop. These forces keep the aircraft in the spin until positive and correct control inputs from the pilot stop them.

In a fully developed spin, the aircraft follows a spiral flight path about an axis going straight down, pitching up as well as rolling and yawing towards the spin axis. Descent rates during a stable spin in light aircraft are typically about 5000 to 8000 feet per minute.

All aircraft will spin, but not all aircraft can be recovered from a spin. Your aircraft's particular spin characteristics are listed in the Pilot Operating Handbook/Flight Manual. The aircraft may be approved for spins, but only under certain weight and balance, and centre of gravity restrictions.

Anatomy of a Spin

A spin will not exist without both stall and yaw.

Stall

The stall angle of attack is the critical angle which, when exceeded, will cause the normally streamlined flow of air that follows the curvature of the upper wing surface to separate from the wing and leave as turbulent air flow. At the stall angle of attack, lift reduces rapidly.

Pilots use a quoted indicated airspeed (for straight and level flight at a given weight and configuration) to correspond to this stall angle for each aircraft. But in reality this speed varies depending on the weight the wing has to support. Airspeed is only an indirect measure of an approaching stall.

The quoted stall speed really reflects the 1G straight-and-level speed at a nominal aircraft weight. Increase aircraft weight, and the stall speed will increase. Enter a turn, and the stall speed will increase.

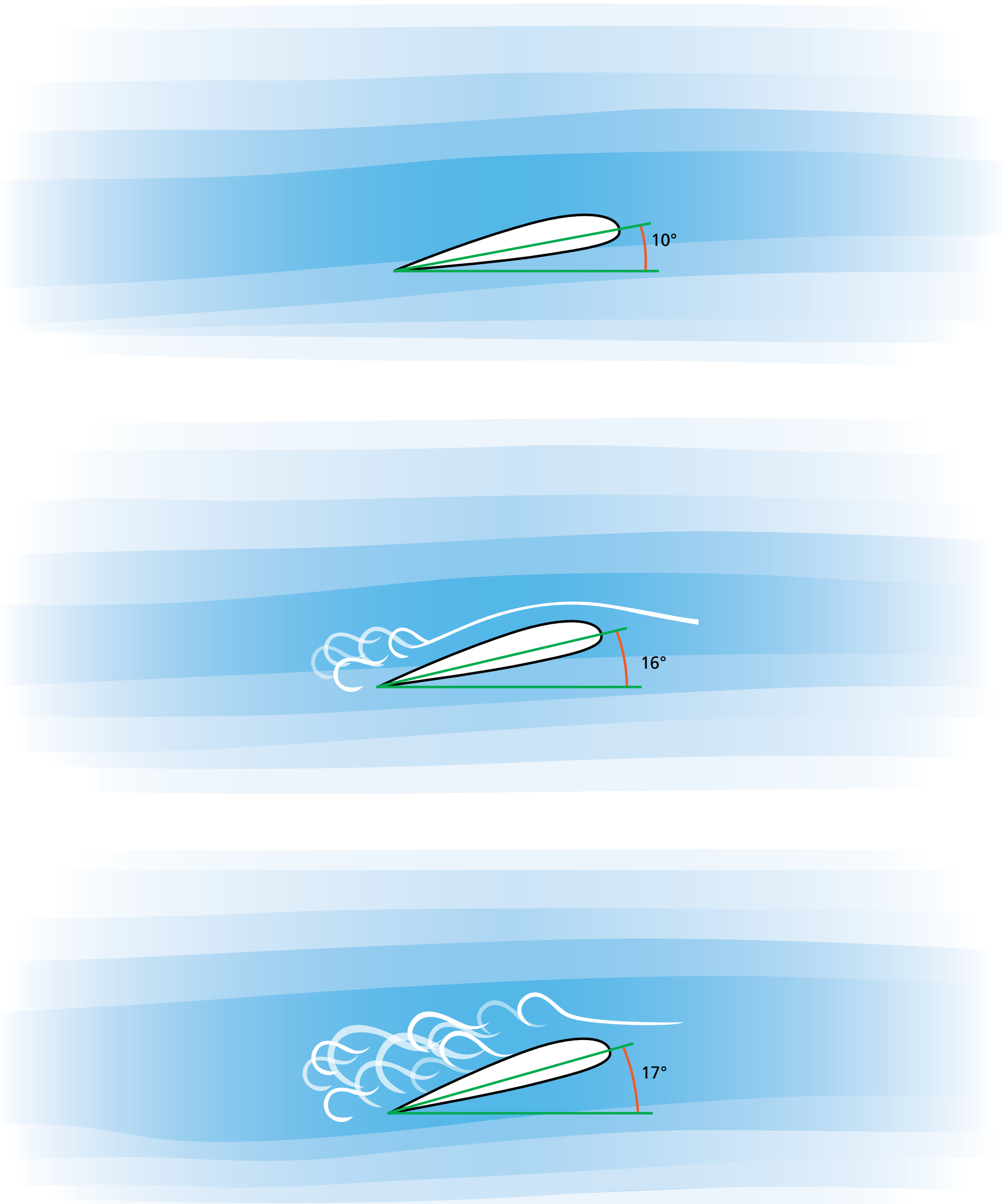
> Airspeed is only an indirect measure of an approaching stall.

