IFALPA
The Global Voice of Pilots

Aircraft Design & Operation
Briefing Leaflet

12ADOBL03 January 2012

Certified versus advisory landing data on Boeing aircraft

Photo: The Boeing Company

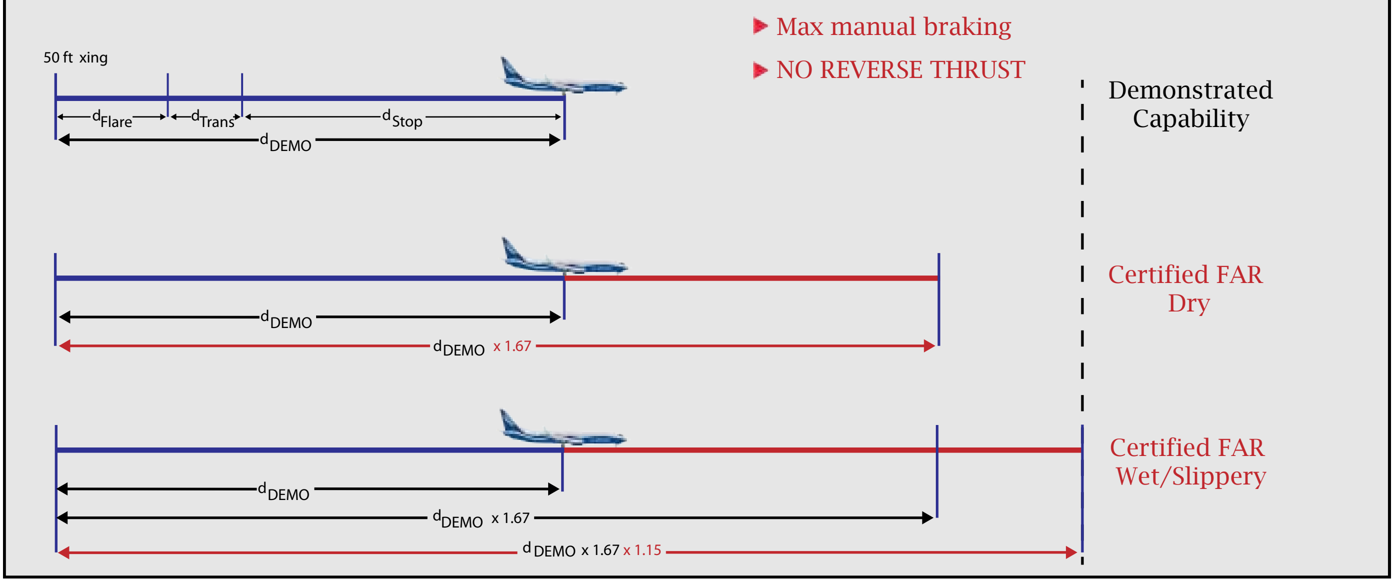
Introduction

This briefing leaflet was with the invaluable assistance of Capt. Tom Phillips of Boeing's Flight Operations Department and discusses landing distance data provided to operators, and the effects of speed brakes and reverse thrust on stopping distance.

Data Sets - Certified versus Advisory

Boeing provides two different landing distance data sets to operators, *Certified* and *Advisory* data. Certified landing data is used during flight planning to determine the maximum takeoff weight at which the aircraft can land within the available landing distance at the destination/alternate airport. The data is based on specific regulator requirements that address dry, wet and slippery runway conditions. This data is also referred to as "dispatch data". It is important to remember that the certified data does not provide distance requirements to cover all operational landing situations. Runway slope, OAT and the effect of thrust reversers is not included in certified data. You will find the Certified data in the Aeroplane Flight Manual (AFM) and in the Performance Dispatch chapter - Landing Field Limit Length Dry/Wet section of the Flight Crew Operations Manual (FCOM). The landing distance is measured from the point at which the main landing gear of the aircraft is 50 feet. above the landing surface to the point where the aircraft is brought to a stop.

