FLIGHT SAFETY FOUNDATION

ALAR

APPROACH-AND-LANDING ACCIDENT REDUCTION

TOOL KIT

FSF ALAR BRIEFING NOTE 5.3

Visual Illusions

Visual illusions result from many factors and appear in many different forms.

Illusions occur when conditions modify the pilot's perception of the environment relative to his or her expectations, possibly resulting in spatial disorientation or landing errors (e.g., landing short or landing long).

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that visual approaches were being conducted in 28 percent of the 76 approach-and-landing accidents (ALAs) and serious incidents worldwide in 1984 through 1997.[1]

Visual approaches at night typically present a greater risk because of fewer visual references, and because of visual illusions and spatial disorientation.

The task force found that disorientation or visual illusion was a causal factor[2] in 21 percent of the 76 ALAs and serious incidents, and that poor visibility was a circumstantial factor[3] in 59 percent of the accidents and incidents.

Visual Illusions

The following factors and conditions affect the flight crew's ability to perceive accurately the environment, resulting in visual illusions.

Airport environment:

- Ground texture and features;
- Off-airport light patterns, such as brightly lighted parking lots or streets;
- "Black-hole effect"[4] along the final approach flight path; and/or,
- Uphill-sloping terrain or downhill-sloping terrain in the airport vicinity.

Runway environment:

- Runway dimensions;
- Runway slope (uphill gradient or downhill gradient);
- Terrain drop-off at the approach end of the runway;
- Approach lighting and runway lighting; and/or,
- Runway condition.

Weather conditions:

- Ceiling;
- Visibility; and/or,
- Obstructions to vision.

Pilot's Perception

Visual illusions result from the absence of visual references or the alteration of visual references, which modify the pilot's perception of his or her position (in terms of height, distance and/or intercept angle) relative to the runway threshold.

Visual illusions are most critical when transitioning from instrument meteorological conditions (IMC) and instrument references to visual meteorological conditions (VMC) and visual references.

Visual illusions affect the flight crew's situational awareness, particularly while on base leg and during the final approach.

Visual illusions usually induce crew inputs (corrections) that cause the aircraft to deviate from the vertical flight path or horizontal flight path.

Visual illusions can affect the decision process of when and how rapidly to descend from the minimum descent altitude/height (MDA[H]).

The following are factors and conditions that create visual illusions that can affect the pilot's perception of:

- The airport and runway environment;
- Terrain separation; and,
- Deviation from the horizontal flight path or vertical flight path.

Usually, more than one factor is involved in a given approach.

Airport Environment

Conditions that create visual illusions include:

- Black-hole effect along the final approach flight path;
- An uphill slope in the approach zone or a drop-off of terrain at the approach end of the runway creates an illusion of being too high (impression of a steep glide path [Figure 1]), thus:
  - Possibly inducing a correction (e.g., increasing the rate of descent) that places the aircraft below the intended glide path; or,
  - Preventing the flight crew from detecting a too-shallow flight path; and,
- A downhill slope in the approach zone creates an illusion of being too low (impression of a shallow glide path [Figure 2]), thus:
  - Possibly inducing a correction that places the aircraft above the intended glide path; or,
  - Preventing the flight crew from detecting a too-steep flight path.

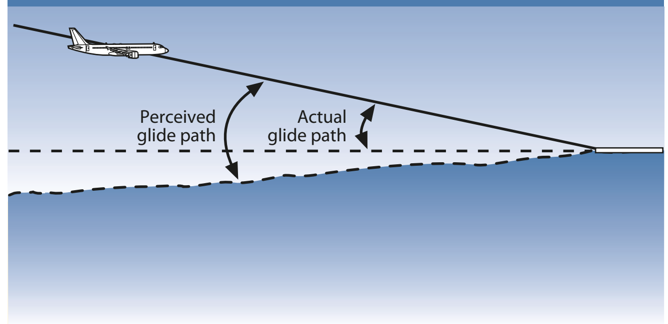
Runway Environment

Conditions that create visual illusions include:

