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

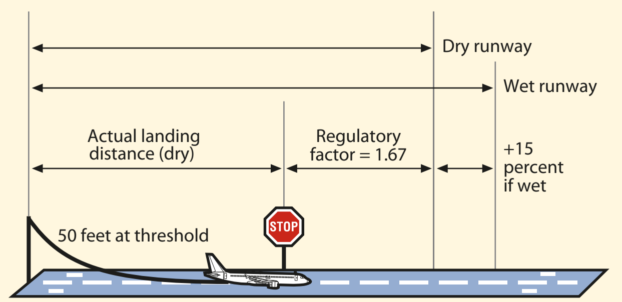
The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force found that runway overruns were involved in 12 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[1]

The FSF Runway Safety Initiative (RSI) team found that of the 435 runway-excursion landing accidents from 1995 through March 2008, 96 percent involved runways that were wet or contaminated by frozen precipitation, 38 percent involved mechanical failures or malfunctions, and 36 percent involved wind factors (e.g., crosswind, gust, tail wind, wind shear).[2]

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 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: FSF ALAR Task Force

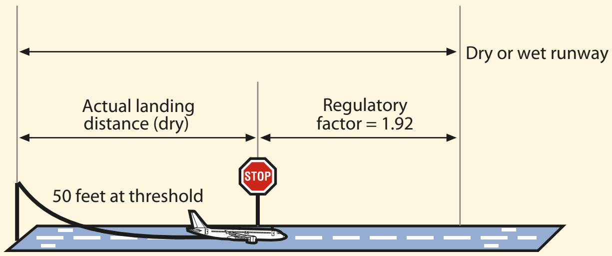
Figure 1

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;
- Type of braking (pedal braking or autobrakes, use of thrust reversers);
- Anti-skid system failure;
- Final approach speed;

Required Runway Length — U.K. CAA



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

CAA = Civil Aviation Authority

Source: FSF ALAR Task Force

Figure 2

- 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/speed brakes);
- Minimum equipment list (MEL)/dispatch deviation guide (DDG) conditions (e.g., thrust reversers, brake unit, anti-skid or ground spoilers/speed brakes 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.

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

Flare Technique

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

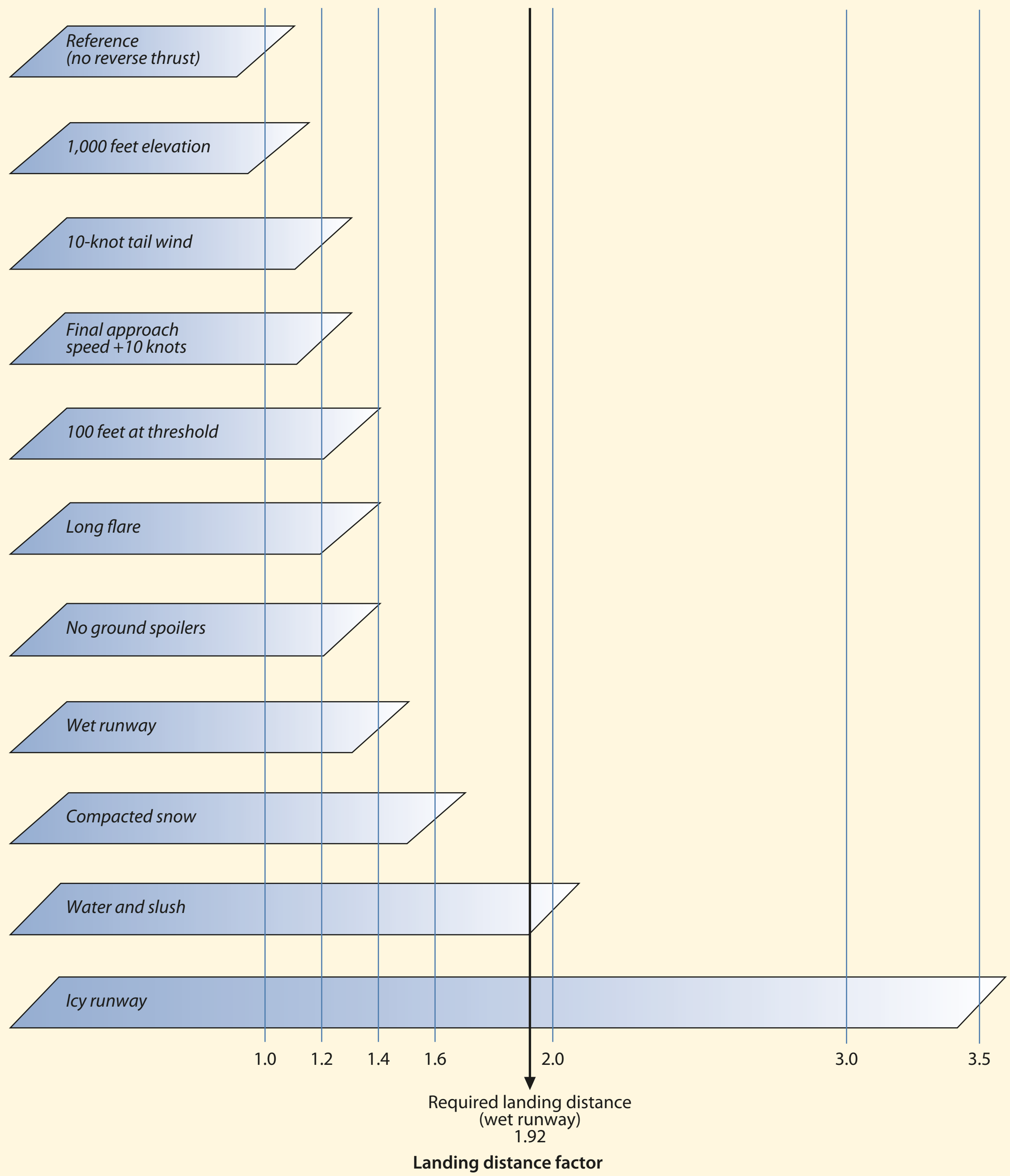
For example, a 5 percent increase in final approach speed increases landing distance by:

