How Pilots Calculate Bringing an Aircraft to the Ground

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by Charlie Page

News

The Art Behind a Comfortable Landing: How Pilots Calculate Bringing an Aircraft to the Ground

They say that what goes up must come down, and landing an airliner is probably the most challenging part of the job. Guiding a 190-tonne aircraft with 220 people on board to an area just 60 metres wide and a few hundred metres long takes great skill, judgement and concentration.

However, the thought process for the landing actually begins even before the flight has taken off. Weights need to be calculated, weather forecasts need to be evaluated and the details of the runways available need to be checked — and not just at the planned destination.

Achieving a safe, successful landing takes a lot of thought and planning. Here’s how we do it.

Aircraft Weight

Before each flight, during the preflight briefing stage, pilots will discuss the weight of the aircraft. This will include the planned take off weight and also the weight at which the aircraft is expected to be on arrival at the destination.

Each aircraft type has a Maximum Landing Weight (MLW), the weight above which the aircraft should not land except in emergency. For the 787-9 this is 192 tonnes. For more info on the other 787 types, check out my previous article, The 787 Dreamliner: What Are the Differences Between a -8, -9 and -10?

If the aircraft has a high load of passengers and/or cargo, it may not reach the MLW until well into the flight. If the planned landing weight is very close to the MLW, there is very little scope to add more fuel for bad weather or to take extra cargo.

Once the pilots are happy with the loading of the aircraft and the planned landing weight, only then will they sign the loadsheet and depart from the gate.

Runway Length

Sometimes, length really is important. For every landing, the first thing pilots need to know is the Landing Distance Available (LDA). Like with all things aviation, there's a complicated wordy definition for this:

> "The Landing Distance Available (LDA) is the length of the runway which is declared available by the appropriate authority and is suitable for the ground run of an aeroplane landing".

In practice, this means the length of the paved surface suitable for landing on. This may seem obvious, but some runways have what is known as a displaced threshold. Due to obstacles (maybe buildings, road, tress, etc.) in the approach path, the aircraft must touchdown further along the runway than the paved surface may suggest. This is the case at London Gatwick, as seen below.

Displaced threshold at Gatwick Airport (Image courtesy of Google Maps)

Even though aircraft taking off can start their takeoff run from the start of the paved surface, landing aircraft must land much farther down — beyond where the runway designator (26L) is written in the image. As a result, the LDA could actually be much less than the Take Off Run Available (TORA).

For more on the science behind takeoff, check out my previous article, The Science Behind a Beautiful Aircraft Takeoff

As the LDA will vary from runway to runway, it is normally depicted on the runway approach chart, which gives pilots information about the approach and runway they are planning to use.

Landing Distance

> "Landing distance is defined as the horizontal distance traversed by the aeroplane by the aeroplane from a point on the approach path at a selected height above the landing surface to the point on the landing surface at which the aeroplane comes to a complete stop".

In plain English, this means the distance required from passing over the start of the runway at 50 feet to becoming stationary. This is also known as the calculated landing distance. However, as this is the minimum distance calculated for a textbook landing, most airlines use a safety factor of 5%-15% on top of this.

This ensures that should the landing not be perfect, for example, if the aircraft touches down a little deeper than planned, there is still sufficient runway remaining. This is known as the required landing distance.

Therefore, in all cases, the landing distance available must be greater than the required landing distance.

