Assignment 3: Runway Length Calculations for Large Aircraft

Solution Instructor: Trani

Problem 1

Design a new runway for an international airport located 4,200 feet above sea level conditions near Pereira, Colombia. The critical aircraft is the Boeing 777-300ER (see picture below). The airline operator wants to fly nonstop 4,500 nautical miles (Great Circle Distance). The temperature at the site can be found at Weather Spark: https://weatherspark.com/y/22431/Average-Weather-in-Pereira-Colombia-Year-Round. 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 777-300ER Landing at Atlanta Hartsfield-Jackson Airport. Source: A. A. Trani.

Aircraft Considered
Boeing 777-300ER with General Electric GE90-115B1 engines. The aircraft maximum design takeoff weight is 775,000 lb. The airline uses an aircraft with 350 seats in a three-class layout (seating layouts vary from airline to airline).


OUTPUT:

The design temperature at PEI is 79 degrees Fahrenheit

The ISA temperature at PEI is 44 degrees Fahrenheit

Use the ISA + 49 degF chart (ISA + 25 deg.C).

The corrected range (accounting for detours) between PEI and the destination is: 4770 nautical miles.

The payload weight is: 69,300 lbs

The OEW + PYL is: 479,300 lbs

Please consult the payload-range diagram for the B77W and obtain the DTW, which is found at the intersection of 4770 nm and an OEW+PL of 479,300 lbs

Please enter the DTW (in lbs) you obtained in the previous step, then press Enter: 675,000 lbs.

The fuel weight for this flight is: 195,700 lbs

The takeoff length required (ft): ~12,200 ft
The landing length required (ft): ~7,350 ft

The takeoff length needed is greater than the landing length needed. Therefore, the takeoff length dominates

Therefore, the minimum runway length needed is: 12,200 ft

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

4,770ft

b) Find the mean daily maximum temperature of the hottest month (design temperature) using the Weather Spark web site cited above.

79 deg F

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

ISA temp: 44 deg F

Design Temp: 79 deg F

Delta = 35 deg F. Therefore, use the Boeing data for Standard Day + 49 deg. F. (also called ISA + 49 deg. F) since there is no data for Standard Day + 35 deg. F.

d) Find the OEW as the lowest value available in the payload-range diagram.

410,000 lb

e) Find the Desired Takeoff Weight (DTW) to fly the longest route. Assume a 90% passenger load factor in your analysis (i.e., 90% of the seats are full). Clearly state the fuel weight, operating empty weight and payload carried. Use the passenger weights discussed in class.

675,000 lb

f) Find the runway length needed to fly the critical route.

See MATLAB program output:
Takeoff length required (ft): ~12,200 ft
Landing length required (ft): ~7,350 ft

The takeoff length needed is greater than the landing length needed. Therefore, the takeoff length dominates

Therefore, the runway length needed is: 12,200 ft.

g) Find the flap setting used by the pilot to operate the Boeing 777-300ER out of the airport.

For takeoff, the flap setting for **takeoff is 15 degrees**. For landing, the highest flap setting available is Flaps 30.

