Assignment 3: Runway Length

Date Due: September 15, 2021 Instructor: Trani

Problem 1

Use the experimental Small Aircraft Runway Length Analysis Tool (SARLAT) demonstrated in class to design the runway length for a new General Aviation airport to be constructed at a site located 2,560 feet above sea level. Data from a temperature survey yields a mean daily maximum temperature of the hottest month of 85-degree F. The aircraft fleet mix expected to operate at the airport is shown in Table 1. The airport is expected to serve single, multi-engine piston aircraft and turboprop aircraft like the Pilatus PC-12 and the Beechcraft King Air B200 (see Table 1). In your analysis, consider all the aircraft listed in the second column of the table. Use the default load factors in the SARLAT tool.

Table 1. Expected Aircraft Fleet at Proposed General Aviation Airport. Aircraft in Boldface Text are shown in the Picture.

Aircraft Type	**Representative Aircraft**	**Sample Picture**
Single Engine Piston	**Cirrus SR-22** Cessna 182 Cessna Columbia 400	
Multi-engine Piston	**Beechcraft Baron 58** Cessna 402B	
Turboprop Aircraft	**Beechcraft King Air B200** Pilatus PC-12	

a) Report the **dry pavement takeoff and landing** conditions for each aircraft.

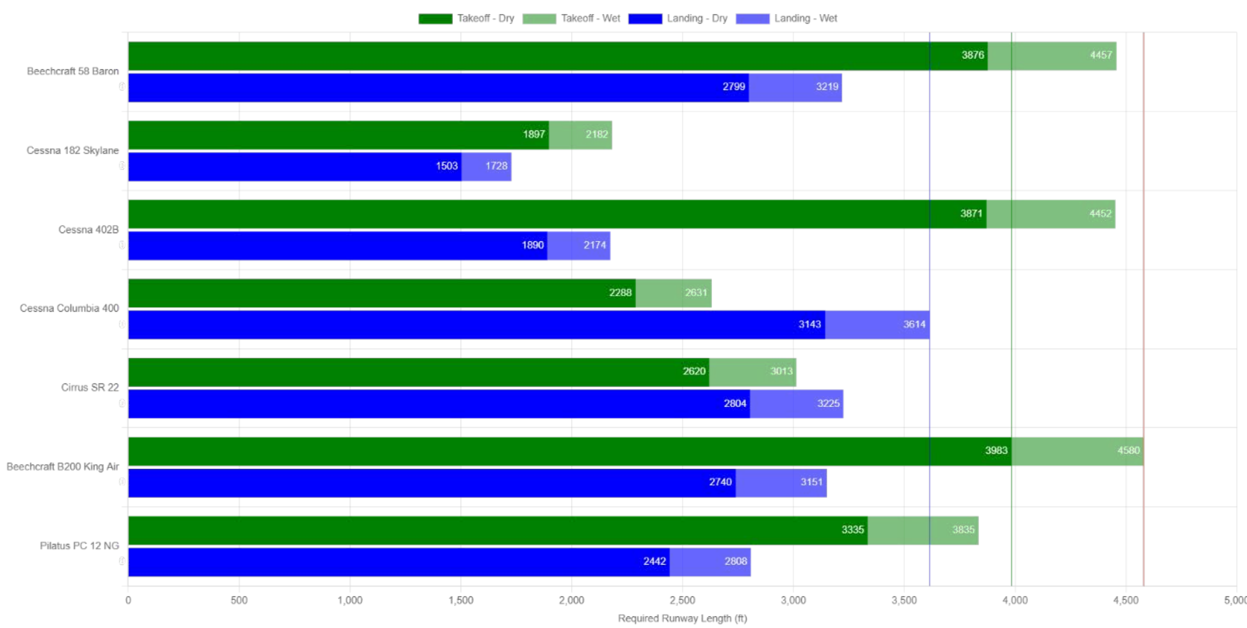
Aircraft Name	Dry pavement takeoff(ft)	Dry pavement landing(ft)
Beechcraft 58 Baron	3876	2799
Cessna 182 Skylane	1897	1503

Cessna 402B	3871	1890
Cessna Columbia 400	2288	3143
Cirrus SR 22	2620	2804
Beechcraft B200 King Air	3983	2740
Pilatus PC 12 NG	3335	2442

b) Report the **wet pavement takeoff and landing** conditions for each aircraft.