A 60 degree banked steep turn at a constant altitude produces a 2G loading in all aeroplanes from Bantam to Boeing. The stall speed will increase with the square root of that loading – e.g.$\sqrt{2}$ is 1.4 and thus a basic stall speed of 40 knots becomes a little more than 56 knots (40 x 1.4) in a 60 degree (2G) steep turn.

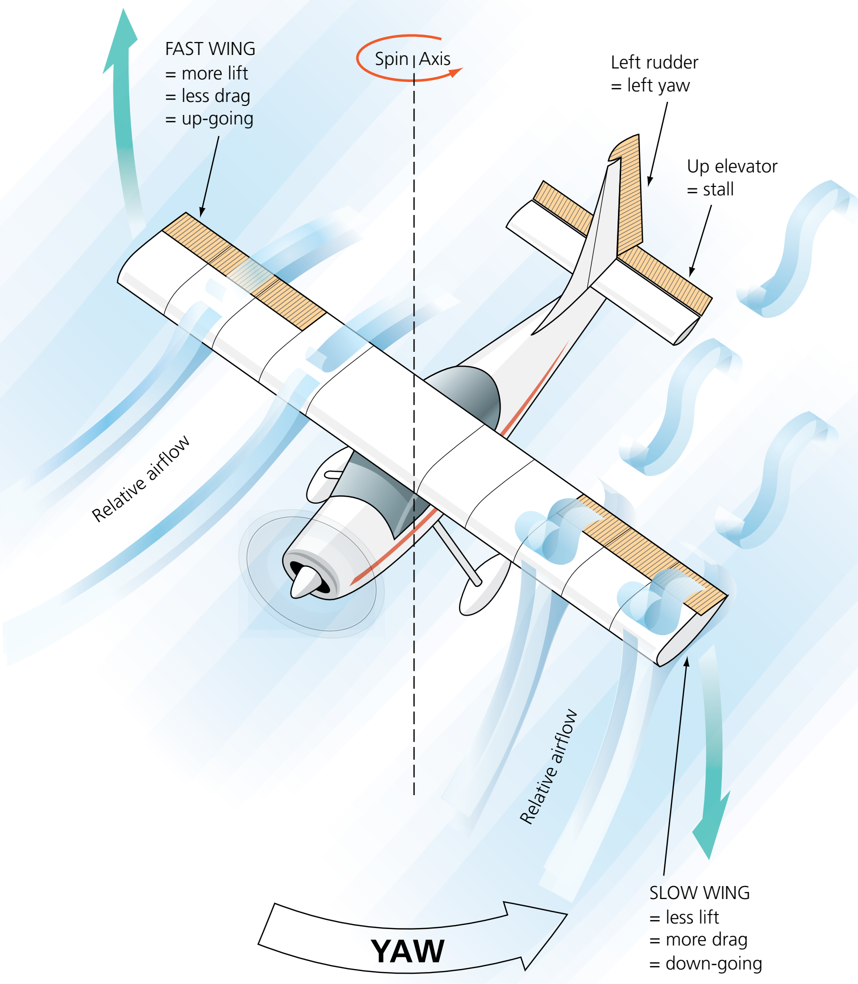
When evaluating how close an aircraft is to the stall, pilots should think angle of attack rather than airspeed. The elevator position (how far back the stick or control column is held), is actually a better indication of how close to the stall the aircraft is.

> Think angle of attack, rather than airspeed.

In a balanced, wings-level stall with the ball in the middle, both wings will remain at the same angle of attack. At the stall, aerodynamic forces may try to pitch the nose forward, but there should be no overall rolling or yawing.



