Flight Operations Briefing Notes

Human Performance

Visual Illusions Awareness

I Introduction

Visual illusions take place when conditions modify the pilot's perception of the environment relative to his / her expectations.

Visual illusions may result in landing short of the runway, hard landing or runway overrun, but may also cause spatial disorientation and loss of control.

This Flight Operations Briefing Note provides an overview of:

- Factors and conditions that may cause visual illusions;
- How visual illusions affect the pilot's perception of the airport / runway environment and runway; and,
- How to reduce the effects of visual illusions by implementing related prevention strategies and lines-of-defense in training and line operation.

II Statistical Data

30 % of approach-and-landing accidents occur during the conduct of visual approaches or during the visual segment of an instrument approach.

Visual approaches at night present a greater exposure because of reduced visual cues, increased likelihood of visual illusions and risk of spatial disorientation.

Low visibility and/or precipitations are a circumstantial factor in more than 70 % of approach-and-landing accidents, including those involving CFIT.

" Visual " Factors	% of Events
Night time	75 %
Low visibility	70 %
IMC	59 %
Darkness or twilight	53 %
Non-ILS approach	53 %
Precipitation (rain or snow)	50 %
Visual approach	30 %
Visual illusions or spatial disorientation	21 %
Absence of : - letdown navaid - approach / runway lighting - VASI / PAPI	21 %

(Source – Flight Safety Foundation 1998 – 2000)

Table 1

" Visual " Factors in Approach-and-Landing Events

III Visual Illusions – Factors and Conditions

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

III.1 Airport Environment

- Ground texture and features;
- Off-airport light patterns such as brightly lighted parking lots or streets;
- "Black hole" along the final approach flight path; and/or,
- Uphill or downhill sloping terrain before the runway threshold or in the approach path environment.

III.2 Runway Environment

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

III.3 Weather Conditions

- Ceiling;
- Visibility (i.e., vertical visibility, slant visibility and horizontal visibility); and/or,
- Cloudiness (e.g., rain, fog or fog patches, haze, mist, smoke, snow, whiteout effect).

IV How do Visual Illusions Affect the Pilot's Perception ?

Visual illusions result from the absence of or the alteration of visual references that modifies the pilot perception of his / her position relative to the runway threshold.

Visual illusions affect perception of heights, distances and/or intercept angles.

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

Visual illusions (such as the black-hole effect) affect the flight crew vertical and horizontal situational awareness, particularly during the base leg and when turning final (as applicable) and during the final approach.

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

Visual illusions can affect the decision about when and how fast to descend from the MDA(H).

The following paragraph provides an expanded overview of all the factors and conditions creating visual illusions to discuss how each factor or condition may affect the pilot perception of:

- The airport and runway environment;
- The terrain separation; and,
- The aircraft vertical or lateral deviation from the intended flight-path.

Usually, more than one factor is involved in a given approach, compounding the individual effects.

IV.1 Airport Environment

- "Black hole" along the final approach flight path:
  - In case of approach over water or with an unlighted area on the approach path, the absence of visible ground features reduces the crew ability to perceive the aircraft lateral and vertical position relative to the intended flight path.

- Uphill or downhill terrain before the runway threshold:
  - 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 (i.e., impression of a steep glide path, as shown on **Figure 1**), thus:
    - Possibly inducing a correction (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.

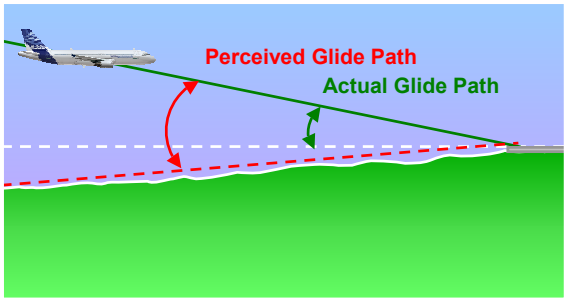
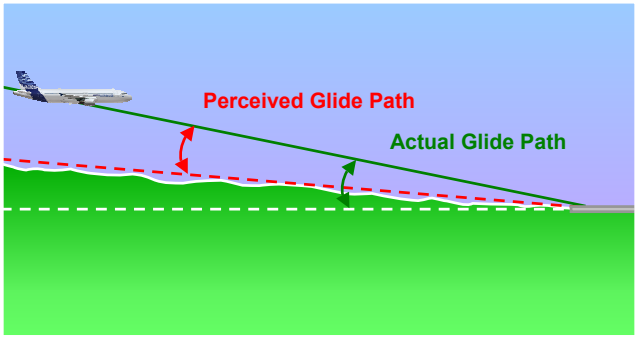


Figure 1

Effect of Terrain Up-hill Slope on Flight Path Perception

– A downhill slope in the approach zone creates an illusion of being too low (i.e., impression of a shallow glide path, as shown on **Figure 2**), thus:
  - Possibly inducing a correction placing the aircraft above the intended glide path ; or,
  - Preventing the flight crew from detecting a too steep flight path.



