Assignment 3: Runway Length Calculations for Large Aircraft

Solution Instructor: Trani

Problem 1

Estimate the runway length required to operate an Airbus A220-300 from a regional airport with a **desired takeoff weight of 145,000 lbs**. The **design temperature is ISA +15 degrees Celsius**. The airport elevation is 3,000 feet. The characteristics of the Airbus 220-300 can be found in the Airbus Documents for Airport Design (https://aircraft.airbus.com/en/customer-care/fleet-wide-care/airport-operations-and-aircraft-characteristics/aircraft-characteristics). The latest document for the Airbus A220 is: BD500-3AB48-13800-00 Issue No. 006.

Table 1. Aircraft Considered in Problem 1. Airbus A220-300 Landing at Norfolk Airport. Source: A. A. Trani.

Aircraft Considered
Airbus A220-300 with Pratt and Whitney Pure PowerTM PW1521G engines (21,000 lbs of thrust). The aircraft maximum takeoff weight is 156,300 lb. The airline uses a standard seating capacity of 140 seat. The Analysis for Problem 1 Uses a Desired Takeoff Weight of 145,000 lbs. Given the Airfield and Temperature Conditions.


a) Find the runway length needed to operate the Airbus A220-300 with the Pratt and Whitney PW1521G engine (21,000 lbs of thrust) at 145,000 lbs. from the regional airport.

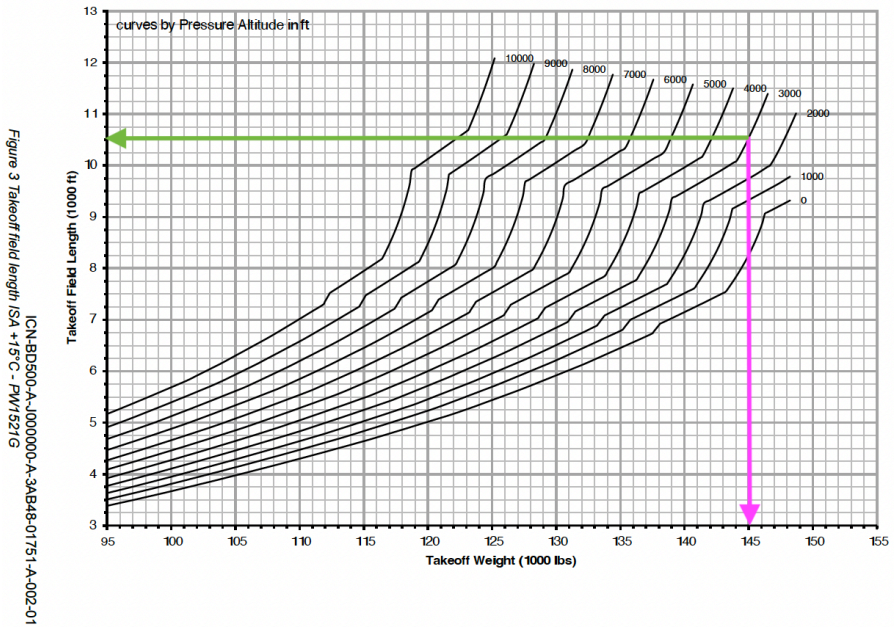

Figure 3 Takeoff field length ISA +15°C - PW1521G

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- The required runway length for takeoff with a takeoff weight of 145,000 lb is 10,500 feet.
- The required runway length for landing at MALW is 5,350. (Dry runway)

