What killed JFK Jr?

Lessons for VFR pilots.

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NTSB Identification: NYC99MA178

Accident occurred: JUL-16-99

at VINEYARD HAVEN, MA

Aircraft: Piper PA-32-R301

Registration: N9253N

Injuries: 3 Fatal

Staff writers

AT 9.41PM ON FRIDAY 16 July a Piper Saratoga crashed off the coast of Martha's Vineyard, Massachusetts. Onboard were three of America's most recognised and admired celebrities – John F. Kennedy Jr, his wife Carolyn, and her sister Lauren Bessette. All were killed on impact.

Within 24 hours the tragedy was the lead story in newspapers and on televisions around the world. The ensuing speculation and commentary centred on the hazards of visual flight at night and the pros and cons of light aircraft travel.

Was this another case of a VFR pilot losing control after flying into instrument meteorological conditions (IMC)? Did Kennedy suffer an incapacitating medical event before the crash? Could he have experienced an instrument failure? The investigation into the accident by the US National Transportation Safety Board (NTSB) is continuing. While the preliminary report was released shortly after the accident, at this point, the NTSB has not drawn any conclusions about the factors involved in the causes of the accident. Even after the final report is released, it's possible that some questions will remain unanswered.

However, the fact that this issue has been the subject of widespread speculation both in the general community and, more importantly, among private pilots, suggests that a discussion about the challenges of visual flight at night is both timely and pertinent.

Discounting the tragic outcome, it appears there was nothing terribly remarkable about Kennedy's flight. According to the NTSB's preliminary report, night visual meteorological conditions prevailed for the flight which originated at Essex County Airport, New Jersey, and was intended to continue to Martha's Vineyard Airport to drop off one passenger before continuing to Hyannis, Massachusetts.

Conditions: The Hyannis forecast was for winds from 230 degrees at 10kt, visibility 6 miles, and sky clear; with winds becoming 280 degrees at 8kt. No AIRMETs or SIGMETs were issued for the route of the flight, and all airports along the route reported visual meteorological conditions.

According to October 1999 issue of *AOPA Pilot*, the magazine published by the US Aircraft Owners and Pilots Association, the 9.53pm METAR from Martha's Vineyard suggested good VFR conditions at the airport. Visibility was 10 miles, and the wind was 10kt from 240 degrees.

No cloud was forecast and "the temperature-dewpoint spread was six degrees – outside the normal range for fog". However, nearby boaters around the time of the crash reported poor visibility due to a heat-wave haze which was affecting much of the east coast of the US. This was substantiated by other pilots in the area who also reported reduced visibility.

The flight from Essex County to Martha's Vineyard and on to the family compound at Hyannis was a familiar one for Kennedy who gained his private pilot's licence on 22 April 1998. Kennedy had trained in Piper Warriors and Arrows before purchasing the 1995-model PA-32R-301 Saratoga in April this year. At the time of the accident he had logged around 300 hours of flight time and is also reported to have started training for an instrument rating – this has not been confirmed by the NTSB.

NTSB preliminary report: Kennedy told the Essex County Airport tower controller that he would be proceeding north of the Teterboro Airport, and then eastbound. There is no record of any further communications between Kennedy and air traffic control. The NTSB preliminary report says that radar data shows the aircraft passed north of the Teterboro Airport, and then continued northeast along the Connecticut coastline at 5,600ft, before beginning to cross Rhode Island Sound near Point Judith, Rhode Island.

A review by the NTSB of the radar data revealed that the aircraft began a descent from 5,600ft about 34 miles from Martha's Vineyard. The airspeed was about 160kt, and the rate of descent was about 700 feet per minute (fpm).

At about 2,300ft, the aircraft began a turn to the right and climbed back to 2,600ft. It remained at 2,600ft for about one minute while tracking on a south-easterly heading. The aircraft then started another descent of about 700fpm and a left turn back to the east. Thirty seconds into the manoeuvre, the aircraft started another turn to the right and entered a rate of descent that exceeded 4,700fpm.

The altitude of the last recorded target was 1,100ft. It was 9.40pm on Friday.

