ACCIDENT

Aircraft Type and Registration:	Tipsy Nipper T.66 Series 3 Nipper, G-ONCS
No & Type of Engines:	1 Volkswagen 1834 piston engine
Year of Manufacture:	1972
Date & Time (UTC):	13 August 2007 at 1745 hrs
Location:	Between West Mersea and Tollesbury, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose, tail, landing gear and left wing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	3,404 hours (of which 35 were on type) Last 90 days - 205 hours Last 28 days - 61 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, and follow-up inquiries to pilot, LAA and others

Synopsis

After intentionally entering a spin, the aircraft adopted a flat attitude, from which the pilot found it difficult to recover. After some 26 turns, he effected a recovery and made an emergency landing on to marshy ground; the aircraft came to rest inverted. Data gathered by a webcam and a laptop computer, fitted to the aircraft by the pilot in order to 'self critique' his aerobatic routines, allowed an analysis of the spin to be made.

History of the flight

The purpose of the flight was to carry out a practice aerobatic sequence, beginning with an intentional spin. After carrying out a clearing turn and completing the 'HASSELL' checks at a height of approximately 3,500 ft, the pilot initiated a spin to the right by closing the throttle and allowing the aircraft to decelerate to approximately 30 kt indicated airspeed. Then, at the onset of the stall, he applied and held full aft stick, combined with full left aileron and full right rudder. Immediately on entering the spin he noted, with some surprise, that the aircraft had not adopted its usual 60º to70º nose-down attitude and, by the time it had completed the first rotation, he realised that the spin 'had gone flat'.

The pilot had not encountered a flat spin before so responded initially by applying the normal spin recovery actions, ie, neutral ailerons, left rudder and then full forward stick. This had no effect. He reported that after about three to four turns, he removed and re-applied these inputs, again with no effect. After a further couple of turns, he applied a series of short bursts of engine power, but this too had no discernible effect, so he closed the throttle and centred the controls before reverting to normal recovery actions. After about 10 turns in total, the engine stopped and, because normal recovery actions appeared to be having no effect, he decided to try 'full in-turn controls', comprising full forward stick, full right rudder, and full right aileron. He estimated that after a further six turns or so in this condition, the mode of the spin reverted to its usual steep nose-down mode, from which he was able to recover normally into a steep dive.

On pulling out from the dive at an estimated height of 500 ft to 700 ft, he found himself disorientated and unable to focus properly. However, after an estimated three seconds, he was able to re-orient himself and start looking for a suitable emergency landing site. The engine was not fitted with an electric starter and had not re-started during the post-recovery dive. As the local area comprised sea and marshland, he turned into wind with the intention of making a forced landing, by stalling into the marshy ground with as little forward speed as possible. During the stall, whilst in a nose-high attitude, the main gear contacted a wire fence that he had not seen previously, and the aircraft flipped over and came to rest inverted in a marshy hollow.

The pilot was uninjured but could not open the canopy because it was resting on the ground. After assessing that there was no immediate danger of fire, he transmitted a 'MAYDAY' on 121.50 MHz, but received no response. As he was unsure as to the integrity of the radio or its antenna, he switched frequency to Essex Radar in the hope that aircraft in the near vicinity working that frequency might receive his calls. After a while, a Ryanair flight acknowledged his 'MAYDAY' and passed on his details. He then reverted to listening-out on 121.50 MHz and, because he was unsure of his exact position, broadcasting at about three minute intervals to assist with direction finding. A short while later, a BA flight also acknowledged his 'MAYDAY' at about the same time as a Police Air Support unit helicopter arrived. With two of its crewmembers lifting the tail of the aircraft, he was able to extricate himself and emerged completely unhurt.

The pilot commented that he had begun all of his previous spins with more of a 'flick', as this provided a much more positive and predictable entry. On this occasion, he allowed the aircraft to stall wings level and used a rapid rudder input. However, G-ONCS was reluctant to spin with ailerons neutral and, for this reason, he habitually used left aileron to encourage a positive entry; on this occasion, however, he believes that he had probably held the ailerons for longer than normal. On all his previous spins in G-ONCS, the aircraft had always recovered within ½ to ¾ of a turn of normal spin recovery actions, ie stick neutral with full opposite rudder, followed by stick forward.