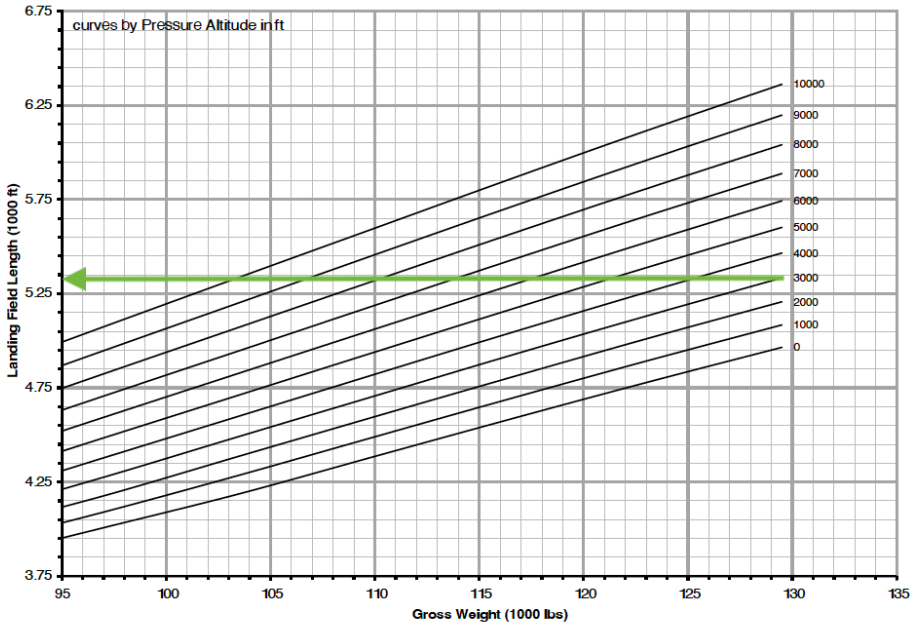

Figure 6 Landing field length - Dry runway

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- The required runway length for landing at MALW is 5,350 * 1.15 = 6,152 ~ 6200 feet. (Wet runway). Note Airbus provides dry runway conditions only. We always design for wet runway conditions (adding 15% above the dry condition if wet pavement solutions are not provided).

- **Therefore, the required runway length is 10,500 ft.**

b) Find the runway length needed to operate the Airbus A220-300 with the Pratt and Whitney PW1524G engine (24,000 lbs of thrust) at 145,000 lbs. from the regional airport.

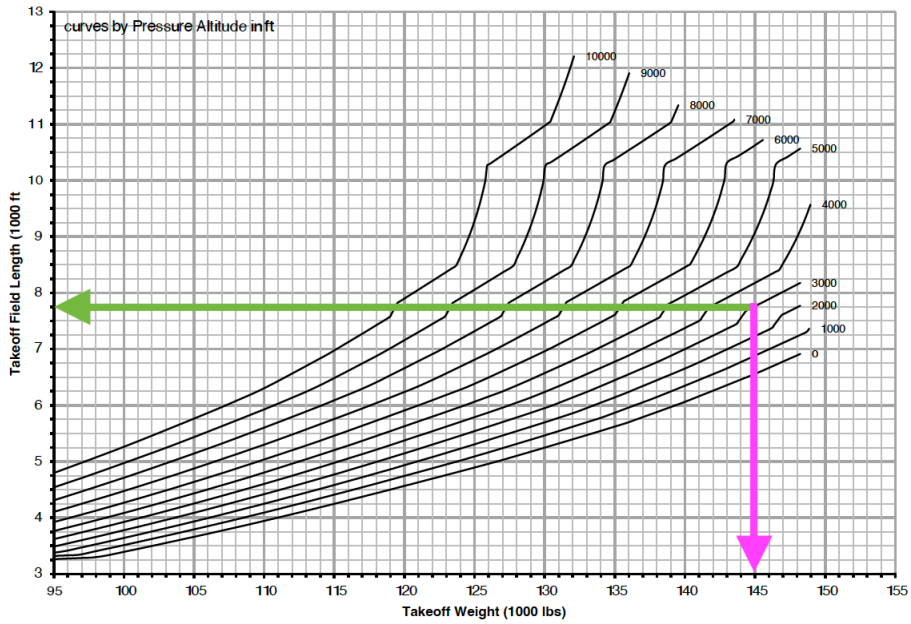

Figure 5 Takeoff field length ISA +15°C - PW1524G

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- The required runway length for takeoff with a takeoff weight of 145,000 lb is 7,750 ~ 7,800 feet.

- The required runway length for landing at MALW is 5,350 * 1.15 = 6,152 ~ 6,200 feet. (Wet runway)

- **Therefore, the required runway length is 7,800 ft.**

c) Compare the two solutions above. Briefly explain the causality between engine thrust and the runway length needed to take off at the same weight.

- The required runway length for takeoff with PW1521G engine (21,000 lbs thrust) is 10,500 feet.

- The required runway length for takeoff with PW152G engine (24,000 lbs thrust) is 7,800 feet.

- Therefore, with greater thrust produced by the aircraft engines, the runway length required for takeoff decreases. This is because more powerful engines yield higher acceleration on the runway, allowing it to reach V1 speed over a shorter distance.

d) Make a recommendation to the airline about which engine (PW1521G or PW1524G) to buy to reduce runway length.

