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For Professional Pilots

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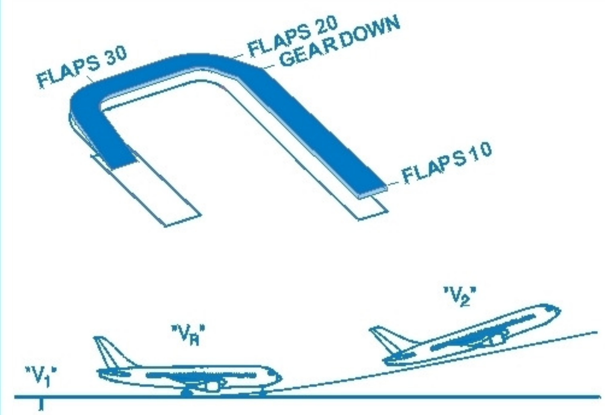

FLIGHT TECHNIQUE ANALYSIS for PROFESSIONAL PILOTS

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INTRODUCTION

Flight technique analysis is the application of aerodynamics to flight technique issues. Unlike aircraft performance and design, where aerodynamic equations provide numerical data, flight technique analysis uses aerodynamic principles to optimize the methods used to precisely fly an airplane. In this sense, aerodynamic principles are applied qualitatively rather than quantitatively.

While most technical books have many words and a few illustrations, most of the principles explained in this book utilize graphical means. Text comments are mainly used for introductory comments and the summarizing of critical points.

A new book series expands coverage of the issues in this book, including new computerized demonstrations, tools and additional related subject areas. The first book in the new series, *Advanced Airmanship Book 1 Precision Flying*, is currently available and the remaining two books are scheduled for release in 2011. Additional information on these new books and updated editions of Professor Les Kumpula's current text books is available on the publisher's web site: www.cchpublishing.com

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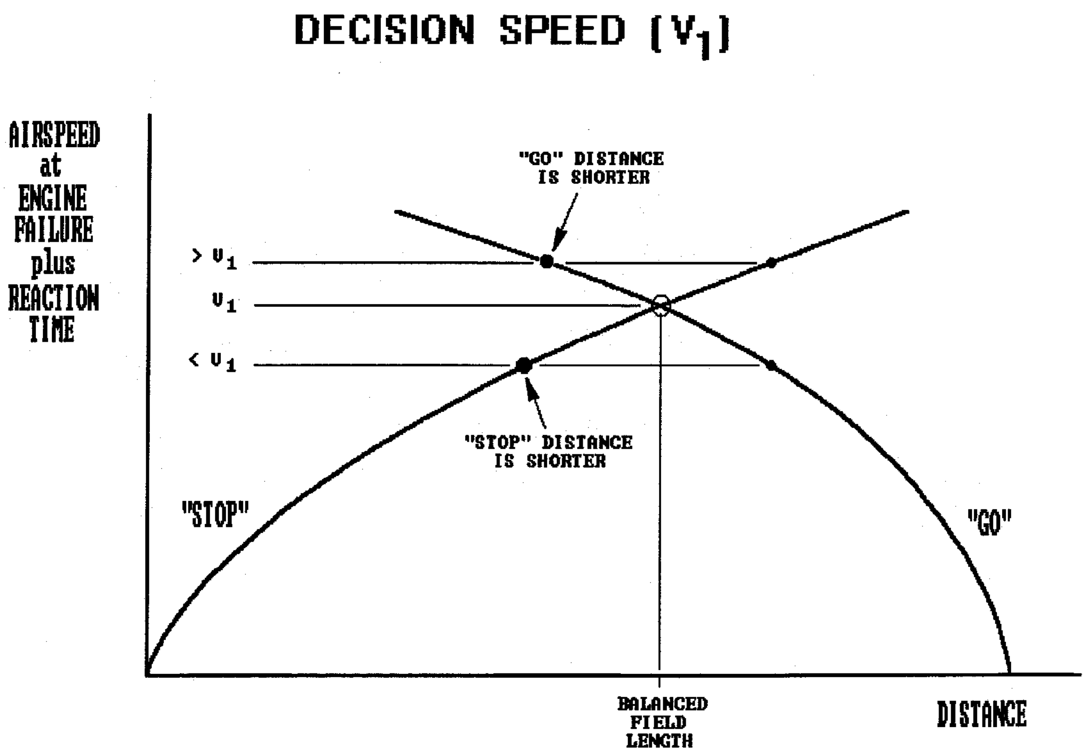
KUMP'S KUMMANDMENTS