- Runway dimensions:
  - The runway aspect ratio (i.e., its length relative to its width) affects the crew's visual perception of the runway (Figure 3, middle panel, shows the expected image of the runway);
  - A wide or short runway (low aspect ratio) creates an impression of being too low (Figure 3, left panel); and,
  - A narrow or long runway (high aspect ratio) creates an impression of being too high (Figure 3, right panel);
- Runway uphill slope or downhill slope:
  - An uphill slope creates an illusion of being too high (impression of a steep glide path); and,
  - A downhill slope creates an illusion of being too low (impression of a shallow glide path);
- Lighting:
  - Approach lighting and runway lighting (including touchdown zone lighting) affect depth perception, depending on:
    - Lighting intensity;
    - Daytime conditions or nighttime conditions; and
    - Weather conditions;
  - Bright runway lights create the impression of being closer to the runway (thus, on a steeper glide path);
  - Low-intensity lights create the impression of being farther away (thus, on a shallower glide path);
  - Nonstandard spacing of runway lights modifies the pilot's perception of distance to the runway and glide path; and,
  - If the runway lighting is partially visible (e.g., while on base leg during a visual approach or circling approach), the runway may appear farther away or at a different angle (e.g., intercept angle is perceived as smaller than actual).

The following runway approach-aid conditions may increase the crew's exposure to visual illusions:

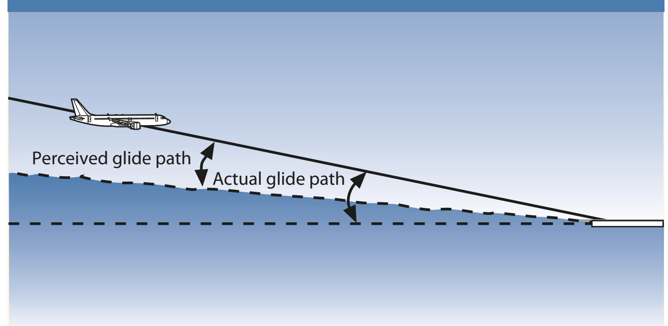
Uphill Slope Creates Illusion That Aircraft Is on Steeper-Than-Actual Glide Path



Source: FSF ALAR Task Force

Figure 1

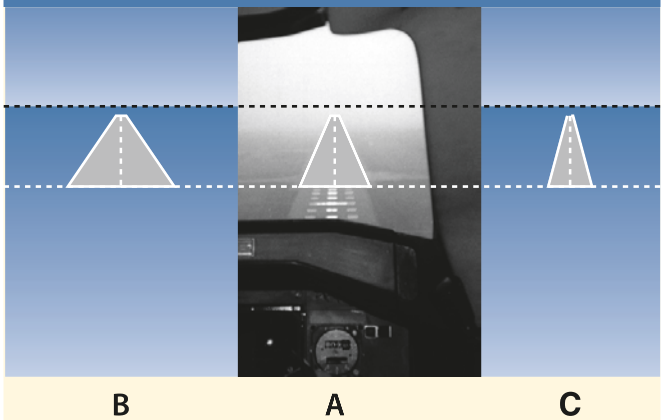
Downhill Slope Creates Illusion That Aircraft Is on Shallower-Than-Actual Glide Path



Source: FSF ALAR Task Force

Figure 2

Effects of Runway Dimensions on Perception of Height



Note: All three panels show a pilot's sight picture from an aircraft at 200 feet and on a three-degree glide path. The runway in panel A is 150 feet (45 meters) wide and 11,500 feet (3,500 meters) long. The runway in panel B is wider/shorter than the runway in panel A; the crew may believe that the aircraft is on a shallower-than-actual glide path. The runway in panel C is narrower/longer than the runway in panel A; the crew may believe that the aircraft is on a steeper-than-actual flight path.

Source: FSF ALAR Task Force

Figure 3

- A glideslope that is unusable beyond a certain point because of terrain or below a certain altitude because of water;
- Offset localizer course; and,
- Two-bar visual approach slope indicator (VASI), if used below (typically) 300 feet height above touchdown (HAT) for glide-path corrections.