The following Tuesday the wreckage of the Saratoga was located in 116ft of water, about 1/4 of a mile north of the 1,100ft radar position.

The engine, propeller hub and blades, and entire tail section were recovered. The entire span of both main wings' spars were also recovered, as well as 75 per cent of the fuselage/cabin area, 80 per cent of the left wing, and 60 per cent of the right wing.

The NTSB's preliminary report states that "examination of the wreckage revealed no evidence of an in-flight structural failure or fire. The right wing structure exhibited greater deformation than the left. Two of the three landing gear actuators were recovered and found in the fully retracted position.

"There was no evidence of conditions found during examinations that would have prevented either the engine or propeller from operating. Visual inspection of the propeller indicated the presence of rotational damage. Detailed examination of the navigation and communication radios, autopilot and vacuum systems are planned for a later date."

Disorientation? Speculation that Kennedy's fatal accident was caused by disorientation and subsequent loss of control is based on the fact that the flight was made over featureless terrain at night and the possibility that the horizon could have been obscured by haze. While there is not enough evidence to suggest that spatial disorientation or visual illusions played a part in the events of 16 July, the accident has caused some aviators to suggest there is insufficient awareness among VFR pilots about the hazards of night flight.

"In the US in 1997, more than 80 per cent of fatal GA weather-related accidents were caused by visual flight into IMC."

"Regardless of what caused the Kennedy accident," wrote columnist Barry Schiff in the September 1999 issue of *AOPA Pilot*, "speculation about it seems to indicate that flight training should place greater emphasis on the imperative need for VFR pilots to maintain visual reference to the ground or to a horizon during VFR night operations. If a pilot departs a shoreline or heads into the desert and discovers that these references do not exist, he or she should have been trained to recognize the need to reverse course immediately and return to those visual references left behind."

"In some cases, flying at night without sufficient references can be more hazardous than inadvertently flying into cloud," he continues. "Cloud penetration usually triggers a conditioned response bred of good training. The VFR pilot knows to reverse course and exit the cloud without hesitation. Losing visual reference at night does not stimulate such decisiveness, because the loss only develops more gradually."

In the US in 1997, more than 80 per cent of fatal GA weather-related accidents were caused by visual flight into IMC. The fatal accident rate was almost three times higher at night in IMC than during day VFR.

In Australia during the 1990s 26 fatal accidents have been attributed to loss of control by VFR pilots flying into IMC. More than a quarter of those occurred at night.

John F. Kennedy's death was tragic. But there is one positive outcome that may come from the accident: greater awareness among visual pilots about the hazards of night VFR.

THE LAST 8 MINUTES

9:33pm

The aircraft begins a descent from 5,600ft about 34 miles from Martha's Vineyard. Radar data indicates the airspeed is about 160kt and the rate of descent is 700fpm.

9:38:20

At about 2,300ft the aircaft begins a turn to the right and climbs back to 2,600ft.

9:39:00

The aircraft remains at 2,600ft for about one minute while tracking on a southeasterly heading.

9:40:00

The aircaft starts a descent of about 700fpm, and makes a left turn back to the east.

9:40:30

Thirty seconds into the manoeuvre, the aircaft starts another turn to the right and enters a rate of descent exceeding 4,700fpm.

9:41:00

The aircaft crashes into the Atlantic, approximately seven-and-a-half miles southwest of Gay Head, Martha's Vineyard, Massachusetts.

