AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

Reference:	CA18/2/3/9361

Aircraft Registration	**ZS-IFK**	**Date of Accident**	15 September 2014	**Time of Accident**	1808Z
Type of Aircraft	Cessna C172 (Aeroplane)	**Type of Operation**	Private		
Pilot-in-command Licence Type	Private pilot (PPL)	**Age**	24	**Licence Valid**	Yes
Pilot-in-command Flying Experience	Total Flying Hours	58		**Hours on Type**	Unknown
Last point of departure	Newcastle Aerodrome (FANC): Kwa-Zulu Natal province.				
Next point of intended landing	Rand Aerodrome (FAGM): Gauteng province.				

Location of the accident site with reference to easily defined geographical points (GPS readings if possible)

On a privately owned farm outside Newcastle at GPS co-ordinates determined to be South 27°43.095´ East 029°49.777´ at an elevation of approximately 4 445 feet above mean sea level (AMSL).

Meteorological Information	Mid-level clouds were observed in the vicinity of the Newcastle area with surface data readings as follows: Temperature 32°C, Dew point temperature -3°C, Wind speed 07 knots.

Number of people on board	1 + 1	**No. of people injured**	0	**No. of people killed**	2

Synopsis

On Monday 15 September 2014, ZS-IFK, a Cessna C172 aircraft, was conducting the last leg of a visual flight rules (VFR) cross-country flight from Newcastle (FANC) aerodrome destined for Rand Aerodrome (FAGM) with the pilot and a passenger on-board. The aircraft was hired with the intention of building hours. At about 1805Z, the aircraft was spotted on the surveillance radar at 5 000 ft after which it initiated a right turn. During the turn, the aircraft descended and subsequently disappeared from the radar. The air traffic services officer at OR Tambo immediately tried to establish radio contact with the aircraft but without success. It was presumed to have crashed and the aeronautical rescue coordination centre (ARCC) in Johannesburg was informed. The wreckage was located on a privately owned farm, approximately 8.3 nautical miles (NM) north-west of Newcastle Aerodrome (FANC). Both occupants were fatally injured and the aircraft was destroyed by the impact and fuel-fed fire that erupted. The investigation revealed spatial disorientation by the pilot after take-off, possibly resulting from limited visual references and low levels of terrestrial lighting at night time.

Probable Cause

Spatial disorientation.

IARC Date		Release Date	

AIRCRAFT ACCIDENT REPORT

Name of Owner	**:** IFK Aircraft Company (Pty) Ltd.
Operator	**:** AFOS School of Flight
Manufacturer	**:** Cessna Aircraft Company
Model	**:** Cessna C172
Nationality	**:** South African
Registration Marks	**:** ZS-IFK
Place	**:** On a privately owned farm
Date	**:** 15 September 2014
Time	**:** 1808Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (1997) this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and ***not to establish legal liability****.*

Disclaimer:

This report is produced without prejudice to the rights of the CAA, which are reserved.

1. FACTUAL INFORMATION:

1.1 History of Flight:

1.1.1 On Monday 15 September 2014, the pilot accompanied by a passenger was conducting a private cross-country flight from Rand Aerodrome (FAGM) under visual flight rules (VFR) conditions, with clear skies and visibility of more than ten kilometres along the intended route. The journey required flying and navigating the aircraft to multiple aerodromes. Those were Newcastle (FANC), Virginia (FAVG), and then the same route back to FAGM the next day before 1900Z. The aircraft was hired with the intention of building hours. However, the pilot commenced the journey despite a flight plan with Johannesburg briefing.

1.1.2 According to the operator's aircraft responsible person, the flight to FANC took place uneventfully on Sunday morning at 0909Z. The operator's aircraft responsible person added that the aircraft proceeded for FAVG that same day and landed at 1411Z where it parked overnight. According to the FAVG control tower's records, the aircraft left for FANC on Monday at 1319Z. The landing time is unknown to the investigating team, yet it appeared that it occurred outside FANC working hours. The person at FANC responsible for fuel reported that the pilot contacted her using his cell phone and asked her to assist in refuelling the ZS-IFK aircraft. She arrived at FANC at about 1650Z and proceeded to the aircraft parking bay. The pilot informed her that he wanted to uplift R800.00 worth of Avgas LL 100 fuel, which amounted to 41 litres. The aircraft was pulled next to the fuel bay where it was refuelled. A cash payment was made and a fuel slip issued to the pilot. The aircraft took off at about 1755Z. At about 1805Z, the aircraft was spotted by the air traffic services surveillance radar at OR Tambo, at 5 000 ft AMSL, after which it initiated a right turn. During the turn, the aircraft's rate of descent and airspeed increased and it subsequently disappeared from the radar. The air traffic services officer at OR Tambo tried to establish radio contact with the aircraft but without success. Figures 1 and 2 below gives the radar footage reflecting the ZS-IFK aircraft without a squawk code and the departure aerodrome.

