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Darkness Increases Risks of Flight

Human perceptual limitations are blamed for specific types of accidents that are more likely to occur in darkness than in daylight. Special hazards associated with night flying continue to cause accidents despite efforts to inform pilots of the risks.

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In December 1972, while a flight crew was troubleshooting a possible landing gear problem, they flew a Lockheed L-1011 into the Florida Everglades, U.S.[1] Twenty-three years later, while on approach to Cali, Colombia, the crew of a Boeing 757 flew the aircraft into a mountainside.[2]

In each accident, a qualified and experienced flight crew, unaware of the proximity of the terrain, allowed an otherwise serviceable aircraft to continue flight toward the terrain until recovery was impossible. The presence of instrument meteorological conditions (IMC) did not preclude these crews from seeing the approaching terrain — in both accidents, good visual meteorological conditions (VMC) prevailed. Instead, the visual impediment was the darkness of night. All else being equal, these two accidents, along with many others like them, might not have occurred in daylight.

Statistical data and anecdotal information show that the level of risk for flight operations that rely only upon external visual cues for guidance — such as flight under visual flight rules (VFR) or during the visual segments of flight under instrument flight rules (IFR) — is greater at night than during the day. In all phases of flight — and during operations on the ground — specific kinds of aircraft accidents occur more frequently and with greater severity during visual flight operations in darkness.

A key reason is human perception — even experienced pilots fall victim to an assortment of visual illusions, which cause runways to appear to be closer than they really are or cause a coastline to appear to be a horizon. Another reason is physiological — the eyes function differently in darkness than they do in daylight.

On the Ground, Low-level Lights Create a Maze Effect

During night operations on the ground, low light levels cause difficulty for pilots navigating to and from the runway. The "sea-of-blue effect" created by taxiway lights compounds the problem, causing difficulty for pilots in differentiating between taxi routes. This is especially true for pilots of smaller aircraft with lower eye-to-wheel heights.[3]

There is a greater risk of colliding with other aircraft during ground operations at night than during the day. Most accidents that result from runway incursions (by other aircraft, vehicles or pedestrians) occur in conditions of reduced visibility, either in fog, in darkness, or both.[4] Five fatal runway incursion accidents involving major air carriers or regional airlines in the United States in this decade have occurred during the darkness of night (or at dusk) in VMC.[5,6,7,8,9] In two of those accidents, flight crewmembers of a Boeing 727 at Atlanta Hartsfield International Airport, Georgia[6], and a Boeing 737 at Los Angeles International Airport, California[7], said later that they had not seen aircraft on the runway ahead of them until the nosewheel of their airplane touched down during landing and the landing lights illuminated the other aircraft.

Takeoff Hazards Increase in Climbouts Over a 'Black Hole'

A study of rejected takeoff incidents reported in the U.S. National Aeronautics and Space Administration Aviation Safety Reporting System database revealed that the darkness of night contributed to wrong-runway takeoffs and taxiway takeoffs by pilots of transport category aircraft. Takeoffs also have been attempted using the runway-edge lights as centerline lights.[10]

A greater hazard occurs after liftoff when the airplane is in the climb phase of flight, especially if that climb is made into what has been called a "black hole." This phenomenon occurs in VMC on dark nights that are moonless or overcast at airports where the terrain off the end of the departure runway is devoid of ground lights and no horizon is discernable. During a 15-year period, the Transportation Safety Board of Canada (TSB) found that 78 percent of night takeoff accidents in Canada occurred in dark-night conditions.[11]

Pilots who rely solely upon external visual cues after a night takeoff may fail to establish the required climb angle to clear unseen rising terrain ahead, or they may experience the illusion of a nose-up attitude. This somatogravic illusion or "false climb" illusion, brought about by postural sensations and inner ear sensations, may lead to a nose-down response by the pilot, causing the airplane to descend into the ground or water.[12]

Somatogravic illusion was cited as a factor in the 1996 fatal accident of an unscheduled Federal Aviation Regulations (FARs) Part 135 cargo flight that occurred after takeoff on a clear dark night in Kamuela, Hawaii, U.S.[13] The U.S. National Transportation Safety Board (NTSB), in its final report on the accident, quoted medical researchers from the U.S. Federal Aviation Administration (FAA) Civil Aeromedical Institute as saying that circumstances of the accident mirror those of a "dark-night takeoff accident."