(Photo No.1 : 12 NM from touchdown – Photo No.2 : 2 NM from touchdown, on PAPI glide path)

Figure 2

Effect of Terrain Down-hill Slope on Flight Path Perception

IV.2 Runway Environment

- Runway dimensions / aspect ratio (**Figure 3**):
  - The runway aspect ratio (i.e., its length relative to its width) affects the crew visual perspective view of the runway:
    - A wide or short runway (low aspect ratio) creates an impression of being too low; and,
    - A narrow or long runway (high aspect ratio) creates an impression of being too high.

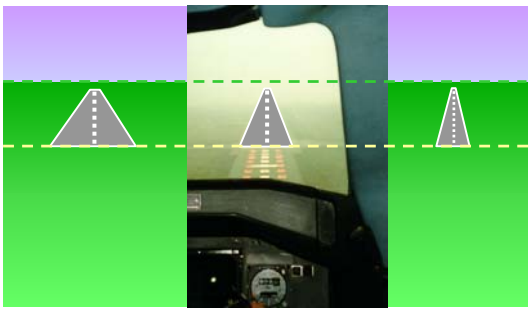


Figure 3

Center Photo : LFBO 14 R (3500 m x 45 m) / 3-degree glide slope / 200 ft RA

- Runway uphill 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).

- Approach and runway lighting:
  - The approach and runway lighting (including the touchdown zone lighting) affects the dept perception as a function of:
    - The lighting intensity;
    - The daytime or night time conditions; and,
    - The weather conditions.
  - Bright runway-lights create the impression of being closer to the runway (hence on a steeper glide path);

- Low intensity lights create the impression of being farther away (hence on a shallower glide path);
- A non-standard spacing of runway lights also modifies the pilot's perception of the runway distance and glide path; and,
- If runway lighting is partially visible (e.g., during the downwind leg or during the base leg of a visual or circling approach), the runway may appear being farther away or at a different angle (i.e., the intercept angle is perceived as smaller than actual).

IV.3 Runway Approach Aids

The following runway approach-aids and conditions may increase the crew exposure to visual illusions:

- Glide slope beam being unusable beyond a specific point because of terrain or below a specific altitude/height because of approach over water;
- Offset localizer course; and/or,
- 2-bar VASI, if used below 300 ft height above touchdown (HAT) for glide path corrections.

IV.4 Weather Conditions

The following weather conditions may cause visual illusions:

- Precipitation's (e.g., rain, fog, snow):
  - Flying in light rain, fog , haze, mist, smoke, dust, glare or darkness usually create an illusion of being too high;

- Flying in haze creates the impression that the runway is farther away, inducing a tendency to shallow the glide path and land long;
- Shallow fog (i.e., fog layer not exceeding 300 ft in thickness) results in a low obscuration but also 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 the forward and slant visibility usually are lost;
  - Entering a fog layer also creates the perception of a pitch up, thus inducing a tendency to push over and place the aircraft below the desired glide path and in a steeper-than-desired attitude;
- In light rain or moderate rain, the runway may also appear fuzzy because of rain halo effect, increasing the risk of not perceiving a vertical deviation or lateral deviation during the visual segment.

  The visual segment is defined as the segment flown after full transition from instruments to visual references;
- Heavy rain affects depth perception and distance perception:
  - Rain on windshields creates a refraction and the perception of being too high, thus inducing a nose down correction that places the aircraft below the desired flight path;
  - In daylight conditions, rain diminishes the apparent intensity of the approach lighting 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;
  - In night time conditions, rain increases the apparent brilliance of the ALS, making the runway appears to be closer, inducing a pitch down input and the risk of landing short of the runway threshold.
- When breaking out of the overcast at both ceiling and visibility minimums (DH and RVR), the slant visibility may not allow sight of the farther bar(s) of the VASI/PAPI, thus reducing the available visual clues for the visual segment in reduced visibility;
- A snow-covered terrain together with a clouds overcast create a phenomenon called "white-out" that eliminate perception of terrain features (slope) and height above terrain.

