Assignment 3: Runway Length Calculations for Large Aircraft

Date Due: September 19, 2025 Instructor: Trani

Problem 1

Estimate the runway length required to operate an Airbus A350-1000 (see Figure 1) from a large international airport with a **maximum takeoff weight of 316,000 kgs**. The **design temperature is ISA +15 degrees Celsius**. The **airport elevation is 2,000 feet above mean sea level**. The characteristics of the Airbus 350-1000 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 A350-1000 is Revision No. 15 - Jul 15/2025.

Airbus A350-1000 with Trent XWB-97 engines (97,000 lbs. of thrust each). The aircraft maximum takeoff weight is 316,000 kgs. The seating configuration is **350 seats in three cabin classes**.

Figure 1. Aircraft Considered in Problem 1. Airbus 350-1000 Taxiing at Atlanta Hartsfield-Jackson Airport. Source: A. A. Trani.

a) Find the runway length needed to operate the Airbus A350-1000 at maximum takeoff weight from the new airport under I**SA +15 degrees Celsius conditions**.

Takeoff distance = 3750 meters (12,300 feet)

Dry runway landing distance = 2256 meters (7400 feet)

Adjustment for wet pavement conditions = add 15% to the dry landing distance

Adjusted landing distance = 1.15 * 2256 = 2594 meters (8,510 feet or round to 8,500 feet)

The recommended runway length is 12,300 feet.

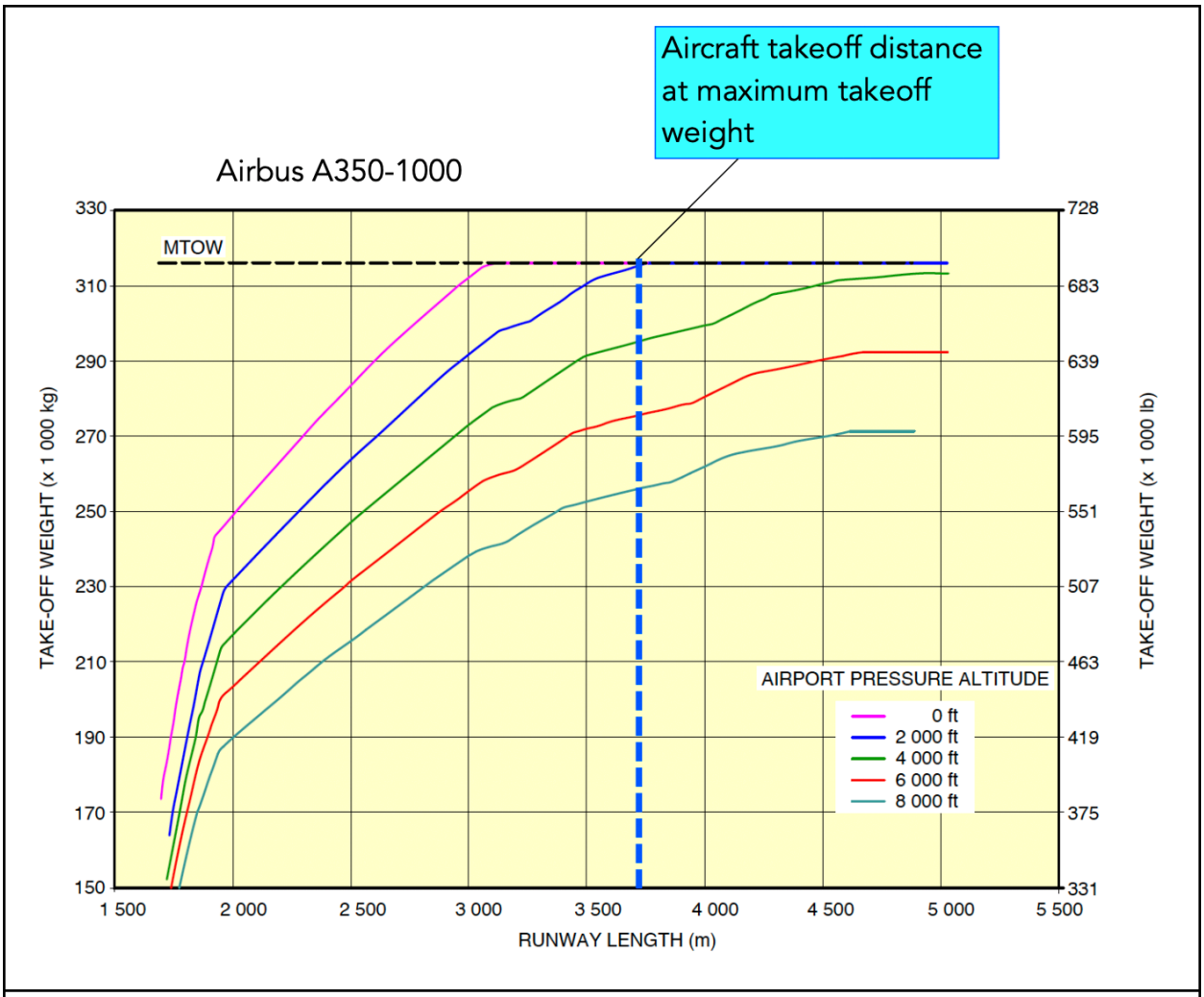


Figure 1. Takeoff Distance Performance for Airbus A350-1000. ISA + 15 deg. Celsius Conditions. Source: Airbus.