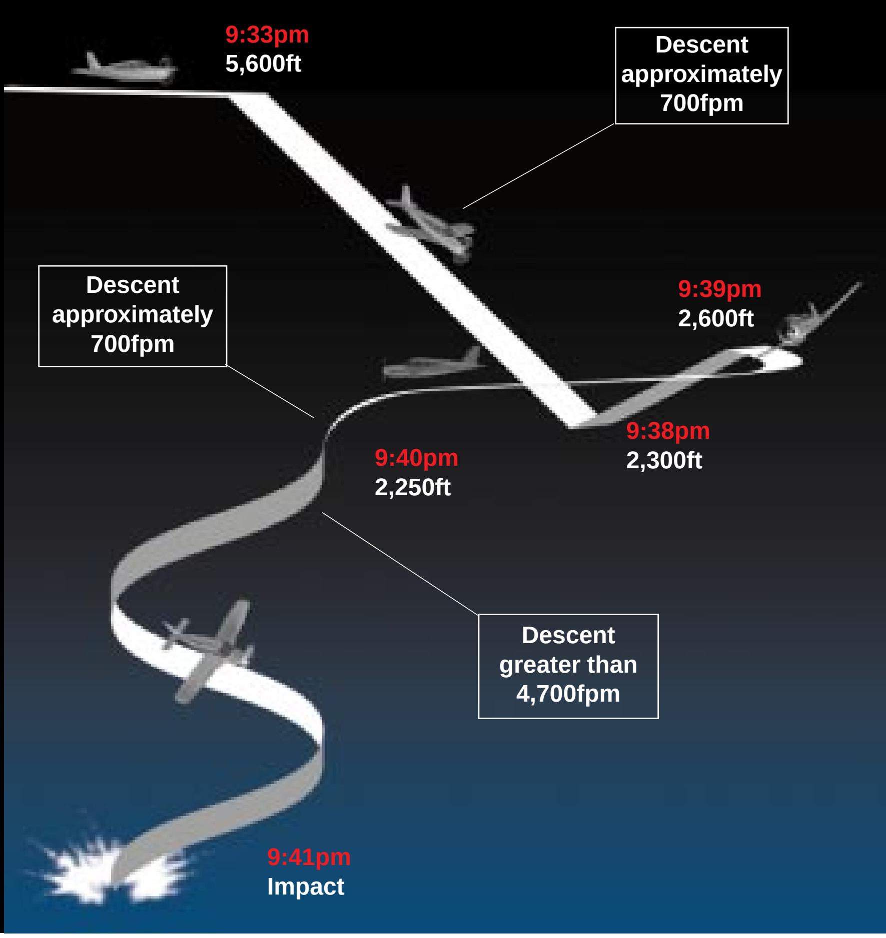

ILLUSTRATION: P. MARKMANN

The hazards of night flight

Kennedy's Saratoga was equipped with a stormscope, three-axis autopilot and GPS.

FLYING AT NIGHT IS IN MANY respects more challenging than day VFR flight, for a variety of reasons. Chief among these is the lack of good-quality outside visual cues and the consequent increased risk of visual illusions and spatial disorientation.

There are many more hazards associated with night flight apart from the graveyard spiral, and JFK Jr's accident serves as a timely opportunity for reviewing these. As a pilot, the more you know and understand about these hazards, the safer you are likely to be at night.

Human beings are not designed for aerial operations, either by day or by night. We can only achieve this by the use of technology and training. Our physiological limitations become very evident under certain flight conditions, and the night environment is perhaps the most significant.

Night flying involves operating an aircraft with much poorer outside visual references than are available during the day. For that reason, our normal ability to orientate ourselves in space can become impaired, with potentially catastrophic consequences. Very strong illusions can result, either visually-based or balance organ-based.

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The temptation to respond to these illusions can be incredibly powerful, but loss of control of the aircraft can readily occur if this is allowed to happen.

Which way is up? How do we orientate ourselves? How do we know which way is up and what is happening around us? Under normal conditions, we rely heavily on the combined efforts of three major body systems: the eyes, the inner ear or vestibular system (balance organs) and the proprioceptive (seat-of-the-pants, or movement sensing) system. Of these three systems, the eyes account for the vast majority of orientation information (approximately 80 per cent). The other two account equally for the remainder.

The visual system is thus a very powerful orientation system. During the day, the eye processes an incredible amount of information. Peripheral vision constantly provides input to the brain of where the horizon is, and whether things are moving or not. Central vision gives very precise information about what you are looking at, be it the distant horizon, ground features or aircraft instruments.