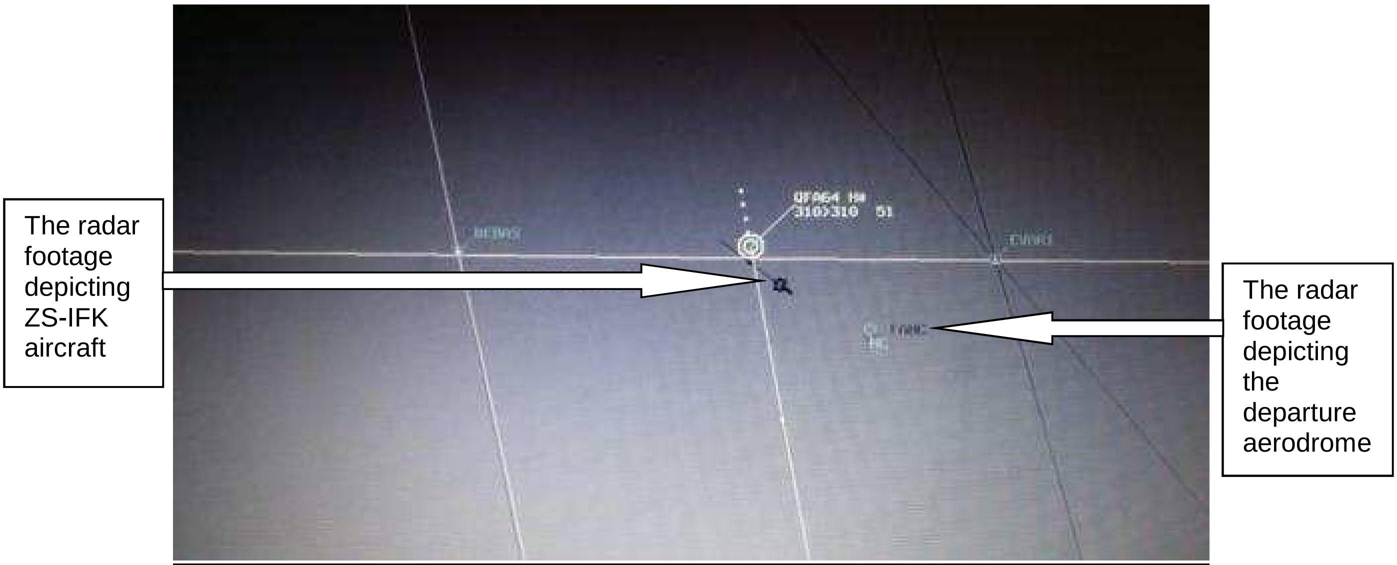


Figure 1: The radar footage depicting the ZS-IFK aircraft and FANC

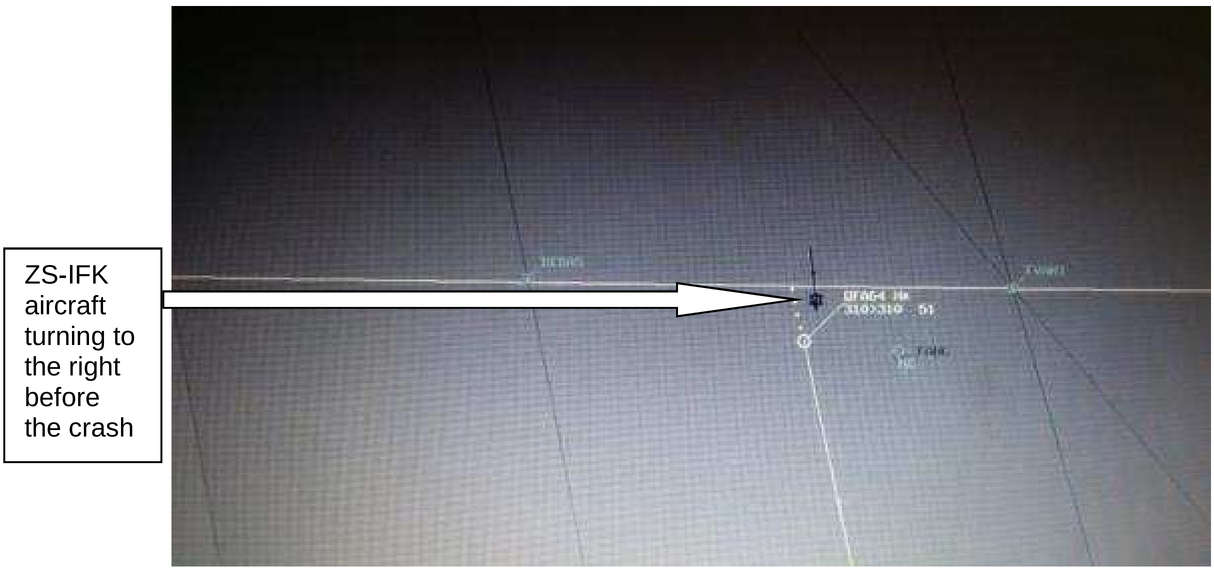


Figure 2: The radar footage depicting ZS-IFK aircraft making a turn just before the crash

1.1.3 The aeronautical rescue co-ordination centre in Johannesburg was informed, together with the Newcastle police station and the emergency services. They were given the GPS co-ordinates of the area. A search commenced but it was hampered by the inaccessibility of the remote location; nevertheless, the wreckage was later located on a privately owned farm approximately 8.3 nautical miles (NM) north-west of FANC. The aircraft was destroyed by the post-impact and subsequent fuel-fed fire that erupted. Both occupants were flung out of the aircraft and fatally injured. The farmer, the only witness to the accident, reported that he heard a small aircraft flying very low and then a loud bang. When he went outside the house, the aircraft was already on fire and there was no movement around the crash site. Farm workers who lived next to the accident site assisted in stopping the fire from spreading further and causing more devastation to the nearby farms. The certificate of airworthiness revealed that the aircraft was certified to operate under the provisions of Part 141 of the South African civil aviation regulations which permitted the aircraft to be used for pilot training operations.

1.1.4 The accident happened at night time at GPS coordinates determined to be S27° 43´ 095″ E029° 49 ´ 777″ at an elevation of approximately 4 445 AMSL. The aircraft crashed approximately 8.3 NM north-west of FANC at 331° magnetic track.

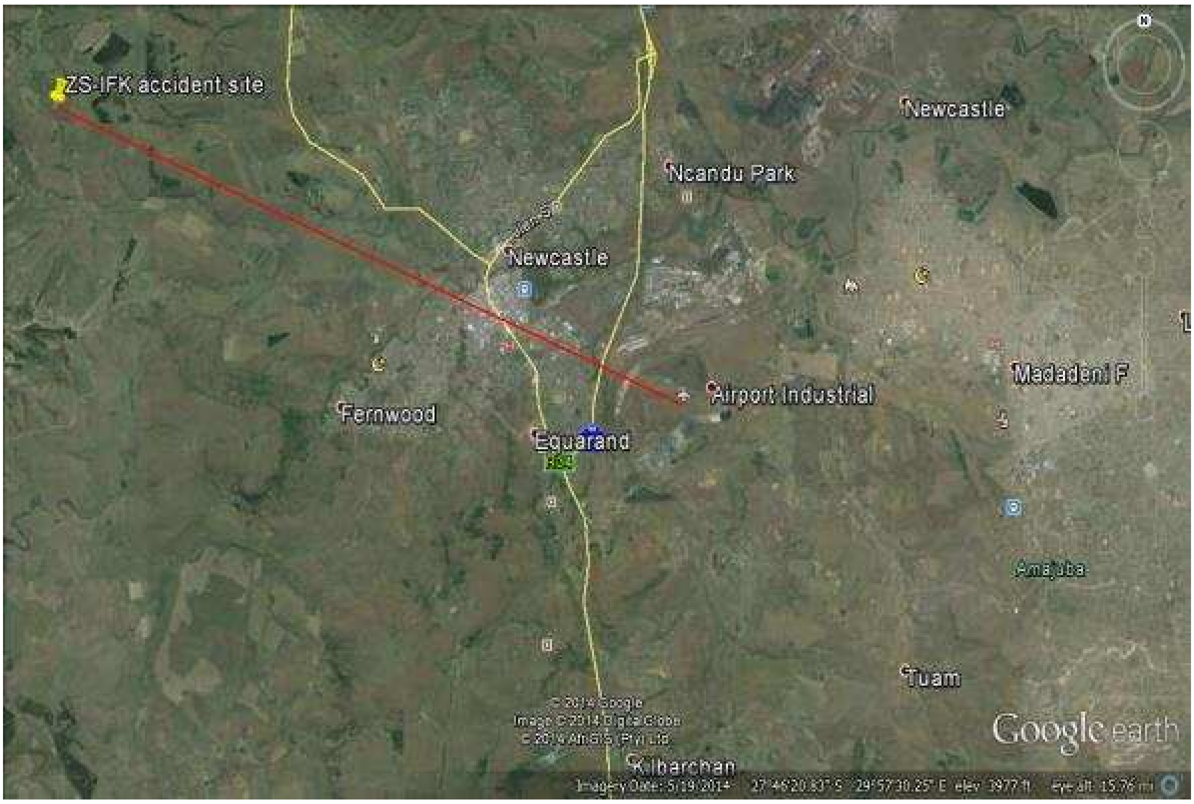


Figure 3: A Google Earth map depicting the positions of FANC and the crash site

1.2 Injuries to Persons:

Injuries	Pilot	Crew	Pass.	Other
Fatal	1	-	1	-
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

1.3 Damage to Aircraft:

1.3.1 The aircraft was destroyed by the post-impact fire that erupted. See Figure 4 below.

Figure 4: Accident site showing the wreckage and burnt vegetation

1.4 Other Damage:

1.4.1 Minor environmental damage was caused by the fuel-fed fire. The accident took place on a privately owned property and the accident site was thoroughly cleaned-up by the owner of the aircraft after the investigation.

