

TAKE OFF

The take off part of the flight is the distance from the brake release point (BRP) to the point at which the aircraft reaches a defined height. This defined height is termed the “screen height”. The screen height varies from 35 ft for class A aeroplanes to 50 ft for class B aeroplanes.

For any particular take-off, it must be shown that the distance required for take-off in the prevailing conditions does not exceed the distance available at the take off aerodrome. However, there are various terms used to describe the available distances at an aerodrome.

AVAILABLE DISTANCES

Most large aerodromes have extra distances associated with the main runway which are used in a variety of ways. These extra distances are Clearways and Stopways.

CLEARWAYS

Clearways are an area beyond the runway, not less than 152 m (500 ft) wide, centrally located about the extended centreline of the runway, and under the control of the airport authorities. The clearway is expressed in terms of a clearway plane, extending from the end of the runway with an upward slope not exceeding 1.25%, above which no object or terrain protrudes. However, threshold lights may protrude above the plane if their height above the end of the runway is 0.66 m (26 inches) or less and if they are located to each side of the runway. Clearways are not physical structures; they are simply an area of defined width and length which are free of obstacles.



Figure 2.1: Clearways extend from the end of the runway with an upward slope not exceeding 1.25%, above which no object or terrain protrudes.

STOPWAYS

Stopways are an area beyond the take-off runway, no less wide than the runway and centred upon the extended centreline of the runway, able to support the aeroplane during an abortive take-off, without causing structural damage to the aeroplane, and designated by the airport authorities for use in decelerating the aeroplane during an abortive take-off. Stopways are physical structures and are usually paved. However, stopways are not as strong as the main length of runway and therefore are only used to help bring an aeroplane to a stop in the event of an abandoned take-off. Stopways are identified by large yellow chevrons on either end of the main runway.



Figure 2.2: Stopways are able to support the aeroplane during an abortive take-off and are marked by large yellow chevrons.

Understanding Stopways and Clearways is essential when examining the available distances published at aerodromes. There are four principal aerodrome distances, although only three will apply to the take-off and these are discussed next.

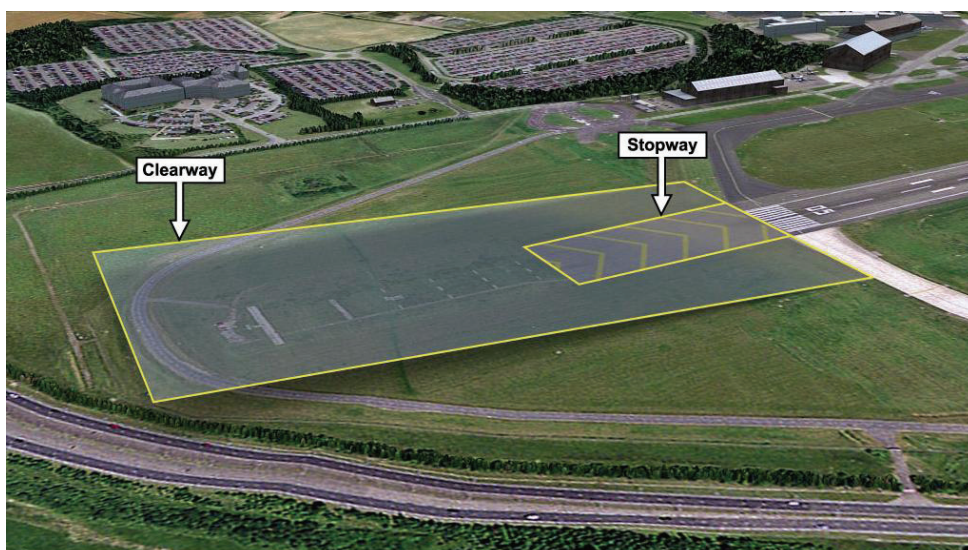


Figure 2.3: Illustrates the stopways & clearways that can be found at aerodromes.

THE TAKE-OFF RUN AVAILABLE (TORA)

The take-off run available is the distance from the point on the surface of the aerodrome at which the aeroplane can commence its take-off run to the nearest point in the direction of take-off at which the surface of the aerodrome is incapable of bearing the weight of the aeroplane under normal operating conditions. At most aerodromes the take-off run available is the length of the runway from threshold to threshold.

THE TAKE-OFF DISTANCE AVAILABLE (TODA)

The take-off distance available is the take-off run available plus any clearway (TORA + Clearway). If there is no clearway at the aerodrome then the take-off distance available will be the same length as the take-off run available.

The take-off distance available must be compared to the aeroplane's actual take-off distance. The requirements for take-off state that the aeroplane must be able to complete the take-off within the take-off distance available. Although clearways can be of any length, there is a limit to the amount of clearway that can be used when calculating the TODA. The maximum length of clearway in this case cannot be more than half the length of TORA.