I. THOU SHALT determine the EXACT *Pitch Attitudes* and *Power Settings* for all normal flight situations.

III. THOU SHALT set the new Pitch Attitude and Power Setting *Together* when changing both flight path *and* airspeed.

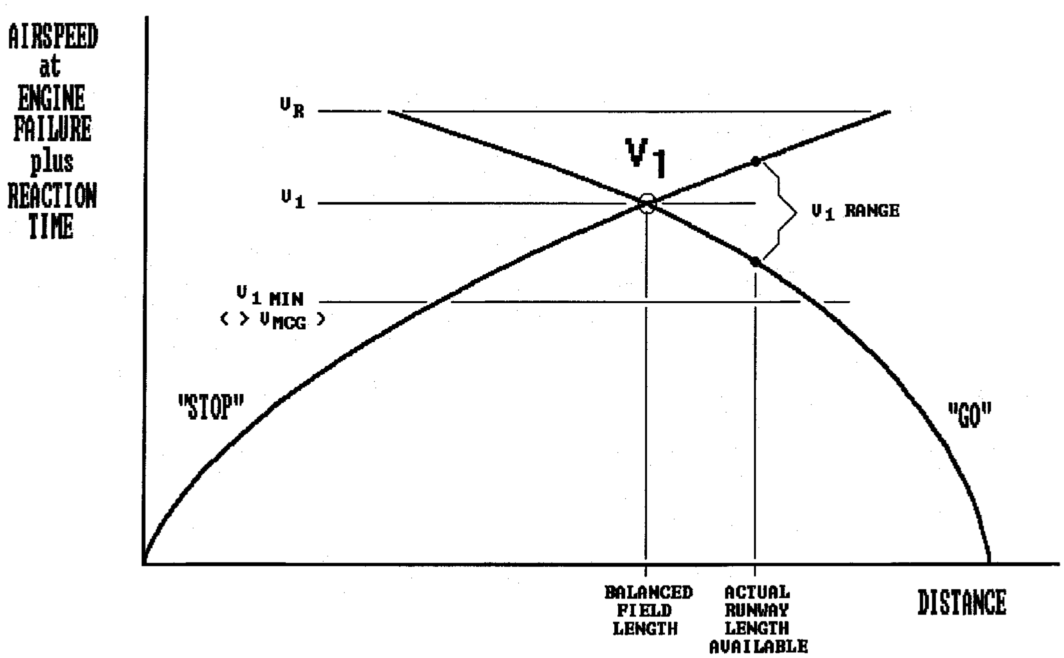
IV. THOU SHALT coordinate PITCH ATTITUDE changes with AIRSPEED changes when CHANGING AIRSPEED while maintaining a constant flight path.

V. THOU SHALT coordinate PITCH ATTITUDE changes with POWER changes when CHANGING FLIGHT PATH while maintaining a constant airspeed.

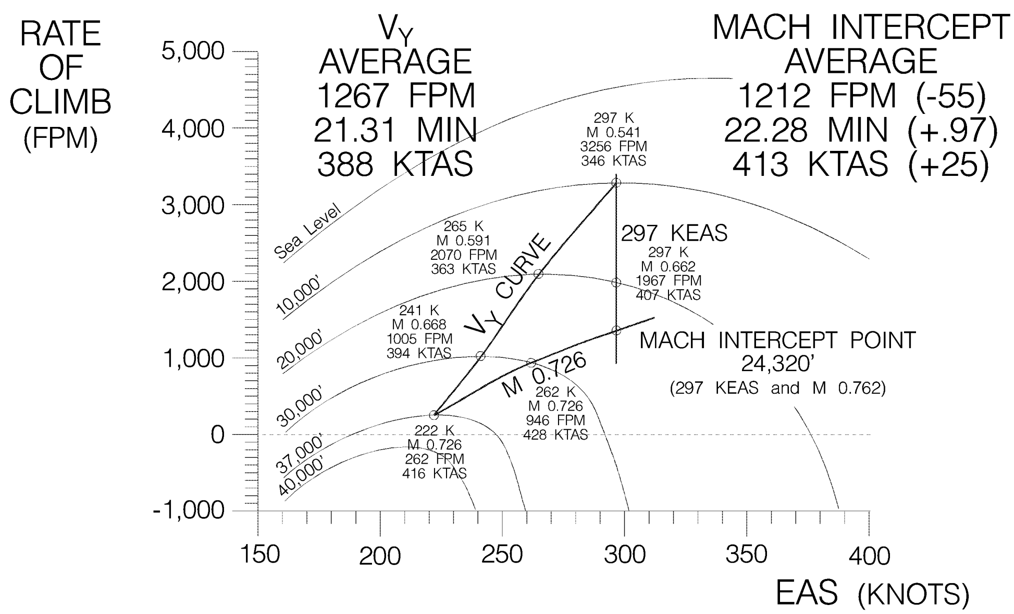


Stopping if the engine fails below V_1 and going if the engine fails above V_1 allows either a takeoff to be completed or a stop to be made on a runway length equal to the balanced field length.

