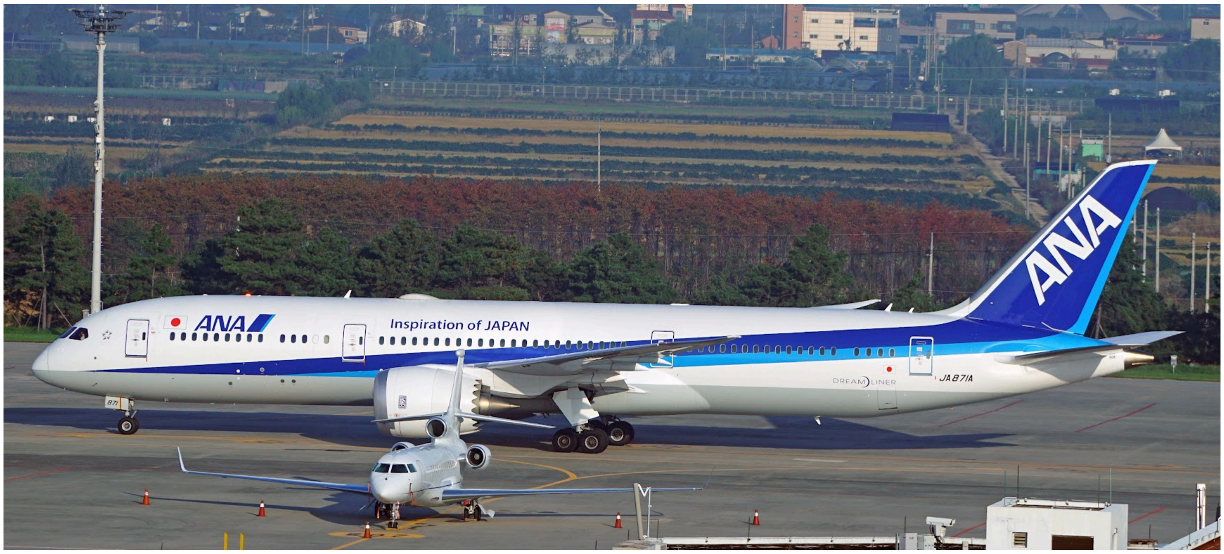
Assignment 3: Runway Length Calculations

Date Due: Solution Instructor: Trani

Problem 1

Evaluate future operations at Mexico City International Airport (MMMX) using the Boeing 787-9 (see picture below). The airline in questions wants to fly to Tokyo Narita Airport (NRT). The temperature at Mexico City can be found at Weather Spark: https://weatherspark.com/y/5674/Average-Weather-in-Mexico-City-Mexico-Year-Round.

Table 1. Aircraft Considered in the Mexico City Airport Evaluation. All Nippon Airways Boeing 787-9 Dreamliner Taxiing at Gimpo Airport (South Korea). Source: A. A. Trani.

Aircraft Considered
Boeing 787-9 with Rolls-Royce engines. Aircraft maximum design takeoff weight is 560,000 lb. 246 seats in a three-class layout. You can find the seating configurations of most airlines at SeatGuru (https://www.seatguru.com/airlines/ANA/ANA_Boeing_787-9_V3.php). **Note:** Boeing does not publish the operating empty weight (OEW) of the Boeing 787-9 aircraft in the tables (all other Boeing aircraft publish OEW in the tables in section 2 of the airport planning documents). 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 787-9 the OEW is approximately 280,000 lbs.


a) Find the typical distance flown length between Mexico City and Tokyo. 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.