1.5 Personnel Information:

Nationality	Sudanese	Gender	Male	Age	24
Licence Number	0272459124	Licence Type	Private pilot licence		
Licence valid	Yes	Type Endorsed	Yes		
Ratings	Night Rating				
Medical Expiry Date	31 May 2015				
Restrictions	None				
Previous Accidents	Nil				

*NOTE: The pilot profile revealed no accident or incident history, enforcement history, pilot certificate or rating failure, or retest history. The pilot applied for a student pilot licence on 29 May 2013. On 23 September 2013 he passed his flight test for his PPL. The pilot log book could not be found at the accident site or during the investigation and attempts were made to locate it from his peers, especially those from his home country (Sudan), but without success. It is believed that the deceased had it on-board the aircraft and that it was probably consumed in the fire that erupted during the accident sequence. In the circumstances, the investigator in charge (IIC) checked the deceased's training profile which was made available to the investigating team. Examination revealed that he had accumulated a total of 58 flight hours during his pilot training. Of those 58 hours flown, 43 were dual and 15 were solo. According to the information in the CAA pilot file, he completed his pilot training on a Cessna C172 type aircraft. During September 2013, he attained a night rating and had accumulated 10 hours under instrument flying conditions, which was part of the training for his night rating.

Experience:

Total Hours	58
Total Past 90 Days	Unknown
Total on Type Past 90 Days	Unknown
Total on Type	Unknown

1.6 Aircraft Information:

1.6.1 The Cessna 172 Skyhawk is a four-seater, single engine, high wing, fixed-wing light touring aircraft produced by the USA manufacturer Cessna Aircraft Company.

Figure 5: ZS-IFK aircraft photo

Airframe:

Type	Cessna C172	
Serial Number	172-59143	
Manufacturer	Cessna Aircraft Company	
Date of Manufacture	1970	
Gross weight	2 454 lbs	
Empty Weight	1 622 lbs	
Service Ceiling	13 500 feet	
Total Airframe Hours (At time of Accident)	Approximately 14 019.28	
Last MPI (Hours & Date)	13 989.28	14 July 2014
Total Hours Flown	±30	
C of A (Issue Date)	28 January 2005	
C of A (Expiry Date)	27 January 2015	
C of R (Issue Date) (Present owner)	09 November 2004	
Recommended fuel used	Avgas LL 100	
Operating Categories	Standard Part 141	

*NOTE: The airframe hours of the aircraft at the time of the accident could not be determined with complete accuracy as no official flight folio was recovered from the accident scene. Also no tachometer or Hobbs meter readings were obtained because the aircraft was destroyed by the impact and subsequent fuel-fed fire that erupted. The Total Airframe Hours indicated in the table above were calculated using the estimate from the operator, taking into account the flight folio's last entry and the planned flight. The AMO that performed the last maintenance on the aircraft prior to the accident flight was in possession of a valid AMO Approval certificate No 1217. All relevant aircraft documentation such as the certificate of registration, the certificate of airworthiness and the mass and balance certificates were inspected during the investigation and were found to be valid. The aircraft maintenance documentation such as airframe logbooks, engines, and propeller log books were obtained from the aircraft maintenance organisation and inspected. All maintenance entries made in the logbooks were appropriately certified in terms of civil aviation regulations, Part 43.

Engine:

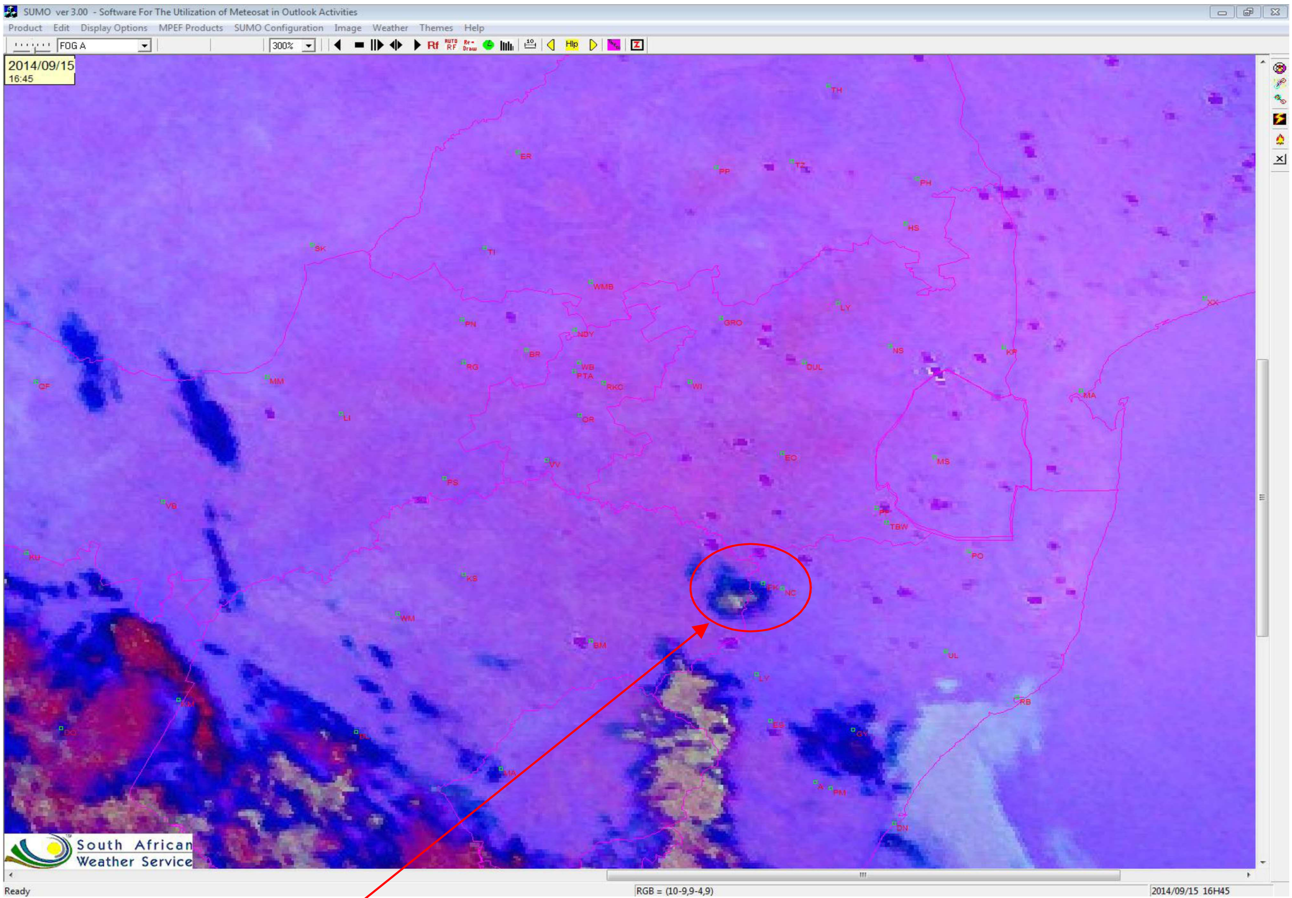
Type	Lycoming O-320-E2D
Serial Number	L-9763-27E
Hours since New	1 264.5
Hours since overhaul	T B O not reached

Propeller:

Type	Hartzell PHC-C3YF-1RF
Serial Number	728786
Hours since New	1 264.5
Hours since Overhaul	T B O not reached

1.7 Meteorological Information:

1.7.1 Weather information obtained from the SA Weather Services indicated mid-level clouds near the Newcastle area at the estimated time of the accident as shown by the satellite image in Figure 6.