When the stall angle of attack is reached, the normally streamlined flow of air over the wing becomes turbulent, reducing lift.



Stall and yaw combine to produce a new axis, the spin axis.

Yaw

If the aircraft is yawed, a roll will develop in the direction of yaw because the outer wing has increased speed, which has increased its lift. The descending (inner) wing gains an increased angle of attack. If this wing is at or near the stall angle, its lift reduces. When one wing goes down, the other will rise, and exactly the opposite happens to the rising wing. The relative airflow now produces a reduction in angle of attack on the up-going wing, which may be below the stall angle (in effect it has become less stalled). The effect of these differences in lift will be to produce an accelerating roll rate in the direction of the initial yaw.

These changing angles of attack also affect drag. The down-going wing with an increased angle of attack suffers increasing drag. The up-going wing gets a drag reduction. The difference causes even more yaw towards the down-going wing.

Autorotation

The yawed and stalled aircraft then starts to rotate. However, it not only rolls about the longitudinal axis due to the differences in lift from each wing, but also simultaneously rotates (yaws) about the vertical axis due to the differences in drag. The combination of these two movements gives us a new axis, the spin axis. The aircraft will continue in a self-perpetuating spin, or autorotation, about this axis until opposing forces come into play.

Causes of Yaw

- Out of balance flight caused by inducing (or not preventing) yaw with rudder.
- Wing drop at the stall, due to rigging or dimensional differences between wings.
- Application of aileron will cause aileron drag. On some aircraft when stalled, this will produce yaw.
- Gyroscopic effect from the propeller when the aircraft is pitching with power on, such as falling out of an aerobatic manoeuvre. This effect is more pronounced in high-powered aircraft.
- Gusts.
- One wing producing more lift, due to ice or damage to a wing surface.
- Asymmetric power on twin-engine aeroplanes.

By far the most common cause of entry to an unintentional spin is the first of these – yaw at the stall caused by out-of-balance flight.

> The most common cause of spin is being out of balance at the stall.

Spin **Characteristics**

The development and characteristics of a spin vary between aircraft types, but an aircraft will usually rotate several times before it settles down into a state of spinning steadily. The spin stabilizes once a complicated balance is reached between the various aerodynamic and inertial forces acting on the aircraft.

The pitch angle it finally adopts may be steep (60 degrees or more with the nose low) or flat (nose on the horizon).

The aircraft will lose altitude rapidly and descend along a vertical path about the spin axis. The rates of roll and yaw, and the pitch attitude, can all oscillate.

Spin characteristics vary depending on aircraft type, but even a given type of aircraft can have markedly changed spin characteristics depending on the aircraft weight, the aircraft centre of gravity, and how the controls (including engine power) are handled during the spin.

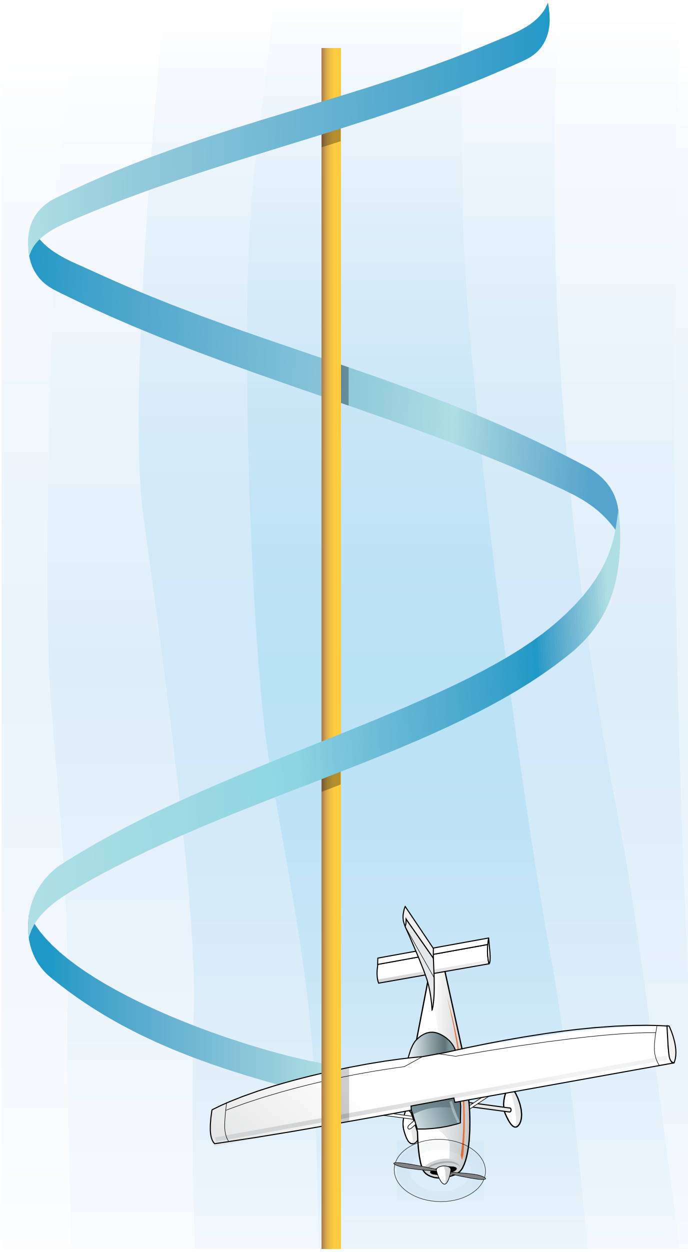
A four-seat aircraft with docile stall and spin characteristics at training weights with two people on board can have very different characteristics at maximum all up weight with an aft centre of gravity due to people and baggage in the back.