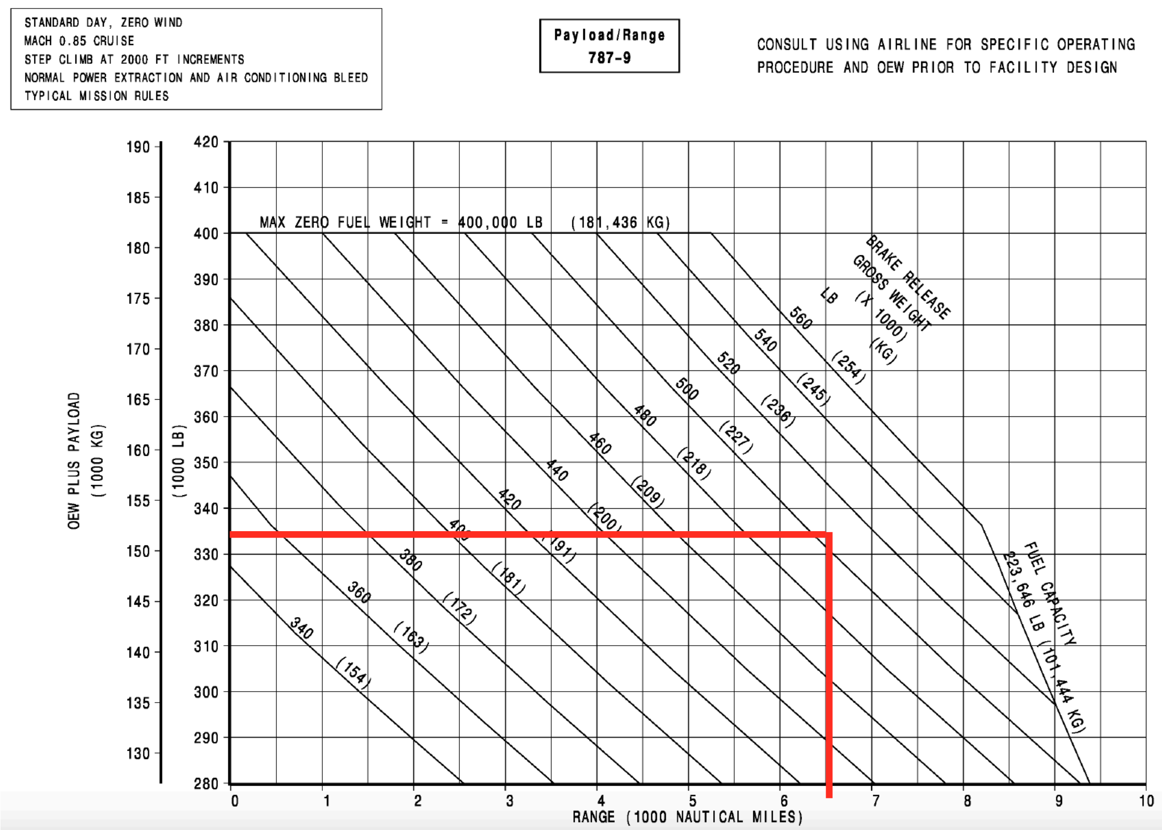
6,086 nautical miles uncorrected. With the 6% correction, the distance is 6,451 nautical miles.

b) Find the Desired Takeoff Weight (DTW) to fly the Mexico City- Tokyo (Narita) route. Assume a 100% passenger load factor in your analysis (i.e., all seats are full). Clearly state the fuel weight, operating empty weight and payload carried. Use the passenger weights discussed in class.

OEW = 280,000 lbs

PYL = 246 seats (220 lbs/seat) = 54,120 lbs

OEW + PYL = 334,120 lbs



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

Use the payload-range diagram to find the Desired Takeoff Weight (DTW). The aircraft DTW for the Mexico City - Tokyo Narita route is 510,000 lbs.

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

80 degrees Fahrenheit. At the airport elevation of Mexico City (7,316 feet above mean sea level conditions), the ISA temperature is 32.9 deg. F (say 33 deg. F). The temperature profile for estimating runway length is ISA + 47 deg. Fahrenheit.

d) Find the runway length needed for each one of the aircraft operating the critical route. Determine if Mexico City has enough runway length to support both flights. Remember to calculate the required takeoff and the landing distances in the analysis.

The aircraft is limited by takeoff weight. The airport elevation is too high to be able to support the non-stop flight from MMMX to NRT. No runway length will change the fact that the aircraft is limited departing

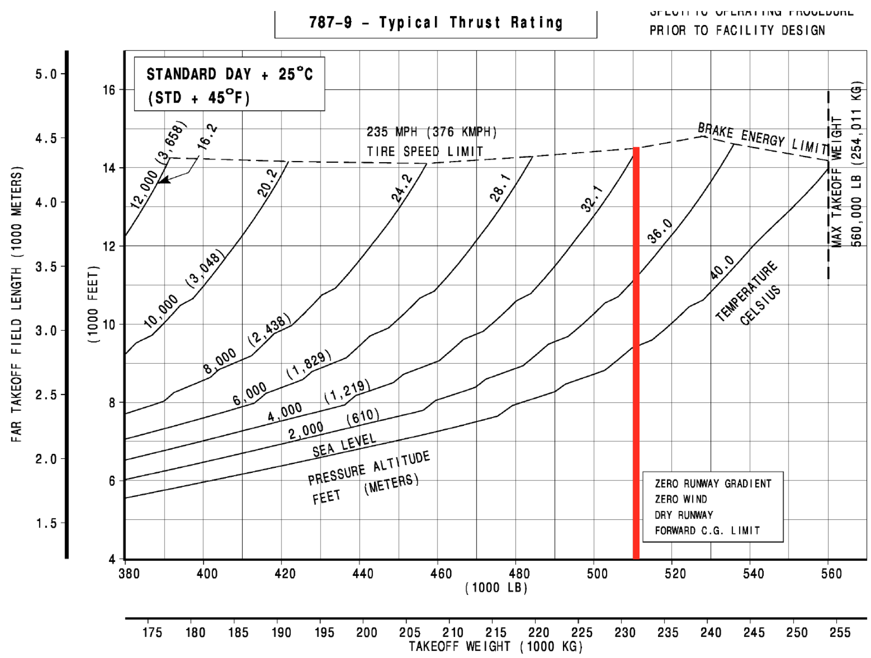
Mexico City. Note that the airport pressure altitude lines quickly bend upwards in the takeoff performance charts. The maximum takeoff weight departing Mexico City at the design temperature is 480,000 lbs. if the airline uses high-thrust engines on the aircraft. That means a penalty of 30,000 lbs. compared to the DTW. The airline could carry 24,120 lbs. of payload (109 passengers) departing Mexico City. Operating at half of the load factor is not economically feasible.

