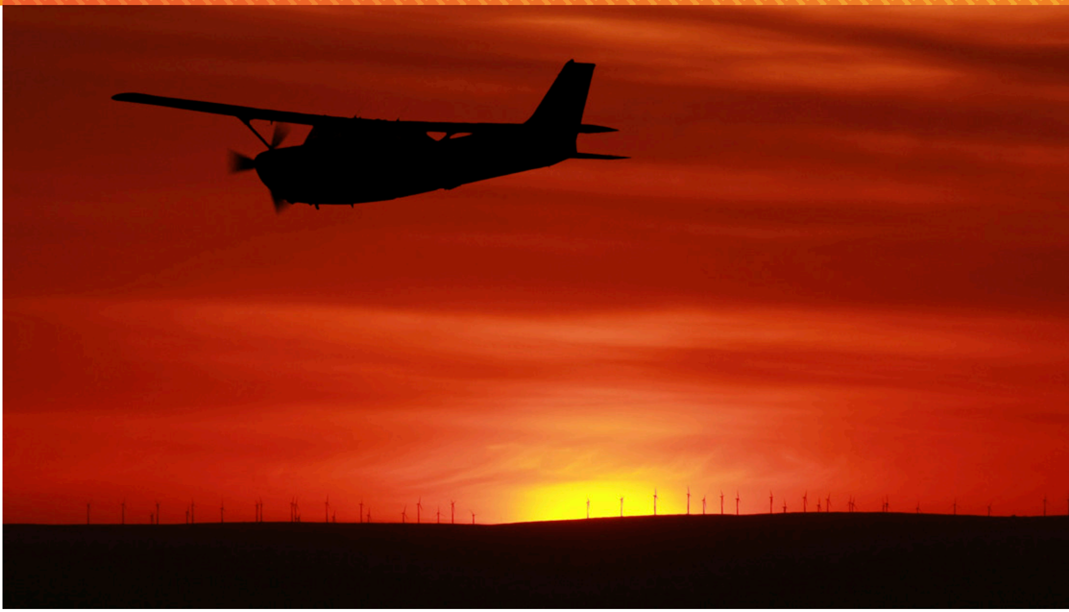
Australian Government

Australian Transport Safety Bureau

Avoidable Accidents No. 7

Visual flight at night accidents:

What you can't see can still hurt you



Australia's national transport safety investigator

AVIATION | MARINE | RAIL

Research

AR-2012-122

Publication title

Avoidable Accidents No. 7
Visual flight at night accidents: What you can't see can still hurt you

Report No. AR-2012-122

Publication date 17 December 2013

ISBN 978-1-74251-320-1

Publishing information

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office: 62 Northbourne Avenue Canberra, Australian Capital Territory 2601
Telephone: 1800 020 616, from overseas +61 2 6257 4150 (24 hours)
Accident and incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6247 3117, from overseas +61 2 6247 3117
Email: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

Introduction

At night, less can be seen outside the cockpit to help you control your aircraft. Although flight instruments are used under both Night Visual Flight Rules (VFR) and Instrument Flight Rules (IFR), at some stage during a night flight you will also need to fly the aircraft with reference to what can be seen outside.

What can be seen outside an aircraft at night varies greatly between the almost day-like conditions of flying over a city under a full moon to the complete darkness of remote areas without any moon or significant ground lighting. Safe flight relies on pilots applying the correct flying skills using the combination of information from flight instruments and from outside the aircraft.

Many pilots fly mostly in daylight. Night flying, even when undertaken by appropriately qualified pilots, presents an added level of complexity. In most cases pilots who operate at night have the necessary knowledge and skills, and are flying suitably equipped aircraft.

A pilot who is qualified to fly visually at night should have the extra skills and equipment to control the aircraft by using flight instruments and by using more detailed flight procedures. Safe night visual flight requires the application, use and integration of all the information sources correctly. Compared with day visual flight, there is more to night visual flight than meets the eye.

The thing that is important is the thing that is not seen.

Antoine de Saint-Exupéry, French pioneer aviator and author of 'Night Flight' and 'Wind, Sand and Stars'

Key messages

The extra risks inherent in visual flight at night are from reduced visual cues, and the increased likelihood of perceptual illusions and consequent risk of spatial disorientation. These dangers can, however, be managed effectively. This report will explain how suitable strategies can significantly reduce the risks of flying visually at night.

- Night flying is more difficult than flying in the day. Ensure you are both current and proficient with disciplined instrument flight. Know your own personal limitations in terms of flying with minimal or no visual references. Only fly in environments that do not exceed your capabilities.
- Before committing to departing on a visual flight at night or close to last light, ensure your aircraft is appropriately equipped and consider all obtainable operational information, including the availability of celestial and terrestrial lighting.
- Some nights and some terrain are darker than others. Excellent visibility conditions can still result in no visible horizon or contrast between sky and ground. Inadvertently flying into instrument meteorological conditions (IMC) is also harder to avoid at night.
- Always know where the aircraft is in relation to terrain, and know how high you need to fly to avoid unseen terrain and obstacles.
- Remain aware of illusions that can lead to spatial disorientation—they can affect anyone. Know how to avoid and recover from illusions by relying on instrument flight.

Example of good visual conditions at night: clear skies, discernible horizon and high levels of terrestrial lighting.

Context

Less flying occurs at night, due in part to the widely held understanding that there is a heightened chance of an accident and a greater chance of a worse outcome when an accident happens at night. The night-time world-wide fatal accident rate for approach and landing accidents for large air transport aircraft is close to three times the rate as during daylight.[i] In general aviation, a similar or even worse difference probably applies.

It is not just visual flight rule (VFR) flights that are affected. In general aviation, the approach and landing accident rate for single-pilot instrument flight rule (IFR) flights have been found to be 8 times higher at night than in the day, and night IFR accidents 2.5 times higher than accidents in day VFR flights.[ii] Flying VFR at night can be expected to have a similar or possibly even higher accident risk than IFR flights at night.

The ATSB reviewed night flying accidents in Australia for the 20 years between 1993 and 2012. Accidents in visual (night) conditions, excluding those that involved any sort of (actual or simulated) mechanical failure, included:

- 13 accidents conducted under visual flight rules by pilots with a night VFR rating
- 8 accidents conducted under instrument flight rules involving visual flying by pilots with a command instrument rating (CIR)
- 5 accidents conducted under visual flight rules by pilots without either a night VFR or CIR rating.

In addition to the above 26 accidents, there were also:[1]

- 10 accidents involving inadvertent VFR flight into IMC at night and/or collision with terrain/obstacle while attempting to flying below cloud at night.

There were other night time accidents during this period that probably fit into one of the above categories, but which have not been included due to a lack of conclusive evidence.