Spiral Dive

The spiral dive can be confused with the spin. Spirals are steep, descending turns that become progressively tighter over time. They occur at lower angles of attack (the wing is not stalled) and display the same over-banking tendency common to all steep turns. They are characterised by high or increasing airspeeds and G forces.

The fundamental problem of the spiral dive is too much bank. Spiral dives become tighter if nose-up elevator inputs alone are applied. Attempting to arrest the rate of descent with more ‘up’ elevator without other remedial inputs will aggravate the spiral dive.

To recover, close the throttle, use the ailerons to reduce the bank angle, and ease the aeroplane out of the ensuing dive. The aircraft is likely to be at a high speed and will be very easily overstressed, so ease out of the dive using gentle back pressure.



An aircraft descends about its spin axis at a steep, nose low attitude.

Three Stages of Spin

Incipient Stage

This is the transitional stage, during which the aircraft progresses from a fully developed stall into autorotation. This progression may be very rapid and is sometimes described as a flick. It may last only two turns, during which time the rotation tends to accelerate towards the rate found in the developed stage. The final balancing of aerodynamic and inertial forces has yet to occur.

The incipient stage is generally driven by pilot inputs. As a very general rule, if pro-spin control inputs are removed in the incipient stage (the elevator is moved forward to unstall the wings, or the out-of-balance yaw is removed), then the aircraft will not continue to enter a stable spin.

In some aircraft, recovery may not be possible if the spin is allowed to progress to the developed stage. Therefore, recovery must be initiated at the first sign of a spin.

Developed Stage

In the developed stage, a state of equilibrium is reached, characterised by a low and constant airspeed. Rates of descent will be as high as 5000 to 8000 feet per minute. At this stage the spin will be self-perpetuating.