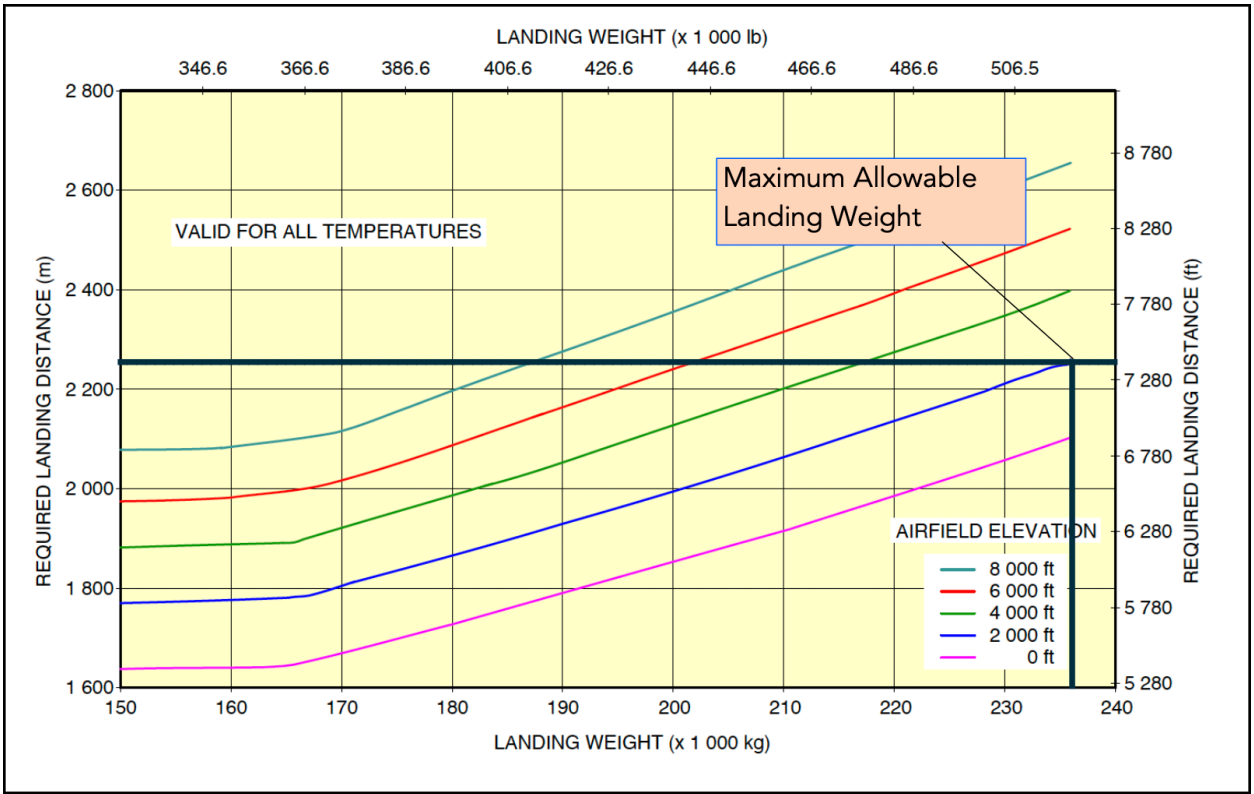


Figure 1. Landing Distance Performance for Airbus A350-1000. Dry Runway. Source: Airbus.

b) State the design temperature for part (a) in degrees Celsius. Consider the airport site is 2,000 feet above mean sea level conditions.

ISA temperature at 2,000 feet is 11.03 deg. Celsius.

Hence, ISA + 15 at 2,000 feet is 26.03 deg. Celsius.

c) Find the runway length needed to operate the Airbus A350-1000 at maximum takeoff weight from the new airport under I**SA conditions**.

The runway length is 3550 meters (11,700 feet - rounded). A reduction in temperature of 15 deg. C reduces the runway length required by 600 feet.