Fig 1: Certified stopping distances
Data source The Boeing Company



The certified landing distance is determined during flight test in accordance FAA Advisory Circular (AC) 25-7a. The AC explains the various means to determine the landing distance. Traditionally, steep approaches and high touchdown sink rates were used but such a demonstration of maximum performance is no longer considered acceptable. Three phases are measured; airborne, transition and stopping. One of the most common demonstrations for measuring the airborne phase targets a touchdown rate of descent that should not exceed six feet per second with no nose depression below 50 feet. The 50 foot height is then geometrically calculated.

During the transition phase landing time delays for manual deployment allow for a one second time delay before pilot activation of first deceleration device and two seconds for activation of second deceleration device. For approved automatic deceleration devices (e.g. autobrakes or auto-spoilers etc) established times determined during certification may be used.

Note, no reverse thrust is used in this stopping demonstration.

The AFM/FCOM landing distance for dry runways is calculated by multiplying the test data by 1.67. For wet or slippery runways the dry runway value is increased by multiplying by a further 1.15. It is important to note that the Federal Aviation Regulation (FAR) certified wet or slippery runway is ***not*** based on an aircraft wet or slippery runway ***demonstration***.

The *Advisory* data provided by Boeing and found in the Performance Inflight (PI) – section of the Quick Reference Handbook (QRH) is based on landings carried out in normal configuration. This *Advisory* data, which may also be referred to as "enroute data" or "operational" data, provided by Boeing has always been based on the use of reverse thrust. For the braking distance calculations to be accurate (to achieve the actual unfactored distance) you must meet the conditions as referenced at the bottom of the chart; adjusted for environmental conditions, 5o feet above the threshold at appropriate approach speed, decelerative devices as specified and all engine reverse thrust.