At the time of the accident, the aircraft was fitted with a 'webcam' light-weight video camera connected to a laptop computer, installed in the luggage area behind the pilot's seat. This was to allow the pilot to review and critique his aerobatic manoeuvres on completion of the sortie. He has stated he was confident that the aircraft's weight and Centre of Gravity (CG) position had both been within the specified limits of 685 lbf (the aerobatic weight limit) and 14.4" to 16.5" aft of the wing leading edge datum, respectively. As the aircraft had not suffered any major damage in the accident that could have altered its weight distribution, the pilot reported that after recovery, the aircraft's CG was physically checked with the same quantity of the fuel on board and with the camera and laptop installed. He found the CG position to be, by calculation and demonstration, 15.82” aft of the datum.

At the request of the AAIB, the pilot provided an extract from the video recording covering the relevant period from the initial clearing turn prior to initiating the spin, up to the time of his first ‘MAYDAY’ call.

Recorded data analysis

The characteristics of the spin

It is clear from the pilot’s account that G-ONCS entered a much flatter mode of spin than he had experienced previously, which he was not expecting. It is also clear that when this particular mode of spin did not respond immediately to his usual recovery actions, he felt compelled to try a range of alternatives in the hope of finding some combination that would have the desired effect. Ultimately, it appears that his use of full right rudder, with full right (in-spin) aileron and full nose-down elevator, maintained for a full six turns or so, caused the spin to steepen into a more normal mode from which he was able to recover in the usual way.

Video analysis of the spin

The camera was fixed to the coaming, looking forward, and consequently did not record any control inputs or instrument displays. The image quality was good during the clearing turn prior to the spin, but the camera’s auto-exposure system was unable to cope initially with the sudden change in lighting conditions between the entry to the spin, which was made in a nose-high attitude pointing into a bright sun, and the much darker landscape visible during the spin. As a consequence, the image during the initial four turns was completely blacked-out, except for brief pulses of sunlight reflected off the top of the engine cowl. By the time of the fifth rotation, however, the exposure system had managed to adapt and the image quality thereafter was good.

A detailed analysis of the video confirmed broadly the pilot’s account of the sequence of events during the spin. Because there was no viable image during the first four turns of the spin, all that could be gleaned from this part of the video was the rate of turn, based on the frequency of the brief pulses of reflected sunlight. From the fifth rotation until the aircraft pitched into its more nose-down attitude just prior to the start of the recovery, it was possible to use a combination of reference points in the visible terrain to study the motion of the spin in terms of both rotation rate and relative changes in pitch attitude.

The plot at Figure 1 shows that from the fifth to the ninth turn, and very probably during the first four turns for which no visual reference was available, the pitch attitude flattened progressively. It then steepened somewhat for couple of turns before flattening again. It then remained substantially unchanged, albeit with some slight oscillations in pitch, for a further 10 turns. At that stage, some 23 turns after entering the spin, the aircraft pitched down rapidly to a much steeper attitude as it began to recover.

The plot at Figure 2 shows an initial rotation rate of the order of 175º per second, increasing progressively to around 250º per second by turn four or five. The actual rotation rate for turn five could not be established as there was no common reference feature in the video from which to determine the relevant time interval. Thereafter, the rotation rate varies between 225º and 275º per second until turn 22 or 23, after which it decays briefly to its initial rate of around 175º per second. The spin ceased altogether some 26 turns, and 40 seconds, after spin entry.

