Assignment 2: Runway Length Analysis for Small Aircraft

Date Due: September 8, 2022 Instructor: Trani

Quick Reading: Review Chapters 1 and 2 of the FAA Advisory Circular 150/5325-4b. Also, review the course notes Aircraft Runway Length Estimation (http://128.173.204.63/cee4674/cee4674_pub/runway_calculations_Aircraft_upTo_60000lbs.pdf).

Problem 1

Use the Small Aircraft Runway Length Analysis Tool (SARLAT) to **design a runway** at a new airport located 3,400 feet above mean sea level conditions. The average maximum daily temperature of the hottest month of the year is 82 degrees Fahrenheit. Table 1 shows the representative aircraft at the airport. To obtain the SARLAT tool, follow the links in the class notes.

a) Find the required runway length to satisfy the runway performance requirements for all aircraft in Table 1. For the critical aircraft, list the following runway lengths: 1) dry runway takeoff distance, 2) wet runway takeoff distance, 3) dry landing distance, and 4) wet landing distance. Use the default "useful load" parameters included in SARLAT (100% for piston aircraft and 90% for turboprop and jet-powered aircraft).

Runway lengths for critical aircrafts

1.a.1.) Dry runway takeoff distance: 4,849 ft. for Cessna Citation Jet 1

1.a.2.) Wet runway takeoff distance: 5,576 ft. for Cessna Citation Jet 1

1.a.3.) Dry landing distance: 3,079 ft. for Cessna Citation Jet 1

1.a.4.) Wet landing distance: 3,541 ft. for Cessna Citation Jet 1

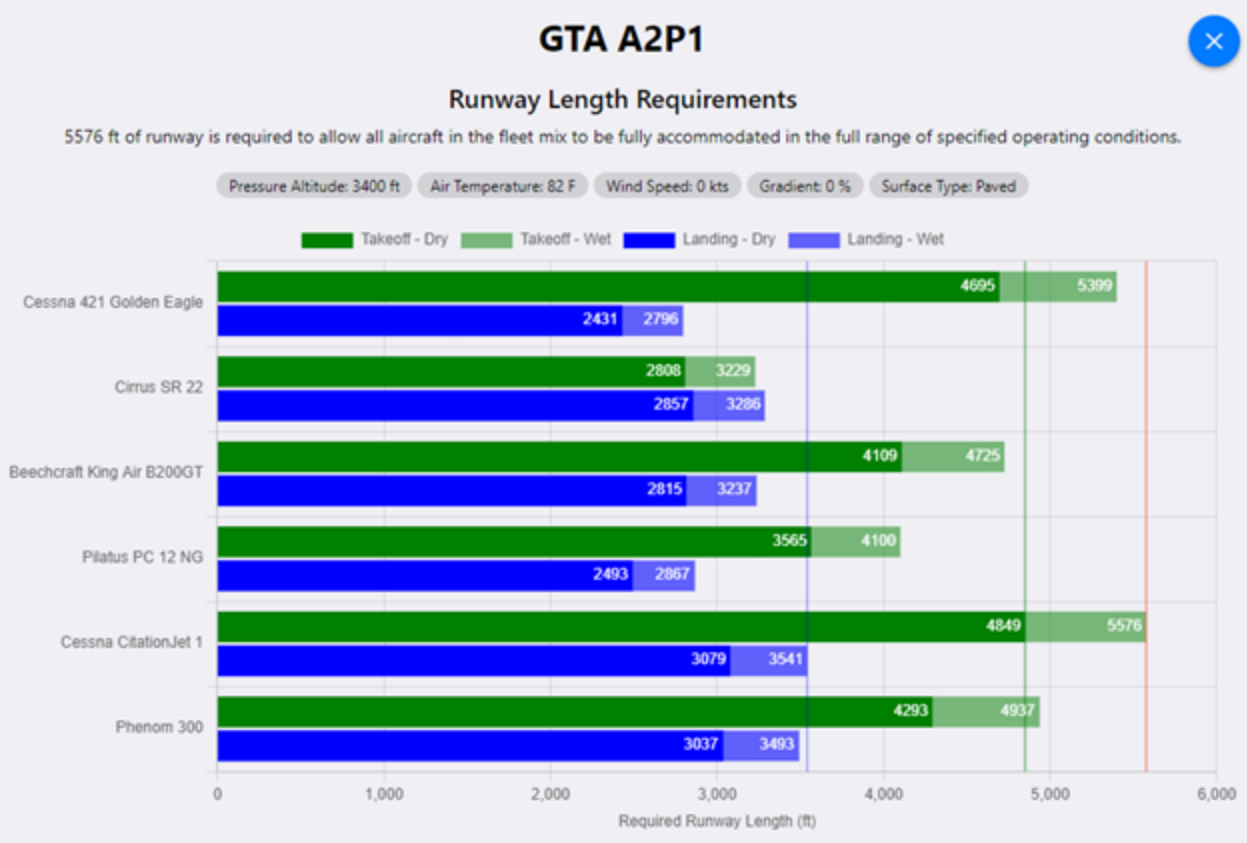
b) The FAA Airport Improvement Program (AIP) pays for a **dry takeoff runway** and a **wet landing runway**. Find the runway length that the FAA AIP Program may approve. State the critical aircraft and the condition used (i.e., takeoff or landing).

The runway length supported through the FAA AIP Program is 4,849 ft (Cessna Citation Jet 1). The critical aircraft for dry takeoff runway (and wet landing runway) is the Cessna Citation Jet 1.

c) If the airport client wants to pay additionally for a runway that satisfies wet takeoff conditions, estimate the runway length needed. State the critical aircraft used in the design.

