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Article **1**

The Migration to Higher Thrust Engines and the Effect on Control Speeds
Status

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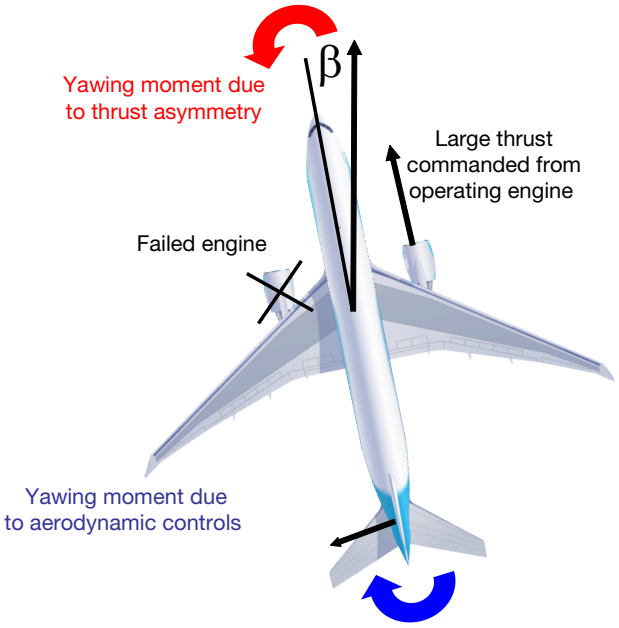
For the 777 airplane the growth in engine thrust levels has increased since the original PW4074 engine. This original engine was rated at 74000 pounds of thrust and was envisioned to grow to around 95000 pounds of thrust. The 777-200LR has a current offering of a 115000 pound thrust engine. With this engine growth the vertical tail and rudder size has remained the same. This has resulted in reduced margins between the normal operating speed and the in-air minimum control speed



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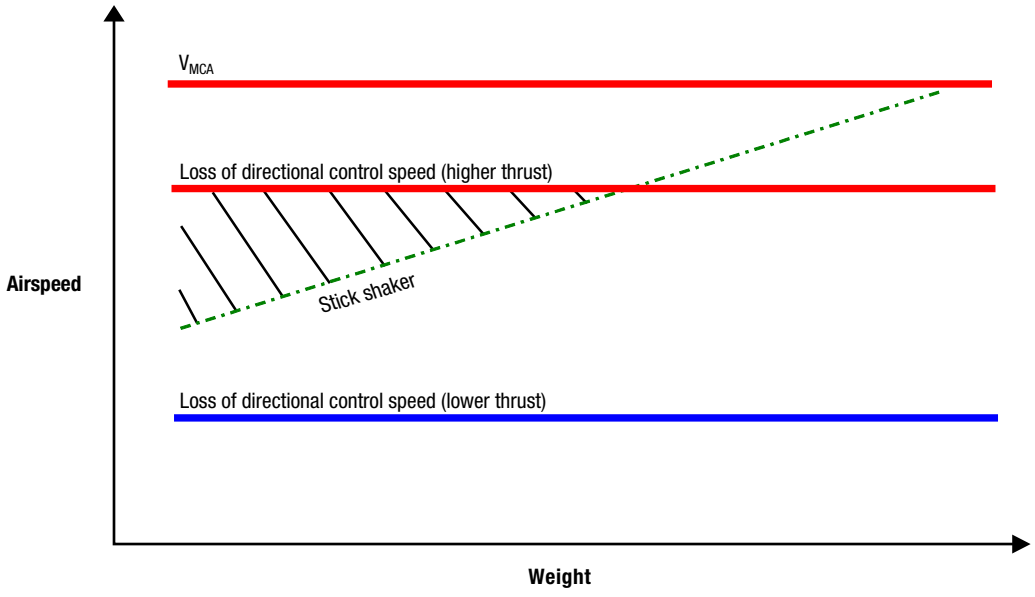
There is a speed below which there is a loss of directional control. This speed is defined by the inability to reliably maintain desired bank angle and/or heading at a given asymmetric thrust. This speed is always lower than the certified minimum control speed (V_{MCA}/V_{MCL}).

FAR 25.149 states: "V_{MC} is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane with that engine still inoperative and maintain straight flight with an angle of bank of not more than 5 degrees. Certified minimum operating speeds (V_2, V_{REF}) are always at greater than or equal to V_{MCA}, and hence, have even greater margin to the loss of directional control speed. All models of the 777 family meet all minimum control speed regulations of all regulatory agencies where they are certified (FAA/EASA, etc). However, higher thrust asymmetry may cause the loss of directional control speed to become greater than stall warning speed at light weights. This raises the possibility that if airspeed were improperly reduced below the published operating speeds at these weights and thrust levels, the limit of full wheel and rudder control inputs could be reached prior to stick shaker activation.

