Assignment 3: Runway Length and EMAS Design

Solution Instructor: Trani

Problem 1

A new airport to be constructed near Mexico City airport would like to request your services to estimate the runway length requirements to support regular operations using the aircraft shown in Table 1. The new airport is to be located in a 6,500 acre parcel located 7,250 feet above sea level conditions. The design temperature condition for Mexico City is 82 deg. F.

Table 1. Aircraft for Airport in Problem 1.

Aircraft	Engine	Remarks
Boeing 737-700 70,307 kg MTOW	CFM56-7B20/-7B22/-7B24 developing 20,000 lb of thrust at sea level	To be used in routes of up to 2,500 nm to Central America destinations i
Boeing 787-8 227,930 kg MTOW	GE Engines Genx (High thrust engines)	To be used in routes of up to 5,000 nm to Europe. Plane has 242 seat three-class configuration

a) Find the runway length needed to operate both aircraft in the types of routes stated in the table. Use standard three-class cabin configurations stated in the Boeing APM documents. Decide the runway length for the new airport. In your solution state the figures used in the Boeing APM documents.

For Boeing 737-700

The design temperature condition is 82 deg. F. At 7,250 feet above sea level, the standard temperature is 274 deg. Kelvin (1 deg. Celsius or 33 deg. F). The temperature of 82 deg. F is equivalent to ISA + 49 deg. F or ISA + 27 deg. C. Note that 82 deg. F is 27.8 deg. C. This is a critical fact in solving the problem.

Payload = 12,800 kg

OEW = 37,648 kg

Payload + OEW = 50,448 kg.

Use payload-range diagram in Figure 3.2.10 and look for the intersection of 50,448 kg and 2,500 nm. This produces a Desired Takeoff Weight (DTW) of 66,500 kg.

Look at Figures 3.3.33 (ISA + 22.2 deg. C) and 3.3.34 (ISA + 35 deg. C) for the Boeing 737-700 with CFM56 engines producing 20,000 lb. of thrust.

Figure 3.3.33 shows the aircraft is not capable to operate at 66,500 kg form Mexico City even with a 15,000 foot runway. Figure 3.3.34 shows the same trend. The airline cannot operate direct flights of that length unless an intermediate stop is made. One solution you could recommend is for the airline to buy Boeing 737-700 with 26,000 lb engines. The takeoff runway requirements for such aircraft are substantially better and shown in Figure 3. Using the 26,000 lb engine the takeoff requirements are 12,000 feet of dry runway.

Verify that the landing distances are shorter than takeoff distances for this aircraft operating from Mexico City.