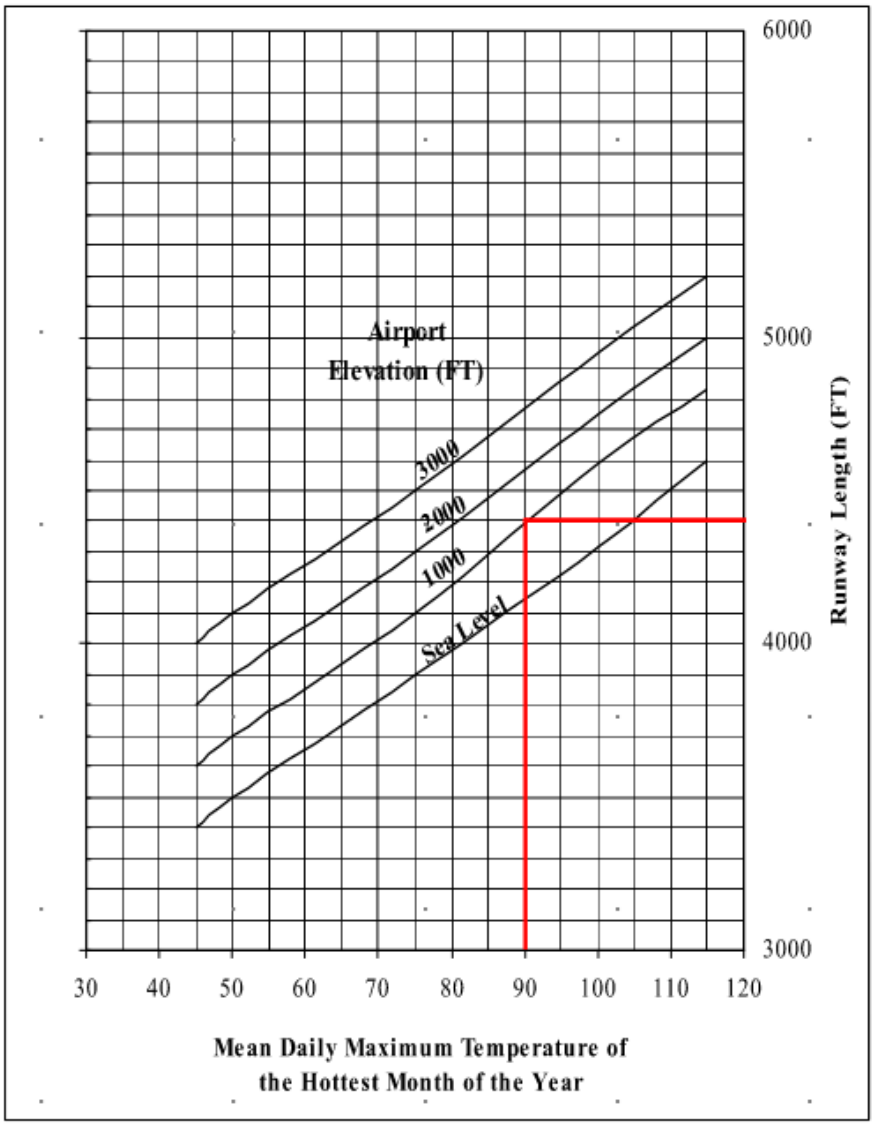
The runway length needed is 5,576 ft for the Cessna Citation Jet 1.(i.e., critical aircraft).

d) Show the SARLAT bar chart of runway length requirements for each aircraft for your solution.



e) Compare the SARLAT solution with the current FAA runway length requirement recommendation for aircraft with more than ten seats (see course notes). Comment on the differences observed.

See below. For aircraft with more than 10 seats and where MTOW <= 12,500 lb, we are required to use guidance outlined in AC 150/5325-4B, Chapter 2 para 205 (Figure 2-2). However, since the airfield elevation is greater than 3,000 ft, the guidance in Figure 2-2 is to use Figure 2-1 at 100% fleet groupings. Thus, according to Figure 2-1, the required runway length is approximately 5,250 ft. I will accept 5,250 ft $\mp$ 5% (4,987 ft – 5,513 ft)

Representative Airplanes	Runway Length Curves
Raytheon B80 Queen Air **Raytheon** E90 King Air **Raytheon** B99 Airliner **Raytheon** A100 King Air (Raytheon formerly Beech Aircraft) **Britten-Norman** Mark III-I Trilander **Mitsubishi** MU-2L **Swearigen** Merlin III-A **Swearigen** Merlin IV-A **Swearigen** Metro II	**Example:** Temperature (mean day max hot month) 90° F (32° C) Airport Elevation (msl) 1,000 feet (328 m) Recommended Runway Length 4,400 feet (1,341 m) **Note:** For airport elevations above 3,000 feet (915 m), use the 100 percent of fleet grouping in figure 2-1. NOTE 

Example:

Temperature (mean day max hot month): 59° F (15° C)
Airport Elevation: Mean Sea Level

Note: Dashed lines shown in the table are mid values of adjacent solid lines.

Recommended Runway Length:

For 95% = 2,700 feet (823 m)
For 100% = 3,200 feet (975 m)

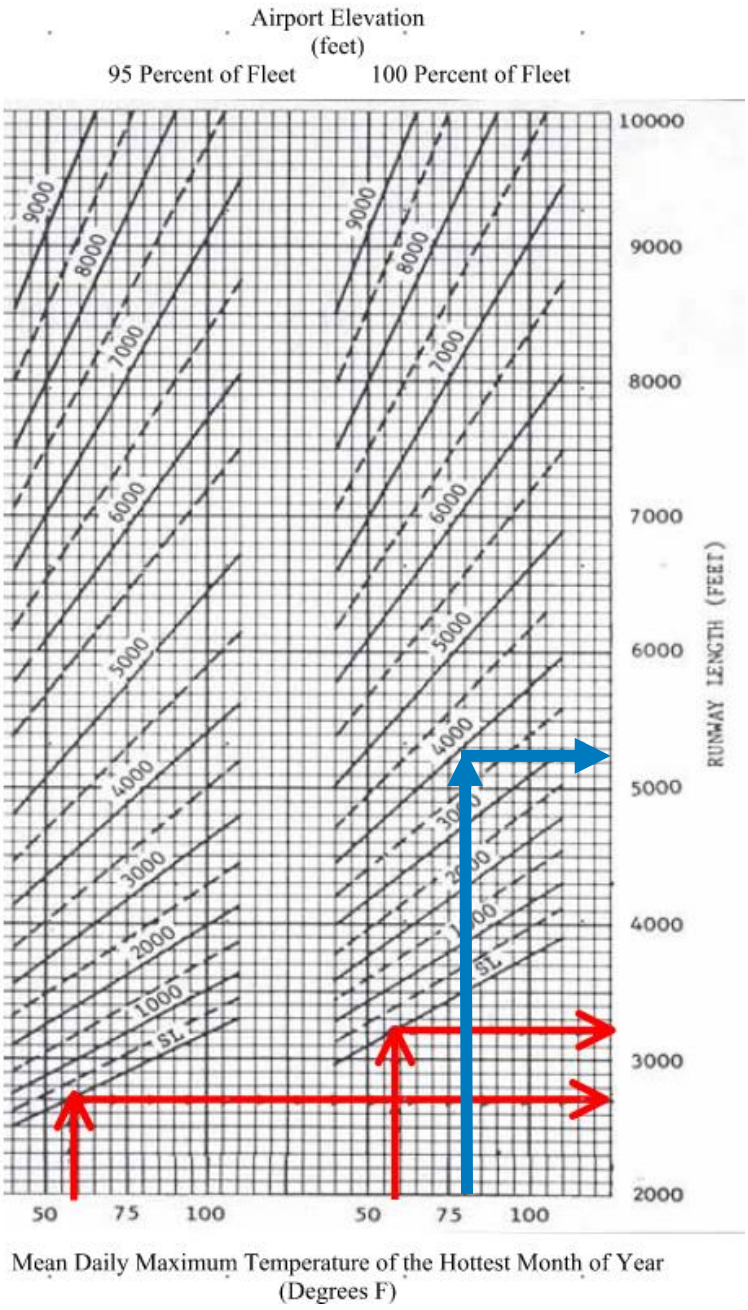


Table 1. Aircraft Fleet Mix for Problem 1.

