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Visual Illusions Can Spoil Your Whole Day

No matter the size or speed of the aircraft, pilots who find themselves in the dark at low altitudes are subject to the misleading effects of spatial disorientation and other visual pitfalls.

by
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Capt. Prosper Cocquyt of Sabena Belgian World Airlines prepared an award-winning paper in 1952 describing a dangerous illusion with respect to night flying, and a single light on the ground which has been, in part, the probable cause of many night accidents; this sensory "deception" has led to the perception of false horizons.

The problem is especially insidious during VFR night flying at a relatively low altitude, for example when approaching or departing an airport, when the natural horizon is not visible.

Figure la shows a wings-level aircraft flying abeam a light on the ground. The pilot senses that he is at a safe altitude because the light appears below the aircraft (as it should). But consider Figure 1b, a situation where the pilot inadvertently allows the aircraft to bank to the left. (Remember, the horizon is not visible.) By glancing at the light, which is sighted by looking parallel to the wing, the pilot perceives that the aircraft and the light are at the same altitude-ground level. This produces the erroneous sensation of an urgent need to climb. The illusion received when a pilot has inadvertently banked toward a light is considered a "safe-slide" illusion because altitude is perceived to be less than actual and the pilot, by climbing, will err on the safe side.

The dangerous illusion is shown in Figure 1c, a situation where the aircraft is inadvertently allowed to bank away from the light. The pilot has no sensation of being too low because he thinks that he is looking down at the light when, in fact, he is not. Unless the pilot sees the silent warning of the artificial horizon, he might be a victim of an accident.

Inadvertent excursions in pitch also can have serious consequences. Figure 2a shows an aircraft approaching a light (or group of lights) on the ground. Since the aircraft is maintaining a constant altitude, the pilot must look down at an angle to see the approaching lights. If this angle is sufficiently great, the pilot senses that he is at a safe altitude. Suppose that he inadvertently allows the nose to rise slightly, while at a dangerously low altitude as shown in Figure 2b. The pilot senses being at a safe altitude because he appears to be looking down at a great angle when, in reality, he is looking primarily forward.

Such an illusion is mostly likely to occur during a nose-high departure at night toward gently rising terrain, especially when there are no visible landmarks between the aircraft and the light(s) toward which the aircraft is heading. A pilot can be easily deceived into believing that he will clear an obstacle.

A night approach to an airport can create an equally dangerous illusion if there are no visible landmarks between the aircraft and the airport. During these conditions, a pilot can be unaware that he is being lured into the ground.

The departure problem can be prevented by climbing in the traffic pattern, until a safe altitude is reached. Arrival difficulties are best resolved by avoiding straight-in

approaches when the approach corridor is dark, or by utilizing a steep descent path toward the airport.

An additional illusion is often encountered during a straight-in approach at night when the visibility is unlimited, a condition frequently found in desert and mountainous areas. Approach and runway lights appear brighter than usual at such times and may cause a pilot to believe that he is closer to the airport than he really is. The result is often a premature descent toward intervening obstacles.

For this reason, experienced mountain pilots often delay a decent until safely within the confines of the traffic pattern. They use another interesting technique which, although quite logical when you think about it, is something that most pilots are not aware.

When descending toward a distant city, for example, keep a sharp eye on the lights at the edge of the city closest to the aircraft. Should any of these lights disappear, then something (such as a ridge) has risen to block the view and dictates an urgent need to arrest the descent and recapture altitude until the lights are again visible. So long as these lights remain in sight, the aircraft is above en route obstacles.

Pilots Led Into "Black-Hole" Approaches

When descending toward an airport during the day, a pilot uses depth perception to estimate distance to and altitude above an airport. It is relatively easy to descend along an approximately three-degree (normal) visual descent profile to a distant runway. On a moonless or overcast night, however, a pilot has little or no depth perception because the necessary visual cues (color variations, shadows and topographical references) are absent. This lack of depth perception makes it difficult to estimate altitude and distance. For example, a pilot flying six miles from, and 2,000 feet above a runway that is 5,000 feet long and 250 feet wide, sees the same "picture" through his windshield as when he is only three miles from, and 1,000 feet above a runway that is only 2,500 feet long and 125 feet wide.

The problem is exacerbated when straight-in approaches are made over water or dark, featureless terrain on an overcast or moonless night. The only visual stimuli are distant sources of light in the vicinity of the destination airport. Such situations are often referred to as "black-hole" approaches. The black-hole refers not to the airport, but to the featureless darkness over which the approach is conducted

The black-hole approach has claimed many lives, but it was not until 1969 that two Boeing Company engineers, Dr. Conrad L. Kraft and Dr. Charles L. Elworth, conducted an extensive study of the problem. The research program involved a specially developed visual night-approach simulator flown under various conditions by a dozen Boeing senior pilot-instructors. The results were published in a Boeing report titled, "Flight Deck Work Load and Night Visual Approach Performance." Their conclusions finally explained what might have caused so many general aviation, military and airline pilots to fly excessively low during black-hole approaches.

