FLIGHT MANUAL PERFORMANCE

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ILLUSTRATIONS

The purpose of this paper is to help the instructor pilot to understand the performance information contained in the Aircraft Flight Manual (AFM) and how it relates to the real world. It will cover airport performance for Transport Category turbojet powered business aircraft.

Aircraft performance is based on FAR Part 25. This Part is the document under which all current generation business aircraft are certified. It determines the operational limitations of the aircraft though not necessarily their operating procedures. Other limitations may be imposed if the aircraft is operated under Part 91 or Part 135. Some of these additional limitations will be addressed.

What goes into the AFM is also determined by Part 25. As the certification document for the aircraft, the AFM contains the charts that are the basis for that certification; that and usually nothing more. The AFM is required to contain charts that reflect all the limitations that affect that aircraft. These will *always* include Takeoff, Obstacle Clearance (net takeoff profile), Enroute Climb and Landing. Since the certification process always addresses the worst case situation, the majority of these charts reflect engine out conditions. There is seldom information for the pilot to determine all-engine performance.

It should go without saying that the charts found in the AFM represent limitations just as if they were found in the Limitations section. The aircraft cannot be operated at weights that exceed those determined by examination of the charts in the Performance section of the AFM!

Some aircraft AFMs reference specific Performance charts in the Limitations section as limits over and above those found in the Maximum Certificated weights. Others reference the Performance charts generically. Even if they are not referenced, the fact that the charts are contained in the AFM makes them limitations by default!

Pilots should be intimate with their AFM! While this should obvious, I have found the opposite to be true with many pilots. They will read the systems manuals and be a whiz with their FMS but wouldn't have a clue where to look for a Climb chart; or why and how it should be used. It is the rare pilot who can answer correctly basic questions on any of the limitations mentioned in the paragraph above.

Any performance that represents non-certification data is usually found in an Operating Manual or Performance Manual. This data will include flight planning information as well as some takeoff information that is not subject to certification. Examples of this can include minimum turnaround time (brake cooling), wet runway, acceleration and the like. Other performance information may be found in Flight Manual supplements. Non-standard performance such as anti-skid inoperative, APR off, engine computers in manual mode, engine out ferry etc, may be found in supplements. The list can be extensive so it is up to pilots to become familiar with all the information that they have available to them.

Later on in the paper I will discuss the use of charts and what factors are included by regulation.

TAKEOFF PERFORMANCE

The takeoff performance of a business aircraft is most easily assessed by determining it's maximum takeoff weight. This weight may be limited by any one of several factors. These factors are influenced by the conditions that the crew encounters at the time of departure.

The limitations always include structural, climb and field length and, depending on the aircraft, may also include brake energy and tire speed which actually affect the field length limit. At various times the takeoff weight may also be limited by the maximum landing weight at the destination, climb requirements for obstacle clearance or departure climb gradients, climb requirements for an emergency return situation, etc. Runway conditions must also be assessed, as many aircraft have information that allows wet or contaminated runway takeoffs. The pilots must be familiar enough with the airport of departure and the AFM to know when to apply these various requirements.

The ambient weather conditions that the pilot encounters must be considered to accurately determine the maximum weight as well as the takeoff “numbers”. Tabulated data furnished by the manufacturer or training vendor take into consideration a limited number of parameters. When conditions are outside these parameters, the AFM must be referenced. FlightSafety provided tabulated data is For Training Purposes Only and should never be used for actual flight operations.

Let’s take a look at the charts.

Maximum takeoff weight is based on the most restrictive of the following (as applicable):

1. Structural Limit (Maximum Certificated Takeoff Weight) - found in the Limitations Section of the AFM.
2. Climb Limit
3. Field Length Limit
   a. Brake Energy Limit (if applicable)
   b. Tire Speed Limit (if applicable)
4. Obstacle Clearance Limit (if applicable)

and possibly:

5. Maximum landing weight at first destination
6. Emergency return

MAXIMUM CERTIFICATED TAKEOFF WEIGHT - self explanatory

CLIMB LIMIT– Maximum Takeoff Weight limited by climb capability. This limit is the ability of the aircraft to climb from liftoff to 1500 feet above the airport elevation and to meet Takeoff Flight Path limiting climb gradients under existing conditions of temperature and pressure altitude. It is often referred to as the WAT limit; the Weight for Altitude and Temperature. It is important to remember that pressure altitude is used and not airport elevation. Non standard altimeter settings can have a significant effect on climb capability. Of course the combination of temperature and pressure altitude references airport density altitude. As density altitude affects the ability of the engine to produce thrust and of the wing to produce lift, the importance of using the correct number cannot be over emphasized.

This limit has nothing to do with obstacle clearance and must be met for all takeoffs.

The Takeoff Flight Path (Figure 1) is a product of the certification process contained in Part 25. It usually consists of 4 segments and is based on one engine out performance, the most critical engine being assumed to have failed in the vicinity of V_1. All gradients in the Takeoff Flight Path are gross gradients. The segments are:

1st Segment – begins at lift off and ends when the landing gear is fully retracted. The climb requirement in 1st segment is a positive gradient, out of ground effect, for 2 engine aircraft and 0.3% for 3 engine aircraft. The rotation speed, V_R, must be selected (by the manufacturer) so that V_2 is achieved by the time the aircraft reaches 35 feet in the air (this defines the end of the Takeoff Distance, which will be covered later).

2nd Segment – begins at the end of the 1st segment and is continued to *not less than* 400 feet above the airport elevation. The climb requirement in 2nd segment is a 2.4% gradient for 2 engine aircraft and 2.7% for 3 engine aircraft. 2nd segment is usually, but not always the most limiting of the segments within the Takeoff Flight Path.

The significance of the 400 foot altitude can be elusive. Part 25 requires that the manufacturer not show a change in configuration, except for gear retraction, until the aircraft reaches 400 feet. Therefore 400 feet is the minimum altitude for retraction of high lift devices, flaps and slats.

There is no other requirement! Most manufacturers end 2nd segment at altitudes greater than 400 feet, often a variable altitude dependent on the actual available performance of the aircraft.

3rd Segment (or Acceleration Segment) – begins at the end of 2nd segment and ends when the aircraft reaches the speed for final segment. While 3rd segment is usually flown in level flight, the *available* gradient must be at least equal to that required in final segment. During 3rd segment the high lift devices are retracted.

Final Segment – begins when the aircraft reaches the final segment speed and ends when the aircraft reaches 1500 feet above the airport elevation. The climb requirement in final segment is 1.2% gradient for 2 engine aircraft and 1.5% for 3 engine aircraft. At the beginning of final segment, the power is reduced to maximum continuous. Each segment must be flown at a constant power setting and the end of the acceleration segment is often coincident with end of the 5 minute limitation on Takeoff thrust.

If the aircraft has reached 1500 feet or greater in 2nd segment, the Takeoff Flight Path is not ended until it has reached the speed for final segment.

The distance from the 35 foot point to 1500 feet is called the Takeoff Flight Path; the distance from brake release to 1500 feet is called the Takeoff Path and includes the Takeoff Distance. As was mentioned above, this assumes the loss of an engine in the vicinity of V_1.

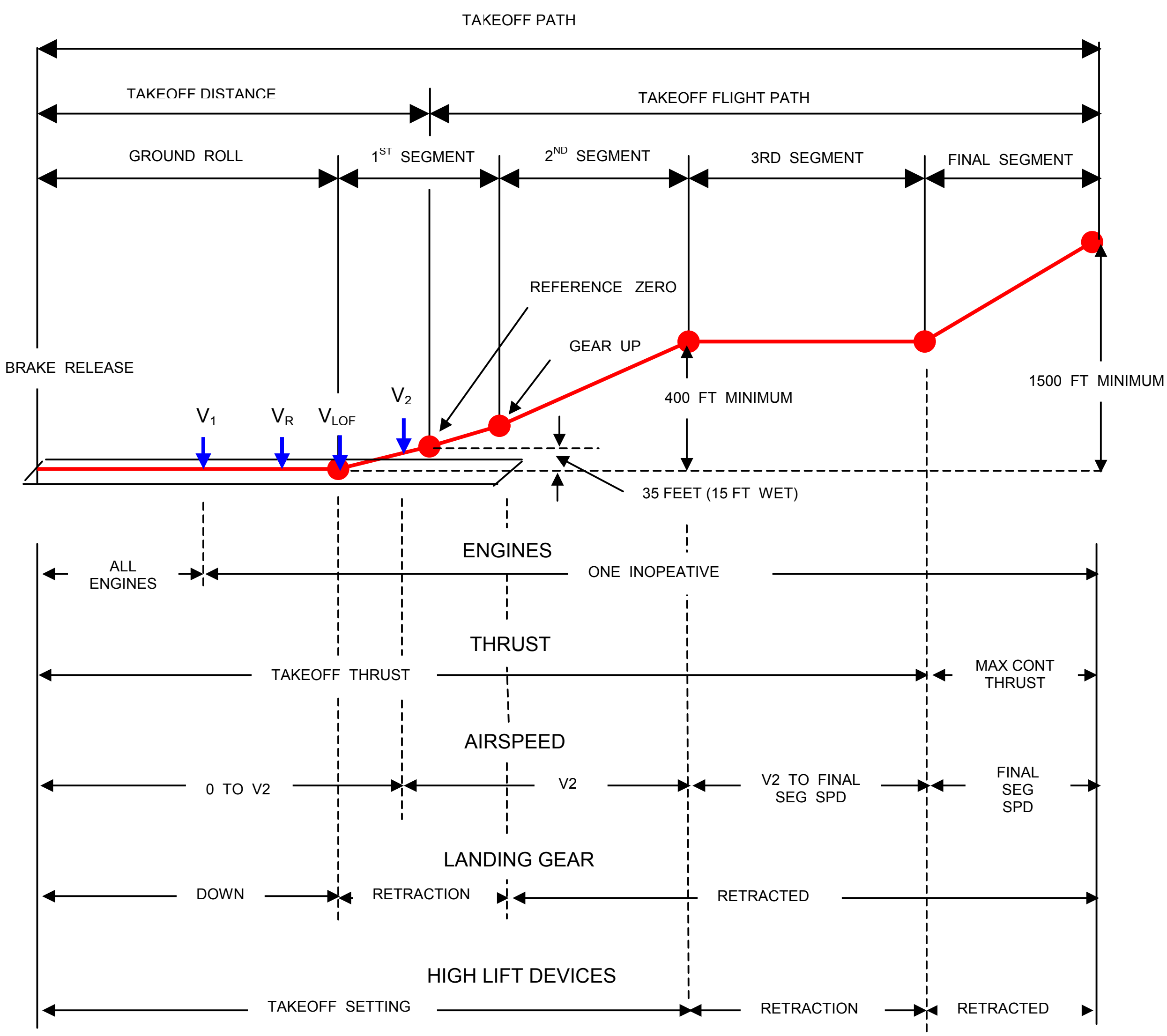


Figure 1 Takeoff Path and Takeoff Flight Path

FIELD LENGTH LIMIT - Maximum takeoff weight for runway available. The field length limit comprises several different events. As in the case of the Climb Limit, ambient conditions must be taken into account. In addition to temperature and pressure altitude, wind and runway slope must also be considered.

Accelerate Stop distance (ASD) (Figure 2) – is the distance required to accelerate on all engines to V1, and to initiate a rejected takeoff (RTO) or accelerate to V1, lose an engine and stop. Newer aircraft (those certificated under Part 25 Amendment 42 and subsequent) must show the RTO with all engines in addition to engine out. Older aircraft just assumed an engine failure. The RTO is accomplished using maximum braking and airbrakes or spoilers. The use of thrust reversers is not allowed for the determination of the accelerate stop distance except for wet runways.

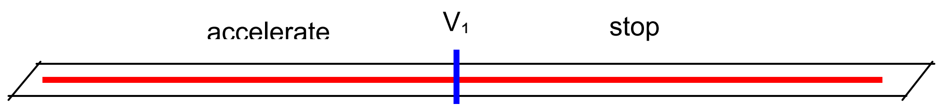


Figure 2 – Accelerate-Stop Distance

Takeoff Distance (TOD) (Figure 3) – is the distance required to accelerate on all engines to the vicinity of V1, lose the critical engine, continue to VR, rotate and reach 35 feet above the runway (15 feet for takeoff on a wet runway). The 35 foot point (15 foot for wet runways) is often referred to as the "screen height". This means that the aircraft could clear a screen of that height at the end of the takeoff distance. As was mentioned before, the rotation speed must be selected so that V2 is reached before the 35 foot point.

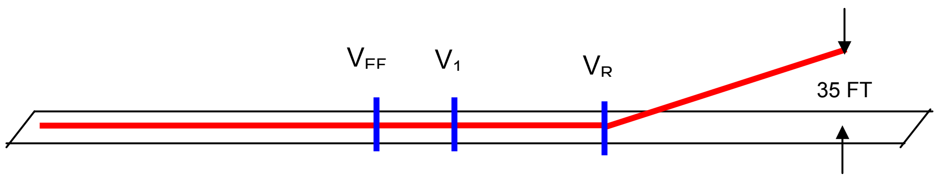


Figure 3 – Takeoff Distance

Factored All Engine Takeoff Distance (Figure 4) – is the distance required to accelerate on all engines to VR, rotate and reach 35 feet above the runway plus 15%. This distance is almost never a factor in determining the field length limit except in very light takeoff weight situations. Under these conditions the engine out performance is excellent and the 15% addition for all engines makes the difference. In any case this limit is never identified by the manufacturer so it is moot.