Aircraft Type	Aircraft	Useful Load (%)	Picture
Piston	Cirrus SR22	100	
Piston	Cessna 421C	100	
Turboprop	Beechcraft King Air B200	90	
Turboprop	Pilatus PC-12	90	
Jet	Cessna CitationJet 1	90	
Jet	Phenom 300	90	

Problem 2

Use the Small Aircraft Runway Length Analysis Tool (SARLAT) to **evaluate a runway extension** for an airport to serve large turboprop and business jet aircraft better. The **existing airport in Madison County, North Carolina,** has a 4,700-foot runway, and the airfield elevation is 1,850 feet above mean sea level conditions. The runway has a grade of 0.5%. Find the average maximum daily temperature of the hottest month of the year using the Climate Explorer website (https://crt-climate-explorer.nemac.org/). Table 2 shows the existing aircraft fleet mix operating at the airport.

Table 2. Future Aircraft Fleet Mix for Problem 2.

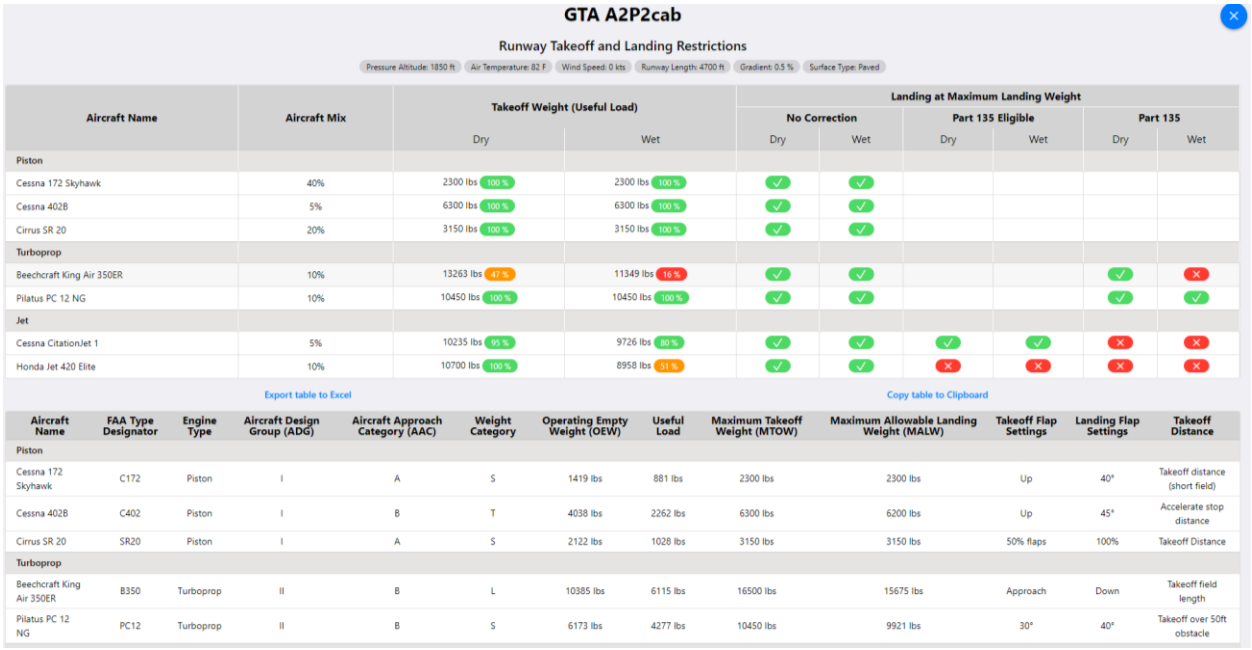
Aircraft Type	Aircraft	Percent of Fleet Mix (%)	Picture
Piston	Cessna 172	40	
Piston	Cirrus SR20	20	
Piston	Cessna 402	5	
Turboprop	Beechcraft King Air B350ER	10	

Aircraft Type	Aircraft	Percent of Fleet Mix (%)	Picture
Turboprop	Pilatus PC-12	10	
Jet	Cessna CitationJet 1	5	
Jet	Honda Jet 420	10	
Total		100	

From figure above, average daily high temp of hottest month (July) in Madison Co., NC is 82 deg. F.

For **existing runway length conditions,** answer the following:

a) For dry runway conditions, find the maximum takeoff weight and useful load for the Beechcraft King Air B350ER, the Honda Jet 420, and Cessna CitationJet 1 operating from the existing runway (i.e., 4,



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Runway Takeoff and Landing Restrictions

Pressure Altitude: 1850 ft | Air Temperature: 82 F | Wind Speed: 0 kts | Runway Length: 4700 ft | Gradient: 0.5 % | Surface Type: Paved

Aircraft Name	Aircraft Mix	Takeoff Weight (Useful Load)		Landing at Maximum Landing Weight					
				No Correction		Part 135 Eligible		Part 135	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Piston									
Cessna 172 Skyhawk	40%	2300 lbs 100 %	2300 lbs 100 %	✓	✓				
Cessna 402B	5%	6300 lbs 100 %	6300 lbs 100 %	✓	✓				
Cirrus SR 20	20%	3150 lbs 100 %	3150 lbs 100 %	✓	✓				
Turboprop									
Beechcraft King Air 350ER	10%	13263 lbs 47 %	11349 lbs 16 %	✓	✓			✓	✗
Pilatus PC 12 NG	10%	10450 lbs 100 %	10450 lbs 100 %	✓	✓			✓	✓
Jet									
Cessna CitationJet 1	5%	10235 lbs 95 %	9726 lbs 80 %	✓	✓	✓	✓	✗	✗
Honda Jet 420 Elite	10%	10700 lbs 100 %	8958 lbs 51 %	✓	✓	✗	✗	✗	✗

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Aircraft Name	FAA Type Designator	Engine Type	Aircraft Design Group (ADG)	Aircraft Approach Category (AAC)	Weight Category	Operating Empty Weight (OEW)	Useful Load	Maximum Takeoff Weight (MTOW)	Maximum Allowable Landing Weight (MALW)	Takeoff Flap Settings	Landing Flap Settings	Takeoff Distance
Piston												
Cessna 172 Skyhawk	C172	Piston	I	A	S	1419 lbs	881 lbs	2300 lbs	2300 lbs	Up	40°	Takeoff distance (short field)
Cessna 402B	C402	Piston	I	B	T	4038 lbs	2262 lbs	6300 lbs	6200 lbs	Up	45°	Accelerate stop distance
Cirrus SR 20	SR20	Piston	I	A	S	2122 lbs	1028 lbs	3150 lbs	3150 lbs	50% flaps	100%	Takeoff Distance
Turboprop												
Beechcraft King Air 350ER	B350	Turboprop	II	B	L	10385 lbs	6115 lbs	16500 lbs	15675 lbs	Approach	Down	Takeoff field length
Pilatus PC 12 NG	PC12	Turboprop	II	B	S	6173 lbs	4277 lbs	10450 lbs	9921 lbs	30°	40°	Takeoff over 50ft obstacle