Mainly mid-level clouds were observed in the vicinity of the accident site (north-west of Newcastle)

Figure 6: Satellite image as on 15 September 2014

(i) Surface data:

- Temperature: 32˚C.
- Dew point temperature: -3˚C (26.6F).
- Wind speed: 07 knots.

1.8 Aids to Navigation:

1.8.1 The aircraft was equipped with basic navigational aids. According to the available information, the pilot had a portable Garmin GPS on board, but it was not found during the investigation. No evidence of any aeronautical maps was found at the scene of the accident.

1.9 Communications:

1.9.1 The aircraft was equipped with a very high frequency (VHF) radio. As far as could be established, no distress or mayday call was picked up by any station or tower or by any other aircraft in the area at any stage during the flight.

1.9.2 The aircraft was identified on surveillance radar and tracked up to the point at which it disappeared from radar.

1.10 Aerodrome Information:

1.10.1 The accident happened at night on a privately owned farm outside Newcastle at GPS coordinates determined to be South 27° 43 ´ 095″ East 029° 49 ´ 777″ at an elevation of approximately 4 445 feet AMSL. Figure 7, below, shows the Google Earth map depicting the accident site.

Figure 7: Google Earth map depicting the accident site

1.11 Flight Recorders:

1.11.1The aircraft was not equipped with a flight data recorder (FDR) or with a cockpit voice recorder (CVR): these were not required by the regulations to be fitted to this aircraft type.

1.12 Wreckage and Impact Information:

1.12.1 The aircraft crashed to the ground while en-route to FAGM aerodrome during the night. The impact sequence indicates that the aircraft was in a nose-down attitude when it hit the ground.

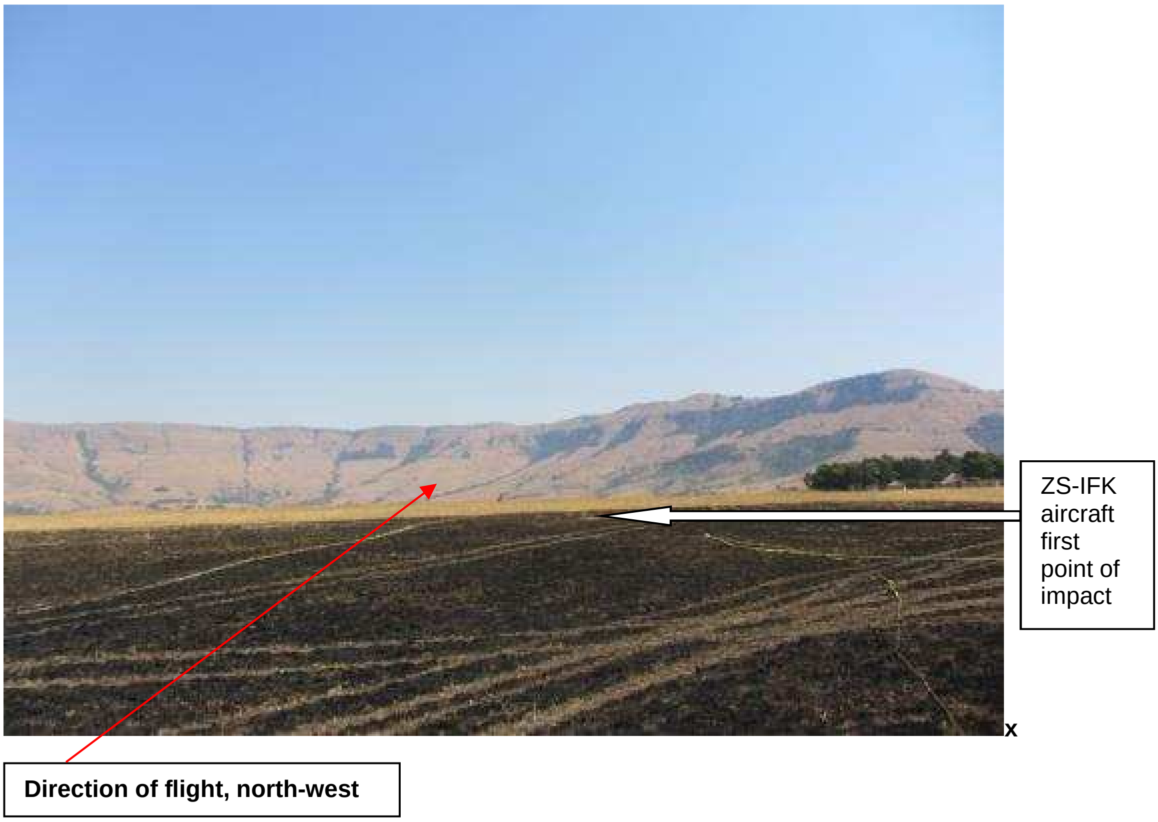


Figure 8: The direction of flight and the accident site. In this photograph, the aircraft flight path was towards the mountain: the accident happened on the flat ground after the turn was initiated.

1.12.2 Examination of the accident site revealed that the aircraft was under power when it collided with the ground. The aircraft struck the ground nose-down, shattering the nose gear strut, shock absorber, wheel assembly and the gear fork. The aircraft flipped over and the safety harnesses securing the occupants failed from overload. Both occupants were then flung out of the aircraft. The occupants were found approximately 73 m from the first point of impact on the other side of the stream. During the accident sequence, the right wing detached from the fuselage and this was probably caused by overload. It was extensively damaged by fire.

1.12.3 The landing light was damaged during the accident sequence. Both the wing fuel bladder cells ruptured and the accident site was set alight, probably by the hot engine. The wreckage excluding the vertical and the horizontal stabilisers was consumed by the fuel-fed fire. The engine detached from the airframe and was found on the other side of the stream next to the bodies and the nose gear fork. The damage on the propeller indicated that the engine was producing power immediately prior to collision with the ground. The engine oil sump ruptured after impact and some of the engine components such as the oil filter, the oil cooler, the carburettor, and the magnetos were destroyed as shown in Figures 9, 10 and 11.