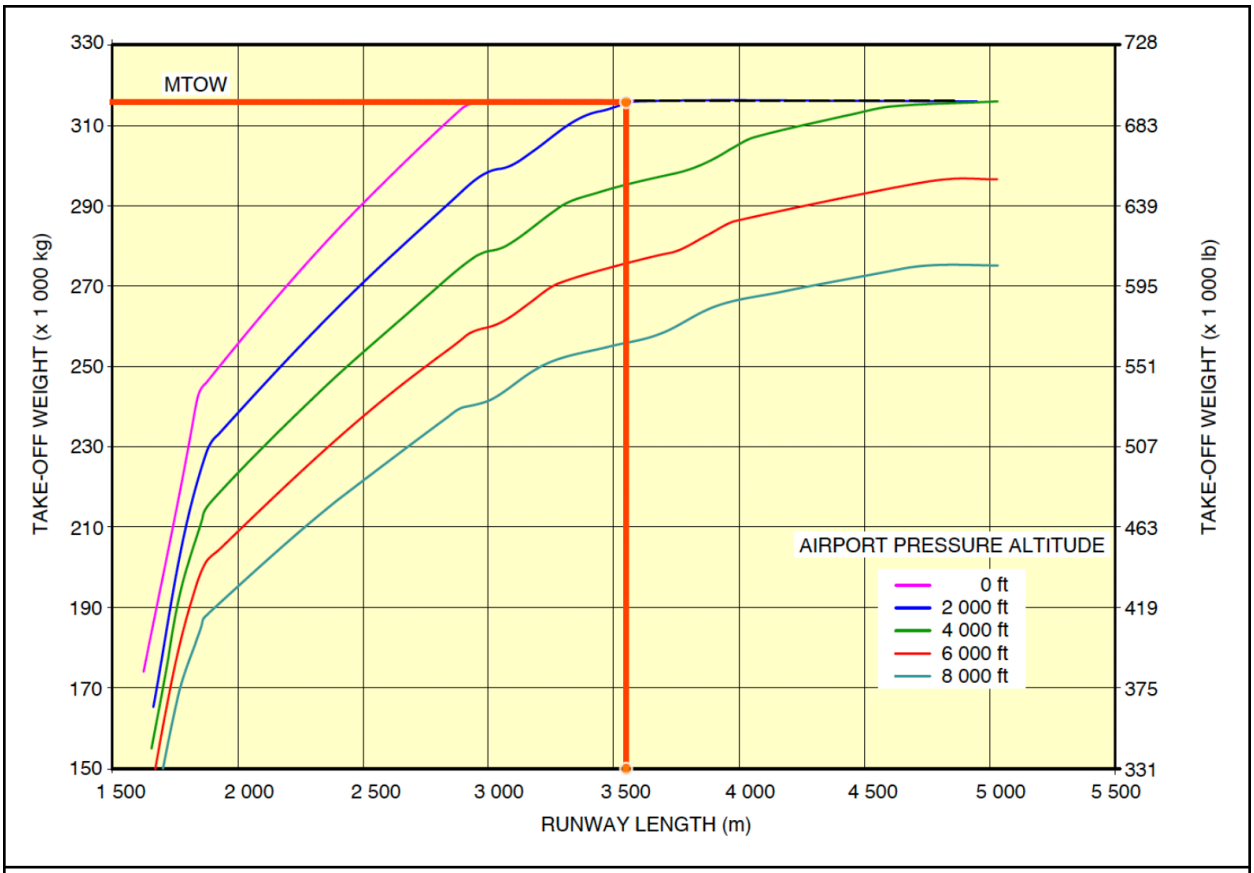


Figure 1. Takeoff Distance Performance for Airbus A350-1000. ISA Conditions. Source: Airbus.

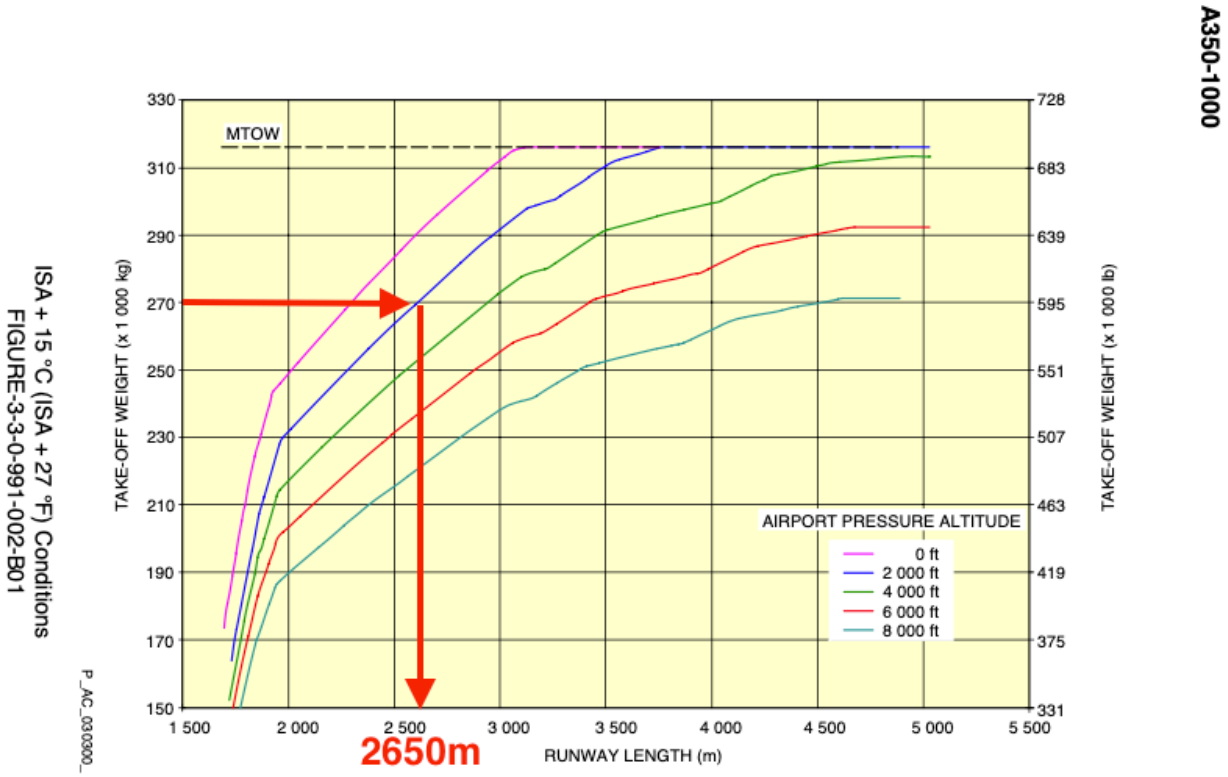
d) Compare the two solutions above. Briefly explain the changes in runway length as the design temperature changes.