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

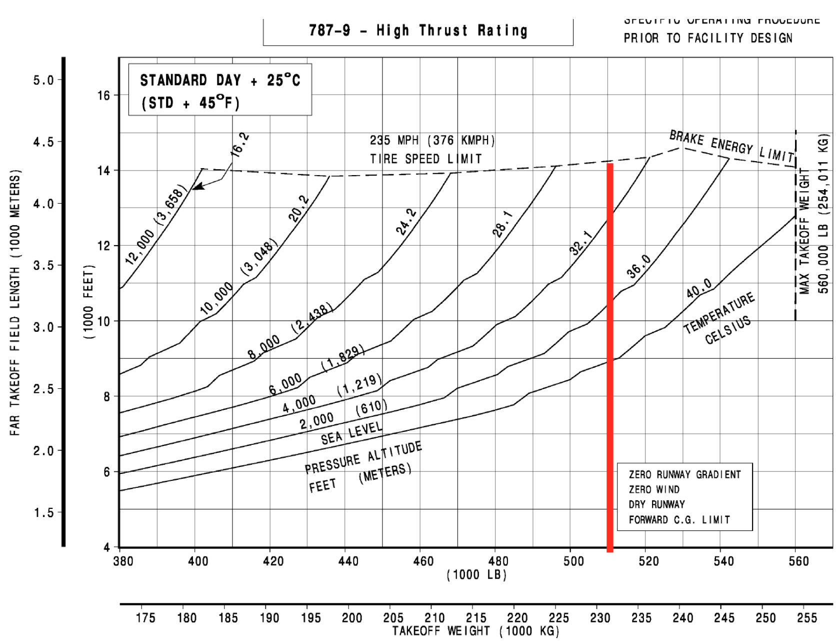
The maximum takeoff weight departing Mexico City is 465,000 lbs. with the typical thrust rating.

The maximum takeoff weight departing Mexico City is 480,000 lbs. with high thrust rating.

f) A new airport opened five months ago near Mexico City (Felipe Angeles Airport - NLU). Can the runways at NLU better support the long-range operations to Japan? No because the aircraft is limited by takeoff weight, not runway length.



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



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

Problem 2

A new airline is discussing future operations from Roanoke/Blacksburg Regional Airport (ROA) airport. The airline plans to use the Boeing 737-8 (also called Boeing 737-8 Max) with characteristics shown in Table 2. The airline would like to fly from ROA to Dallas Love Field (DAL) and to Denver (DEN). For this analysis, use the latest version of the Boeing 737-8 Max documents for airport design (Revision G published on May 2022).

Table 2. Aircraft Considered in the ROA 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 179,800 lb. 178 seats in a two-class layout. **Note:** Boeing does not publish the operating empty weight (OEW) of the Boeing 737-8 Max series aircraft in the tables (all other Boeing aircraft publish OEW in the tables in Section 2 of the airport planning documents). 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 104,000 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.

ROA-DAL 872 nautical miles (924 nautical miles with 6% additional distance to account for weather detours and ATC deviations)

ROA-DEN 1,168 nautical miles (1,238nautical miles with 6% additional distance to account for weather detours and ATC deviations

b) Find the Desired Takeoff Weight (DTW) to fly the two proposed routes. Assume a 100% passenger load factor in your analysis (i.e., all seats are full). Clearly state the fuel weight, operating empty weight and payload carried. Use the passenger weights discussed in class.

The existing runway is 6,800 feet.