- Crosswind:
  - In crosswind conditions, the runway lights and environment will be angled with the aircraft heading; flight crew should maintain the drift correction and resist the tendency to align the aircraft heading with the runway centerline.

- Runway surface condition (e.g., wet runway):
  - A wet runway does not reflect light, thus affecting depth perception by appearing to be farther away.

    This visual effect usually results in a late flare and in a firm touchdown.

    When landing on a wet runway, peripheral vision of runway edge lights should be used to increase the depth perception and determine the flare point.

V Typical Crew Actions and Results

The following crew actions and their consequences often are cited in the analysis of approach-and-landing incidents or accident resulting from visual illusions:

- Unconscious modification of the aircraft trajectory to keep a constant perception of visual references;
- Natural tendency to descend below the glide slope or the initial glide path (i.e., "ducking under");
- Inability to arrest the rate of descent after descending below the intended glide path (i.e., late recognition of the flattening of runway and runway environment);
- Absence of 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, while both crew members are involved in the identification of visual references.

The following table provides a summary of the various factors and conditions together with their effects on the pilot's perception and unintended actions that may result in a hazardous situation:

Condition	Perception	Unintended Action	Result
Narrow / long runway	Being too high	Push	Land short / Land hard
Wide or short runway	Being too low	Pull	Land long / overrun
Runway or terrain uphill slope	Being too high	Push	Land short / Land hard

Condition	Perception	Unintended Action	Result
Runway or terrain downhill slope	Being too low	Pull	Land long / overrun
Bright runway lighting	Being too close (too steep)	Push	Land short / Land hard
Low intensity lighting	Being farther away (too shallow)	Pull	Land long / Overrun
Light rain, fog, haze, mist smoke, dust	Being too high	Push over	Land short / Land hard
Heavy rain	Being too close	Push over	Land short / Land hard
Entering fog (shallow layer)	Increasing pitch	Push over	Steep glide path / CFIT
Flying in haze	Being farther away (too shallow)	Pull up	Land long / Overrun
Drifting rain, snow or sand	Aircraft drifting sideways	Undue drift correction	Off-runway landing
Wet Runway	Being farther away (too high)	Late flare	Hard landing
Crosswind	Being angled with runway	Cancel drift correction	Drifting off track / off runway centerline

Table 1

Effects of Visual Illusions on Pilot's Perception and Actions

VI Prevention Strategies to Reduce the Effects of Visual Illusions

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

VI.1 Hazard Awareness

Operators should assess their exposure to visual illusions in their operating environment (i.e., over the entire route network).

Flight crews should be educated and trained on the factors and conditions creating visual illusions and their effects on the perception of the environment and aircraft position:

- Perception of heights / depth, distances, and angles;
- Assessment of aircraft lateral position and glide path.

The awareness of visual illusions can be supported by an identification of all hazard-airports and/or hazard-runways (in the operator's network) as a function of the available navaids, visual aids and prevailing hazards.

VI.2 Hazard Assessment

Approach hazards – and any combination thereof - should be assessed for each individual approach, during the approach and go-around briefing, by reviewing the following elements:

- Ceiling and visibility conditions;
- Weather:
  - Wind, turbulence;
  - Rain showers;
  - Fog or smoke patches;
  - Drifting snow or sand;
  - Snow-covered terrain / runway (white-out phenomenon); and/or,
  - Sun height over horizon;
- Crew experience with airport and airport environment:
  - Surrounding terrain (i.e., texture); and/or,
  - Specific airport and runway hazards (runway condition, obstructions, black-hole, off-airport light patterns, …);

- Runway approach and visual aids:
  - Type of approach;
  - Availability and location of DME with respect to runway threshold;
  - Let-down aid restriction, if any, such as glide slope unusable beyond a specific point or below a specific altitude;
  - Type of approach lighting system; and,
  - VASI or PAPI availability.

VI.3 Terrain Awareness

When requesting or accepting a visual approach, 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 threshold may prevent the flight crew from correctly perceiving the rising terrain.

VI.4 Flying Techniques

Type of approach

At night, when an instrument approach is available, prefer this approach to a visual approach to reduce the risk of accident caused by visual illusions:

- ILS approach, with use of VASI / PAPI (as available) for the visual segment; or,
- Non-precision approach, supported by a VASI / PAPI (as available).