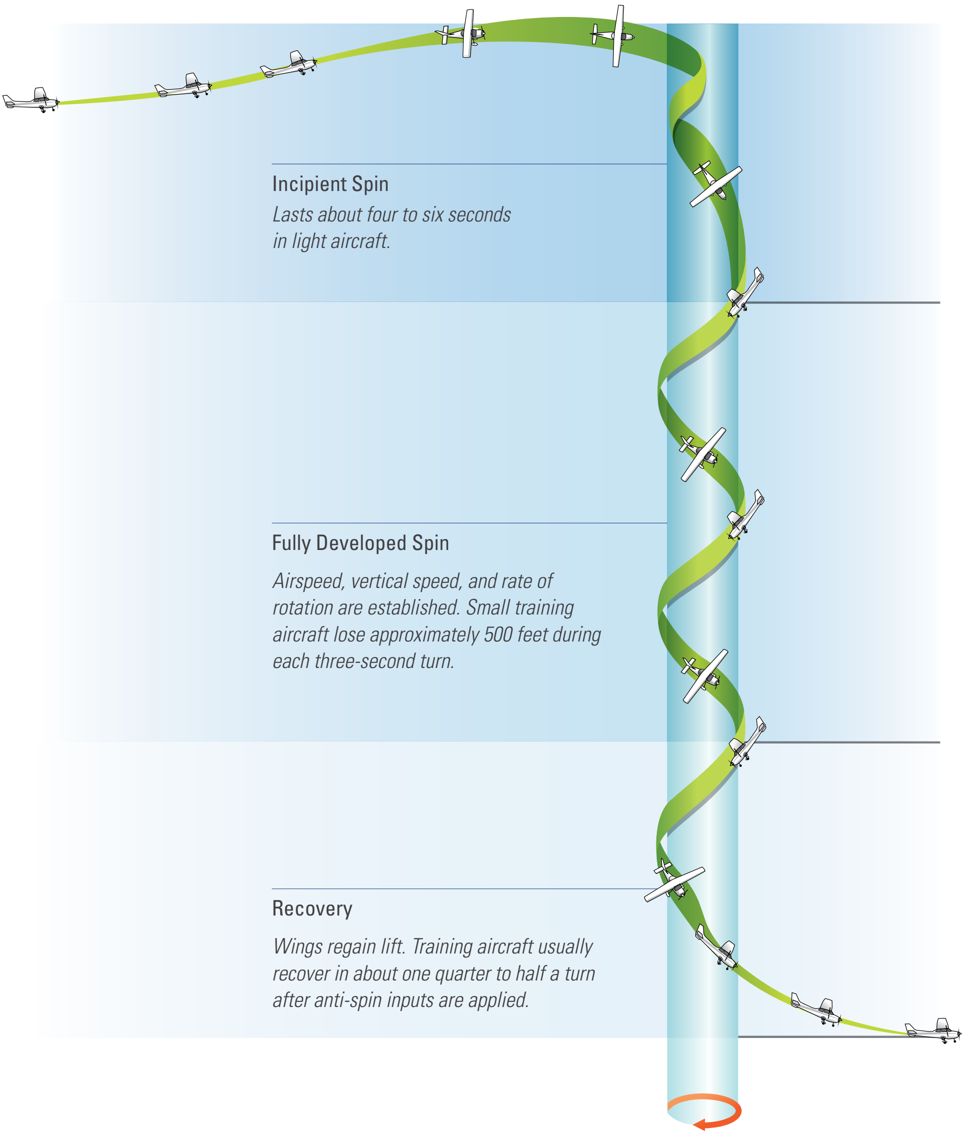
If the pilot does nothing about it, the spin is likely to continue until the aircraft hits the ground. Positive anti-spin control inputs will be required to recover from the fully developed spin.

Recovery Stage

Spinning ceases only if and when opposing forces and moments overcome auto-rotation. Since yaw coupled with roll powers the spin, the pilot must forcibly uncouple them by applying full opposite rudder. After a brief pause, this is followed by forward movement on the stick or control column.

During the recovery phase, the nose attitude typically steepens and the rate of rotation may momentarily accelerate as well, giving the impression that the spin is actually getting worse. It is not, and the anti-spin control inputs must be maintained until the spin stops.

Spin recovery is not instantaneous. It may take up to several turns for the anti-spin control inputs to finally overcome pro-spin forces. The longer an aircraft is in a spin, the more turns it may take to recover. Spins are recoverable only when the cumulative effects of the interacting variables favour recovery and there is enough altitude.


Incipient Spin
Lasts about four to six seconds in light aircraft.
Fully Developed Spin
Airspeed, vertical speed, and rate of rotation are established. Small training aircraft lose approximately 500 feet during each three-second turn.
Recovery
Wings regain lift. Training aircraft usually recover in about one quarter to half a turn after anti-spin inputs are applied.

Disorientation

Pilots understand which way is up via three sensory mechanisms – proprioceptive (seat of the pants), visual (eyes) and vestibular (inner ears).

Proprioceptive inputs provide information about joint position and muscle tension, but generally play only a small part in the total picture. Visual sensation is the most reliable, whereas vestibular inputs are very powerful but frequently misrepresent the rotational motion of flight. Therefore the eyes, through the interpretation of instruments and outside references are important to orientation. Disorientation occurs when there is a conflict between the visual and vestibular sensations – your eyes tell you one thing, but your inner ear says something else.

Within the ear, three semicircular canals are structured perpendicular to each other, so that a canal lies in each of the three planes of the human body. Information from these semicircular canals affects visual tracking.

During the initial stages of a spin, the eye is able to remain oriented. However, in a spin that continues beyond about two turns, disorientation often occurs and it will be very difficult for the pilot to make the correct recovery inputs, unless properly trained and experienced in spinning.

After about five turns, the eye becomes out of synch with the aeroplane rotation. Vision will blur and the speed of rotation appears to increase. Now the pilot has difficulty in determining the number of turns in the spin, its direction, and the effectiveness of any actions taken to exit the spin.

