

FIRST APPROXIMATION TO TAKE-OFF DISTANCE TO 50 ft (15.2 m) FOR LIGHT AND GENERAL AVIATION AEROPLANES

1. NOTATION AND UNITS^{*†}

		SI	British
C_L	lift coefficient, $L/\frac{\rho}{2}\left(\frac{r V}{3\ 600}\right)^2 S$		
D	propeller diameter	m	ft
f_N	net thrust per engine, for turbo-jet and turbo-fan engines (see Section 3)	N	lbf
g	acceleration due to gravity	m/s ²	ft/s ²
L	lift	N	lbf
m	aeroplane mass	kg	slug
n	number of engines or propellers installed		
P	rated engine shaft power per engine (see Section 3)	kW	hp
r	conversion factor (1 000 m/km, 1 852 m/n.mile, 6 076.12 ft/n.mile)	m/km, m/n.mile	ft/n.mile
S	wing area	m ²	ft ²
s	unfactored take-off distance to 50 feet (15.2 m)	m	ft
T	thrust per propeller, no losses (see Section 3)	N	lbf
V	true airspeed	km/h, kn	kn
V_2	take-off safety speed [†] , i.e. the minimum permitted true airspeed of the aeroplane with all power units operating at the 50 ft (15.2 m) screen	km/h, kn	kn
W	aeroplane weight, mg	N	lbf
ρ	density of air	kg/m ³	slug/ft ³
σ	relative density ρ/ρ_0		
Subscripts			
<i>stall</i>	denotes value at stall		
0	denotes value at sea level in International Standard Atmosphere, ISA		
0.7	denotes value at $0.7 V_2$		
2	denotes value at V_2		

* It is customary British practice to work in terms of aeroplane weight; however, when using SI units, aeroplane mass is used. Expressions and figures in this Item are presented in terms of aeroplane weight only, but they are equally applicable if aeroplane mass is used, provided that the substitution $W = mg$ is made.

† References 8 and 9 define V_2 in terms of equivalent airspeed. For the larger transport aeroplanes considered in Reference 5 the take-off safety speed is also denoted by V_2 but it applies there to a continued take-off with one engine failed.

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2. INTRODUCTION

This Item presents data in Figures 1 to 4 which allow a rapid estimation of the take-off distance to 50 ft (15.2 m) for light and general aviation aeroplanes from hard, level, dry runways in still-air conditions. For the purposes of this Item, the term “general aviation” denotes aeroplanes whose take-off weight is less than or equal to 12 500 lbf ($m \leq 5\,700$ kg), have take-off distances less than about 3 000 ft, or 1 000 m, and comply with the airworthiness requirements of References 8 and 9.

The parameters used in the correlation of the data to produce Figures 1 to 4 are

$$\frac{W^2}{C_{L_2} n P S \sigma} \text{ and } \frac{W^2}{C_{L_2} n T_{0.7} S \sigma} \text{ or } \frac{W^2}{C_{L_2} n f_{N_{0.7}} S \sigma}$$

respectively. The power-based parameter in Figures 1 and 3 uses engine shaft power and applies only to propeller-driven aeroplanes. The use of thrust in the correlation of the data in Figures 2 and 4 allows a wider range of aeroplanes to be considered than is possible with engine power alone (see Section 7) and permits the inclusion of those powered by turbo-jets, turbo-fans, and ducted-fans. A derivation of the thrust-based parameter is given in Appendix A of Reference 5. Thrust data for propeller-driven aeroplanes were derived from Reference 7, which can also be used as a general method for project estimation.