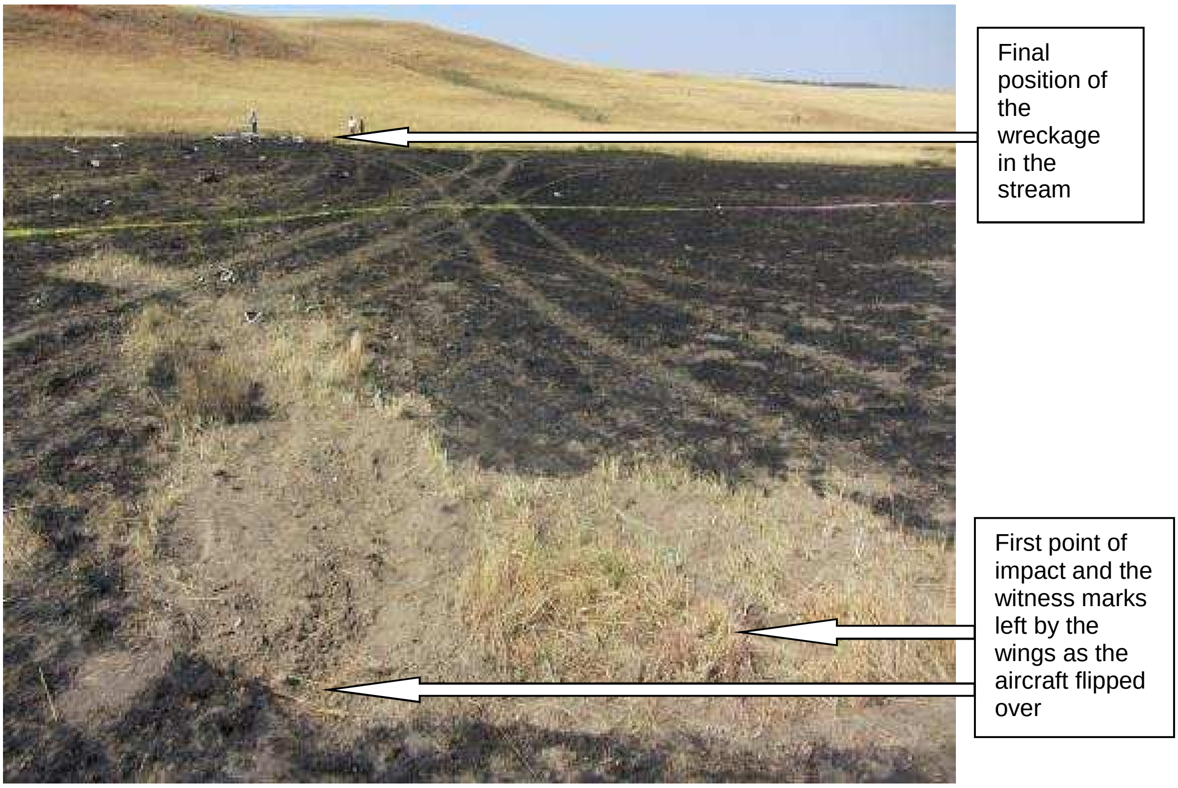


Figure 9: First point of impact and position of wreckage

Figure 10: The engine and the nose wheel on the other side of the stream

Figure 11: The right wing and the propeller

1.12.4 The tail section displayed wrinkling attributable to impact forces.The aircraft battery was dislodged from its mounting point and was found in the stream. The aircraft's electrical system and associated wiring were destroyed. Both control columns were destroyed. The wing flaps were in a neutral position and the position of the ailerons could not be confirmed. The spring-loaded main landing gear and the wing struts were destroyed by impact forces. Flight controls continuity could not be established and most of the engine and flight instruments were destroyed during the accident sequence. All the antennas, including that of the transponder, were destroyed by impact. Those instruments that survived the accident sequence, such as the turn co-ordinator and the heading indicator, provided no usable information regarding their pre-accident configuration or condition. The pilot and the passenger seats were detached from their respective mounting points and thrown out of the aircraft. The entire cockpit/cabin was consumed by fire leaving no evidence. Overall examination of the wreckage determined that the aircraft was intact prior to impact. Figures 12 and 13 show the crash damage.

Figure 12: Closer view of the wreckage

Figure 13: A damaged instrument panel

1.12.5 The aircraft crashed approximately 8.3 NM north-west of FANC at 331° magnetic track. The track between FANC and FAGM calculated as 334.54°M and the distance was 133.62 NM as shown in Figure 14. This does not take into account any wind or wind correction, and supports the suggestion that the aircraft could have been flown slightly off track. The correct procedure that the pilot should have followed was to circle the aircraft overhead FANC to the planned altitude and then set track/time before heading towards FAGM; this is standard procedure.

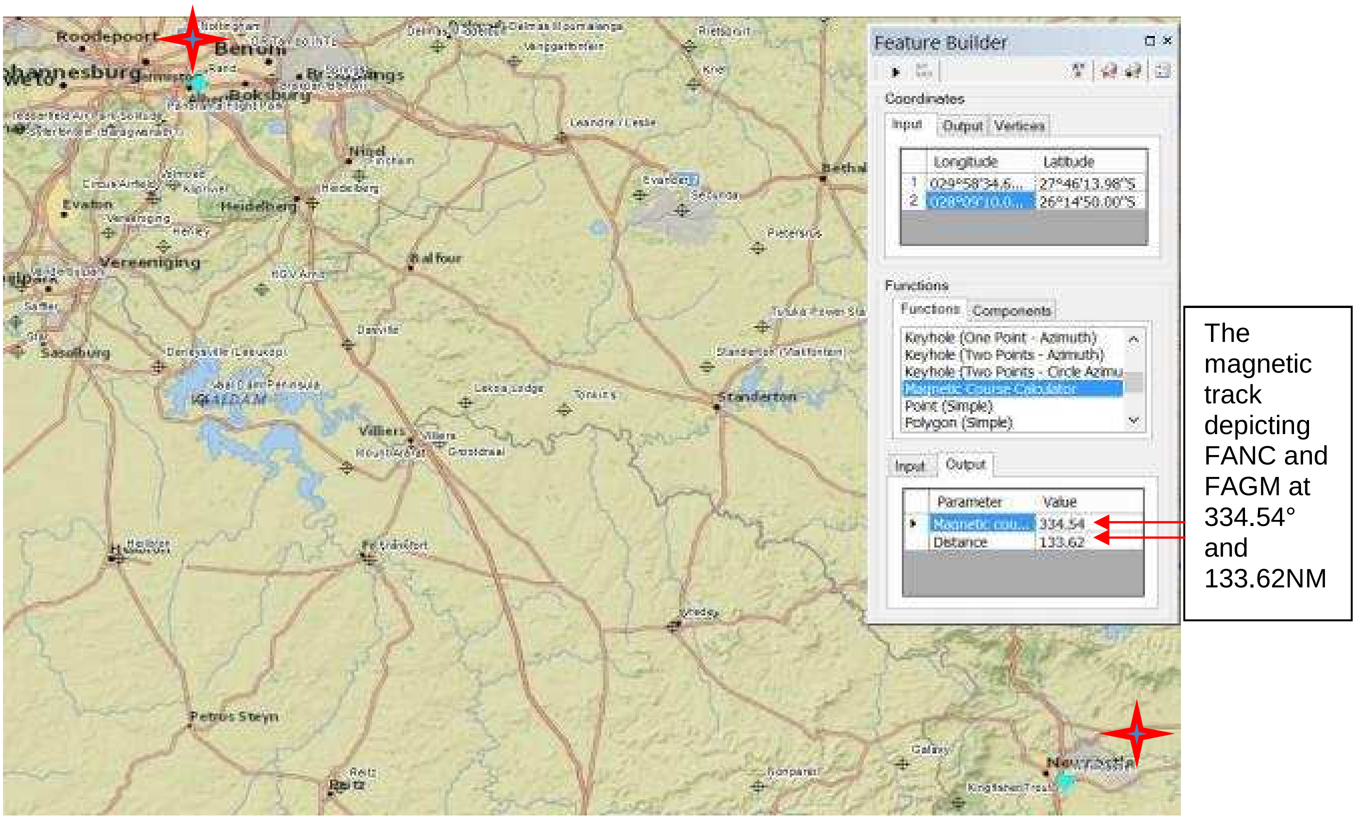


Figure 14: An area map depicting the distance between FANC and FAGM

1.13 Medical and Pathological Information:

1.13.1 According to the post-mortem report, the cause of death was determined to be multiple injuries incurred during the accident sequence.

1.13.2 The blood toxicology report was still outstanding at the time of compiling this report. If any of the results should have a bearing on the circumstances leading to this accident then this information will be treated as new evidence that will require the reopening of this investigation.