Aircraft Name	FAA Type Designator	Engine Type	Aircraft Design Group (ADG)	Aircraft Approach Category (AAC)	Weight Category	Operating Empty Weight (OEW)	Useful Load	Maximum Takeoff Weight (MTOW)
Piston								
Cessna 172 Skyhawk	C172	Piston	I	A	S	1419 lbs	881 lbs	2300 lbs
Cessna 402B	C402	Piston	I	B	T	4038 lbs	2262 lbs	6300 lbs
Cirrus SR 20	SR20	Piston	I	A	S	2122 lbs	1028 lbs	3150 lbs
Turboprop								
Beechcraft King Air 350ER	B350	Turboprop	II	B	L	10385 lbs	6115 lbs	16500 lbs
Pilatus PC 12 NG	PC12	Turboprop	II	B	S	6173 lbs	4277 lbs	10450 lbs
Jet								
Cessna CitationJet 1	C525	Jet	II	B	L	7000 lbs	3400 lbs	10400 lbs
Honda Jet 420 Elite	HDJT	Jet	I	B	T	7153 lbs	3547 lbs	10700 lbs

From figure and table above,

Beechcraft King Air B350ER:

takeoff weight – 13,263 lbs on dry runway

useful load – 47% of 6,115 lbs. = 2,874 lbs.

Honda Jet 420:

takeoff weight – 10,700 lbs on dry runway

useful load – 100% of 3,547 lbs. = 3,547 lbs.

Cessna Citation Jet 1:

takeoff weight – 10,235 lbs on dry runway

useful load – 95% of 3,400 lbs. = 3,230 lbs.

b) How many miles can the King Air B350ER fly with ten passengers for the estimated useful load in part (a)?

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Range vs Useful Load Table for Beechcraft B350ER

Table assumes a full load of passengers except when mission range requires off loading passengers to carry more fuel.

For example: a mission range of 300 nm carrying 10 passengers is equivalent to 61.5% useful load for this aircraft.

Mission Range (nm)	Maximum Number of Passengers	Useful Load (%)
100	10	50.4
150	10	53.5
200	10	56.4
300	10	61.5
600	10	73.7
1000	10	87.0
1316	10	97.4
1400	10	100.0
1500	9	100.0
1600	8	100.0
1700	7	100.0
1800	6	100.0
1900	5	100.0
2223	3	100.0

All values in the table assume two pilots and 30 lbs of luggage for each pilot

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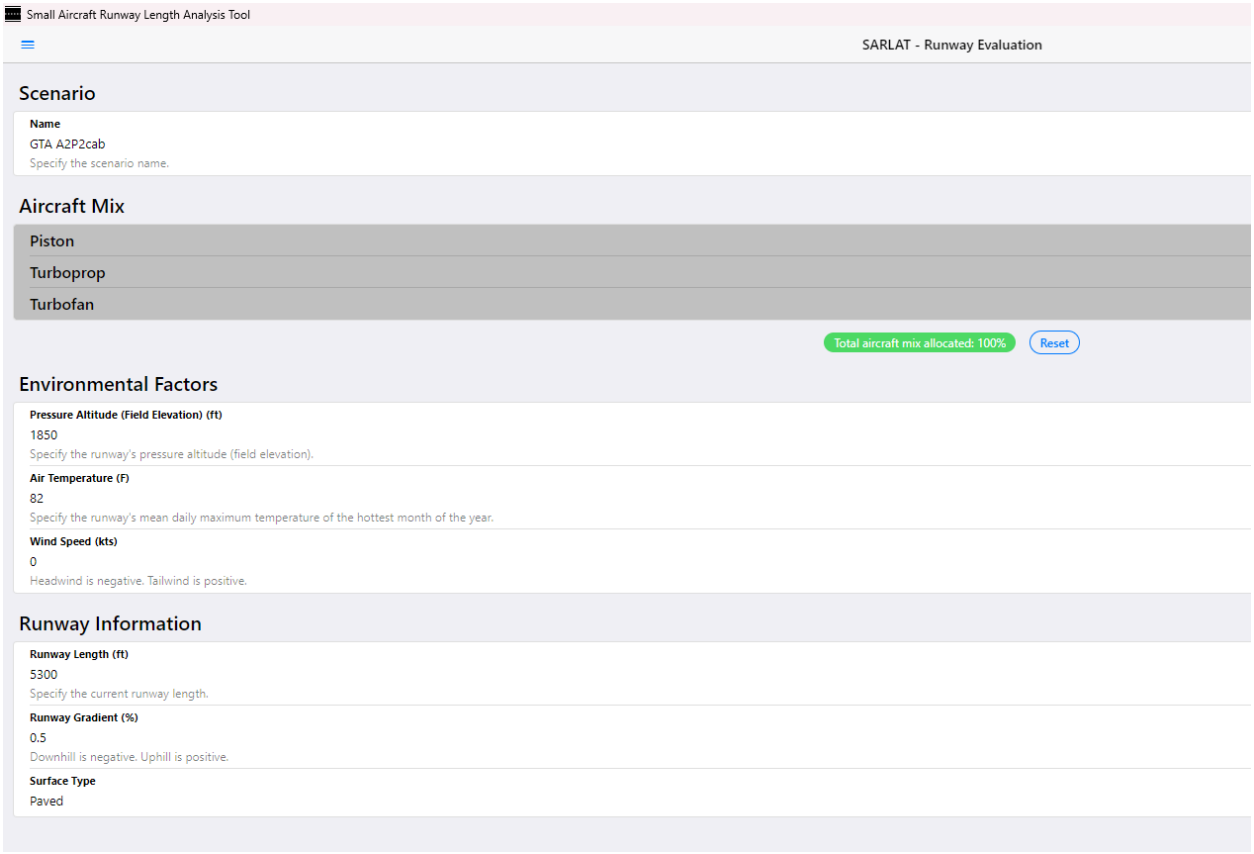
By interpolation of the above table in course notes, when useful load is 47%:

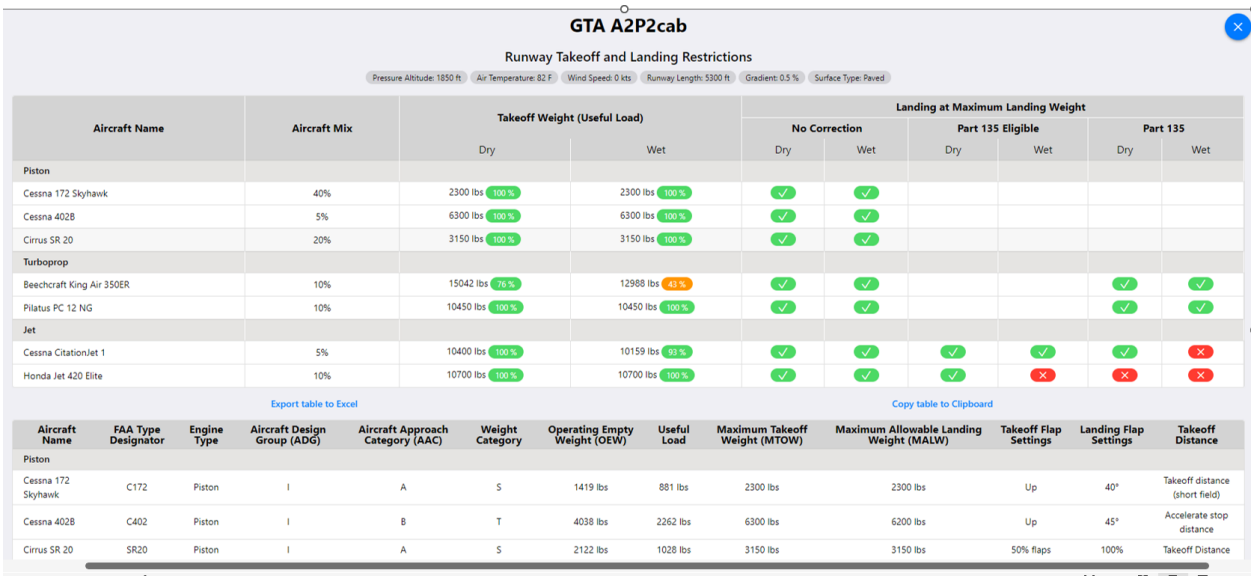
$$miles = -\left(\frac{(150-100)(53.5-47)}{(53.5-50.4)} - 150\right) = 45\ nm$$

I will accept 45 nm ∓ 5% (42 nm – 48 nm)

For the **proposed runway extension,** answer the following:

c) If the runway is extended to 5,300 feet, find the improved useful load parameters for the Beechcraft King Air B350ER and the Honda Jet 420.





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Runway Takeoff and Landing Restrictions

Pressure Altitude: 1850 ft | Air Temperature: 82 F | Wind Speed: 0 kts | Runway Length: 5300 ft | Gradient: 0.5 % | Surface Type: Paved

Aircraft Name	Aircraft Mix	Takeoff Weight (Useful Load)		Landing at Maximum Landing Weight					
				No Correction		Part 135 Eligible		Part 135	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Piston									
Cessna 172 Skyhawk	40%	2300 lbs 100 %	2300 lbs 100 %	✓	✓				
Cessna 402B	5%	6300 lbs 100 %	6300 lbs 100 %	✓	✓				
Cirrus SR 20	20%	3150 lbs 100 %	3150 lbs 100 %	✓	✓				
Turboprop									
Beechcraft King Air 350ER	10%	15042 lbs 76 %	12988 lbs 43 %	✓	✓			✓	✓
Pilatus PC 12 NG	10%	10450 lbs 100 %	10450 lbs 100 %	✓	✓			✓	✓
Jet									
Cessna CitationJet 1	5%	10400 lbs 100 %	10159 lbs 93 %	✓	✓	✓	✓	✓	✗
Honda Jet 420 Elite	10%	10700 lbs 100 %	10700 lbs 100 %	✓	✓	✓	✗	✗	✗

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Aircraft Name	FAA Type Designator	Engine Type	Aircraft Design Group (ADG)	Aircraft Approach Category (AAC)	Weight Category	Operating Empty Weight (OEW)	Useful Load	Maximum Takeoff Weight (MTOW)	Maximum Allowable Landing Weight (MALW)	Takeoff Flap Settings	Landing Flap Settings	Takeoff Distance
Piston												
Cessna 172 Skyhawk	C172	Piston	I	A	S	1419 lbs	881 lbs	2300 lbs	2300 lbs	Up	40°	Takeoff distance (short field)
Cessna 402B	C402	Piston	I	B	T	4038 lbs	2262 lbs	6300 lbs	6200 lbs	Up	45°	Accelerate stop distance
Cirrus SR 20	SR20	Piston	I	A	S	2122 lbs	1028 lbs	3150 lbs	3150 lbs	50% flaps	100%	Takeoff Distance

Aircraft Name	Aircraft Mix	Takeoff Weight (Useful Load)		Landing at Maximum Landing Weight					
				No Correction		Part 135 Eligible		Part 135	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Piston									
Cessna 172 Skyhawk	40%	2300 lbs 100 %	2300 lbs 100 %	checkmark	checkmark				
Cessna 402B	5%	6300 lbs 100 %	6300 lbs 100 %	checkmark	checkmark				
Cirrus SR 20	20%	3150 lbs 100 %	3150 lbs 100 %	checkmark	checkmark				
Turboprop									
Beechcraft King Air 350ER	10%	15042 lbs 76 %	12988 lbs 43 %	checkmark	checkmark			checkmark	checkmark
Pilatus PC 12 NG	10%	10450 lbs 100 %	10450 lbs 100 %	checkmark	checkmark			checkmark	checkmark
Jet									
Cessna CitationJet 1	5%	10400 lbs 100 %	10159 lbs 93 %	checkmark	checkmark	checkmark	checkmark	checkmark	multiply
Honda Jet 420 Elite	10%	10700 lbs 100 %	10700 lbs 100 %	checkmark	checkmark	checkmark	multiply	multiply	multiply

From figure and table above,

Beechcraft King Air B350ER:

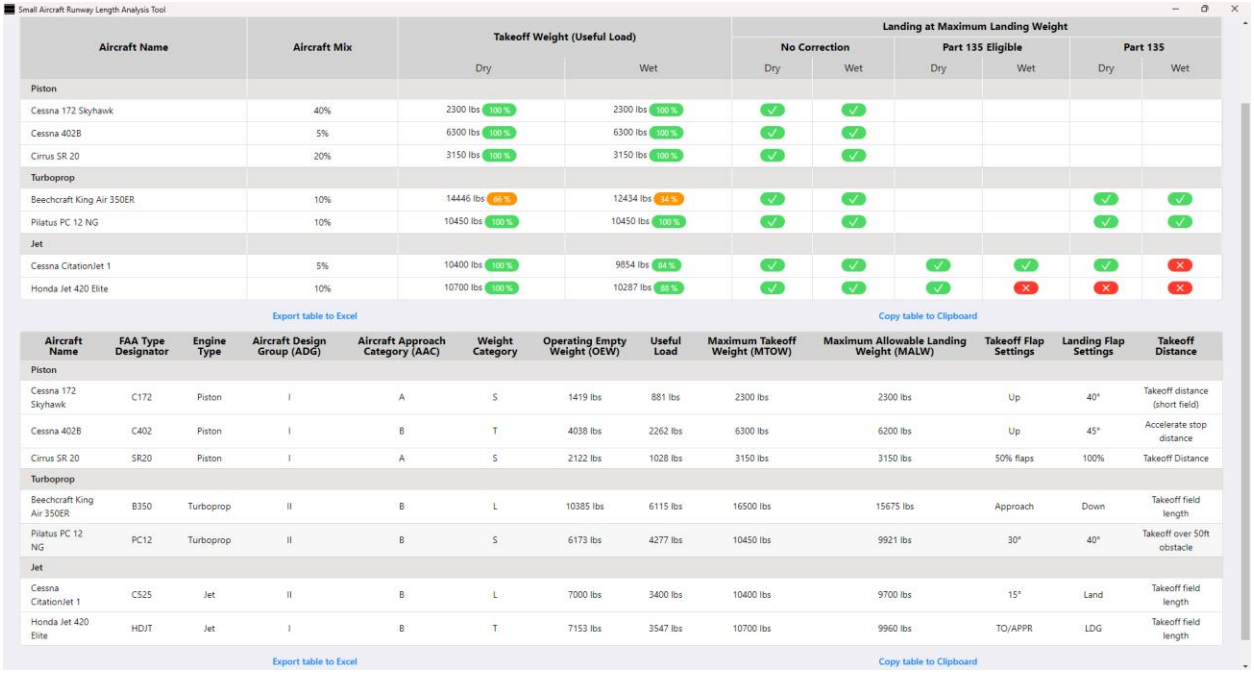
takeoff weight – 15,042 lbs on dry runway

useful load – 76% of 6,115 lbs. = 4,647 lbs.

Honda Jet 420:

takeoff weight – 10,700 lbs on dry runway

useful load – 100% of 3,547 lbs. = 3,547 lbs.



Small Aircraft Runway Length Analysis Tool

Aircraft Name	Aircraft Mix	Takeoff Weight (Useful Load)		Landing at Maximum Landing Weight					
				No Correction		Part 135 Eligible		Part 135	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Piston									
Cessna 172 Skyhawk	40%	2300 lbs 100 %	2300 lbs 100 %	✓	✓				
Cessna 402B	5%	6300 lbs 100 %	6300 lbs 100 %	✓	✓				
Cirrus SR 20	20%	3150 lbs 100 %	3150 lbs 100 %	✓	✓				
Turboprop									
Beechcraft King Air 350ER	10%	14446 lbs 66 %	12434 lbs 34 %	✓	✓			✓	✓
Pilatus PC 12 NG	10%	10450 lbs 100 %	10450 lbs 100 %	✓	✓			✓	✓
Jet									
Cessna CitationJet 1	5%	10400 lbs 100 %	9854 lbs 84 %	✓	✓	✓	✓	✓	✗
Honda Jet 420 Elite	10%	10700 lbs 100 %	10287 lbs 88 %	✓	✓	✓	✗	✗	✗

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Aircraft Name	FAA Type Designator	Engine Type	Aircraft Design Group (ADG)	Aircraft Approach Category (AAC)	Weight Category	Operating Empty Weight (OEW)	Useful Load	Maximum Takeoff Weight (MTOW)	Maximum Allowable Landing Weight (MALW)	Takeoff Flap Settings	Landing Flap Settings	Takeoff Distance
Piston												
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Cessna 402B	C402	Piston	I	B	T	4038 lbs	2262 lbs	6300 lbs	6200 lbs	Up	45°	Accelerate stop distance
Cirrus SR 20	SR20	Piston	I	A	S	2122 lbs	1028 lbs	3150 lbs	3150 lbs	50% flaps	100%	Takeoff Distance
Turboprop												
Beechcraft King Air 350ER	B350	Turboprop	II	B	L	10385 lbs	6115 lbs	16500 lbs	15675 lbs	Approach	Down	Takeoff field length
Pilatus PC 12 NG	PC12	Turboprop	II	B	S	6173 lbs	4277 lbs	10450 lbs	9921 lbs	30°	40°	Takeoff over 50ft obstacle
Jet												
Cessna CitationJet 1	C525	Jet	II	B	L	7000 lbs	3400 lbs	10400 lbs	9700 lbs	15°	Land	Takeoff field length
Honda Jet 420 Elite	HDJT	Jet	I	B	T	7153 lbs	3547 lbs	10700 lbs	9960 lbs	TO/APPR	LDG	Takeoff field length

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d) Comment on the significance of adding 600 feet to the existing runway. Use the table below that applies to the Beechcraft King Air B350ER. Specifically, estimate the additional aircraft range that can be flown in the King Air B350ER after the runway extension.

VIRGINIA TECH

Range vs Useful Load Table for Beechcraft B350ER

Table assumes a full load of passengers except when mission range requires off loading passengers to carry more fuel.

For example: a mission range of 300 nm carrying 10 passengers is equivalent to 61.5% useful load for this aircraft.

Mission Range (nm)	Maximum Number of Passengers	Useful Load (%)
100	10	50.4
150	10	53.5
200	10	56.4
300	10	61.5
600	10	73.7
1000	10	87.0
1316	10	97.4
1400	10	100.0
1500	9	100.0
1600	8	100.0
1700	7	100.0
1800	6	100.0
1900	5	100.0
2223	3	100.0

All values in the table assume two pilots and 30 lbs of luggage for each pilot

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By interpolation of the above table in course notes, when useful load is 76%:

$$miles = \frac{(1000 - 600)(76 - 73.7)}{(87 - 73.7)} + 600 = 669\, nm$$

From part (b), the old range (when useful load was 47%) was 45 nm. The new range (when useful load is 76%) is about 669 nm. Thus, the addition of 600 ft to the existing runway allows the aircraft to add 624 nm to its mission range (will accept 624 nm $\mp$ 5%

Problem 3

Use the Small Aircraft Runway Length Analysis Tool (SARLAT) to **design a runway** for a small airport to serve exclusively Light Sport Aircraft (LSA). The proposed airport is located 2,350 feet above mean sea level conditions. The average of the maximum daily temperatures of the hottest month of the year is 85 degrees F. Table 3 shows the aircraft fleet mix for this problem.

Table 3. Aircraft Fleet Mix for Problem 3. All Aircraft are LSA Aircraft.