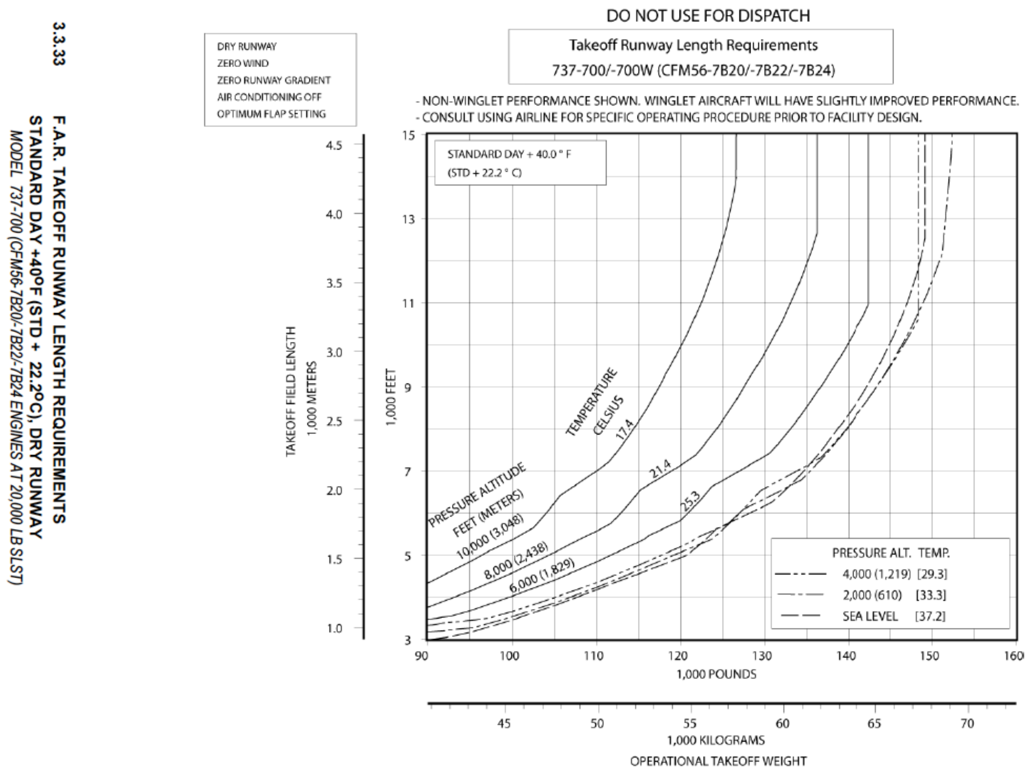

Figure 1. ISA + 22.2 deg. C Takeoff Runway Length Required. Boeing 737-700.

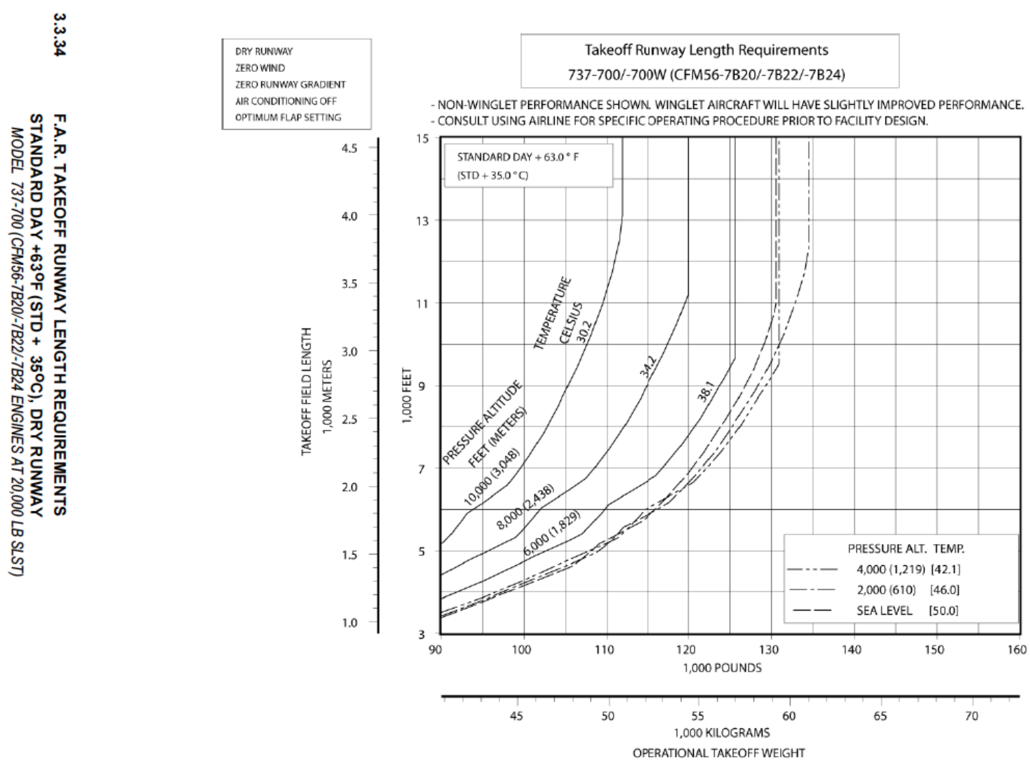

Figure 2. ISA + 35 deg. C Takeoff Runway Length Required. Boeing 737-700.