1.14 Fire:

1.14.1 A post-crash fuel-fed fire destroyed the aircraft.

1.15 Survival Aspects:

1.15.1 The accident was regarded as non-survivable due to the high energy impact forces associated with it. These resulted in the complete destruction of the cockpit/cabin area and the intense post-impact fuel-fed fire. Overall examination of the accident site indicated that there was no fire before the aircraft crashed.

1.16 Tests and Research:

1.16.1 The wreckage layout was consistent with high energy impact. There was nothing to suggest that there were any defects in the flight instruments, or anomalies in the engine and flight controls, that might have contributed to the accident. Analysis or examination of components or parts of the aircraft was considered not necessary. An assessment of the site where the accident took place showed a high risk of the pilot developing spatial disorientation due to limited visual references and low terrestrial lighting at night time. This supports the suggestion that the pilot may have experienced somatogravic illusion during the climb phase which may have led him to believe that the aircraft was climbing. During the process the pilot may have compensated without monitoring or paying enough attention to flight instruments, particularly the attitude indicator. This would have resulted in loss of aircraft attitude/control rendering ground impact inevitable.

1.17 Organizational and Management Information:

1.17.1 This was a private cross-country flight.

1.17.2 The aircraft maintenance organisation (AMO) that performed the last mandatory periodic inspection (MPI) on the aircraft was in possession of a valid AMO approval certificate No 1217. The MPI was carried out in accordance with SA CATS general maintenance rules (GMR) and Cessna maintenance manual D7922-4-13, revised on 15 January 2008.

1.18 Additional Information:

1.18.1 None.

1.19 Useful or Effective Investigation Techniques:

1.19.1 None

2. ANALYSIS:

2.1 The pilot was licenced in accordance with the regulations. After the accident the pilot's logbook could not be found and no records of the pilot's hours, other than PPL and night rating training, could be retrieved. Therefore the investigator was unable to determine if the pilot was night current. The pilot departed from FANC, which is fairly isolated and with few visual references at night, following take-off. A combination of low terrestrial lighting and only a few visual references may have caused the pilot to have become disorientated, resulting in a crash. The wreckage distribution was consistent with high energy impact. Both occupants were fatally injured during the accident. The aircraft had valid documentation prior to departure and no defects were reported to the operator. Weather conditions at the time of the accident were conductive for VFR flights and therefore were not considered to be a factor in the accident.

3. CONCLUSION:

3.1 Findings:

3.1.1 The pilot was a holder of a valid private pilot licence and had the aircraft type endorsed in his logbook.

3.1.2 The pilot was fatally injured as a result of the accident in which he suffered multiple blunt force injuries.

3.1.3 All control surfaces were accounted for and there was no evidence of any defect or malfunction on the aircraft that could have contributed to or caused the accident.

3.1.4 The flight was operated as a general aviation flight under VFR rules.

3.1.5 Fine weather conditions prevailed at the time of the accident and the weather was not considered to have any bearing on the accident.

3.1.6 The aircraft was in possession of a valid C of A and C of R.

3.1.7 The AMO that performed the last maintenance inspection on the aircraft prior to the accident flight was in possession of a valid AMO approval certificate No 1217.

3.1.8 Examination of the aircraft's technical logbooks revealed no anomalies or deficiencies with the aircraft.

3.1.9 The accident was not considered to be survivable.

3.2 Probable Cause/s:

3.2.1 Spatial disorientation.

3.3 Contributory factor:

3.3.1 Lack of experience.

4. SAFETY RECOMMENDATIONS:

4.1 None.

5. APPENDICES:

5.1 Spatial disorientation:

Source: http://www.skybrary.aero

Spatial disorientation, if not corrected, can lead to loss of control *and* controlled flight into terrain. The possibility of becoming spatially disorientated is hard-wired into all humans. Moreover, it is the proper functioning of our spatial orientation system which provides this illusion and because this is a system that we have learnt to trust, it is particularly difficult, in some circumstances, to accept that our perceptions of orientation are incorrect. Despite the capability, accuracy, reliability and flexibility of modern flight displays and instrumentation, pilots can still find themselves questioning what the aircraft is telling them, because it contradicts their own perceptions. Nobody is immune to this type of reaction. Therefore, learning and regularly refreshing one's knowledge about spatial disorientation, how and why it happens, how to recognise it, and what to do to about it, are all essential in improving and maintaining flight safety.

Spatial orientation:

The term "spatial orientation" refers to our ability to perceive motion and three-dimensional position in relation to the surrounding environment. Humans and most animals are able to maintain correct spatial orientation by automatic, subconscious, integration of multiple sensory inputs: thus the key **senses** of sight and hearing provide broad peripheral awareness as well as focused attention on details;

pressure and touch, through the somatosensory system (the whole body) provide **proprioception;** and the vestibular system in the inner ear provides three-dimensional movement and acceleration sensation.

There are three aspects to spatial ''position'' orientation:

1. Knowing where the extremities of our body and our limbs are.
2. Knowing what is up, down, left and right.
3. Knowing our position in relation to our immediate environment.

This is then complicated by factoring in, for each aspect, awareness of direction of movement, change in direction, speed of movement and change of speed. This automatic system and process has evolved to help us perform all our activities such as running, sitting and climbing, to name just a few. Moreover, it provides for stabilised eyesight, which is our most convincing sense, whilst doing all these things. This system even works when one or more sensory inputs are degraded. Consequently, many blind, deaf, and disabled people can be active, naturally and effortlessly. Note, however, that this adaptation has occurred on the ground, and under the constant force of gravity, and not in-flight!

Spatial orientation in-flight:

Fully functional flight instruments must be the primary source for pilots to ascertain their spatial orientation. Effective use of those instruments requires good eyesight and good use of that eyesight; we can then read, regularly, those flight instruments that indicate attitude, altitude, position, heading and speed. Even pilots flying VFR (visual flight rules) will need to consult their flight instruments regularly.

In everyday life our vision is mostly correct and we trust our vision implicitly above all other senses. Because of this, there is a strong compulsion to believe in what we see when flying visually, despite what our instruments are telling us. This makes us prone to several visual illusions, especially during landing. There are many occasions in-flight when we cannot use, or rely on, our vision at all, such as when flying in IMC (instrument meteorological conditions), or when there is no visible horizon and at night. Furthermore, there are many situations when flying in VMC (visual meteorological conditions) when a pilot *should not* rely on his vision, such as when flying an instrument approach, instrument departure, or in response to an ACAS (airborne collision avoidance system) or Advisory alert.

When our sense of sight is degraded, then our perception of spatial orientation becomes dependent on proprioception (pressure on muscles, joints, ligaments and nerves) and the vestibular system. Without any (or any reliable) external visual references, pilots will subconsciously become more sensitive to their proprioception and vestibular systems, and this is where spatial disorientation can manifest itself.

Spatial disorientation in-flight:

When we are in an airplane, we are often subject to motion, speed, forces and variations in gravity (both positive and negative) for which our orientation system was not designed. This can lead to an incorrect perception of where we believe we are, what direction we are moving, and how fast. Although we might feel certain of our orientation and relative movement, our actual orientation and movement may be different. The flight safety foundation describes spatial disorientation as occurring "*when a pilot fails to properly sense the aircraft's motion, position or attitude relative to the horizon and the earth's surface."*

Spatial disorientation can happen to any pilot, regardless of his or her flying experience, and is often associated with fatigue, distraction, highly demanding cognitive tasks and/or degraded visual conditions.