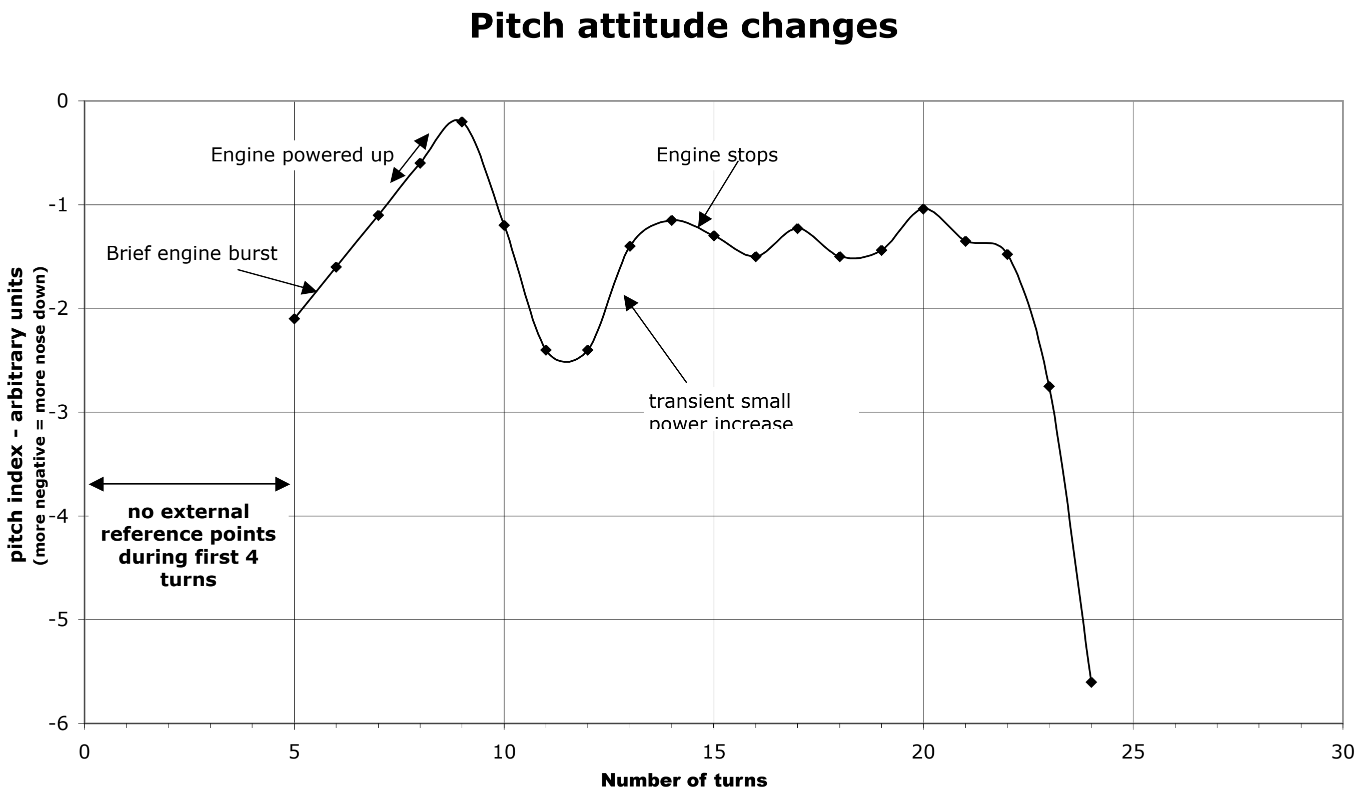

Figure 1

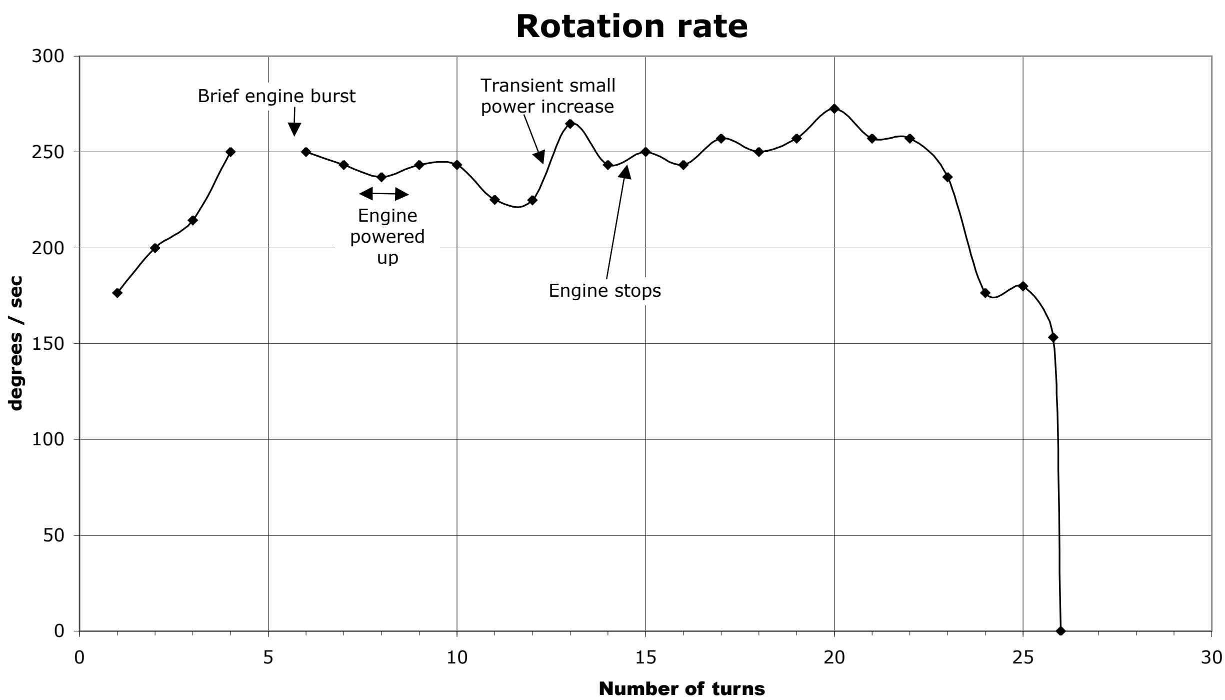

Figure 2

It is possibly significant that the pitch rate was trending towards a flattened attitude during the periods when power increases were made. However, there is insufficient data to draw any convincing inferences as to the precise effect, if any, which the changes in engine power might have had on the aircraft's motion. Nor is there any obvious correlation between the pilot's reported control inputs and the motion of the aircraft.

Video analysis – the post-spin recovery and landing

The video showed that as the rotation stopped, the aircraft entered a vertical dive and it is evident from wind noise on the soundtrack that the airspeed was, and subsequently remained, very high during the pull-out.

The aircraft levelled approximately 43 seconds after spin entry. This was followed by a period of approximately 15 seconds of level flight, incorporating a series of turns to left and right using bank angles of 15º to 30º, presumably as the pilot tried to find a viable landing ground. However, it is apparent in the video that the terrain in the area comprised marshland intersected by numerous water channels, and that his options were limited. The aircraft then rolled briskly into a steep turn to the left at a bank angle initially of between 55º and 60º, which was held for about eight seconds. The bank angle then reduced to around 30º, as individual pieces of vegetation started to become discernible in the video. About three seconds later, the aircraft's nose started to rise and the wings were levelled. This was followed by a brief lowering of the nose and a pitch up coincident with the impact some two seconds later. The total elapsed time between entering the spin and the impact was 73.5 seconds. The first 'MAYDAY' call was made a little over 30 seconds after impact.

Video analysis – descent rates

It was not possible from the video evidence to determine the height of the aircraft as it levelled out after recovering from the spin. The pilot estimates that his height at that time was between 500 ft and 700 ft above the ground. If correct, this would imply a height loss (between spin entry and the recovery to level flight) of the order of 2,750 ft and 3,000 ft. The height consumed during the recovery dive is not known, but if a figure of 300 ft were to be assumed then that would suggest an average height loss of the order of 100 ft per turn and an average rate of descent during the spin of between 3,600 ft/min and 4,000 ft/min.

The time interval between levelling out from the post-recovery dive and impact was approximately 30 seconds. If the aircraft had levelled at 500 ft to 700 ft as the pilot believes, then that would imply an average rate of descent from the time he levelled up to the time of impact of between 1,050 ft/min and 1,400 ft/min. This confirms the strong visual impression given by the video that both airspeed and rate of descent remained high throughout the 'glide' descent and the initial part of the steep left-hand turn immediately preceding touchdown. Excess speed appears to have bled off only as the bank angle was reduced and the nose raised during the pilot's attempt to flare the aircraft back towards a stalled condition at touchdown.