During the project, Kraft and Elworth hypothesized and then confirmed that pilots executing black-hole approaches tend not to vary their descent profiles according to runway perspective as they normally do during conventional straight-in approaches. Instead, they discovered that pilots descend during such approaches while unwittingly maintaining a constant visual angle. The visual angle is the angle occupied by the destination airport (and surrounding lighting) in a pilot's vertical field of vision.

Figure 3 shows an aircraft overflying an airport at a constant altitude. At position A, the pilot looks at the airport (and its surrounding lighting). Note that the airport occupies five degrees of the pilot's vertical field of vision. As the aircraft proceeds to position B, the airport fills a larger and larger portion of the pilot's field vision. At position B, it occupies 10 degrees of the visual angle. All of this is a fancy way of saying that the airport seems to grow bigger as the pilot gets closer.

Figure 1

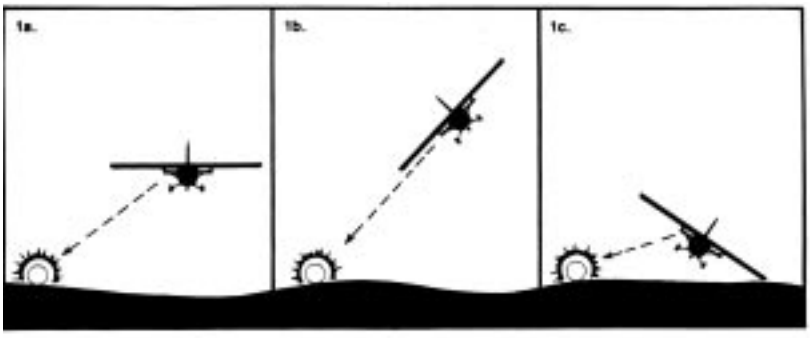
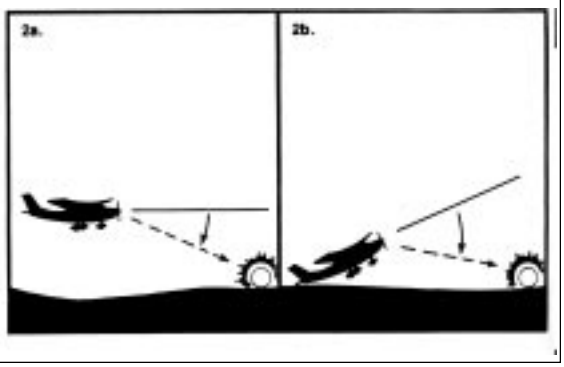


Figure 2



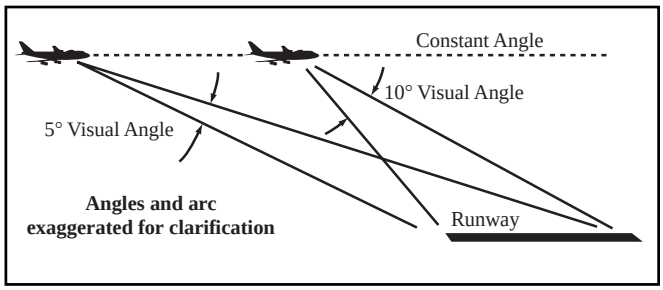


Figure 3

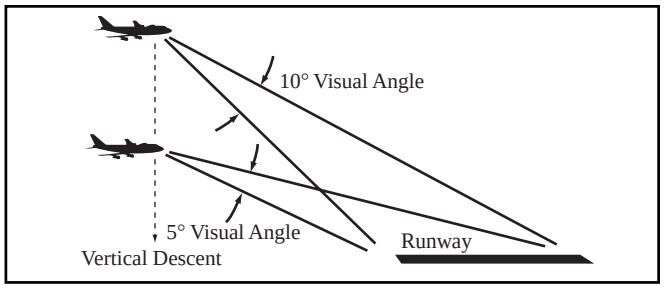


Figure 4

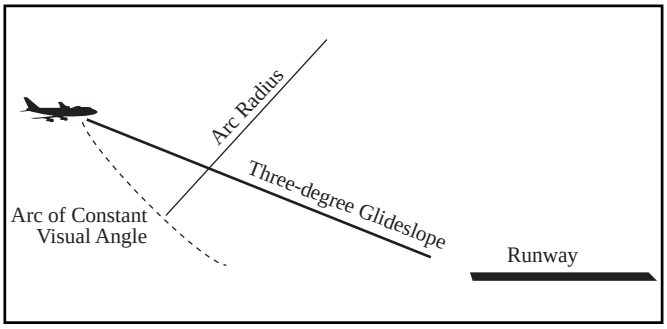


Figure 5

Figure 4 shows what happens to the visual angle as an airplane descends vertically (assuming such a thing were possible) at some distance from the airport. At the higher altitude (position A), the airport occupies 10 degrees of a pilot's visual field, but as the aircraft descends, the visual angle becomes smaller. Finally, at position B, the visual angle is only five degrees. In other words, the visual angle decreases as the altitude decreases.