The balance organs, comprising the

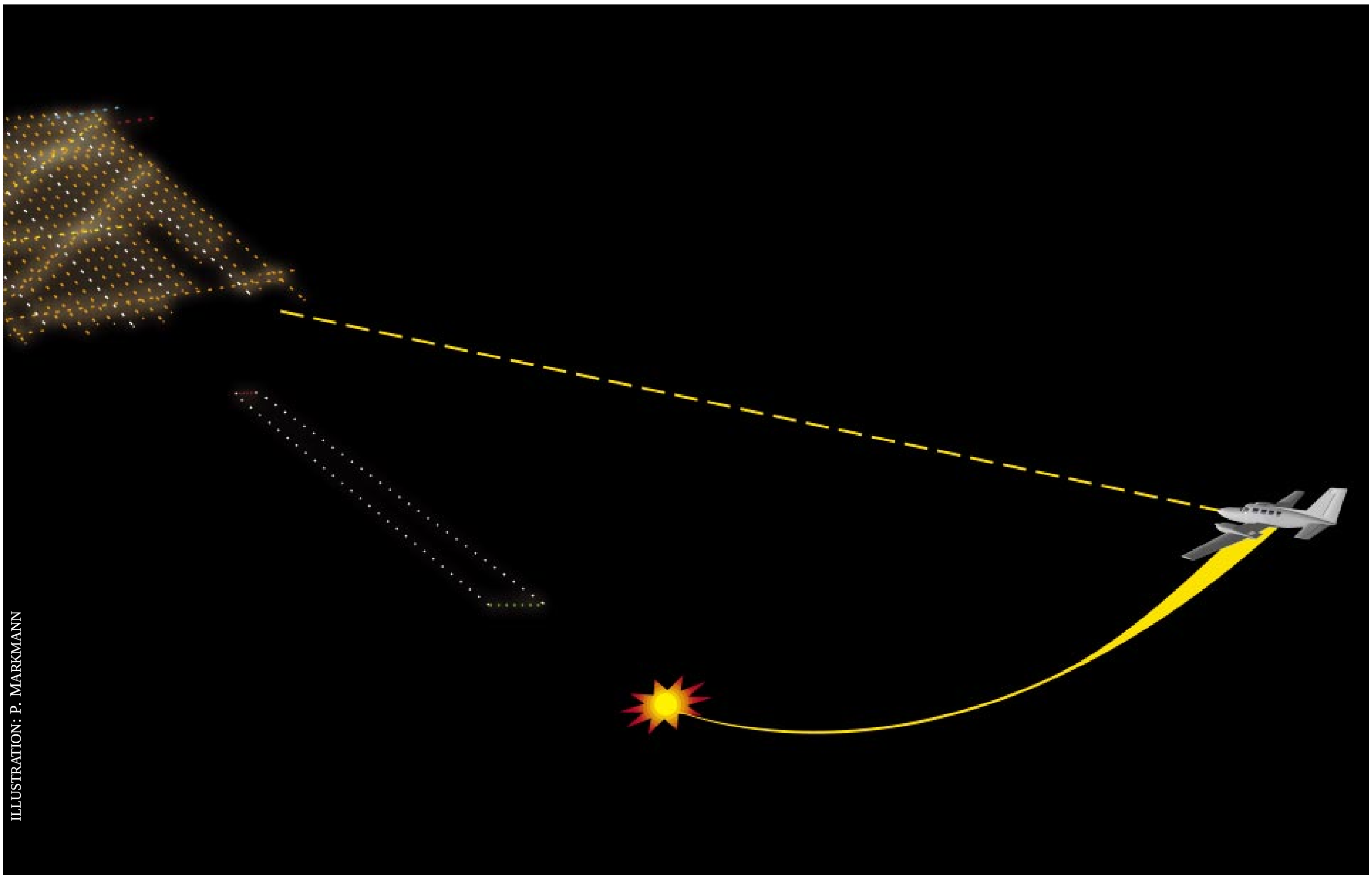


ILLUSTRATION: P. MARKMANN

Black hole illusion: The pilot on approach to an airfield at night with few surrounding lights gets the false impression of being too high. The tendancy is to fly an approach that is too low, with the danger of undershooting.

semicircular canals and the otolith organs, are located in each inner ear. They accurately tell the brain what angular (rotation) and/or linear acceleration the body is being subjected to. When you turn your head around to look behind you, the semicircular canals tell the brain that the head is moving. The otoliths constantly tell the brain that it is at 1G, or that you are accelerating down the runway on the take-off roll.

