Flight Safety Foundation

ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 8.3 — Landing Distances

When discussing landing distance, two categories must be considered:

- *Actual landing distance* is the distance used in landing and braking to a complete stop (on a dry runway) after crossing the runway threshold at 50 feet; and,
- *Required landing distance* is the distance derived by applying a factor to the actual landing distance.

Actual landing distances are determined during certification flight tests without the use of thrust reversers.

Required landing distances are used for dispatch purposes (i.e., for selecting the destination airport and alternate airports).

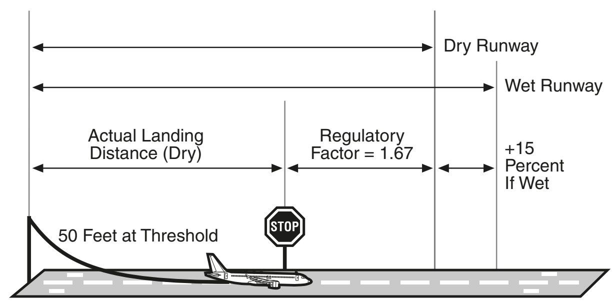
Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that runway overruns were involved in 12 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[1]

Defining Landing Distances

Figure 1 shows the definitions of actual landing distances and required landing distances used by the European Joint Aviation Authorities (JAA) and by the U.S. Federal Aviation Administration (FAA). Figure 2 (page 168) shows the definitions of actual landing distance and required landing distance used by the U.K. Civil Aviation Authority (CAA).

Required Runway Length — JAA/FAA



Required runway length (dry) = Actual landing distance (dry) x 1.67
Required runway length (wet) = Actual landing distance (dry) x 1.92

JAA = (European) Joint Aviation Authorities
FAA = (U.S.) Federal Aviation Administration

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

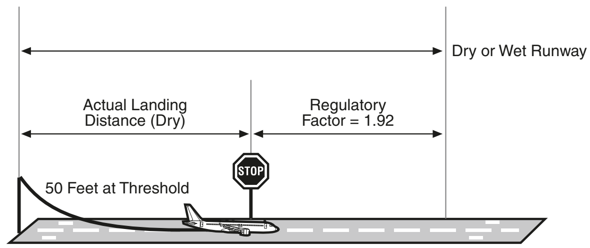
Figure 1

Factors Affecting Landing Distance

Actual landing distance is affected by various operational factors, including:

- High airport elevation or high density altitude, resulting in increased groundspeed;
- Runway gradient (i.e., slope);
- Runway condition (dry, wet or contaminated by standing water, slush, snow or ice);
- Wind conditions;

Required Runway Length — U.K. CAA



Required runway length (dry or wet) = Actual landing distance (dry) x 1.92

CAA = Civil Aviation Authority

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 2

- Type of braking (pedal braking or autobrakes, use of thrust reversers);
- Anti-skid system failure;
- Final approach speed;
- Landing technique (e.g., height and airspeed over the threshold, thrust reduction and flare);
- Standard operating procedures (SOPs) deviations (e.g., failure to arm ground spoilers);
- Minimum equipment list (MEL)/dispatch deviation guide (DDG) conditions (e.g., thrust reversers, brake unit, anti-skid or ground spoilers inoperative); and,
- System malfunctions (e.g., increasing final approach speed and/or affecting lift-dumping capability and/or braking capability).

The approximate effects of these factors on landing distance are shown in Figure 3 (page 169).

Airport Elevation

High airport elevation or high density altitude results in a higher true airspeed (TAS) and groundspeed, and a corresponding longer landing distance, compared to low airport elevation or low density altitude.

For example, at 1,000 feet airport elevation, a landing distance factor of 1.05 to 1.10 (depending on runway condition) must be applied to the landing distance achieved at sea-level airport elevation.

Runway Slope

Runway slope (gradient) has a direct effect on landing distance.

For example, a 1 percent downhill slope increases landing distance by 10 percent (factor of 1.1). However, this effect is accounted for in performance computations only if the runway downhill slope exceeds 2 percent.

Runway Conditions

Although runway contamination increases rolling resistance and spray-impingement drag (i.e., drag caused by water or slush sprayed by tires onto the aircraft), it also affects braking efficiency.

The following landing distance factors are typical:

- Wet runway: 1.3 to 1.4;
- Standing-water or slush-contaminated runway: 2.0 to 2.3;
- Compacted-snow-covered runway: 1.6 to 1.7; and,
- Icy runway: 3.5 to 4.5.

Wind Conditions

Certification regulations and operating regulations require correction factors to be applied to actual landing distances to compensate for:

- Fifty percent of the head-wind component; and,
- One hundred fifty percent of the tail-wind component.

Type of Braking

Actual landing distances are determined during certification flight testing under the following conditions:

- Flying an optimum flight segment from 50 feet over the runway threshold to the flare;
- Achieving a firm touchdown (i.e., not extending the flare); and,
- Using maximum pedal braking, beginning at main-landing-gear touchdown.

Published actual landing distances seldom can be achieved in line operations.