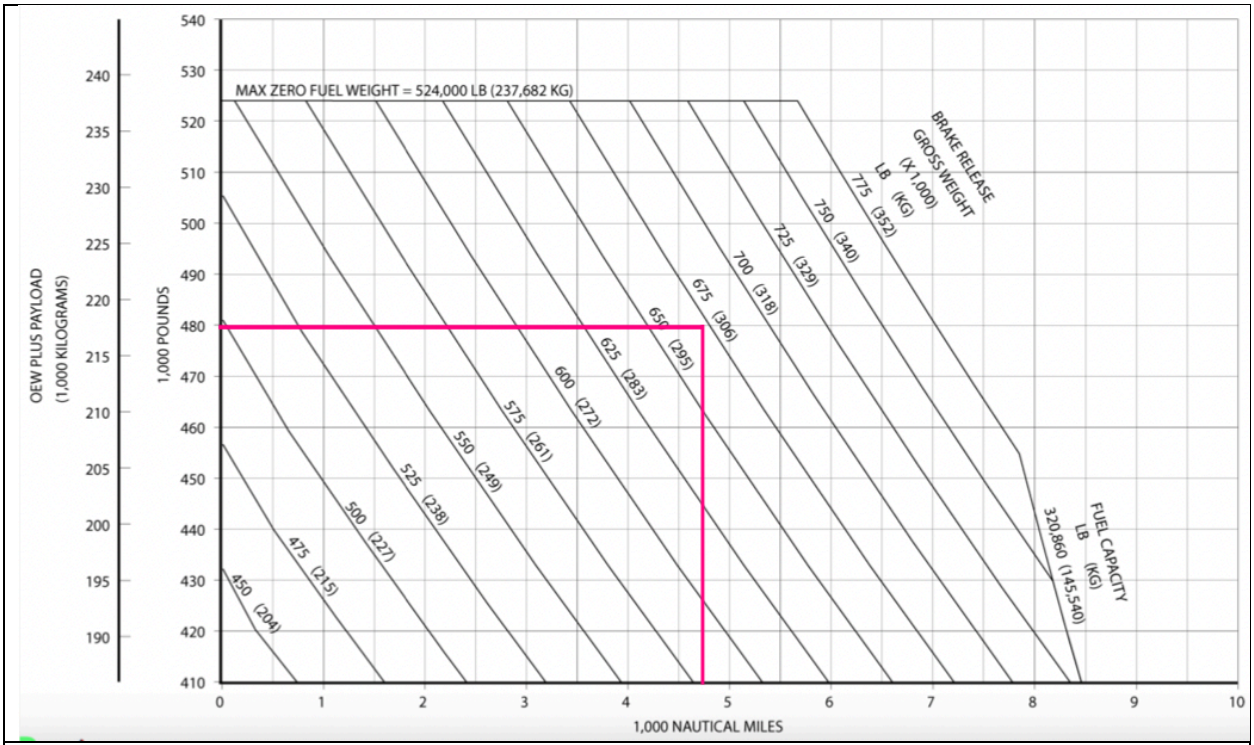


Figure 1. Payload-Range Diagram for Boeing 777-300ER in Problem 1.

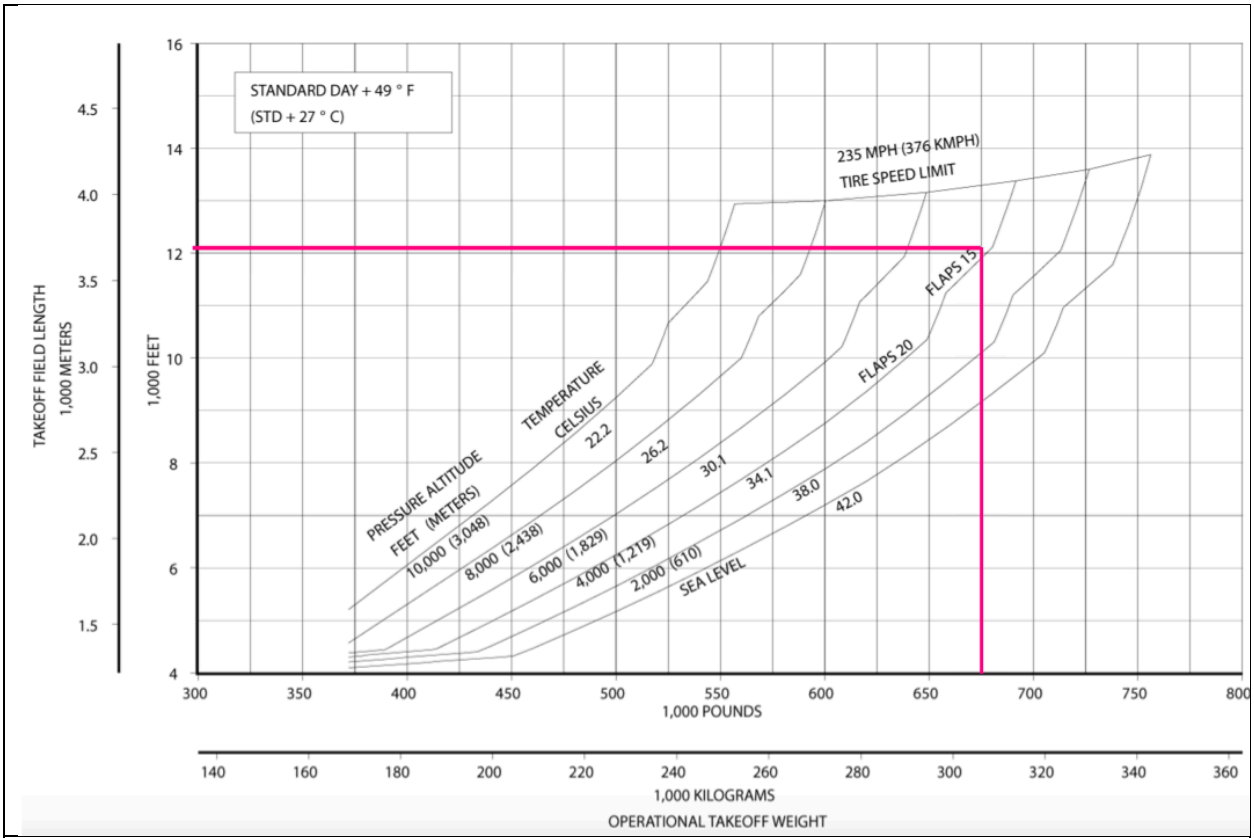


Figure 2. Runway Length Required for Boeing 777-300ER Operating at 675,000 lbs. (DTW). Note **the Airport Conditions are Standard Day + 49 deg.F.**

Problem 2

A new airline is discussing future operations from John Wayne/Orange County Airport (SNA) airport. The airline plans to use the Boeing 737-8 max with characteristics shown in Table 2. The airline plans to fly from SNA to Seattle-Tacoma (SEA) and to Salt Lake City (SLC). For this analysis, use the latest version of the Boeing 737-8 Max documents for airport design (Revision H published on March 2023).

Table 2. Aircraft Considered in the SNA Airport Evaluation. Picture Source: A.A. Trani.

Aircraft	*Engine*	*Remarks*
Boeing 737-8 (Max) with CFM LEAP-1B28B1 engines. Aircraft maximum design takeoff weight is 182,200 lb. 178 seats in a two-class layout. See Table 2.2.2 in Boeing 737-8 Document (revision H). **Note:** Boeing does not publish the operating empty weight (OEW) of the Boeing 737-8.However, The payload range diagram for this aircraft provides the value of OEW indirectly because the y-axis in the payload-range diagram is OEW + Payload. For the Boeing 737-8 Max the OEW is approximately 98,000 lbs.		
		

a) Find the adjusted distance to be flown between the two Origin-Destination airport pairs. Use the Great Circle Flight Path mapper link provided in our interesting web sites (http://www.gcmap.com//). Add 6% to the distances estimated by the Great Circle mapping application to account for real Air Traffic route conditions and to account for possible weather deviations from the shortest flight path.