Upon stopping a spin, the fluid within the semicircular canals continues to move in the same direction as the spin rotation. The brain must contend with a conflict between this indication of turning one way and a visual indication of turning in the opposite direction, when there may be no actual rotation at all.

Photo: John King

Special Spins

Flat Spin

In a flat spin, both wings end up at highly stalled angles of attack. The aircraft attitude is about level with the horizon and it lacks the roll and pitch oscillations of a conventional spin. Instead it consists almost entirely of yaw about the vertical axis. With the exception of some specialised aerobatic aircraft, flat spins may be unrecoverable.

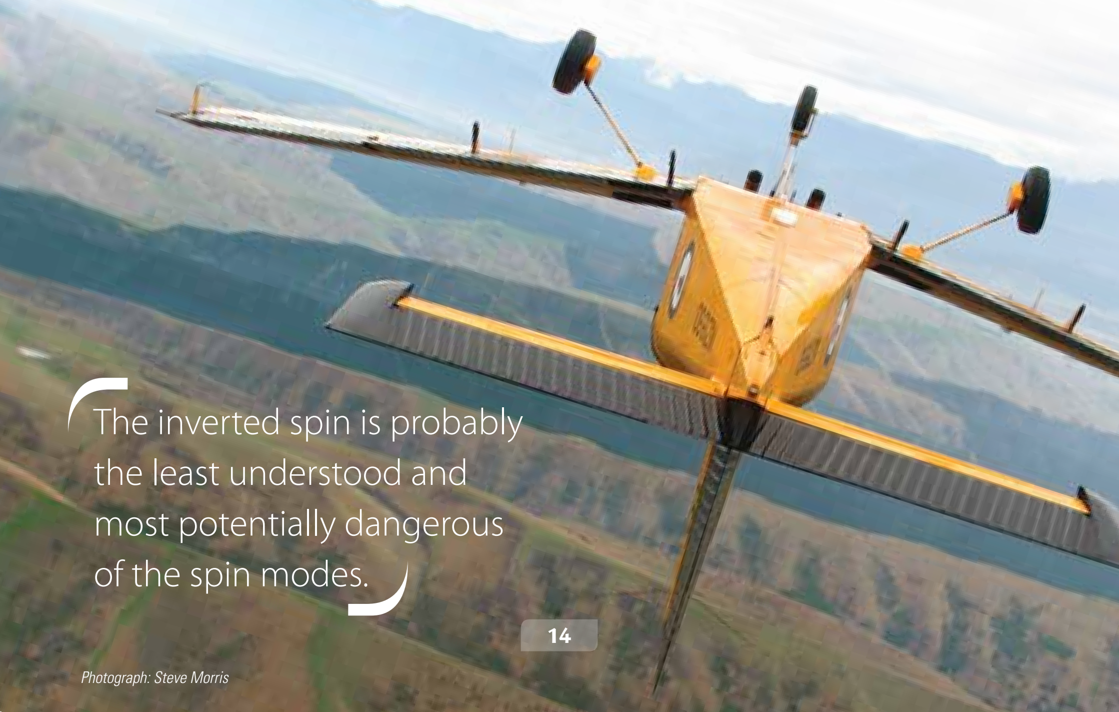
Most general aviation aircraft have design features that preclude a flat spin, but not all. Those that are prone to unintentional flat spins are likely to have an annotation in the Pilot Operating Handbook/Flight Manual that spins are not authorised.

Flat spins rotate at a slower rate than upright spins, but to the pilot they appear to be rotating much faster. That's because the pilot's line of sight is parallel to the horizon – you see much more going past. Yaw rates in a flat spin are usually very fast, but the rate of altitude loss per turn is usually less than in a steep nose-down spin.

Recovering from an established flat spin requires the nose to be forced down. In the initial stages of recovery, this will increase the rate of rotation, which can be disconcerting.

Spins in IMC

In Instrument Meteorological Conditions (IMC), pilots should rely primarily on the airspeed indicator and the turn needle. The needle uses a rate gyro, not a free gyro, and cannot suffer from gimbal lock.



The inverted spin is probably the least understood and most potentially dangerous of the spin modes.

Photograph: Steve Morris

The turn needle will indicate the direction of yaw, which will be the same as the direction of spin. During a spin to the left, the turn needle will show a turn to the left. The ball cannot be trusted. It is likely to be centrifuged away from the centre of the aeroplane and its reaction may depend on where it is mounted on the aircraft in relation to the centre of gravity.