THE ACCELERATE-STOP DISTANCE AVAILABLE OR EMERGENCY DISTANCE AVAILABLE (ASDA/EMDA)

The accelerate-stop distance available is the length of take-off run available plus any stopway (TORA + Stopway). If there is no stopway at the aerodrome then the accelerate-stop distance available will be the same length as the take-off run available.

The accelerate-stop distance available must be compared to the aeroplane's actual accelerate stop distance. The requirements for take-off state that the aeroplane's accelerate-stop distance must not exceed the accelerate-stop distance available.

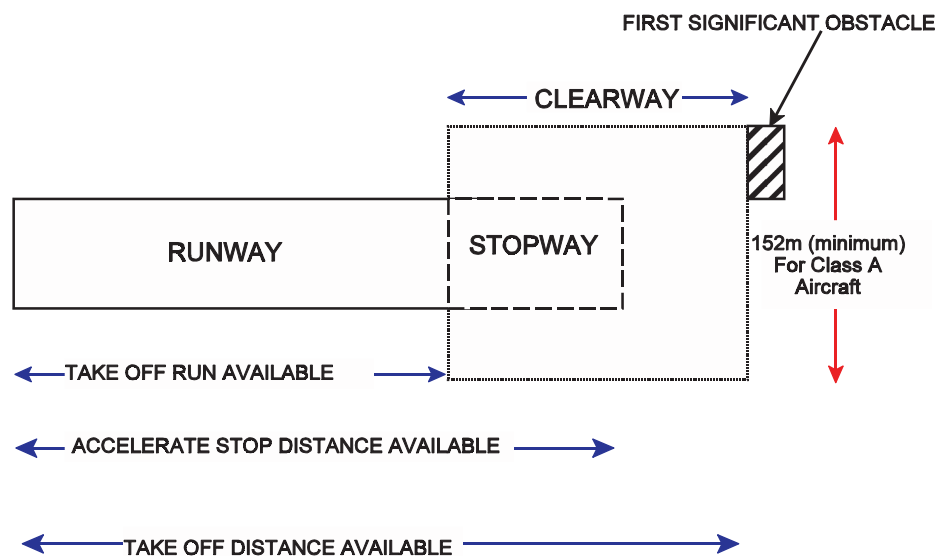


Figure 2.4: A summary of the available distances at an aerodrome.

REQUIRED DISTANCES

The distance required for take-off may be considered as two segments:

- The take off roll or ground run.
- The airborne distance to a "screen" of defined height.

The total distance from the brake release point to the screen height is called the Take-off Distance (TOD). The speed at which the pilot will attempt to raise the nose wheel off the ground is called " V_R ". This is the speed for rotation. At this speed the pilot will pull back on the control column and eventually the nose wheel will lift off the runway. This action will increase the lift and eventually the main wheels themselves will lift off the runway. The speed at which this occurs is called " V_{LOF} " which means the speed for lift off.



Figure 2.5: The take-off distance (TOD) is the total distance from brake release until the screen height.

Calculating the take-off distance is an important consideration but it is essential to a pilot to understand that there is a chance, albeit a remote chance, that the actual calculated take-off distance will not be achieved. To this end, the aviation authorities have created a set of safety regulations to ensure that poor performance is accounted for in the calculations. These safety regulations require factors to be applied to the estimated distances to give a satisfactory safety margin. The application of safety factors changes the terminology used. The calculated take-off distance is called the Gross Take-off distance, but applying the safety factors changes this to the Net Take-off Distance. The regulations and their associated safety factors will be discussed later in the relevant chapters on the different classes of aeroplanes.

CALCULATING THE TAKE-OFF DISTANCE

The two formulas shown below are used to help understand the key components in calculating the take-off distance. The upper formula is used to calculate the distance required (s) to reach a specified speed (V) with a given acceleration (ā). Beneath the first formula is the formula to calculate that acceleration.

$$D = \frac{V^2}{a}$$

$$\bar{a} = \frac{T - D_A - \mu (W - L)}{m}$$

| | | | | | |
|------|------------------|------------------|------------|-----------------------------------|----------|
| Key: | S = Displacement | ā = Acceleration | W = Weight | D _A = Aerodynamic Drag | m = Mass |
| | V = Speed | T = Thrust | L = Lift | μ = Coefficient of Friction | |

Figure 2.6: A simplified take-off distance and acceleration formula.

For an aircraft taking off, the acceleration is thrust minus drag. However, both of these forces will change as the speed changes, and so the acceleration will not be constant during the take off. Also, during the airborne part of the take-off, the laws of motion will be somewhat different, and the upper formula will change somewhat, but the distance required will still depend on the speed to be achieved and the acceleration.