A reduction in temperature produces higher air density. Higher air density allows the aircraft engines to generate more thrust allowing the aircraft to accelerate more quickly on the runway. Higher density also reduces the stalling and takeoff speeds. Both effects reduce the runway length.

$$a_x = \frac{1}{m}\left(T\left(V,\rho\right) + \frac{1}{2}\rho V^2 S\left(C_L f_{roll} - C_D\right) - mg f_{roll}\right)$$

e) One day, the plane departs from the new runway with takeoff weight at 270 metric tons. Estimate the runway used assuming a design temperature of **ISA +15 degrees Celsius.**

A takeoff with a Desired Takeoff Weight of 270 metric tons requires 2,650 meters (8,700 feet) of takeoff distance. Note that this takeoff distance is very close to the landing distance estimated in part (a).



Problem 2

This problem is a series of follow-up questions to Problem 1. The aircraft in question is the Airbus A350-1000 operating from a new airport located 2,000 feet above mean sea level conditions. Problem 2 assumes that you calculated the runway length (part a of Problem 1 allowing the aircraft to depart at maximum takeoff weight.

a) Considering your solution to Problem 1 part (e), use the basic equation of motion discussed in class to explain the change in runway length with changes in aircraft mass.

The basic equation of motion is shown below. A reduction in the aircraft mass (weight) produces higher acceleration in the takeoff run. Higher acceleration yields shorter times to reach the desired takeoff speed.

A reduction in takeoff mass (weight) produces lower stall and takeoff speeds. This second effect contributes to a reduction in runway length.

$$a_x = \frac{1}{m}\left(T\left(V,\rho\right) + \frac{1}{2}\rho V^2 S\left(C_L f_{roll} - C_D\right) - mg f_{roll}\right)$$

b) Use the A350-1000 payload-range diagram to estimate the maximum range for the aircraft with **350 passengers** (no cargo). Use the average passenger weight provided in class. Use the payload-range diagram under ISA conditions (only one given in the Airbus document).

The aircraft range is estimated to be 8,300 nautical miles (see figure below). The aircraft departs at the maximum takeoff weight.

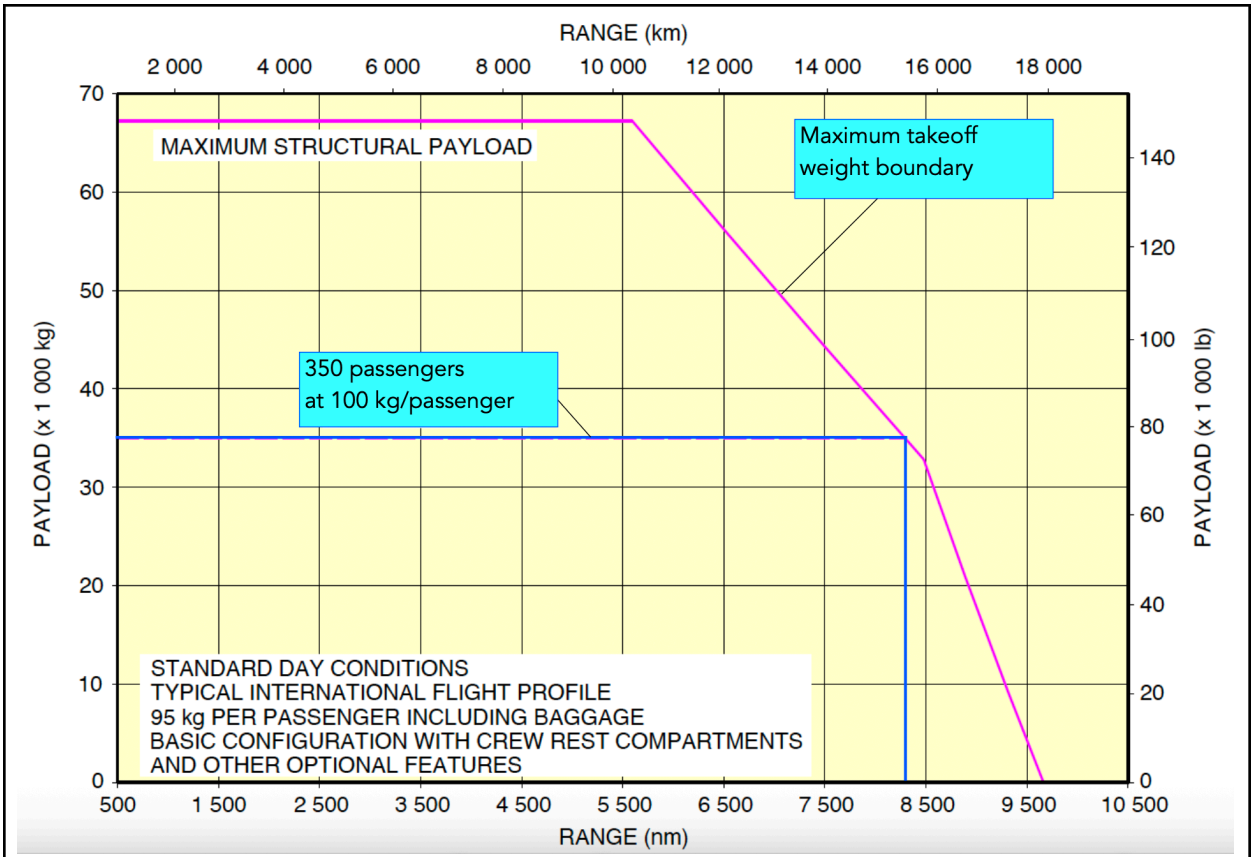


Figure 1. Payload-Range Diagram for Airbus A350-1000. Source: Airbus.

c) Use the A350-1000 payload-range diagram to estimate the maximum range for the aircraft with 350 passengers plus 20 metric tons of cargo.