"For this to occur," the report said in its summary of the researchers' statement, "the pilot will have limited outside visual cues but will not be flying the aircraft with reference to instruments. The aircraft may then enter an undetected descent while flying straight ahead or in a coordinated turn. The perception of a descent is masked by the fact that the aircraft is accelerating, which allows the pilot to continue until ultimately experiencing controlled flight into terrain. This perception will persist unless detected and corrected by the pilot through reference to the airspeed indicator, vertical speed indicator or altimeter."[13]

The scarcity of external visual cues in dark-night VMC also was cited as a factor in a takeoff accident over Lake Erie in the United States that claimed the life of the instrument-rated private pilot and two passengers in 1995.[14] The NTSB report on the accident said that the Beech 58 Baron had just departed from Burke Lakefront Airport in Cleveland, Ohio, U.S., and was following instructions from a tower controller to maneuver the airplane into a right turn at an altitude of 100 feet or 200 feet. One minute or two minutes later, smoke and flames were seen rising from Lake Erie. The pilot of a Gulfstream IV that departed shortly afterward said later that he was disoriented when he turned his airplane north after departure and that there was no perceptible horizon, no light from the sky and no lights on the lake to provide visual reference.[14] NTSB said that the probable cause of the accident was "the pilot('s) improper IFR procedure, by failing to maintain a positive rate of climb (and terrain clearance) after takeoff. Factors relating to the accident were darkness and the lack of visual references over water and under overcast cloud conditions."

Six years earlier, the darkness over Lake Erie in Canada contributed to a fatal accident involving an air ambulance flight. Canadian investigators cited the somatogravic illusion in their report on this accident, which occurred in VMC during dark-night conditions.[15]

Although the frequency of dark-night takeoff accidents is relatively low, the accidents usually are fatal. During a 15-year period in Canada, for example, 83 percent of takeoff fatalities at night occurred during dark-night conditions.[11]

Darkness Obscures Inclement Weather

Reduced visual perception at night also creates hazards during the cruise portion of flight. For the VFR pilot, there is an increased risk of inadvertent entry into IMC during cruise flight at night.[16] Between 30 percent and 35 percent of all VFR-into-IMC accidents in the United States and Canada occur at night.[16,17,18,19] Inclement weather is more difficult to see during darkness. Accident data show that the typical scenario is that a pilot inadvertently enters clouds and either experiences spatial disorientation and loses control of the aircraft, or continues under controlled flight into terrain.

Pilots also have difficulty seeing terrain in darkness, even in VMC. Though relatively few in number, accidents occur in which pilots fly into unseen mountainous terrain on clear dark nights. One of the most publicized of these accidents claimed the lives of eight members of country music singer Reba McEntire's band and the two flight crewmembers. While flying below controlled air space in San Diego, California, U.S., and awaiting an IFR clearance, the flight crew of the Hawker Siddeley DH125 flew under controlled flight into mountainous terrain. The night was clear and moonless; visibility was 10 miles.[20]

Although the probability of flying into volcanic ash is low, the consequences of such action can be catastrophic. Total engine failure resulting from inadvertent flight into volcanic ash occurred during the darkness of night in clear weather conditions as a Boeing 747 was in cruise flight over Indonesia.[21] The pilots were able to restart one engine and land at a nearby airport. Detection of volcanic ash is unlikely at night or in clouds.

On starry nights, pilots can confuse lights on the ground with stars. That confusion can alter the pilot's perception of the horizon, and with the perceived horizon lower than the actual horizon, the pilot risks flying an aircraft into terrain. Similar types of illusions can cause pilots to confuse a vast unlighted space on the ground with an overcast sky or to interpret a ground feature, such as a coastline, as the horizon.[22]

Darkness Adds Risks To Approach, Landing

Approximately half of all worldwide commercial jet accidents occur during final approach and landing, even though these phases account for about 4 percent of flight time.[23] Recent data, however, confirm the increased risk that the darkness adds to these phases of flight.