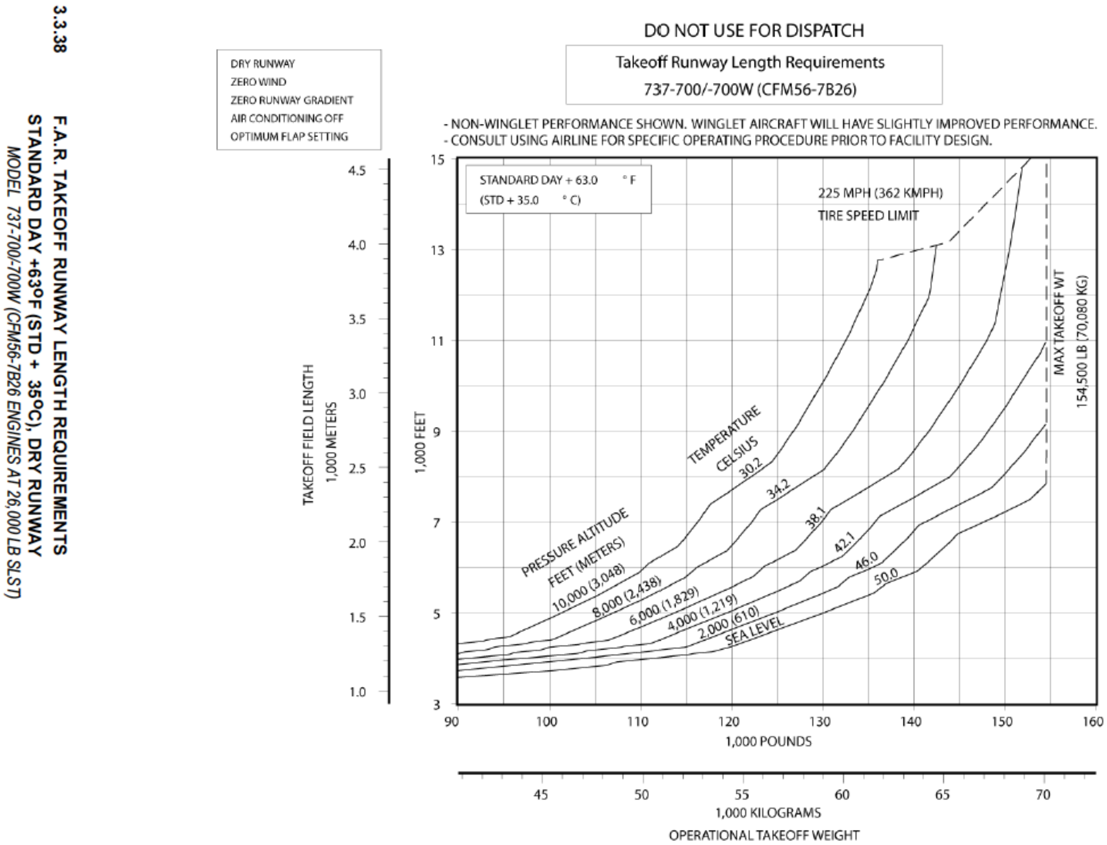

Figure 3. ISA + 35 deg. C Takeoff Runway Length Required for Boeing 737-700.

For Boeing 787-8

Payload = 24,200 kg

OEW = 117,707 kg

Payload + OEW = 141,907 kg.

Use payload-range diagram in Figure 3.2.1 and look for the intersection of 141,907 kg and 5,000 nm. This produces a Desired Takeoff Weight (DTW) of 196,000 kg.

Look at Figures 3.3.8 (ISA + 35 deg. C) for the Boeing 787-8 with Hi-Thrust engines.

Figure 3.3.8 shows the aircraft is not capable to operate at 196,000 kg form Mexico City even with a 15,000 foot runway. The tire speed limit is reached for such high elevation airfield. The airline cannot operate direct flights of 5,000 nm unless an intermediate stop is made. In order to provide maximum flexibility to the airlines, a 15,000 ft runway would be required. However, the Boeing 787-8 would still be slightly limited in its operations. One problem that is important to mention is that Boeing provides a payload-range diagram for the typical engines and not for the Hi-thrust engines.