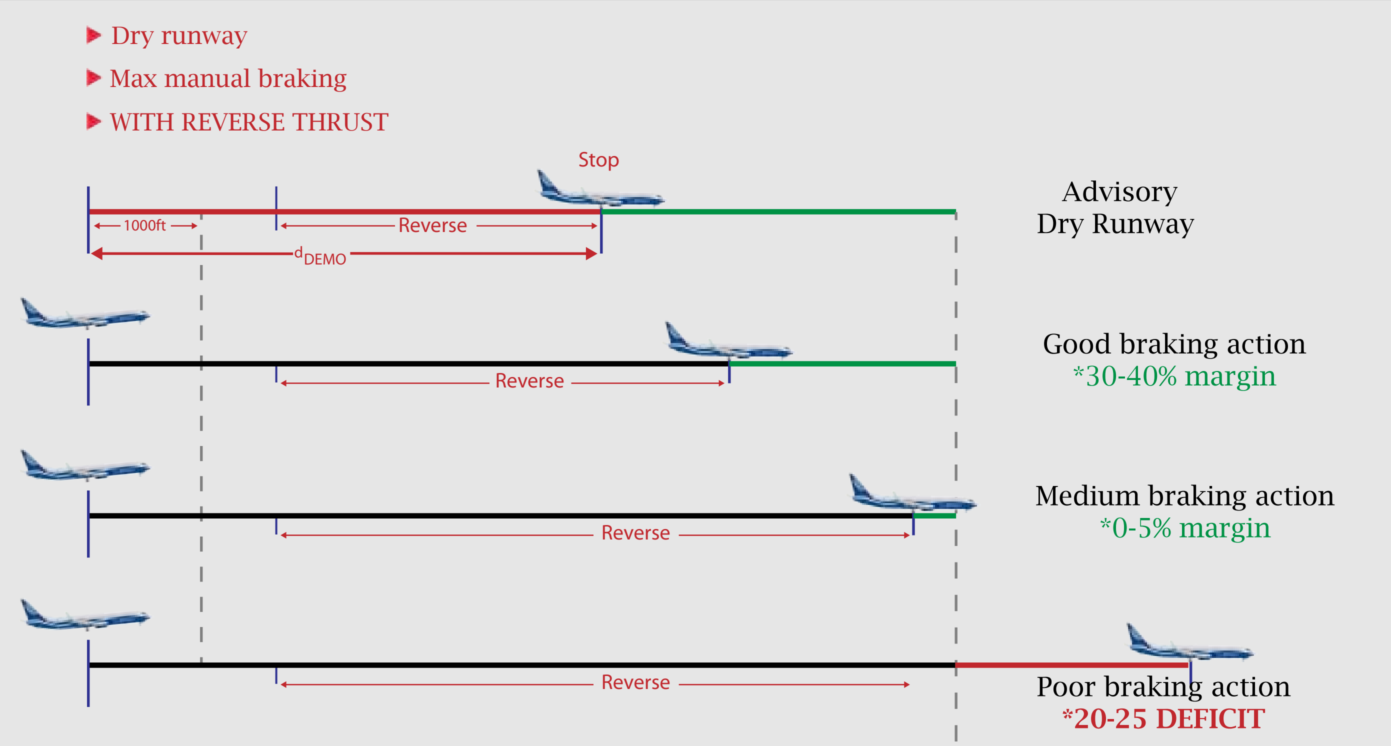


Fig 2: Stopping performance vs. Advisory data
Data source The Boeing Company

Comparing *Certified* to *Advisory* data is, as the saying goes, like "comparing apples with oranges". *Certified* data (that is factored dry test landing distance, with ***no reverse thrust***, multiplied by 1.67 plus an additional .15 for wet runways) is used as a flight planning tool. Certified data allows you to determine the maximum takeoff weight which will allow the aircraft to land at the destination or alternate airport. FAA Advisory data is non-factored and assumes the ***use*** of ***reverse thrust*** in addition to all the conditions met or adjusted as referenced from the chart at the bottom of the PI page. *Advisory* data is provided to meet operational needs on varying runway conditions with the expectation that crews will assess landing performance based on actual weather and runway conditions at the time of arrival as opposed to those prevailing at the time of dispatch, when *Certified* data is used.

Use of speedbrake to enhance braking performance

To understand the importance that the speedbrake has in braking performance, consider the following scenario: The landing is on a critical runway, short and slippery. Flaps 30°, 120 knots at touchdown and the pilot monitoring (PM) calls "speed brakes not up". Fortunately your training kicks in and you promptly select the speed brakes, deploy the thrust reversers and successfully bring the aircraft to a stop within the remaining runway.

So how effective were the speed brakes and how did they affect the stopping performance of the aircraft during landing?
Speed brakes act primarily as drag increasers and crucially, lift reducers. Reducing the lift increases the weight on wheels, improves the wheel brake performance and thereby reduces the stopping distance.
Let's look at some numbers that illustrate this point. In this example the aircraft, a 737-900, weighs 145,000lbs, travelling at 120kts and flaps 30°. The drag force is 6,010lbs which more than doubles to 12,620lbs with the speed brakes deployed. Clearly, this has a significant retarding force. But consider the effect on lift. Remember, the aircraft weighs 145,000lbs. Without speed brakes at 120kts the wing will already be producing 50,410lbs of lift, even at zero pitch. When the speed brakes are deployed not only is all of this lift removed from the equation but an additional 10,530lbs of down force is created! The resulting increase in the weight on wheels translates directly into extra brake force, in this example around 24,400lbs. When added together with the increased drag this additional brake force adds around 37,990lbs or 70% increase in the total stopping force! This is even more acute on a wet or contaminated runway (where friction is reduced to a seventh of the equivalent clean/dry surface) when the effect of speed brakes is magnified resulting in a ***90% increase*** in stopping force.

As can be seen proper deployment of the speed brake will increase drag and weight on wheels, reducing your stopping distance on a contaminated runway which may make the difference between a safe stop and an overrun.

The effect of thrust reversers

To appreciate the role that thrust reversers consider the landing is to a critical runway; short, slippery with the braking action reported POOR. Immediately following touchdown the pilot monitoring calls "Speed Brakes Up" and you hesitate several seconds in your selection of reverse thrust. This prompts two questions:

- Will your hesitation selecting reverse thrust significantly affect your stopping distance?
- How effective is reverse thrust?