- 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).

Ground Spoilers/Speed Brakes Not Armed

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

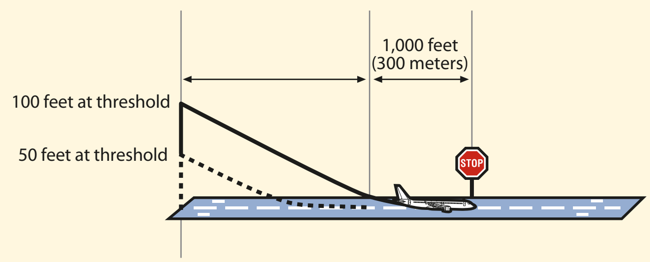
Landing Distance Factors



Source: FSF ALAR Task Force

Figure 3

Effect of Threshold-Crossing Height on Landing Distance



Source: FSF ALAR Task Force

Figure 4

On most transport category aircraft, the ground spoilers/speed brakes extend when reverse thrust is selected (regardless of whether the ground spoilers/speed brakes are armed or not); *this design feature must not be relied upon*. The ground spoilers/speed brakes 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/speed brakes should be monitored. Failure of the ground spoilers/speed brakes to deploy automatically should be called; the crew then should manually activate the ground spoilers/speed brakes.

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. Depending on the aircraft design, 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/speed brakes (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/speed brakes 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.

The following RSI Briefing Notes also provide information to supplement this discussion:

- Pilot Braking Action Reports; and,
- Runway Condition Reporting.

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. Flight Safety Foundation. "Reducing the Risk of Runway Excursions." Report of the FSF Runway Safety Initiative, May 2009.

Related Reading From FSF Publications

Darby, Rick. "Keeping It on the Runway." *AeroSafety World* Volume 4 (August 2009).

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

Mook, Reinhard. "Treacherous Thawing." *AeroSafety World* Volume 3 (October 2008).

Lacagnina, Mark. "Missed Assessment." *AeroSafety World* Volume 3 (October 2008).

Werfelman, Linda. "Safety on the Straight and Narrow." *AeroSafety World* Volume 3 (August 2008).

Lacagnina, Mark. "Margin for Error." *AeroSafety World* Volume 3 (August 2008).

Lacagnina, Mark. "Overrun at Midway." *AeroSafety World* Volume 3 (February 2008).

Werfelman, Linda. "Blindsided." *AeroSafety World* Volume 3 (February 2008).

Lacagnina, Mark. "High, Hot and Fixated." *AeroSafety World* Volume 3 (January 2008).

Johnsen, Oddvard. "Improving Braking Action Reports." *AeroSafety World* Volume 2 (August 2007).

Lacagnina, Mark. "Streaking Into Vegas." *AeroSafety World* Volume 2 (April 2007).

Fahlgren, Gunnar. "Tail Wind Traps." *AeroSafety World* Volume 2 (March 2007).

Rosenkrans, Wayne. "Knowing the Distance." *AeroSafety World* Volume 2 (February 2007).

Berman, Benjamin A.; Dismukes, R. Key. "Pressing the Approach." *AviationSafety World* Volume 1 (December 2006).

Rosenkrans, Wayne. "Rethinking Overrun Protection." *AviationSafety World* Volume 1 (August 2006).

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. "B-737 Crew's Unstabilized Approach Results in Overrun of a Wet Runway." *Accident Prevention* Volume 60 (July 2003).

FSF Editorial Staff. "MD-82 Overruns Runway While Landing in Proximity of Severe Thunderstorms." *Accident Prevention* Volume 59 (February 2002).

FSF Editorial Staff. "Runway Overrun Occurs After Captain Cancels Go-around." *Accident Prevention* Volume 58 (June 2001).

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).

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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