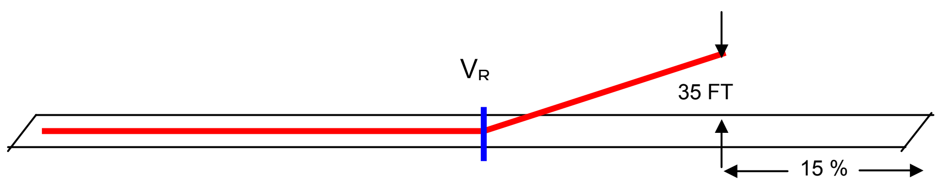


Figure 4 – Factored All Engine Takeoff Distance

In actual practice the concept of **Balanced Field Length (BFL)** (Figure 5) is used for most aircraft. To achieve Balanced Field Length, a value of V1 is chosen (by the manufacturer) such that the Takeoff Distance is equal to the Accelerate Stop Distance. The utility of the Balance Field concept is that it allows for the maximum takeoff weight for a given runway length.

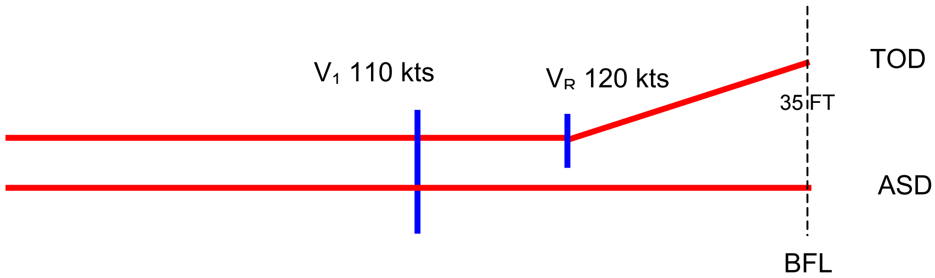


Figure 5 – Balanced Field Length

Changing the value of V_1 in either direction will increase either the TOD or the ASD and will thus require more runway. Let's see why this is true.

In figure 5, for the balanced length, let's say that V_1 is 110 knots and V_2 is 120 knots. What happens to the TOD and ASD if V_1 is reduced to 100 knots (Figure 6)? Most people correctly see that ASD becomes shorter but it is less obvious what happens to TOD. What do you think;

A. the TOD become longer
B. the TOD become shorter
C. the TOD remains the same????

Figure 6 – Reduce V_1

A large percentage of pilots will say that it remains the same!! What they forget is that we assume the critical engine fails at V_1 (or so). If the engine does not fail it is true that the TOD is unaffected by any change in V_1. But since we assume that it does fail, the answer is A, the TOD becomes longer. In the original example the airplane must accelerate 10 knots with one engine inoperative. In the second example, while the V_1 is reduced, the V_R remains the same so that now the airplane must accelerate 20 knots with one engine inoperative. The TOD will therefore obviously be increased!

If V_1 is increased (Figure 7), just the opposite will occur, the ASD will increase and the TOD will be reduced. You can see how choosing a particular value of V_1 will make the two distances the same and produce Balanced Field Length!

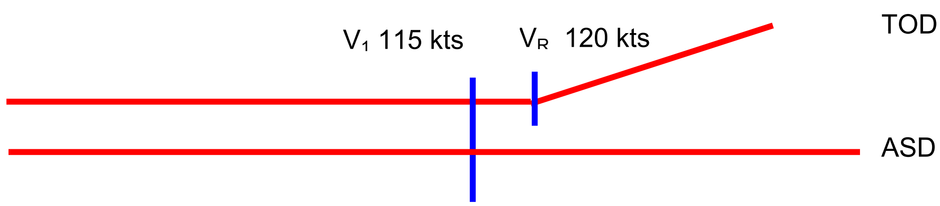


Figure 7 – Increase V_1

Part 25 allows the use of "rolling takeoffs". To be used, the method must be specified in the AFM or the pilot must assume that a "static takeoff" is required. This means that takeoff thrust must be attained before the brakes are released. Read your flight manual to determine what the case is for your airplane.

While balanced field will yield the highest takeoff weight for runway available, it may not be the best way to operate the aircraft. On short runways where the balanced field length is close to the runway available, there is little benefit in any other method. Many aircraft offer only balanced field length charts in the AFM but some offer the alternative of unbalanced field data. Unbalanced field charts are primarily for use with clearways and stopways but can be used to make better use of "excess" runway available.

Clearways and stopways are designed to allow the completion of takeoff or rejected takeoff past the end of the usable runway.

A **Clearway** is an area beyond the takeoff end of the runway that is clear of all obstacles above a 1.25% plane. It must be at least 250 feet wide on either side of the runway centerline and can be no longer than ½ the length of the runway. Furthermore it must be approved and must be under the control of the airport authority. The runway plus the clearway is called Takeoff Distance Available.

A **Stopway** is a surface at least as wide as the runway, centered on the runway, that is capable of supporting the aircraft. It must be designated by the airport and is used to decelerate the aircraft during an aborted takeoff. Runway plus stopway is called Accelerate Stop Distance Available. Curiously, a stopway is not considered as usable runway during a landing rollout, even if it is at the far end of the runway!

When using a clearway the operating regulations allow a portion of the takeoff distance to be accomplished in the clearway past the end of the runway. The charts must be designed such that no more than ½ the airborne distance between lift off and 35 feet is over the clearway. The other ½ must be over the runway (Figure 8). The available runway is called Takeoff Run Available. The Takeoff Roll (distance from brake release to liftoff) plus ½ the airborne distance to 35 feet is called Takeoff Run. The Takeoff Run obviously cannot exceed the Takeoff Run Available (the length of the runway). This effectively limits the amount of clearway that can be used and assures that the rotation and liftoff occur over the runway.

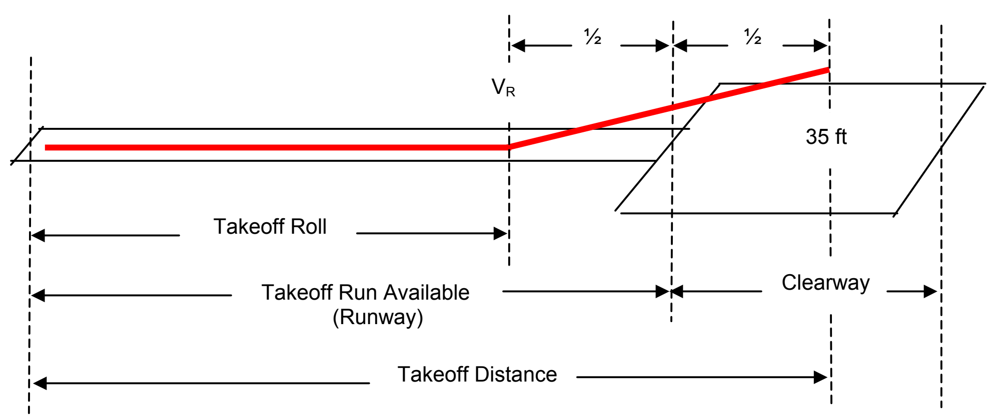


Figure 8 – Use of Clearway

The unbalanced field concept is obviously designed to allow takeoff weights higher than the available runway will support. It is useful to airline operations where extremely high takeoff weights cannot always be accommodated, even on long runways. It is much less useful to corporate operators for two reasons:

1. Most corporate aircraft, even the newer, extremely long range aircraft, just do not require long runways.
2. Only major airports have clearways. These airports have runways long enough that the clearway is redundant for most corporate aircraft. Jeppeson charts do not depict clearways anyway although they do show stopways. Determining if a clearway exists requires a call to the airport manager's office.

In spite of all the above, the use of unbalanced field charts can yield certain operating advantages. When the runway available is much greater than the balanced field and V_1 is significantly less than V_2, an engine failure or other malfunction after V_1 can force the pilot to continue the takeoff even when there is enough runway to stop the aircraft. In a case like this V_1 can be increased toward and possibly up to equal V_R. This will increase the accelerate-stop distance but if the ASD is still less than the runway length, all of the available runway can be used to stop the aircraft (Figure 9). The Takeoff Brief is also simplified: "Up to V_R we will abort for anything."

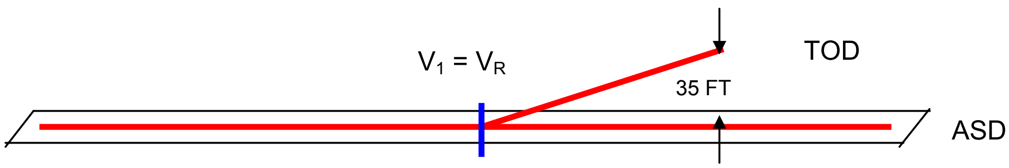


Figure 9 – Increase V_1 to equal V_R

Similar benefit can be gained from reducing V_1. Have you ever taken off on a short runway and thought as you passed V_1; "I wouldn't want to try to abort with this little runway left." (haven't we all had that thought)? If there is any extra runway, V_1 is reduced until the takeoff distance equals the runway length (Figure 10). This reduces the accelerate-stop distance and maximizes the distance available to stop the aircraft in the event of a malfunction before V_1..

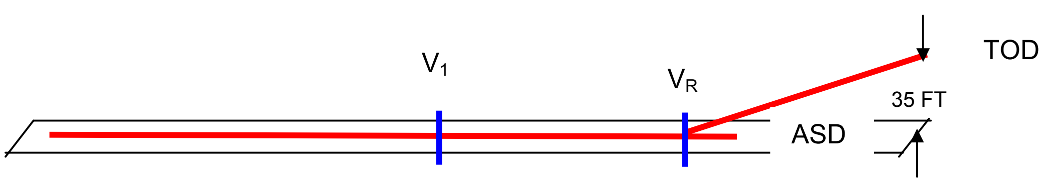


Figure 10 – Reduce V_1 to Maximize Stopping Margin

Changing V_1 must be done using whatever constraints exist in the AFM to assure that all applicable limitations are observed. Rejected takeoffs will be covered in more detail later.

Even aircraft that have field length charts that are called Balanced Field often have situations where the charts do not actually reflect the balanced field condition. No matter what, the charts will always show the minimum runway required for the existing conditions. Let's take a look at some conditions that will unbalance the field.

As mentioned above, an optimum value of V_1 is chosen so that the TOD equals the ASD. There are cases where the calculated V_1 cannot be used. In an optimum situation the acceleration of the aircraft will look something like this (Figure 11):

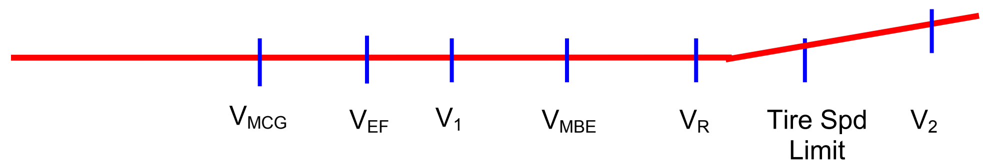


Figure 11 – Limits on V_1

V_{MCG} - is minimum control speed on the ground
V_{EF} - is the engine failure speed
V_{MBE} - is the maximum break energy speed

These will be futher defined later.

Absolute limits on V_1 are that it cannot be less than V_{MCG} or greater than the Tire Speed Limit, V_{MBE} or V_R. If V_1 falls outside these parameters it must be made equal to the limit value. For instance, if the calculated V_1 exceeded V_{MBE}, then V_1 must be reduced to equal V_{MBE}. In this case the TOD would be increased and the ASD decreased from the optimum balanced field length as we saw in Figure 6. The same would be true if V_1 must be increased to be greater than V_{MCG}. The ASD is increased and the TOD is decreased as in Figure 7. In both cases the charts would reflect the runway required but it would not be balanced field.

Wet Runways

Some aircraft AFMs provide charts for use on wet runways. Under the current Part 25, wet runway takeoff data must be shown. Before looking at these charts we should define what constitutes a wet runway. According to the FAA a wet runway is one that is well soaked but without significant areas of standing water. Aren't you glad you asked? Another way of looking at it is that the surface will be reflective if it is wet. You can see that a sprinkle will not cause reflectivity; it will require a pretty good amount of water on the runway.

There are some operational changes when making and using wet runway balanced field charts. The use of thrust reversers is allowed by the regulations and the screen height (the end of the takeoff distance) is reduced from 35 feet to 15 feet. This reduction will sometimes produce a wet runway balanced field length that is less than the dry runway balanced field length. Because of this the minimum runway is the longer of the dry or wet BFL or the more restrictive of the two if the field length is limiting. Pilots should refer to their AFM to determine the exact rules that apply and whether or not the use of thrust reversers is assumed for the wet runway rejected takeoff.

How does the wet runway affect the TOD and ASD? The TOD is virtually unaffected as long as there is no standing water, which is part of the criteria for the wet runway. The ASD will be most effected; the FAA says that "At high speeds, the wet runway braking coefficient is typically one-half the dry runway braking coefficient."

To allow the airplane to stop better, the wet runway V_1 is usually reduced significantly from the dry runway V_1. As we saw earlier, this will increase the TOD if there are no other changes. When the screen height is reduced to 15 feet and if thrust reversers are used, the overall wet runway balanced field length comes more into line with dry runway values and may actually be less. The reason for the reduction to 15 feet is a long story. The short version is that the FAA adopted a British rule as their standard. The British CAA has required wet runway certification for a long time and the FAA apparently decided not to re-invent the wheel.