In order to answer these questions, first, consider stopping distance landing on a dry runway. On a dry runway deceleration available with Max Manual (Figure 3.) wheel brakes is based on wheel brake capability. Reverse thrust will increase this deceleration available therefore the stopping distance will be shortened.

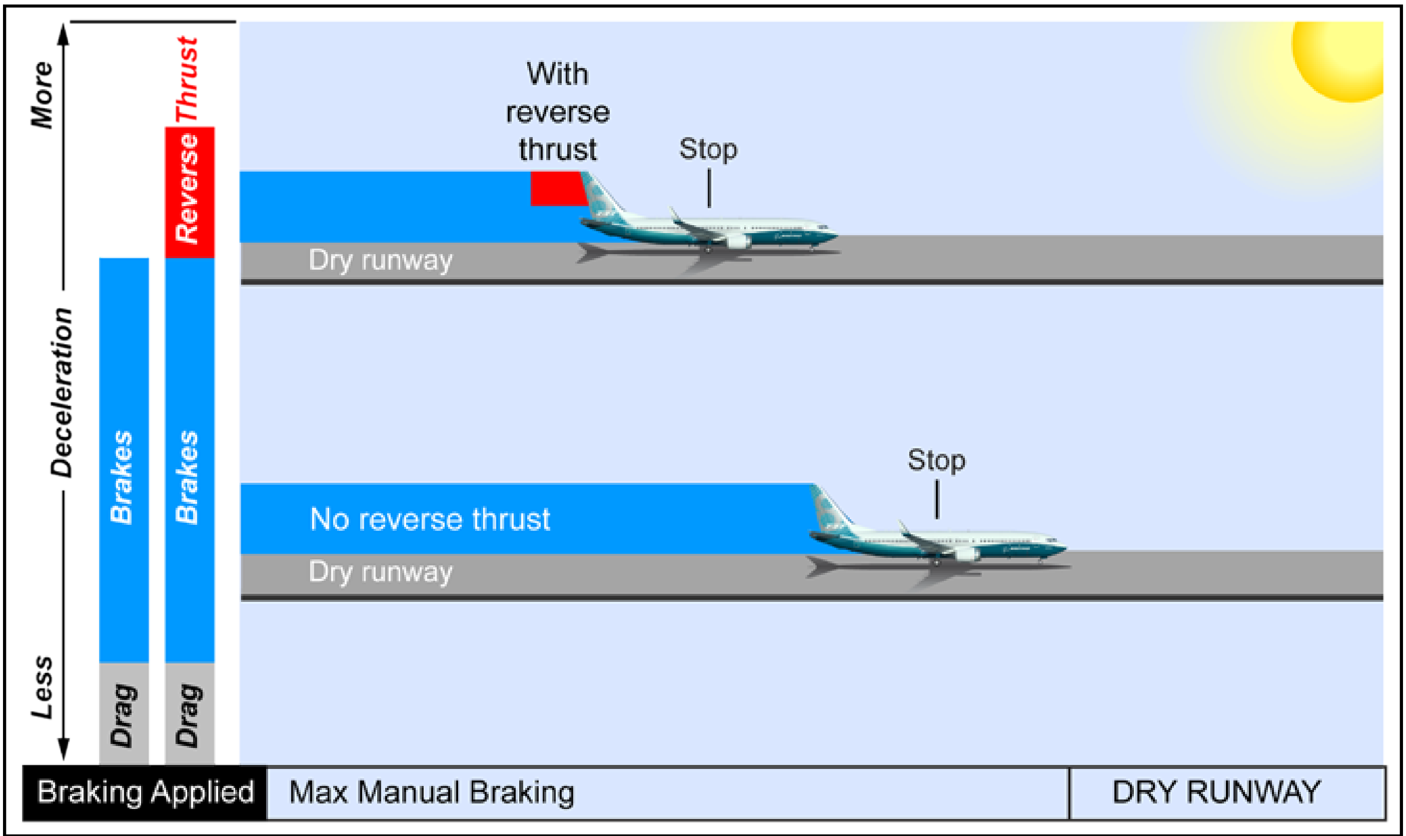


Fig 3: Ratio of stopping forces Data source The Boeing Company

Use of autobrake

Since we know autobrakes target ***a deceleration rate*** rather than a braking force on a dry runway, using reverse thrust with Autobrake 2 will not increase your deceleration rate it will simply reduce the energy applied to the wheel brakes (Figure 4.)
So what is the point of using reverse thrust at all? Landing on a dry runway reverse thrust provides minimal additional deceleration with manual braking and no additional deceleration with auto brakes. However when landing on a runway with poor braking action , like wet melting ice, the effects of reverse thrust can make a dramatic difference; the difference between a safe landing or an overrun.