Aircraft Name	Wet pavement takeoff(ft)	Wet pavement landing(ft)
Beechcraft 58 Baron	4457	3219
Cessna 182 Skylane	2182	1728
Cessna 402B	4452	2174
Cessna Columbia 400	2631	3614
Cirrus SR 22	3013	3225
Beechcraft B200 King Air	4580	3151
Pilatus PC 12 NG	3835	2808

c) Copy the graph from the application (PNG file) and include in your report.



d) The Federal Government (through FAA) helps public airports to pay for the runway infrastructure. Based on economic analyses, the Federal Government will fund a **wet landing runway and dry takeoff runway** as part of the Airport Improvement Program funds. Find the critical aircraft and the runway length needed for this airport that meets the AIP criteria.

The critical aircraft for wet landing runway is the Cessna Columbia 400 (3,614ft). The critical aircraft for dry takeoff runway is the Beechcraft B200 King Air (3983ft). Overall, the critical aircraft is Beechcraft B200 King Air. Rounding the runway length up to the nearest 100 feet, And the runway length needed for this airport is 4,000ft.

Blacksburg used to have a 4,500-foot runway before the runway extension. Therefore, the runway was appropriate for the three classes of aircraft presented in Table 1.

e) For the same scenario above, the airport client would like to attract business jet customers similar to the Cessna CitationJet 3 and The Embraer Phenom 300. Recalculate the runway length needed. Do light jets require more runway than turboprops and piston-powered aircraft? Comment.

Aircraft Name	dry pavement takeoff(ft)	dry pavement landing(ft)	Wet pavement takeoff(ft)	Wet pavement landing(ft)
Citation Jet 3	3832	3106	4407	3572
Phenom 300	4080	2987	4692	3435

The critical aircraft is Embraer Phenom 300. The Phenom would require 4,080 feet (dry takeoff). Since light jets require more runway than turboprops and piston-powered aircraft, Virginia Tech airport extended the runway length to accommodate light and medium size jets (RDC C-II as explained in class). Note that the airport runway expansion to 5,500 feet was justified to accommodate medium size jets such as the Bombardier Challenger 350 (see below).

Figure 2. Bombardier Challenger Operating at Virginia Tech Montgomery Executive Airport (A. Trani).

Problem 2

An airline is discussing future operations from Reagan National Airport (DCA) airport with the Metropolitan Washington Airport Authority (MWAA). The airline plans to use the Boeing 737-9 Max with characteristics shown in Table 2 in routes from DCA to Seattle-Tacoma (SEA) and San Diego (SAN). For this analysis, use the latest version of the Boeing 737-9 Max documents for airport design (https://www.boeing.com/commercial/airports/plan_manuals.page).

Table 2. Aircraft Considered in the DCA Airport Evaluation.

Aircraft Considered
Boeing 737-9 Max with CFM LEAP-1B engines. Aircraft maximum design takeoff weight is 194,700 lb. 193 seats in a two-class layout. **Note:** Boeing does not publish the operating empty weight (OEW) for the Boeing 737-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 a good way to estimate the value of OEW indirectly because the y-axis in the payload-range diagram is OEW + Payload. For the Boeing 737-9Max the OEW is approximately 104,000 lbs. Verify this number.

a) Find the average stage length to be flown between each one of the critical 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.

Distance from DCA to SEA:2,329 miles 2,329*1.06=2468.74 miles

Distance from DCA to SAN: 2,276 miles 2,276*1.06=2412.56 miles

Since the average stage length is similar, it can be rounded to 2,469 miles (2,145.5 nm).