DECISION SPEED (V_1)



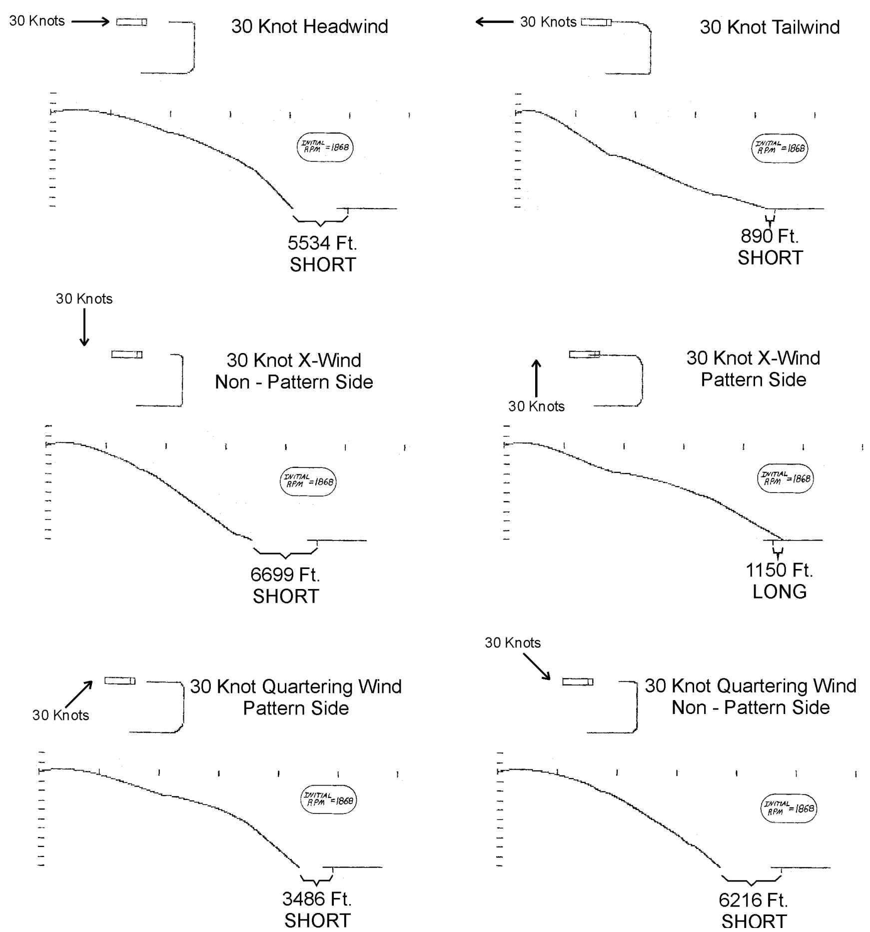
CLIMB PROFILE COMPARISON
TYPICAL HEAVY JET TRANSPORT
GROSS WEIGHT = 320,000#



Jet climb profiles are complicated by the aircraft's high altitude capability, due to the many changes in pitch attitude required during a traditional climb at best rate of climb speed. Also, this type of profile cannot easily be flown by the autopilot. Since the rate of climb curves are relatively flat, a climb profile beginning at the low altitude best rate of climb airspeed until reaching and then maintaining the high altitude best rate of climb Mach number almost matches the traditional best rate of climb performance.

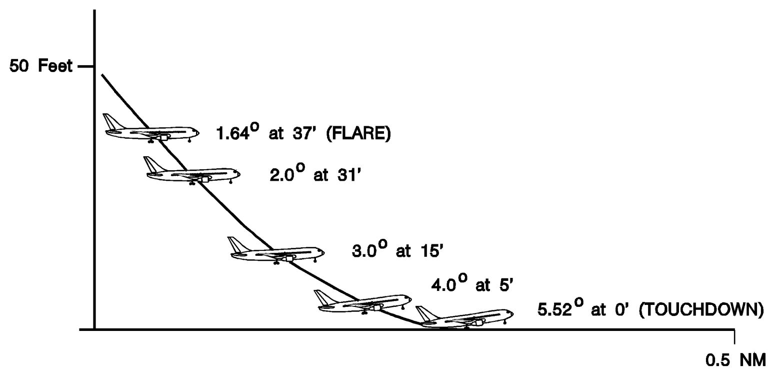
TRAFFIC PATTERN WIND EFFECT

30 Knot WIND from VARIOUS DIRECTIONS



Note that the effect of wind is to cause the approach to be short in all cases except for a tailwind on base leg. Therefore, a higher power setting than the no-wind setting is required for most winds.