Issues of general relevance to spinning

The generic term 'spin' applies not to a single condition but rather to a complex family of conditions involving, potentially, a range of modes, the individual characteristics of which can vary markedly. The key factors in what is conventionally defined as a spin are as follows:

(i) The incipient stage will involve what is essentially a departure (ie a loss of aerodynamic control) in all three axes simultaneously, which precipitates the motion leading to the fully developed spin that follows. When the spin is unintentional, this departure most often takes the form of an asymmetric stall in which one wing drops before the other, and so becomes more deeply stalled than the other, particularly when this occurs with an already existing yaw imbalance towards the dropped wing.

(ii) Once established in the spin, the aircraft will adopt a self-sustaining, stable, tightly spiralling descent in a stalled condition about a vertical axis of rotation, its path through the air being akin to descending on a very steep helter-skelter, possibly with oscillations in pitch, during which the following conditions will apply:

- The incidence to the local airstream will be such that the wings will be in a substantially stalled state, though not necessarily, and indeed probably not, uniformly stalled across the whole of the lifting surfaces.

- The aircraft will be descending with a high rate of descent, and with a relatively low horizontal velocity component.

- It will be yawing at a high rate about an axis of rotation either within the aircraft's span, or at most within a few semi-spans from the aircraft's centre of mass.

- The overall motion will comprise a stable auto-rotation, sustained by the combination of dynamic, aerodynamic, and gravitational forces acting on the aircraft.

Type-specific factors influence how a given aircraft will tend to spin. These include not only its aerodynamic characteristics, especially the configuration and positioning of the tail, but also its mass moments of inertia about all three axes, and the position of its centre of mass (CG position). For propeller driven aircraft, the direction of rotation will also have an influence, tending to favour a spin to the left for propellers turning clockwise (from behind), and to the right for propellers turning anti-clockwise. The rotational inertia of the propeller will give rise to gyroscopic precessional forces, which can also have an influence. Minor variations in these physical characteristics between individual examples of a given type can also affect spinning behaviour, in the same way that different aircraft of the same type can exhibit variations in stall characteristics, particularly the tendency to drop a wing.

The manner in which the spin is entered can also have a strong influence on the characteristics of the spin that results, in particular:

- Attitude (pitch, yaw and bank angles)

- rates of pitch, roll and yaw (determining the aircraft's momentum about these axes at the critical point as it stalls)

- control inputs, including not just displacement but also the manner and timing of their application (ie gradual, or snap-application;

the precise point during the entry sequence that the input is made; how long the input is maintained, etc.)

- propeller rotation speed

Precisely how all of these factors combine to influence an aircraft's spinning characteristics is highly complex and beyond the scope of this Bulletin; suffice to say that extensive flight trials are usually required before a given type's spin characteristic can be fully understood. During such trials, it is common practice to fit the aircraft with an anti-spin parachute or rocket devices which can be activated in an emergency, to help force the aircraft out of its stable autorotative state.

Through careful design, and by imposing limitations on aircraft weight and CG, designers and certificating authorities endeavour to ensure that aircraft certificated for spinning can be relied upon, firstly, to adopt a predictable mode of spin and, secondly, to be amenable to recovery using either standard spin recovery actions or an appropriate alternative laid down in the flight manual. Very often, a lack of elevator authority at the stall will result in aircraft showing a marked reluctance to spin at all. When such aircraft do spin, the limited ability to raise the nose high at the point of stall during spin entry, will encourage it to adopt a nose-down attitude in the spin, from which recovery is usually straightforward. However, as alluded to above, it should not be presumed that such aircraft could not be made to adopt other, possibly much less benign, spinning modes, some of which may not be amenable to recovery using standard spin recovery techniques. Indeed, in such circumstances, standard recovery methods may actually be counter-productive.