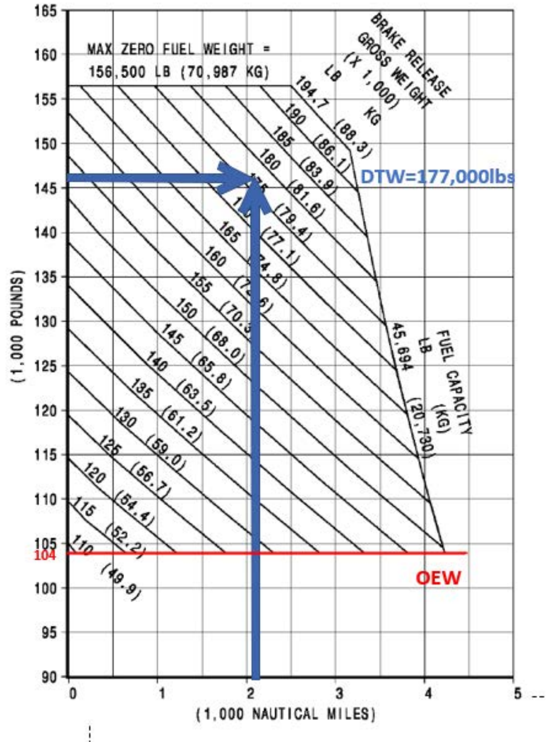
b) Find the Desired Takeoff Weight (DTW) to fly the two proposed routes. Assume a 100% passenger load factor in your analysis (i.e., all seats are full). Clearly state the fuel weight, operating empty weight and payload carried. Use the passenger weights discussed in class.

Use the Boeing 737-9 Max manual supplied by Boeing.

Operating empty weight=104,000 lbs payload carried=193*220=42,460 lbs

OEW+PL=146,460 lbs   DTW=177,000 lbs (from the payload-range diagram)

Fuel Weight = DTW-(OEW+PL) = 30,540 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 mean daily maximum temperature of the hottest month is 88.3°F.

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

Airport Elevation=14.1ft

ISA Temperature at 14.1ft is 59.04F

59.04+27=86.04 deg. F and 86.04+3=89.04F>88.3F

We can use takeoff figures for ISA+27F

Takeoff length=7,600 (see the figure below). The runway needs to be corrected for runway gradient.

Runway gradient analysis. Airnav does not report a gradient for runway 1-19 (the longest runway at DCA). This probably means the runway is relatively flat. The FAA airport diagram reports runway elevations of 12.1 feet for runway threshold 19 and 11.4 feet for runway threshold 1. The runway difference for runway 1/19 at DCA is only 0.7 feet. Assuming a maximum difference in centerlines of 0.7 feet,

Takeoff length=7,600+10*0.7=7,607ft≈7,600 ft

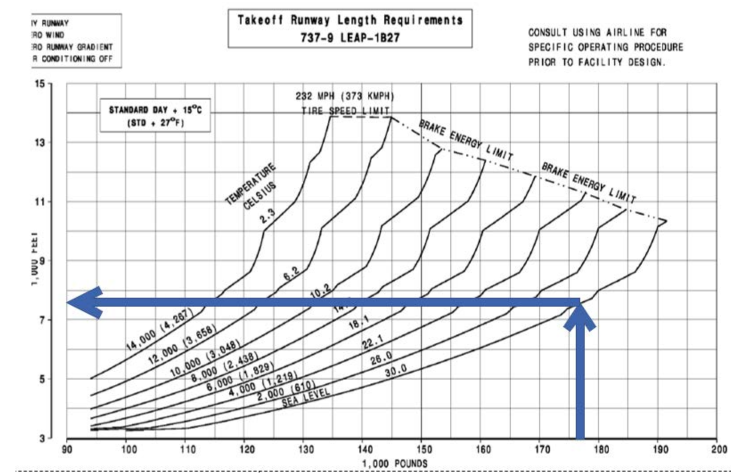
Since DTW> MALW, we use the maximum allowable landing weight. (Flaps=40°)

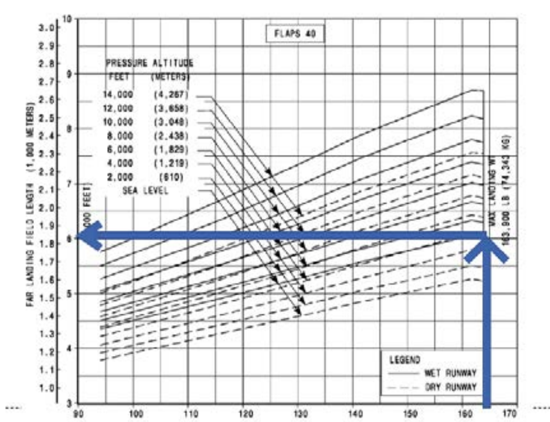
Landing length=6,000ft.