A study by the Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that, of 287 fatal accidents between 1980 and 1996 that involved jet and turboprop aircraft, 39 percent occurred at night. The task force estimated that the rate of approach-and-landing accidents at night is nearly three times the rate for approach-and-landing accidents during the day. The task force based its conclusion in part on discussions with airline officials and airport operators around the world and on their estimates that about 20 percent to 25 percent of landings occur at night. The report said, "There might be an assumption that night approaches may result in more difficulties caused by factors such as reduced visual cues or spatial disorientation."[24]

The ALAR study also found that about 60 percent of all aircraft incidents, or occurrences, during the approach-and-landing phase of flight occurred at night or at twilight.[24]

Visually locating the destination airport and the runway environment can be difficult during low-light conditions. For example, in 1987, 20 U.S. air carrier flight crews conducted approaches to the wrong airport or landed at the wrong airport. During the six-year period that ended in 1987, 21 percent of these wrong-airport incidents occurred at night, usually in VMC.[25] In one accident, four crewmembers and 26 passengers died when a Convair 640 struck terrain 28 miles short of its destination, on a clear moonless night while on approach to a site mistaken for the airport.[26] In 1992, a McDonnell Douglas DC-8 struck terrain several miles from Kano airport in Nigeria after the flight crew mistook the lights of an army barracks for runway lights.[27] A nearly identical accident occurred nine months later when a Boeing 707 struck terrain not far from the DC-8 accident site.[27]

Conducting approaches only by external visual references during dark-night conditions has led to excessively low approaches and to premature contact with ground or water short of the runway.

One explanation, according to research conducted in the 1960s for The Boeing Co., centers on the angle of the light pattern on the ground as seen by pilots approaching a city — and the city's nearby airport — at a constant altitude.[28] As the airplane approaches the city, the angle becomes increasingly greater, but from any specific altitude and distance, there is one specific flight path that enables the pilot to keep the visual angle constant. That path follows the arc of a circle (Figure 1) that is centered above city lights with its circumference contacting the ground, and the pilot believes — incorrectly — that the aircraft is in a straight-line descent. Following that path to the airport is satisfactory as long as the pilot is flying over flat terrain. But the research, which included simulator flights by senior instructor-pilots, found that

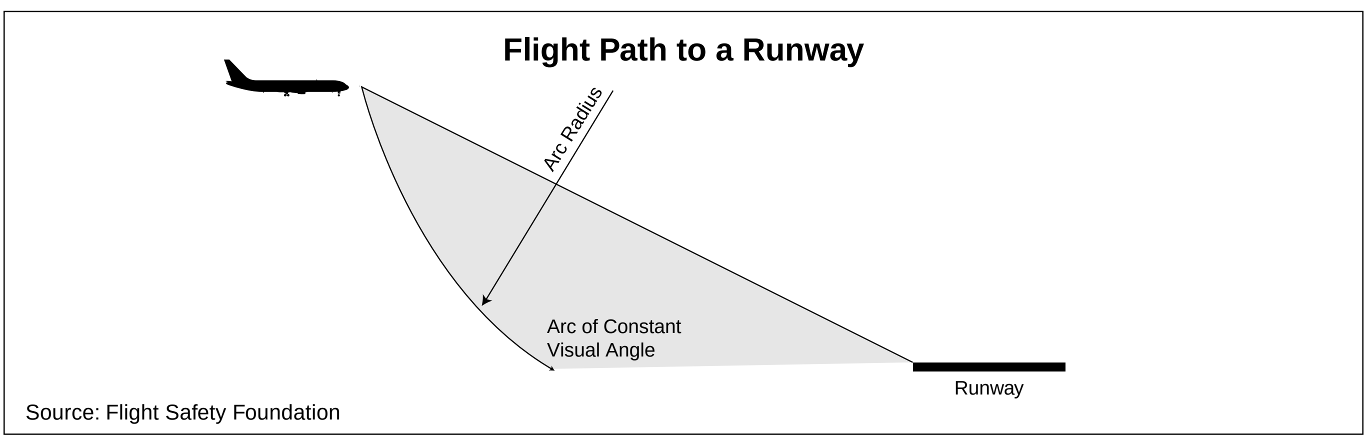


Figure 1

when irregular light patterns or upslope lights or other variations were introduced, a number of pilots flew approach paths that were too low — and in one simulation, a pilot flew to an altitude 2,500 feet below airport elevation.

The Boeing research also verified the hazards of the black-hole illusion.[29]

During the day, a pilot's depth perception helps estimate the distance to an airport, as well as the aircraft's height above it (Figure 2). But in darkness, with the absence of visual clues, such as shadows, topographical references and color variations, the pilot has little or no depth perception. Without depth perception, estimating distance and height becomes more difficult.[30]

The Boeing research also found that the black-hole illusion is aggravated in several circumstances, including when:

- The pilot flies a long, straight-in approach to an airport located on the near side of a city;
- The pilot is not familiar with the runway's length-width relationship;
- The airport is at a lower elevation and on a different slope than surrounding terrain;
- The runway lighting is poor, and other landing aids are unavailable;
- The city lights are spread in an irregular pattern across hills on the far side of the airport; and,
- The lights are obscured by smog, fog or other elements. With obscuration, lights appear dimmer and farther away than they really are.[28]

Despite the attention that the aviation community has directed to the black-hole illusion, accidents continue to occur as a result of the phenomenon.