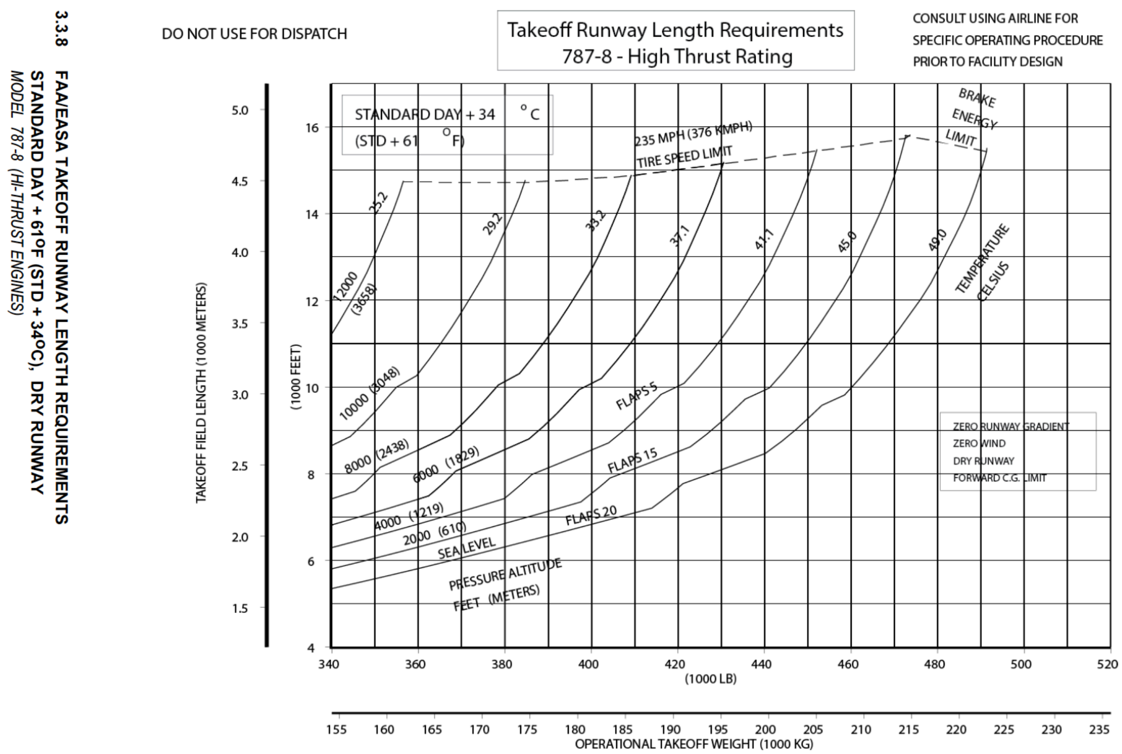

Figure 4. ISA + 34 deg. C Takeoff Runway Length Required. Boeing 737-700.

b) Find the dimensions of the runway safety area, runway protection zones, object free areas and obstacle free zone for one of the runways found in part (a). The new runway is expected to have a Category I Instrument Landing System (ILS).

c) Draw all 4 basic runway protection areas to scale using Autocad or any drawing program of your choice (just planview). Estimate the dimensions of the OFZ surface.

The dimensions of al four surfaces are found in Table A7-10 in Appendix 7 of the FAA AC 150/5300-13a. We select Aircraft Design Group V since the Boeing 787-8 belongs to that group based on its wingspan (197.25 feet). The table is partially reproduced here. For a commercial airport with international operations select the lowest visibility minima since airlines like to offer reliable service. The lower than 3/4 mile visibility is used in the analysis.