Spatial disorientation is more likely to occur at night, in bad weather, in IMC (instrument meteorological conditions), and when there is no visible horizon. Other risk factors are malfunctioning flight instruments, increased workload (especially during approach and departure), and a breakdown in CRM (crew resource management). When these hazards combine with poor visibility, the risk of spatial disorientation is much greater.

There are two main types of common spatial disorientation "illusions" that humans are susceptible to in flight:

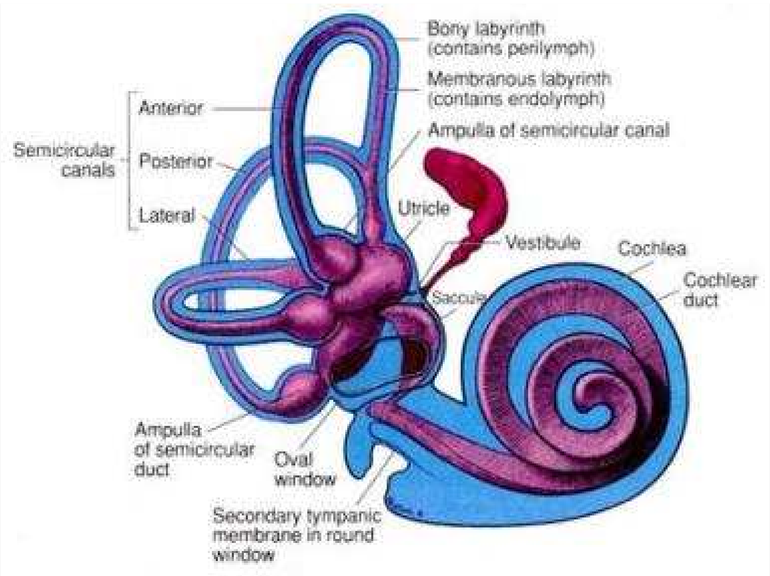
Somatogravic – perceiving linear acceleration and deceleration incorrectly, as climbing and descending.

Somatogyral – not detecting movement, or alternatively, experiencing movement in a different and mostly opposite direction to that actually being flown.

Both categories of spatial disorientation are caused by the normal functioning of the vestibular system, in the relatively unusual environment of flight. The most common somatogravic and somatogyral illusions that occur are explained in more detail below.

Vestibular system:

The vestibular system (or apparatus) is located within the inner ear and provides evidence to the brain of angular accelerations of the head in three dimensions (roll, yaw and pitch) and also linear acceleration/deceleration of the head. It consists of three semi-circular canals and two otolithic detectors.



The inner ear

The semi-circular canals comprise the following:

Anterior (or Superior) canal – combines with the posterior canal to detect roll.

Posterior canal – combines with the anterior canal to detect pitch.

Lateral (or Horizontal) canal – detects yaw.

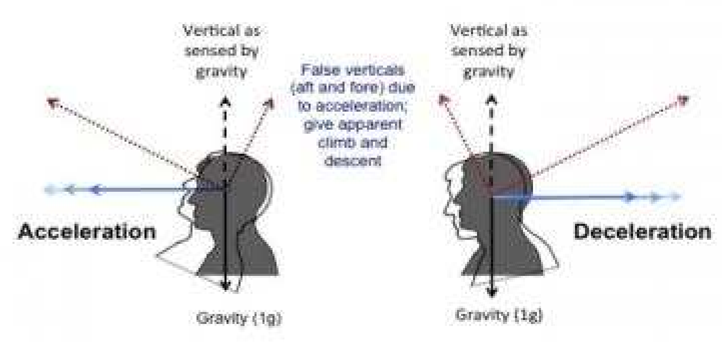
The two otolithic detectors, the **utricle** and **saccule**, provide the brain with a sense of the head's position in relation to gravity, and they combine by detecting accelerations in the horizontal and vertical planes.

There are physiological and anatomical differences between the canals and the otoliths but their operation can be described using the same model. Thus, contained within each organ is a free-flowing fluid, and whenever the head is turned, tilted or accelerated, that fluid will not move with the head immediately, but will lag behind somewhat; this is because the fluid has its own mass and momentum. In contrast, hair-like detectors, attached to the walls of each organ, do move with the head; the resulting force that the deflected hairs are subject to by the lagging fluid is proportional to the angular acceleration.

It should be noted that once the acceleration or deceleration ceases, and a constant velocity is reached, including zero velocity, the fluid “catches-up” with the head and becomes still, closely followed by the hair-like detectors. With no force exerted by the fluid on the detectors a person perceives no movement until there is a change in speed or direction. Our vestibular system components have thresholds of detection, below which we do not sense any acceleration or deceleration. It is possible for us to be gradually accelerated or decelerated to very high or low speeds respectively without sensing any change in speed. Similarly, it is possible to enter a roll, pitch or yaw movement without being able to sense any change.

Somatogravic illusions:

Generally the only force experienced in straight and level flight is the vertical force of gravity. If a linear acceleration or deceleration occurs during straight and level flight, then the “sensed” vertical reference of gravity will move back or forward, giving an illusion that the aircraft is climbing or descending respectively. When an aircraft is in a turn, the bodies of the occupants will be pushed back into their seats, giving them the illusion of climbing. When exiting a turn the opposite can occur, giving the sensation of descending. If a pilot reacts to any of these sensations without reference to a true visual horizon and/or flight instruments, then the pilot is likely to start an unnecessary descent or climb depending on whether the aircraft is accelerating or decelerating. Such a reaction can lead to a fatal outcome.



Somatogravic illusion

Illusion of Climbing – The illusion of climbing is typically perceived when accelerating at take-off, initiating a go-around with full power, pulling out of a dive, levelling off from a climb and entering (or tightening) a turn.

In the case of a pilot of an aircraft, an automatic somatic reaction to the illusion of climbing is to push the nose forward with the intention of stopping the illusory climb or initiating a descent. If the pilot considers that the illusory climb is dangerous (for example, possibly leading to a stall) then the instinctive and automatic reaction is liable to be a fast and large "bunt" forward. Another automatic reaction may be to apply more power. Unfortunately, both these reactions (bunting forward and applying more power) will increase the sensation of climbing and therefore will motivate the pilot to increase the rate at which the aircraft nose is lowered: this sets up a dangerous positive feedback loop.

A large bunt forward can reduce the vertical force of gravity perceived by the pilot, which moves the sensed vertical reference backwards, as if climbing. Therefore, if an abrupt change is made from climbing to level flight (note that this is an opposite scenario to those outlined above), the reduced G-force can give the illusion of climbing; this will cause the pilot to push forward even more, making the situation worse. This particular scenario is often referred to as the illusion of tumbling backwards**.**

The application of power and elevator to maintain a level turn can also give the illusion of climbing, or of the nose rising too fast and too much. Any reaction here to lower the nose and/or reduce power can quickly result in a loss of height and an increase in bank angle.

Illusion of diving – The illusion of diving or descending can typically occur when decelerating the aircraft; in other words, when reducing power quickly, deploying air brakes or lowering the undercarriage. It can also occur when recovering to level flight following a banked turn.

