

Aircraft Performance Prediction: Comparison of Classical Handbook Methods to Detailed Time Integration Computer-Aided Methods

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ABSTRACT

The purpose of this paper is to compare classical handbook methods used to predict performance parameters such as range and endurance to computer based methods. Three different methods are compared: classical handbook methods are based on simple drag polars and engine performance data, spreadsheet methods use more detailed engine data and drag polars and third is the use of APP (Aircraft Performance Program), a commercially available software program. The advantages and disadvantages of each method are described and accuracy listed based on existing airplanes. One example is used: a business jet type aircraft. Methods used are described and inputs and outputs of the different programs used are shown.

INTRODUCTION

The flight performance of the Cessna 525 CitationJet, over a prescribed mission profile, is analyzed with three different methods. The results of the performance calculation of CitationJet, generated by each method, are presented.

The three methods involved in the analysis are:

1. Classical handbook method, i.e. Breguet equations for calculating the range and endurance in the cruise segment.
2. Spreadsheet method on the entire mission profile.
3. The Aircraft Performance Program, APP, on the entire mission profile.

The three-view of the CitationJet is shown in Figure 1 through Figure 3

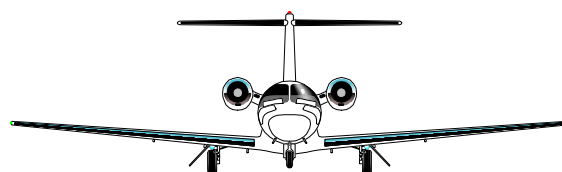


Figure 1 Example Airplane Front View

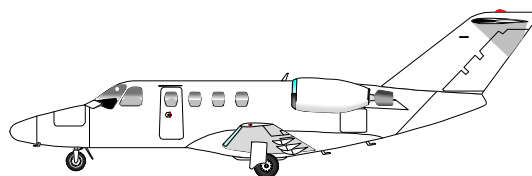


Figure 2 Example Airplane Side View

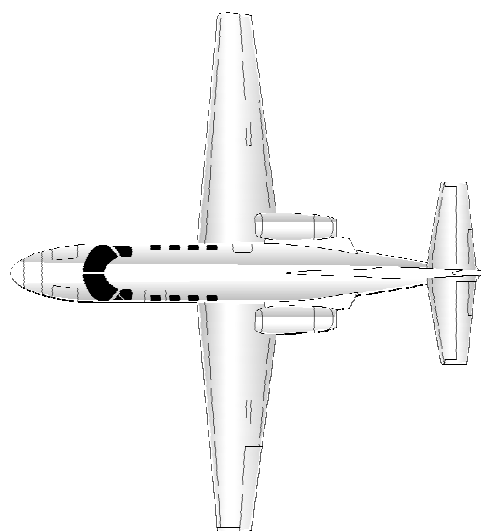


Figure 3 Example Airplane Top View

MISSION PROFILE

The mission profile defined for the present analysis consists of seven flight segments, as shown in Figure 4

Payload: 3 passengers and 1 pilot at 180 lb each, and 60 lb baggage (20 lb each per passenger), for a maximum payload weight of 780 lb.

Fuel : Full fuel weight at 3413 lb.

Range : 1,485 nm at Mach 0.659 at a maximum take-off weight of 10,400 lb (at maximum fuel and payload weights).

Altitude : 35,000 ft (for the design range).

Cruise Speed: Design cruise speed of 380 kts at 35,000 ft (Mach 0.659).

Climb : Climb from sea level to 35,000 ft at 250 kts, at maximum continuous engine thrust setting.

Descent : Descent from 35,000 ft to 10,000 ft at 250 kts, followed by a descent from 10,000 ft to sea level at 200 kts, at idle engine thrust setting.

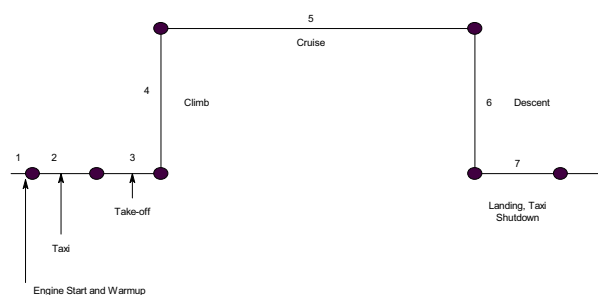


Figure 4 Mission Profile

For the given mission profile, the following assumptions are made:

1. Fuel-fraction (Reference 1) for warm-up and taxi segments, for a business jet type airplane, equal to 99.0% and 99.5% of W_{TO} respectively. This translates to a fuel burn of 155.5 lb.
2. Fuel-fraction (Reference 1) for landing and taxi segments, for a business jet type airplane, equal to 99.8% of W_{TO} . This translates to a fuel burn of 25 lb.
3. The calculations of the overall range and endurance do not include those in the warm-up and taxi, nor landing and taxi segments.

CLASSICAL HANDBOOK METHOD

The equations used to predict the range and endurance of a given aircraft in the classical handbook method are called the Breguet equations. For a constant speed cruise, they are as follows:

Breguet range equation in constant speed cruise segment (Reference 2):

$$R = \left(\frac{V C_L / C_D}{c_j} \right) \ln \left(\frac{W_{Cruise_{begin}}}{W_{Cruise_{end}}} \right)$$

Breguet endurance equation in constant speed cruise segment (Reference 2):

$$E = \left(\frac{C_L / C_D}{c_j} \right) \ln \left(\frac{W_{Cruise_{begin}}}{W_{Cruise_{end}}} \right)$$

where: c_j is the engine specific fuel consumption, SFC, at the design cruise altitude and at the design cruise Mach number.

The inputs required for the calculation of Breguet range and endurance equations are:

1. $W_{Cruise_{begin}} = 9846$ lb.
2. $W_{Cruise_{end}} = W_{Cruise_{begin}} - W_{Fuel\ Cruise} = 9,846 \text{ lb} - 2,462 \text{ lb} = 7,384$ lb.
3. C_L / C_D (at the mid point of the cruise segment) = 8.83.
4. c_j (Mach 0.659 at altitude of 35,000 ft) = 0.715 lb/(hr-lb)
5. V (Mach 0.659 at altitude of 35,000 ft) = 380 kts

The advantages of the classical handbook method are:

1. Very few inputs are needed for the calculation.
2. Both range and endurance equations are short and straight forward.

The disadvantages of the classical handbook method are:

1. Throughout the entire cruise segment, as fuel is gradually burned, the weight of the aircraft gradually reduces, thus the aircraft lift-to-drag ratio, C_L / C_D , is not really constant.