SNA-SEA:

Unadjusted range (nm): 850

Adjusted stage length = actual stage length * 1.06:
Adjusted stage length = 850 nm * 1.06 = 901 nm

SNA-SLC:

Unadjusted range (nm): 511

Adjusted stage length = 511 nm * 1.06 = 542 nm

b) Find the Desired Takeoff Weight (DTW) to fly the two proposed routes. Assume a 90% passenger load factor in your analysis (i.e., 90% of seats are full). Clearly state the fuel weight, operating empty weight and payload carried. Use the passenger weights discussed in class.

Route 1 (SNA-SEA):

The corrected range (accounting for detours) between SNA and SEA is: 901 nautical miles

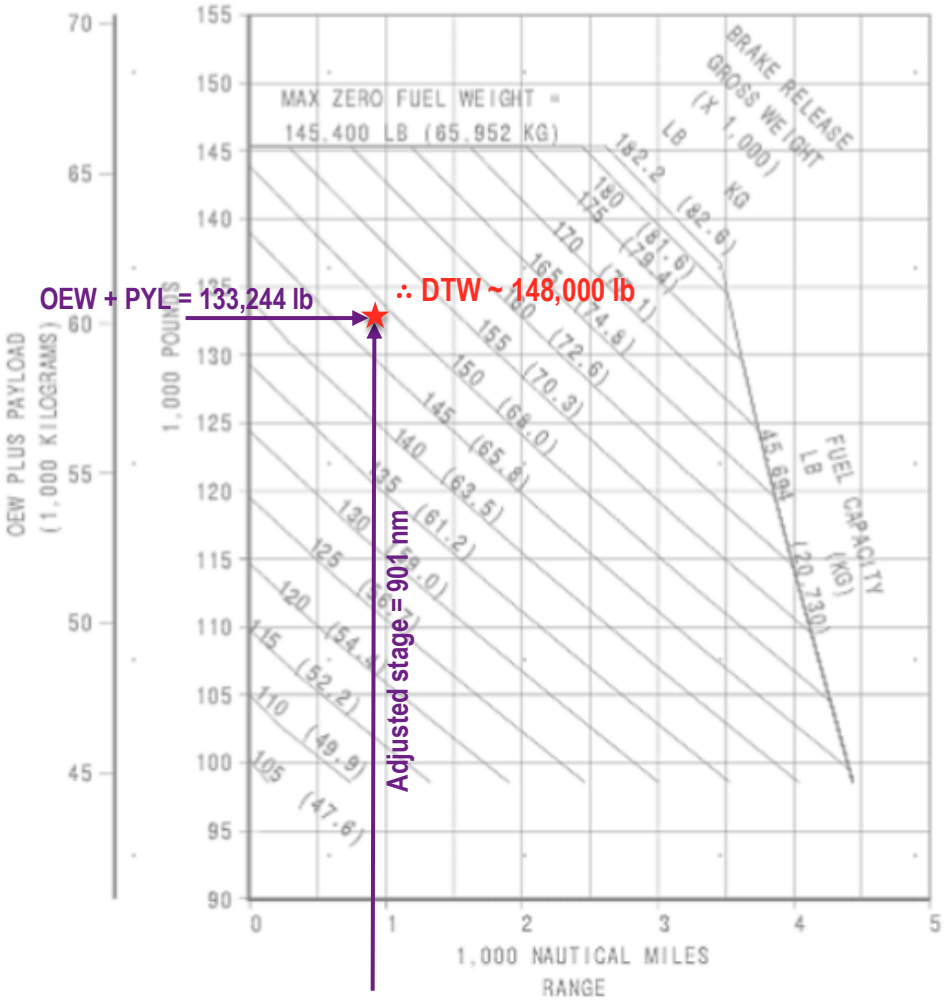
The payload weight is: 35,244 lbs

The OEW + PYL is: 133,244 lbs

Please consult the payload-range diagram for the B737-8 MAX and obtain the DTW, which is found at the intersection of 901 nm and an OEW+PL of 133244 lbs.

Payload/Range
737-8 / -8-200 (LEAP-1B Series)

- STANDARD DAY, ZERO WIND
- CRUISE MACH = LRC
- NORMAL POWER EXTRACTION AND AIR CONDITIONING BLEEDS
- TYPICAL MISSION RULES
- CONSULT USING AIRLINE FOR SPECIFIC OPERATING PROCEDURE AND OEW PRIOR TO FACILITY DESIGN



Manual Calculation:

Payload weight (PYL):

$$PYL = no.pax \times \frac{weight}{pax} \times \frac{load\ factor\ (in\ \%)}{100}$$

$$= 178\ pax \times \frac{220\ lb}{pax} \times \frac{90}{100}$$

$$= \mathbf{35,244\ lbs}$$

Operating empty weight (OEW) Plus PYL:

$$OEW + PYL = 98{,}000\ lbs + 35{,}244\ lbs$$

$$= \mathbf{133,244\ lbs}$$

Fuel Weight (FW):