On average, there have been nearly two accidents per year as a result of visual flight at night. Importantly, accidents at night tend to be unforgiving. Of these 36 accidents, 27 had fatal outcomes leading to 58 fatalities. This is consistent with past research from other countries which shows that like accidents in instrument meteorological conditions (IMC), accidents at night are more likely to have fatal outcomes.[iii]

Of the 26 accidents during night visual conditions, half involved a loss of aircraft control, most likely due to the influence of perceptual illusions caused by the lack of visual cues. The other half involved controlled flight into terrain (CFIT), where the pilot probably did not know of the terrain's proximity immediately before impact. About two-thirds of each accident type involved aeroplanes and one-third involved helicopters. Of the three types of pilot/flight rule combinations involved in these accidents (night VFR flights by pilots with an appropriate rating, IFR flights being controlled visually, and night VFR flights by pilots without an appropriate night or instrument rating), each involved a mixture of loss of control and CFIT accidents.

Pilots involved in accidents with visual (night) conditions came from all levels of pilot experience. Generally, the pilots in command for those night accidents involving a loss of control were less experienced (median 1,516 total hours, 114 hours on type) than those involved in night CFIT accidents (median 3,789 total hours, 548 hours on type). However, both groups generally involved pilots with a lot of experience. Furthermore, pilots in these accidents had a range of licences, including air transport (5), commercial (10), private (10) and student (1) pilot licences, and these were fairly evenly distributed across loss of control and CFIT accidents. Together, these facts show that experience alone is not a defence against these types of accidents and that pilots of all experience levels are susceptible to either type of accident.

Nearly all of these accidents occurred on dark nights. Overseas accident analyses have also found that most accidents related to flying visually at night occurred on dark nights.[iv]

Accidents during night visual operations happened in all phases of flight including cruise; however, the greatest number of accidents occurred when the aircraft was either on approach or climbing after take-off.

1 In addition to the 36 accidents mentioned, there were also five accidents involving agricultural spraying activities at night using landing lights for illumination.

Having and using the right operational information

Compared with day visual flight, more requirements exist to ensure that night visual flights remain safe. A pilot must be competent and current with all the required additional skills and knowledge. Knowledge of weather, lighting, navaids, NOTAMs (Notices to Airmen) and airport information are necessary to make sure that a flight may be flown safely, before it is even started. Pilots must have and use additional skills to combine the often sparse external visual information with information from the aircraft's instruments and the correct operational procedures to provide the best situational information to control the aircraft. The aircraft must also have the extra equipment to enable the pilot to control it. Unless all these requirements are complied with, the pilot will likely be operating the aircraft at an elevated risk.

A safe landing can only be assured if a pilot knows about the aerodrome weather, runway lighting, and serviceability of essential equipment like runways and navaids, which can be accessed through NOTAMs. Although airfield infrastructure is normally in good condition, it should never be assumed that infrastructure is serviceable or that it is in the same condition as when you last used it. The consequences of not knowing the status of some vital information, even just once, can jeopardise the safety of a flight.

En route night flight relies on good knowledge of the lowest safe altitude (LSALT) for the flight. The forecast weather conditions are also needed because although a visual flight should not enter cloud, pilots may not be able to see approaching cloud until the aircraft is in it.

External visual information is insufficient for pilots to see and avoid terrain or obstacles that are not illuminated. During cruise, avoiding this risk by the application of rules associated with LSALT has generally been effective. Risks associated with unintentionally getting too close to terrain are commonly associated with a loss of either horizontal or vertical situational awareness, and/or purposely flying below cloud to remain clear of IMC.

A lack of horizontal situational awareness arises from an incorrect understanding of where the aircraft is, or being lost. This situation can be dangerous if the pilot is not aware that the aircraft is flying over higher terrain than planned for.

A lack of vertical situational awareness arises from an incorrect understanding of the aircraft's height, or the elevation of the terrain, even though the knowledge of the aircraft location is correct. This can happen if the altimeter is providing the wrong information or the pilot has misinterpreted the altitude information, or the pilot has miscalculated the correct altitude to fly.

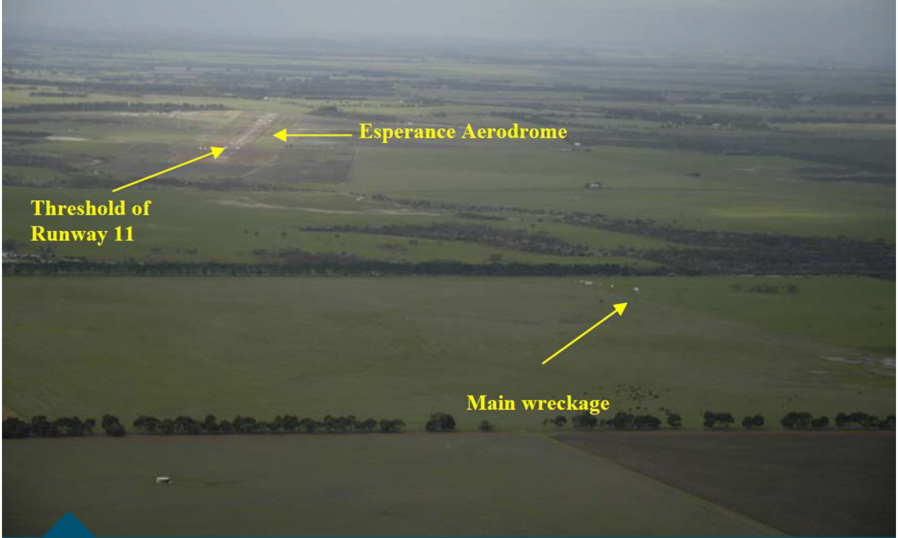
Accidents also occur because pilots inadvertently fly towards cloud. Inadvertent flight into IMC is more likely at night because cloud is harder to see[v], and there have been many accidents as a result of unintentionally flying in IMC at night. By night, advanced visual warning of IMC is often not obtainable and the first realisation the aircraft is close to encountering deteriorating weather is at a point where diversion and holding options are already limited, and precautionary landing is also often not feasible. Collision with terrain accidents have also occurred because pilots have flown below this cloud to avoid it, and ended up flying lower than they would have otherwise. Very accurate vertical and horizontal awareness is then required to keep safe.

Aircraft operating in a circuit pattern are by necessity much closer to terrain. In these circumstances accurate vertical navigation is vital to ensure separation from that terrain and any (often unlit) obstacles (such as poles, wires, fences, trees, buildings).

As terrain cannot reliably be seen in the circuit at a remote aerodrome, a pilot needs to know the correct altitudes for all stages of the flight, including every leg of the circuit, overflying and circuit joins. Pilots can orient their position in the circuit pattern by reference to runway lights, the windsock and aircraft instruments. Risk is reduced by matching the expected perspective from the runway lights with the expected altitude at any position in the circuit pattern. That way, there are two different, independent methods for pilots to ensure they are at the right altitude in the right place in the circuit, checking that both methods provide the same information. Remember, however, that some airfields are not surrounded by lights, so depending on the aircraft's orientation and position relative to the runway, no visual ground reference may be available in parts of the circuit as the aircraft flies away from the runway lights.

It is common for pilots to perceive their aircraft is high on approach during a long straight-in approach when there is nothing but blackness between their aircraft and the runway. This 'black hole illusion' can lead pilots to initiate an aggressive descent so that their perceived approach path based on their perception of the runway lights looks correct. This illusion has contributed to many approach accidents at night around the world.[vi]

The risks of getting too low, too early on final can be mitigated by pilots being alert to this phenomenon. Where there are no visual approach guidance aids like VASIS or PAPI, a pilot must actively monitor the aircraft's actual altitude against the expected altitude during the approach. This is essential to ensure that a normal flight path is flown and is not affected by any perceived visual illusions. That is, the visual appearance of the runway lights must be cross-checked against the aircraft's height and its distance from the runway at each part of the approach.