The aircraft range is estimated to be 6,700 nautical miles (see figure below). The aircraft departs at the maximum takeoff weight (316 metric tons).

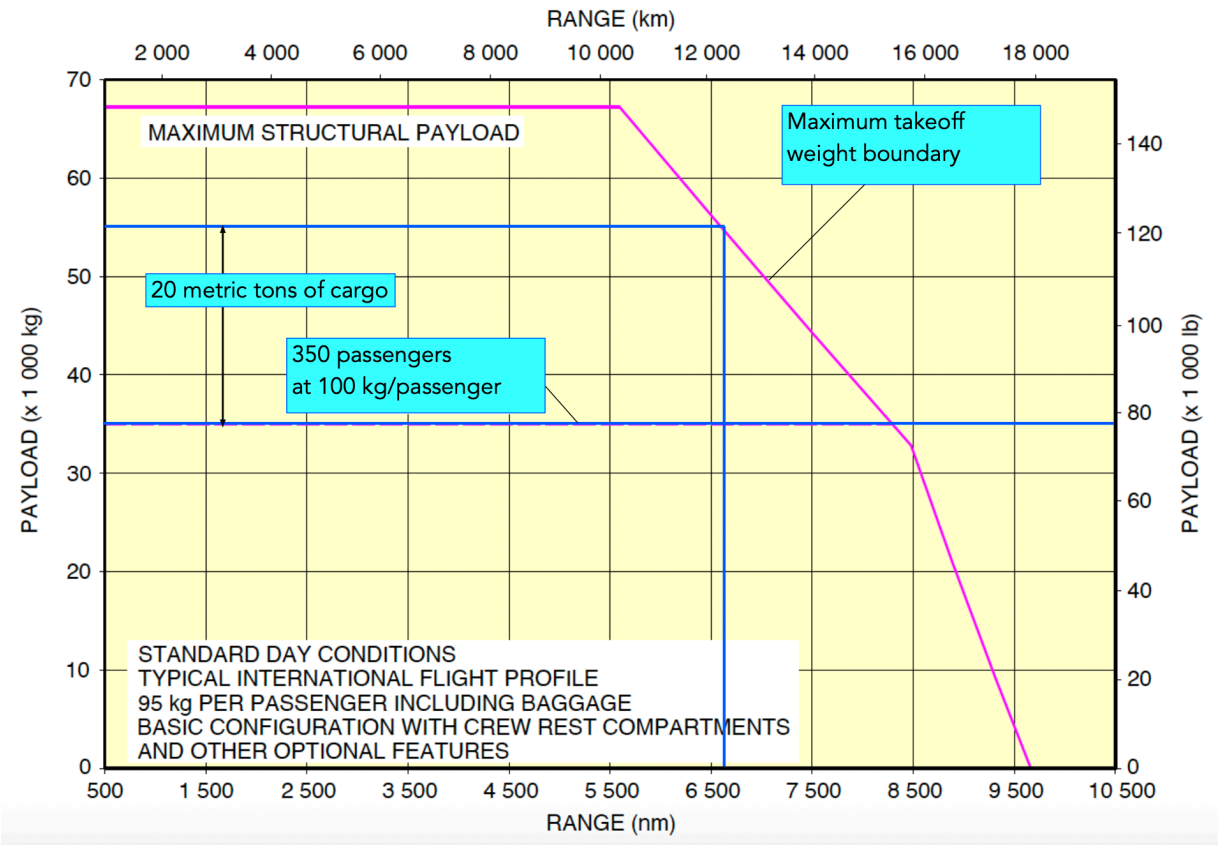


Figure 1. Payload-Range Diagram for Airbus A350-1000. Source: Airbus.

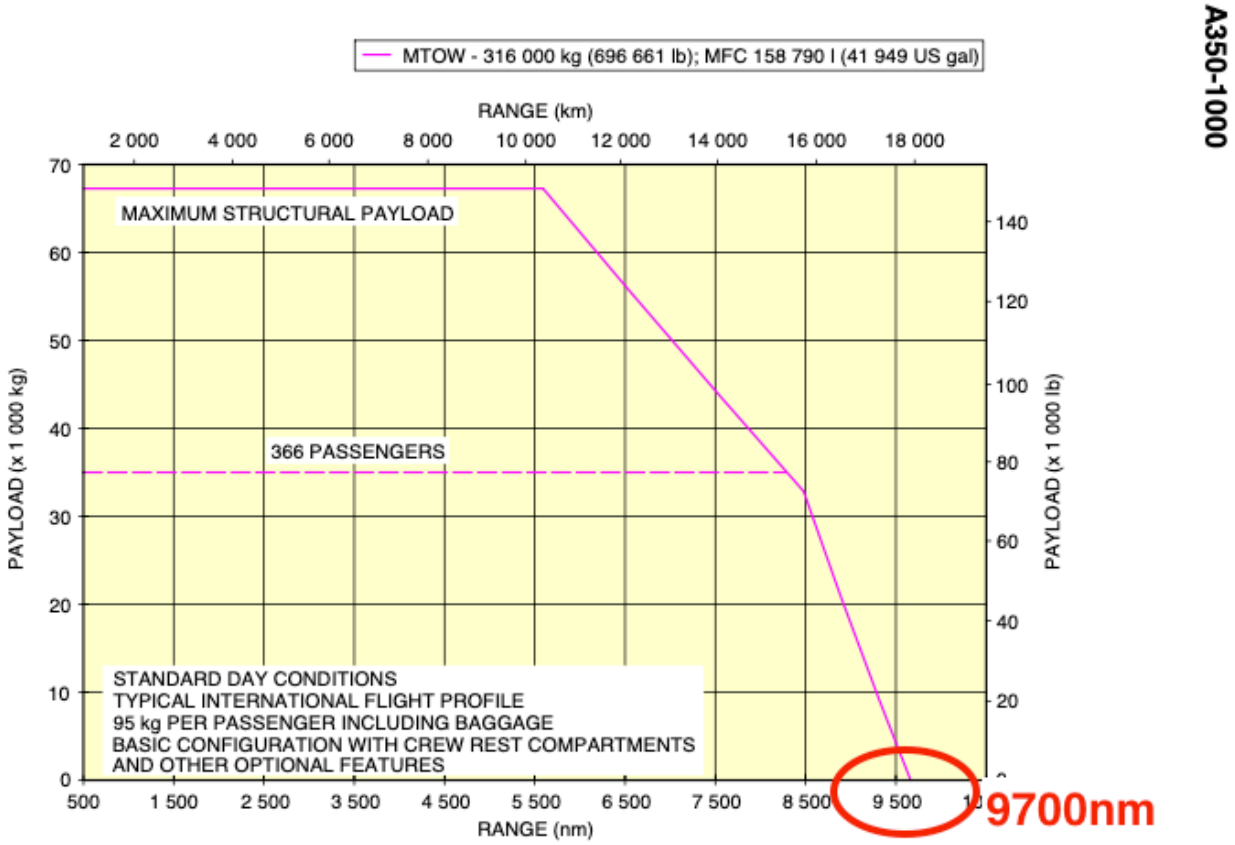
d) Find the change in aircraft range for each metric ton added to the flight.