If / when performing a step-down (i.e., dive-and-drive) non-precision approach, do not descend below the MDA(H) before reaching the visual descent / decision point (VDP) - if defined - even if adequate visual references have been acquired before reaching the VDP.

To prevent going too early to visual references and descending prematurely below the MDA(H), the PF should maintain reference to instruments until reaching the VDP. This provides further protection against visual illusions in hazard conditions.

During a visual or circling approach, if the VASI / PAPI indicates below glide slope level off or climb until the VASI/PAPI shows on-glide-path.

Flight path monitoring

Resist the tendency to pitch down and "duck under"; this is the greatest challenge during the visual segment of the approach, this includes:

- Pitching down into the approach light in an attempt to see the runway during a precision approach; or,
- Ducking under because of the impression of being too high when affected by visual illusions.

Maintain a combination of visual flying supported by monitoring of instruments (including the glide slope deviation during the visual segment of an ILS approach).

Monitor the VASI/PAPI, whenever available; this provides additional visual cues to resist the tendency to increase or decrease the rate of descent.

On runways equipped with an ALSF-II approach lighting system, be aware of the two rows of red lights aligned with the touchdown zone lights as an additional safeguard against "ducking under".

The following provides a summary of the techniques available to counter visual illusions (and prevent from ducking under):

- Maintain instruments scan down to touchdown;
- Cross-check instrument indications against outside visual cues to confirm glide path;
- Use an ILS approach, whenever available;
- If no ILS approach is available, fly a constant-angle non-precision approach (CANPA) supported by the use of the Flight Path Vector / Flight Path Target (Director) or use the FMS FINAL APPR mode (as available);
- Use available references and indications such as the ND extended runway centerline, the ILS-DME (or VOR-DME) distance – or the FMS track distance to runway threshold - and the altitude above airfield elevation to confirm the glide path (based on a typically 300 ft-per-nm approach gradient); and,
- Use VASI / PAPI, if available, down to runway threshold (**only when using a 3-bar VASI or a PAPI**).

In summary, the main line-of-defense against visual illusions and disorientation is to use and rely on flight instruments.

VI.5 Coordination

The defined task sharing ensures a continued monitoring of visual and instrument references, throughout the transition to visual references and thereafter (i.e., during a visual approach or during the visual segment of an instrument approach).

In known or anticipated hazard conditions, the PNF should reinforce his / her monitoring of instrument references and of flight progress, for an effective cross-check and back-up of the PF.

Altitude and excessive-parameter-deviation callouts should be the same for instrument approaches and visual approaches, and should be continued during the visual segment (i.e., including glide slope deviation during an ILS approach or vertical speed deviation during a non-precision approach).

In case of a go-around, specific excessive-parameter-deviation callouts should be considered (as indicated in SOPs).

VII Summary of Key Points

The following critical keypoints need to be emphasized:

- Awareness of weather factors;
- Awareness of surrounding terrain and obstacles;
- Awareness and assessment of approach hazards (i.e., conditions that may result in visual illusions, such as "black hole");
- Adherence to defined PF/PNF task sharing for acquisition of visual references and for flying the visual segment; this includes:
  - Monitoring by PF of outside visual cues while transiently referring to instruments to support and monitor the flight path during the visual segment; and,
  - Monitoring by PNF of head-down cues for effective cross-check and back-up (i.e., for calling any excessive-parameter-deviation).

VIII Associated Briefing Notes

The following Briefing Notes complement the above discussion on the acquisition of visual references and on visual illusions:

- **Standard Operating Procedures**
- **Conducting Effective Briefings**
- **Enhancing Terrain Awareness**
- **Acquisition of Visual References**
- **Flying Visual Approaches**

IX Regulatory References

- ICAO – Preparation of an Operations Manual (Doc 9376).
- FAR 91.175 – Takeoff and landing under IFR – Paragraph (b), Loss of visual references.
- JAR-OPS 1 – Subpart E – All Weather Operations - 1.1430 – Aerodrome Operating Minima.
- JAR-OPS 1 – Subpart E – All Weather Operations - 1.435 - Terminology.

X Additional Reading Material

- FAA brochure on Spatial Disorientation :
  - " Seeing is not Believing ", available from:

    http://www.cami.jccbi.gov/aam-400A/Brochures/SpatialD.htm

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