Weather Conditions

The following weather conditions can create visual illusions:

- Ceiling and visibility (vertical, slant and horizontal visibility):
  - Flying in light rain, fog, haze, mist, smoke, dust, glare or darkness usually creates an illusion of being too high;
  - Shallow fog (i.e., a fog layer not exceeding 300 feet thickness) results in a low obscuration and in low horizontal visibility:
    - When on top of a shallow fog layer, the ground (or airport and runway, if flying overhead) can be seen; but when entering the fog layer, forward visibility and slant visibility are lost; and,
    - Entering a fog layer also creates the perception of a pitch-up, which causes the pilot to respond with a nose-down correction that steepens the approach path;
  - Flying in haze creates the impression that the runway is farther away, inducing a tendency to shallow the glide path and land long;
  - In light rain or moderate rain, the runway may appear indistinct because of the "rain halo effect," increasing the risk of misperception of the vertical deviation or horizontal deviation during the visual segment (the segment flown after transition from instrument references to visual references);
  - Heavy rain affects depth perception and distance perception:
    - Rain on a windshield creates refraction effects that cause the crew to believe that the aircraft is too high, resulting in an unwarranted nose-down correction and flight below the desired flight path;
    - In daylight conditions, rain diminishes the apparent intensity of the approach light system (ALS), resulting in the runway appearing to be farther away. As a result of this illusion, the flight crew tends to shallow the flight path, resulting in a long landing; and,
    - In nighttime conditions, rain increases the apparent brilliance of the ALS, making the runway appear to be closer, inducing a pitch-down input and the risk of landing short of the runway threshold;
  - When breaking out at both ceiling minimums and visibility minimums, the slant visibility may not be sufficient for the crew to see the farther bar(s) of the VASI or precision approach path indicator (PAPI), thus reducing the available visual cues for the visual segment in reduced visibility;
- Crosswind:
  - In crosswind conditions, the runway lights and environment will appear at an angle to the aircraft heading; the flight crew should maintain the drift correction and resist the tendency to align the aircraft with the runway centerline; and,
- Runway surface condition:
  - A wet runway reflects very little light; this can affect depth perception and cause the flight crew to perceive incorrectly that the aircraft is farther away from the runway. This effect usually results in a late flare and hard landing.

Table 1 provides a summary of visual illusions factors and their effects on the pilot's perception and actions.

Lessening the Effects

To lessen the effects of visual illusions, company accident-prevention strategies and personal lines of defense should be developed and implemented based on the following recommendations.

Factors That Cause Visual Illusions and Result in Incorrect Pilot Responses

Factor	Perception	Action	Result
Narrow or long runway Runway or terrain uphill slope	Too high	Push	Land short/ hard
Wide or short runway Runway or terrain downhill slope	Too low	Pull	Land long/ overrun
Bright runway lighting	Too close (too steep)	Push	Land short/ hard
Low-intensity lighting	Farther away (too shallow)	Pull	Land long/ overrun
Light rain, fog, haze, mist, smoke, dust	Too high	Push	Land short/ hard
Entering fog (shallow layer)	Pitch-up	Push over	Steepen glide path/(CFIT)
Flying in haze	Farther away (too shallow)	Pull	Land long/ overrun
Wet runway	Farther away (too high)	Late flare	Hard landing
Crosswind	Angled with runway	Cancel drift correction	Drifting off track

CFIT = controlled flight into terrain

Source: FSF ALAR Task Force

Table 1

Hazard Awareness

Companies should assess their exposure to visual illusions on their route network and in their operating environment(s).

Flight crews should be trained to recognize and to understand the factors and conditions that cause visual illusions and their effects, including:

- Perception of height/depth, distances and angles; and,
- Assessment of the aircraft's horizontal position and glide path.

Hazard Assessment

Approach hazards should be assessed during the approach briefing by reviewing the following elements:

- Ceiling conditions and visibility conditions;
- Weather:
  - Wind and turbulence;
  - Rain showers; and/or,
  - Fog or smoke patches;
- Crew experience at the airport and in the airport environment:
  - Surrounding terrain; and/or,
  - Specific airport hazards and runway hazards (obstructions, black-hole effect, off-airport light patterns); and,
- Runway approach aids and visual aids:
  - Type of approach (let-down navaid restriction, such as a glideslope that is unusable beyond a specific point or below a specific altitude);
  - Type of approach lights; and,
  - VASI or PAPI availability.

Terrain Awareness

When requesting or accepting a visual approach, the flight crew should be aware of the surrounding terrain features and man-made obstacles.

At night, an unlighted hillside between a lighted area and the runway may prevent the flight crew from correctly perceiving the rising terrain.