Finally, how much water can there be before the runway goes from wet to contaminated? The criteria for contaminated runways begins at $^1/_8$ of an inch. If the runway has a water depth of more than $^1/_8$ of an inch or more than $^1/_8$ of an inch of equivalent water depth, the runway is contaminated, it is not wet. Equivalent water depth is how much water there would be if the contaminant were melted. In this case the character of the acceleration and deceleration are changed and a whole new set of charts (if provided) applies.

> Here's an interesting quote from FAR 135.379 (e): "Wet runway distances associated with grooved or porous friction course runways, if provided in the Airplane Flight Manual, may be used only for runways that are grooved or treated with a porous friction course (PFC) overlay, and that the operator determines are designed, constructed and maintained in a manner acceptable to the Administrator." Now how do you apply that?!

Finally, because of the reduced screen height, wet runway charts cannot be used with a clearway. This is no big deal for the corporate operator as we saw above.

Definitions:

V_{MCG} - is minimum control speed on the ground. Below this speed the takeoff cannot be safely continued. During certification the test pilot must keep the aircraft within 30 feet of runway centerline (25 feet for pre Amendment 42 aircraft) using aerodynamic controls only. This means rudder only and no nose wheel steering. An exception to this is that pre Amendment 42 aircraft may use rudder pedal nose wheel steering for use on wet runways.

Of course the line pilot is free to use nose wheel steering to aid in maintaining runway alignment during an actual RTO. The above information can also be used to determine the minimum runway width that should be used for takeoff. Take the distance of the main gear from the fuselage centerline, add 25 or 30 feet, multiply by 2 and that is the minimum runway width that should be used. This last is my interpretation.

V_{EF} - is the speed where the critical engine is assumed to fail. It is chosen by the manufacturer and cannot be less than V_{MCG}.

V_1 – is, well, this gets a little complicated. Over the years the definition of V_1 has changed from "engine failure speed" to "engine failure recognition speed" to "decision speed" to what it is now. Reference to these old definitions, especially to "decision speed", is still common today, in fact many AFMs still define V_1 as decision speed. This is incorrect. What V_1 is now is:

> "The maximum speed in the takeoff at which the pilot must take the first action to stop the airplane within the accelerate-stop distance (Figure 12); and,
>
> the minimum speed in the takeoff, following a failure of the critical engine at V_{EF}, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface (35 feet or 15 feet) within the takeoff distance."

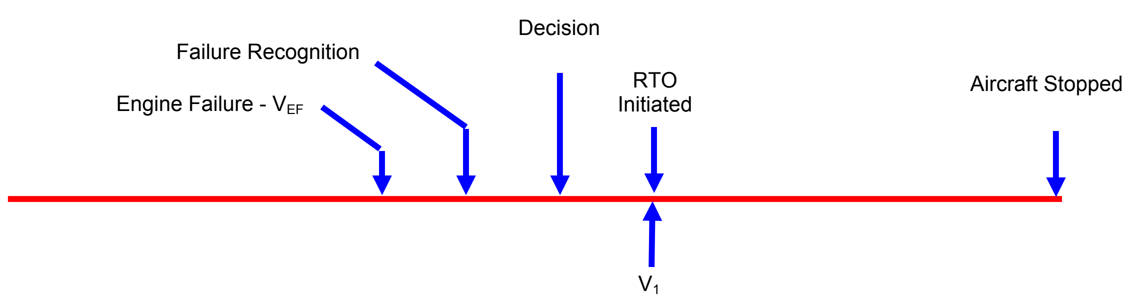


Figure 12 – Defining V_1

V_1 cannot be less than V_{EF} plus the speed gained during the time between the failure of the critical engine and the instant at which the (test) pilot applies the first deceleration action (Figure 13).

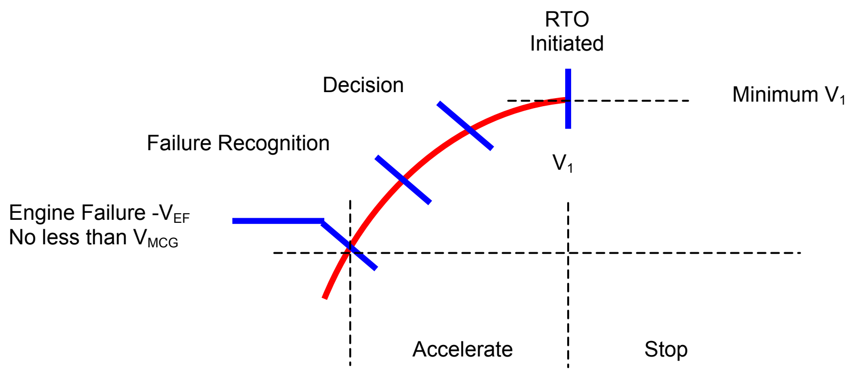


Figure 13 – Minimum V_1

In a rejected takeoff scenario, V_1 is the maximum speed for pilot action. Any first action, usually power reduction and brake application, past V_1 will insure a rejected takeoff that will exceed the computed accelerate-stop distance.

V_{MBE} - is the maximum break energy speed or the maximum V_1 speed from which maximum demonstrated brake energy is not exceeded. Current regulations (since 1998) require accelerate-stop distance to be calculated with brakes worn to within 10% of replacement.

V_R - is the speed at which rotation is initiated. Among other things, V_R cannot be less than V_1, although they can be equal; it cannot be less than 105% of V_{MCA}, and it cannot be less than 110% of the minimum unstick speed (the minimum speed at which the aircraft *can* become airborne). V_R also must be high enough so that V_2 is reached before the end of the Takeoff Distance (35 feet). V_R is sometimes artificially increased in order to allow the minimum V_2 for climb gradient to be reached within the takeoff distance.

Part 25 specifies that an early rotation of up to V_R minus 5 knots cannot increase the takeoff distance. It also says the " … reasonably expected variations in service …. (such as over-rotation…) may not result in unsafe flight characteristics or marked increases in the … takeoff distances.."

The rate of rotation is not specified but is usually in the neighborhood of 3° per second. For an initial rotation attitude of 15° a time span from initial pull to takeoff attitude would be 5 seconds. It is not necessary to jerk the airplane off the ground.

Tire Speed Limit – is self explanatory.

V_2 - is Takeoff Safety Speed. It must be at least 110% of V_{MCA} and 120% of V_S. The aircraft must attain V_2 by 35 feet with an engine failure at V_{EF}. V_2 is the minimum speed the aircraft must have in order to meet the 2nd segment climb gradient.

Most Flight Manuals will have a statement to the effect that should the engine fail at a speed greater than V_2, the higher speed should be maintained. This is sometimes limited to a speed increase of 10 knots or so. The reason for maintaining the higher speed is found in basic aerodynamics (Figure 14). As V_2 is on the back-side of the power curve, any increase in speed moves the aircraft toward L/D max.

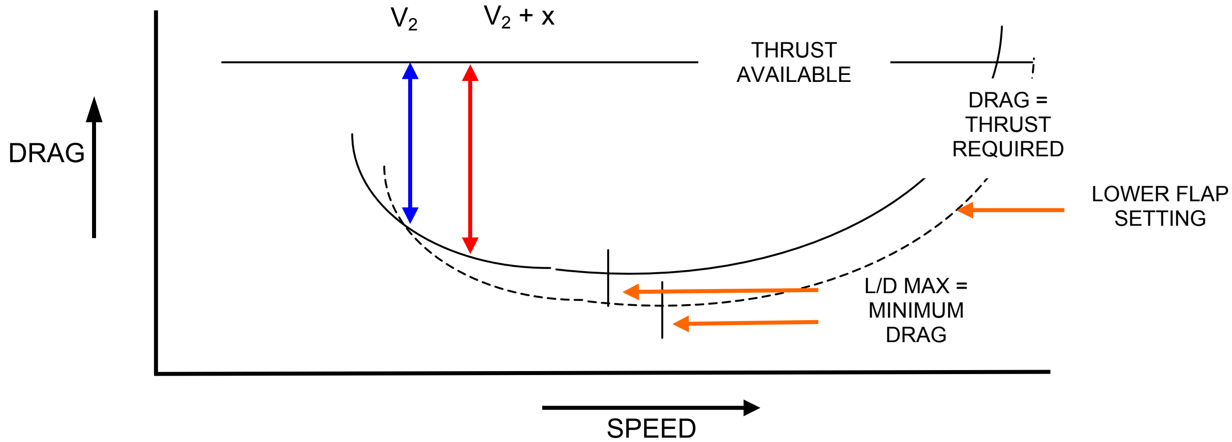


Figure 14 – V_2 Versus Speed Increase

The climb gradient of an aircraft is dependent on excess thrust available. The Lift/Drag curve defines thrust required and it (thrust required) decreases, as a result of decreased induced drag, as the airspeed increases toward L/D max. For all practical purposes, thrust available is constant for a jet powered aircraft as speed increases. Therefore if the aircraft is flown at a higher airspeed, the excess thrust available increases up until it reaches L/D max and the climb gradient will therefore also increase. At L/D max there is maximum excess thrust available, or maximum climb gradient. I am unaware of any manufacturer that publishes the L/D max speed except for a clean wing. This is the speed for enroute climb and, usually, for final segment.

This particular principal, maintaining the higher speed, is a relatively new one that came to light in the aftermath of the American Airlines DC-10 accident at O'Hare about twenty years ago.

The aircraft got airborne with all engines at a speed in excess of V_2 when the left engine came off the wing (due to improper maintenance). Now with everything else being equal the aircraft should have continued fly. This is almost the exact scenario we train for in our initial and recurrent simulator sessions. The crew, doing what they were trained to do at that time, pulled up the nose to slow to V_2. Again the aircraft should have continued to fly. But, unfortunately, everything was not equal. When the engine departed the aircraft it took the hydraulic lines for the left wing with it and the hydraulic fluid drained out. When the fluid drained out the slats on the left wing retracted. The V_2 speed was below the stall speed for the wing with the slats retracted so the left wing stalled, precipitating the crash.

In reviewing the accident, training specialists realized that the crew had done precisely as they were trained to do, but it turned out to be the wrong thing to do. Since that time, emergency procedures have been amended to include the caveat to maintain the higher speed attained in the event of liftoff at a speed great than V_2.

This same principle explains why airplanes have multiple flap settings for takeoff and why there is always a tradeoff. When a lower flap setting is used for takeoff, the airplane must still produce the same amount of lift as for the basic flap setting. The only way to do this is to accelerate to a higher speed. While the higher speed will produce more excess thrust (decreased induced drag) and a higher climb gradient, it will also require more runway due to the higher necessary speed. Of course the entire Lift/Drag curve is moved down, because of reduced drag, and to the right when the flap setting is changed, but that does not change the principle.

The proper rotation pitch attitude is also important in order to achieve both V_2 and the initial climb gradient. An under-rotation will achieve an initial speed higher than V_2 but an initial gradient less than that which is available. Similarly an over-rotation yields a speed less than V_2 and still a gradient that is less than optimum. Either will compromise any obstacle clearance solution. Knowing the V_2 and climb gradient is useless without the rotation attitude that is specified for both. This should be determined for every takeoff.

OBSTACLE CLEARANCE LIMIT – We now enter the area of WAG versus SWAG. Corporate aircraft manufacturers do not always do a great job of providing useful information in their obstacle clearance charts. Part 25 requires that the manufacturer include charts in the AFM that allow the pilot to construct the entire Net Takeoff Flight Path. However, as we recall, the Takeoff Flight Path ends at 1500 feet above the airport elevation. There are many airports where a climb is required that exceeds 1500 feet. Aspen, Eagle, South Lake Tahoe and Reno are just a few of them. If your Flight Manual charts end at 1500 feet, what do you do to prove that you can make the climb? ---------- Y'all be careful out there!

(A WAG is a Wild Assed Guess and a SWAG is Scientific Wild A__ --- you get the idea)

This portion of the discussion will hit three topics:
① gross versus net gradients
② the defined obstacle problem
③ TERPS requirements and the required climb gradient departure problem

① First a short discussion of gradients:

The **Gross Gradient** referenced above is the actual demonstrated performance as achieved by the manufacturer (read test pilot) during certification. The 2.4% or 2.7% gradient of 2nd segment simply means that the aircraft will climb 2.4 feet (or 2.7 feet) for every 100 feet of horizontal distance it flies. Gradient = Rise over Run or the change in height divided by the change in horizontal distance traveled (multiplied by 100 to put the decimal in the right place).

Net Gradient is the Gross Gradient reduced by 0.8% for 2 engine aircraft and 0.9% for 3 engine aircraft. Net gradient is required for Part 135 operators for obstacle clearance purposes. Part 135.379 (d) requires that all obstacles in the Net Takeoff Flight Path be cleared by 35 feet vertically or by 200 feet horizontally within the airport boundary or by 300 feet horizontally beyond the airport boundary. It is also assumed that no turns are initiated before 50 feet and that the maximum angle of bank is 15°. The Net Takeoff Flight Path begins at reference zero (the 35 foot height or the end of the takeoff distance) and ends at a minimum of 1500 feet above the airport elevation.

Part 25 requires that the manufacturer include the entire Net Takeoff Flight Path in the AFM. The same is not true of the Gross Takeoff Flight Path. There is usually insufficient data for the pilot to determine the complete gross path. The purpose of using Net versus Gross is to provide a margin of error (read safety) during obstacle clearance situations. It is unlikely that the average line pilot can achieve test pilot climb performance in service, therefore the use of Net Gradient provides some assurance that obstacles will be cleared safely (Figure 15 and 16).