The runway length needed for both trips (DCA−SEA and DCA −SAN) is 7,600ft.

Runway 1/19 at DCA Dimensions: 7169 x 150 ft. / 2185 x 46 m

DCA does not have the runway length to support both flights. A runway extension of 431 feet will be needed.





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

Runway 1/19 at DCA Dimensions: 7169 x 150 ft. / 2185 x 46 m

The runway length extension needed to support the proposed flights is 431ft.

Problem 3

A new airport will be constructed at a site located 3,500 feet above sea level. Temperature data collected at the site shows the mean daily maximum temperature of the hottest month to be 26 degrees Celsius. Table 1 shows the design aircraft. Figure 1 shows a picture of the design aircraft.

Aircraft	*Engine*	*Remarks*
Boeing 747-8 (passenger version) *987,000 Maximum Takeoff Weight*	*GEnx 2B engines*	*Passenger configuration with a total of 513 seats*

Figure 1. Boeing 747-8 Passenger Version (A.A. Trani).

a) Find the runway length required to satisfy FAA and EASA regulations to operate the critical aircraft without takeoff restrictions from the new airport. This implies the airline will be able to depart at the maximum takeoff gross weight from the airport.

ISA Temperature at 3,500ft is 8.1C (remember temperature is linear with altitude).

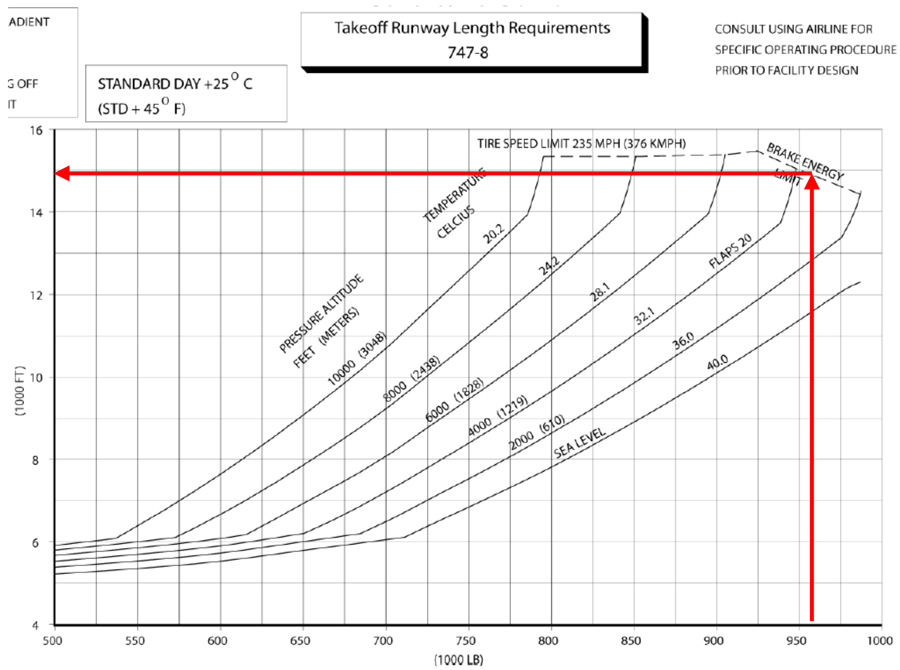
8.1+15=23.1C   23.1+1.7 <26

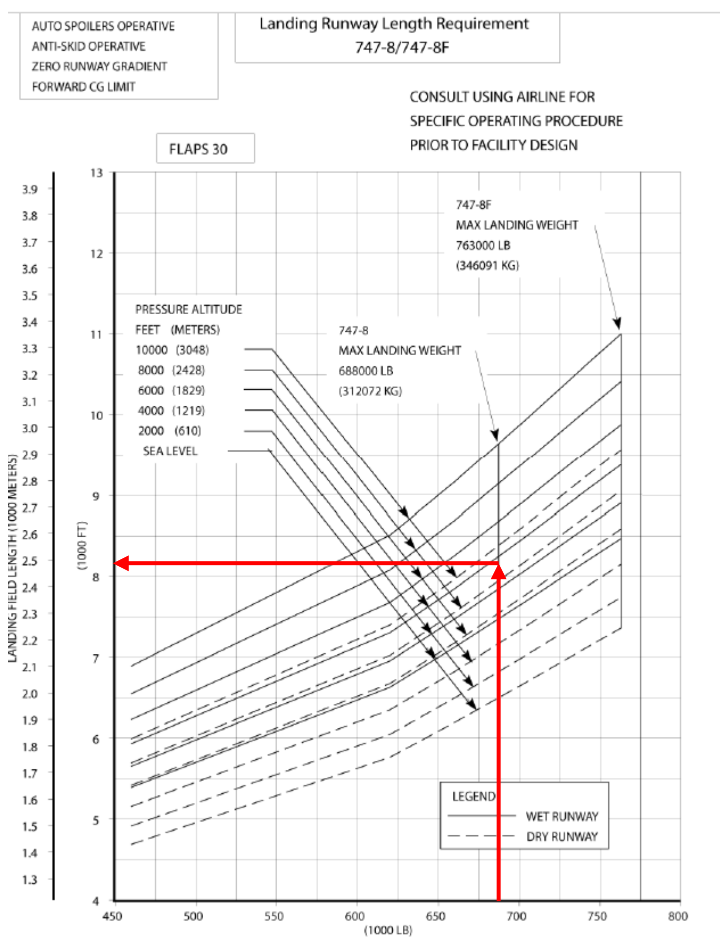