- If the current passenger load typically supports lower takeoff weights, and the runway length at desired airports meets the requirement, the PW1521G may be the more cost-effective option. However, the PW1524G could be worth the investment for flexibility and future operational needs if runway limitations or higher payloads are expected to become more common.
- Note, for the sake of only reducing the runway length without considering the cost-benefit analysis, PW1524G is the best option.

Problem 2

Design a new runway for an international airport located 2,323 feet above sea level conditions near **Guadalajara, Spain**. The critical aircraft is the Boeing 787-9 (see picture below). The airline operator wants to fly nonstop 4,800 nautical miles (Great Circle Distance) with a full passenger load and an additional 25,000 lbs. of cargo.

The temperature at the site can be found at Weather Spark: https://weatherspark.com/y/36868/Average-Weather-in-Guadalajara-Spain-Year-Round#Sections-Temperature. If you need to find the ISA atmospheric values, you can use the table in the notes (you need to interpolate) or use a web site like Digital Dutch (https://www.digitaldutch.com/atmoscalc/).

Table 1. Aircraft Considered in Problem 1. Boeing 787-9 Landing at Atlanta Hartsfield-Jackson Airport. Source: A. A. Trani.

Aircraft Considered
Boeing 787-9 with Rolls-Royce Trent 1000 **Hi-Thrust Engines** engines. The aircraft maximum design takeoff weight is 561,500 lbs. The airline uses an aircraft with 290 seats in a two-class layout.

Aircraft Considered

a) Find the design distance flown using the Great Circle Flight Path and adjust as needed. The additional distance accounts for actual Air Traffic route conditions and to account for possible weather deviations.

- Great Circle Distance = 4800 nm
- Typical distance = 4800*1.06 = 5088 nm ~ 5100 nm

b) Use the Weather Spark website cited above to find the mean daily maximum temperature of the hottest month (design temperature) at the airport location.

- Design temperature = 90 F ~ 32 C

c) Find the difference between ISA conditions at the airport site and the design temperature.

- ISA temperature at 2323 ft above the sea level =10.4 C
- The difference between ISA conditions at the airport site and the design temperature 32 C - 10.4 C = 21.6 C

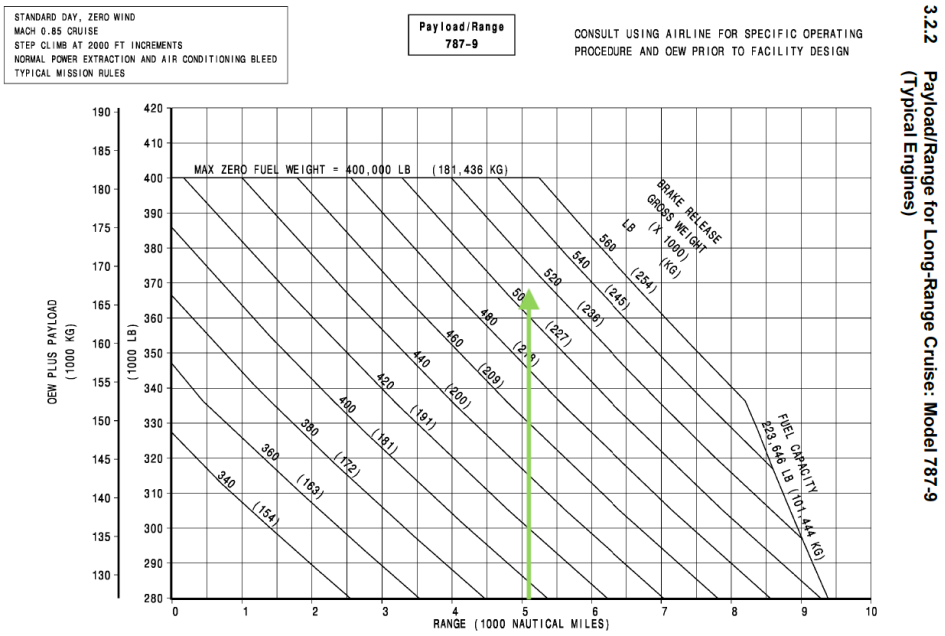
d) Estimate the Operating Empty Weight (OEW) as the lowest value in the payload-range diagram.

