18

FAR REQUIRED LANDING FIELD LENGTH

GENERAL CONCEPT AND DEFINITIONS

The regulations for civil aircraft, FAR 23 and FAR 25, as well as the specification for military aircraft, MIL-C-5011 B, define the actual landing distance as an air run from 50 ft above the runway to touchdown, and the ground deceleration from touchdown to a full stop on a dry, hard surface runway. A sketch of the landing distance concept and definitions is shown in Fig. 18-1.

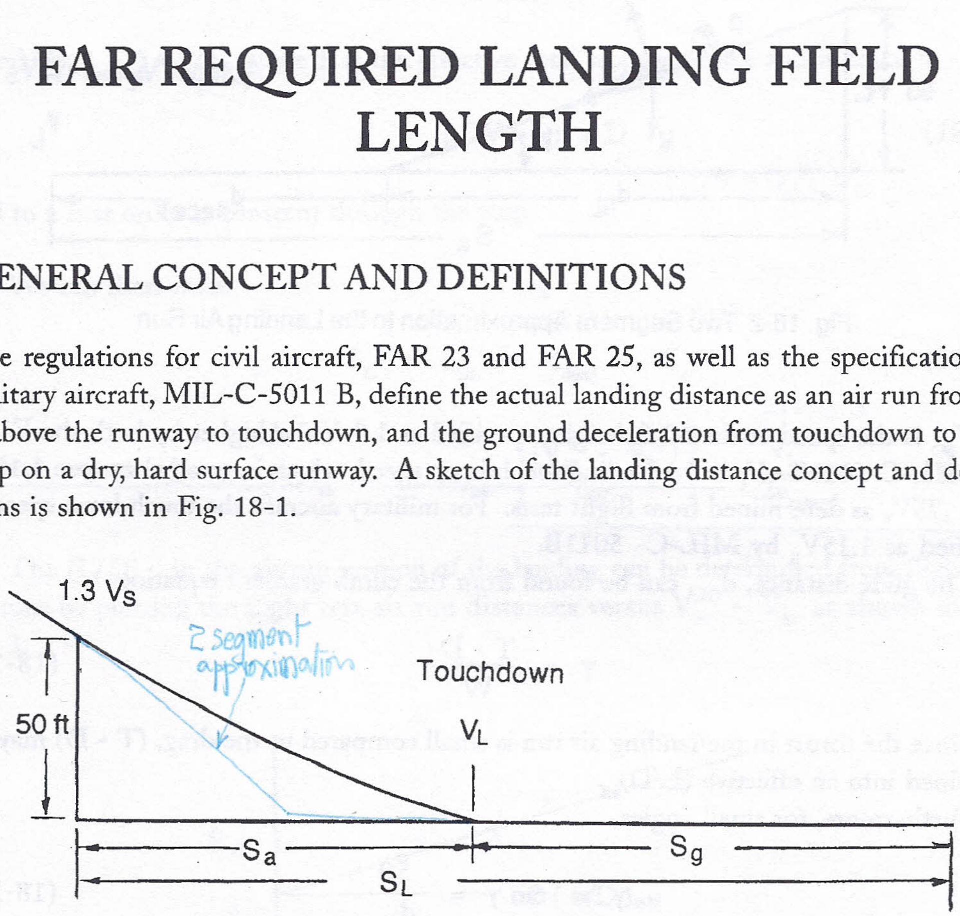
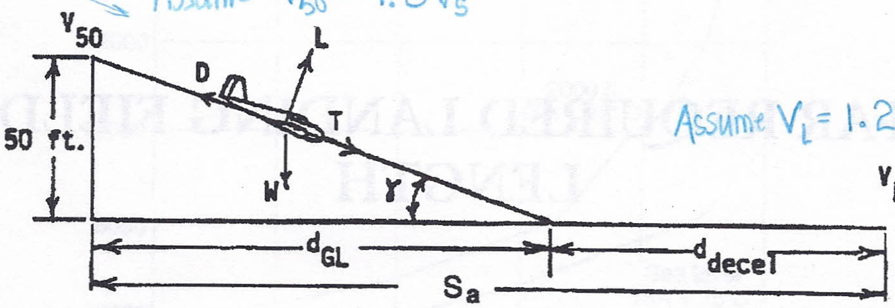


Fig. 18-1 Landing Distance Concept

The air run portion of the landing distance S_a, is not easily calculated from first principles, since the actual trajectory is influenced by the steady glide angle at the 50 ft height, the pilot technique in making the flare from 50 ft to touchdown, and the ground effect on the aircraft drag. Most preliminary design estimates of landing distance are based on correlations with flight test data using the model described in the following paragraphs.