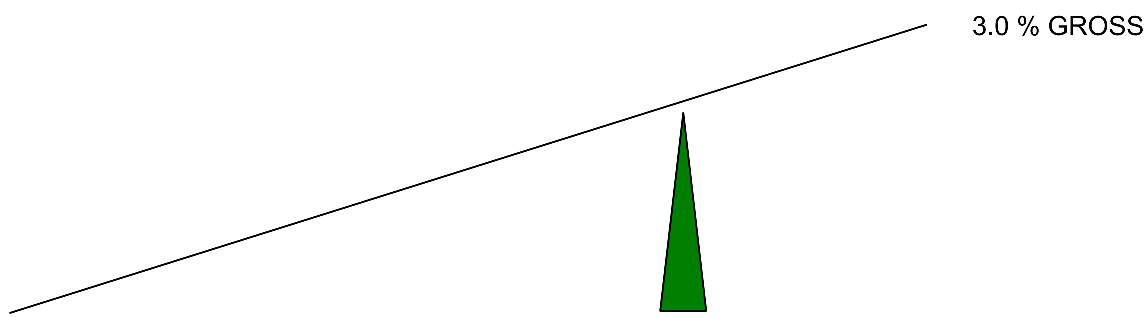


Figure 15 – Obstacle Clearance

Let's assume that the gradient required to clear the obstacle in Figure 15 is 3.0% gross. If we go to a hypothetical aircraft's charts it says we can make that gradient with a weight of 25,000 lbs.

Now say we want to use Net performance, the required gradient becomes 3.0% net (Figure 16). In order to make the 3.0% net gradient, the aircraft must be able to make a 3.8% (or 3.9%) gross gradient in order to meet the criteria of 135.379. It should be clear in this case that we will have to reduce the weight to something less than 25,000 lbs, say 23,000 lbs. It should then logically follow that using Net Performance instead of Gross performance will decrease the maximum takeoff weight allowable and increase the margin of clearance (safety) over the obstacle. In actual instruction, I have found that this is one of the most difficult concepts for pilots to understand. Good luck.

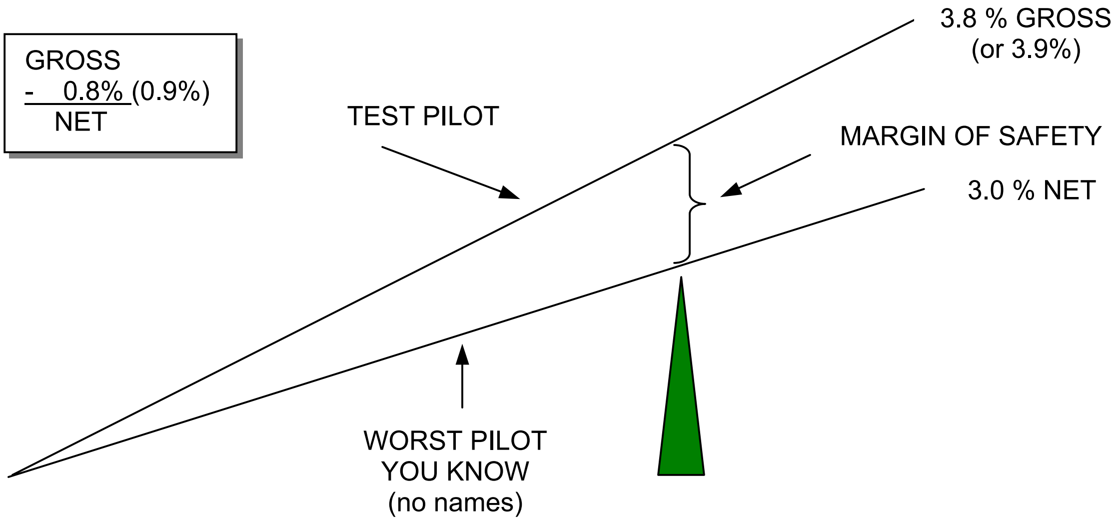


Figure 16 – Gross versus Net Gradient

As the Gross gradients are produced by the manufacturer's test pilot, it is highly unlikely that the line pilot can duplicate them. The rest of us are somewhere between the gross gradient and the net gradient; higher or lower in the margin of safety depending on whether or not we are having a good day. Commercial operators, Part 121 and Part 135, are required to use Net gradient in determining obstacle clearance. Part 91 says nothing specific regarding the procedures that must be used. However, the AFM may often specify that obstacle clearance is accomplished when the net performance clears all obstacles. In addition, the Aeronautical Information Manual, under Departure Procedures in paragraph 5-2-6, says in part:

e. Responsibilities.
   1. Each pilot, prior to departing an airport on an IFR flight should consider the type of terrain and other obstacles on or in the vicinity of the departure airport; and:
   2. Determine whether a DP is available; and:
   3. Determine if obstacle avoidance can be maintained visually or if the DP should be flown; and:
   4. *Consider the effect of degraded climb performance and the actions to take in the event of an engine loss during the departure*. (emphasis added)

From paragraph 5-2-6 you can see that it is expected that obstacle clearance should be determined using engine out performance. Whether or not Net performance is used by the Part 91 operator is a matter of company policy or pilot initiative.

A side bar: The following is my opinion:

Corporations have aircraft for many reasons: security, comfort, convenience, etc. Regarding convenience; executives just do not have the time to waste in airliners and in airports, especially if they are not able to fly directly to their ultimate destination. I feel that they should not sacrifice the safety of airline operation (read net obstacle clearance in this instance) for the convenience and comfort of their own aircraft.

② **The Defined Obstacle Problem**

The AFM obstacle clearance charts are usually designed to accommodate a defined obstacle. By this I mean an obstacle that is so many feet high and so many feet from Reference Zero. Reference Zero is the end of the takeoff distance or the 35 foot height. If the obstacle is measured from the end of the runway and you are not using all the runway, the added distance from Reference Zero to the end of the runway should be added to the distance to the obstacle to reduce the required climb gradient. The obstacle is plotted on the chart and the required climb gradient is read. The required gradient is then entered into the 2nd segment chart to determine the maximum weight that can be used under the existing conditions of pressure altitude and temperature.

By regulation (Part 25), the obstacle clearance charts in the AFM will be for Net Performance. Even if the 2nd segment gross charts are used to find the maximum weight, the result will still be net. This is because the gradients depicted in the obstacle clearance charts have been depressed to take into account the difference between net and gross.

Some Flight Manuals will also provide data that allows the pilot to determine the degradation of the climb gradient due to turns and even to figure in the effect of a head wind or tail wind.

Often just finding out where the obstacle is is the hard part. Jeppesen charts are of limited value as they do not pretend to show all terrrain or obstructions. VFR navigation charts are not of sufficiently large scale to show all man made obstructions but are useful for terrain. The government publishes Airport Obstruction Charts and Obstruction Data Sheets but only for a limited number of airports, about 700 to 800. These are available from NOAA's Distribution Branch in Maryland. Additionally, the airport manager's office should have the necessary data on obstacles.

Jeppesen Ops Data, along with some other commercial sources provide obstruction data. Jeppesen has two services, airport data reports which list all obstacles for each runway at an airport and airport analyses which are customized data prepared for a particular aircraft, engine, flap setting and runway. This is similar to what the airlines use.

For those of us without scheduled airline background, let's pause and count the number of times that we have accomplished an obstacle clearance problem in actual line flying - All right. What was the total? That's OK, I never did it either.

The scheduled airline pilot has a huge advantage over the Part 135 charter pilot or the Part 91 pilot; airport analysis! Airport analysis simply means that the airport and its environs have been surveyed and a maximum weight determined that takes into account all variables, including obstacles. A typical analysis will show for each runway at an airport all the data needed for takeoff; maximum weights, runway requirement, speeds and specific departure procedures (more about these later).

It takes a lot of resources (money) to produce airport analysis data and an airline only goes into a limited number of airports. The corporate or charter operator could go into literally thousands of airports! Even if they could get the data, the cost of the analysis would be prohibitive.

No matter what the source of the data, the aircraft charts must be flexible enough to allow useful computations. Charts where second segment always ends at 400 feet are useless in a mountain environment. Similarly, charts that do not show the end of the takeoff flight path at an altitude higher than 1500 feet are of little value if you have to show a climb to 2000 to 3000 feet above the airport. Critical obstacles can often be as far away as 30 miles from the airport if we take into account the loss of an engine, high density altitude and high terrain.

But even the airlines do not provide all the data that pilots need to ensure an airtight, 100% safe departure. I have documents from the Airline Pilot's Association querying the FAA and asking for clarification and guidance on certain aspects of departures involving obstacles and climbs.

③ TERPS and the Required Climb Gradient Problem

The required climb gradient problem is one where the Departure Procedure specifies a particular rate of climb in feet per minute.

First a short dissertation on Departure Procedures. A short while ago, all IFR departures and Standard Instrument Departures (SIDs) were renamed as Departure Procedures (DPs). There are Pilot Nav DPs, Radar Vector DPs, RNAV DPs, Obstacle DPs, and ATC DPs. Whether you knew it or not, the old IFR Departures were *always* for the purpose of obstacle clearance or avoidance and are now called Obstacle DPs. Additionally, all DPs provide obstacle clearance. The subject of instrument departures and DPs is covered in extensive detail in the AIM in paragraph 5-2-6.

At any airport with an Instrument Approach Procedure (IAP) the FAA is obligated to survey the departures for obstacles. The survey looks for any obstacles that penetrate a 40:1 plane. This works out to 152 feet per nautical mile or 2.5% climb gradient. If the plane is free of obstacles, another 48 feet per nautical mile is added to bring the gradient to 200 feet per nautical mile or a gradient of 3.3%. In a case such as this (Figure 17) there is no requirement to publish an Obstacle DP with a required climb gradient.

On the other hand if an obstacle does penetrate the plane, then a required gradient must be shown. An exception to this rule exists. If the obstacle can be avoided by a turn or by maintaining heading until a certain altitude, then that simple procedure will suffice for obstacle avoidance.

So what do you do as the pilot of an aircraft at an unfamiliar airport at night or under IMC and you want to depart safely? What should you assume if there is no Obstacle DP? Remember that the FAA looks for that 40:1 plane.

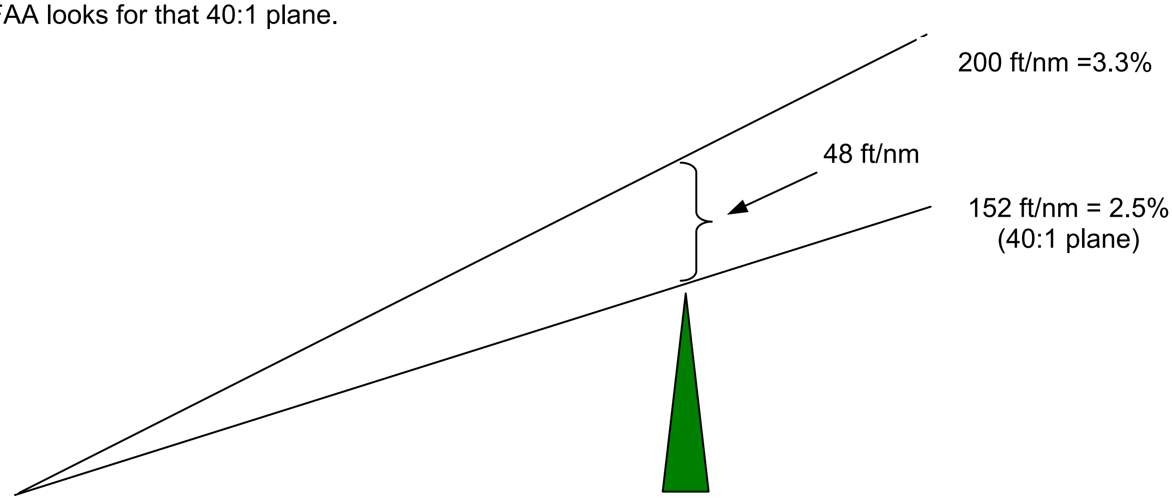


Figure 17 – TERPS Departure Criteria

It seems obvious that you must assume that there is an obstacle that is close to but does not penetrate the plane, that is, that there is an obstacle, say one nautical mile away, that is 152 feet high. This would lead you to a climb gradient of 3.3% if you want to maintain the 48 feet per nautical mile clearance that the FAA seeks. This is obviously much greater than the climb gradient required for second segment that we looked at originally.

So now that we have decided to make a 3.3% gradient the question is; is the gradient all engine, engine out, gross or net?

The answer may be unexpected. When the FAA makes a procedure, they make a normal procedure! If an engine fails, that is an emergency and the published departures are for normal operations. It is now up to the operator to decide what criteria to apply. If it's an airline, then management must decide how to apply the rules. They may require engine out (and therefore Net) climb or they may provide an alternate Emergency Procedure. If you fly for a Part 91 operator, you as the pilot probably get to make the decision yourself. Remember the AIM paragraph 5-2-6, (e) I quoted earlier. It seems obvious that for the 91 operator, the gradient should be figured with an engine inoperative. Gross or net depends on how much you feel like Chuck Yeager that day!

On page 14, I mentioned special departure procedures in the discussion of airport analysis. What this means is that it is not always necessary to go over the obstacle or to make the specified climb gradient. This is always true and is alluded to in the Takeoff & Obstacle Departure Procedures section of the Jeppesens. A typical one might look like Figure 18.