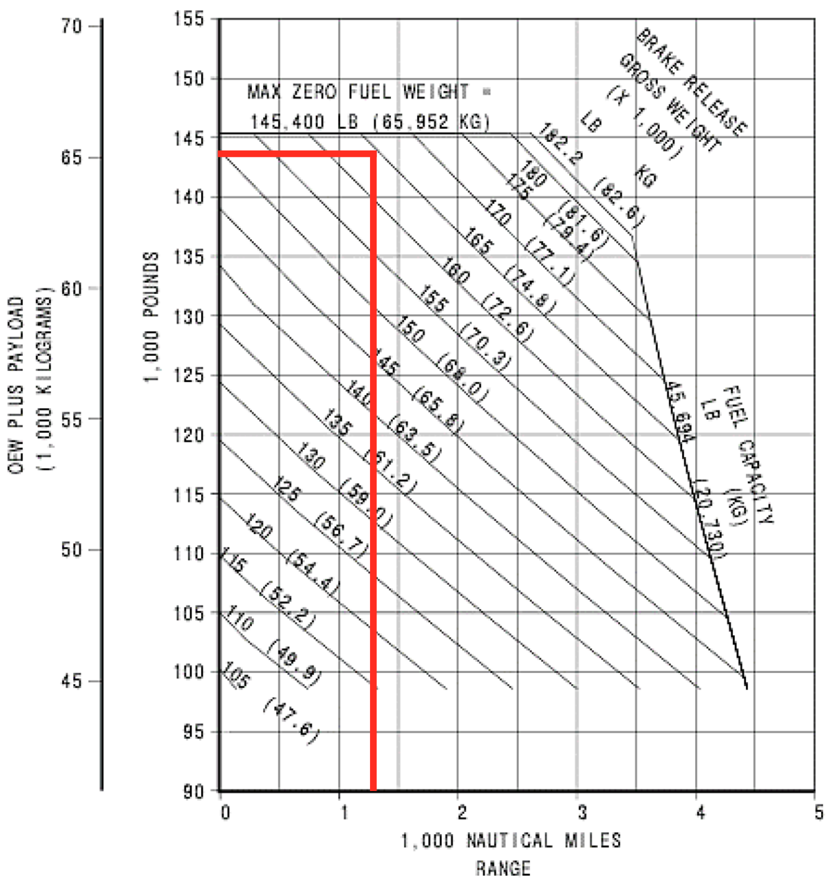
OEW = 104,000 lbs

PYL = 178 seats (220 lbs/seat) = 39,160 lbs

OEW + PYL = 143,160 lbs

Use the payload-range diagram to find the Desired Takeoff Weight (DTW). The aircraft DTW for the critical Denver route is 165,000 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).

ROA is located 1175 feet above mean sea level conditions. ISA temperature at airport elevation in Roanoke is 55 degrees F. Design temperature is 84.7 deg. F. ROA design temperature is ISA + 29.7 deg. F. Use the ISA + 27 deg. F performance curves (within 3 degrees of the actual design temperature).

d) Find the runway length needed for each one of the routes. Determine if ROA has enough runway length to support both flights. Remember to calculate the required takeoff and the landing distances in your analysis.

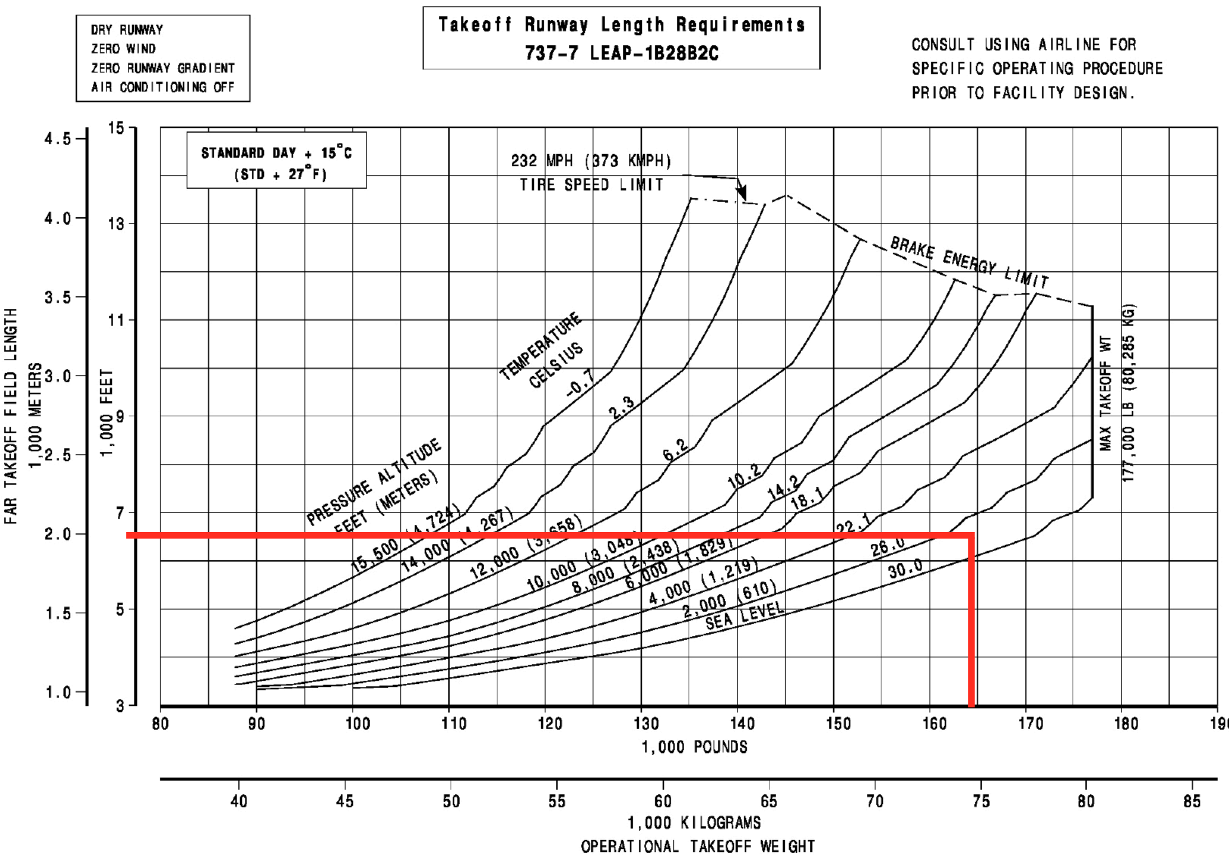
The runway length needed using the ISA + 27 deg. F performance chart is approximately 6,800 feet. Roanoke has enough runway to support a ROA-DEN flight with all seats full.

