"BLACK HOLE" APPROACH

Based on a story by Barry SCHIFF

"Black hole" approaches posed a significant hazard to airlines during the 1970s. Since then, a number of advances - ground proximity warning systems, the successful push to have VASI and ILS systems installed on more air carrier runways, and head-up displays - have greatly reduced the incidence of "black hole" approach incidents and accidents among carriers flying large jet aircraft. Pilots of regional airlines, however, typically fly more total approaches, more "black hole" approaches, and more approaches to runways without vertical guidance. All pilots may benefit from this review of "black hole" approaches - especially the explanation of why pilots may be lured into flying into terrain or obstacles despite having the runway in sight throughout the approach.

During the 1940s, the bible for student pilots in the USA was the *Civil Pilot Training Manual,* published by the Civil Aeronautics Administration (predecessor of the FAA). For its day, the CAA manual was a no-nonsense book that pulled few punches. It stated, for example, that "night flights should not be made in single-engine aircraft unless all occupants are provided with parachutes".

This advice seems to imply that bailing out is the preferred method of coping with an engine failure at night. Consider, however, that this was written during an era when aircraft power plants were no more reliable than a politician's promise. (Even today, however, an off-airport landing at night often requires more luck than skill.)

Despite claims to the contrary, night operations are still more hazardous than daylight flying. This is because the horizon is often not visible, optical illusions are more prevalent, and fatigue is often more of a factor. Also, obstructions and clouds may be difficult or impossible to see. Regarding this last point, consider that hundreds, if not thousands, of pilots and passengers have collided with terrain that was never seen, even though visibility was unlimited.

NIGHT VISIBILITY

Such accidents occur because night visibility is determined by the greatest distance at which prominent lighted objects can be seen and identified. Seeing a distant light, however, does not mean that the pilot can see rising terrain directly in front of the aircraft on a moonless, overcast night.

Executing visual arrivals and departures over certain areas and under certain conditions is much like instrument flying and requires the same attention to minimum safe altitudes. Obviously, the crew is responsible for ensuring that the aircraft is always at a high enough altitude to keep from flying headlong into unseen obstructions.

Avoiding obstructions, however, can be easier said than done, particularly during a long, straight-in approach to the airport at night. A subtle danger associated with some night visual approaches can lead airline crews to fly at dangerously (and sometimes fatally) low approach altitudes.

When descending toward an airport during the day, a pilot uses depth perception to estimate distance to and altitude above an airport. The pilot can fairly easily descend along an approximately three-degree visual approach slot to a distant runway.
On a moonless or overcast night, however, the pilot has little or no depth perception because the necessary visual cues (colour variations, shadows & topographical references) are absent. This lack of depth perception makes estimating altitude and distance difficult.

For example, a pilot flying six miles from and 2000 feet above a runway that is 12,000 feet long and 300 feet wide sees the same "picture" through the windshield as when the aircraft is only three miles from and 1 000 feet above a runway that is only 6000 feet long and 150 feet wide.

APPROACHES OVER WATER

The problem is exacerbated when straight-in approaches are made over water or over dark, feature-less 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.

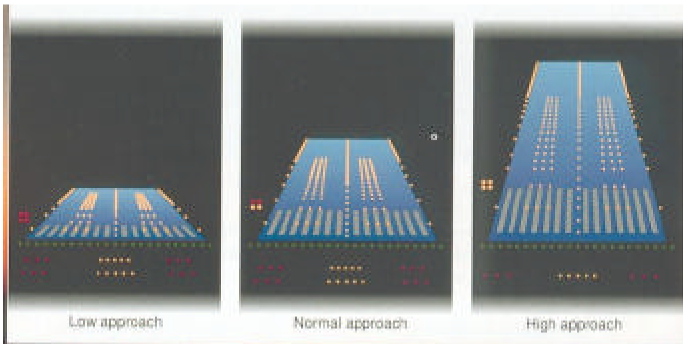

Figure 1. These three illustrations show the pilot's visual perspective of the runway for approaches that are too low, normal and too high. Pilots usually maintain this perspective even when making *black-hole* approaches.