Aircraft Type	Aircraft	Useful Load (%)	Picture
Piston	Flight Design CTLS	100	
Piston	Vans RV-12	100	

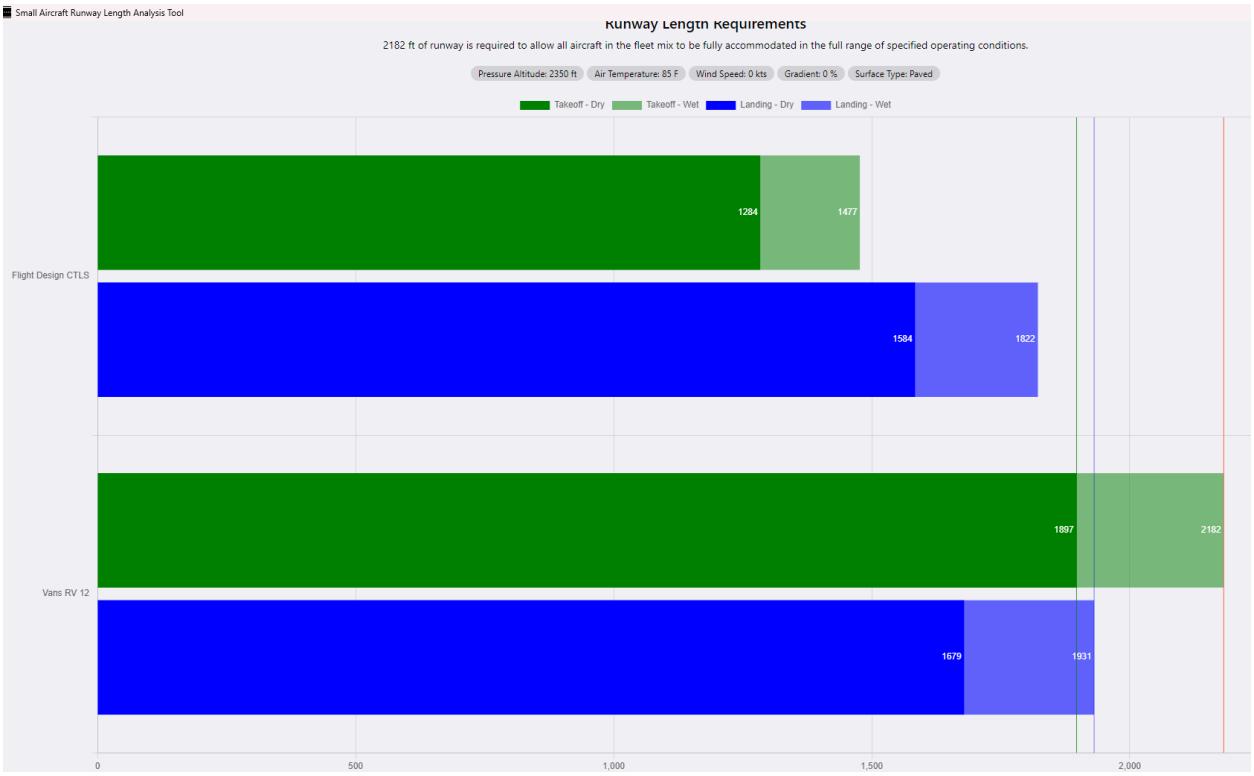
a) Find the required runway length to satisfy the fleet mix in Table 3. For the critical aircraft, list the following runway lengths: 1) dry runway takeoff distance, 2) wet runway takeoff distance, 3) dry landing distance, and 4) wet landing distance. Use the default useful load parameters programmed in SARLAT (100% for piston aircraft).

Runway lengths for critical aircrafts
3.a.1.) Dry runway takeoff distance: 1,897 ft. for Vans RV 12
3.a.2.) Wet runway takeoff distance: 2,182 ft for Vans RV 12
3.a.3.) Dry landing distance: 1,679 ft. for Vans RV 12
3.a.4.) Wet landing distance: 1,931 ft. for Vans RV 12

b) Find the runway length that the FAA AIP Program may approve. State the critical aircraft and the runway condition (i.e., takeoff or landing).

The FAA AIP Program will pay for a dry takeoff runway and a wet landing runway. Here, the highest dry runway takeoff distance is 1,897 ft, and the highest wet landing distance is 1,931 ft. Since the wet landing distance is dominant, the runway length needed is 1,931 ft (rounded to 2,000 ft). The critical aircraft (the one requiring this highest distance) is the Vans RV 12.

c) Show the SARLAT bar chart of runway length requirements for each aircraft for your solution.



d) Compare the SARLAT solution with the current FAA runway length requirement recommendation for LSA aircraft (see course notes). Comment on the differences observed.

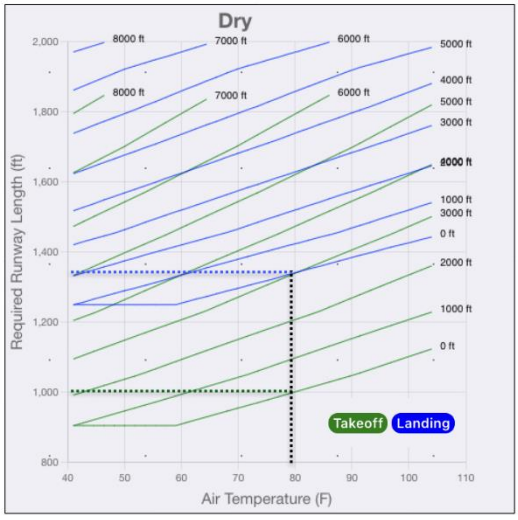
From course notes:

VirginiaTech
Invent the Future

Virginia Tech Recommendation for LSA Aircraft

- Based on recent analysis at Virginia Tech for the FAA we recommend:
  - 1,000 ft for takeoff at sea level and 80 deg. F.
  - **1,350 ft** for landing at sea level at 80 deg. F.