Approach to Esperance Aerodrome, WA Source: ATSB

Not using the available information pre-flight

Investigation AO-2007-009

In the late afternoon of 26 May 2007, the pilot of a Piper Arrow took off from Jandakot airport in Perth for a flight home to Esperance with two friends as passengers. The flight time was about two and a half hours, and the aircraft arrived in the vicinity of Esperance about 90 minutes after the end of daylight, after last being observed on radar at 9,500 ft.

Forecast weather conditions indicated significant amounts of cloud along the flight path, at and below the cruising altitude. The forecast for Esperance aerodrome indicated that a VFR flight would have required the carriage of an extra 30 minutes holding fuel in case of intermittent weather deterioration.

Other than the runway lighting, there was no significant ground lighting near the airport. Combined with cloud and rain obscuring celestial lighting, the area was very dark. The aircraft crashed into a flat paddock in a late downwind/early base position for runway 11. All three occupants were fatally injured.

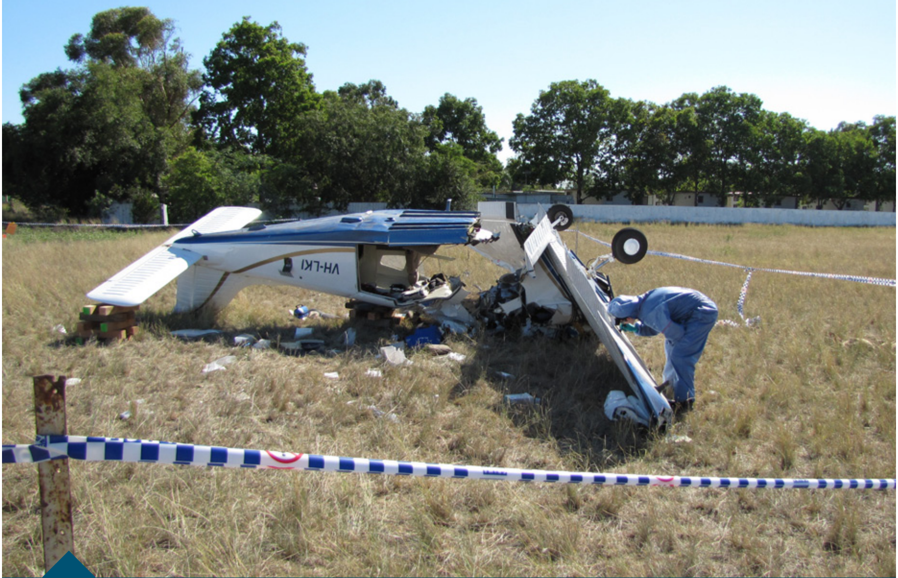
The weather forecasts described weather conditions incompatible with visual flight at night. The pilot almost certainly flew the aircraft through cloud before arriving in the vicinity of Esperance. The forecast indicated a chance of intermittent weather deterioration on arrival, and that is what happened. Even if the pilot had elected to wait until the weather improved before attempting to land at Esperance, he would not have been able to see enough to find a suitable area to visually hold because the dark night conditions would have precluded him from seeing the weather around him.

Based on the forecasts, the pilot should never have taken off for a night VFR flight. During day time, it would have been a marginal VFR flight with a high likelihood of a diversion to an alternate aerodrome; but at night, safety could not be assured because the pilot could not see or avoid any approaching bad weather.

The aircraft was probably in controlled flight at the time of the accident in that it appeared to be flying at an expected speed and in an expected direction and configuration; however, the pilot probably did not have a correct understanding of how close the terrain was to the aircraft.

Lessons learnt

Information that can be obtained pre-flight will normally tell a pilot if a planned flight is even possible and will provide sufficient information to indicate whether the conditions fall within a pilot's personal abilities. Flying visually at night without being confident of remaining in visual meteorological conditions (VMC) and within your own personal limitations will compromise the safety of yourself and your passengers. Running out of altitude or visibility leaves you without alternatives because you cannot see where to go.



Accident site of the Piper Saratoga near Moree Airport, NSW Source: ATSB

The wrong height at the wrong place in the circuit

Investigation AO-2011-043

The owner and pilot of a Piper Saratoga had held a private pilot licence with a night VFR rating for many years. The pilot was not current in night flying. On 30 March 2011, he had flown from Moree to Brewarrina with five passengers, intending to return that evening.

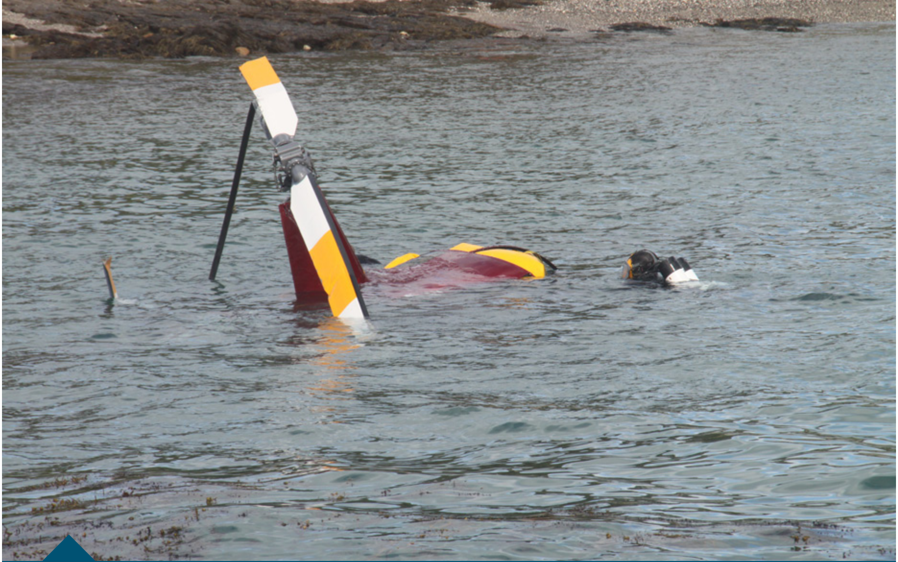
On the return flight, the pilot made a number of detours to allow the passengers to see particular landmarks, and by the time the aircraft returned to Moree, it was dark.

Two legs of the circuit at Moree Airport were flown toward Moree town centre, which provided enough ground lighting to allow the pilot to control the aircraft. The final approach was over a caravan park and highway. However, there was relatively limited ground lighting along the aircraft's intended flight path in the last 500 m before the runway, except for the runway lighting ahead.

The aircraft was very low on the final leg of the circuit. The left wing impacted the top of a tree in the caravan park, 700 m north of the runway. The aircraft rolled inverted and impacted the ground about 150 m later. Two passengers survived the accident.