PITCH ATTITUDE vs. ALTITUDE

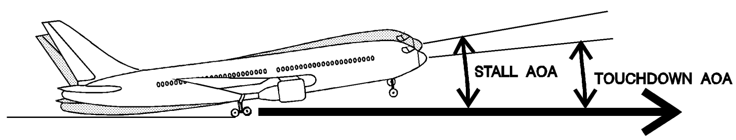


DURING LANDING:

COMPARE PITCH ATTITUDE vs. ALTITUDE!

NOTE that the TOUCHDOWN PITCH ATTITUDE does NOT CHANGE with WEIGHT or DENSITY ALTITUDE for the same configuration and stall safety factor!

TOUCHDOWN ATTITUDE ANALYSIS



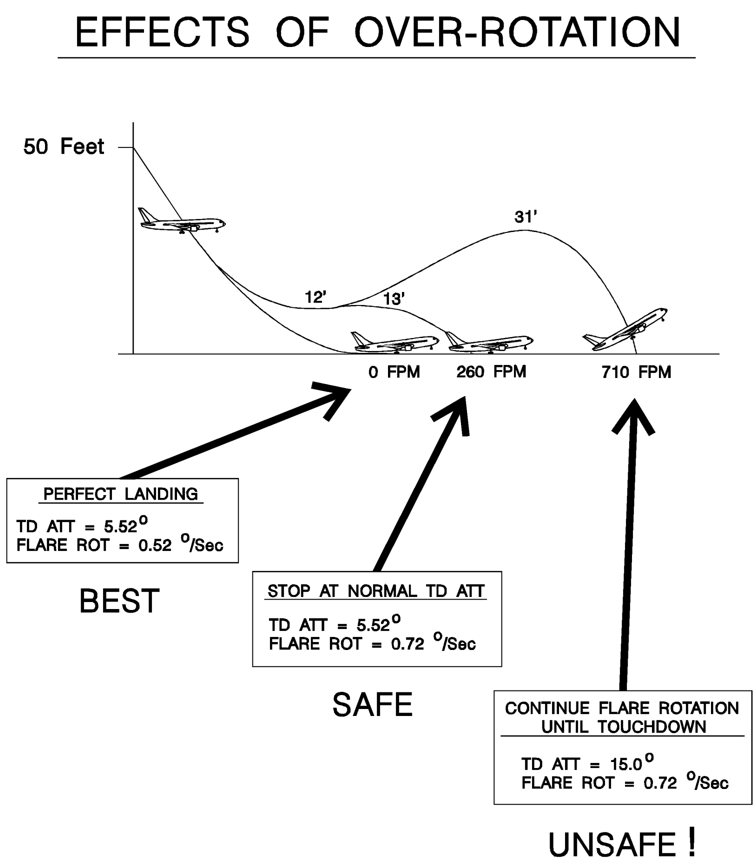
The stall safety factor is determined by how close the TOUCHDOWN AOA is to the STALL AOA.

Since stall AOA is not affected by weight or density altitude, then desired touchdown AOA will not be affected either.

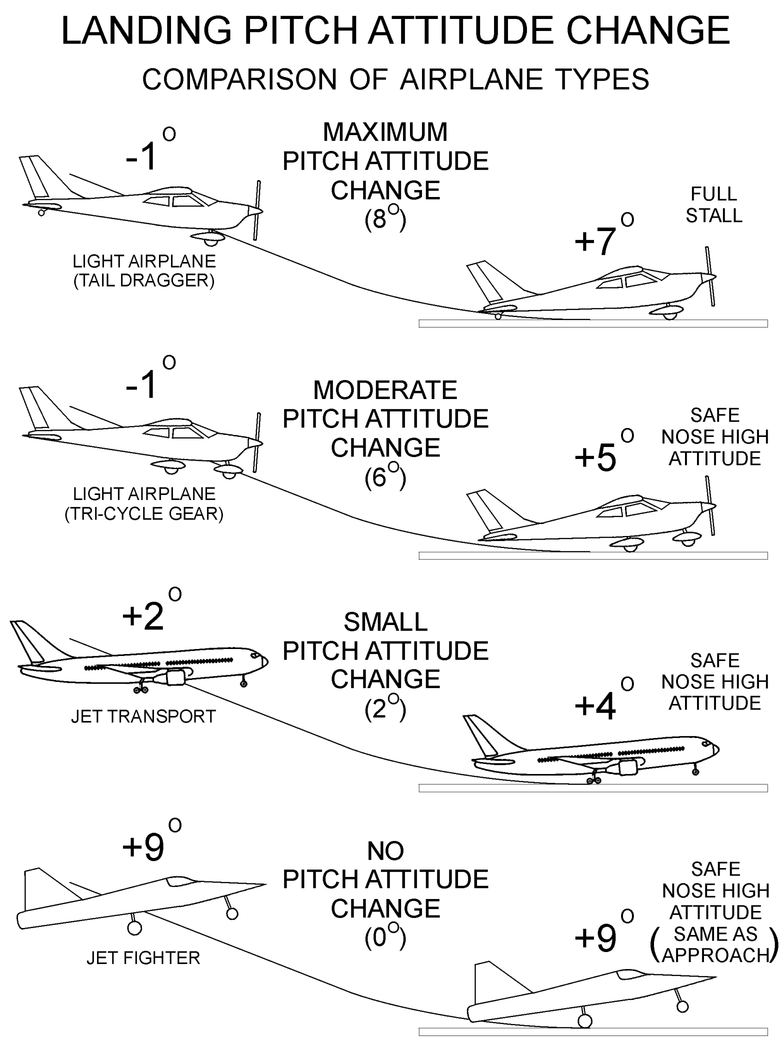
If there is no change in the touchdown AOA, then there will be NO CHANGE in the TOUCHDOWN PITCH ATTITUDE.