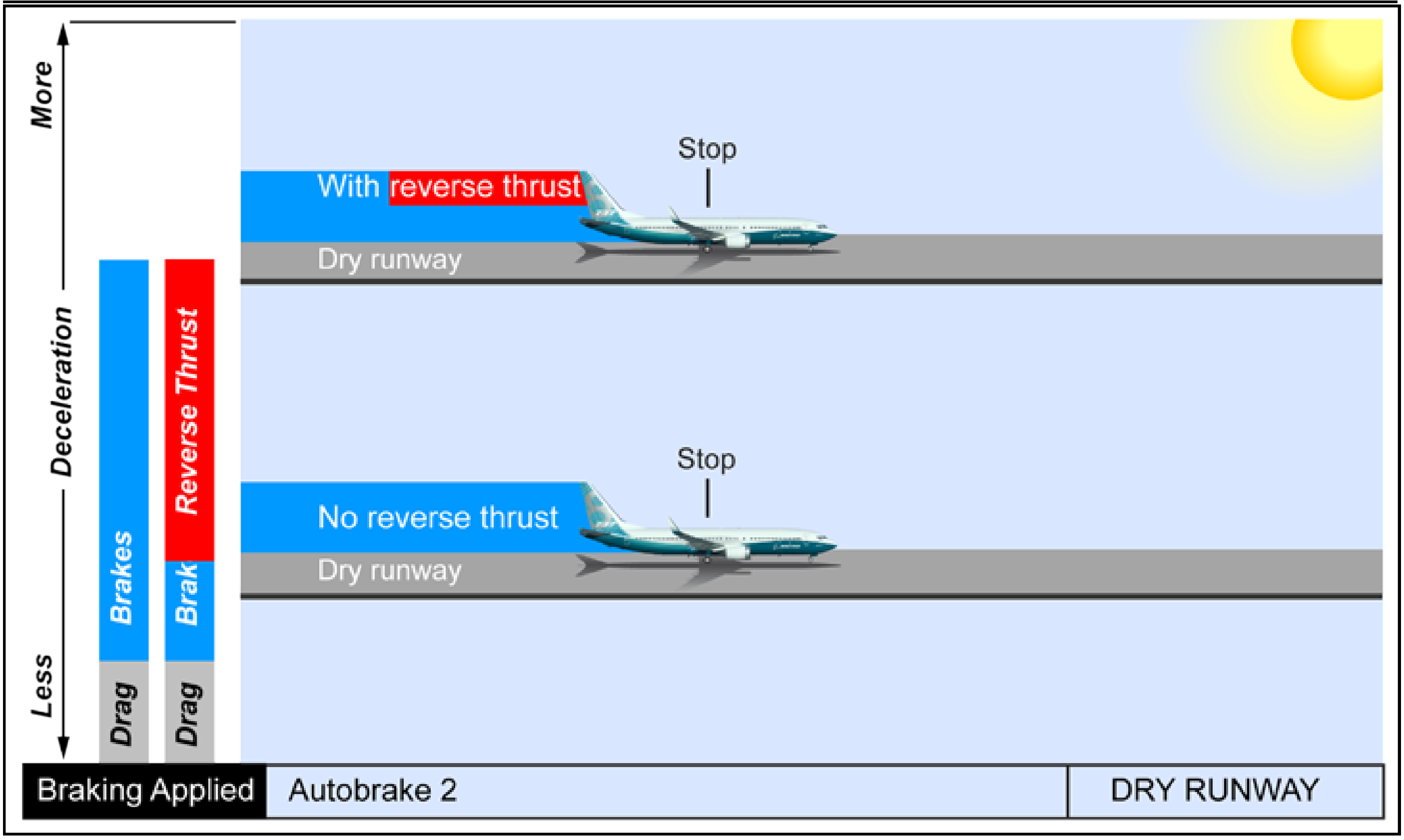


Fig 4: Impact on brake engery using rev thrust with autobrakes
Data source The Boeing Company

Figure 5 shows when using Max Manual brakes, reversers are additive, that is, they increase the deceleration. Note in Figure 5 how deceleration due to drag has remained the same for all runway conditions but the deceleration from reverse thrust has proportionally increased considerably while brake efficiency has noticeably decreased due to the slippery runway conditions.

The differences in effect of the reverse thrust can be significant. If you're a number's person look at the Performance In-flight (PI)