Lessons learnt

Even if there is ground lighting, terrain clearance will be assured by continually matching the aircraft's position in the circuit and on the approach against the expected altitude. This check allows a pilot to correct the height early if needed. Night currency enables a pilot to maintain the necessary skills and judgement to safely fly at night, such as an earlier detection and correction of an undershoot or shallow approach path.



Robinson R44 helicopter in the sea off Lilli Pilli, NSW Source: ATSB

Being aware of nearby obstacles or terrain

Investigation AO-2011-051

The pilot and owner of a Robinson R44 helicopter regularly used the helicopter to commute between a farm and his home, a little over an hour's flying away. Late in the afternoon of 24 April 2011, he took off from the farm to fly home with one passenger on board. The planned departure time would have got the helicopter home just before dark, however the departure was delayed. About 10 minutes before arrival at the destination, at about the end of daylight, the pilot turned around because of a line of dark and stormy weather between him and the destination. Neither the pilot nor the helicopter was approved for night flight.

The pilot decided to divert to a coastal holiday home that had ocean frontage about half way between the farm and his home. The trip took about 20 minutes, mostly along the coast. During that time overcast cloud developed preventing celestial lighting from illuminating the terrain. As the helicopter got near the holiday home, the pilot flew over the sea to approach the landing site. Lights above the cliff face were not visible to the pilot from the low altitude at which he was flying. The helicopter was flying slowly forward and downward as it gently flew towards the cliff and into the sea. Both occupants exited the helicopter before it sank, but the passenger did not survive the accident and recovery sequence. The cliff face was about 250 m ahead of where the helicopter entered the sea.

Lessons learnt

Pilots who are not qualified to fly at night need to know when daylight will end and plan to land well before then. Applying a buffer between the planned arrival time and the end of daylight time will allow the pilot to manage any unexpected delays and ensure they do not end up flying in environments without the necessary skills and experience.

A day-qualified pilot who comes to realise that the planned flight will not be completed well before the end of daylight and does nothing about it will put the flight at risk. Safety can be maintained by changing the flight plan in sufficient time to land well before dark, however inconvenient that may be. Simply hoping, or wishing to reach the destination sooner does not work. As a pilot 'pushes on', the number of safe alternatives in response to unforseen problems will diminish.

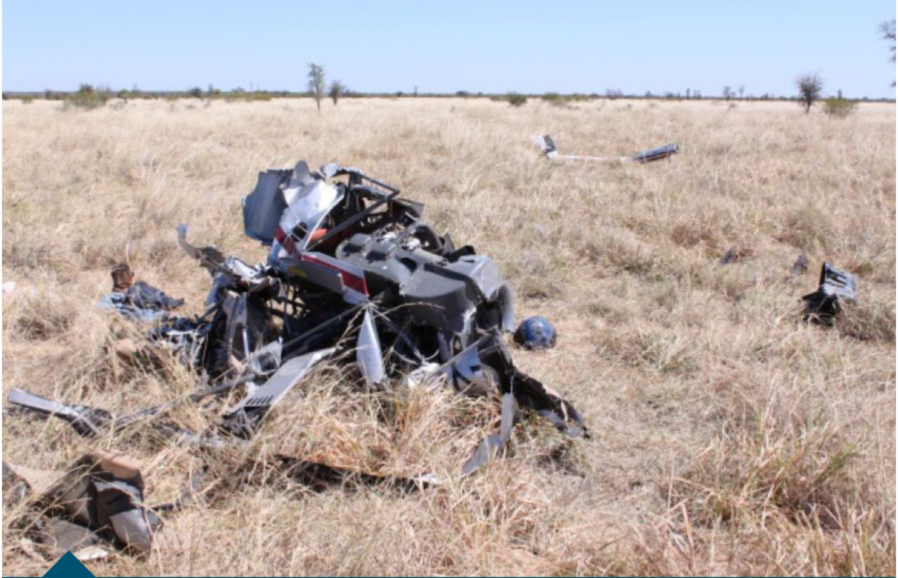
Flying within your limits

Pilots must operate within personal limits when flying in darker environments. Night ratings and instrument ratings entitle pilots to fly at night, but the skills needed to fly over a city at night are very different from the skills necessary to fly when there is nothing to be seen. In very dark environments, VMC is essentially the same as IMC in terms of available external visual information. The only real difference is that lights on the ground may be seen in VMC. In remote areas where there are no lights or ambient illumination, there is essentially no difference. Pilots cannot see the ground and have no external visual cues available to assist with their orientation.[v]

The required skills for safe flight on a dark night are not retained over time without practice. Although a pilot may be legally entitled to fly on a dark night based on recent flights over an urban area at night, the flight will probably be at a higher risk if the pilot does not have recent experience in a dark night environment. While night flight ratings allow flight to and from airstrips with minimal nearby lighting, many pilots rarely fly in that environment. Instrument flying is a complex skill and, once developed, needs to be maintained by regular practice.[vi] If a pilot does not have recent experience in dark night operations, it is preferable not to take off, fly or land in these conditions unless assisted by a suitably competent and qualified pilot.

Civil aviation regulations have specific requirements for night flight that include additional aircraft equipment, pilot's operational information, pilot qualifications, and pilot recency. These are explained in the Civil Aviation Advisory Publication 5.13-2 (*Night Visual Flight Rules rating*). Setting your own personal operational limitations that are more conservative than the minimum standards specified by regulations can be an effective method of risk reduction. Personal minima enable a pilot to assess personal risks more accurately and implement suitable methods to control those risks. A pilot who actively considers the risks that specifically apply to a planned flight is more likely to identify and apply measures to manage all the relevant risks.

Pre-flight planning for night VFR should include an assessment of visual conditions in addition to meteorological conditions. Consider what terrestrial lighting will be present—flying over national parks, farmland, deserts, and oceans can be particularly devoid of terrestrial lighting. Also consider celestial lighting, taking into account observed light levels at your departure point and forecast meteorological conditions en route and at your destination, as cloud can significantly reduce available moonlight and starlight. Although forward visibility may be excellent, there may be nothing to see.[v]



Robinson R22 helicopter accident site near Fitzroy Crossing, WA Source: ATSB

Not knowing which way is up, when there is nothing to see

Investigation AO-2011-087

Ten minutes after the end of daylight on 27 July 2011, the pilot of a Robinson R22 helicopter took off from Big Rock Dam stockyards on Brooking Springs station to fly back to the homestead, a flight that would normally take 30–40 minutes.

The route normally used flew over an area devoid of ground lighting, then over a limestone ridge to a plain, from which the lights of Fitzroy Crossing would come into view. At some point from there, the flight would be diverted to the Brooking Springs homestead.

The pilot took off at about sunset, and initially flew at normal cruising speed, but gradually slowed until the helicopter orbited over a dirt track before heading towards Fitzroy Crossing. Thirty minutes after the end of daylight, the helicopter flew very low and very slow, possibly flying by reference to terrain visible through illumination from the helicopter's landing lights. Ten minutes later, when it would have been fully dark, the helicopter climbed from about 100 ft to 600 ft above ground level, and turned towards the homestead. During the turn, the helicopter increased groundspeed from 5 to 95 knots, attained a rate of descent, and collided with the terrain. The pilot sustained fatal injuries during the accident.