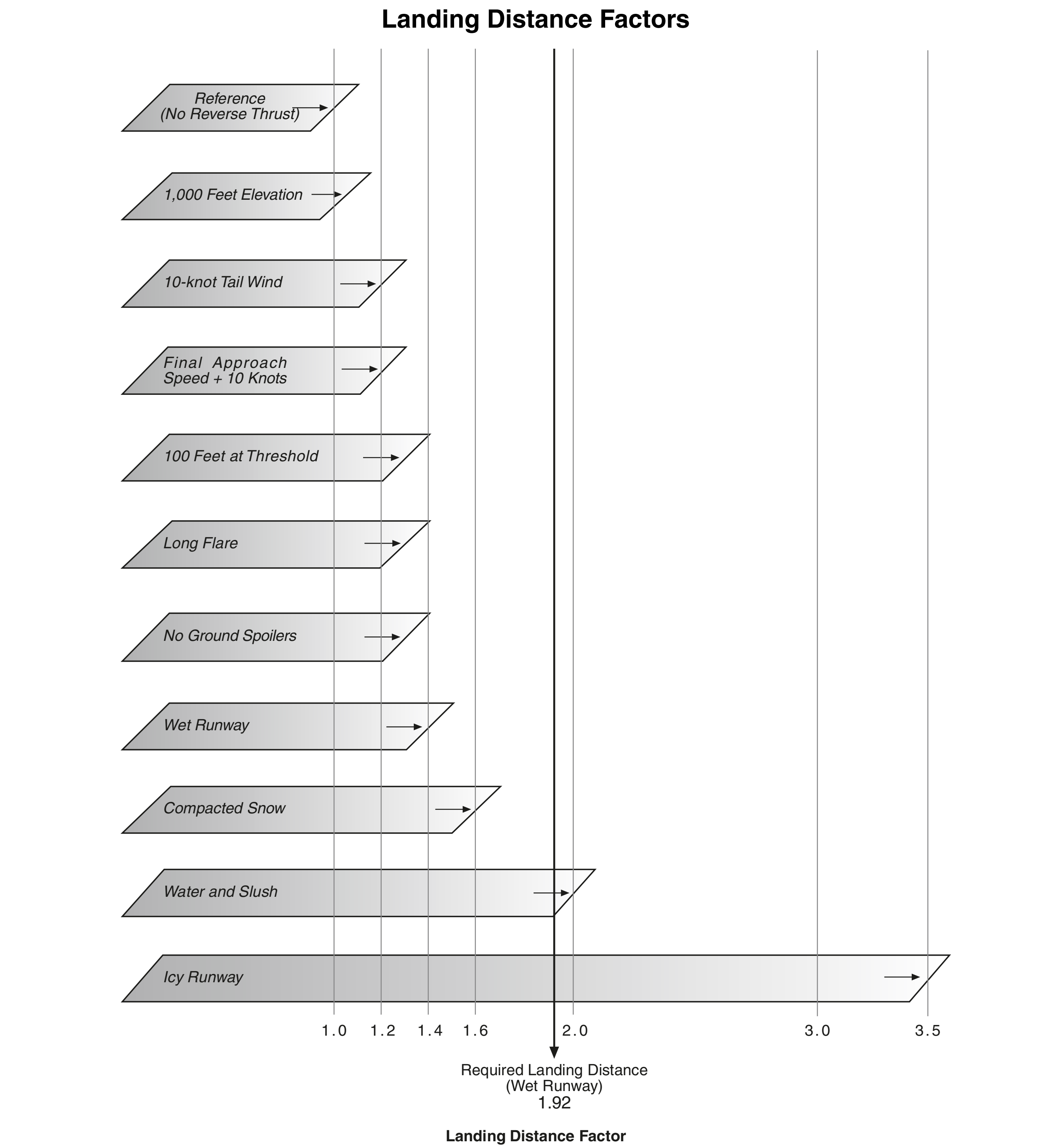
Landing distances published for automatic landings with autobrakes are more achievable in line operations.

Airspeed Over Runway Threshold

A 10 percent increase in final approach speed results in a 20 percent increase in landing distance. This assumes a normal flare and touchdown (i.e., not allowing the aircraft to float and bleed excess airspeed).

Height Over Threshold

Crossing the runway threshold at 100 feet (50 feet higher than recommended) results in an increase in landing distance of



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

about 1,000 feet (305 meters), regardless of runway condition and aircraft model (Figure 4, page 170).

Flare Technique

Extending the flare (i.e., allowing the aircraft to float and bleed excess airspeed) increases the landing distance.

For example, a 5 percent increase in final approach speed increases landing distance by:

- Ten percent, if a normal flare and touchdown are conducted (deceleration on the ground); or,
- Thirty percent, if touchdown is delayed (deceleration during an extended flare).