Type of Approach

At night, whenever an instrument approach is available (particularly an instrument landing system [ILS] approach) the instrument approach should be preferred to a visual approach, to reduce the risk of accidents caused by visual illusions.

If an ILS approach is available, fly the ILS and use VASI or PAPI for the visual portion of the approach.

If an ILS approach is not available, a nonprecision approach supported by a VASI or PAPI should be the preferred option.

On a nonprecision approach, do not descend below the MDA(H) before reaching the visual descent point (VDP), even if visual references have been acquired.

To help prevent transitioning too early to visual references and descending prematurely, the pilot flying (PF) should maintain instrument references until reaching the VDP.

During a visual or circling approach, when on the base leg, if the VASI or PAPI indicates that the aircraft is below glide path, level off or climb until the VASI or PAPI indicates on-glide-path.

Flight Path Monitoring

Resisting the tendency to pitch down or to descend intentionally below the appropriate altitude is the greatest challenge during the visual segment of the approach. This includes:

- Pitching down toward the approach lights in an attempt to see the runway during a precision approach; or,
- Descending prematurely because of the incorrect perception of being too high.

The pilot not flying/pilot monitoring (PNF/PM) must maintain instrument references, including glideslope deviation, during the visual portion of an ILS approach.

Monitoring the VASI or PAPI, whenever available, provides additional visual references to resist the tendency to increase or to decrease the rate of descent.

On runways with an ALS with sequenced flashing lights II (ALSF-II), flight crews should be aware that two rows of red lights are aligned with the touchdown zone lights; this will provide an additional guard against descending prematurely.

The following can counter visual illusions (and prevent a flight crew from descending prematurely):

- Maintain an instrument scan down to touchdown;
- Cross-check instrument indications against outside visual references to confirm glide path;
- Use an ILS approach whenever available;
- Use a VASI or PAPI, if available, down to runway threshold; and,
- Use other available tools, such as an extended runway centerline shown on the flight management system (FMS) navigation display, ILS-DME (distance-measuring equipment) or VOR (very-high-frequency omnidirectional radio)-DME distance, altitude above airport elevation to confirm the glide path (based on a typical 300-feet/one-nautical-mile approach gradient).

Crew Resource Management (CRM)

CRM should ensure continuous monitoring of visual references and instrument references throughout the transition to the visual segment of an instrument approach.

In demanding conditions, the PNF/PM should reinforce his or her monitoring of instrument references and of the flight progress for effective cross-check and backup of the PF.

Altitude calls and excessive-parameter-deviation calls should be the same for instrument approaches and for visual approaches, and should be continued during the visual portion of the approach (including glideslope deviation during an ILS approach or vertical-speed deviation during a nonprecision approach).

Consequences

The following are cited often in the analysis of approach-and-landing incidents and accidents resulting from visual illusions:

- Unconscious modification of the aircraft trajectory to maintain a constant perception of visual references;
- Natural tendency to descend below the glideslope or the initial glide path;
- The preceding tendencies combined with the inability to judge the proper flare point because of restricted visual references (often resulting in a hard landing before reaching the desired touchdown point);
- Inadequate reference to instruments to support the visual segment;
- Failure to detect the deterioration of visual references; and,
- Failure to monitor the instruments and the flight path because both pilots are involved in the identification of visual references.

Summary

To guard against the adverse effects of visual illusions, flight crews should:

- Be aware of all weather factors;
- Be aware of surrounding terrain and obstacles;
- Assess the airport environment, airport and runway hazards; and,
- Adhere to defined PF-PNF/PM task sharing after the transition to visual flying, including:
  - Monitoring by the PF of outside visual references while referring to instrument references to support and monitor the flight path during the visual portion of the approach; and,
  - Monitoring by the PNF/PM of head-down references while the PF flies and looks outside, for effective cross-check and backup.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- 1.6 — Approach Briefing;
- 5.2 — Terrain;
- 7.3 — Visual References; and,
- 7.4 — Visual Approaches.

Notes

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
2. The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force defined *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

3. The FSF ALAR Task Force defined *circumstantial factor* as "an event or item that was judged not to be directly in the causal chain of events but could have contributed to the accident [or incident]."