The pilot had never received night flying training or obtained a Night Visual Flight Rules rating. The aircraft was equipped with suitable lighting for night flight, but it did not have the necessary instrumentation or other equipment necessary to enable a pilot to fly safely by night.

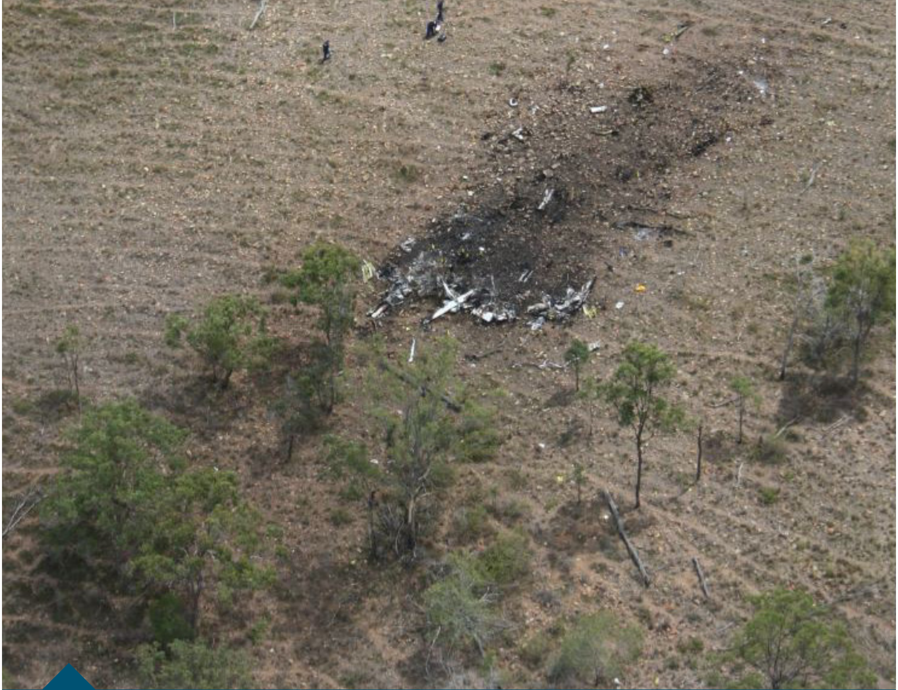
In the previous accident case study (AO-2011-051), the pilot retained control as the helicopter impacted terrain that the pilot was not aware of. In this accident it is likely that the pilot lost control of the helicopter due to spatial disorientation from insufficient visual reference to keep the helicopter the right way up.

Lessons learnt

Many things must be in place for a safe night flight to happen. Do not fly at night unless you are trained and qualified to do so and you know all the requirements and are able to apply them.

A flight that cannot be completed by nightfall should not even be started unless all the necessary requirements are in place to allow a safe night flight and landing.

In very dark conditions such as rural areas, the skills needed to fly an aircraft at night are vastly different to day VFR flight, and may even exceed the capabilities of some pilots trained in night VFR operations.



Piper Chieftain accident site near Raglan, Qld Source: ATSB

Loss of control without a visible horizon

Investigation AO-2006-001

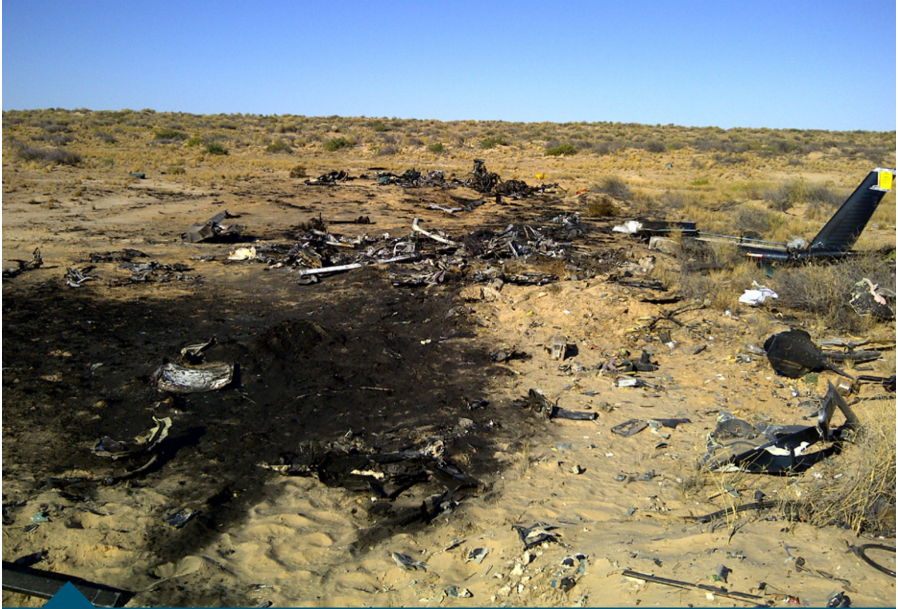
The pilot of a Piper Chieftain was experienced, with many flight hours and had been busy flying over the previous 2 years. However, he did not have much recent experience in night flight or instrument flight, and had only recently been endorsed on this aircraft type. All his previous multi-engine aircraft endorsements had been on lighter, slower, smaller aircraft with different handling characteristics.

On 25 October 2006, the pilot took off with two passengers from Emerald in Queensland to fly to Gladstone on the coast. The timing of the flight meant it would finish in darkness. The aircraft appears to have cruised normally at 9,000 ft. Twenty-five minutes after the end of daylight, however, when it was passing about 5,000 ft on descent, the rate of descent increased dramatically. Shortly after, the aircraft crashed in a turn at high speed.

The conditions were dark with cloud, and any light from the setting sun would initially have been behind the aircraft. The nature of the impact made it impossible to determine if there was anything wrong with the aircraft or its engines, or if the fuel supply to the engines had been compromised. However, the aircraft flew normally until it entered a spiral descent. Due to the dark conditions, once the aircraft diverged from its normal flight path, recovery could only have been achieved through sole reference to the flight instruments. Although flown by an experienced pilot, this would have been difficult given the lack of terrestrial and celestial lighting combined with the pilot's low currency on night or instrument flight and little experience on aircraft of this size or performance. These combined conditions may have been beyond the pilot's ability to maintain control of the aircraft.

Lessons learnt

A particular flight may meet all the necessary regulatory requirements, but when many different risk factors come into play together, it is more likely that an otherwise minor upset will compound with the existing risk factors, leading to an accident.



Twin Squirrel helicopter accident site, Lake Eyre, SA Source: ATSB

Nothing to see in the desert

Investigation AO-2011-102

In August 2011, the pilot of a Twin Squirrel AS355F2 helicopter and two film crew were travelling to various locations in the Lake Eyre region of South Australia for a television documentary. On the second day, they arrived at an island in the Cooper Creek inlet at about 1715 to meet and interview a tour group.