<table>
<tr><td rowspan="4"></td><td colspan="7">TAKE OFF & OBSTACLE DEPARTURE PROCEDURE</td></tr>
<tr><td colspan="3">Rwy 19</td><td colspan="4">Rwy 1</td></tr>
<tr><td rowspan="2">CL & RCLM</td><td rowspan="2">Adequate Vis Ref</td><td rowspan="2">STD</td><td colspan="3">With Min climb of 370’ / NM to 700’</td><td rowspan="2">Other</td></tr>
<tr><td>CL & RCLM</td><td>Adequate Vis Ref</td><td>STD</td></tr>
<tr><td>1 & 2 Eng</td><td rowspan="2">TDZ RVR 6
ROLLOUT RVR 6</td><td rowspan="2">RVR 16 or ¼</td><td>RVR 50 or 1</td><td rowspan="2">TDZ RVR 6
ROLLOUT RVR 6</td><td rowspan="2">RVR 16 or ¼</td><td>RVR 50 or 1</td><td rowspan="2">600 - 2</td></tr>
<tr><td>3 & 4 Eng</td><td>RVR 24 or ½</td><td>RVR 24 or ½</td></tr>
</table>

Figure 18 – Takeoff & Obstacle Departure Procedures
Washington, National

Let’s look at a commercial operator departing this airport, which happens to be Washington National, using runway 1. Using Operations Specifications the pilot may elect to take off with as low as 600 RVR if there are Centerline Lights and Runway Centerline Markings and if the aircraft can make the 370 ft/nm. But what if the weather is better than 600 and 2? In this case obstacle clearance is not necessary because the pilot can see the obstacle and avoid it. The numbers basically mean that the obstacle is within 2 miles of the end of the runway and is about 600 feet high.

Airlines will very often have special departure procedures that are designed to get out of the airport safely but do not require reducing the weight to clear the obstacles. These are called “procedures in lieu of making the climb gradient,” and are perfectly acceptable. They allow the pilots to depart under IMC and carry a heavier payload than would be allowed by the climb gradient. An often used example of this can be seen at Aspen, Colorado.

The typical responsible pilot (Part 91) would not consider going out of Aspen in IMC. Very few corporate aircraft can make the required gradient with an engine out and carry enough fuel to make even Denver. So they wait till it’s VFR and say, “If we lose an engine we’ll fly down the valley and land at Rifle or Grand Junction.” This is essentially a “procedures in lieu of making the climb gradient,” although the latter can be used in IMC.

What does the Part 91 or Part 135 charter operator do if there is no ”out” and it’s IMC? The only sound answer is to plan on making the required climb gradient with an engine inoperative.

Along with the above table there would usually be a textual rendition of the IFR OBSTACLE DEPARTURE PROCEDURE. As a result of a U.S. Air Force C-130 crew’s failure to follow the IFR Departure Procedure (now called an Obstacle Departure Procedure) at Jackson Hole, Wyoming and subsequent crash into the mountains to the east of the airport, and some successful lobbying by user groups, the FAA has begun to chart the more complicated Obstacle DPs. Take a look at the old textual Obstacle Departure Procedure and the new charts and see the difference!

(I am not placing blame here, I am just reciting the facts. The crew was probably not trained in the niceties of IFR Departures in a non-radar environment)

I know that this has gone somewhat far afield of the discussion of obstacle clearance and aircraft performance but if the pilots understand what they are looking at it makes the discussion a lot more meaningful and interesting. This is ALWAYS one of the most requested topics for discussion during recurrent performance classes. Anyway, let's get back to the discussion of obstacle clearance and the defined climb gradient.

So we have figured that we need 370 ft/nm to meet the minimum climb gradient of the Obstacle DP. Let's assume that we decide to depart in IMC and want to assume an engine out and net performance: what is our required climb gradient? Remember that "Gradient = Rise over Run or the change in height divided by the change in horizontal distance traveled". Well the rise is 370 feet and the run is a nautical mile or approximately 6000 feet. Six goes into thirty-seven, 6.1 times so that is the approximate gradient in percent.

> You can also use the Gradient to Rate Table in the Terminal tab of the Jeppesens to figure the required gradient (partially repeated in Figure 19). If you go down the 100 kt column to the rate of climb in Feet Per NM found in the left margin you can read the gradient if you put the decimal two from the right. As you can see in Figure 20 below, the Rate of Climb for a 370 Feet Per NM climb is 617, which then works out to a gradient of 6.2%. It's a mathematical trick and don't ask me how it works, I was a Literature major.

GRADIENT	GROUND SPEED IN KNOTS										
FEET PER NM	60	75	100	120	140	150	160	180	200	220	240	250
330 340 350			550 567 583									
360 370 380 390			600 617 633 650									

Figure 19 – Gradient to Rate Table

We would enter the 2nd segment climb gradient chart in the AFM to find what weight would yield a 6.2% gradient under the existing conditions of pressure altitude and temperature. Some AFMs have net gradient charts and some have only gross charts. If the only charts are gross we would have to add the 0.8% (or 0.9%) to the gradient to achieve the required net performance. Simple, right?

Well, it gets a little more complicated. The second segment climb gradient charts are only accurate for up to 400 feet above the airport. So what do we do if the DP requires a climb of several thousand feet to meet the lowest MEA or the low altitude structure? Let's take a look at the procedure for Eagle, Colorado (Figure 20, next page).

Eagle has an airport elevation of 6535 feet. From the Obstacle DP, you can see that we must climb about 4000 feet above the airport if we are departing from runway 25 and 5300 feet if departing from runway 7.

One thing that we can do is take the required gradient at the altitude to which the DP specifies the climb must be made, 10,500 feet for runway 25, or 4000 feet above the airport. This would take into account the degradation of performance with the increase of density altitude. This method could also be used for AFMs that have obstacle clearance charts that end at an altitude less than that of the defined obstacle height.

<table>
<tr><th></th><th colspan="4">TAKE OFF & OBSTACLE DEPARTURE PROCEDURE</th></tr>
<tr><th></th><th colspan="2">Rwy 7</th><th colspan="2">Rwy 25</th></tr>
<tr><th></th><th>With Min climb of 480’ / NM to 11,800’</th><th>Other</th><th>With Min climb of 750’ / NM to 10,500’</th><th>Other</th></tr>
<tr><td>1 & 2 Eng</td><td rowspan="2">700 - 2</td><td rowspan="2">5100 - 3</td><td rowspan="2">1300 - 2</td><td rowspan="2">5400 - 3</td></tr>
<tr><td>3 & 4 Eng</td></tr>
</table>

OBSTACLE DP: Rwy 7, 25: Use GYPSUM departure

Figure 20 – Takeoff & Obstacle Departure Procedures
Eagle, Colorado

The only draw back to this method is that it doesn’t take into account how long we can maintain the second segment gradient of climb. Aircraft are limited to 5 minutes at takeoff thrust and there is no way we can determine how long we must maintain our climb. Obstacle clearance charts, on the other hand, will not depict clearances that exceed the 5 minute takeoff thrust limit.

Why don’t we use the entire Takeoff Flight Path? This would involve using the acceleration segment and the final segment at a reduced power setting and climb gradient. It would be extremely complicated to figure the average gradient over the entire range of the required flight path.

Now you can see why this procedure can deteriorate to a WAG.

At the bottom of the Takeoff & Obstacle Departure Procedure table for Eagle you see a reference to the Gypsum Departure. This refers to a graphic depiction of what used to be a long and complicated textual description of the Departure Procedure. Take my word for it that the chart is much easier to fly than the textual description!

A few items of interest that pertain to departures. The departures assume that the aircraft will pass the end of the runway at 35 feet and climb to 400 feet before making any turns. The only exception to this is if the departure specifies a turn “as soon as practicable” or “an immediate turn”. In this case the turn would be made at 50 feet. In the case of this immediate turn, the takeoff minimums will be a least 400 feet and 1 sm. If a turn is to be made, it is assumed that it is not begun until the aircraft reaches a height of 50 feet and that the angle of bank is limited to 15°. After the aircraft reaches the altitude specified in the departure, the assumed gradient returns to 200 ft/nm.

The actual vertical distance between the net flight path and the gross flight path at any given point can be determined (if you need to know) by applying the following formula:

Distance from Reference Zero x 0.008 (0.009 for 3 engine aircraft)

For instance, if you want to know the difference at 1 nautical miles, it would be: 6,000 x 0.008 or 48 feet. I just learned this, so it proves you can always learn something new (learn it early in the day and you can go home).

What else does this show? For a two engine aircraft, the difference between net and gross is the same as that provided for in TERPS. Recall that the original gradient is 152 ft/nm and that 48 ft/nm is added to attain the 200 ft/nm or 3.3% gradient.

On the general subject of TERPS: the best source of information I know is the following web site: www.terps.com

This site is called “Wally’s Web Site” and is maintained by Wally Roberts, a retired TWA Captain and former chairman of the Air Line Pilot’s Association (ALPA) TERPS committee. He consults for ALPA and writes articles for various publications. All his articles as well as other related information are in the site and can be downloaded in PDF format. It’s a very valuable resource. I have most of the articles printed and available in my office.

A little additional information;

The AIM, under Pilot/Controller Responsibilities in paragraph 5-5-14, has similar wording to what we saw in Paragraph 5-2-6 on Instrument Departures but also says:

a. The pilot
    4. At airports where IAP’s have not been published, hence no published departure procedures, determines what action will be necessary and takes such action that will assure a safe departure.

As we saw above. The FAA only surveys for departures if there is an Instrument Approach Procedure (IAP). If there are no IAPs there will not be any published departure procedures. The Part 135 operator cannot use these airports without permission from the administrator. The Part 91 operator is able to depart under IMC at his own discretion. Notice that the spelling of “discretion” is very close to “cretin” in this instance.

Now let’s go back and look at a couple of miscellaneous limitations on maximum takeoff weight.

MAXIMUM LANDING WEIGHT LIMIT AT FIRST DESTINATION

If the destination is relative close and it is desired to carry extra fuel for subsequent legs or because the fuel is cheaper or whatever, the takeoff weight must obviously be limited so that the aircraft does not arrive at the destination over maximum landing weight. This could also be extended to include being able to make an excessive climb gradient on the departure from the first destination airport!

EMERGENCY RETURN LIMIT

Part 25 provides that the aircraft must be capable of meeting Approach and Landing Climb requirements within 15 minutes of takeoff. This is to allow for the event of an emergency return either for an engine loss or some other malfunction. As we will see in the section on landing limitations, the approach climb requirement assumes an engine out at a gross gradient of 2.1% for two engine aircraft and 2.4% for three engine aircraft and the landing climb requirement assumes all engines at a gross gradient of 3.2% for all aircraft.

A comparison of the Approach Climb gradients and the second segment requirements will reveal that they are 0.3% less in the landing regime than for takeoff. It becomes obvious that if you make the engine out approach at the same flap setting that you used for takeoff you will be able to make the Approach Climb gradient! What could be simpler?!. Well, not all aircraft have the same flap settings available for approach as they do for takeoff. For example, an aircraft may have provisions for a 0° flap approach but may only approach with, say, 10° flap. These aircraft must either restrict the *takeoff weight* or they must have a fuel jettisoning system that allows them to dump enough fuel in 15 minutes to meet the above requirements. There are aircraft where the charts for the Takeoff Climb Limitation are actually restricted by Approach Climb or Landing Climb in some cases, rather than by the Takeoff Flight Path.

The procedure of approaching with the takeoff flap setting also does not take into account situations that are Landing Climb limited. You must be familiar enough with your AFM to know what limitation to apply.

An interesting aside for the aircraft with a fuel dump system: “----means must be provided to prevent jettisoning the fuel in the tanks ---- below the level allowing climb from sea level to 10,000 feet and thereafter allowing 45 minutes cruise at a speed for maximum range.”

ENROUTE CLIMB LIMITATIONS

The requirements of enroute climb are specified in FAR Part 25 in paragraph 25.123 and they are:

- The one engine inoperative net flight path must represent the actual climb gradient available decreased by 1.1% for two engine aircraft and 1.4% for three engine aircraft.
- The two engine inoperative net flight path for three engine aircraft must represent the actual climb gradient available decreased by 0.3%.

There will be charts in the AFM that show the aircraft climb gradients and speeds required to meet the above requirements.

But; how does the pilot use this information? Again, Part 91 says nothing and, in this case, neither does the AIM. So that leaves us Part 135.

The requirements of Enroute Limitations for one engine inoperative and two engine inoperative (for three and four engine aircraft) are contained in FAR Part 135.381 and FAR 135.383 (c) respectively. I leave this for you to read. If, when you finish reading these Parts, you still think that it is possible for the on-demand charter operator to operate legally, I have some ocean front property to sell you in Irving!

I have not once in 20 years of teaching performance had anyone ask a question on enroute climb requirements. Of course that means that YOU will probably get a question during your first performance class!

LANDING PERFORMANCE

The limitations in the landing phase are very similar to those in the takeoff phase. There are structural, climb, field length and, on some occasions, tire speed or brake energy limitations. However they are applied differently in the landing phase. We will examine the limits as in takeoff by trying to determine the maximum landing weight.

Everything that I said regarding the takeoff charts applies equally to the landing charts. They are legally limiting, must allow for ambient conditions, etc.

MAXIMUM CERTIFICATED LANDING WEIGHT - self explanatory. As before, this is a structural limit. I used to have a picture that was a great illustration of a "structural" limit. During the landing distance certification the test pilot is trying to descend at the highest possible rate allowable (about 360 ft/sec) to decrease the distance between 50 feet and touchdown. In the certification of the MD-80 the test pilot allowed the rate of descent to reach about 1500 ft/min (OK for a Navy plane but not OK for transport category). The landing distance was really short but the main gear collapsed, the fuselage buckled between the mains and the nose gear and the tail cone fell off! I'm going to guess that the aircraft failed the hard landing inspection.