Table A7-10. Runway design standards matrix, C/D/E - V

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		C/D/E - V			
ITEM	**DIM** [1]	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
RUNWAY DESIGN					
Runway Length	A	*Refer to paragraphs 302 and 304*			
Runway Width	B	150 ft	150 ft	150 ft	150 ft
Shoulder Width		35 ft	35 ft	35 ft	35 ft
Blast Pad Width		220 ft	220 ft	220 ft	220 ft
Blast Pad Length		400 ft	400 ft	400 ft	400 ft
Crosswind Component		20 knots	20 knots	20 knots	20 knots
RUNWAY PROTECTION					
Runway Safety Area (RSA)					
Length beyond departure end [10, 11]	R	1,000 ft	1,000 ft	1,000 ft	1,000 ft
Length prior to threshold [12]	P	600 ft	600 ft	600 ft	600 ft
Width	C	500 ft	500 ft	500 ft	500 ft
Runway Object Free Area (ROFA)					
Length beyond runway end	R	1,000 ft	1,000 ft	1,000 ft	1,000 ft
Length prior to threshold [12]	P	600 ft	600 ft	600 ft	600 ft
Width	Q	800 ft	800 ft	800 ft	800 ft
Runway Obstacle Free Zone (ROFZ)					
Length		*Refer to paragraph 308*			
Width		*Refer to paragraph 308*			
Precision Obstacle Free Zone (POFZ)					
Length		N/A	N/A	N/A	200 ft
Width		N/A	N/A	N/A	800 ft
Approach Runway Protection Zone (RPZ)					
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
Acres		29.465	29.465	48.978	78.914

d) An airline wants to build a 83 foot tall hangar to accommodate the Boeing 767-200 at the site. The proposed hangar wall will be located 850 feet from the runway centerline. Does the proposed location violate the OFZ surface of the airport? Explain.

Here we have to check the dimensions of the Runway OFZ. Note that for Category 1 operations (see table in course notes for all 3 categories of instrument landing systems) - visibility less than 3/4 mile - we need to estimate the dimensions of the inner transitional surface. FAA AC 150/5300-13a paragraph 308 or our course notes offer detailed information to estimate the OFZ. The FAA diagram is reproduced below.

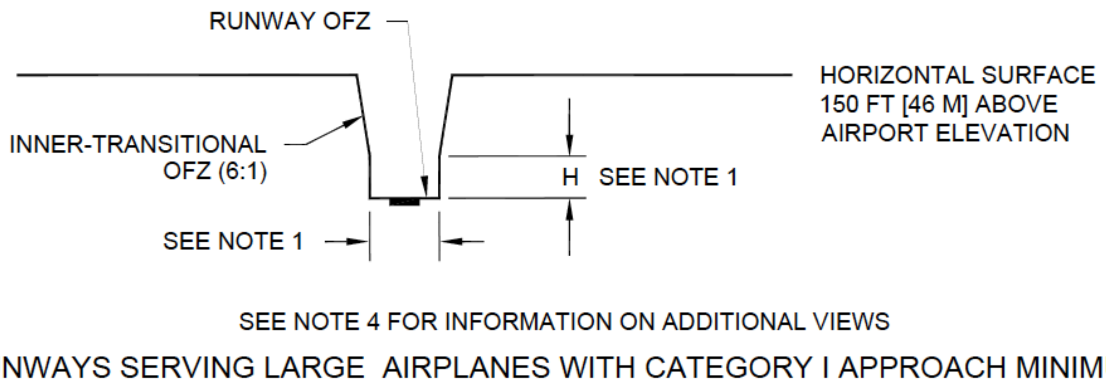

Figure 5. Runway OFZ Dimensions for Runways Serving Large Airplanes with Category I Approach Minimums.

The runway OFZ width is 400 feet (122 m) for operations by large aircraft. However, we also need to estimate the value of the critical height H and the sloping surface (inner transitional OFZ at 6:1). Here is a diagram showing the results.

H(feet) = 61 - 0.094(Sfeet) - 0.003(Efeet)

H = 20.7 feet.

The solution is shown graphically in Figure 6. Note that an 83 feet-tall proposed hangar located 850 feet from the runway centerline is below both Category I and II OFZ surfaces. The hangar is the at a permissible location.