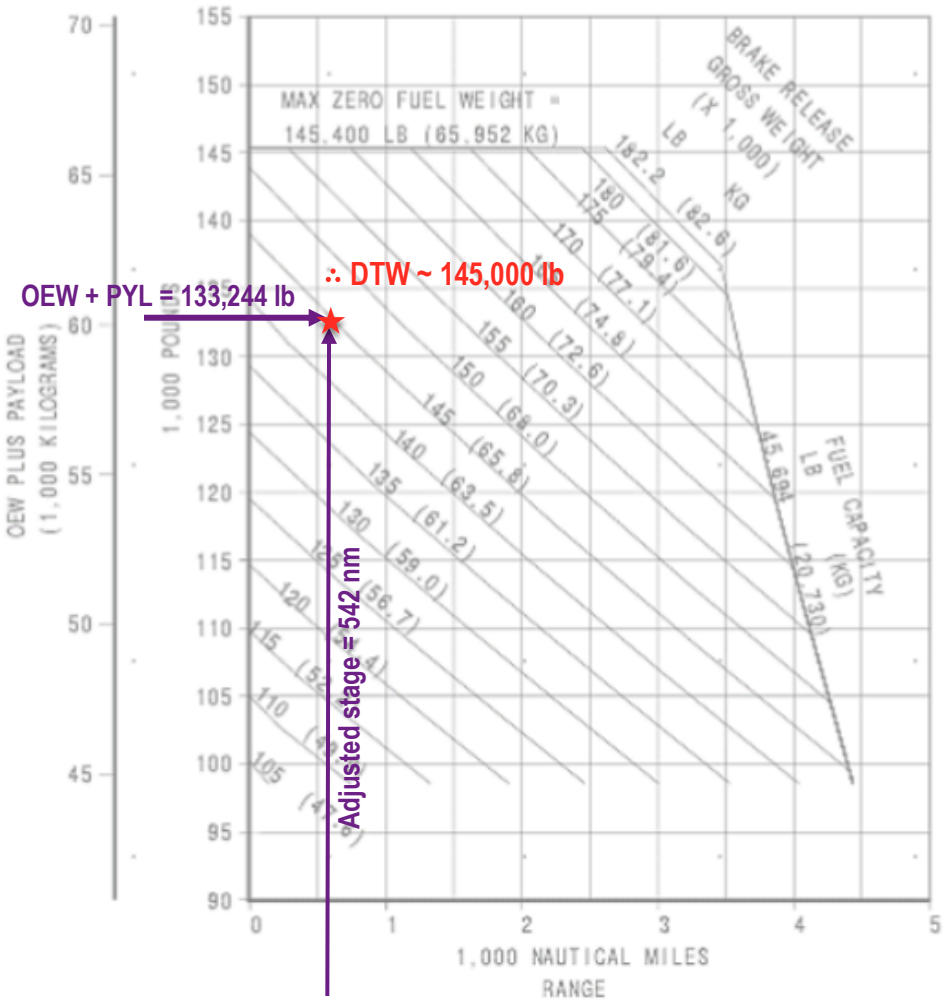
$$FW = DTW - (OEW + PYL) = 148{,}000\ lbs - 133{,}244\ lbs$$

$$= \mathbf{14,756\ lbs}$$

Route 2 (SNA-SLC):

Payload/Range
737-8 / -8-200 (LEAP-1B Series)

- STANDARD DAY, ZERO WIND
- CRUISE MACH = LRC
- NORMAL POWER EXTRACTION AND AIR CONDITIONING BLEEDS
- TYPICAL MISSION RULES
- CONSULT USING AIRLINE FOR SPECIFIC OPERATING PROCEDURE AND OEW PRIOR TO FACILITY DESIGN



Manual Calculation:

Payload weight (PYL):

$$PYL = no.pax \times \frac{weight}{pax} \times \frac{load\ factor\ (in\ \%)}{100}$$

$$= 178\ pax \times \frac{220\ lb}{pax} \times \frac{90}{100}$$

$$= \mathbf{35,244\ lbs}$$

Operating empty weight (OEW) Plus PYL:

$$OEW + PYL = 98{,}000\ lbs + 35{,}244\ lbs$$

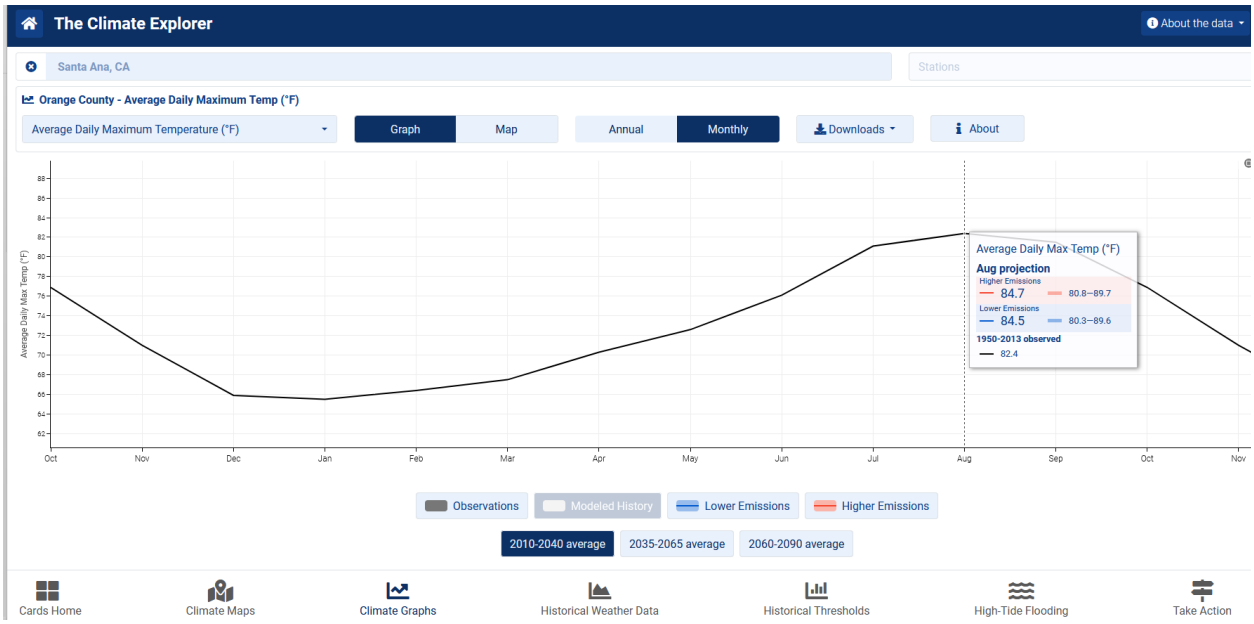
$$= \mathbf{133,244\ lbs}$$

Fuel Weight (FW):

$$FW = DTW - (OEW + PYL) = 145{,}000\ lbs - 133{,}244\ lbs$$

$$= \mathbf{11,756\ lbs}$$

c) Find the mean daily maximum temperature of the hottest month (design temperature) using the Climate Explorer website (https://crt-climate-explorer.nemac.org/climate_graphs).



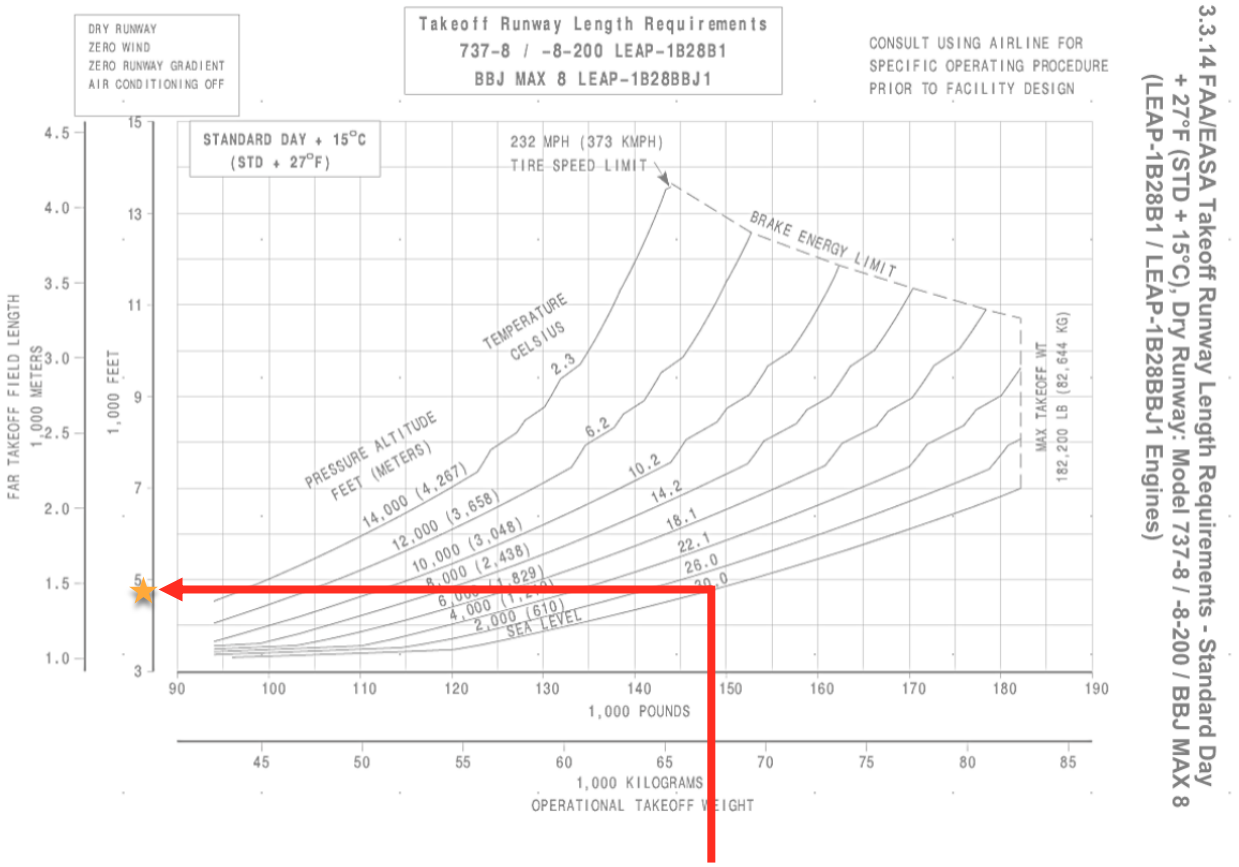
The hottest month of the year in Santa Ana, CA is August, where the average daily max temperature is 82.4 deg F.

d) Find the runway length needed for the critical route. Determine if SNA has enough runway length to support the flight. Remember to calculate the required takeoff and the landing distances in your analysis.