Since the visual angle becomes larger as a pilot nears the airport and becomes smaller as he loses altitude, it should be obvious that it is possible to approach an airport while maintaining a constant visual angle, but this is what pilots tend to do — without realizing it — while executing black-hole approaches.

The problem is shown in Figure 5. The flight path during which the visual angle remains constant consists of the arc of a circle centered high above the light pattern toward which the pilot is descending. Note that flying such an arc places the aircraft well below the three degree descent profile normally used when a pilot has better depth perception. Also, the circumference of this arc is sufficiently large that the pilot has no way of detecting that he is flying along an arc instead of a straight line. The pilot actually makes a low approach to a point about two or three miles from the runway. Upon arriving at this point, the error starts to become apparent and corrective action is taken, unless the aircraft first strikes terrain or obstructions.

Some may wonder how it is possible to crash during a straight-in approach without first losing sight of the airport. A pilot about to collide with terrain or obstructions does begin to lose sight of the airport, but this can be too late to effect a timely recovery.

The Boeing researchers also discovered that if the airport were at the edge of a small city, the additional lighting cues do not provide improved reference information as long as the approach was made over dark terrain or water. Curiously, their experiments suggested that the addition of light around the airport caused more dangerous approach deviations than when only the airport was visible in the distance. Their report notes also that "the complex pattern of a city at night can replace to a large extent the normal daylight [visual] cues, and the experienced pilot can rely on them to get his bearings. However, an approach over water or unlighted terrain means that the visual reference points are at a distance where altitude and sink rate would be more difficult to judge."

Kraft and Elworth concluded that the problems associated with a black-hole approach appear to be aggravated by:

- A long, straight-in approach to an airport located on the near side of a small city.
- A runway length-width combination that is unfamiliar to a pilot.
- An airport that is situated at a slightly lower elevation and on a different slope that the surrounding terrain.
- Substandard runway and airport lighting.
- A sprawling city with an irregular matrix of light spread over various hillsides beyond the airport.

Other Factors Mislead Pilots

There are, of course, other factors that mislead pilots during night visual approaches:

- Brightly lit runway lighting displays appear to be closer than they are and cause pilots to descend prematurely. This is easily demonstrated by requesting a tower controller to vary runway lighting intensity during your next long, straight-in approach. As the lights dim, you will tend to flatten out the approach; as they brighten, you will tend to steepen the approach.

- Extremely clear air, such as often is found in the desert, encourages early descents because lighted objects seem closer than they really are.
- When the horizon cannot be seen, scattered and distant ground lights can be mistaken for stars. These suggest to a pilot that he is maintaining a nose-high attitude, which results in a tendency to lower the nose and fly below the proper approach guidepath. A similar effect can be caused by the distant (upper) edge of city lights, which also can make the horizon seem lower than it is.
- Peering through a rain-soaked windshield can convince a pilot (because of refractions) that he is too high and result in as much as a 200-foot altitude error per nautical mile from the runway. Refraction distorts the visual approach path in the same way that it bends a straw in a glass of water.
- Viewing an airport through a rainshower makes the runway lights seem bigger then they are, causing a pilot to believe that he is too high.
- An upslope runway or surrounding city lighting always — day or night — provides the illusion of being too high during a straight-in approach. This results in a strong tendency to descend prematurely. Conversely, a downslope condition frequently leads to an overshoot.

There are certain precautions a pilot can use to maintain his altitude and distance awareness during long straight-in approaches at night. When available, use an electronic glideslope or VASI (visual approach slope indicator) for descent guidance. Consider, however, that although the VASI may be visible for up to 30 miles at night (three to five miles during the day), safe obstruction clearance is guaranteed only when within four miles of the runway threshold.

DME might be useful to establish a safe descent profile using the principle that a three-degree glideslope is determined by maintaining 300 feet of altitude for each nautical mile from the runway (for example, an airplane three miles from the runway should be at least 900 feet agl.) A four-degree descent is established by maintaining 400 feet for each nautical mile from the airport, and so forth.

Always maintain a watchful eye on airspeed, altitude and sink rate (for the airspeed being flown). They will indicate either a strong tail wind or an abnormally steep descent profile. Remain alert.

Finally, be certain that you are descending toward an airport. Pilots have been deceived by highway lights and other parallel rows of lights that — from a distance — give the illusion of being runway lights. Maintain a safe altitude until the airport and its associated lighting are distinctly visible and identifiable.

The best way to combat these subtle and insidious influences is to avoid long, straight-in approaches at night, especially when overflying a black hole. Instead, maintain a safe altitude until in the vicinity of the airport and descend in or near the traffic pattern. Pilots seldom are victim to illusions when their final approach legs are less than two or three miles long.

Like most people, pilots usually believe what they see. In the case of a black-hole approach, however, there are compelling reasons not to do so. ♦

(Adapted from an article by Capt. Barry Schiff in the AOPA Pilot, *all rights reserved, in the interest of sharing aviation safety information with the worldwide aviation community. Schiff flies for TWA and is a flight instructor. He is a regular contributor the* AOPA Pilot *and is the author of "The Proficient Pilot.")*

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