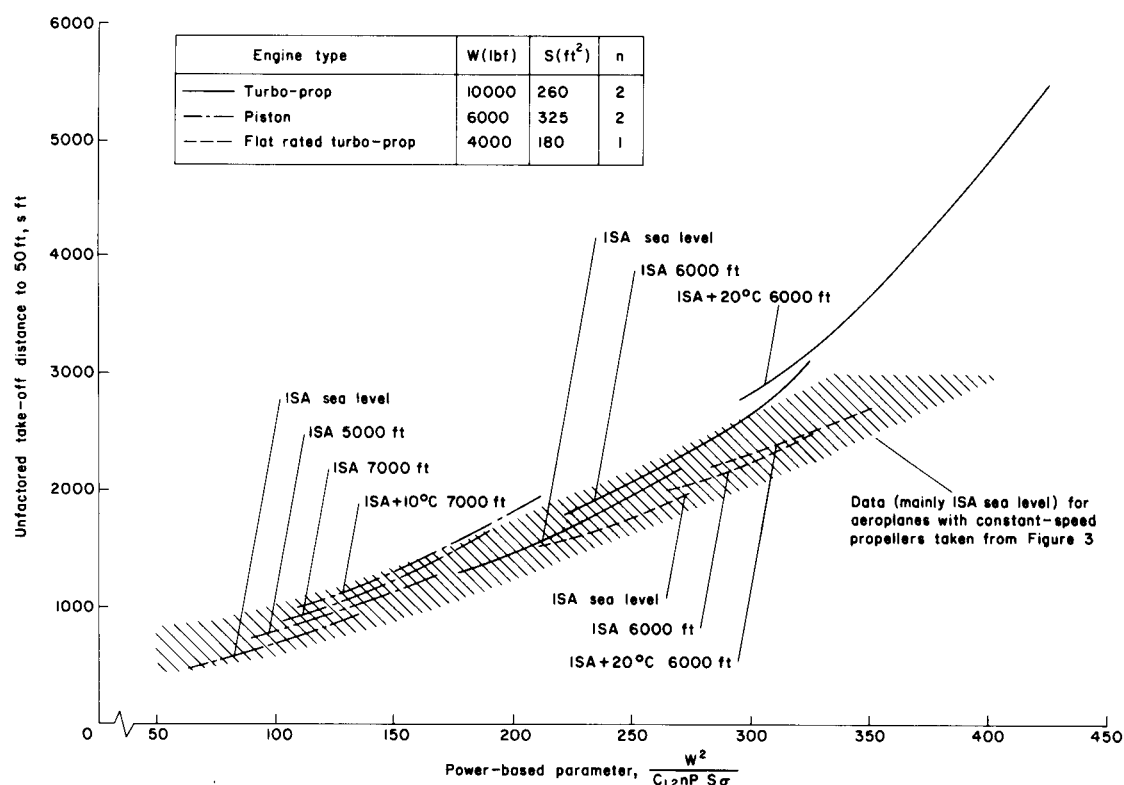
For aeroplanes with gross weights above 12 500 lbf ($m > 5\,700$ kg), Reference 5 should be used to estimate the take-off field lengths.

3. LIMITATIONS AND ASSOCIATED CONDITIONS

The majority of the data used were for ISA sea level conditions. Figures 1 to 4 can be used to obtain estimates of take-off distance **for a limited range of ambient conditions**, provided the effects of altitude and temperature on density, power and thrust are taken into account. However, for aeroplanes with low take-off climb gradients, take-off distances greater than those given in the figures are possible, see Sketch 3.1. The Sketch shows that for individual aeroplanes in particular configurations (flap setting *etc.*) the take-off distance data can usually be correlated for a wide range of atmospheric conditions. Where Sketch 3.1 shows the data for the individual aeroplanes to lie outside the shaded region in the Figures, it is most likely due to the effect of extreme atmospheric conditions – usually associated with low take-off climb gradients. In addition, conservatism in the scheduling of flight-manual performance data beyond the range of conditions tested may also have increased the quoted take-off distances.

Rated engine shaft powers* and propeller thrusts were used in the analysis. No allowances were made for installation effects incurred by either engine or propeller, such as those due to nacelle blockage, slipstream drag, intake total pressure loss, accessory drives and residual jet or exhaust thrust on turbo-prop or piston engines *etc.* Therefore, in using the Item no such allowances should be made.

* Manufacturers' stated power at the appropriate altitude and temperature.