Over the years, many aircraft types which were believed initially to have predictable and safe spinning modes were found subsequently to exhibit other (usually flatter) modes of spin from which recovery was difficult, or even impossible. These aircraft usually required modification by the addition of anti-spin strakes on the rear fuselage, for example, and/or changes to the tail configuration, to effect a cure. Usually, these more unusual modes of spin were associated with very specific entry conditions, often achieved unintentionally on the first occasion, and exploited subsequently. An accident involving one such example, which has direct relevance to this accident, occurred in 1976 and was subject of AAIB Aircraft Accident Report No 3/77, G-BCCO.[1]

Issues specific to G-ONCS' spin

The direction of spin was that which the direction of propeller rotation would have pre-disposed it to adopt. It would seem that the combination of the CG position towards the aft limit, together with the sustained application of full out-spin (left) aileron during entry, were critically important in precipitating the flat mode of spin which followed. The former would have helped to overcome the inherent lack of elevator authority at the point of the stall, and encouraged a more nose-up attitude subsequently; the latter would have promoted a more pronounced right wing drop by causing the wing on the 'inside' of the spin to become more deeply stalled, and that on the 'outside' to be less so, thereby increasing the autorotative moment due to asymmetric lift. Together with additional aileron drag and associated adverse yaw, this would have tended to yaw the aircraft to the right at the point of stall and through the incipient stages of the spin. The result was a classical flat spin, involving a highly stable, high rate, autorotation with a small radius of gyration and a relatively small bank angle.

Footnote

[1] See AAIB web site at: www.aaib.gov.uk

The first requirement in recovering from any fully developed spin is to stop the yaw: only when the yaw has been stopped and stable autorotation ceases, can the stalled condition of the aircraft be addressed to complete the recovery. Rudder effectiveness is therefore a key requirement in spin recovery generally. However, a flat spin can, potentially, reduce the effectiveness of the rudder. The tail configuration of the Tipsy Nipper is such that a flattening of the pitch attitude in the spin may have affected the aircraft in this way, as shown in Figures 3a and 3b, due to the blanking effect of turbulent air in the wake from the (stalled) tailplane and elevator. It can be seen that in a flat mode of spin (Figure 3a), not only would this blanking be potentially more severe than at steeper pitch angles, but would have been exacerbated by application of full forward stick.

Indeed, it is possible that the use of full forward stick in this particular case may have critically reduced the rudder's effectiveness below the threshold required to overcome the auto-rotational yaw, preventing or delaying recovery until it was complemented by the adverse yaw associated with in-spin aileron.

It is notable that the Tipsy Nipper Owners Manual applicable to G-ONCS, and indeed (as far as could be established) the equivalent manuals for other marks of the Nipper, lists spins as one of the permitted aerobatic manoeuvres. However, it provides no specific guidance as to how the spin should be entered, save for the entry speed which, in G-ONCS' case, is listed as 38 mph. Additionally, it states under the heading '*Spinning*':