The pilot and film crew departed the island at about 1900. It was after last light and, while there was no low cloud or rain, it was a dark night. The moon had not risen and there was no visible horizon. Apart from the tour group's camp fire on the island, there was no other source of terrestrial lighting, and there would have been very little ambient illumination from any sources other than stars. Witnesses reported that the helicopter initially climbed vertically while moving rearwards. This was most likely to maintain a visual reference to the camp fire, which was the only available ground light source. The witnesses then observed the helicopter depart in an easterly then north-easterly direction. This was contrary to what they expected as they understood that the crew were returning to their accommodation at Muloorina Station, which was to the south.

The helicopter levelled off at 1,500 ft AMSL and then commenced a turn to the right. As the helicopter had initially travelled in the wrong direction, it is probable that the pilot engaged in programming a GPS for their journey to their accommodation during this turn. Twelve seconds after beginning the turn, the helicopter started descending with the bank angle increasing. Based on the GPS data and flight path estimations, it was calculated that the helicopter impacted terrain at about 1902, about 38 seconds after it started descending. Wreckage examination indicated that the helicopter impacted terrain in a 90° right-side low attitude.

The pilot had been flying for over 30 years as a commercial pilot with over 16,000 hours experience, mostly in helicopters. He also had a night VFR rating and had 483 night flying hours in total, but only 3.4 hours in the last 12 months, and 30 hours in the past 4 years. Although he had some instrument flight time, this was more than 30 years before the accident. As such, he probably did not have enough recent night flying experience nor the level of instrument proficiency at the time of the accident needed for the very dark conditions.

The ATSB investigation concluded that the pilot probably became spatially disoriented after initiating the right turn and did not recognise the descent and increasing bank angle in sufficient time to recover.

Lessons learnt

In very dark conditions, VMC essentially equates to IMC in terms of available external visual information. Pilots need to reassess their night flying experience, recency and proficiency before every night flight, taking into account the level of instrument flying required based on the level of darkness.

Any pilot can become spatially disoriented given the right conditions. Distractions and high workload can inadvertently remove attention away from monitoring instruments, reducing the chance of recognising spatial disorientation.

Illusions in the night

When very little can be seen, there is limited context to interpret what is actually being seen and so there is a greater potential to misinterpret what is seen. Distant, sparse illumination can invoke doubt—a single light could be a star or it could be a car, and concern about such doubt can increase the potential for disorientation. The ability to disregard or discount ambiguous information in favour of more certain information that provides more confidence can help mitigate the risk of pilot disorientation.

In the absence of visual information, a pilot's perception (or lack of perception) of movement obtained from their vestibular system (inner ear) can lead to spatial disorientation. Accidents that were probably associated with pilots experiencing spatial disorientation at night have involved pilots at all experience levels. Pilots flying in this environment appear to remain vulnerable to the risks associated with night visual flight throughout their flying career.[vii] The risks can be managed by remaining alert to vestibular-based illusions as a normal part of night visual operations, and having methods in place to cope with the illusions when they happen.

A pilot's situational awareness based on external visual cues at night can be reinforced by the use of all available information sources from inside and outside the cockpit, and being aware of confounding influences and illusions that can compromise situational awareness.

However, pilots also need to be aware that their ability to monitor instruments, and then understand and use that information to fly the aircraft, can be reduced by several psychological factors:

- High workload and distractions can result in a pilot scanning fewer instruments and checking each instrument less frequently.[viii] Not having an autopilot, especially in helicopters, can greatly increase pilot workload.
- When a pilot's attention is focussed on another task, they may not recognise, or take longer to recognise, an unusual instrument reading, even when they are looking directly at it.[ix]
- Misinterpretation of the attitude indicator, especially in times of high stress or workload, can occur when pilots mistakenly revert to trying to control the moving part (horizon indication) rather than the fixed aircraft symbol. Although more common in pilots with lower experience, experienced pilots can still make this type of error in emergency situations.[x]

- Fatigue can increase the risk of spatial disorientation, and it can lead to delayed response times as well as a range of pilot errors.[xi]

Two vestibular-based illusions particularly associated with night flying are the somatogravic and somatogyral illusions.

Somatogravic illusion

Any vehicle that accelerates will push a forward-facing occupant backward in their seat. This generates a vestibular sense that is very similar to the sensation of tilting back. In the absence of supporting visual cues, it is possible for pilots to mistake this vestibular sense when accelerating (such as for take-off) with a sense of a pitch-up change in attitude. This vestibular illusion, known as somatogravic illusion, is more pronounced with greater acceleration during the take-off run, a greater take-off speed, and particularly if the aircraft continues to accelerate after take-off where the absence of significant external visual cues can further amplify the illusion.

The risk of somatogravic illusion can be mitigated by pilots being aware of it and understanding it, and by effective use of flight instruments to control the aircraft in the seconds after take-off. This illusion is most prevalent and hazardous immediately after take-off in fixed wing aircraft, but can also occur when the aircraft is longitudinally accelerated.

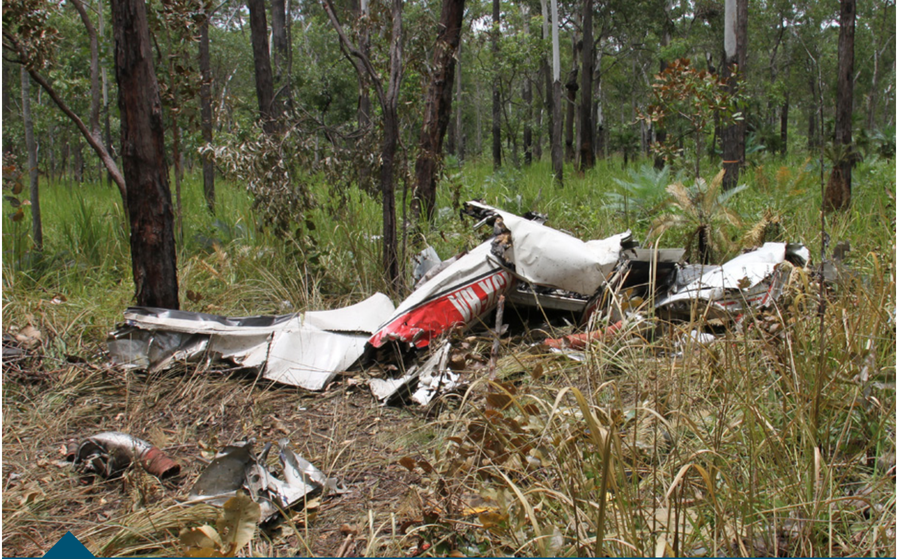
Somatogyral illusion

This illusion relates to a pilot's incorrect understanding of an aircraft's angle of bank. When the angle of bank is changed, the pilot's vestibular system will register any angular acceleration above a threshold level of activation. Once the aircraft is in a constant turn, the pilot's vestibular system will stop registering any input because there is no angular acceleration. In the absence of any other sensory information or vestibular input a pilot may experience a sensation that the aircraft is no longer turning.

This sensation is normally overridden by the visual system that is influenced by seeing the outside visual world rotating as the turn continues. However, in the absence of external visual cues, successful orientation relies on the use of the information available from the aircraft's flight instruments. The perceived conflict of information between the vestibular and the visual cues requires a pilot to disregard vestibular sensations in preference to flight by reference to the flight instruments alone.