The air distance, S_a, can be approximated by a steady state glide distance, d_{GL}, plus an air deceleration glide distance, d_{decel}, at constant altitude, as shown in Fig. 18-2.

Assume $V_{50} = 1.3V_S$



Assume $V_L = 1.2V_S$

Fig. 18-2 Two Segment Approximation to the Landing Air Run

V_{SO} is the speed at the 50 ft height, specified as 1.3 Vs or higher by both the FARs and MIL-C-5011B. V_L is the landing touchdown speed, which is usually between $1.15V_S$ and $1.25V_S$ as determined from flight tests. For military aircraft, the touchdown speed is specified as $1.15V_S$ by MIL-C- 5011B.

The glide distance, d_{GL}, can be found from the climb gradient equation

$$\gamma = \frac{T - D}{W} \tag{18-1}$$

Since the thrust in the landing air run is small* compared to the drag, (T - D) may be combined into an effective $(L/D)_{eff}$

Furthermore, for small angles,

$$\gamma = \tan \gamma = \frac{50}{d_{GL}} \tag{18-2}$$

$$d_{GL} = 50\,(L/D)_{eff} \tag{18-3}$$

Assume = 18.0

* small, but not negligible. Approach thrust decreases glide slope angle and increases 'effective' $\frac{L}{D}$.

The air deceleration distance, for a constant deceleration, a_{air}, is

$$d_{decel} = \frac{V_{50}^2}{2a} - \frac{V_L^2}{2a} \qquad (18\text{-}4)$$

The ground deceleration distance to a stop ($V = 0$), for a constant deceleration, is

$$S_g = \frac{V_L^2}{2a_{ground}} \qquad (18\text{-}5)$$

In reality, $a_{ground} = F/m$ where F is the effective total stopping force and is equal to

$$F = \overset{0.30}{\mu}(W - \overset{0}{L}) + D \leftarrow C_{D_{RTO}}\rho V^2 S \qquad (18\text{-}6)$$

value @ $0.7 V_L$

and to a first order is constant through the stop.

We can then write

$$S_L = \overset{=\text{n}18.3}{d_{GL}} + \overset{=\text{n}18.4}{d_{decel}} + \overset{=\text{n}18.5}{S_g} \qquad (18\text{-}7)$$

and

$$= \overset{=\text{n}18.3}{50(L/D)_{eff}} + \overset{=\text{n}18.4}{(L/D)_{eff}\left[\frac{(V_{50}^2 - V_L^2)}{2g}\right]} + \overset{=\text{n}18.5}{\frac{V_L^2}{2a_{ground}}} \qquad (18\text{-}8)$$

The $(L/D)_{eff}$ in the air run portion of the landing can be determined from flight test air runs by plotting the flight test air run distances versus $V_{50}^2 - V_L^2$ as shown in Fig. 18-3.

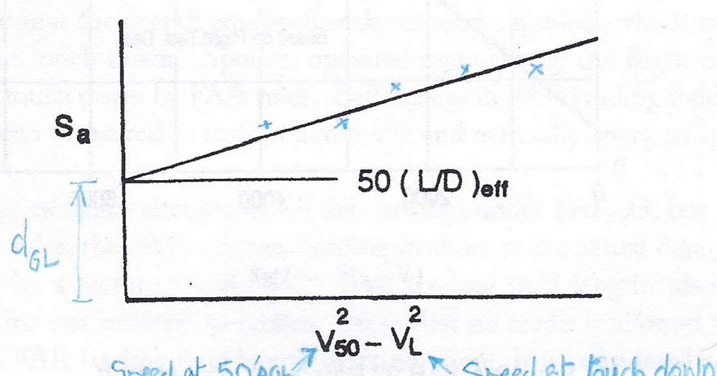


Fig. 18-3 Landing Air Run Correlation

	$L/D)_{eff}$	γ
Personal/Util	4.0	-14.0°
Turboprops	8.0	-7.1°
Jet transports	18.0	-3.2°