FORCES DURING TAKE-OFF

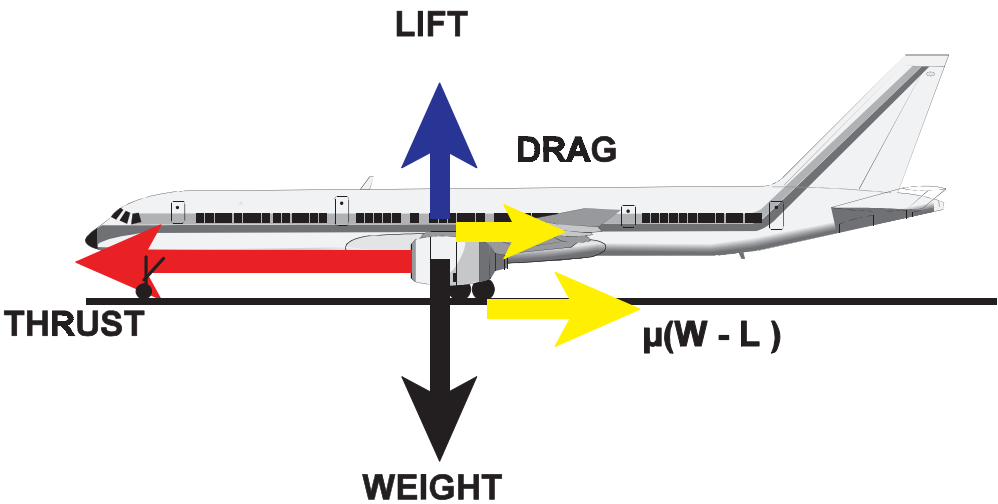


Figure 2.7: Forces in the take-off.

Looking back at the formula for acceleration during take-off it can be seen that thrust and drag play a very crucial part in the take-off performance. Therefore a little extra detail will be covered on these two important forces.

THRUST

The engine thrust will vary during take off, and the variation of thrust with speed will be different for jet and propeller engines.

- **Jet engine.** For a jet engine the net thrust is the difference between the gross thrust and the intake momentum drag. Increasing speed increases the intake momentum drag, which reduces the thrust. However, at higher speeds the increased intake pressure due to ram helps to reduce this loss of thrust, and eventually at very high speeds it will cause the net thrust to increase again. During take-off the aeroplane speed is still low and as such the ram effect is insufficient to counteract the loss of thrust due to intake momentum drag, therefore during the take-off there will be a decrease of thrust. In later chapters and in some performance graphs you will notice that the assumption is made that jet thrust is constant with speed. This is done so as to simplify some of the teaching points.

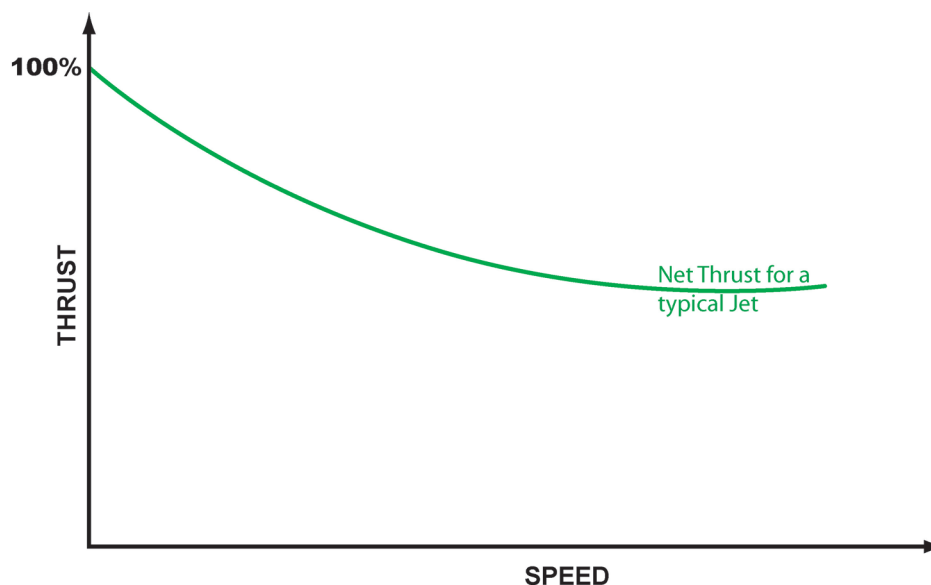


Figure 2.8: Net thrust with speed for a typical modern jet engine.

- **Flat rated engines.** The thrust produced by an engine at a given rpm will depend on the air density, and hence on air pressure and temperature. At a given pressure altitude, decreasing temperature will give increasing thrust. However, many jet engines are "flat rated", that is, they are restricted to a maximum thrust even though the engine is capable of producing higher thrust. The reason being that at lower temperatures too much thrust may be generated and the pressures within the compressors may be exceeded. Consequently at temperatures below the flat rating cut off, (typically about ISA + 15°C) engine thrust is not affected by temperature.