However, even though there is no change in touchdown attitude or AOA, touchdown IAS and TAS will change with weight and touchdown TAS will change with density altitude, but the stall safety factor will remain constant.

In other words, the DIFFERENCE between TOUCHDOWN SPEED and STALL SPEED will REMAIN THE SAME.



The most important message on this page is **DON'T OVER ROTATE!** If the aircraft has not touched down when the correct landing pitch attitude has been reached, ***stop rotating!*** Any further action at this point depends on the aircraft's ground effect characteristics and will be discussed on later pages.



Jets, with their swept wings and low aspect ratios, require a greater angle of attack on approach and therefore have a more nose up pitch attitude compared to light airplanes. Since a jet's approach attitude is appropriate for landing, only a small pitch change in the flare is necessary to change the flight path for a smooth touchdown. A light airplane must change both its pitch attitude and flight path during flare.

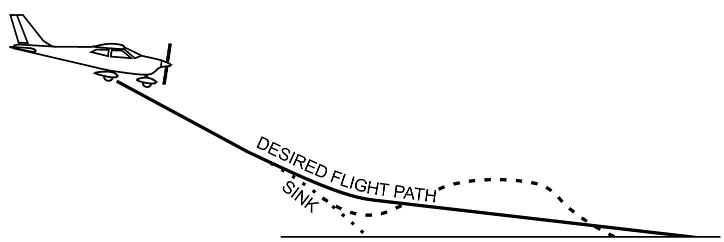
SPECIAL CONSIDERATIONS

FLARE POWER REDUCTION EFFECTS

Since some weight is being supported by prop induced lift and a vertical thrust component, when power is reduced and these engine related forces are reduced, an UNWANTED SINK CAN OCCUR.

This effect is maximum for wing mounted multi-engine prop driven airplanes, moderate for single engine low wing airplanes and minimum for high wing single engine and all jet airplanes.

This sink can reduce the space necessary to smoothly reach the desired touchdown attitude and sink rate.



THIS SINK CAN BE PREVENTED BY INCREASING THE PITCH ATTITUDE (i.e. Angle of Attack) AS THE POWER IS REDUCED, thereby preventing the lift loss from occurring. The attitude change would be greater for wing mounted multi-engine prop airplanes than for single engine high wing airplanes.

SUMMARIZING:

IX. THOU SHALT during flare for landing, INCREASE PITCH ATTITUDE as POWER IS REDUCED TO IDLE to prevent an unwanted sink.

LANDING SUMMARY

(EXCEPT FIGHTERS)

PREPARATION:

Experimentally determine the flare height and pitch rate that will give the desired touchdown speed at zero FPM. Note the touchdown pitch attitude and how pitch attitude varied with altitude.

PROCEDURE:

1. At Flare Height, begin a constant nose up rotation at the appropriate Pitch Rate.

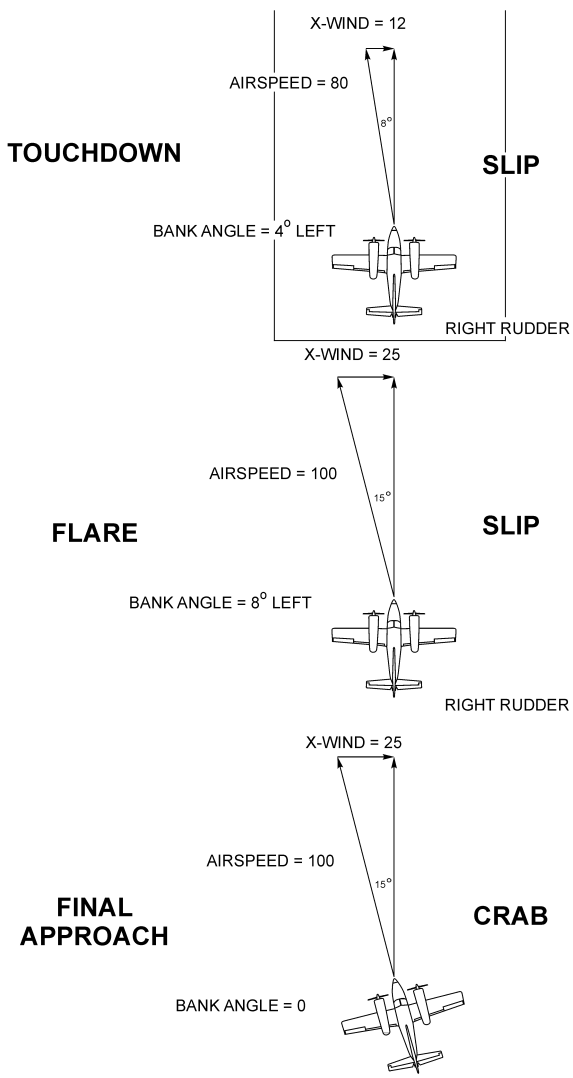
2. Compare Pitch Attitude vs. Altitude and adjust pitch rate accordingly.

3. If touchdown has not occurred at or before the desired touchdown pitch attitude, stop rotation at the touchdown pitch attitude.

For most jets, immediately rotate 1/2 to 1 degree nose down and wait for touchdown.

For light aircraft, hold the desired touchdown pitch attitude and wait for touchdown.

LIGHT X-WIND



NEAR TOUCHDOWN:

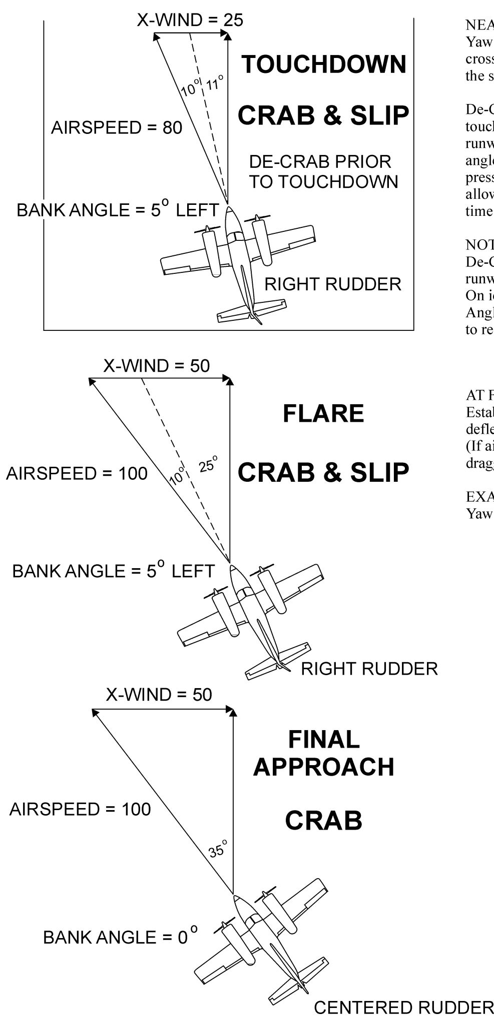
Gradually reduce Bank Angle by Half and reduce rudder pressure to maintain the Longitudinal axis aligned with the runway centerline

EXAMPLE:
Reduce Bank Angle from 8° to 4° while reducing rudder pressure.

AT FLARE:
Yaw to align the Longitudinal axis with the centerline while banking *HALF of the WCA* required in the Crab.

EXAMPLE:
Yaw 15° Right while Banking 8° Left.

STRONG X-WIND



NEAR TOUCHDOWN:
Yaw toward the centerline as friction reduces the crosswind, adding opposite aileron to maintain the same bank angle.

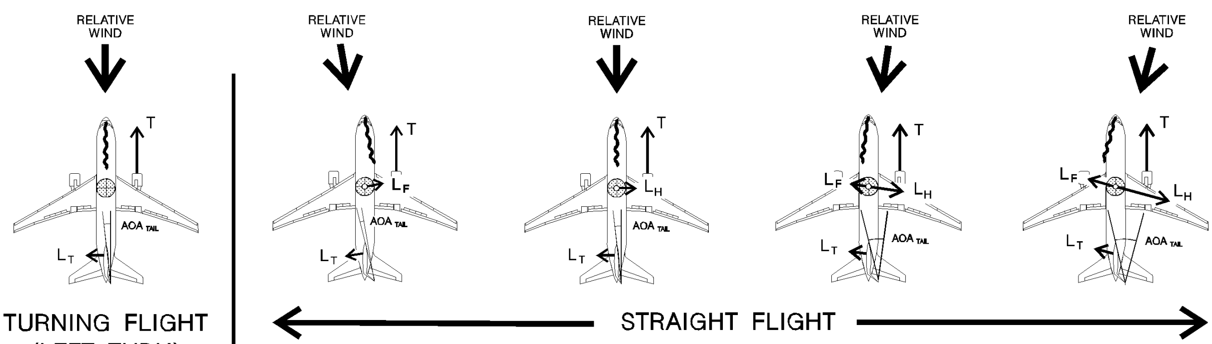
De-Crab with rudder pressure immediately before touchdown to align the longitudinal axis with the runway centerline, while maintaining the bank angle constant with additional opposite aileron pressure. De-Crabbing just before touchdown allows wheel alignment before the flight path has time to change significantly.