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

No runway extension needed for the ROA-DEN flight. The future runway extension proposed in the ROA master plan would allow longer flights and allow compliance with RSA areas.

f) If the runway length estimated in part (d) is less than the runway length available at ROA, find the additional cargo that can be carried for each flight (to DFW and DEN).

No additional cargo can be carried in the ROA-DEN flight.



Problem 3

Perform a runway length analysis for an existing airport located 4,200 feet above sea level. The airport has a 3,500 meter long runway (11,480 feet). Temperature data collected at the site shows the mean daily maximum temperature of the hottest month to be 22.8 deg. Celsius (73 degrees Fahrenheit). Table 3 shows the design aircraft - the Airbus A350-900.

Table 3. Airbus A350-900 in Tow at Atlanta Hartsfield-Jackson International Airport. Picture Source: A.A. Trani.

Aircraft	*Engine*	*Remarks*
Airbus A350-900	*Rolls-Royce engines*	*Maximum Takeoff Weight is 280,000 kilograms. 330 seat configuration.*

a) Find the maximum allowed takeoff weight of the aircraft for the existing airport conditions (3,500 meter runway constraint and 73 degrees F.).

At 4,200 feet the ISA temperature is 44 degrees Fahrenheit. The design temperature is 73 degrees Fahrenheit. The design temperature is 29 deg. F. above the ISA temperature. Use the ISA + 27 degrees Fahrenheit charts. Recall that the closest chart within 3 deg. F can be used. The maximum takeoff weight is 265 metric tons (265,000 kilograms).

b) Estimate the runway extension needed to allow the aircraft to depart at maximum takeoff weight. State the maximum takeoff weight.

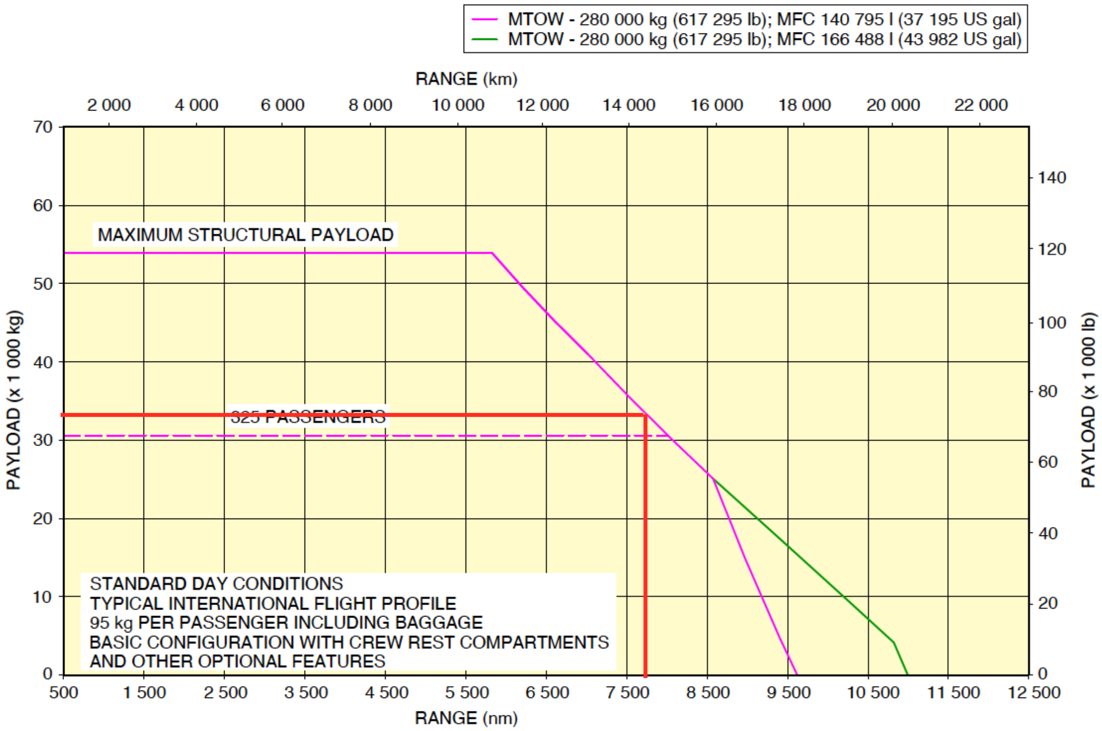
A runway 4,600 meters long would support the operation from 4,200 feet at the maximum takeoff weight (~280,000 kilograms).