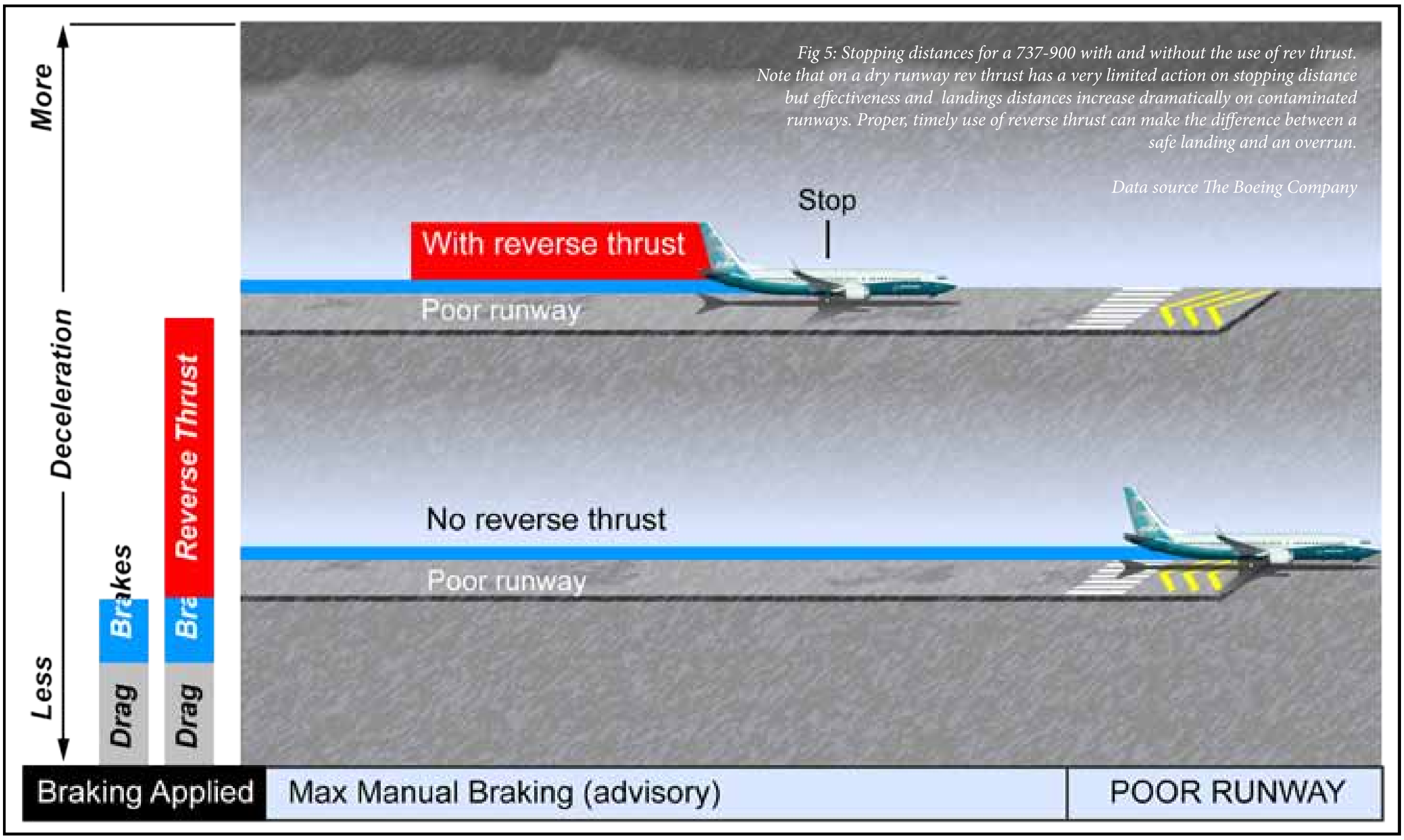


Fig 5: Stopping distances for a 737-900 with and without the use of rev thrust. Note that on a dry runway rev thrust has a very limited action on stopping distance but effectiveness and landings distances increase dramatically on contaminated runways. Proper, timely use of reverse thrust can make the difference between a safe landing and an overrun.

Data source The Boeing Company

data section in the Quick Reference Handbook (QRH) and consider the landing distance adjustments with and without reverse thrust.

Returning to the scenario set out earlier, the example used will be a 737-900 with a gross weight of 130,000lbs and flaps 40° landing on a runway reporting poor braking. Dry runway landing distance using maximum manual braking and reverse thrust would be 860m (2820ft). Without the use of reverse thrust only 34m (110ft) is added to the landing distance increasing it to 894m (2,930ft). But remember the runway braking action is reported as poor? Therefore, the charts indicate that the landing distance required using maximum manual braking and reverse thrust will be 2,069m (6,790ft) – ***more than double the dry runway distance.***

To stop the aircraft in this distance you must meet ALL conditions referenced at the bottom of the advisory page – 50ft threshold crossing height, 304m (1000ft) of air distance, auto speedbrakes, maximum braking, two engine reverse thrust, and standard day, no wind or slope. Furthermore, unlike certified data ***there is no margin***. If you do not use or you can't deploy reverse thrust your landing distance will increase by 896m (2,940ft) requiring a total stopping distance of 2,965m (9,730ft), in short, three times more than for a landing on a dry runway.