Attitude and heading indicators should also be distrusted as either could have toppled or be confusing to interpret.

During recovery from a spin in IMC, the change in rotation will act upon the ear semicircular canals and create an illusion of spinning in the opposite direction. This may well tempt the pilot to put the aircraft back into its original spin. The turn needle must be trusted implicitly during IMC spin recovery.

In IMC, rely on the turn needle to show direction of spin.

Inverted Spin

The inverted spin is probably the least understood and most potentially dangerous of the spin modes because an unintentional inverted spin is so confusing to the senses of sight and feel.

Unlike the conventional upright spin, where roll and yaw are in the same direction, in the inverted spin roll is opposite to yaw.

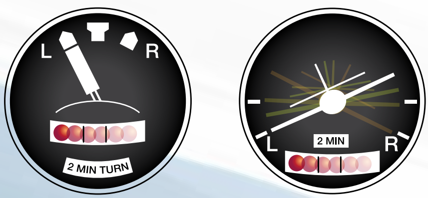
Because of the near overwhelming tendency to identify a spin by the direction of roll rather than yaw, the surest way to determine the direction of the inverted spin is by reference to the turn needle. The turn needle always acts as the yaw indicator in the spin.

The turn coordinator has a tilted gyro, which indicates both yaw and roll. It may give unreliable readings in an inverted spin, although its readings will be valid in an upright spin.

The ball should not be used because of its unreliability in different aircraft types.

It is often difficult to tell at the incipient stage if an upright or inverted spin will result.

The recovery actions for an upright spin will guarantee an inverted spin keeps autorotating. The recognition and recovery of the inverted spin is a specialised aerobatic skill, and is not described here.



In an inverted spin, only the turn needle (left) can be trusted to show the spin direction. The ball, and the turn coordinator (right) may give unreliable readings.

Avoiding Spins

Prevention is better than cure. The following situations can cause a spin.

Low-speed Climbing Turns

The aircraft is already vulnerable by being at low speed and in a nose-up attitude and therefore close to the stall. Low-energy, low-powered aeroplanes in this situation will suffer some performance loss during a turn. If this is not compensated for by lowering the nose, the speed will further diminish. Turning – or even the application of aileron – may give the required yaw to precipitate the spin.

Photo: Alex Mitchell

Photo: John King

Skidding Turn on to Final

Consider a late turn on to final approach, overturning the centre line, particularly on a glide or forced-landing approach, or in a crosswind. If any attempt is made to correct the situation by increasing rudder in the direction of the turn without increasing bank, this coupled with a reducing or low airspeed will result in a skidding turn, and will provide all the ingredients needed to start a spin. The low altitude will preclude the chance of recovery.

False Visual Horizons

Flying in hilly terrain may distort the visual cues needed to ascertain both the pitch and roll attitudes of the aircraft. It is easy to allow airspeed to reduce further than anticipated. When combined with a turn, particularly in confined areas, this can produce stall and yaw, the two components needed for a spin.

Photo: Alex Mitchell

Engine Failure After Takeoff

In a high nose-up attitude, with high power and low speed, the immediate priority is to lower the nose and preserve existing airspeed. In most cases, there is little option but to land ahead. Attempting a turn back to the runway or to a limited selection of landing areas will provide the G loading to increase the stall speed. Any yaw will now put the aeroplane into the incipient spin situation.

The pull up and reversal turn from a high-speed, low run (beat up) may produce the same result.

> Attempting a turn back to land will increase G loading and stall speed.

Photo: John King

Spin **Recovery**

To have a chance at recovery, the pilot must immediately recognise the spin, and its direction, know exactly what to do in the right order, and then execute the procedure correctly the first time.

In most aircraft there is only about three seconds to do all this. The minimum altitude loss for a text-book recovery will be about 1000 to 1500 feet.

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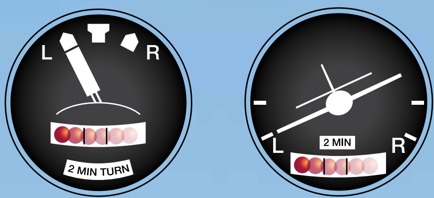
Direction of Spin

A serious problem in perceiving spin direction occurs when the pilot's attention is directed, perhaps unconsciously, to roll direction. The spin (yaw) direction will always be correctly indicated by the turn needle, as this reacts to rotation only in the yawing plane.