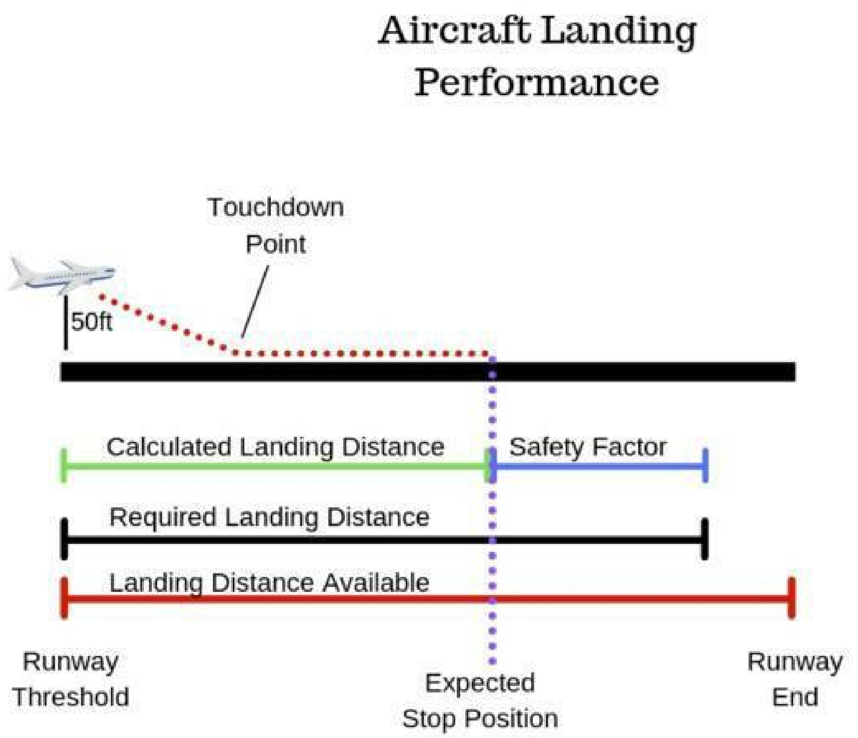


Diagram showing landing distances (Image by author)

When it comes to calculating the landing distance, it’s not as simple as just plugging in the landing weight and coming up with a number. The major elements which affect the landing distance are: aircraft weight, flap setting, wind, runway surface and runway slope.

Aircraft Weight

The obvious factor already mentioned. The higher the aircraft weight, the greater the speed it has to fly in order to generate lift. The speed at which the aircraft crosses the 50-feet threshold height is know as its approach speed.

This speed, also known as Vapp, is a fine balance between being too fast and too slow. Fly too fast and the landing distanced required would be immense. Fly too slow and the aircraft would be at risk of stalling (losing lift over the wings) and thus falling out of the sky.

As most runways are only a few thousand metres long, aircraft must fly as slow as possible. To help them do this, the pilots use the flaps on the wings.

Flap Setting

When the wing flaps are extended from the back of the wing (and the slats from the front of the wing), the surface area of the wing increases. This means that more lift is generated for a given airspeed — perfect if you're trying to keep your landing distance required as low as possible.

The 787 Dreamliner has two main flap settings for landing: Flap 25 and Flap 30. In most situations, the use of either F25 or F30 is down to the pilot's discretion. F25 produces less drag, thus reducing fuel burn and noise but results in a higher Vapp. F30 creates more drag but the Vapp is normally around 5kts less than at F25.

This may not seem a massive amount, but it can make all the difference when landing in performance restricted airfields such as Mexico City and San Diego.

Wind

For the same airspeed on touchdown, the speed over the ground will vary with the wind. Say the aircraft is flying at 100 knots — this is the speed of air over the wings in order to generate lift. If there is a 20-knot headwind, the speed of the aircraft over the ground is just 80 knots — the ideal situation as it results in a shorter required landing distance. This is why pilots prefer to land their aircraft into the wind. However, the reverse is therefore the case with a tailwind.

For an aircraft approaching at 100 knots with a 20-knot tailwind, the ground speed is 120 knots. This will massively increase the required landing distance, much more than most people think. As a result, pilots are acutely aware of the wind shifting during their approach.

When calculating the required landing distance, 150% of any reported tailwind must be used, but only 50% of any head wind may be used. This ensures that a comfortable safety margin is maintained should the actual wind on touchdown differ from what was reported.

Runway Surface

Once the wheels are on the ground, it's time for the wheel brakes to start to slow the aircraft. However, like in your car, the condition of the runway surface can have a huge affect on the effectiveness of the brakes.

As you might imagine, the ideal conditions to land are on a dry runway. With maximum friction between the tyres and the runway, the brakes are far more effective. However, a dry runway isn't always possible, particularly in the UK.