Both the air deceleration distance, d_{decel}, and the ground stopping distance, Sg, are directly proportional to V_{50}^2 and/or V_L^2. Both V_{50} and V_L are fixed percentages above V_S. Therefore, the landing distance is linear with V_S^2, except for the glide distance from 50 ft which depends only on the $(L/D)_{eff}$ in the landing configuration. Based on this logic, for airplanes with similar $(L/D)_{eff}$ values and similar braking systems, the landing distances should correlate reasonably well when plotted versus V_S^2. Figs. 18-4, 18-5, and 18-6 present the results of such correlations based on flight test data for three classes of airplanes. It should be noted that these correlations are for the actual landing distances demonstrated during the FAA certification tests. The $(L/D)_{eff}$ in the air run varies significantly for the different types of aircraft . For personal/utility aircraft, the $(L/D)_{eff}$ from Fig. 18-4 is 4.0, while for regional turboprops the $(L/D)_{eff}$ is 8.0 from Fig. 18-5. For jet transports, from Fig. 18-6, the $(L/D)_{eff}$ is 18.0. These values indicate that significantly more power is carried in the landing air run, and the glide angle, γ, becomes more shallow, as the aircraft become larger and heavier.

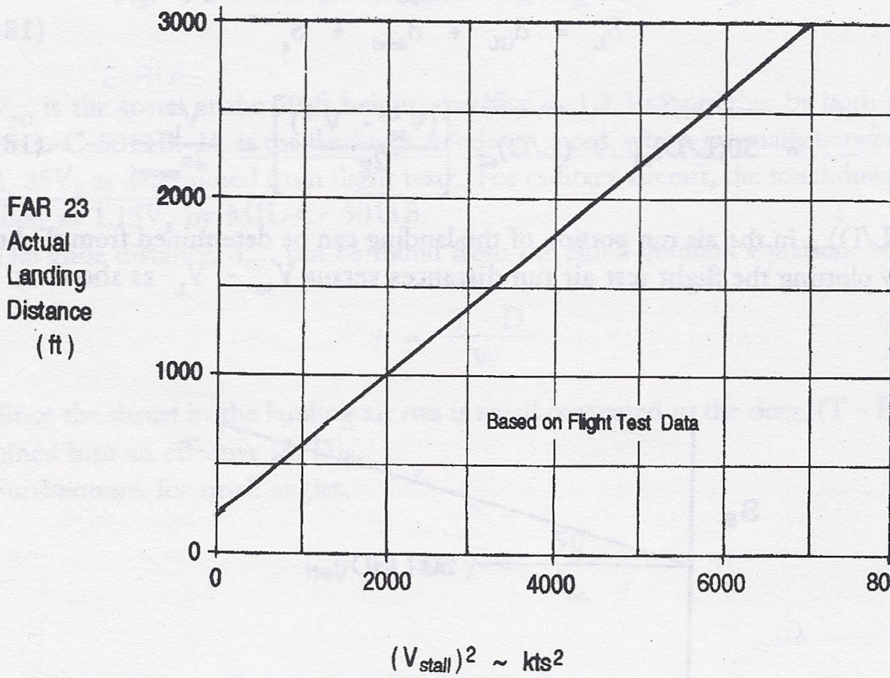


Fig. 18-4 FAR 23 Personal/Utility Aircraft

Adapted with permission from Ref. 18.2

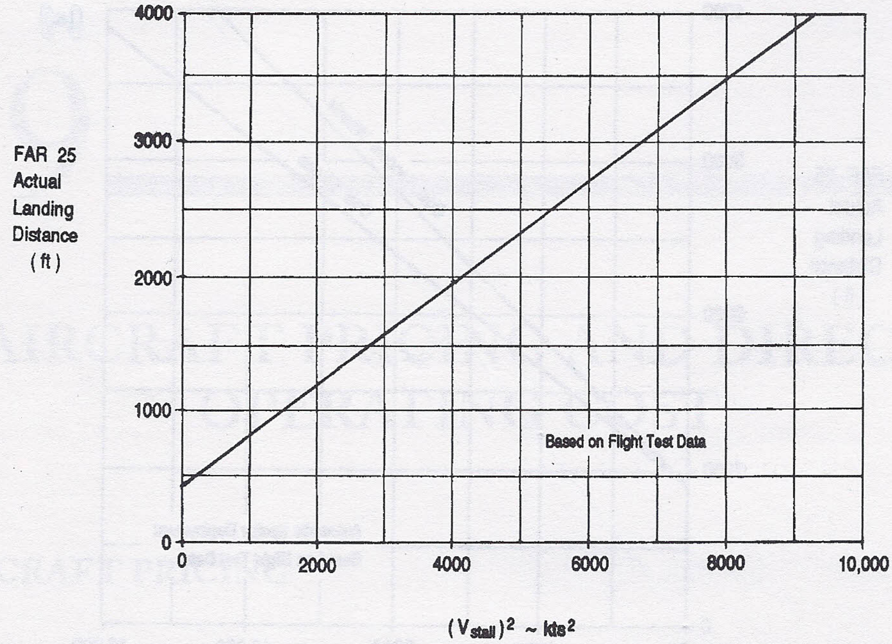


Fig. 18-5 FAR 25 Regional Turboprop Aircraft