CLIMB LIMIT – Maximum Landing Weight limited by climb capability, sometimes called the Landing WAT (Weight for Altitude and Temperature, as you recall from the takeoff discussion). Unlike the takeoff situation, which has a defined path, the climb limits for landing are called Approach Climb and Landing Climb and they are not connected. The criteria are:

Approach Climb

- One engine inoperative.
- The remaining engine(s) at takeoff thrust.
- Flaps in the designated configuration.
- Landing gear retracted.
- A climb gradient of 2.1% for 2 engine aircraft and 2.4% for 3 engine aircraft.
- A maximum speed of 1.5 $V_{S.}$

Landing Climb

- All engines operating "at the thrust that is available 8 seconds after initiation of movement of the thrust controls from the minimum flight idle position to the takeoff position".
- Flaps in the landing configuration.
- Landing gear down.
- A climb gradient of 3.2%.
- A maximum speed of 1.3 V_S for all aircraft.

As in takeoff, these are all gross gradients.

So what does this mean in practical application? I equate them like this:

The approach climb situation is like making an engine out approach in IMC. At the MDA the runway is not in sight so the missed approach is begun. The Go-Around button is pushed, maximum power is applied, the flaps are retracted to the go-around setting and the aircraft is rotated to the go-around attitude. When a positive rate is recognized, the gear is retracted. At this point you are in the Approach Climb configuration and your gradient required is as indicated above.

The landing climb is more like a balked landing. You reach 50 feet above the runway at V_{REF}, reduce the power to idle in preparation to touch down. At this time the tower calls for a go-around for a vehicle on the runway. As above you hit the Go-Around button, apply maximum power and rotate to the V bars. You are in the Landing Climb configuration!

If we recall the discussion of the Emergency Return limits, it's obvious that the climb limits for landing ought not to be a problem under normal circumstances. If they can be made within 15 minutes of takeoff, then the likelihood of a problem at the end of a normal flight is slim. The most likely problem is a flight that goes from a low altitude airport to a high altitude destination. In a case like this there may be some limits.

It's often more useful to approach this from the point of view of the normal landing weight or even the maximum landing weight and see at what altitudes and temperatures any limitations actually occur.

FIELD LENGTH LIMIT – is the landing weight limited by the runway available. In practical application this is almost never going to be a limit. Airplanes can always get into shorter runways than they can get out of at the same weight and flap setting!

The field length is better addressed by looking at the operational requirements imposed by the regulations. Once again Part 91 says nothing, and neither does the AIM, so the private operator is free to land on a runway no longer than the AFM calls for in the Landing Distance chart (I'll go over the definitions shortly).

On the other hand the Part 135 operator has restrictions. Part 135.385 and 387 contain the runway requirements for destination and alternate airports respectively. 135.385 (b) requires a "--- landing within 60% of the effective length of each runway --- from a point 50 feet above the intersection of the obstruction clearance plane and the runway." This requirement is usually referred to as Landing Field Length or Factored Landing Distance. 135.387 has the same requirement for alternate airports.

135.385 (d) states that the distance in 135.385 (b) be increased by 15% if the runway will be wet or slippery at the ETA. This is called Landing Field Length Wet.

I'll define the Landing Distance (or Unfactored Landing Distance) and then compare the others.

The Landing Distance – is the horizontal distance from a point 50 feet above the landing surface to a complete stop. That is, it contains no margins. The following is assumed:

- The airplane arrives 50 feet above the runway from a 3° glideslope,
- at idle power,
- at V_{REF} (no less than 1.3 V_S), and
- continues to a touchdown at a rate of no more than 6 ft/sec (360 ft/min).

Landing distance charts do not require correction for temperature; but an increase in temperature will increase the True Airspeed at the same indicated airspeed and will require more distance. They also are not required to show the effects of slope, which are obvious.

The airplane must exhibit satisfactory flight characteristics at a speed down to V_{REF} – 5 knots and, among other things, the "--- landings may not require exceptional piloting skill or alertness". I think I rode with this guy recently!

The stopping distance from the touchdown point includes 1second time delays from the actual flight tests as follows:

- From touchdown to the pilot actuation of the first deceleration device (usually brakes)
- From the actuation of each succeeding deceleration device (airbrakes, etc.)
    – This last requirement does not have to added if the decelerating devices are automatically deployed.

The requirement for **Landing Field Length** means that the Landing Distance cannot exceed 60% of the runway available. This can be computed, if it isn't shown in the AFM, by multiplying the Landing Distance by 1.67 or dividing it by 60%; for example:

- Landing Distance = 3000 ft
- 3000 × 1.67 = 5010 (it's closer if you use 1.667, then 3000 × 1.667 = 5001)
- 3000 ÷ 60% = 5000 (3000 is 60% of 5000)

Let’s see how the distances compare (Figure 21):

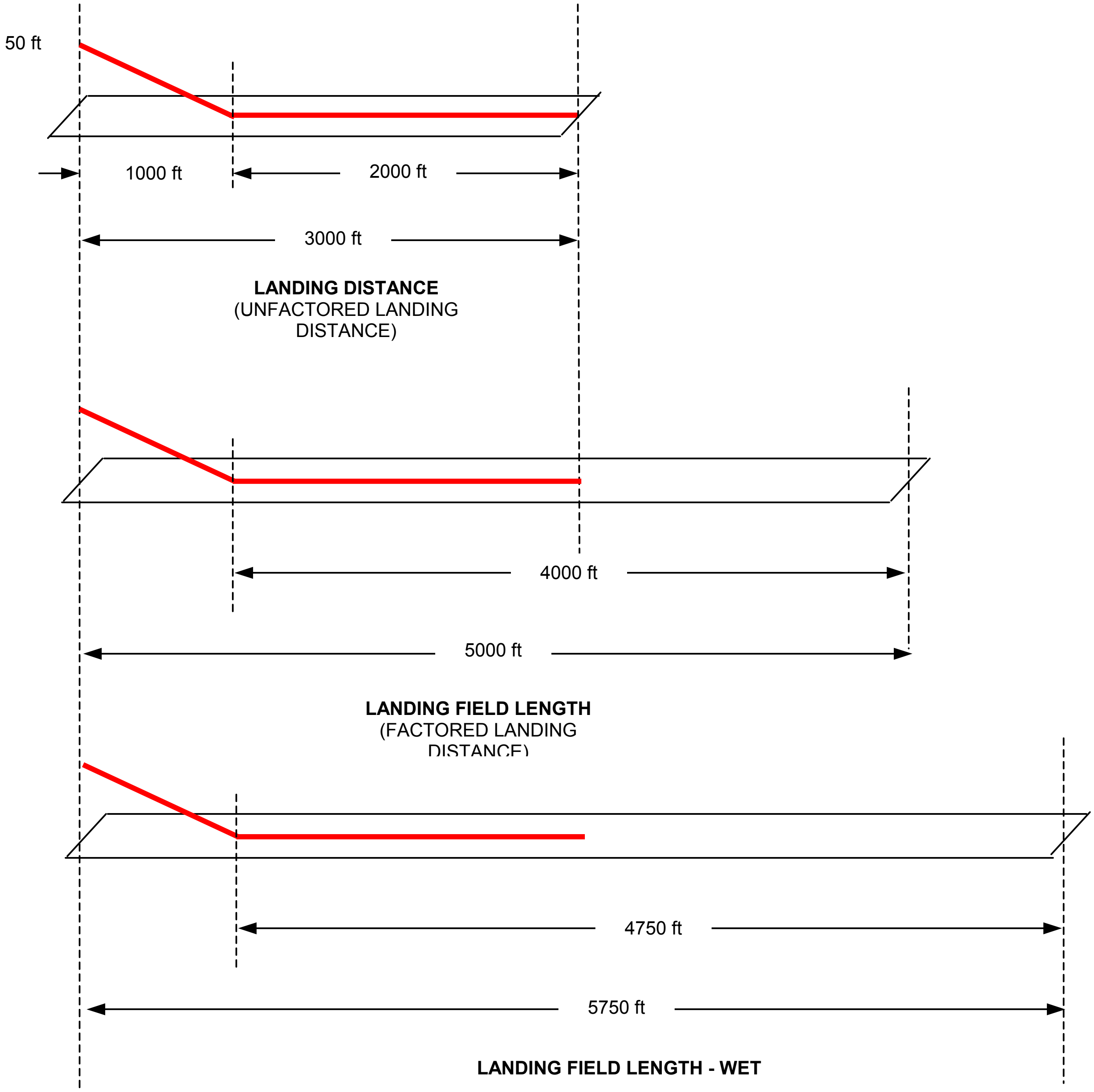


Figure 21 – Landing Requirements

In the diagram for Landing Distance we see that the airborne distance of about 1000 feet leaves a stopping distance of about 2000 feet. When we compare that to the Landing Field Length, we see a stopping distance *available* of about 4000 feet or approximately twice the actual stopping distance. In the **Landing Field Length – Wet**, the available stopping distance of 4750 is almost 2 ½ times that required on a dry runway. Recall from the discussion of takeoffs on wet runways that the braking coefficient for a wet runway is about ½ that on a dry runway.

The AIM, in paragraph 4-3-8 and 4-3-9, discusses braking action reports and runway friction reports. Braking action reports are “good’, “fair’, “poor” and “nil”. When runways are reported to have braking action of poor or nil, the ATIS will broadcast, “Braking action advisories are in effect”. The problem with braking action reports is that they are subjective based on pilot perception.

Runway friction reports, when you can get them, are designated by the Greek letter MU and are derived from actual friction measuring devices. They range from 0 to 100 with 0 being the lowest value. For frozen contaminents, a MU value of 40 or less indicates conditions where braking performance starts to deteriorate and directional control becomes less responsive.

The AIM states that no correlation has been established between MU readings and braking action reports.

What else can we use?

The Canadians use the “Canadian Runway Friction Index (CRFI)” which used to be called the “James Brake Index (JBI)”. The discussion of this can be found in the Air Traffic Control section of the Canadian Jeppesens. It also contains an excellent discussion of hydroplaning. As this is a fairly length piece, I won’t try to repeat it all.

The runway friction is measured (and reported in MU values). The values, from 0 to 1 in this case, are then compared to the AFM *Landing Distances* (no margins) and a *recommended* Landing Distance is shown. The distances were actually measured using a Falcon 20 and do not include factors for thrust reversers. Well this is all fairly useless as most of the operations we will be discussing do not occur in Canada!

However, there is a chart that can be used without the reported runway friction reports. I have reproduced it in Figure 22.

RUNWAY SURFACE CONDITON (RSC) AND CRFI EQUIVALENT

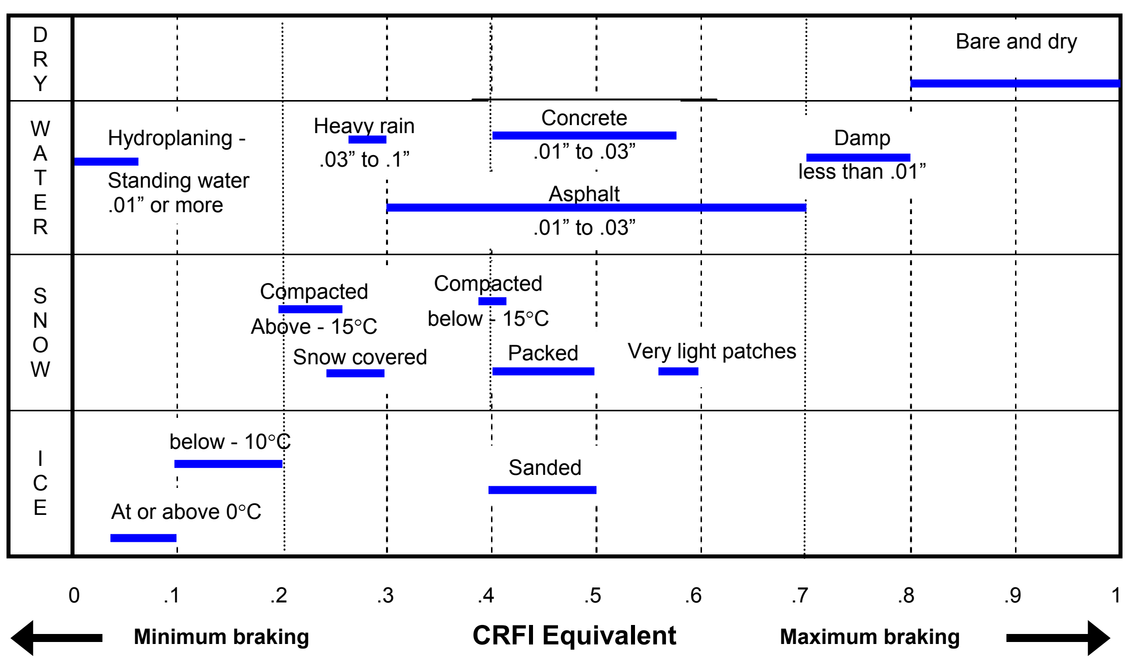


Figure 22 – Runway Surface Condition and CRFI Equivalent

With the CRFI Equivalents from this table and the Recommended Landing Distances table from the Canadian Jepps, partially reproduced in Figure 23, you can approximate the runway required based on a knowledge of what kind of contaminent is on the runway. Take for instance a concrete runway with between .01 and .03 inches of water. The CRFI is about .5. In the chart (next page) for a 3000 foot AFM Landing Distance, the recommended landing distance is 5630 feet.