If a roll movement occurs gradually, it may be below the level that a pilot can detect through the vestibular senses. The human threshold for detecting a short-duration roll movement (5 seconds or less) is about 2° per second, and for longer durations, it is about 0.5° per second.[xii] When flying, these sensory thresholds are often higher, particularly when a pilot's attention is directed elsewhere.[xiii] With limited or no external visual information, gentle rolls can continue unnoticed unless detected through the monitoring of instruments.

However, if noticed from instruments and corrected, as the return roll to straight flight often occurs faster and so is perceived by the vestibular senses, the pilot may end up with the sensation that the aircraft is now in a turn (in the opposite direction). This can also occur in longer turns when the initial sense of roll stops during the turn. Commonly known as ‘the leans’, this sensation will wear off in time each occasion it is experienced, but unless the aircraft is flown solely by instruments, it has the potential to disorientate the pilot.[vi]



Cessna 310R accident site on Bathurst Island, NT Source: ATSB

Take-off towards blackness

Investigation AO-2011-017

On 5 February 2011, a number of aircraft were chartered to return passengers from Darwin to two different Tiwi islands. One aircraft was a Cessna 310R. This aircraft flew from Darwin to Bathurst Island with five passengers who disembarked there. The single pilot then took off to the north-west to return to Darwin.

The terrain to the north-west of Bathurst Island aerodrome is flat and there is no ground lighting, only mangroves and eventually the sea. Daylight had ended about an hour before take-off, and the moon had set at about the same time. There was absolutely nothing to see outside the aircraft after it had passed the far end of the runway, and control could only be maintained by reference to the aircraft's flight instruments. This aircraft type normally accelerates from about 100 kt to 120 kt immediately after take-off as the landing gear is retracted.

The aircraft crashed at high speed into the mangroves about 1 km beyond the end of the runway, with the engines at a high power setting and the wings level. It looked as if the take-off and initial climb had been normal until the aircraft was controlled into descending flight instead of climbing flight, until it crashed.

The pilot had been flying as a commercial pilot for 3 years, and he had recently flown the same aircraft to the same location at night. There was nothing to indicate the pilot was not properly qualified, trained or competent, and there was nothing to indicate any pre-existing defect in the airframe, engines or flight instrumentation. The pilot had a command instrument rating.

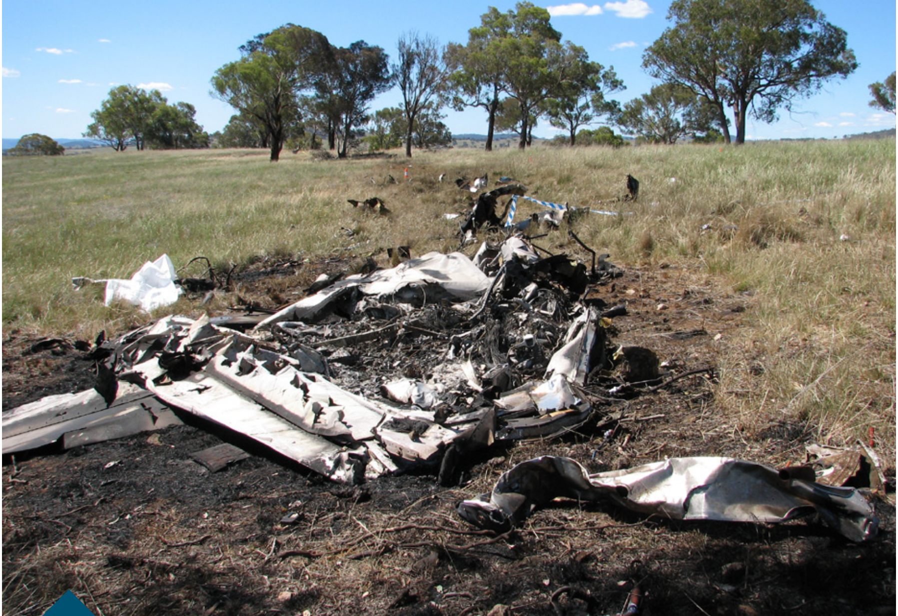
The pilot may have experienced somatogravic illusion that could have led him to believe that the aircraft was at a higher nose-up attitude, and he may have compensated for this illusion without sufficient reference to the flight instruments, particularly the attitude indicator. The pilot's perceived workload would have been high just after take-off, with a number of tasks to demand his attention away from monitoring the flight instruments to ensure that the aircraft continued to climb.

There was nothing to indicate the pilot was aware of the impending crash. This behaviour is consistent with the pilot becoming affected by sensory vestibular illusions without being aware of the fact.

Lessons learnt

Pilots who are flying without an external visible horizon need to be constantly prepared for illusions and perceptions that they may experience when no external visual cues are available. Pilots are more susceptible to such illusions during high workload phases of a flight such as after take-off, when they are reconfiguring the aircraft, intercepting outbound track and communicating over the radio. While all this is going on, safety can only be maintained if the key task of aviating takes priority; everything else is subsidiary. Aviating includes always applying enough attention to the instruments to keep the aircraft flying in the intended direction and at the appropriate speed and attitude.

Safe flight in night visual conditions requires a very different approach to flight management compared with flight in day visual conditions. Pilots who usually fly by day will be able to fly more safely at night if they make a conscious decision to fly in a different manner to suit the needs of night flight. This requires a conscious decision to fly by instruments at certain phases of a night flight. This approach should increase the likelihood of pilots being prepared for the possibility of becoming affected by vestibular illusions, and to have plans ready to manage them if they happen.



Piper Chieftain accident site near Bathurst, NSW Source: ATSB

Bank after take-off

Investigation AO-2008-076

A Piper Chieftain was being flown by its owner with three passengers from Moorabbin in the south of Victoria to Port Macquarie, New South Wales. The aircraft had stopped at Bathurst to refuel, and took off again at about 20 minutes after the end of daylight, with cloud and light rain in the area.

Shortly after take-off, the Chieftain crashed with a high power setting and a high forward speed, with the right wing low, about 3 km from the airport. The accident site was to the right of the extended runway centreline and the aircraft had turned about 180° from the take-off direction. The occupants did not survive the accident.

The pilot held endorsements to fly a number of multi-engine aircraft, and held a command instrument rating that entitled him to conduct the flight, and there was no indication of any aircraft malfunction. Control of the aircraft for the period shortly after take-off would have been broadly similar for either a flight conducted under instrument flight rules or flight under night visual flight rules.

The flight path could not be accurately determined, but it was consistent with a right turn being started in the expected location after take-off to fly to the intended destination, but with the turn not being stopped, continuing past the desired heading and the bank angle possibly becoming steeper until the aircraft crashed. The pilot may have experienced somatogyral illusion and did not notice the aircraft angle of bank.

There was nothing to indicate the pilot was aware of the impending crash. This behaviour is consistent with the pilot becoming affected by sensory vestibular illusions without being aware of the fact.