c) Find the maximum aircraft range with all seats full. Assume the value suggested in class of 100 kilograms per passenger.

Using the 4,600 meter long runway and MTOW of 280,000 kgs. the aircraft can travel 7,600 nautical miles (see the payload-range diagram below). The payload-range diagram shows a dotted line for 325 passengers (at 95 kilograms per passenger). The answer for 330 passengers (at 100 kilograms per passenger) is equivalent to a payload of 33,000 kilograms.

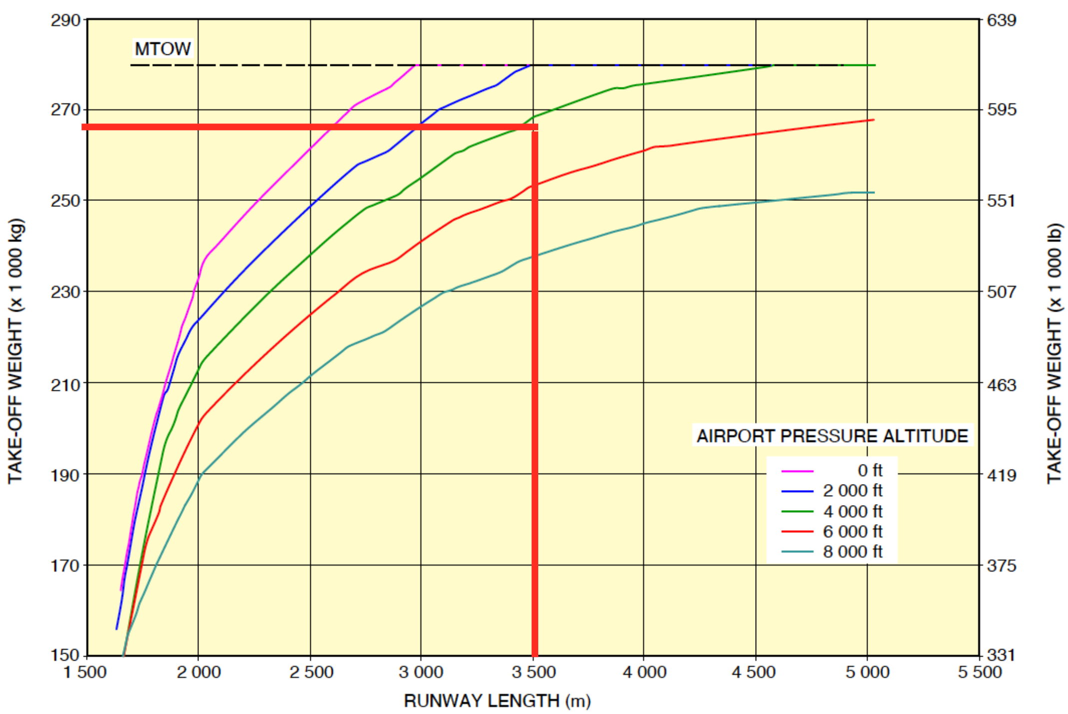
If the runway length available is 3,500 meters instead, the aircraft can depart with takeoff weight of 265,000 kilograms. The MTOW slant line in the payload-range diagram provides information on the tradeoff between payload and range. The slope of the MTOW line is -10.35 kgs/nm. That means for every additional nautical mile of range, the payload needs to be reduced by 10.35 kgs. If the aircraft departs from the existing runway at 265,000 lbs, the approximate payload to be carried is reduced by 15,000 kilograms and hence the range is estimated to be 1,450 nm less than the range predicted above with unconstrained runway length. Hence the estimated range is 6,150 nm.

d) Find the dimensions of the runway safety area (RSA), runway protection zones (RPZ), runway object free areas (ROFA) and obstacle free zone (including dimensions of the inner transitional surface) for the runway at the new airport. The new runway is expected to have a Category 1 Instrument Landing System (ILS) with visibility minima of 2200 feet RVR.



Payload/Range - ISA Conditions
FIGURE-3-2-0-991-001-A01

P_AC_03



ISA + 15 °C (ISA + 27 °F) Conditions
FIGURE-3-3-0-991-002-A01

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NOTE:
THESE CURVES ARE GIVEN FOR INFORMATION ONLY. THE APPROVED VALUES ARE STATED IN THE "OPERATING MANUALS" SPECIFIC TO THE AIRLINE OPERATING THE AIRCRAFT.