Reported Canadian Runway Friction Index (CRFI)

Landing Distance Bare and Dry Unfactored	0.6	0.55	0.5	0.45	0.4	0.35	0.3	0.28	0.25	0.22	0.2	0.18
	Recommended Landing Distances (Dispatch Factors Removed) [All distances expressed in feet] 95% Confidence Level											
1800			3390									
2000			3810									
2200			4210									
2400			4590									
2600			4960									
2800			5300									
3000			5630									
3200			5940									

Figure 23 – Recommended Landing Distances from CFRI

The 95% confidence factor mentioned in the chart header merely means that for 19 landings out of 20, the stated distance will be conservative for properly executed landings. They assume a 50 foot threshold crossing height, minimal delay in deploying ground spoilers, applying brakes and sustaining maximum antiskid braking until the aircraft is stopped. The distances do not include factors for thrust reversers.

A little more information about runways. Those runways that are grooved or have a coarse aggregate surface are designed to ameliorate the effects of water. Aggregate, in this case, means the size of the grains in the concrete; the rougher the better. If the depth of the water does not cover the grooves or the rough concrete surface, the braking effectiveness can approach 95% of that of a dry runway. Only if the surface is completely covered does a degradation in braking occur.

When the runway surface is completely covered with water we need to address the problem of hydroplaning. This could be the subject of another paper entirely and there are plenty of other sources to read so I will summarize. The three well known types of hydroplaning are viscous, dynamic and reverted rubber. Viscous hydroplaning is just the normal loss of friction associated with any wet runway. It does not prevent wheel spin-up and anti-skid function. Reverted rubber is somewhat arcane and I won't address it. The type of hydroplaning we usually associate with the phenomena is dynamic.

In dynamic hydroplaning, the tire is lifted up off the runway and "surfs" on top of the water. The tire can eventually slow to a complete stop even though the aircraft is still moving. When will the aircraft hydroplane? There are two formulae:

- for a tire that is still spinning, such as on takeoff, hydroplaning will occur at $9\sqrt{TP}$, where TP is the tire pressure
- for a tire that is not spinning, such as on landing, the formula is $7.7\sqrt{TP}$.

Do the math for the airplane that you teach. You can see that on landing the aircraft will hydroplane at a speed much less than it will on takeoff. As a matter of fact the aircraft will continue to hydroplane below the initial onset speed once it gets "up on the step".

It should be obvious that hydroplaning will prevent loss of directional control as well as loss of braking capability. Braking should not be started until the aircraft slows to less than hydroplaning speed. An excellent, though old, video on hydroplaning is "Project Slush" which we have in the video library.

Something else to consider is weather cocking. Most aircraft will tend to turn into the prevailing wind; this is called positive weather cocking. Some few aircraft will actually turn out of the wind or will demonstrate negative weather cocking. Whether or not the aircraft turns into or out of the wind depends on whether there is more surface area in front of or behind the aircraft pivot point, which is the main landing gear (visualize the weathercock on top of your barn).

The amount of tendency of the plane to turn into the wind depends on the relative amount of surface area aft of the main gear, the length of the fuselage and the amount of rudder available. The length of the fuselage determines the moment or effectiveness of the rudder.

On a slippery runway the combination of weather cocking and thrust reversers can cause problems. If the aircraft begins to turn into the wind and the reversers are used, the actual vector of thrust, combined with the wind, will tend to pull the aircraft off the runway (Figure 24).

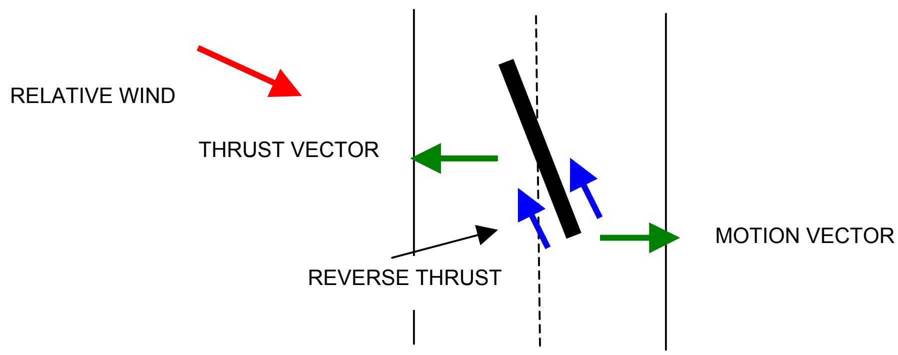


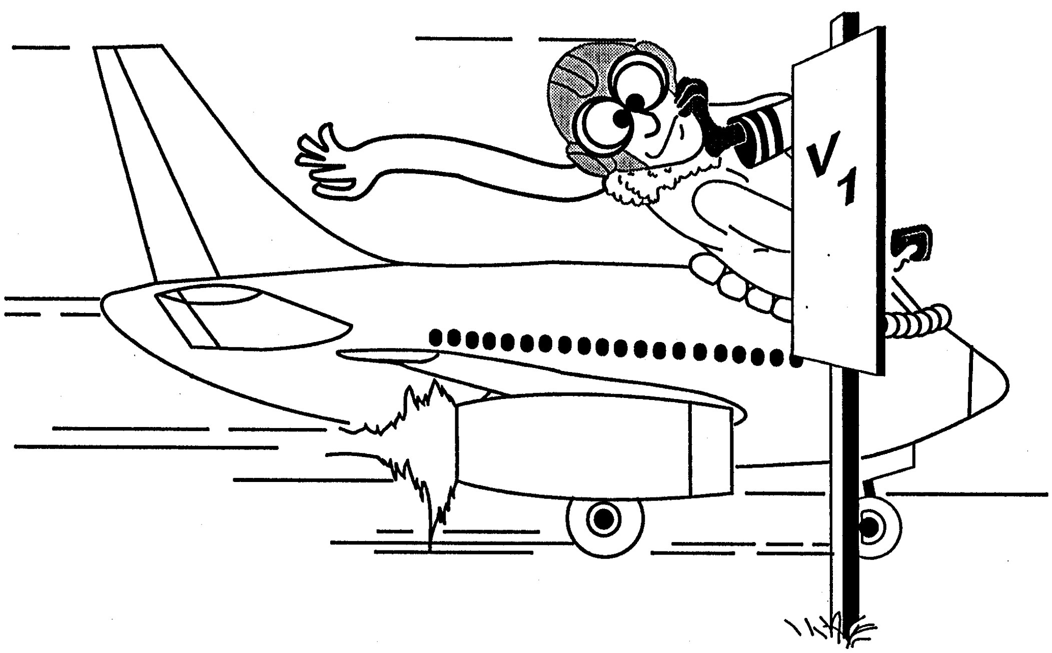
Figure 24 – Thrust Vectors

Let's go back to the Landing Field Length and Part 135.385. You have been dispatched to an airfield with a 6000 foot runway and a 4500 foot runway. Your projected Landing Distance of 3000 feet yields a required Landing Field Length of 5000 feet. When you arrive at your destination you find they are landing on the 4500 foot runway; can you land? -------------------------
----
------------------------------------ Well, what do you think?

Part 135.385 (b) says, " --- no person --- *may take off* that airplane --- unless its weight on arrival ----would allow a full stop landing --- within 60% of the --- runway ---." The rule is for dispatch purposes and is not intended to preclude the pilot from landing if the winds or whatever have caused the runway to be changed. The pilot is supposed to figure the "probable wind velocity and direction –" prior to departure, but is not prevented from making the landing.

Now some rules of thumb:

- a 1% change in airspeed = 2% change in stopping distance
- a 1% change in weight = 1% change in stopping distance
- a 1000 ft change in field elevation = 4% change in stopping distance
- a 15° F deviation from standard = 4% change in stopping distance
- crossing the threshold 50 ft too high increases the runway required by 24%
- a 1% reduction of glide path angle increases the runway required by 13%
- a wet runway increases the stopping distance by 25 to 50%
- an icy runway can increase the stopping distance by 100%
- a 10 knot tail wind = 16% increase in stopping distance
  a 20 knot head wind = 28% reduction in stopping distance
  a 30 knot head wind = 41% reduction in stopping distance
- inoperative spoilers require 25% more runway
- thrust reverser on a <u>slick</u> runway will decrease stopping distance by 10 to 30%


V_1

REJECTED TAKEOFF (RTO)

The Rejected Takeoff is relatively simple as far as certification is concerned, but extremely complicated in line flying. Under current certification the (test) pilot performs the RTO with all engines, anti-skid, airbrakes and spoilers but without thrust reversers, except for the wet runway. The certification process also requires the RTO to be demonstrated after an engine failure, which under the old rules, was all that was required.

Without going into extensive detail, critical RTOs (those performed close to V_1 and under runway limiting or near limiting conditions) are seldom encountered in line operation. Here are some statistics compiled by Boeing for airline RTOs that resulted in accidents or incidents and are compiled in the Rejected Takeoff Training Aid; there are no similar data for corporate operations.

- RTO overrun accidents principally result from the 2% of RTOs initiated at high speed; above 120 kts
- 58% of the accident RTOs were initiated at speeds greater than V_1!
- approximately 1/3 occurred where the runway was wet or contaminated
- the unsuccessful RTOs could have been prevented by:

continuing the takeoff	55%
correct stopping technique	16%
better preflight planning	9%
unavoidable accidents	20%

- virtually no continue decisions were made where the aircraft was incapable of continuing the takeoff
- the unsuccessful RTOs were a result of:

engine	24.3%
wheel and tire	22.9%
configuration	12.2%
indicator, light	9.5%
crew coordination	8.1%
bird strike	6.8%
ATC	2.7%
Other	13.5

What can we learn from these numbers? As the speed approaches V_1, the successful completion of the RTO becomes increasingly more difficult. Who knew? This is actually a quote from the Rejected Takeoff Training Aid compiled by Boeing.

1. What it means is that the crew must always be prepared to make the Go/No Go decision. Let me repeat that; the crew must always be prepared to make the Go/No Go decision.
2. Furthermore they must be prepared to act as a well-coordinated team.
3. Lastly they must differentiate between those situations where the takeoff must be rejected and those where the takeoff should be continued.

This last statement is probably the crux of the problem. An adequate brief, discussed below, with a knowledge of what truly constitutes a really flight-critical event can make all the difference in the runway limiting or near limiting RTO.

We can see that engine failures cause only a small proportion of the accidents. This is of interest to us as this is what we usually use to in our briefings and what we usually use in the simulator to cause the reject. Try using a brake or tire failure to demonstrate the RTO on your next simulator period. You may be surprised by what you see.

We can also see that, as the pilot approaches V_1, he or she must be aware of the relative speed and be able to differentiate from critical and non-critical situations. A complete and appropriate takeoff briefing is essential. By appropriate I mean that a briefing on a runway critical takeoff should be different from one where there is excess runway. Where there is excess runway, sloppiness in briefing, decisions and execution of the RTO can be overcome. This is not the case in field length limiting situations.

Let's revisit the definition of V_1. For the RTO, the portion of V_1 we consider is that it is:

> "The maximum speed in the takeoff at which the pilot must take the first action to stop the airplane within the accelerate-stop distance." (Figure 25)

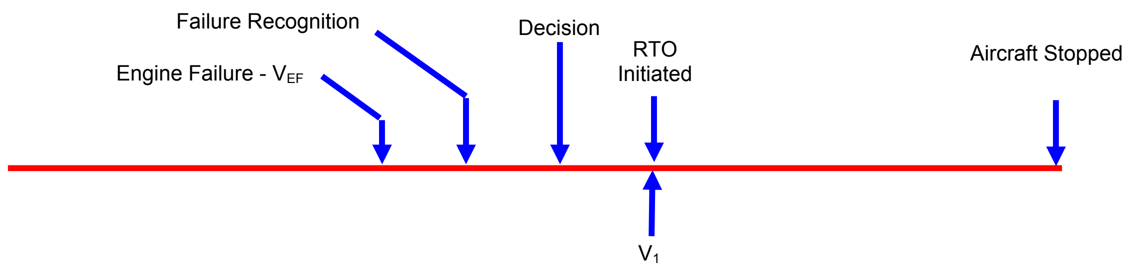


Figure 25 – V_1 Defined

The key factor here is that the RTO **must be initiated** by V_1 in order to achieve AFM accelerate-stop distance.

The criteria for establishing V_1 has changed over the years but the above statement has been true throughout the changes. Whether or not there is a 1second delay or a 2 second delay built in does not alter the fact that V_1 is an **action speed** and not a decision speed.

Some changes do affect the RTO. The recent change to require the abort with worn tires and brakes is significant. The abort of a heavy DC-10 right here in Dallas was unsuccessful even though the crew did everything right. The brakes were so worn that they were incapable of stopping the heavy aircraft and it departed the runway at over 90 knots. This accident is what led to the change in the certification requirements. Remember that this rule only went into effect in 1998, so it may or may not apply to the airplane you teach.

The rules now also require the consideration of wet runways. Wet runways were discussed under takeoff performance so I won't repeat it. But having data from the manufacturer is always superior to the WAG or even the SWAG. Again, your airplane may or may not have this data. The key to having wet runway data is to use it……… Do you really think that just because there is wet runway data that pilots will use it? Remember we're talking about pilots here. However, if you teach an aircraft that does have wet runway data, pilots should be cautioned about its use. If the data is available, it must be used! Why so? To not use all data available would probably be viewed as "careless and reckless". Even more importantly, from some perspectives, the insurance company probably wouldn't pay off!