Lessons learnt

Nothing seemed to be wrong with this aircraft or its pilot, yet it still crashed. The risk of loss of control in a dark environment shortly after take-off can be mitigated by being prepared for vestibular illusions, using the flight instruments to initially maintain aircraft control, and making decisions pre-flight so that workload shortly after take-off is not increased as the pilot works out what to do next. This approach allows the pilot to apply more attention to maintaining control of the aircraft. Similarly, if the aircraft has a reliable autopilot, early engagement separates a pilot's vestibular perceptions from the aircraft's control, reduces pilot workload, and allows the pilot to concentrate more on the flight instruments.

Conclusion

Data from accidents associated with the risks from night visual flight indicate that they can affect pilots at all stages of experience or qualification, in any type of aircraft. Pilots do not become immune from these risks as experience increases. The harsh outcomes of night accidents can be seen in the photos throughout this booklet. Three in four accidents involving visual flight at night have fatal outcomes.

The risks associated with night visual flying cannot be avoided—they must be understood, identified and managed. Control problems can be identified by cross-referencing information from flight instruments.They can be managed by focussing on aircraft control and using the most reliable information source. The risks from controlled flight into terrain can be managed by calculating LSALTs, knowing terrain elevation during the cruise, and knowing where hills and obstacles are in the circuit area during take-off and landing. The knowledge can be obtained by thorough pre-flight preparation, by accurate horizontal navigation to know where you are, and accurate vertical navigation to know your distance from obstacles below. Everything is more difficult to see at night. Terrain and obstacles are often not illuminated, and it is more difficult to detect cloud. When it is time to fly low enough to land, a detailed plan of how to avoid all obstacles along the expected flightpath is necessary to maintain safety.

Visual night flying is sufficiently different from both day visual flight and (except in very dark conditions) instrument flight that it needs to be treated as a separate skill in its own right. It requires a disciplined integration of two very different skill sets of instrument flight and degraded visual flight to develop sufficient situational awareness to enable safe flight. To maintain these skills, a pilot needs to have enough recent experience and practice. When flying over land or oceans without light sources, on dark nights with no visible moon, visual flight at night is essentially the same as instrument flight.

Before every night flight, systematically assess the potential for the flight to encounter dark night conditions by considering weather conditions, celestial illumination and available terrestrial lighting. Only fly in environments that do not exceed your capabilities. In very dark conditions, consider following instrument procedures if you are rated or avoid areas with limited terrestrial lighting if you are not.[xiv]

In night visual flight, there is more chance of any pilot becoming influenced by illusions. Have a coping strategy in place, and be prepared to revert to instrument flight to recover from any spatial disorientation.

Further reading

Night Visual Flight Rules rating
Civil Aviation Safety Authority (CASA)
Civil Aviation Advisory Publication 5.13-2(0), (December 2006)
www.casa.gov.au/wcmswr/_assets/main/download/caaps/ops/5_13_2.pdf

Controlled flight into terrain in visual conditions at night: Nighttime visual flight operations are resulting in avoidable accidents
National Transportation Safety Board (NTSB)
Safety Alert SA 013 (2008)
www.ntsb.gov/doclib/safetyalerts/SA_013.pdf

Reduced visual references require vigilance: Preparation and proficiency for visual flight with reduced visual references
National Transportation Safety Board (NTSB)
Safety Alert SA 020 (2006)
www.ntsb.gov/doclib/safetyalerts/SA_020.pdf

An overview of spatial disorientation as a factor in aviation accidents and incidents
Australian Transport Safety Bureau (ATSB)
Aviation Research and Analysis Report B2007/0063 (2007)
www.atsb.gov.au/publications/2007/b20070063.aspx

Dark night take-off accidents in Australia
Australian Transport Safety Bureau (ATSB)
Aviation Research and Analysis Report (1995)
www.atsb.gov.au/publications/1995/dark-night-take-off-accidents-in-australia.aspx

References

i Flight Safety Foundation (1998). Killers in Aviation: FSF Task Force presents facts about approach –and-landing and controlled-flight-into-terrain accidents. *Flight Safety Digest*, *vol. 17 (no. 11-12) & vol. 18 (no. 1-2).*

ii Bennett, C. T. & Schwirzke, M. (1992). Analysis of accidents during instrument approaches. *Aviation, Space, and Environmental Medicine*, April, 253-261.

iii Li, G & Baker, S.P. (1999) Correlates of Pilot Fatality in General Aviation Crashes, *Aviation, Space, and Environmental Medicine, 70*, 305-309.
Price, J.M. & Groff, L.S. (2005) Risk Factors for Fatal General Aviation Accidents in Degraded Visual Conditions, *Proceedings of the 13th International Symposium on Aviation Psychology*, 469-474.

iv Transport Canada (1997). *A study into the safety of flight in marginal visibility*. Transport Canada.

v Civil Aviation Authority (UK) (2007). *Helicopter flight in degraded visual conditions*, Paper 2007/03, Safety Regulation Group.

vi Newman, D. G. (2007). *An overview of spatial disorientation as a factor in aviation accidents and incidents*. ATSB Aviation Research and Analysis Report B2007/0063.

vii Holmes, S., Bunting, A., Brown, D., Hiatt, K., Braithwaite, M., & Harrigan, M. (2003). Survey of spatial disorientation in military pilots and navigators. *Aviation, Space, and Environmental Medicine, 74*, 957-965.

viii Staal, M. A. 2004, *Stress, cognition, and human performance: A literature review and conceptual framework,* National Aeronautics and Space Administration Technical Memorandum NASA/TM 2004-212824.

ix Casner, S.M., Geven, R.W. & Williams, R.T. (2013). The effectiveness of airline pilot training for abnormal events. *Human Factors, 55*, pp.477-485.
Chabris, C., & Simons, D. (2010). *The invisible gorilla and other ways our intuition deceives us*, HarperCollins: Hammersmith UK.

x Bramble, W.J. (2008). *Spatial disorientation accidents in large commercial airplanes: Case studies and countermeasures*, paper presented at the Flight Safety Foundation's 61st International Air Safety Summit, Honolulu, Hawaii.

xi Gawron, V. (2004). Psychological factors, in FH Previc & WR Ercoline (Eds.) *Spatial disorientation in aviation*, Lexington MA, American Institute of Aeronautics and Astronautics, pp. 145-195.
Battelle Memorial Institute (1998). *An overview of the scientific literature concerning fatigue, sleep, and the circadian cycle*, Report prepared for the Office of the Chief Scientific and Technical Advisor for Human Factors, Federal Aviation Administration.

xii Cheung, B. (2004). Nonvisual spatial orientation mechanisms, in FH Previc & WR Ercoline (Eds.) *Spatial disorientation in aviation*, Lexington MA, American Institute of Aeronautics and Astronautics, pp. 37-94.

xiii Benson, A.J. (1999). Spatial disorientation – general aspects, in J Ernsting, AN Nicholson & DJ Rainford (Eds.), *Aviation Medicine* (3rd ed.), Oxford: Butterworth Heinemann, pp. 419-436.

xiv National Transportation Safety Board (NTSB) (2006) *Reduced visual references require vigilance: Preparation and proficiency for visual flight with reduced visual references* Safety Alert SA 020.

Australian Transport Safety Bureau

24 Hours 1800 020 616
Web www.atsb.gov.au
Twitter @ATSBinfo
Email atsbinfo@atsb.gov.au