In reality, humans have no absolute sense of where they are. Our orientation system is designed to tell us where we are in relation to something else. Humans orientate themselves with respect to a horizontal feature (the horizon or Earth's surface) and a vertical feature (the force of gravity).

Under normal conditions, we can maintain a constantly updated, very accurate sense of our position or motion relative to these two features. This works well when you consider that we have evolved to become fairly successful terrestrial creatures operating in a 1G environment.

However, when we take to the sky and go flying, we can change the goalposts significantly. We can operate independently of the horizon and Earth's surface, and we can change the force of gravity that we are subjected to. Our orientation mechanisms have not evolved at the same rate as aerospace technology, yet spatial disorientation is a frequent phenomenon in the flight environment.

> **"The United States Navy has reported that between 1980 and 1989, some 112 major aircraft accidents involved spatial disorientation of the crew."**

Spatial disorientation: What is spatial disorientation? It is defined as the failure to correctly sense your (or your aircraft's) position, attitude or motion relative to the Earth's surface and the force of gravity. Spatial disorientation is not always recognised. If pilots realise that they are disoriented they are then in a position to at least attempt to reorient themselves.

If they do not realise that they are disoriented (unrecognised spatial disorientation) they are far more likely to have an accident, as no attempt is made to rectify the abnormal situation. Indeed, even when a pilot realises that he is suffering the effects of spatial disorientation, recovery can still be difficult.

Spatial disorientation is a well-recognised cause of aviation accidents. The United States Navy has reported that between 1980 and 1989, some 112 major aircraft accidents involved spatial disorientation of the crew. The United States Air Force for the same period reported that spatial disorientation led to 270 major aircraft mishaps.

The problem is by no means limited to military aviation. Spatial disorientation is a very real concern in the civilian aviation community. In a 1994 report, the US Federal Aviation Administration (FAA) found that many of the 1,000 domestic aviation accidents attributed to human error were caused by spatial disorientation.

Helicopter operations are also susceptible to spatial disorientation. Between 1987 and 1995, 291 major helicopter accidents in the United States Army were attributed to spatial disorientation. These accidents accounted for the loss of 110 lives and US$468,000,000 in material costs.

Spatial disorientation is therefore a relatively common experience for both fixed-wing and rotary-wing aircrew. The reported career incidence of spatial disorientation in aircrew is in the range of 90 to 100 per cent. Of perhaps greater significance is the finding that experienced pilots are not immune from the effects of spatial disorientation.

It is a commonly held view that disorientation affects the junior, inexperienced pilot – this is not the case. Analysis of accidents involving spatial disorientation suggests that even highly proficient senior pilots are susceptible to the effects of spatial disorientation.

The fundamental problem is that in the absence of good external visual cues, our sense of orientation is provided by input from the seat-of-the-pants and the inner ear balance organs. This 20 per cent contribution is far less reliable than the more dominant visual system, and as such is far more likely to give you a false representation of what is going on. This is exactly the situation at night.

The outside visual world is dark and featureless. While there are often lights on the ground, and in some cases moonlight available, the levels of light are generally low and will be highly variable in quality, frequency and intensity. The higher you fly, the darker it becomes as you put a greater distance between you and any ground-based lighting. With poor visual cues, you are far more likely to become disoriented.

Visual illusions at night: Your eyes still work at night, obviously, but they are far less effective. In the absence of a good set of outside visual references, your eyes will concentrate on the few visual cues that are available. As such, there are a number of visual illusions that can occur at night. Because the visual system is so dominant (remember it accounts for 80 per cent of our orientation information) these illusions can be particularly powerful and quickly lead to disorientation and loss of control.