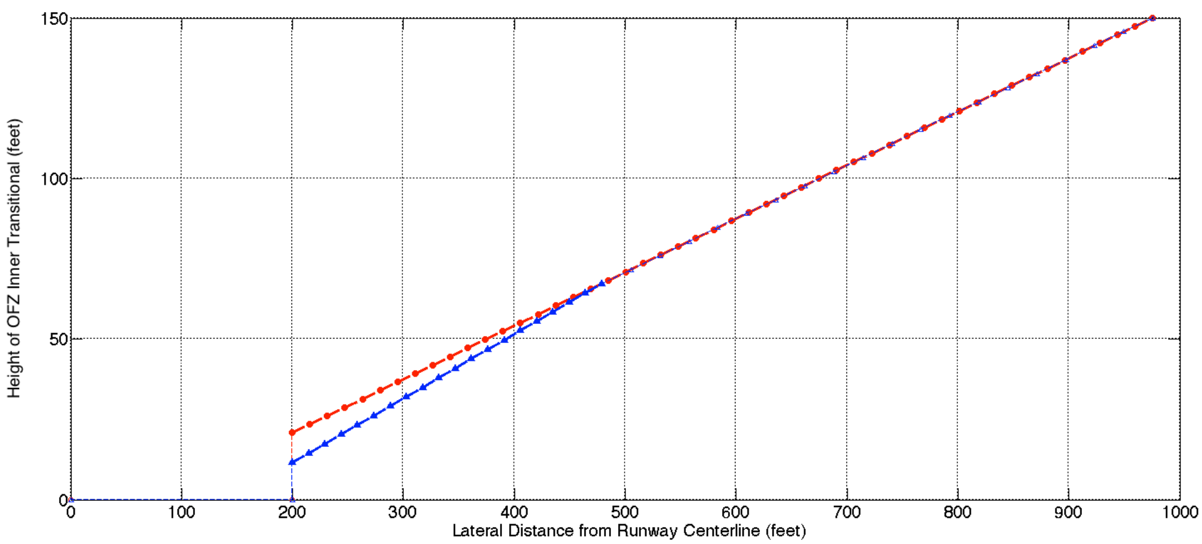

Figure 6. Runway OFZ Dimensions for Runways Serving Large Airplanes with Category I Approach Minimums. Blue Line = Category II Approaches, Red = Category I Approaches.

Problem 2

The Lehigh Valley International International (ABE) would like to request your services to estimate the runway length requirements needed to operate a new nonstop service from Lehigh Valley to Moscow using Boeing 777-200LR. The airline in question has Boeing 777-200LR powered by two *GE90-115BL engines* rated at 115,300 lb. of thrust.

a) Find the route distance from Lehigh (ABE) to Moscow. Use 5% the detour factor.

4,300 nm including a 5% detour factor.

b) Find the runway length needed to operate this non-stop service from ABE. Assume the aircraft has a two class configuration and you would like to provide maximum flexibility to the airline.

Airport elevation is 394 feet above mean sea level conditions. Design temperature is 84 deg. F. (29 deg. C). This is equivalent to ISA + 25 deg. F or ISA + 14 deg. C.

Payload = 27,900 kg (2-class layout)

OEW = 145,150 kg

Payload + OEW = 173,050 kg.

Use payload-range diagram in Figure 3.2.1. This produces a Desired Takeoff Weight (DTW) of 238,000 kg.

Look at Figure 3.3.6 (ISA + 15 deg. C) for the Boeing 777-200LR. The figure shows the takeoff runway length required to be 5,600 feet assuming dry runway conditions. Correcting for 15% we obtain a takeoff runway length of 6,210 feet. The landing runway distance is 6,150 feet with 30 degrees of flaps and wet pavement conditions.

Takeoff dominates over landing. The runway length available today suffices for this service. ABE has one 7,599 feet long runway.