The design temperature at SNA is 82.4 degrees Fahrenheit
The ISA temperature at SNA is 58.8 degrees Fahrenheit
Use the ISA + 27 degF chart

The critical route is SNA-SEA because it requires the higher DTW, therefore the higher runway length.

Takeoff analysis:



***Conclusion*: *Runway Length required for takeoffs* $\cong 4,800\ ft$**

Landing analysis:

Inputs needed:

- Maximum allowable landing weight (MLW) for B737-8 MAX (in lbs): 150,300

Calculations:

If DTW > MLW, use **MLW** for landing analysis
Elseif MLW > DTW, use **DTW** for landing analysis

Desired takeoff weight (DTW): 148,000 lbs.
Max allowable landing weight (MLW): 150,300 lbs.
MLW > DTW

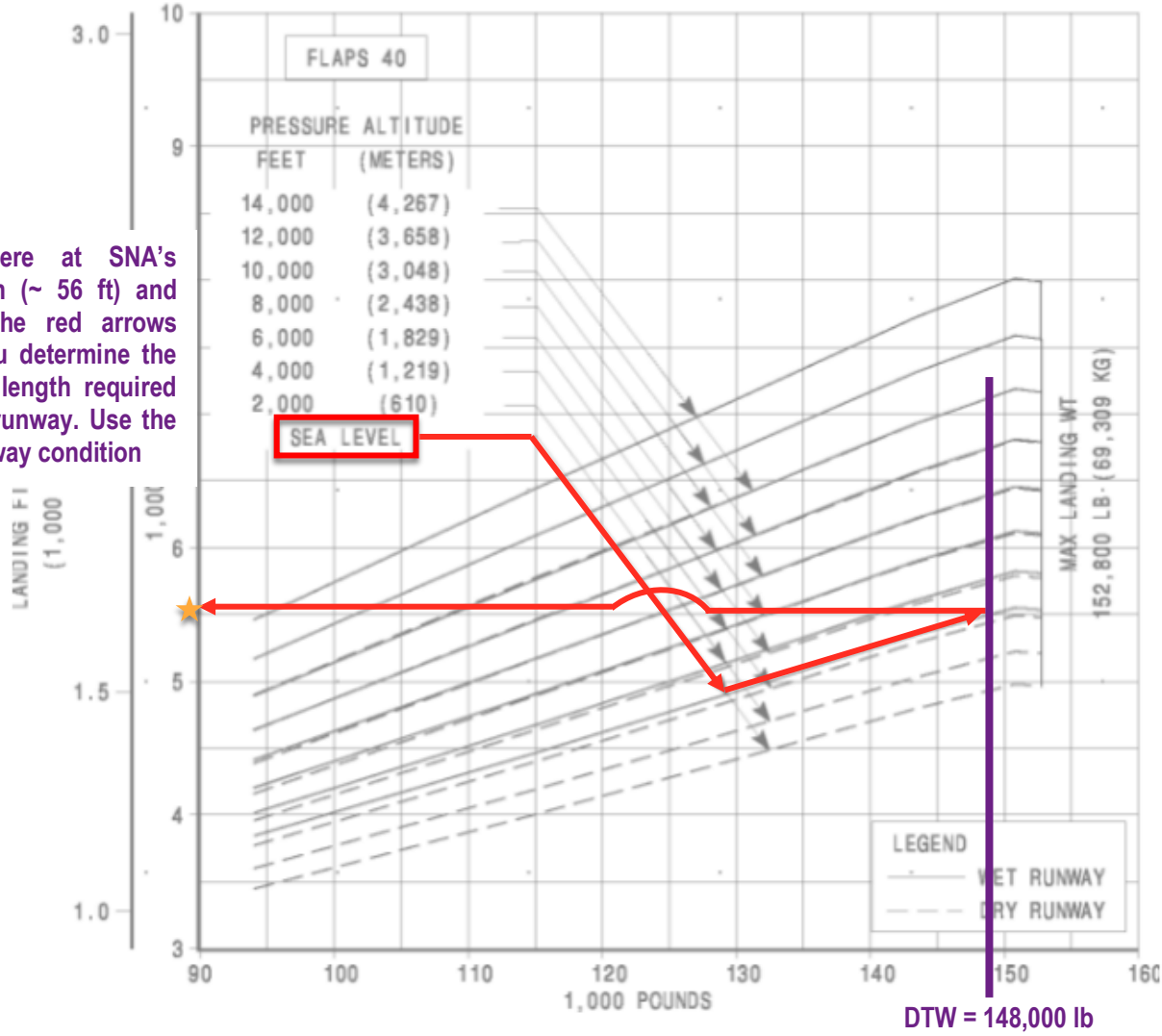
Therefore, we will use the DTW to determine runway length required for landings

3.4.6 FAA/EASA Landing Runway Length Requirements - Flaps 40: Model 737-8 / -8-200 / BBJ MAX 8

Landing Field Length
737-8 /. -8-200 and BBJ MAX 8
LEAP-1B Series

- STANDARD DAY, ZERO WIND
- AUTO SPOILERS OPERATIVE
- ANTI-SKID OPERATIVE
- ZERO RUNWAY GRADIENT
- CONSULT USING AIRLINE FOR SPECIFIC OPERATING PROCEDURE PRIOR TO FACILITY DESIGN

Start here at SNA's elevation (~ 56 ft) and follow the red arrows until you determine the landing length required for the runway. Use the wet runway condition



Conclusion: Runway Length required for landings $\cong 5,500\ ft$

Since the length required for landings (5,500 ft) is greater than the length required for takeoffs (4,800 ft), the landing length dominates and the **required length for the runway is 5,500 ft.**

e) If the runway length estimated in part (d) exceeds the runway length available at SNA, find the runway length extension needed to support the proposed flights.