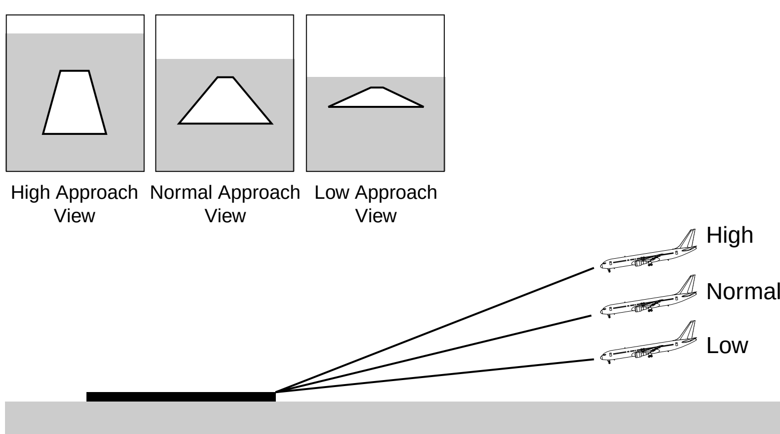
In 1991, a Canadian Armed Forces Lockheed C-130 struck terrain short of Canadian Forces Station Alert in Canada's Northwest Territories while conducting a visual approach on a clear night.[31] In 1997, a Cessna 402, operating as a scheduled passenger flight under FARs Part 135, descended into water three miles from the runway in St. Thomas, U.S. Virgin Islands, while conducting a visual approach in VMC in black-hole conditions.[32] That accident, in which two of the seven people on the airplane were killed, prompted NTSB in October 1998 to recommend that FARs Part 135 scheduled passenger flights that are operated at night be conducted under IFR.[33]

In the recommendation, NTSB said, "According to the pilot's account of the accident, the sky was dark, and few or no lights were visible over the water. The evidence suggests that the absence of visual cues caused by the combination of dark sky and darkness over the water produced a 'black-hole' effect in which the pilot lost a visual sense of the airplane's height above water. … Further, because the flight was conducted under VFR, the pilot had no assistance from air traffic control (ATC) regarding proximity to the surface… . Had the pilot operated under [IFR], radar would have enabled the controller to monitor the flight's altitude, as well as its position."

In an investigation of a similar accident at Moosonee, Ontario, Canada, TSB of Canada determined that the captain of a Beechcraft C99 Airliner was unaware of the black-hole illusion and that neither the captain nor the first officer had received training in aviation medicine or aviation psychology.[34]

Awareness of the black-hole illusion does not guarantee immunity. A flight instructor, who understood and had

Runway Approach Views



Source: Flight Safety Foundation

Figure 2

explained the hazards of the black-hole illusion to his passenger, a student pilot, flew the aircraft into trees on final approach even while he was consciously aware of the visual illusion.[35]

Sloped runways exacerbate the problems associated with black-hole illusions. An upsloping runway (Figure 3) creates an illusion of being too high, causing pilots to fly a low approach that might result in premature surface contact short of the runway. In one of the Boeing simulator experiments[29], 12 Boeing instructor-pilots, whose experience averaged 10,000 flight hours, flew visual approaches in black-hole conditions to an upsloping runway environment without the aid of an instrument landing system or an altimeter. Eleven of the 12 pilots flew into terrain or water short of the runway—in some instances, several miles from the runway.

In March 1996, the upsloping portion of a runway at Halifax International Airport in Nova Scotia, Canada, created an illusion of increased height for the crew of a Boeing 767. This black-hole illusion was so strong that, despite visual cues provided by the precision approach path indicator lights, the crew prematurely reduced power, which resulted in a short, hard landing that damaged the aircraft's tail.[36]

One method for avoiding the black-hole illusion is to avoid long, straight-in approaches in darkness without guidance from a glideslope. The illusion seems less likely to occur when the final approach is less than two miles or three miles (3.2 kilometers or 4.8 kilometers).[30]