We have to use the takeoff figures for ISA+25C instead of standard+15C. The temperature at the airport is well above ISA + 15 deg. C.

Takeoff length=14,800ft

Landing length=8,200ft

The runway length required to satisfy FAA and EASA regulations is 14,800 ft. See the solution in the Boeing charts below.


Takeoff Runway Length Requirements
747-8
STANDARD DAY +25° C
(STD + 45° F)
CONSULT USING AIRLINE FOR
SPECIFIC OPERATING PROCEDURE
PRIOR TO FACILITY DESIGN
TIRE SPEED LIMIT 235 MPH (376 KMPH)
BRAKE ENERGY LIMIT
TEMPERATURE CELCIUS
FLAPS 20
PRESSURE ALTITUDE FEET (METERS)
10000 (3048)
8000 (2438)
6000 (1828)
4000 (1219)
2000 (610)
SEA LEVEL
(1000 FT)
(1000 LB)


AUTO SPOILERS OPERATIVE
ANTI-SKID OPERATIVE
ZERO RUNWAY GRADIENT
FORWARD CG LIMIT
Landing Runway Length Requirement
747-8/747-8F
CONSULT USING AIRLINE FOR
SPECIFIC OPERATING PROCEDURE
PRIOR TO FACILITY DESIGN
FLAPS 30
747-8F
MAX LANDING WEIGHT
763000 LB
(346091 KG)
PRESSURE ALTITUDE
FEET (METERS)
10000 (3048)
8000 (2428)
6000 (1829)
4000 (1219)
2000 (610)
SEA LEVEL
747-8
MAX LANDING WEIGHT
688000 LB
(312072 KG)
LEGEND
WET RUNWAY
DRY RUNWAY
LANDING FIELD LENGTH (1000 METERS)
(1000 FT)
(1000 LB)

b) What is the flap setting expected during the takeoff at maximum takeoff weight?

Normally, the flap setting for takeoff is 20 degrees according to the Boeing takeoff chart above.

c) 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 2 Instrument Landing System (ILS) with visibility minima of 1200 feet RVR.