4. The *black-hole effect* typically occurs during a visual approach conducted on a moonless or overcast night, over water or over dark, featureless terrain where the only visual stimuli are lights on and/or near the airport. The absence of visual references in the pilot's near vision affects depth perception and causes the illusion that the airport is closer than it actually is and, thus, that the aircraft is too high. The pilot may respond to this illusion by conducting an approach below the correct flight path (i.e., a low approach).

Related Reading From FSF Publications

Brotak, Ed. "Extreme Weather Makers." *AeroSafety World* Volume 4 (July 2009).

Lacagnina, Mark. "Short Flight, Long Odds." *AeroSafety World* Volume 4 (May 2009).

Werfelman, Linda. "Flying Into the Sea." *AeroSafety World* Volume 4 (January 2009).

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Carbaugh, David. "Good for Business." *AeroSafety World* Volume 2 (December 2007).

Bateman, Don; McKinney, Dick. "Dive-and-Drive Dangers." *AeroSafety World* Volume 2 (November 2007).

Tarnowski, Etienne. "From Nonprecision to Precision-Like Approaches." *AeroSafety World* Volume 2 (October 2007).

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Gurney, Dan. "Last Line of Defense." *AeroSafety World* Volume 2 (January 2007).

Rash, Clarence E. "Flying Blind." *AviationSafety World* Volume 1 (December 2006).

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Flight Safety Foundation (FSF) Editorial Staff. "Fast, Low Approach Leads to Long Landing and Overrun." *Accident Prevention* Volume 63 (January 2006).

FSF Editorial Staff. "DC-10 Overruns Runway in Tahiti While Being Landed in a Storm." *Accident Prevention* Volume 62 (August 2005).

FSF Editorial Staff. "Freighter Strikes Trees During Nighttime 'Black-hole' Approach." *Accident Prevention* Volume 62 (February 2005).

FSF Editorial Staff. "Nonadherence to Approach Procedure Cited in Falcon 20 CFIT in Greenland." *Accident Prevention* Volume 61 (November 2004).

FSF Editorial Staff. "Noncompliance With Instrument Approach Procedures Cited in King Air CFIT in Australia." *Accident Prevention* Volume 60 (November 2003).

FSF Editorial Staff. "Sabreliner Strikes Mountain Ridge During Night Visual Approach." *Accident Prevention* Volume 60 (April 2003).

FSF Editorial Staff. "Nonadherence to Standard Procedures Cited in Airbus A320 CFIT in Bahrain." *Accident Prevention* Volume 59 (December 2002).

FSF Editorial Staff. "Reduced Visibility, Mountainous Terrain Cited in Gulfstream III CFIT at Aspen." *Accident Prevention* Volume 59 (November 2002).

Wilson, Dale R. "Darkness Increases Risks of Flight." *Human Factors & Aviation Medicine* Volume 46 (November–December 1999).

Enders, John H.; Dodd, Robert; Tarrel, Rick; Khatwa, Ratan; Roelen, Alfred L.C.; Karwal, Arun K. "Airport Safety: A Study of Accidents and Available Approach-and-landing Aids." *Flight Safety Digest* Volume 15 (March 1996).

FSF Editorial Staff. "Fatal Commuter Crash Blamed on Visual Illusion, Lack of Cockpit Coordination." *Accident Prevention* Volume 50 (November 1993).

FSF Editorial Staff. "Spatial Disorientation Linked to Fatal DC-8 Freighter Crash." *Accident Prevention* Volume 50 (March 1993).

Notice

The Flight Safety Foundation (FSF) Approach-and-Landing Accident Reduction (ALAR) Task Force produced this briefing note to help prevent approach-and-landing accidents, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team's Joint Safety Analysis Team and the European Joint Aviation Authorities Safety Strategy Initiative.

This briefing note is one of 33 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that also have been developed to help prevent approach-and-landing accidents.

The briefing notes have been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines, but they can be adapted for those who operate airplanes with fuselage-mounted turbine engines, turboprop power plants or piston engines. The briefing notes also address operations with the following: electronic flight instrument systems; integrated autopilots, flight directors and autothrottle systems; flight management systems; automatic ground spoilers; autobrakes; thrust reversers; manufacturers'/operators' standard operating procedures; and, two-person flight crews.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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