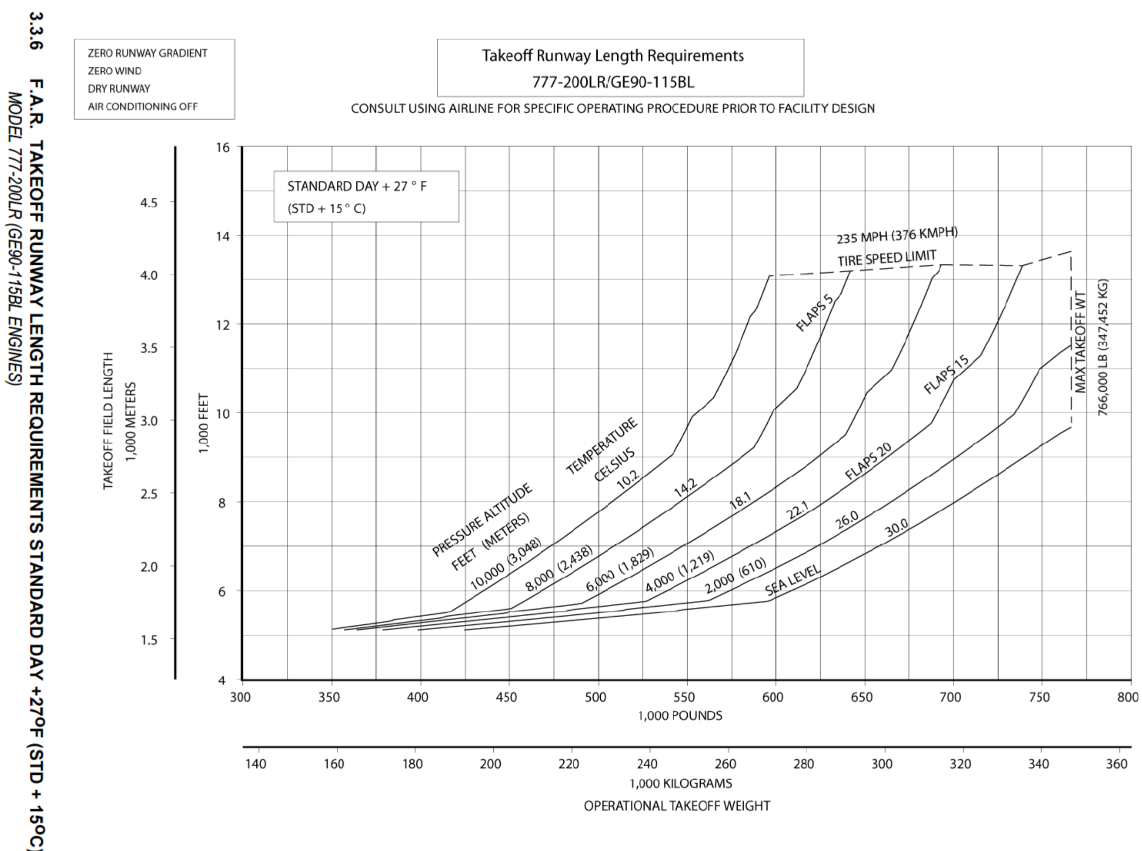

Figure 7. Runway Performance for Boeing 777-200LR.

c) Do you need a runway extension at ABE? Comment.

None.

Problem 3

A new international airport is exploring the installation of an Engineered Materials Arresting System (EMAS).

a) Find the length of the EMAS system to contain a Boeing 747-400 (or equivalent) departing the new airport. Refer to FAA AC 150/5220-22A available on our home page. Use the recommended FAA design speed for EMAS systems.

The EMAS should be 590 feet long using a design exit speed of 70 knots.

b) Why are the dimensions of the EMAS different for various aircraft? Explain using your knowledge of Physics.

Each aircraft has different mass characteristics and also inertia to be decelerated.

Problem 4

Use Wikipedia to learn the details of the following landing systems:

a) Explain in two paragraphs the what is the purpose and the components of the Instrument Landing System (ILS).

b) Explain in two paragraphs what is the purpose of the Ground Base Augmentation System (GBAS system) and how it compares to the ILS system.