Adding 20,000 kilograms (44,000 lbs.) of cargo reduces the aircraft range by 1,600 nautical miles from 8,300 nm to 6,700 nm. The relationship between range and cargo is:

For each kilogram added in cargo, the aircraft range is reduced by 0.08 nautical miles (1600 nm / 20000 kgs).

e) State the Airbus A350-1000 ferry range?

The ferry range is 9700 nautical miles.



Problem 3

The airport authority of Salt Lake City Airport International Airport (SLC) wants to evaluate the current runway length for runway 35. The airport authority plans to add additional service with wide body aircraft using the Boeing 787-9 (see picture below). The airline operator wants to fly nonstop from Salt Lake City to Seoul Incheon International Airport (ICN) with a full passenger load. Use the latest Boeing 787-9 data provided by Boeing (see document D6-58333 in Figure 2). You can find the airport elevation conditions at Salt Lake City using Airnav.com.

The design temperature at the site can be found using the Climate Explorer web site. 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 to facilitate the analysis (https://www.digitaldutch.com/atmoscalc/).

Boeing 787-9 with **Rolls-Royce Typical 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. Assume the Operating Empty Weight is 280,000 lbs. (from the payload range diagram).

787 Airplane Characteristics for Airport Planning

DOCUMENT NUMBER:	REVISION:	REVISION DATE:
D6-58333	**REV P**	**December 2024**

Figure 2. Aircraft Considered in Problem 3. Boeing 787-9 Taxiing at Seoul Gimpo Airport. Source: A. A. Trani.

a) Find the design distance flown using the Great Circle Flight Path Mapper demonstrated in class and adjust the flight path distance by 6%. The additional distance accounts for actual Air Traffic route conditions and to account for possible weather deviations.