One of the common forms of night flying illusion is ground light confusion. Imagine a scenario where you are flying on a clear night over an area dotted with farmhouses. The lights at random intervals from the ground can be confused with the stars above. Which way is up? A pilot can convince himself that the farmhouse lights are stars and vice versa. Military aircraft have been known to fly inverted with the pilot completely happy that they are up the right way. The experience of not knowing which is the ground and which is the sky is very disconcerting.

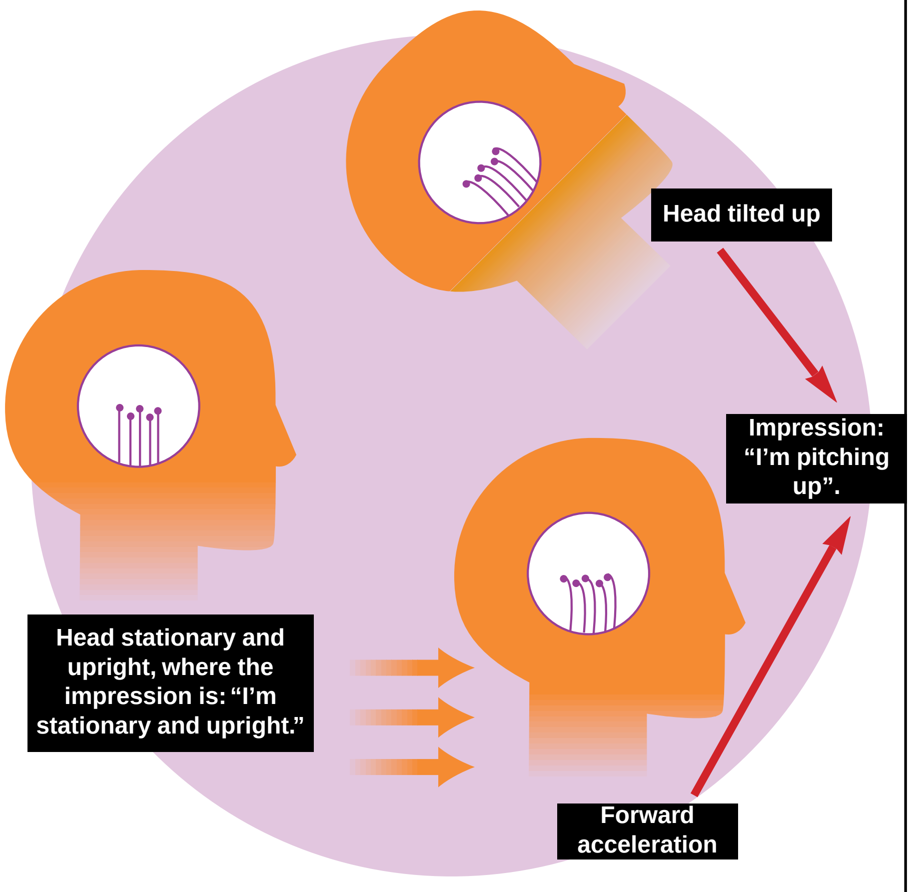
The black hole illusion can occur during approach to an airfield at night, when there are few (if any) lights on the ground between you and the threshold. This area appears to the pilot as a black hole. The pilot unwittingly flies a lower approach than appropriate, as if landing in the black hole. The obvious endpoint to this illusion is landing short of the runway, or hitting an unseen obstacle such as rising terrain. In most cases the undershoot becomes apparent and the aircraft is recovered and landed, but there is clearly little margin for error in such circumstances.

Yet another night visual illusion is the autokinesis phenomenon. Here, a single point source of light appears to move at random around the visual field. It gives the impression that the light source is moving when in reality it is fixed in place. The explanation for this is that your eyes are continually moving, in order to expose different parts of the retina to the incoming light. The rods and cones in the retina that turn light into an electrical nerve signal to the brain contain photopigments that react to light.

If the eye remains perfectly still, a given number of cones, for instance, will be doing all the work. They will eventually run out of photopigments and will no longer generate a signal to the brain. In effect, the eye stops working. To prevent this, the eye is constantly adjusted so that fresh cones are brought into the picture (so to speak) while other cones regenerate their photopigments. During the day, when the visual field is rich with detail and colour, these eye movements are not apparent to the individual.