If the airfield weather states that it is raining, or it may rain during the time of landing, pilots will treat the runway as wet and calculate the performance accordingly. Rain is fairly common, so a wet runway is nothing abnormal. However, what happens when it's snowing? Or even worse, icy?

If aircraft couldn't takeoff or land when there's some snow on the runway, many airfields around the world would have to shut down for the winter. Not ideal. In order to ensure that aircraft can continue to takeoff and land safely, once the runway has been cleared of most of the snow, the snow team have one final job. Using special equipment, they take a reading of the depth and type of contaminant on the runway. This can include frost, slush, snow and ice. Some airfields will also use a special vehicle to measure the friction coefficient of the runway. This information is then made available to the pilots. As the aircraft approaches the airport, the pilots obtain the latest airfield information, including the state of the runways. Pilots then refer to the table below which is found in their operational manuals.

Assessment Criteria		Control/Braking Assessment Criteria	
Runway Condition Description	**RwyCC**	**Deceleration or Directional Control Observation**	**Pilot Reported Braking Action**
• Dry	6	---	---
• Frost • Wet (Includes damp and 1/8 inch depth or less of water) ***1/8 inch (3mm) depth or less of:*** • Slush • Dry Snow • Wet Snow	5	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.	Good
-15ºC and Colder outside air temperature: • Compacted Snow	4	Braking deceleration OR directional control is between Good and Medium.	Good to Medium
• Slippery When Wet (wet runway) • Dry Snow or Wet Snow (any depth) over Compacted Snow ***Greater than 1/8 inch (3 mm) depth of:*** • Dry Snow • Wet Snow ***Warmer than -15ºC outside air temperature:*** • Compacted Snow	3	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.	Medium
Greater than 1/8 inch(3 mm) depth of: • Water • Slush	2	Braking deceleration OR directional control is between Medium and Poor.	Medium to Poor
• Ice	1	Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.	Poor
• Wet Ice • Slush over Ice • Water over Compacted Snow • Dry Snow or Wet Snow over Ice	0	Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.	Nil

Runway Condition Assessment table (Image courtesy of icao.int)

Entering the table on the left, they find the row which relates to the conditions reported at the airfield, for example, dry snow, less than 1/8 inch (3mm). Moving to the right, this gives a Runway Condition Code of 5 and, the most important part, a braking action of Good.

Runway Slope

At new, purpose-built airports, the runways tend to be fairly flat. During the excavation process, serious time is spent ensuring that the runways are as close to perfectly flat as possible. The new runway at Manchester Airport (MAN) is a good example of this. However, some airports, like Leeds/Bradford (LBA) are built on old WW2 airbases and can be anything but flat. In fact, coming in to land at Leeds is like looking at an undulating piece of ribbon.