There is a difference in the landing distance correlation between jet transport aircraft with dual tandem (4 wheel) trucks and smaller aircraft with dual (2 wheel) trucks. It appears that the effective coefficient of friction is less for wheels braking immediately behind other wheels.

The correlation is for aircraft equipped with automatic spoilers, which are operated by wheel rotation at touch down. Spoilers operated manually by the flight crew involve a time delay after touch down by FAA rules. Differences in FAR landing field length of up to 500 ft have been measured in tests of automatic and manually operated spoilers on the same aircraft.

For transport category aircraft, which are certified under FAR 25, but must operate under FAR 121 rules, the FAR required landing distance is the actual demonstrated distance, increased by a factor of 1.00/0.60. FAR landing field lengths also must be increased by 15% for wet runway operations. Note that no credit is allowed for the use of reverse thrust in FAR landing field length determination. It is considered an operational "pad" for adverse braking situations, in addition to the 1/.60 factor.

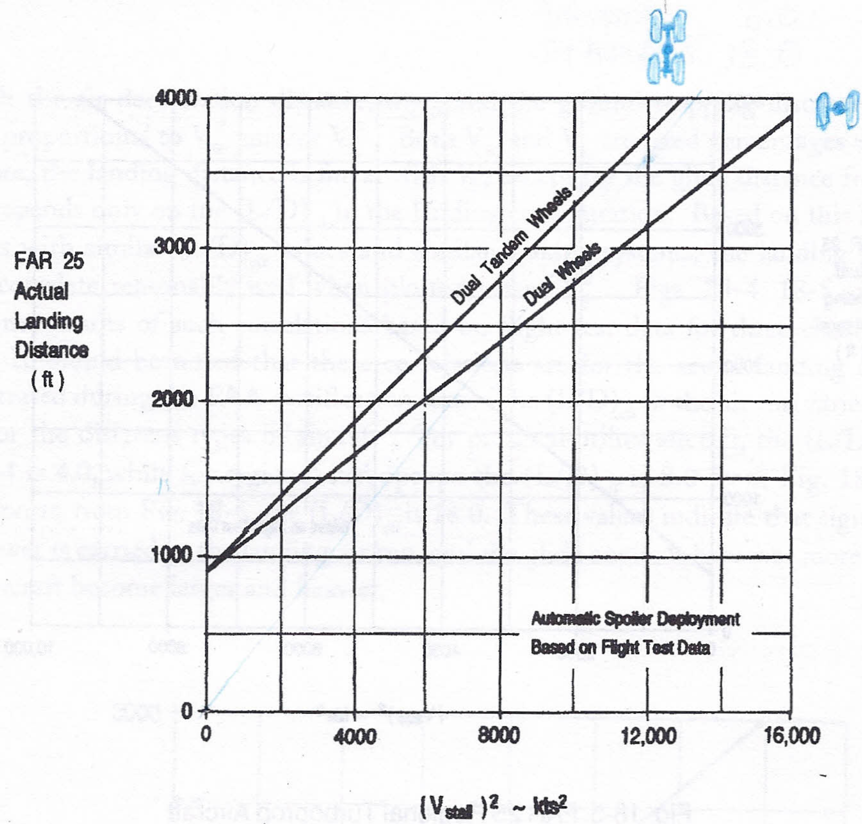


Fig. 18-6 FAR 25 Jet Transport Aircraft

DESIGN EXERCISE

Determine the landing field length required for your design at the maximum landing weight, using the appropriate correlation curves.

REFERENCES

18.1 Perkins, Courtland D., and Hage, Robert E., Airplane Performance Stability and Control, Wiley, New York, 1949.

18.2 Loftin, Laurence K. Jr., Subsonic Aircraft Evolution and the Matching of Size to Performance, NASA Reference Publication 1060, 1980.

18.3 Shevell, Richard S., Fundamentals of Flight, PrenticeHall, Englewood Cliffs, NJ, 1989.