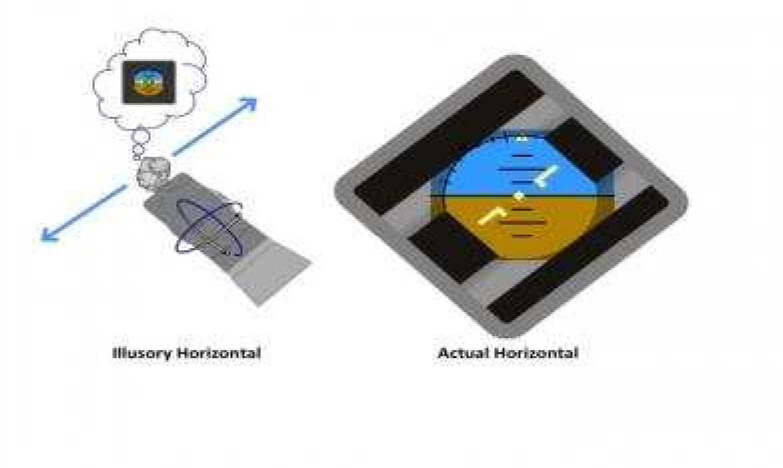
The automatic somatic response to a perceived dive is to increase the aircraft's attitude. If the pilot considers that the situation poses immediate danger (if, for example, the aircraft is close to the ground or even over the threshold), then any pull-up response will slow the aircraft even further and increase the risk of stalling or a heavy landing and tail-scrape.

Somatogyral illusions:

There are three common somatogyral illusions, each of which involves the normal functioning of the semi-circular canals in the vestibular system:

- The Leans – a false perception of the horizontal.
- illusion of turning in the opposite direction, and
- coriolis – a sensation of tumbling, or turning on a different axis.

Either of the first two illusions above, if not corrected, can lead to what is known as a “graveyard dive” or “graveyard spiral”.



The leans

The Leans – When an aircraft is entering a turn, the vestibular system of an occupant will usually sense the initial rolling and turning movement. However, once the aircraft is stabilised in a steady rate-of-turn and angle of bank (usually around 30 seconds), a pilot’s vestibular system will “catch-up” with the aircraft movement as described in the review of the vestibular system, above, and so he or she will perceive that the aircraft is straight and level. The pilot may even adjust his body, and the aircraft, to this new neutral position, hence the term: “the leans.” Only by looking at a true horizon and/or the flight instruments will the pilot know that he is suffering an illusion. The leans can often occur when an aircraft is not trimmed correctly and starts to roll or turn at a rate which is too slow to be detectable; in other words, below the detection threshold.

The illusion of turning in the opposite direction will often occur when returning to the straight and level from an established turn that was long enough (>30 seconds) to re-set the pilot’s internal horizontal reference, as described above. At this point the vestibular system is no longer detecting a turn; therefore, when the pilot initiates a return to straight and level flight, the vestibular system detects a bank and a turn in the same direction of movement. If the aircraft is recovering from a left-hand turn to straight and level, the body of an occupant perceives a turn from straight and level towards the right, and a pilot will be tempted to turn again to the left in order to correct this perception.

Graveyard dive – If the pilot does not detect a turn, because of the leans or some other spatial disorientation, then eventually the nose of the aircraft will lower, thereby increasing the speed. The pilot then perceives that the wings are level, but the nose is dropping, and therefore will pull back on the elevator to stop the descent and reduce the speed. However this perception is wrong because the aircraft is actually banked and so the turn will steepen, which in turn increases the likelihood of the nose dropping further. This positive feedback scenario, if not corrected, will result in an uncontrolled spiral dive.

Coriolis – this effect typically occurs when a pilot makes an abrupt head movement such as reaching down and over to collect a chart, while the aircraft is in a prolonged turn. Once a turn is established and after about 30 seconds, the fluid in all three semi-circular canals will be "neutral" and waiting to detect any difference in movement. If the pilot then makes a sudden head movement then one, two, or all three semi-circular canals will suddenly "sense" the turning aircraft, but because the pilot's head is at a random angle, the brain will compute an illusory movement. Such an illusion can produce a sensation of tumbling, or merely a turn in a different direction, or at a different rate. The pilot's instinctive reaction might be to correct any perceived movement.

Other illusions:

Vertigo and dizziness can occur as a result of illness, such as a cold or possibly other long-term health issues.

Some pilots report various "out-of-body" experiences which are typically associated with high altitude flights, and periods of low stimulation; thus, they may "sense" that they are on the wing looking back in at themselves flying the aircraft. Under similar conditions, some pilots have also reported feeling that the aircraft is precariously balanced on a knife edge and extremely sensitive to small control inputs; possibly they perceive that the controls have become ineffective. These are often one-off events, and pilots will benefit from sharing this information in the right forum. However, pilots experiencing any inexplicable form of spatial disorientation should always consult their flight surgeon or doctor as soon as possible to rule out any long-term health issues.

Other causes of spatial disorientation:

Sometimes pilots can become spatially disorientated in relation to an aerodrome or runway when flying an approach; this event is more commonly referred to as **loss of situational awareness**. This event is of a different nature to somatogravic and somatogyral illusions. However, the perception that the aircraft is in a different location in the air than it actually is, can also be designated as a type of spatial disorientation. Certainly, the potential consequences of this incorrect perception, if not corrected, are the same as for the other illusions. When pilots perceive that they are in a location differing from the actual position, then they may initiate descent early or late, or "turn-in" early or late, configure the aircraft too early, or maintain a high speed for too long. All of these actions can result in adverse outcomes: these include rushed approaches, high-energy late touchdowns, overruns and runway excursions, heavy landings, balked approaches, excess fuel usage, descent below minimum safety, or vectoring, altitude and even CFIT (controlled flight into terrain).

The possible causes of this type of spatial disorientation include the following:

- insufficient attention and inadequate focus on flight and navigational instruments;
- incorrect selection of navigation instruments;
- inadequate selection of flight displays;
- malfunctioning navigation equipment (on the ground or on the aircraft);
- errors in arrival and approach charts;
- errors in data entry;
- inadequate flight crew cross-checking and monitoring;
- inadequate or omitted approach briefing; and
- high workload; and
- inadequate procedures, omitting to follow procedures or omitting some elements of a procedure.

There are many more possible contributory factors; however, as with other forms of spatial disorientation, the primary solution is to ascertain one's true position from the best available data (flight and navigation instruments, and in this case ATC) rather than from one's own perceptions.

Avoiding and recovering from spatial disorientation:

The remedy for avoiding or recovering from all types of spatial disorientation and visual illusions is always the same: *always scan, read and follow serviceable flight* *and navigation instruments*.

In order to reduce the risks of pilots reacting inappropriately to spatial disorientation, then a multi-track approach is recommended, including the following:

- aviation medicine training to include understanding of the vestibular system;
- human factors training to include understanding of the causes of all forms of spatial and visual disorientation;
- safety information discussions to include discussions of those accidents and incidents attributed to spatial disorientation;
- SOP (standard operating procedures) for recovery from any suspected case of spatial disorientation;
- SOPs for flight instrument scanning, flight display management, cross-checking and monitoring, for all phases of flight;
- SOPs to ensure adequate briefing on critical phases of flight (departure, descent, approach and landing) and also to include contingency measures in case of unforeseen events, such as balked landing;
- SOPs for flying, managing and monitoring, stabilised approaches;
- SOPs always favouring instrument approaches in preference to visual approaches, and perhaps even banning night visual approaches;
- SOPs for flying, managing and monitoring go-arounds;
- where possible, exposure to disorienting conditions in the flight simulator, and practicing recovery SOP;
- Safety reporting system that encourages self-reporting of human factors, including disorientation and
- regular refresher training that covers all elements discussed above.

On the issue of self-reporting; there may be some resistance from pilots who fear that they will lose their medical category, hence the need for effective education and possibly an anonymous reporting system.