Great circle distance: 5131nm

6% adjustment for deviation: 307.86nm

Total = 5438.86nm

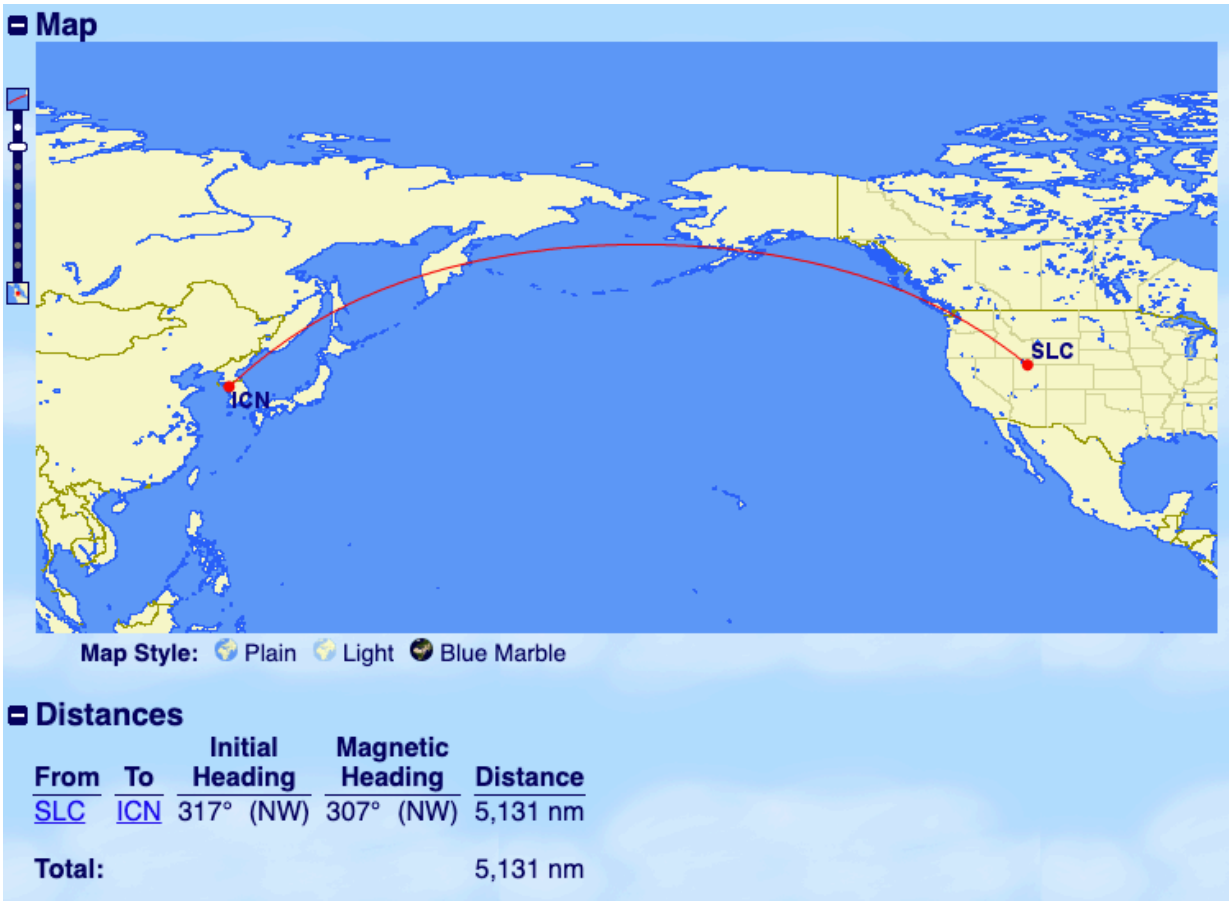


Figure X. Great Circle Distance between SLC and ICN

b) Find the mean daily maximum temperature of the hottest month (design temperature) at the airport location. **Use higher emissions in the calculation.**

SLC airport elevation is 4,131 feet above mean sea level conditions.

Runway 17/35 is 9596 feet long.

SLC design temperature is 90.5 degrees Fahrenheit (higher emissions 2020-2040).

ISA temperature at 4,131 feet is 44.3 degrees Fahrenheit.

Difference in temperatures is 46.2 degrees Fahrenheit.

Use ISA + 45 deg. Fahrenheit takeoff performance charts in your analysis.

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

Difference in temperatures is 46.2 degrees Fahrenheit. (90.5-44.3 = 46.2)

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

Table 1 shows the calculations. DTW is 490,000 lbs. DTW is below the maximum takeoff weight (561,500 lbs.).

Table 1. Boeing 787-9 Analysis with 100% Load Factor. Maximum design takeoff weight of 561,500 lb (254,692). With 290 seats in a two-class layout.		
Parameter	Kilograms	Pounds
OEW	127,273	280,000
PYL	29,000	63,800
OEW + PYL	156,273	343,800
DTW	**222,727**	**490,000**
FW	66,455	146,200
Passengers	290	
Runway Length (takeoff)	**11,800 feet**	**11,800 feet**
Corrected Runway Length (Takeoff)	**11,900 feet**	**11,900 feet**
Runway Length (Landing)	7,600 feet	7,600 feet
Route Distance (nm)	5131	
Adjusted Route Distance (nm)	5439	

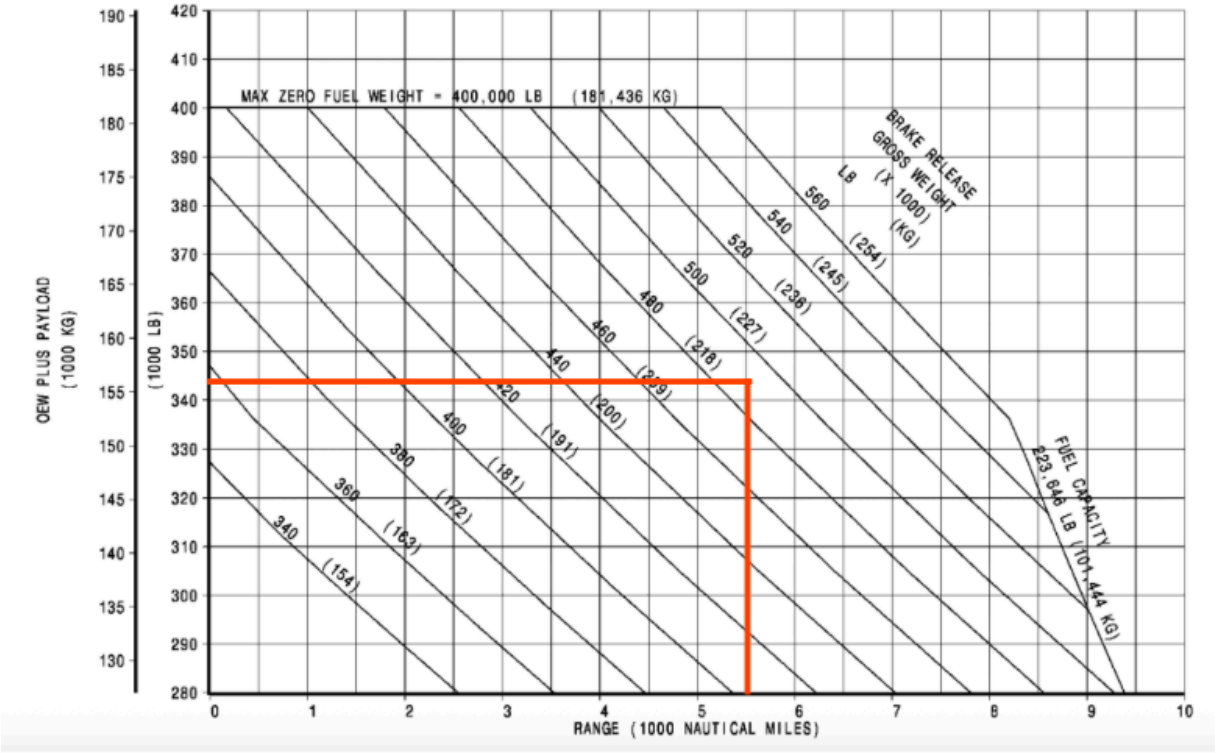


Figure 2. Payload-Range Diagram Boeing 787-9. DTW ~ 490,000 lbs.

e) Find the runway length needed to fly the route SLC-ICN from runway 35.