- 280,000 lb

e) Find the Desired Takeoff Weight (DTW) to fly the proposed route. Assume a 100% passenger load factor in your analysis and add 25,000 lbs. of cargo. Clearly state the fuel weight, operating empty weight, and payload carried. In your calculations, use the passenger weights discussed in class.

- $OEW = 280{,}000\ lb$
- $Passengers\ Load = (290\ passengers) \times (100\ kg/passenger) = 29{,}000\ \text{kg} \approx 63{,}934\ \text{lb}$
- $PYL = Passengers\ Load + 25{,}000\ lb = 63{,}934 + 25{,}000 = 88{,}934\ lb$
- $OEW + PYL = 280{,}000\ lb + 88{,}934\ lb = 368{,}934\ lb \approx 369{,}000\ \text{lb}$

- Route Length calculated in part a is 5,100 nm.
- Based on the Payload Range Diagram of the Boeing 787-9, the <u>DTW/TOW would be 510,000 lb.</u>



3.2.2 Payload/Range for Long-Range Cruise: Model 787-9 (Typical Engines)

Therefore:

- $Fuel\ Weight = DTW - (OEW + PYL) = 510{,}000\ lb - 369{,}000\ lb = 141{,}000\ lb$

f) Find the runway length needed to fly the critical route. Assume a modest 0.2% grade for the new runway.

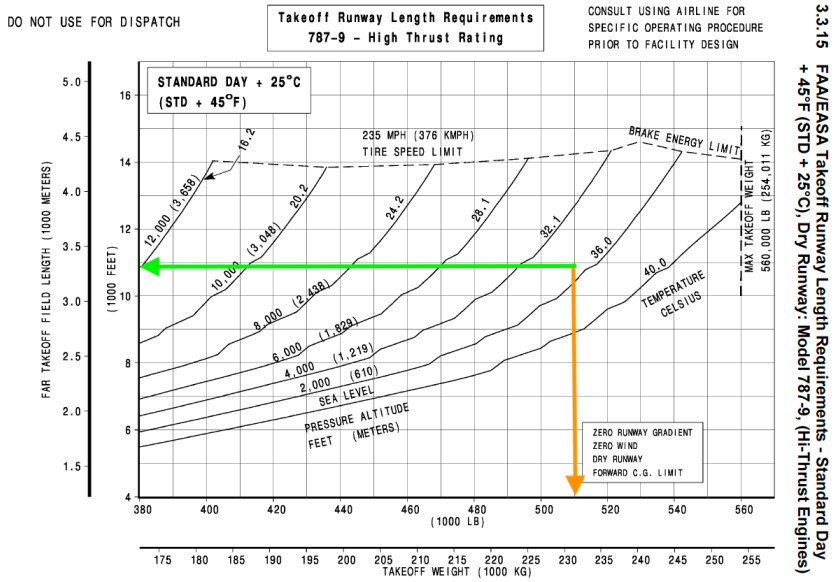
- The difference between ISA conditions at the airport site and the design temperature 32 C - 10.4 C = 21.6 C
- Use ISA + 25 C chart in the Boeing 787 document

- Takeoff runway length required is 10,900 ft without considering the runway grade.

- 10,900 * 0.002 = 21.8 ~ 22 ft difference in elevation
- 22 ft * 10 ft (runway extension for each foot of runway elevation difference) = 220 ft

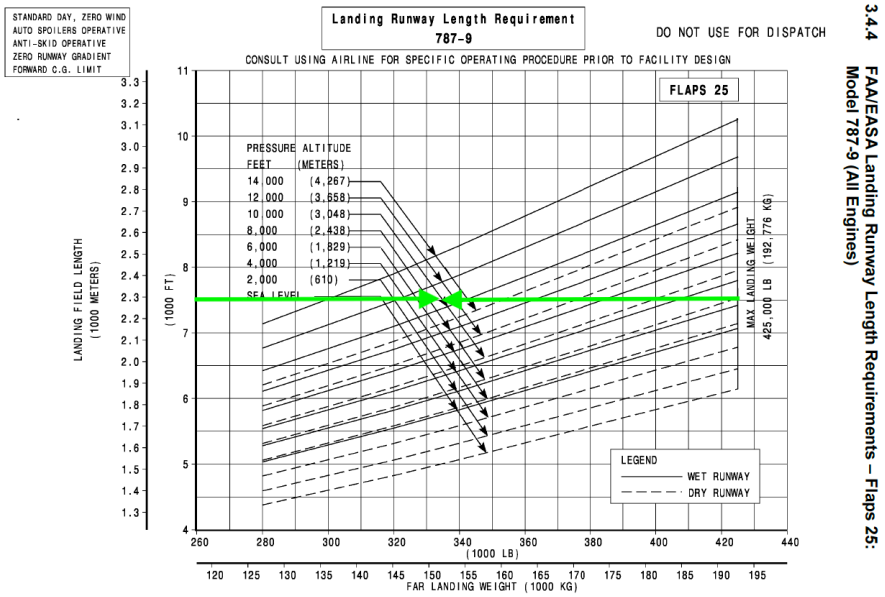
Therefore the runway length adjusted for grade is:

10,900 ft + 220 ft = 11,120 ft ~ **<u>11,100 feet</u>**



3.3.15 FAA/EASA Takeoff Runway Length Requirements - Standard Day + 45°F (STD + 25°C), Dry Runway: Model 787-9, (Hi-Thrust Engines)

- The required runway length for landing at MALW on a wet runway (using flaps 25-degrees) is 7,500 ft.
- **Therefore, the required runway length is 11,100 ft. Takeoff field length is critical.**



3.4.4 FAA/EASA Landing Runway Length Requirements – Flaps 25: Model 787-9 (All Engines)

g) Find the maximum cargo load that could be carried in the 4,800 nm (GCD) trip before reaching the Brake Energy or the Tire Speed limits.

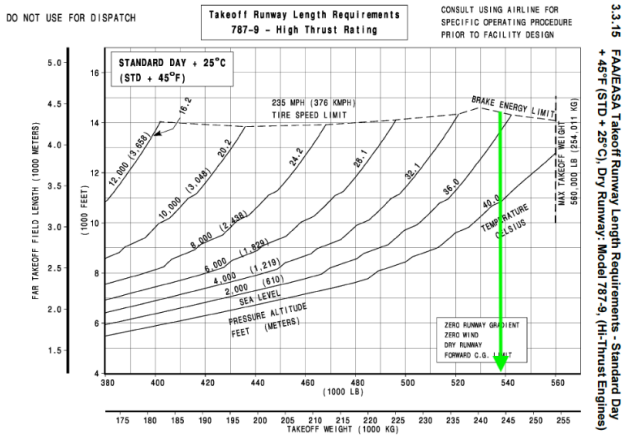
- Typical distance = 4800*1.06 = 5088 nm ~ 5100 nm
- Note: If we carefully consider the takeoff length diagram, we see that for the pressure altitude of 2,323 ft, the maximum TOW would be 539,000 lb before the airplane reaches its braking energy limit.

Based on the Payload range diagram, with a 5,100 nm range, and 539,000 lb TOW:

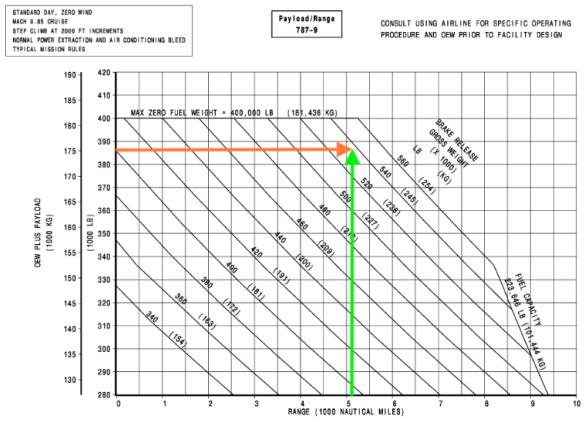
- $OEW + PYL = 385{,}000\ lb$
- $Maximum\ Payload = 385{,}000\ lb - OEW = 385{,}000 - 280{,}000\ lb = 105{,}000\ lb$
- $Passengers\ Load = (290\ passengers) \times (100\ kg/passenger) = 290{,}00\ \text{kg} \approx 63{,}934\ \text{lb}$

Therefore:

- $Maximum\ Cargo\ Load = 105{,}000\ lb - 63{,}934\ lb = 41{,}066\ lb$



3.3.15 FAA/EASA Takeoff Runway Length Requirements - Standard Day + 45°F (STD + 25°C), Dry Runway: Model 787-9, (Hi-Thrust Engines)



3.2.2 Payload/Range for Long-Range Cruise: Model 787-9 (Typical Engines)