However, at night when the only thing to look at is a single point source of light, these eye movements give the individual the impression that the light is moving, when in fact it is the eyes that are moving. The autoki-

The somatogravic illusion



As an aeroplane accelerates forward after take-off, the somatogravic illusion results in an overwhelming sensation of pitching to a high-nose attitude. The illusion is produced by the otolith organs in your ears which sense orientation.

Set your own standards

When are you too tired to conduct a safe flight? How do you judge if you are too stressed? Do you have sufficient experience in the aircraft type you intend to fly? Personal minimums checklists are an easy way for pilots to determine when they should and should not fly.

A personal minimums checklist is a tool which is tailored to your level of skill, knowledge and ability. Checklist items help you control and manage risk by quickly evaluating the internal and external pressures affecting flight safety. CASA's personal minimums checklist uses four categories, each with a number of topics where you, the pilot, set the minimum conditions under which you feel comfortable conducting a flight.

Items to consider include:

Pilot

- Experience/Recency (such as take-offs/landings, hours in make/model, instrument approaches and more)
- Physical condition (including sleep, food and water, alcohol and drugs/medication consumption in the last 24 hours and more)

Aircraft

- Fuel reserves (cross-country)
- Experience on type
- Aircraft performance
- Aircraft equipment

Environment

- Airport conditions
- Weather
- Weather for VFR
- Weather for IFR

External pressures

- Trip planning
- Diversion or cancellation alternate plans
- Personal equipment

Personal minimums checklists should be used before every flight – you may be surprised how a quick glance before flight increases your awareness of the pressures (some of which are very subtle) which can affect your flying.

As a guide, be wary if you have an item that's marginal in any single risk factor category. If you are exceeding any of your personal minimums in two or more of the above categories, don't go! Pressures which seem negligible on the ground can easily get out of control in the air.

CASA has personal minimums checklists (for individuals) and kits (for flying schools/organisations) available free of charge. To order, call 131 757 and ask for extension 1375.

nesis phenomenon has led to aircraft attempting to formate on a star, thinking it was another aircraft.

Vestibular illusions: In the absence of good visual cues, the information from the vestibular system (balance organs) can be potentially misleading. There are a number of vestibular illusions, but we'll examine only the more important ones.

The somatogravic illusion is also known as the dark night take-off or pitch-up illusion. The typical scenario is an aircraft on departure, accelerating down the runway. It rotates, and shortly after is observed to pitch forward and fly at full power into the upwind threshold of the runway.

Why does this happen? The otoliths tell the brain that acceleration down the runway is occurring. In the absence of good visual cues, the brain interprets this as pitching up, made worse by aircraft rotation. The pilot, not wanting to stall at low-level, instinctively pitches forward and flies into the ground. The whole sequence can take less than a minute.

Importantly, you don't need to be flying an afterburning fighter aircraft to get this illusion.

The next time you fly as a passenger in a commercial jet, close your eyes during the take-off roll and see if you get the sense of pitching up. It is a very powerful sensation, and has led to the loss of many aircraft, both civil and military.

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The graveyard spin or spiral affects the semicircular canals. Again, this occurs in the absence of good visual cues. The semicircular canals are designed to register angular acceleration, but only if it exceeds a certain threshold (approx $2°s^2$). A few unintentional degrees of bank (with the pilot head-down in the cockpit, for instance) leads to a spiral descent.

If this descent occurs at a sub-threshold rate of turn, or if constant velocity is reached, then the canals will not detect it. With no visual reference to tell it otherwise, the brain believes that it is still straight and level. If the pilot checks the instruments and realises what is happening and recovers to actual straight and level flight, the canals will almost certainly be given a big stimulus and register the angular acceleration as the aircraft recovers.

The canals then give the temporary sensation of a turn in the opposite direction, often accompanied by a short-lived series of flicking eye movements which makes scanning the instruments difficult. The desire to then re-enter the original turn is very strong as this will cancel out the false sense of rotation. Given the difficulty in seeing, re-entering the turn is an easy thing to do. Very quickly the pilot can get into a vicious cycle of turn, recover, turn, recover until ground impact occurs.