Existing runway length = 9596 x 150 ft. (source: airnav.com)

Base runway 11,800 feet (from our calculation)

Grade correction is necessary in your solution. Use Airnav to estimate the runway gradient.

Elevation of runway threshold 17 = 4221.7 ft.

Elevation of runway threshold 35 = 4226.8 ft.

Difference in elevations = 5.1 feet

Add 51 feet to the solution.

Average grade = $\frac{5.1}{9596} * 100 = 0.05\%$

Corrected runway length = 11,851 or 11,900 ft rounding to the nearest 100.

f) Find the runway extension needed on runway 35 to support the Boeing 787-9 departures.

Runway extension = 11,900 - 9596 = 2,304 feet.

g) Compare the runway length with the extension and other runways at SLC.

The new runway 35 will have similar length to runways 16L/34R (12,002 feet) and 16R/34L (12,000 feet).

Runway	Length (feet)	Width (feet)
16L/34R	12,002	150
16R/34L	12,000	150
17/35	11,900	150
14/32	4,893	150

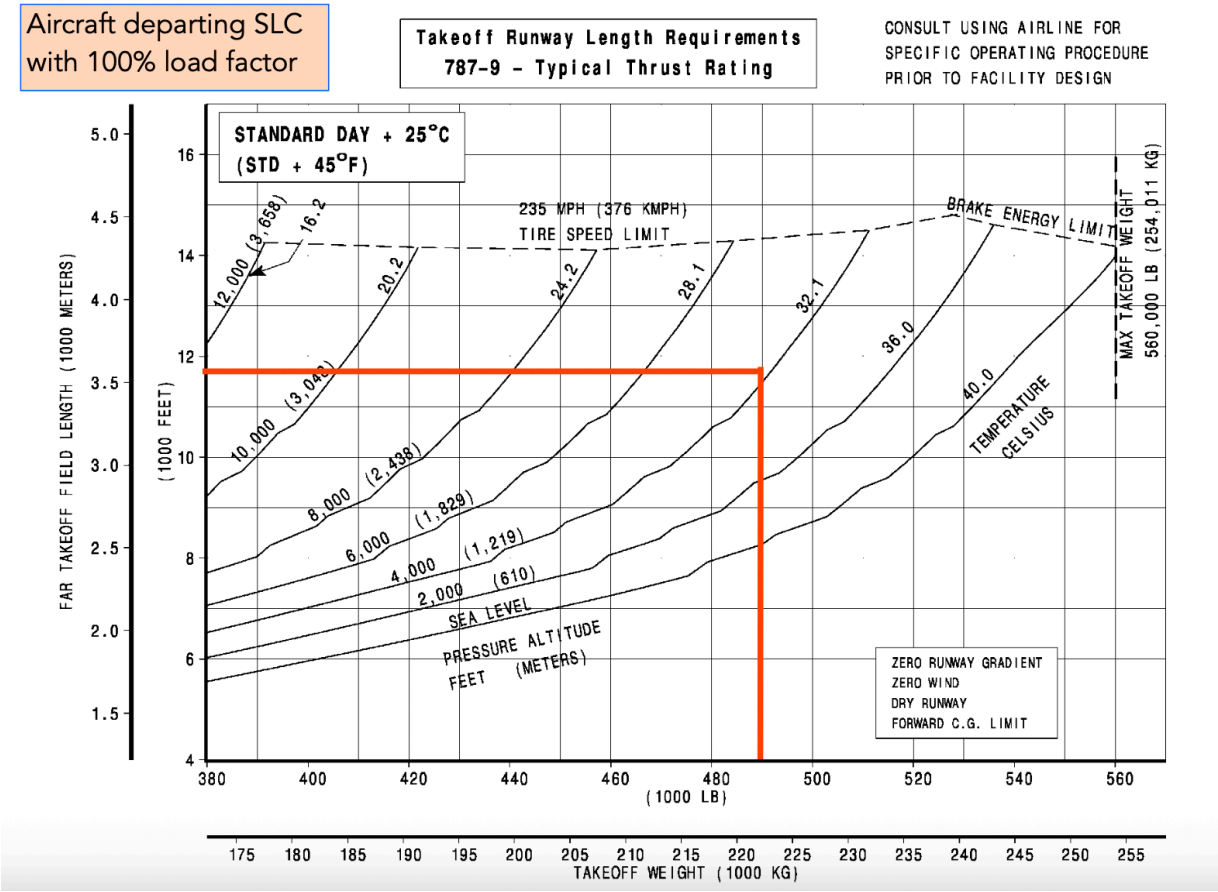


Figure 3. Takeoff Runway Length Required for Boeing 787-9. DTW ~ 222,000 kilograms. ISA + 45 deg. Fahrenheit.