With one of the thrust reversers MEL'd you may be tempted on a slippery runway to NOT use the operating thrust reverser due to concerns of directional control. The decision should not me made in haste. Checking your PI you see that using no thrust reversers versus the one will increase your stopping distance 338m (1,110ft)! Reverse thrust plays a significant role in decelerating the aircraft on a runway with poor braking action.

Furthermore, if your braking distance calculations are to be accurate to achieve the actual unfactored distance you must meet the conditions as referenced at the bottom of the chart; adjusted for environmental conditions, 5o feet above the threshold at appropriate approach speed, decelerative devices as specified and all engine reverse thrust.

Summary

The goal of this Briefing Leaflet is enhance your understanding of the landing performance data and to appreciate the role that speed brakes and thrust reversers play in deceleration especially when landing.

As a review:

- *Certified* data is factored, used for dispatch purposes and does not use reverse thrust.
- *Advisory* data is non-factored (FAA), used enroute and has always been based on the use of reverse thrust.
- Speed brakes increase drag and decrease lift allowing your brakes to be considerably more effective.
- Reverse thrust provides significant deceleration when landing on a critical runway; short, slippery with the braking action reported POOR.

References:

Boeing Flight Operations Technical Bulletin:
23 August 2007 "LANDING ON SLIPPERY RUNWAYS"

NTSB Accident Report Runway Overrun and Collision Chicago, Midway 8 December 2005

FAA SAFO- LANDING PERFORMANCE ASSESSMENT AT TIME OF ARRIVAL (turbojet)

FAA AC 25-7a: Flight Test Guide for Certification of Transport Category Aircrafts
http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/99840