Project 3 – Runway performance

3.1 Context and objectives

The objective of this project is to study the dynamics of an aircraft take-off.

You are working for an established aircraft manufacturer designing a family of long-range twin-engined widebody airliners intended to finally break into a market segment dominated by its historical competitor. You are tasked with quantifying the runway length required for a safe, certified, maximum-weight takeoff.

Based on calculations as well as your best judgment,

- Write an expression for the distance required for any arbitrary jet aircraft to reach an arbitrary speed, as it accelerates rolling down a runway;
- Calculate the runway distance required for the new aircraft to clear a ground height of 10,4 m in normal conditions, and plot approximately its speed as a function of distance along the runway;
- Plot approximately the aircraft speed as a function of distance for the main incident cases (rejected takeoff, engine failure before, at, or after decision speed);
- Provide a precise estimate for the aircraft's decision speed V_1 and its balanced field length.

Your mark will be based on the validity of your simplifications and calculations, and the clarity of your work. You may use any tool you wish (e.g. software, books), but you are required to quote all of your sources.

Groups handing in written reports must hand in one single printed or PDF (A4-size) document, no longer than 8 pages.

Groups making an oral presentation must aim for less than 15 minutes (all members participating), and then answer questions from the class. Please hand in your slides as a print-out or PDF file.

3.2 Aircraft specifications

The aircraft is designed as a long-range twin-engined widebody airliner combining a modest number of technological improvements with long-established technologies and manufacturing processes. It is shown in Figure 3.1 and its primary specifications are listed in Table 3.1.

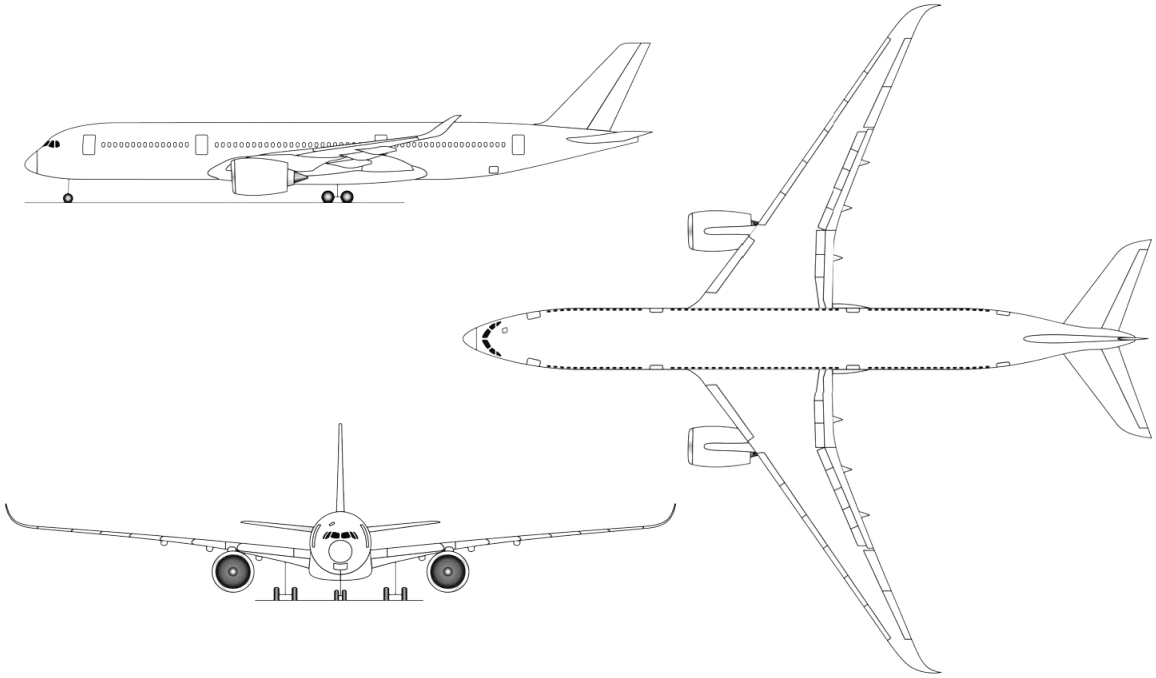

Figure 3.1: Three-view plan of the new aircraft
Image derived/reconstructed from the manufacturer's Airport and Maintenance Planning manual

Cockpit Crew	2
Capacity	315 pax (3-class)
Length	66,9 m
Wingspan	64,8 m
Height	17,1 m
Wing area	443 m^2
OWE	129 t
MTOW	268 t
Powerplant	2 × RR Trent XWB; 374 kN SL-SA each
Cruise speed	M 0,85
Max. range	7 750 NM (14 300 km)

Table 3.1: Specifications of the planned aircraft

3.3 Propulsion

The aircraft is powered by two bleed-air, three-spool, high bypass ratio, high pressure ratio Rolls-Royce *Trent XWB* turbofans. TOGA thrust (SL, SIA) for each is $T_{max,SL} = 374\,\mathrm{kN}$; thrust decreases proportionally with the ambient air density and the throttle level, and is assumed independent of speed.

The thrust angle relative to the wing chord is set at $\beta_T = -3{,}8°$.

3.4 Aerodynamics

In takeoff configuration, the aircraft has the following characteristics:

- Lift-independent drag coefficient: $C_{D0} = 0{,}033$
- Lift-dependent drag factor: $\frac{\mathrm{d}C_D}{\mathrm{d}C_L^2} = 0{,}04$
- Lift coefficient slope: $C_{L,\alpha} = 0{,}095\,°^{-1}$
- Lift coefficient at zero alpha: $C_{L|\alpha=0} = 0{,}175$
- Maximum lift coefficient: $C_{Lmax} = 2{,}4$

Ground roll attitude allows a low value for wing angle of attack: $\alpha_{ground} = 3°$.

3.5 Landing gear

The landing gear consists of a 2-legged, 8-wheel braked main landing gear supporting 80 % of the weight, and a free-wheel steering nose gear.

- Rolling friction coefficient: $\mu_{roll} = 0{,}04$
- Friction coefficient at maximum breaking: $\mu_{braking} = 0{,}2$