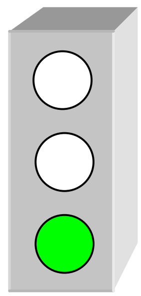
The purpose of the Rejected Takeoff Training Aid I mentioned above is to educate the pilot to all the factors regarding the recognition and execution of the high-speed abort. The relevant portion of the document is about 40 pages long and is well worth the read for anyone interested in discussing RTOs, and all instructors should have the basic facts at their disposal. Again, I have a copy in my office.

Part of the problem of rejected takeoffs is in how we call it. As the airspeed needle winds around the dial (or up the scale), the PNF will call V_1 as it (the needle) reaches the V_1 speed. This is somewhat akin to "close enough for government work"; (measure with a micrometer, mark with a chalk and cut with a chain saw). The manufacturer and the test pilot go to great expense and time to produce an accurate V_1 that takes into account all the variables and, if applicable, balances the field. But if the PNF calls "V_1" at that speed, it is already too late to make the abort. Remember that the abort **must be started at V_1** in order to duplicate flight manual stopping distance.

A couple of ways around this problem are employed by various operators and airlines. One is to insure that the V_1 call is completed by the time that the airspeed reaches V_1. Another is an "approaching V_1" call with the 'V_1' being completed as the speed reaches V_1. Some operators will even make the V_1 call at 5 knots below V_1. This allows the PF time to recognize a critical failure and still have a fighting chance to begin the reject by the actual V_1 speed.

Whatever method is employed it is imperative that proper briefings take place and that airspeed calls are made. It's amazing how many NTSB accident reports note that adequate briefings did not take place and that airspeed calls were omitted! We do tend to become casual about takeoffs, briefs are made but no one actually pays attention to them. I flew with a company where we briefed, "…up to V_1 we will abort for anything." We got airborne once without any airspeed indication on the copilot's instruments ; that would certainly be "anything". It wasn't my fault. Honest……it really wasn't me.

The crew must anticipate the vicinity of V_1 in order to successfully execute the critical RTO. We all employ an analogy of a V_1 situation in our cars:



> You come around the corner and there you see a traffic light; it's green but you don't know how long it's been green. As you approach it, you fix a spot in the road ahead. If the light hasn't turned yellow by the time you reach that spot, you continue; if it turns before the spot, you stop. This is exactly how V_1 should be treated, with a certain anticipation that heightens as you near that spot.

Once again, the crux of the matter is determining what conditions call for a reject and which do not. At speeds approaching 120 knots and within a couple of knots of V_1, the recognition and decision making process must be rapid and, above all, accurate. The statistics above reflect the problem with depressing regularity. Aborts are made too late in the takeoff, for the wrong reasons and with the wrong technique! You can see that a thorough analysis of RTOs is essential for the proper decisions.

For example, the blown tire at high speed is seldom reason enough to abort and will often prevent a successful stop. And yet brake and tire problems account for virtually the same number of unsuccessful RTOs as do engine problems. The blown tire will not affect the ability of the aircraft to fly but it will prevent it from stopping. It would be better to continue and use all of the available runway to stop the aircraft on the subsequent landing. Remember that 55% of RTO accidents could have been prevented by continuing the takeoff.

Another problem with runway limiting conditions are the difficulties involved in duplicating AFM stopping distances. Most of these have to do with pilots using SWAGs in takeoff computations as well as improper techniques.

- Using field elevation instead of pressure altitude
- Using an inaccurate or non current temperature
- Not correctly determining aircraft weight
- Not properly accounting for runway slope or wind
- Using a rolling takeoff where inappropriate
- Not allowing for lineup distance in determining runway available
- Not allowing for wet runways (1/3 of accidents were on wet or contaminated runways)

Other problems are associated with pilot technique. Accelerate-stop distances are determined using a specific sequence of actions that are often at odds with normal pilot technique. Brakes are fully depressed simultaneously with the reduction in power and are followed by airbrake extension. Pilots tend to use the stopping technique they use on a normal landing, that is, thrust reversers, airbrakes and only then braking. If there is any delay in applying maximum braking and extending the airbrakes, the results can be disastrous. The airbrakes not only produce drag but make the braking more effective by increasing the weight on wheels! This is most effective at high speeds.

How about reaction times? The FAA allows for a 1 second delay to be added between the engine failure speed, V_{EF}, and the test pilot's initiation of the RTO. 1 second delays are also added for additional steps in the RTO process, such as the deployment of airbrakes or ground spoilers. This just means that a distance corresponding to 1 second is added for each additional step. Current certification also requires a distance corresponding to 2 seconds at V_1 be added to the demonstrated accelerate-stop distance. As I mentioned earlier, worn brakes and tires are also now required.

The reaction times above are <u>not</u> margins above the V_1 that the pilot can use as a buffer to get into the RTO. They are there only to put a certain margin of safety into the RTO. Remember that the test pilot has virtually zero reaction time as he knows the failure is coming and he knows when it is coming.

While the accelerate-stop has a distance added at V_1, the aircraft is actually still accelerating. A transport category aircraft can be traveling at 220 to 270 feet per second and accelerating at 3 to 6 knots per second while in the speed vicinity of V_1. This is partly why some RTOs initiated below V_1 are unsuccessful. If an improper technique is used the acceleration eats up more runway than is allotted for in the certification process. A slow transition to the RTO configuration (3 seconds to reduce thrust to idle, 2 seconds to begin braking and 1 second to deploy airbrakes) can add over 1000 feet to the stopping distance and cause you to go off the runway at 80 knots!

So why isn't there a built in margin, such as net performance required for obstacle clearance? The airline industry and the aircraft manufacturers have successfully lobbied the FAA to not require more stringent certification measures. Remember that each foot of additional accelerate-stop distance in the charts reduces the maximum takeoff weight in a runway limiting situation. We are talking revenue here!

Some pilots will argue that the use of thrust reversers makes up the difference as they are not counted in the dry runway abort. Boeing estimates that the use of one reverser in an engine out RTO in a B-737 will reduce the accelerate-stop distance by only 70 to 100 feet. The DC-10's 2 engine stopping distance is reduced by about 300 feet, not a lot if you are still accelerating and chewing up 200 to 300 feet per second!

Again, the successful outcome of a rejected takeoff can depend on a careful pre-takeoff briefing, not just the standard. "Up to 80 knots we'll abort for anything, between 80 knots and V_1, we'll abort for engine fire, engine failure or loss of directional control. After V_1 we'll treat anything as an airborne problem. Any question? OK, let's go." This is acceptable if the runway required is not close to being runway limiting.

What should the brief sound like if the takeoff is field length limited? Well, what will actually prevent the aircraft from flying? When I brief this in a performance class, I am careful not to be specific here. It is not our job to tell pilots what they should or should not reject the takeoff for. I merely provide information and attempt to get the pilots to think about what they are doing and not get stuck in the rut of complacency!

The phrase that aviation is "hours and hours of boredom interspersed by moments of stark terror" should give one pause to reflect: most accidents occur on takeoff or approach and landing. If we can get pilots to give these moments their undivided attention then they can enjoy their hours of boredom and we will have done our job.

I could go on at great length on this subject but let me close with a discussion of the theory of relativity; that is, the relative merits of continuing the takeoff versus rejecting the takeoff.

The following diagram (Figure 26) compares those merits.

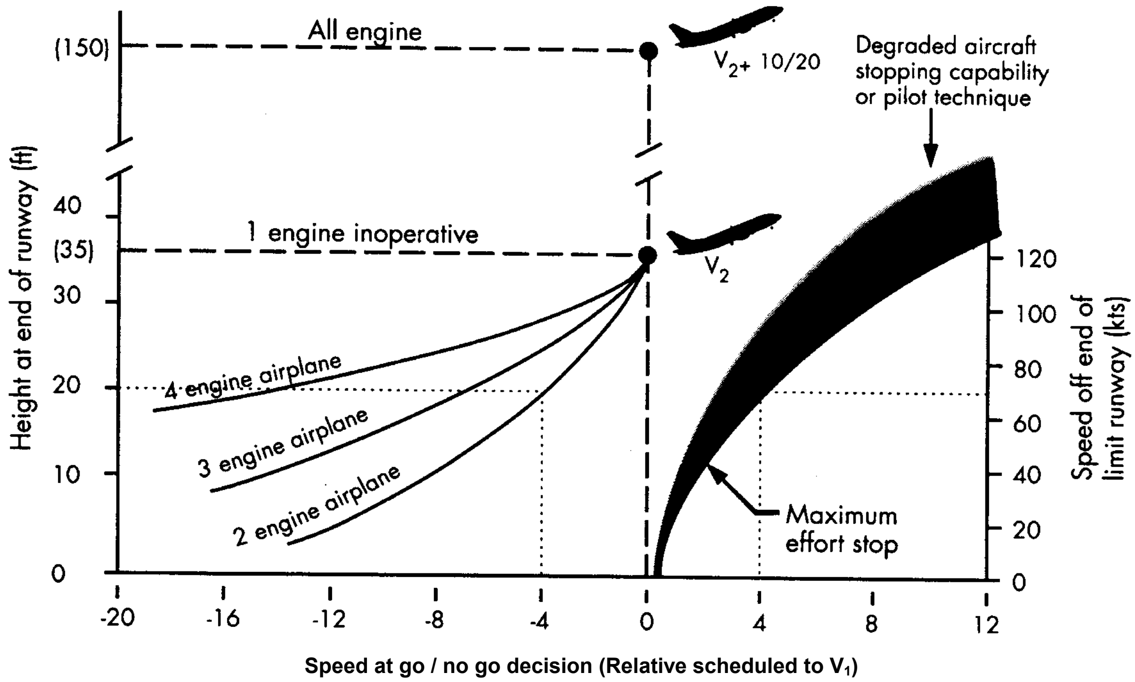


Figure 26 – The Theory of Relativity

Essentially what the diagram shows is this:

- If a takeoff in a 2 engine airplane is continued with an engine failure 4 knots (about 1 second) below V_1, the plane will cross the end of the takeoff distance at about 20 feet rather than the 35 feet specified.
- If the takeoff is rejected 4 knots after V_1, (again about 1 second) it will run off the end at about 75 knots!
- If the takeoff is continued with all engines, the aircraft will cross the end of the takeoff distance at about 150 feet.

So, what do you think? Is it better to go or is it better to stop? Once again, I am careful not to answer the question. This is information and the more information the pilot has, the more likely he or she is to make the critical decision correctly. As I said above, the crux of the matter is to make the correct decision based on all the factors at hand. This is certainly not easy as one goes rocketing down the runway, but that's what they get the big bucks for.

Well, I'm done. I hope you find this document useful. As I said before, I have been teaching performance for about 20 years now. Most pilots approach the performance class with dread because it can be deadly dull. If you have enough information you can make the subject interesting. I certainly didn't learn all this in just a few months. I have been learning for all those 20 years and I am always on the lookout for articles and information to add to my bag of tricks.

And, I enjoy it!! If you develop some enthusiasm for teaching this subject the pilots you teach will become much more involved in the discussion. Remember that while they are discussing, you don't have to teach! Lead the discussion and you will be surprised how much some pilots really know and, more importantly, how much they care about performance.

Performance is one area of pilot training that they will actually use on every flight. They will probably use the emergency procedures on very few occasions, but they cannot get airborne without performance. It is our obligation to make sure that they understand it and that they use it.

ADDENDUM

This is a short discussion of performance charts. Each AFM must have charts that allow the pilot to determine the following:

- maximum weight limited by climb in the takeoff, enroute and landing phases
- runway requirements for takeoff and landing
- the net takeoff flight path
- appropriate speeds for the above operations
- buffet onset envelope

Further, the AFM must show the conditions under which the performance information was obtained and the procedures established that pilots may use to obtain the desired performance. Explanations of significant or unusual handling characteristics must be included.

Factors must be included that allow corrections to be made for different weights, altitudes, temperatures, runway gradients and winds, where applicable. For instance, the charts must only allow corrections for 50% of any headwinds but 150% of tailwinds for both takeoff and landing. On the other hand, slope and temperature deviations are not required for landing distances as they are for the takeoff computations. Standard conditions of relative humidity are assumed.

Crosswinds must be demonstrated for at least 20 knots but need not exceed 25 knots.

Regarding brakes; they must now be worn to within 10% of replacement for accelerate-stop and landing distance demonstrations. The parking brake must be capable of preventing the aircraft from moving at takeoff thrust.

Care must be taken when using the charts themselves. Each chart is designed to be used in a particular direction: for instance to determine the runway required using weight, temperature, altitude, wind and slope. When used in the designed direction, all grid corrections are made from a Reference line. For example, if a correction is to be made for wind, the computation line is first drawn to the reference line, usually 0 wind, and then the correction for headwind or tailwind is made. A “reasonableness” check can be made: a headwind should shorten the required runway; an uphill slope should increase the required runway.

If the charts are used opposite to the designed direction, just the opposite is true: the line would be drawn to the value of the correction and then to the reference line. Again the “reasonableness” check should be made. If trying to figure the maximum weight for conditions, a headwind should increase the weight and an uphill slope should decrease the weight.

Be careful to read all the notes associated with the various charts. Certain conditions, such as using anti-ice, may require weight or speed adjustments. Some times the notes are on the charts themselves but they may be located in the general section of the performance charts. A careful reading of all these notes is essential for a complete understanding of the procedures that must be applied for these various condition.

There is a list of references attached that I have used extensively. There is much illuminating information, diagrams and discussions in the texts. I maintain most if not all of the material and you are welcome to use any of it. There are many other references in the articles that would be useful, but I do not have most of them.

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