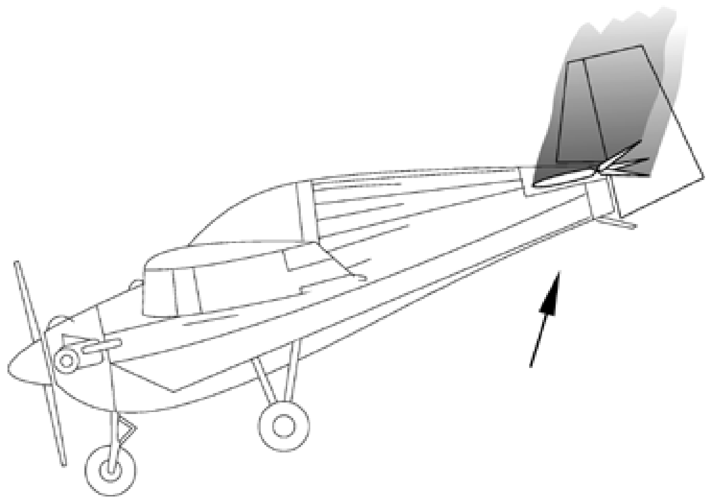

Figure 3a

Flat spin attitude

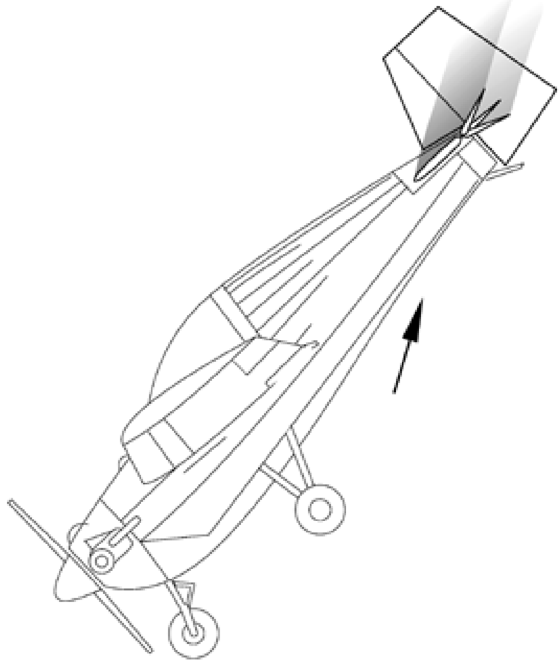

Figure 3b

Steep spin attitude

> *'The aircraft is very reluctant to enter a spin and just as reluctant to maintain it. Normal recovery methods are quire adequate, and the action is immediately effective.'*

Additional information

Spin recovery

Advice was sought from a highly experienced pilot about the spinning characteristics of the Tipsy Nipper. He had for many years, not only displayed the aircraft and competed in aerobatic competitions, but also had wide experience of its spinning behaviour, including flat spins. He advised that, provided the entry was progressive, using a little power helps the effectiveness of the controls. Applying full back stick and in-spin rudder as the nose drops and, if needed, momentary out-spin aileron (neutralised as soon as rotation starts), followed by closing the throttle once the spin starts, results in spin (up to three turns) that is consistent and predictable. Recovery usually occurred within a quarter of a turn of applying standard recovery actions. However, he also advised that the Nipper can be readily induced into a flat spin with full use of out-spin aileron - effectively to increase the drag on the in-spin wing and accelerate rotation. The progressive use of forward stick will further increase the rate of rotation and hence is totally counter-productive in initial recovery. In addition, the use of engine power will flatten the spin further and also oppose recovery.

He found that full out-spin rudder combined with full in-spin aileron and aft stick, with the throttle closed, gave optimal recovery from a flat spin, but stressed that it nevertheless could still take up to four turns before the rotation stopped, even without an aft CG. He emphasised that whilst he had found these actions to be effective in recovering from a flat spin in a Nipper, it should not necessarily be assumed that they would be appropriate for other aircraft types. He also commented that it was not unusual for normally aspirated engines to stop during a spin.

Disorientation

The pilot of G-ONCS reported that he became disorientated and unable to focus on the instruments for a period after the aircraft recovered from the spin. This condition is associated with Type III disorientation which can lead to failure to recover an aircraft into normal flight.

Type III disorientation can manifest itself in the following way:

> If an object is held stationary, and one's head is moved around, the eyes can easily focus on the object; indeed it is difficult to avoid this happening. This is because the eyes share a neuronal connection with the body's vestibular system (the balance system in the inner ear) such that the vestibular apparatus causes eye movement opposite to the direction of head rotation. This involuntary eye movement is called the vestibulo ocular reflex (VOR), and is caused by inner ear fluid remaining static inside the 'moving' semicircular canals (which are fixed in relation to the head). When a pilot is subject to spinning, the VOR moves the eyes in opposition to the direction of rotation. However as the spin continues, the eyes soon reach the extent of their travel. At this point, the eyes quickly reset, and the VOR starts again; this process repeats itself for the duration of the spin and is called ocular nystagmus. Ocular nystagmus normally helps the pilot maintain awareness of orientation but, if prolonged, it can get out of phase, causing a

disorientating condition called vestibulo-ocular disorganisation (VOD) and can lead to difficulty in initiating a recovery from the spin.