NOTE:
De-Crabbing is not necessary on slippery runways due to light friction sideloads.
On ice covered runways, maintaining a Crab Angle after touchdown allows residual idle thrust to reduce downwind drift.

AT FLARE:
Establish a Slip at less than maximum rudder deflection or near maximum landing bank angle (If aircraft is bank angle limited, to avoid dragging a wing tip), as appropriate.

EXAMPLE:
Yaw 10° Right while Banking 5° Left.

EXPLANATION OF VMC BANK ANGLE EFFECT



TURNING FLIGHT (LEFT TURN)

0^{o} BANK

MINIMUM DRAG

MODERATE V_{MC}

The left engine fails and right rudder causes tail lift that produces a right moment to balance the left moment caused by engine thrust. However, since the wings are level and there are no side forces to balance the tail lift, a turn to the left occurs, i.e. tail lift is producing the centripetal force necessary to turn the airplane.

STRAIGHT FLIGHT

0^{o} BANK

MODERATE DRAG

HIGHER V_{MC}

Maintaining wings level, the left turn is stopped by yawing to the right which produces a sideslip angle and a resulting fuselage lift to the right which balances the tail lift, making the centripetal force zero, which stops the turn. Note that the angle of attack on the tail is very small, requiring a high airspeed to produce the tail force necessary to balance the moments.

2^{o} BANK

MINIMUM DRAG

MODERATE V_{MC}

An alternative method of preventing a turn is to balance the tail lift with horizontal wing lift, keeping the centripetal force at zero. This zero sideslip condition causes a larger angle of attack on the tail than the previous case, allowing the necessary tail lift to be developed at a slower airspeed i.e. Vmc will be reduced. In addition, this situation produces the least drag and best performance, since the relative wind is straight down the longitudinal axis.

5^{o} BANK

HIGH DRAG

LOW V_{MC}

If a greater bank angle toward the operating engine is applied, the airplane has an imbalance of forces toward the right, i.e. a centripetal force toward the right, and a right turn will occur. To prevent the turn, a left yaw is necessary to balance the forces and make the centripetal force zero. In this situation, the relative wind is coming from the operating engine (right) side, which increases the angle of attack on the tail. As before, this allows the necessary tail force to be produced at a still slower airspeed, i.e. Vmc if further reduced.

8^{o} BANK

VERY HIGH DRAG

VERY LOW V_{MC}

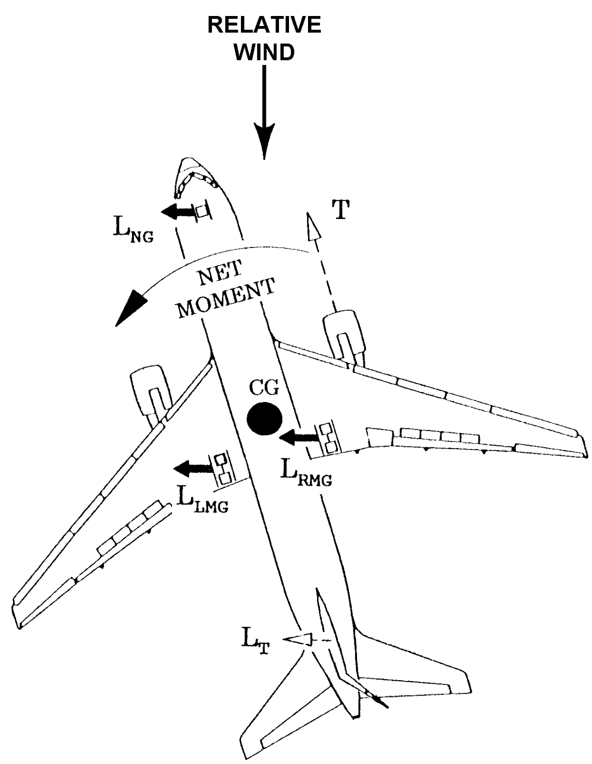
As bank angle is further increased and additional fuselage lift is required to prevent a turn, the resulting shift of relative wind toward the operating engine will continue to increase the angle of attack on the tail, with a resulting reduction in Vmc as long as the tail produces an increased C_L at increased AOA's. Generally this will continue until Vmc is driven well below stall speed. Normally, at relatively small bank angles, usually less than 15^{o}, the shift in relative wind is great enough to produce the necessary tail force moment to balance the engine thrust moment with no rudder deflection at all!