Boeing 747-8 AAC D ADG VI

1200ft=0.227mile Visibility minimum lower than 3/4 mile (Reference Table: A7-12)

Dimensions of RSA:

Length beyond departure end	1,000 ft
Length prior to threshold	600 ft
Width	500 ft

Dimensions of RPZ:

Approach	Length	2500 ft
	Inner Width	1000 ft
	Outer Width	1750 ft
	Acres	78.914
Departure	Length	1700 ft
	Inner Width	500 ft
	Outer Width	1010 ft
	Acres	29.465

Dimensions of ROFA:

Length beyond departure end	1000 ft
Length prior to threshold	600 ft
Width	800 ft

Dimensions of obstacle free zone:

a. The ROFZ extends 200 feet (61 m) beyond each end of the runway. Its width is as follows: 400 feet (122 m) for operations by large aircraft

b. No Inner-approach OFZ since it applies only to runways with an ALS but no information for ALS.

c. Inner-transitional OFZ:

S is the wingspan of the aircraft. E is the airport elevation in feet. The following:

S=224.42ft E=3500ft

H= 16.13ft, Y=598.37ft

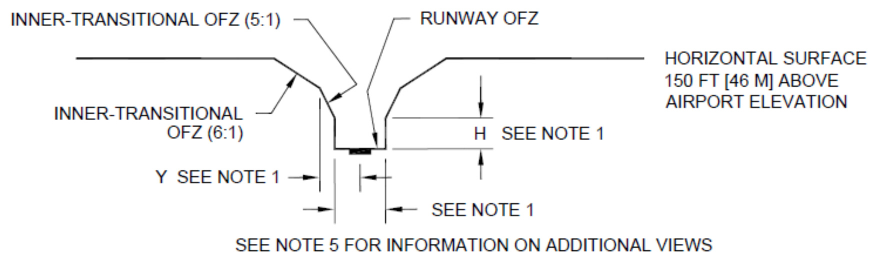
150-(598.37-200)/5-H=54.20ft

Distance to centerline of runway=54.20*6+Y=923.57ft

(i) In U.S. customary units,

$H_{feet} = 53 - 0.13(S_{feet}) - 0.0022(E_{feet})$ and

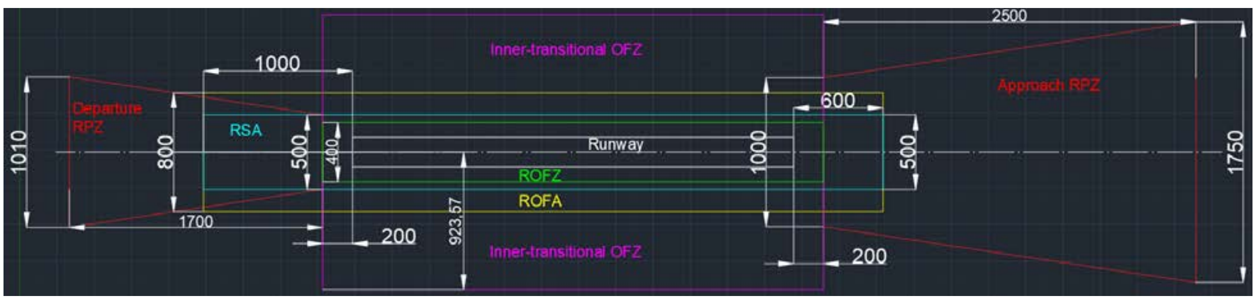
$Y_{feet} = 440 + 1.08(S_{feet}) - 0.024(E_{feet})$.



RUNWAYS SERVING LARGE AIRPLANES WITH CATEGORY II AND III APPROACH MINIMUMS

d) Draw all 4 basic runway protection areas to scale using Autocad or any drawing program of your choice (top view is required). Comment on the size of the runway protection zones need at the airport.

Note that the runway is shortened to accommodate the plot.



Comments: The shape of runway protection zone is trapezoid. The size of the approach runway protection zone is longer than the RPZ needed for departures.