Flight crews following Boeing published procedures and flying recommended speeds will maintain directional control. However, loss of directional control prior to reaching stick shaker may occur after an engine failure in combination with: light weights, airspeeds lower than recommended, and higher than recommended thrust settings.

Landing Go-Around

One push of TO/GA button provides adequate thrust for most situations, and provides substantial speed margin to loss of directional control speed in the event of an engine failure. Two pushes of TO/GA button provides full G/A thrust, reducing margin to loss of control speed in the event of an engine failure.



Analysis for Probability of Violating Minimum Control Speed:

Assumptions are as follows:

- Engine failure is very rare
- Engine failure during critical takeoff phase (V_1 to V_2 + 15) is very rare
- Engine failure during go-around prior to acceleration is very rare
- With a fixed derate takeoff with an engine failure the pilot advances the throttle on the remaining engine to full thrust (against Boeing published procedures)

Conclusions are:

When making conservative assumptions all cases are extremely improbable (and at light weights)

The Takeoff Case:

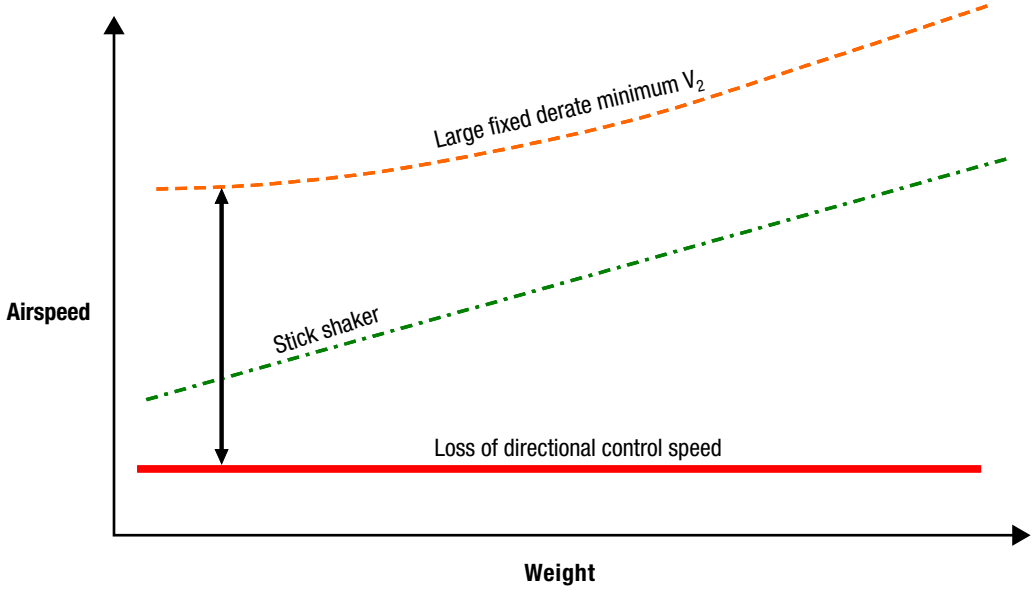
FULL-RATED or ASSUMED TEMPERATURE METHOD (ATM) Takeoff:
Full-rated takeoff V_2 provides substantial speed margin to V_{MCA} and loss of directional control speed. Assumed Temperature Method (ATM) provides same or greater margin, even if thrust is pushed (no reduction in V_{MC} speeds assumed).

FIXED DERATE Takeoff:
Fixed derate takeoff limit thrust in takeoff calculations (VMC speeds are set by de-rated thrust level), yielding lower takeoff speeds and shorter field lengths. Pushing thrust higher upon engine failure violates procedures and reduces or eliminates margin to V_{MCG} and V_{MCA}, and reduces margin to loss of directional control speed

Thrust levers should not be advanced beyond the fixed derate limit unless one of the following conditions apply:

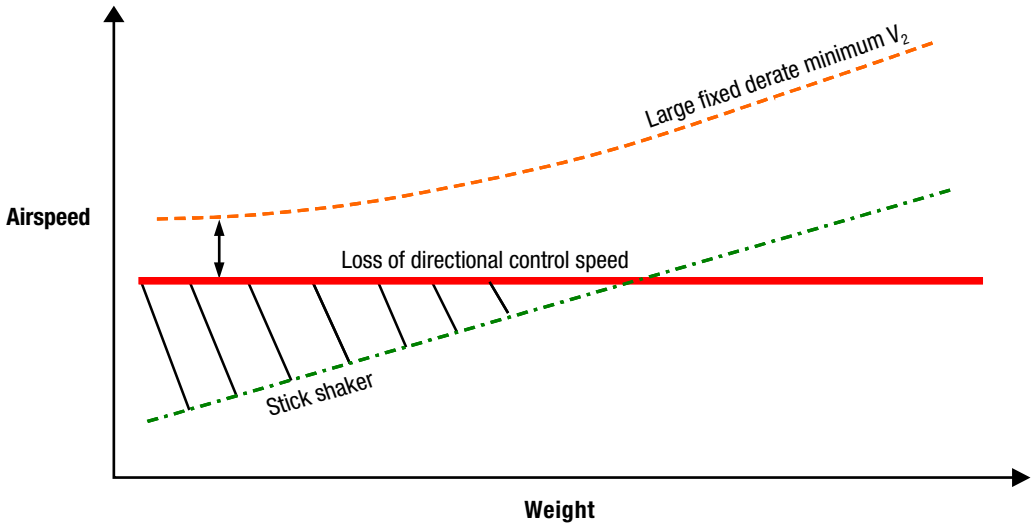
1) Conditions are encountered during the takeoff where additional thrust is needed on both engines such as windshear.
2) Thrust increase following an engine failure, especially near V1, could result in a loss of directional control, and should not be accomplished unless in the opinion of the Captain, terrain contact is imminent.

Flying Boeing procedures and recommended speeds will maintain directional control.



Not following Boeing procedures and advancing thrust reduces the margin to loss of directional control speed.

A V_2 floor is one of the technical solutions that we are looking at. The V_2 floor would maintain the larger speed margin to the loss of directional control speed that is found on the lower thrust engines.



LANDING GO-AROUND:

If an engine fails during a go-around, an immediate loss of airspeed will occur. It is important that airspeed loss be recovered. Airspeed recovery is accomplished by following flight director guidance and Boeing recommended procedures.

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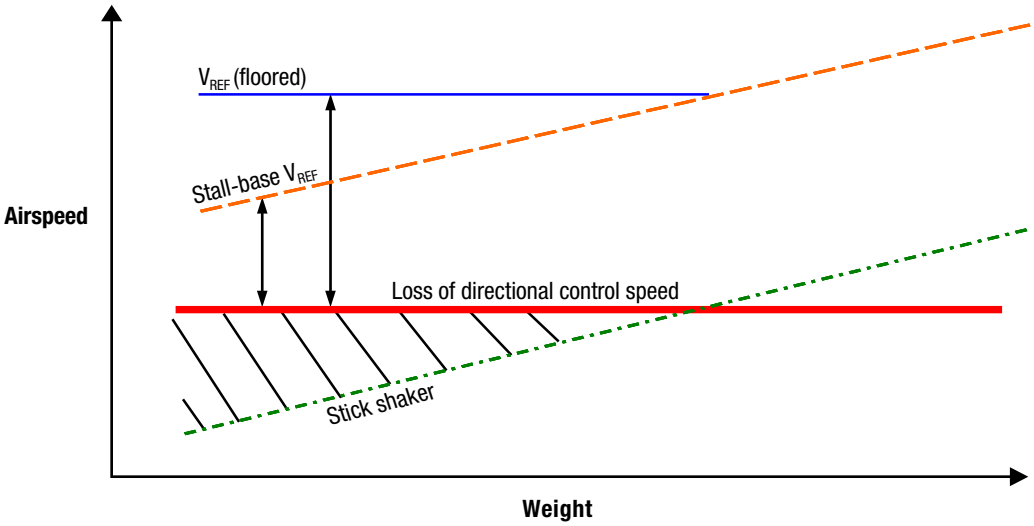
Two pushes of TO/GA button provides full G/A thrust, reducing margin to loss of control speed in the event of an engine failure.

Note: the minimum recommended approach speed is V_{REF} + 5 knots.

The 777-200LR maintains an excellent margin to loss of control speed due to a V_{REF} speed floor.

Boeing is currently evaluating speed margins for the 777-200ER at light weights to match 777-200LR methodology.



The Final Effect is of minimal impact (but not zero):

Minor model	Engine	Exposure (loss of control speed > stick shaker speed)
777-300/-300ER	ALL	NONE
777-200/-200ER	PW4074, 4077, 4084 RR 877, 884 GE90-76B, -85B	NONE
777-200ER	PW4090 RR 892 GE90-90B	Landing weights below ~365000 lb
777-200ER	RR 895 GE90-94B	Takeoff weights below ~380000 lb Landing weights below ~400000 lb
777-200LR 777 Freighter	GE90-110B1L (GE90-115BL)	Takeoff weights below ~445000 lb (Takeoff weights below ~465000 lb)

The Plan from Here:

Boeing will revise the 777 Flight Crew Training Manual in October 2007. This revision will further clarify and emphasize the importance of following recommended crew procedures and maintaining adequate speed margins. Boeing will also publish a Flight Operations Review and an *Aero* Magazine article to provide additional background and clarifying information. Along with this emphasis on adhering to procedures we are also looking at technical solutions.