RUNWAY PROTECTION	
Runway Safety Area (RSA)	
Length beyond departure end [9, 10]	1,000 ft
Length prior to threshold [11]	600 ft
Width	500 ft
Runway Object Free Area (ROFA)	
Length beyond runway end	1,000 ft
Length prior to threshold [11]	600 ft
Width	800 ft
Obstacle Free Zone (OFZ)	
Runway, Inner-approach, Inner-Transitional	
Precision Obstacle Free Zone (POFZ)	
Length	200 ft
Width	800 ft
Approach Runway Protection Zone (RPZ)	
Length	2,500 ft
Inner Width	1,000 ft
Outer Width	1,750 ft
Departure Runway Protection Zone (RPZ)	
Length	1,700 ft
Inner Width	500 ft
Outer Width	1,010 ft

Your solution should also include the dimensions of OFZ surfaces: basic OFZ (400 feet) Approach and inner transitional.

Problem 4

Use Google Earth and Airnav.com to learn about the runway features of the Virginia Tech/Montgomery County Executive Airport (BCB). The current airport is designed for Runway Design Code (RDC) group C-II and visibility minima no less than one mile. The airport has approach capability with 1 mile visibility conditions. Last summer, the airport expanded the runway to 5,500 feet and the airport infrastructure was designed for RDC C-II category which includes medium size corporate jets like the Bombardier Challenger 350 and the Cessna Citation X.

a) Compare the RSA and ROFA dimensions of the existing airport and a future BCB airport that may serve B-III operations allowing larger business aircraft like the Bombardier Global Express 5000 (see Figure 1). Comment on the changes needed for the upgrade.

Use the FAA Design Standards Matrix. The RSA and ROFA dimensions are lower for design group B-III compared to those required for C-II. For example, the RSA length beyond the departure end is 800 feet for B-III compared to 1,000 feet for C-II.

Runway Safety Area (RSA)

C/D/E - II

RSA Dim.	DIM[1]	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Length beyond departure end [9, 10]	R	1,000 ft	1,000 ft	1,000 ft	1,000 ft
Length prior to threshold [11]	P	600 ft	600 ft	600 ft	600 ft
Width [13]	C	500 ft	500 ft	500 ft	500 ft

A/B - III

RSA Dim.	DIM[1]	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Length beyond departure end [9, 10]	R	600 ft	600 ft	600 ft	800 ft
Length prior to threshold [11]	P	600 ft	600 ft	600 ft	600 ft
Width	C	300 ft	300 ft	300 ft	400 ft

Runway Object Free Area (ROFA)

C/D/E - II

ROFA Dim.	DIM[1]	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Length beyond runway end	R	1,000 ft	1,000 ft	1,000 ft	1,000 ft
Length prior to threshold [11]	P	600 ft	600 ft	600 ft	600 ft
Width	Q	800 ft	800 ft	800 ft	800 ft

A/B - III

ROFA Dim.	DIM[1]	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Length beyond runway end	R	600 ft	600 ft	600 ft	800 ft
Length prior to threshold [11]	P	600 ft	600 ft	600 ft	600 ft
Width	Q	800 ft	800 ft	800 ft	800 ft

b) Compare the dimensions of the approach and departure RPZ surfaces of the existing and the future airport design standard. Comment.

The POFZ for both groups is the same. The dimensions of the RPZ for C-II and B-III are the same if the visibility criteria used is either "Not Lower than 3/4 mile" or "Lower than 3/4 mile".

Approach Runway Protection Zone (RPZ)

C/D/E - II

RPZ Dim.	DIM[1]	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Length	L	1,700 ft	1,700 ft	1,700 ft	2,500 ft
Inner Width	U	500 ft	500 ft	1,000 ft	1,000 ft
Outer Width	V	1,010 ft	1,010 ft	1,510 ft	1,750 ft

A/B - III

RPZ Dim.	DIM[1]	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Length	L	1,000 ft	1,000 ft	1,700 ft	2,500 ft
Inner Width	U	500 ft	500 ft	1,000 ft	1,000 ft
Outer Width	V	700 ft	700 ft	1,510 ft	1,750 ft

c) Why is the airport able to receive Global Express flights today?

Aircraft like the Global Express 5000 can fly to BCB routinely as long as they do not do conduct 500 operations per year. The Global Express 5000 may fly into BCB 20 times a year (40 operations counting takeoffs and landings).