Even if a visual approach slope indicator (VASI) is available for runway guidance, its usefulness is limited; the VASI may be visible from as far away as 30 miles, but obstruction-clearance is guaranteed only within four miles of the runway threshhold.[30]

Other recommended precautions call for[30]:

- Maintaining a safe altitude until the airport and associated lighting are clearly visible and identifiable;

- Remaining aware of the airplane's airspeed, altitude and sink rate. An unusually high sink rate may indicate an unusually steep descent profile;

- Using distance-measuring equipment to help establish a safe descent profile in VMC. A pilot can fly the airplane on a three-degree descent profile by remaining 300 feet above the ground for each nautical mile (1.9 kilometers) from the runway; and,

- During short-final approach, do not descend below 50 feet (15 meters) above runway elevation until the aircraft crosses the runway threshold.

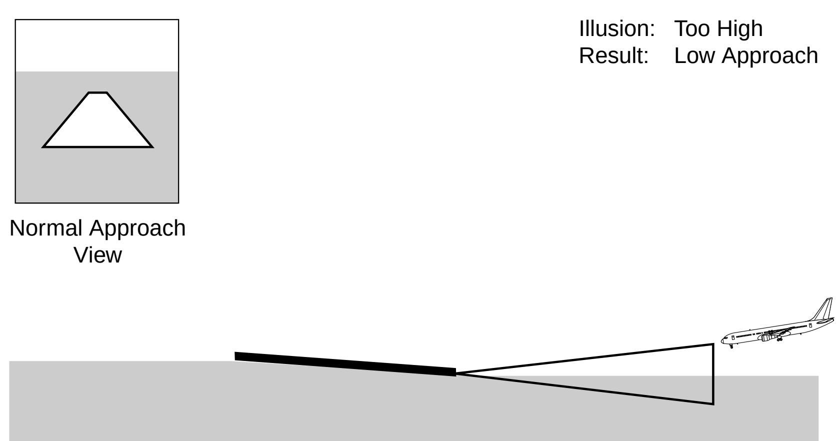
In its recommendations, the ALAR study called for special training for flight crews on conducting approaches and landings during periods of low light and poor visibility. Aircraft operators also should implement constant-angle, stabilized-approach procedures to help crews during approach operations and should implement a policy for using appropriate levels of automation aids and navigation aids for the approach being flown, the study said.[24]

Knowledge of Hazards Is Not Universal

The accident record indicates not only that the risk of specific types of accidents increases at night (in the form of dark-night takeoffs, inadvertent VFR flight into IMC, CFIT, black-hole illusion and other phenomena) but also that the accidents usually are fatal.

Even though most hazards associated with visual flight at night have been known in the aviation industry for many years, the

Illusion Presented by an Upsloping Runway



Source: Flight Safety Foundation

Figure 3

frequency with which these types of accidents continue to occur indicates that pilots' knowledge or awareness of these hazards is not universal. In response to a question about the safety of night flights, a pilot who later died in a dark-night takeoff accident at the Grand Canyon National Park Airport in Arizona, U.S., said that flying at night was no different than flying during the day.[37] The captain of a Beech C99, transporting passengers on a scheduled commercial flight, said that he was unaware of the black-hole illusion.[34]

Research indicates that the visual difficulties of piloting an aircraft in darkness arise not only from perceptual limitations but also from the physiological limitations inherent in the human visual system. The retina — the light-sensitive tissue that lines the back of the eye — contains two types of cells: the cones, which are the key to color perception and are most useful in daytime vision, and the rods, which detect objects and movement and make night vision possible. Because the rods are located in a ring around the cones rather than directly behind the eye's pupils, an object can be seen best in darkness not by looking directly at the object but by "off-center" viewing. For vision to be at its best for night flights, a pilot's eyes need about 30 minutes to adapt to darkness.

However, despite physiological mechanisms that help humans adapt to reduced lighting conditions, if external visual stimuli are sparse or ambiguous, as they often are during flight operations in darkness, then the ability to accurately perceive the external visual world is impaired.♦

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safety presentations on subjects including the visual limitations of night flying at aviation safety seminars in Canada and the United States.

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A 90-page supplemental ALAR reading package, which includes material cited in "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents," can be ordered from the Foundation for US$30 per copy, including postage. The material includes several reports on simulator research done for The Boeing Co. and originally published in various issues of the *Boeing Airliner*, a technical report on the precision approach path indicator from the U.K. Defence Evaluation Research Agency and information on spatial disorientation from the *U.S. Air Force Manual*. Contact:

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