The "black hole" refers not to the airport, but to the featureless darkness over which the approach is being conducted. Over water approaches are notable examples.

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

CONSTANT VISUAL ANGLES

During the project, Kraft and Elworth had 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 (see figure 1). Instead, the researchers discovered that pilots maintain a constant visual angle while descending during such approaches. The visual angle is the angle that the destination airport (and surrounding lighting) occupies (or subtends) in a pilot's vertical field of vision.

Figure 2 shows an aircraft overflying an airport at a constant altitude. At position A, the pilot looks at the airport (and its surrounding lighting). Let us assume 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 of vision.

At position B, it occupies 10 degrees of visual angle. All of this is a fancy way of saying that the airport seems to get bigger as the pilot gets closer.

Figure 3 shows what happens to the visual angle as an aircraft descends vertically (assuming such a thing were possible in a fixed-wing aircraft) 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 altitude decreases.

Because the visual angle becomes larger as a pilot nears the airport and becomes smaller as the aircraft loses altitude, a pilot can descend toward an airport in such a way that the resultant visual angle remains constant.

Not only can a pilot approach an airport in this manner, but this is exactly what pilots tend to do without realizing it - while executing "black hole" approaches.

The problem is shown in figure 4. 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.

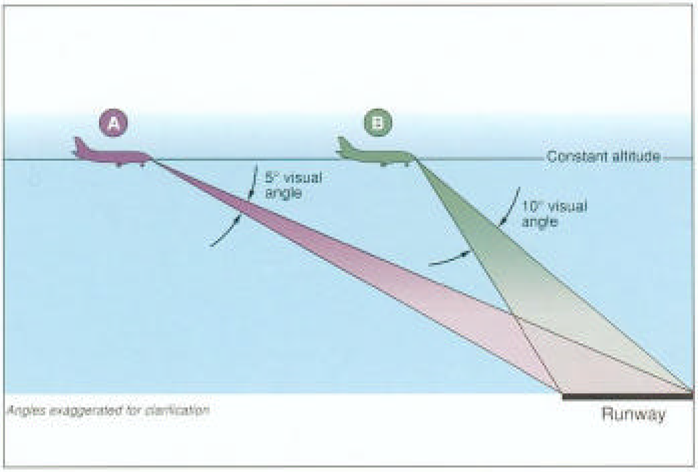

Figure 2. Distance and altitude from an airport effect the pilot's perspective. If a constant altitude is maintained, the airport will subtend a greater visual angle, and therefore appear larger, as the airplane approaches the airport.

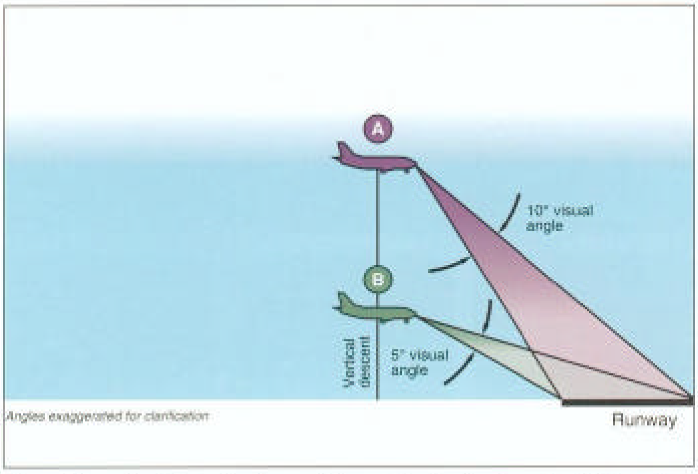

Figure 3. Assuming that an airplane could descend vertically at a constant distance from an airport, the visual angle would decrease, making the airport appear to move farther away.

LOW APPROACH SHORT OF RUNWAY

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 the pilot takes corrective action (unless the aircraft's striking an intervening obstruction interrupts the process). Some may wonder how a pilot can possibly crash during a straight-in approach without first losing sight of the airport. A pilot about to collide with terrain or an obstruction does begin to lose sight of the airport, but this can occur after it is too late to effect a timely recovery.