Runway Information:

According to airnav.com, SNA has two (2) runways, 02L/20R, and 02R/20L

Runway 02L/20R:

Dimensions: 5700 x 150 ft.

Runway 02R/20L:

Dimensions: 2886 x 75 ft.

Conclusion: Runway 02L/20R can accommodate flights between SNA and SEA with the B737-8 Max.

Problem 3

Perform a takeoff runway length analysis for a new airport located 800 meters above sea level. Temperature data collected at the site shows the mean daily maximum temperature of the hottest month to be 24 deg. Celsius. Table 3 shows the design aircraft - the Airbus A321neo with Pratt & Whitney's PurePower PW1100G engines.

Table 3. Airbus A321neo Landing at BWI International Airport. Picture Source: A.A. Trani.

Aircraft	*Engine*	*Remarks*
Airbus A321neo	*Pratt and Whitney*	*Maximum Takeoff Weight is 97,000 kilograms. Aircraft configuration is WV072 in Airbus Document.*

a) Find the runway need allowing the A321neo to depart at the maximum allowable takeoff mass (~97,000 kgs).

Standard temperature at 800 meters is 9.8 deg. Celsius (49.6 deg.Fahrenheit)

The design temperature conditions are Standard + 14.2 degrees Celsius. Use ISA + 15 deg.C. charts in your analysis.

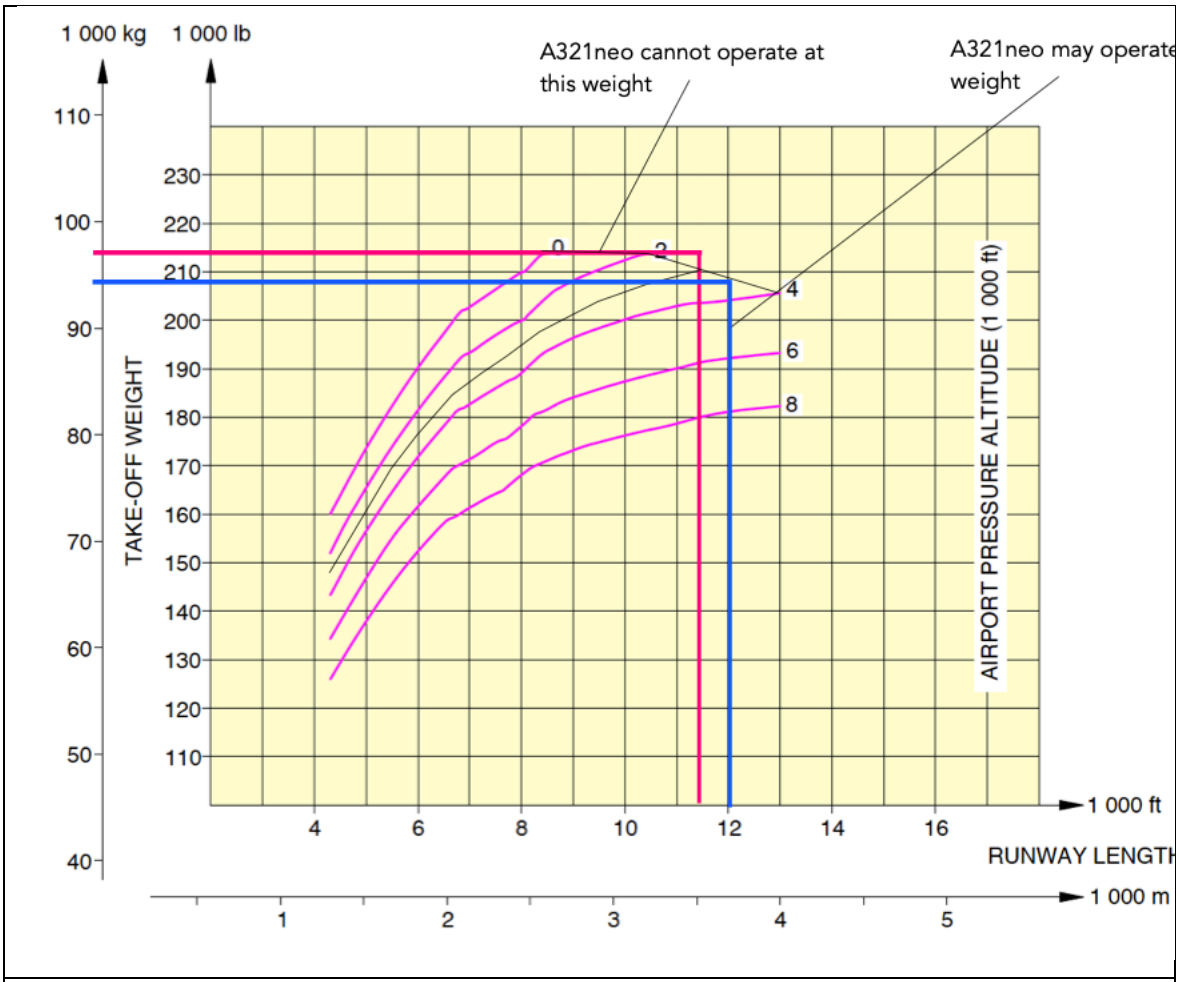


Figure 3. Airbus A321neo Takeoff performance at ISA + 15 deg. Celsius.