After stopping a prolonged spin, inner ear fluid continues to move for a period, due to its inertia, despite the head (and hence the semicircular canals) now being still. The relative movement between the fluid and the semicircular canals causes further nystagmus after the spin has stopped, and is referred to as post-rotatory nystagmus. This can lead to a false feeling that the aircraft has begun spinning the opposite way and can prompt inappropriate control actions, such as full rudder, thus risking inadvertent spin re-entry, particularly if the airspeed has yet to increase. Additionally, the nystagmus makes reading instruments extremely difficult. The process is easily demonstrated by a person performing ten rapid turns on the spot and stopping, then immediately trying to read from a page of text.

Spinning accidents

The subject of spinning accidents in General Aviation has been addressed in various AAIB reports over recent years. Relevant extracts from two such reports, one concerning a glider (HCD, Bulletin 1/2005), the other an aerobatic single engine aircraft (G-BUUD, Bulletin 10/2007), are reproduced below for information.

One of the recommendations made to the British Gliding Association in the report concerning HCD, for pilots and instructors intending to perform intentional spins, included the following:

> *'…………that instructors and pilots establish and brief students on, minimum entry heights, minimum recovery initiation heights and minimum recovery heights, whenever intentional spinning is planned. These heights should take into account the characteristics of the glider type being flown, the experience and ability of the crew, and the possible need to abandon the glider.'*

Glider pilots normally wear parachutes on all aerobatic, recreational and training flights.

In the report on the accident to G-BUUD, the following was included:

> *'The CAA General Aviation Safety Sense Leaflet 19a, entitled Aerobatics, advises pilots who are learning to fly aerobatics to become familiar with the entry to and recovery from a fully developed spin since a poorly executed aerobatic manoeuvre can result in an unintentional spin. Training in recovery from incorrectly executed manoeuvres and unusual attitudes is essential.*
>
> *Following a spinning accident to G-BLTV on 3 November 2002, the AAIB made the following recommendation: 'The Civil Aviation Authority should conduct a review of the present advice regarding the use of parachutes in GA type aircraft, particularly those used for spinning training, with the aim of providing more comprehensive and rigorous advice to pilots.'*

This was accepted by the CAA and an updated Safety Sense Leaflet 19a *Aerobatics* was published containing the following information on parachutes:

'While there are no requirements to wear or use specific garments or equipment, the following options are strongly recommended:

..... Parachutes are useful emergency equipment and in the event of failure to recover from a manoeuvre may be the only alternative to a fatal accident. However, for physical or weight and balance reasons their carriage may not be possible or practicable, the effort required and height lost while exiting the aircraft (and while the canopy opens) must be considered. If worn, the parachute should be comfortable and well fitting with surplus webbing tucked away before flight. It should be maintained in accordance with manufacturer's recommendations. Know, and regularly rehearse, how to use it, and remember the height required to abandon your aircraft when deciding the minimum recovery height for your manoeuvres.'

Conclusions

It is evident that the pilot of G-ONCS had not appreciated fully the potential for his aeroplane to adopt a mode of spin outside his experience and understanding, or the factors likely to pre-dispose it to do so. In this regard, he is likely to have been no different from large numbers of pilots in general aviation and. indeed, commercial pilots. However, the fact that he was able to remain calm in a stressful situation and apply different control configurations which eventually effected the spin recovery, and had sufficient height to overcome his disorientation, meant that a more serious outcome was avoided.

Although there is no shortage of information available concerning intentional spinning and the avoidance of, and recovery from, unintentional spins, from various AAIB reports, the CAA, flying training organisations and various organisations associated with sporting and general aviation, the following Safety Recommendation is made:

Safety Recommendation 2007-115

It is recommended that the Civil Aviation Authority, in conjunction with the Light Aircraft Association, should publish information relating to UK registered aircraft approved for spinning, with a view to ensuring that guidance is given on how a spin should be entered, so as to maximise the probability of the aircraft spinning in a predictable manner, one that is amenable to recovery using standard actions.