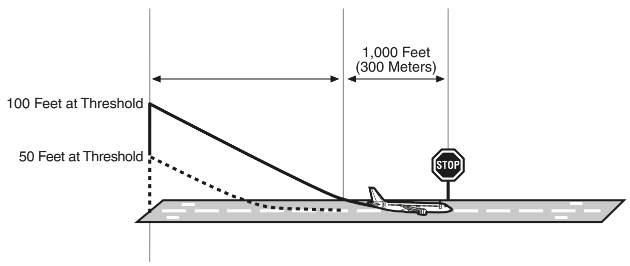


Figure 4

Ground Spoilers Not Armed

Several runway-overrun events have been caused by ground spoilers not being armed while the aircraft were being operated with thrust reversers inoperative.

On most transport category aircraft, the ground spoilers extend when reverse thrust is selected (regardless of whether the ground spoilers are armed or not); *this design feature must not be relied upon*. The ground spoilers must be armed per SOPs.

Failure to arm the spoilers results in a typical landing distance factor of 1.3 (1.4 if combined with inoperative thrust reversers).

The automatic extension of ground spoilers should be monitored. Failure of the ground spoilers to deploy automatically should be called; the crew then should manually activate the ground spoilers.

Delay in lowering the nose landing gear to the runway maintains lift, resulting in less load on the main landing gear and, hence, less braking capability. This also delays the nosewheel spin-up signal, which is required for optimum operation of the anti-skid system on some aircraft.

MEL/DDG Conditions

When operating with an MEL/DDG condition affecting landing speed or braking capability, the applicable landing speed correction and landing distance factor must be included in landing-distance computation.

System Malfunctions

System malfunctions, such as hydraulic system low pressure, may result in multiple adjustments to landing speed and landing distance, such as:

- Increased landing speed because of inoperative slats/flaps (stall margin);
- Increased landing speed because of inoperative roll spoilers (maneuverability);
- Increased landing distance because of inoperative ground spoilers (lift-dumping capability); and,
- Increased landing distance because of inoperative normal braking system (braking capability).

The aircraft operating manual (AOM) and the quick reference handbook (QRH) provide the applicable landing speed corrections and landing distance corrections for many malfunctions (including their effects).

Landing Distance Factors

Landing distance factors result from either:

- A landing speed correction (e.g., because of a failure affecting stall margin or maneuverability); or,
- Reduced lift-dumping capability or reduced braking capability (e.g., because of a failure affecting ground spoilers or brakes).

Whether published in the AOM/QRH or computed by the pilot, the combination of landing distance factors for multiple failures usually complies with the following:

- If landing speed corrections are added, the corresponding landing distance factors must be multiplied;
- If only the highest airspeed correction is considered, then only the greatest landing distance factor must be considered; or,
- If two landing distance factors are considered, and one (or both) are related to lift-dumping or braking, the landing distance factors must be multiplied.

Figure 3 shows typical landing distance factors for various runway conditions and operational factors.

Summary

When assessing the landing distance for a given landing, all the following factors should be considered and should be combined as specified in the applicable AOM/QRH:

- MEL/DDG dispatch conditions, as applicable;
- In-flight failures, as applicable;
- Weather conditions (e.g., wind and gusts, suspected wind shear, icing conditions/ice accretion);
- Runway condition;
- Use of braking devices (e.g., thrust reversers, autobrakes); and,
- Airport elevation and runway slope.

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

- *1.4 — Standard Calls*;
- *8.2 — The Final Approach Speed*;
- *8.4 — Braking Devices*; and,
- *8.5 — Wet or Contaminated Runways*.♦

Reference

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.

Related Reading from FSF Publications

Flight Safety Foundation (FSF) Editorial Staff. "Business Jet Overruns Wet Runway After Landing Past Touchdown Zone." *Accident Prevention* Volume 56 (December 1999).

FSF Editorial Staff. "Unaware of Strong Crosswind, Fokker Crew Loses Control of Aircraft on Landing." *Accident Prevention* Volume 56 (November 1999).

Yager, Thomas J. "The Joint FAA/NASA Aircraft/Ground Vehicle Runway Friction Program." *Flight Safety Digest* Volume 8 (March 1989).

Regulatory Resources

International Civil Aviation Organization (ICAO). *Preparation of an Operations Manual*. Second edition – 1997.

U.S. Federal Aviation Administration (FAA). *Federal Aviation Regulations*. 121.97 "Airports: Required data," 121.117 "Airports: Required data," 121.171 "Applicability," 121.195 "Airplanes: Turbine-engine-powered: Landing limitations: Destination airports." 121.197 "Airplanes: Turbine-engine-powered: Landing limitations: Alternate airports." January 1, 2000.

FAA. Advisory Circular 91-6A, *Water, Slush, and Snow on the Runway*. May 24, 1978.

Joint Aviation Authorities. *Joint Aviation Requirements – Operations 1. Commercial Air Transportation (Aeroplanes)*. 1.515 "Landing – Dry Runways," 1.520 "Landing – Wet and contaminated runways." March 3, 1998.

U.K. Civil Aviation Authority (CAA). Aeronautical Information Circular (AIC) 11/98, *Landing Performance of Large Transport Aeroplanes*. January 27, 1998.

U.K. CAA. AIC 61/1999, *Risks and Factors Associated with Operations on Runways Affected by Snow, Slush or Water*. June 3, 1999.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, 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 (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

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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