The performance chart for the Airbus A321neo (see Figure 3) indicates that the aircraft cannot operate at maximum takeoff weight from and airfield located 800 meters above sea level and 24 deg. C (see Figure 3). Note that the aircraft may operate (using interpolation) at 95,000 kilograms from the airport (ISA + 27 deg.F.) requiring 12,000 feet of runway (see blue lines in Figure 3.)

If you stated that the aircraft cannot operate from the airport conditions, your should receive full credit.

b) Use the Airbus A321neo payload-range diagram to estimate the maximum payload possible at 97,000 kgs. If the airline would like to fly 3,500 nm effective distance.

The payload-range diagram for the Airbus A321neo (see Figure 4) indicates that the aircraft could carry 21 metric tons of payload (21,000 kilograms) under ISA (standard) atmospheric conditions. Since the aircraft operates from ISA + 27 deg.F conditions, the payload for the airport operation in question will be less than 21,000 kilograms. Airbus does not provide payload-range diagrams for higher temperature conditions.

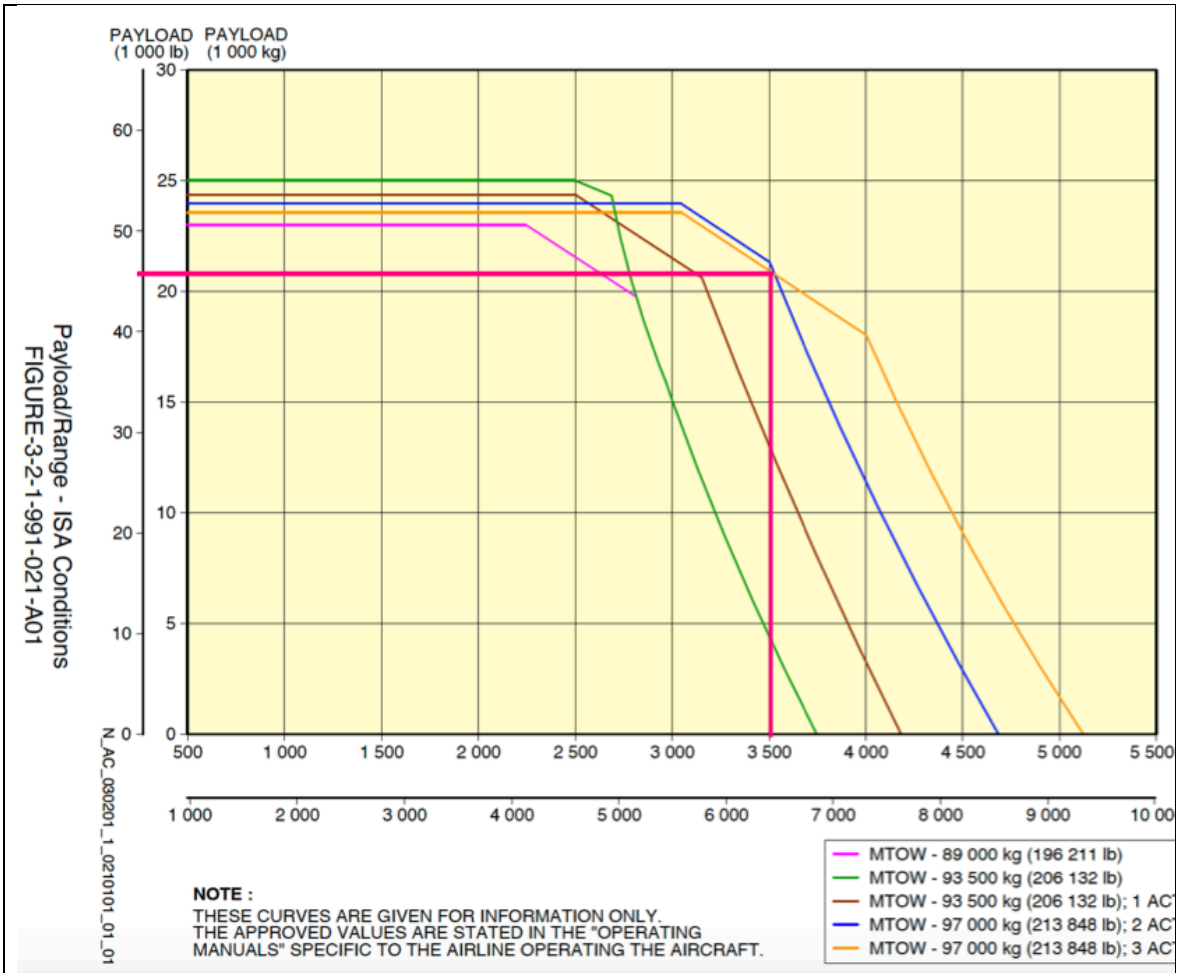


Figure 4. Airbus A321neo Payload-Range Diagram. ISA Conditions.