C/D/E - II

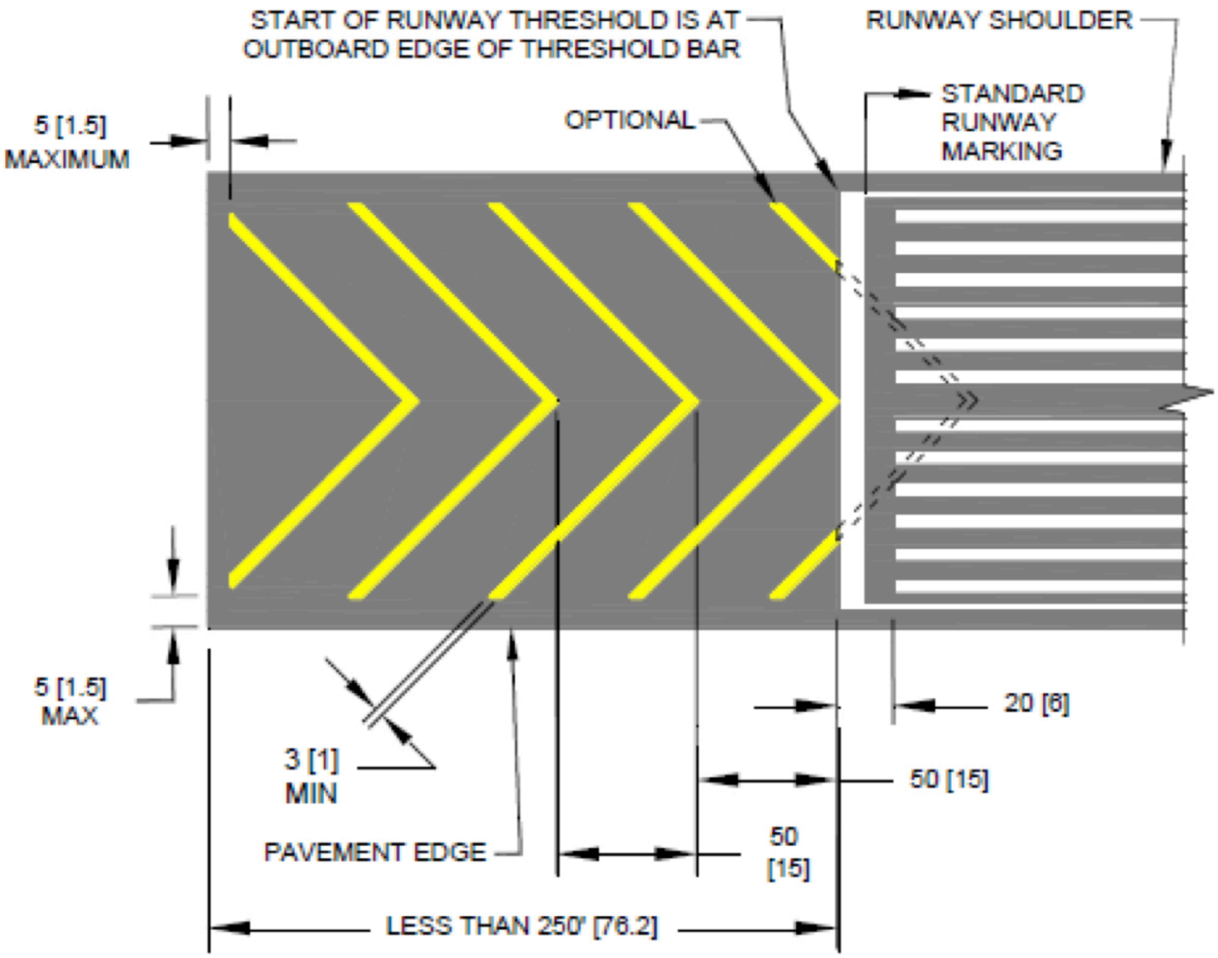
Runway Dims	DIM[1]	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Runway Width	B	100 ft	100 ft	100 ft	100 ft
Shoulder Width		10 ft	10 ft	10 ft	10 ft
Blast Pad Width		120 ft	120 ft	120 ft	120 ft
Blast Pad Length		150 ft	150 ft	150 ft	150 ft
Crosswind Component		16 knots	16 knots	16 knots	16 knots

A/B - III

Runway Dims	DIM[1]	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Runway Width	B	100 ft	100 ft	100 ft	100 ft
Shoulder Width		20 ft	20 ft	20 ft	20 ft
Blast Pad Width		140 ft	140 ft	140 ft	140 ft
Blast Pad Length		200 ft	200 ft	200 ft	200 ft
Crosswind Component		16 knots	16 knots	16 knots	16 knots

Conclusion:

The only requirements to operate a Global Express 5000 at the C-II compliant airport would be to increase the blast pad areas according to the FAA Design Matrix (see graphic below). The blast pad area length increases from 150 feet to 200 feet. The blast pad area width increases from 120 feet to 140 feet. This is expected because the large wingspan of the aircraft implies larger distance between engines that are responsible for the erosion avoided by the blast pad area. A graphic of a runway blast pad area is shown below.



Source: Quick Reference to Airfield Standards. FAA Southern Airports Region Office, 2018.