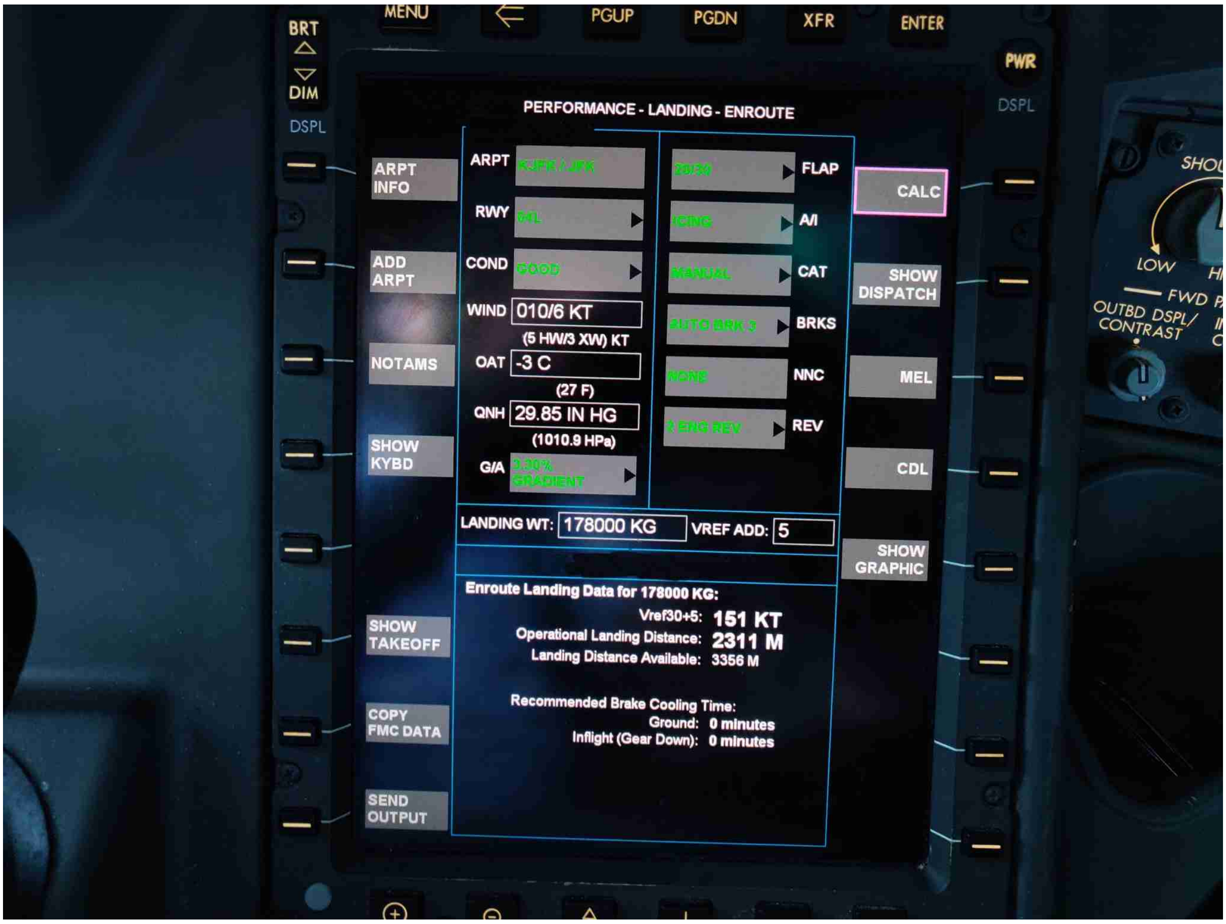
As a result, the slope of the runway must be taken into consideration. As you might expect, an aircraft landing on a runway sloping up will stop far quicker than on a runway sloping down. An extreme version of this can be seen at the Altiport in Courcheval, France. Whilst this airfield is only for very small aircraft, the massive upslope of the runway is used to drastically reduce the landing distance required, as seen in the video below.

https://youtu.be/_3MtFLgli24

Calculating the Distance

Many older aircraft require the pilots to use complicated tables with multiple rows and columns to collate all the above factors and work out the required landing distance. At times of high workload and reduced personal performance from tiredness, just the smallest mistake can result in an erroneous calculation. To help combat this threat, the 787 Dreamliner has the Onboard Performance Tool.

Using this computer, pilots enter all the relevant information as seen in the image below. The OPT then calculates the distance required. Not only does it reduce potential errors but it also allows pilots to quickly carry out a new calculation if the reported wind or runway in use changes. With some very short runways around the world, a shift in the wind could make all the difference between landing safely and going off the end of the runway.



(Photo courtesy of the author)

Bottom Line

Bringing an aircraft to a safe stop takes more than just throwing it on the ground and hitting the brakes. Detailed calculations go into each and every landing to ensure that the aircraft will come to a safe stop within the available distance. Even if the runway is covered in snow, there is still a chance that the aircraft can land. In these situations, the pilots must ensure they have the latest runway information to ensure that the performance which they have calculated is valid for the current conditions.

Featured photo by NurPhoto/Getty Images.

Charlie Page Charlie Page is an airline pilot flying the Boeing 787 Dreamliner. Each Saturday he gives you a 'behind the cockpit door' insight to life in the flight deck.
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