The turn coordinator has a tilted gyro. This indicates both yaw and roll and may give unreliable readings in an inverted spin, although its readings will be valid in an upright spin.

The ball cannot be trusted. It is likely to be centrifuged away from the centre of the aeroplane and its reaction may depend on where it is mounted on the aircraft in relation to the centre of gravity.



In an upright spin, both the turn needle and the turn coordinator will correctly indicate the direction of spin. The ball cannot be trusted.

Recovery Technique

Spin recovery does not follow a pilot's natural instincts.

Incipient Spin

Recovery from an incipient spin (a spin that has just started) requires instant recognition (critical at low level), an immediate check forward on the stick or control column (to unstall the wing) and sufficient opposite rudder to eliminate yaw and further wing drop. This must be instinctive. Be wary of pitching forward too much. Applying only sufficient forward stick or control column to unstall the wing ensures maximum lift is still being achieved and height loss is minimised. Jamming the stick or control column fully forward could make the aircraft enter an inverted spin. Similarly, only sufficient rudder to eliminate yaw should be used. Any more applied at high angles of attack may cause the aircraft to flick or spin the other way.

With control now restored, aileron may be used to reduce bank angle.

Developed Spin

In a developed spin, full deflection of controls is required. Although there is no universal spin recovery technique, one of the most widely used is PARES. Be warned that this technique may worsen a spin in certain aircraft. You should follow the procedures outlined in your aircraft's Pilot Operating Handbook/Flight Manual.

PARES Spin Recovery

P	POWER	off (close throttle)
	Identify you are in a spin and the direction of rotation	
A	AILERONS	neutral
R	RUDDER	full opposite to direction of spin… Pause
E	ELEVATOR	move stick or control column progressively and centrally forward until spin stops
	Perform steps sequentially – centralise when spinning stops	
S	Spin STOPS	rudder neutral and ease out of ensuing dive

Power

Check that the throttle is closed.
This decreases forces from the propeller that might tend to hold the nose up, flattening the spin and possibly blanketing the elevator. It will also keep the engine from overspeeding during later stages of the recovery.

Photo: John King

Ailerons

Never use aileron in an attempt to roll out of a spin. The result could be a flatter, faster, steadier spin.

The most appropriate aileron position for recovery from an unintentional spin in most standard light aeroplanes is neutral.

Photo: John King

Rudder

Identifying which rudder is opposite to the direction of spin is critical.

- Look at the turn needle. It does not lie. Do not trust the artificial horizon, heading indicator or the ball. A turn coordinator will indicate the direction of yaw (and therefore spin) in an upright spin, but it may not indicate the right direction in an inverted spin.
- Change your field of vision by sighting straight down the nose of the aeroplane. By doing so, you will see only the yaw component of the spin. Force yourself to look beyond the nose and observe the ground movement. The ground will appear to flow past the windshield – apply the rudder fully in the direction of this flow. In a left spin the ground moves in a blur to the right – use right rudder for the recovery.
- Sample the rudder pedals – feeling for the one that offers the most resistance. Press the heavier one all the way to the control stop. Unless you have a lot of experience in spinning a particular type of aircraft, this technique may be the most difficult of the three to implement during an unintentional spin. It is not uncommon to lock both feet on the rudder pedals during an unintentional spin. Consciously relaxing your feet improves your sense of feel and will also reduce your tendency to oppose the application of full opposite rudder.

Photo: John King

Elevator

Move the stick or control column progressively forward until the spin stops to reduce the angle of attack and unstall the aircraft.

Stops

Once the spin stops, centralise rudder and aileron and ease gently out of the dive.

Photo: John King

Photo: John King

Learn more

Spin recovery may sound reassuringly simple, but statistics show the most likely outcome from an unintentional spin is that the aircraft will be destroyed and the pilot killed.

Knowing the right steps for recovery in the right order may help you. Knowing and avoiding the situations most likely to precipitate a spin certainly will help you.

Practising these skills with a suitably qualified instructor is highly recommended.

To learn more about spin recovery and avoidance, and aerobatic training, contact the Tiger Moth Club of New Zealand www.tigermothclub.co.nz or the New Zealand Aerobatic Club www.aerobatics.co.nz.

Civil Aviation Rules, Part 61 *Pilot Licences and Ratings* Subpart L (available free on the CAA web site) details the requirements for an Aerobatic Rating.

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Spin Avoidance and Recovery was reprinted in June 2014.
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