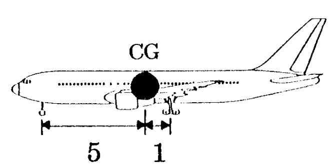
NOTE:
Centripetal force is the name given to any net force acting perpendicular to the direction of travel. It is caused by the combination of real forces, such as L_H, L_F, L_T, etc. Without this unbalanced force a turn will not occur.

In the above diagrams, L_H is shown where F_B would be more precise. Although $F_B = W \sin(BA)$ is the exact force, L_H is approximately the same value and is easier to visualize.

As bank angle toward the operating engine is increased, the aircraft accelerates in that direction until opposite forces, mainly fuselage lift, balance the new horizontal lift component. The relative wind is now further on the operating engine side and therefore the angle of attack on the tail is greater. This greater angle of attack allows the required tail lift to be obtained at a slower airspeed, i.e. VMC has been reduced. This process continues until additional angle of attack on the tail no longer produces additional tail lift.

EFFECT OF LANDING GEAR on Vmc



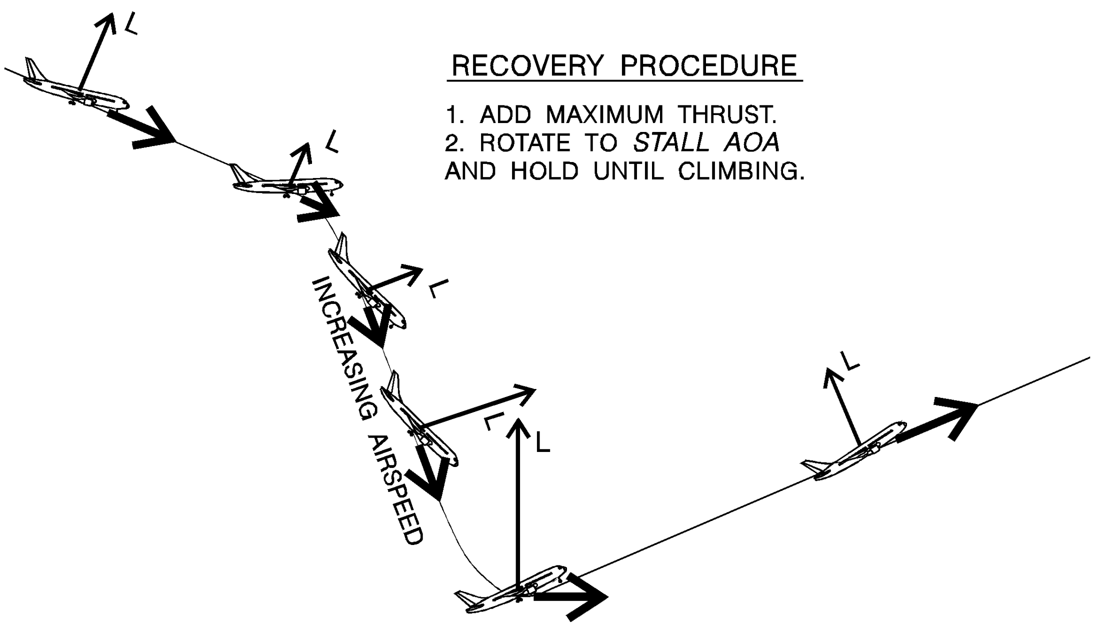


NOTE: The net landing gear effect is a moment toward the inoperative engine (due to the large nose gear moment arm). This causes an increase in Vmc due to a larger required L_{tail}.

From experiments conducted by Darren Clemente at Embry-Riddle Aeronautical University.

WIND SHEAR RECOVERY PROCEDURE

AIRSPEED < STALLING SPEED



WINDSHEAR RECOVERY AERODYNAMICS

When practicing stalls, the stall angle of attack and stalling speed arrive at the same time. The correct action is to lower the nose to decrease the angle of attack. However, when windshear causes an airspeed reduction, the angle of attack is still low and an angle of attack increase is required to regain the lift lost when airspeed was reduced.

If the windshear induced airspeed is at stall speed or greater, an increase in angle of attack can recover the lost lift and no change in flight path need occur. However, if airspeed drops below stalling speed, flight path cannot be maintained, even if angle of attack is increased to stall angle of attack. In this case, it is important to remember that stall angle of attack produces more lift than any other angle of attack, regardless of speed. Since lift is always perpendicular to flight path, keeping the angle of attack at stall throughout the recovery will maximize lift as airspeed increases and produce the quickest change in flight path direction.