Sketch 3.1 Effect of increasing altitude and temperature on take-off distance

4. TAKE-OFF FIELD LENGTH

The **take-off distance** is defined as the distance required to reach a screen height of 50 ft (15.2 m) with all engines operating. Certification or operational regulations may factor the take-off distance, s , to obtain a corresponding **take-off field length** requirement (for example, Reference 9 specifies $1.25 \times s$).

5. ESTIMATION OF TAKE-OFF DISTANCE BASED ON ENGINE POWER

Figures 1 and 3 present take-off distance data (in SI and British units respectively) using the power-based parameter given in Section 2 and can be used to give an indication of the engine shaft power, P , required to achieve a given take-off distance. Figures 1 and 3 are applicable to aeroplanes where the propeller disc loading is such that $P/\sigma D^2 < 8$ hp/ft² (64 kW/m²), where D is the propeller diameter. "Recommended lines" and the spread of the data are presented for aeroplanes with constant-speed propellers and for those with fixed-pitch propellers optimised for the climb and cruise phases of flight. Distances comparable with those obtained with a constant-speed propeller can be obtained by using a fixed-pitch propeller which is optimised for take-off.

6. ESTIMATION OF TAKE-OFF DISTANCE BASED ON THRUST

Figures 2 and 4 present take-off distance data (in SI and British units respectively) using the thrust-based parameter given in Section 2. The method employs a single value of thrust calculated at $0.7V_2$, where V_2 is the take-off safety speed, and is applicable to all classes of light and general aviation aeroplanes, including those powered by turbo-jet, turbo-fan and ducted-fan engines. “Recommended lines” and the spread of the data are presented for propeller-driven aeroplanes and for a limited number of turbo-jet and turbo-fan powered types.

6.1 Thrust Data

Reference 7 provided the propeller thrust data used in developing Figures 2 and 4. Thrust data for propulsion sources other than propellers can be used, for example, ducted-fans, turbo-jets and turbo-fans, see Reference 6.

For **fixed-pitch propellers** the thrust lapse differs from that for constant-speed types, because the former are not usually able to operate at the rotational speed for rated engine shaft power when static or at low forward speeds. To use the curves labelled “fixed-pitch propellers” in Figures 2 and 4 this loss is ignored and the thrust is evaluated assuming rated engine shaft power and rotational speed can be attained. Distances comparable to those obtained with a constant-speed propeller can be achieved by using a fixed-pitch propeller which has been optimised for take-off.

7. NOTES ON THE METHOD OF CORRELATION

Two methods are offered. The first, which uses engine power as a primary variable, gives “at-a-glance” values of take-off distance for a range of propeller-driven light aeroplanes but is restricted to disc loadings such that $P/\sigma D^2 < 8$ hp/ft² (64 kW/m²). The second method, which uses powerplant thrust, allows a wider range of aeroplanes to be covered, including propeller-driven aeroplanes having values of $P/\sigma D^2$ greater than that specified above and also those powered by ducted-fans, turbo-jets and turbo-fans. Together, the methods give an approximate guide to the engine power and propeller characteristics necessary to achieve specified take-off distances.

For both methods all the data considered (except those mentioned in Section 7.3) are enclosed within the hatched areas of Figures 1 to 4. The power-based parameter correlates 65 per cent of the data considered (45 aeroplanes) to within about ± 10 per cent of the “recommended line”. The thrust-based parameter, correlates 60 per cent of the data considered (54 aeroplanes) to within about ± 10 per cent of the “recommended line.”

7.1 Take-off Data

Table 7.1 lists some of the properties and characteristics of the aeroplanes used in the correlations, the take-off data being taken primarily from flight manuals or pilot’s handbooks, as appropriate. The data presented in the flight manuals represent the performance of the aeroplane as agreed by the manufacturer and certification authority. Consequently, the data are likely to have been influenced by factors such as:

- (i) the extent and repeatability of the flight tests and the degree to which computed take-off performance can be correlated with measured values,
- (ii) differences in national airworthiness requirements (for example, alternative safety margins).

Before using the data, any field length factors were removed to obtain unfactored distances (see Section 4).