The leans is a similar illusion, and is the most common example of disorientation. In this situation, the pilot recovers from a few degrees of unintentional bank, thus giving the canals their first input. Having recovered, the pilot now feels the sensation of bank in the other direction. To resolve the conflict, the pilot leans in the direction of the original turn, while flying straight and level.

Prevention of disorientation: One way of preventing disorientation is to be aware of the many potential illusions and the situations in which they can occur. Pre-flight preparation is very important. For instance, if you are going to take-off at night, remember the dark night take-off illusion. At least that way you'll be prepared for it if it happens.

You should only fly when you are physically and mentally fit. Flying with a cold will affect your inner ear balance organs, making disorientation more likely to occur. The same can be said for alcohol.

If you do get disoriented, what should you do? The answer is to believe your instruments – they do not suffer the same limitations that you do.

Clearly proficiency with instrument flight is essential. If disorientation occurs, get on your instruments and make them read straight and level (despite what your head might be telling you) until the disorientating sensation has gone. If necessary (and if possible), hand over control to another pilot.

Flying at night can be a rewarding experience, and can be done safely if you are aware of the unique hazards associated with it.

Article researched and written by James Ostinga, Mark Wolff, David Newman, and Sue White.

Not to be confused with a spin, which occurs when one or both wings are stalled, a spiral dive is a steep descending turn – neither wing is stalled and the airspeed and rate of descent is high. The correct recovery from a spiral dive is to reduce power, roll the wings level, and gently raise the nose.

Anatomy of a graveyard spiral

Stanley N. Roscoe

IN THE PARLANCE OF FLIGHT instructors and flight researchers, the term "graveyard spiral" refers to any high-speed spiral dive, as distinguished from a "graveyard spin" in which the aircraft is actually stalled at a low airspeed. A pilot can enter a graveyard spiral in many different ways, but most often the entry is subtle rather than violent. The spiral dive typically follows a gentle, unnoticed entry into a banked attitude below the pilot's threshold for angular acceleration.

The sensory nerves in the semicircular canals of the inner ear are the receptors that provide inputs to our "sense of balance" that, among other services, keeps us from falling in the shower when we get soap in our eyes. Because these sensors respond only to linear and angular accelerations, they tell the brain nothing dependable about rates or positions, such as roll rates and bank angles.

Furthermore, these sensors have relatively high thresholds, below which they do not sense accelerations. As a consequence a pilot can gradually enter a bank without feeling any change in aircraft attitude, and this is the most common beginning of a graveyard spiral.

"In a steep bank, the nose of the airplane drops, and it starts to lose altitude. To hold altitude the pilot pulls back on the wheel, which tightens the turn and steepens the spiral dive."

When the pilot notices the banked attitude on the artificial horizon, several bad things can happen:

- If the pilot makes the correct aileron input to roll out of the bank and the resulting roll acceleration is above the pilot's threshold, the wings may be levelled, but the pilot will now "feel" that the aircraft is banked in the opposite direction. This experience is known as having "the leans" because of the compelling urge to lean in the direction of the original banked attitude even though the wings-level attitude is maintained. If the illusion is overpowering, the pilot will often roll back into the original turn to restore a feeling of wings-level and become confused, then totally disoriented.
- If the pilot makes the incorrect aileron input, as occasionally happens, the bank angle will start to increase, with the aircraft rolling farther away from wings-level with a consequent lowering of the nose and a loss of altitude. The pilot may be able to catch this mistake immediately and make the proper responses to recover, but not always. The pilot may also try to stop the rotation of the horizon bar by a hard-over rotation of the control yoke in the opposite direction and pull back on the yoke to stop the loss of altitude. This tightens the turn and steepens the dive.

Dr Stanley Roscoe is the senior vice president of Aero Innovation, Inc. an aviation human factors company based in Montreal, Canada.

For more information about horizon control reversal and graveyard spirals, visit www.casa.gov.au/fsa/