LIGHTS AT SMALL CITIES

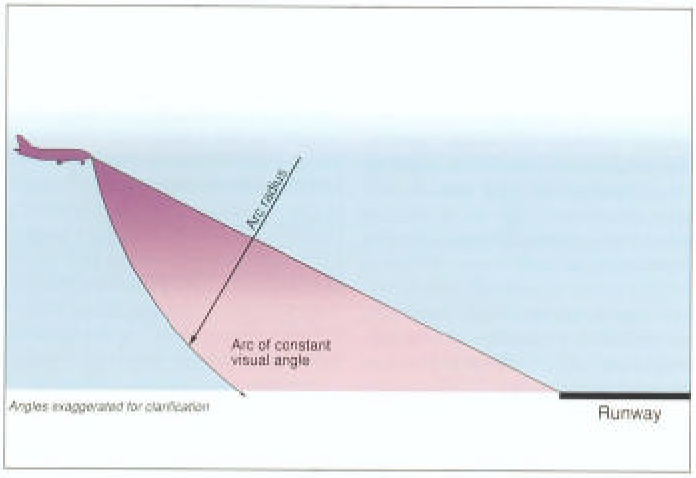

Figure 4. With the poor depth perception usually associated with *black-hole* approaches, the pilot tends to fly a gentle, and almost imperceptible arc, which can place the airplane well below the 3° normal descent profile.

The Boeing researchers also discovered that if the airport is at the edge of a small city, the additional lighting cues do not provide improved reference information as long as the approach is made over dark terrain or water. Curiously, their experiments suggested that adding lights around the airport caused greater and more dangerous approach deviations than when only the airport was visible in the distance. Their report notes also that "the complex [light] 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 unlit 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 conclude 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 than the surrounding terrain,
- substandard runway and airport lighting, and
- a sprawling city with an irregular matrix of lights spread over various hillsides behind the airport.

Other factors, of course, may mislead pilots during night visual approaches. Among these are the following :

- Brightly lit runway-lighting displays appear to be closer than they really are and cause pilots to descend prematurely. This is easily demonstrated by requesting a tower controller to vary runway lighting intensity during your next lengthy, 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, also 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 the aircraft's attitude is excessively nose high, which results in a tendency for the pilot to lower the nose and fly below the proper approach glide path. 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 refraction) that the aircraft is too high and can result in an error of as much as 200 feet of altitude per nautical mile from the runway. (Refraction bends the visual approach path in the same way that it "bends" the straw in a glass of water.)

- Viewing an airport through an intervening rain shower makes the runway lights seem bigger than they are, causing a pilot to believe the aircraft is too high.
- An upslope runway (and/or surrounding city lighting) - 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 can lead to an overshoot.)

GLIDE SLOPE GUIDANCE

The best way to combat these often subtle and insidious factors is to avoid long, straight-in, visual approaches at night without glide slope guidance, especially when overflying the infamous "black hole". Pilots seldom are victimized by illusions when the final approach is less than two or three miles long.

A pilot can use certain precautions to increase altitude and distance awareness during long, straight-in approaches at night when an ILS or VASI is unavailable for descent guidance. (Although a VASI may be visible for up to 30 miles at night, safe obstruction clearance is guaranteed only within four miles of the runway threshold.)

DME (if available and appropriate) can help to establish a safe descent profile using the principle that a three-degree descent profile can be maintained by being 300 feet above ground level (AGL) for each nautical mile from the runway. (For example, an aircraft three miles from the runway should be at 900 feet AGL.) A four-degree descent is established by maintaining 400 feet per nautical mile, and so forth.

Always maintain a watchful eye on airspeed, altitude, and sink rate. An excessive sink rate (for the airspeed being flown) indicates either a strong tailwind or an abnormally steep descent profile. Remain alert.

Although stating this might seem silly, be certain that you are descending towards an airport. Pilots have been deceived by highway lights or 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.

Like most people, pilots usually believe what they see. In "black hole" approaches, however, pilots have compelling reasons not to do so.