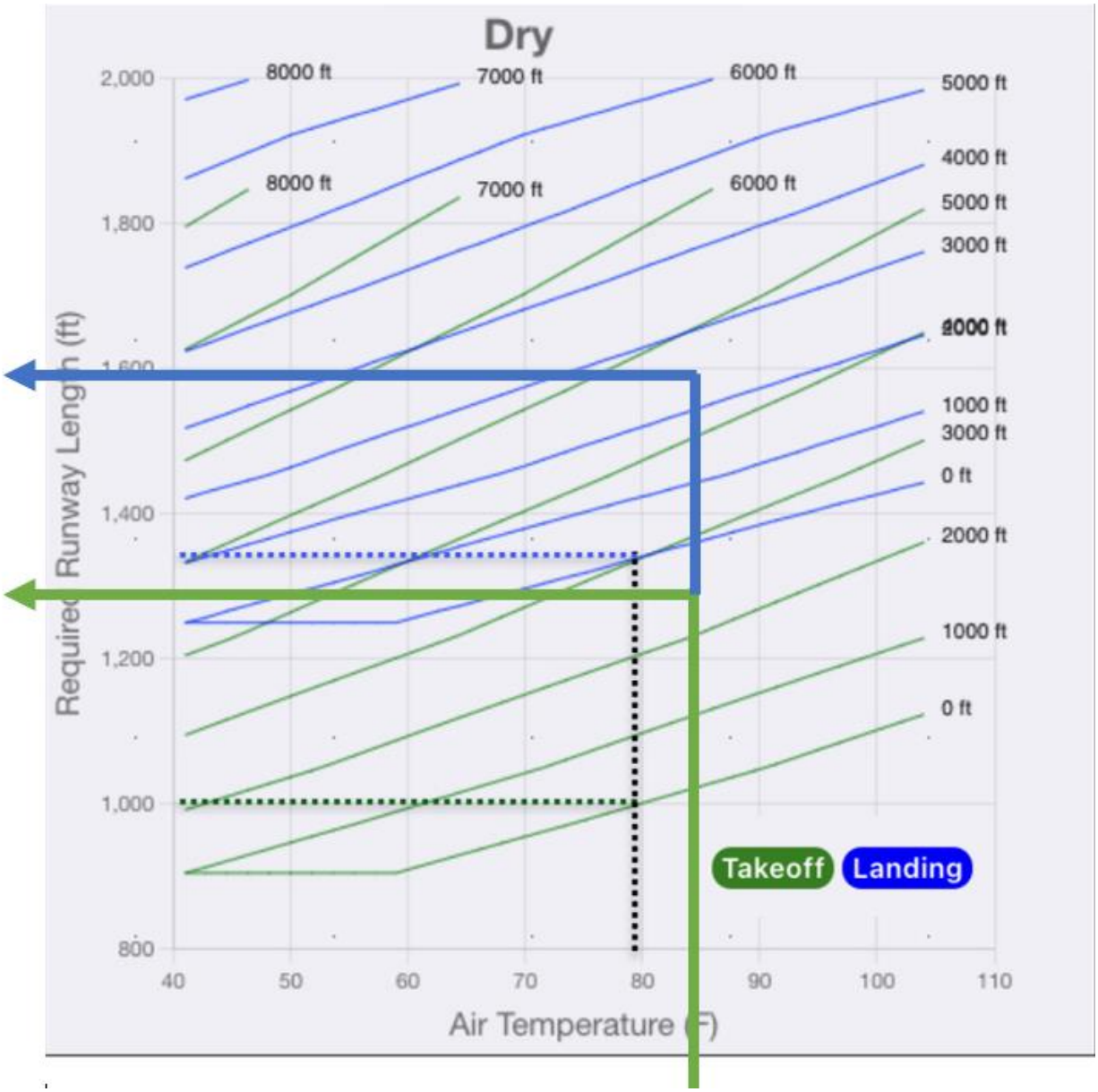
Data for the Flight Design CTLS



Small Aircraft Runway Length Analysis Tool

CEE 4674 – Airport Planning and Design 15

Thus:



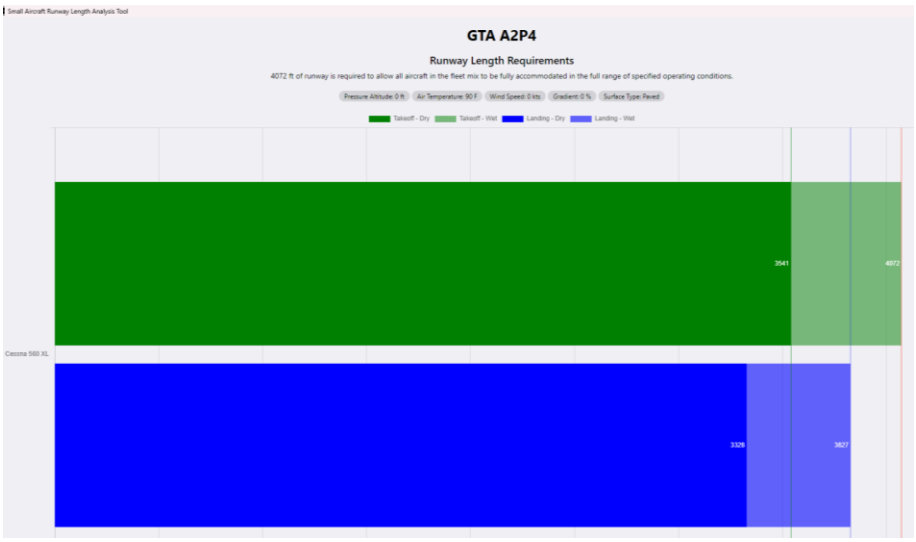
Interpolating for temperature (85 deg F) and airfield elevation (2,350 ft), the required runway lengths are ~1,300 ft for takeoff and ~1,600 ft for landing.

Problem 4

Use the SARLAT tool to estimate the takeoff runway length needed for the Cessna Citation 560 XL (see Figure 1).

a) Find the required runway length at sea level conditions with a design temperature of 90 degrees Fahrenheit, 80% load factor, and zero runway grade.

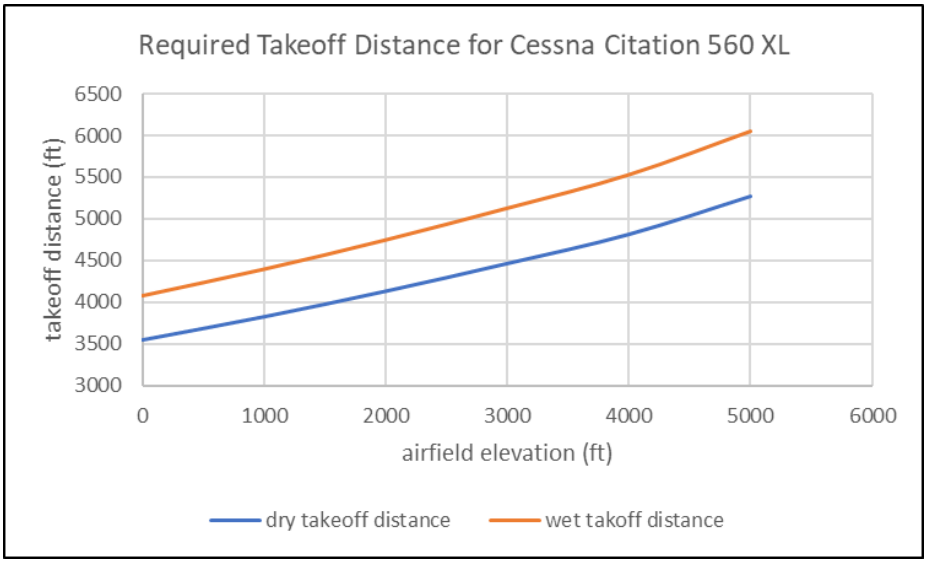
Sample Screenshot (@airfield elevation equals 0 ft):



b) Repeat part (a) for the same temperature conditions but airport elevations of 1000, 2000, 3000, 4000, and 5000 feet.

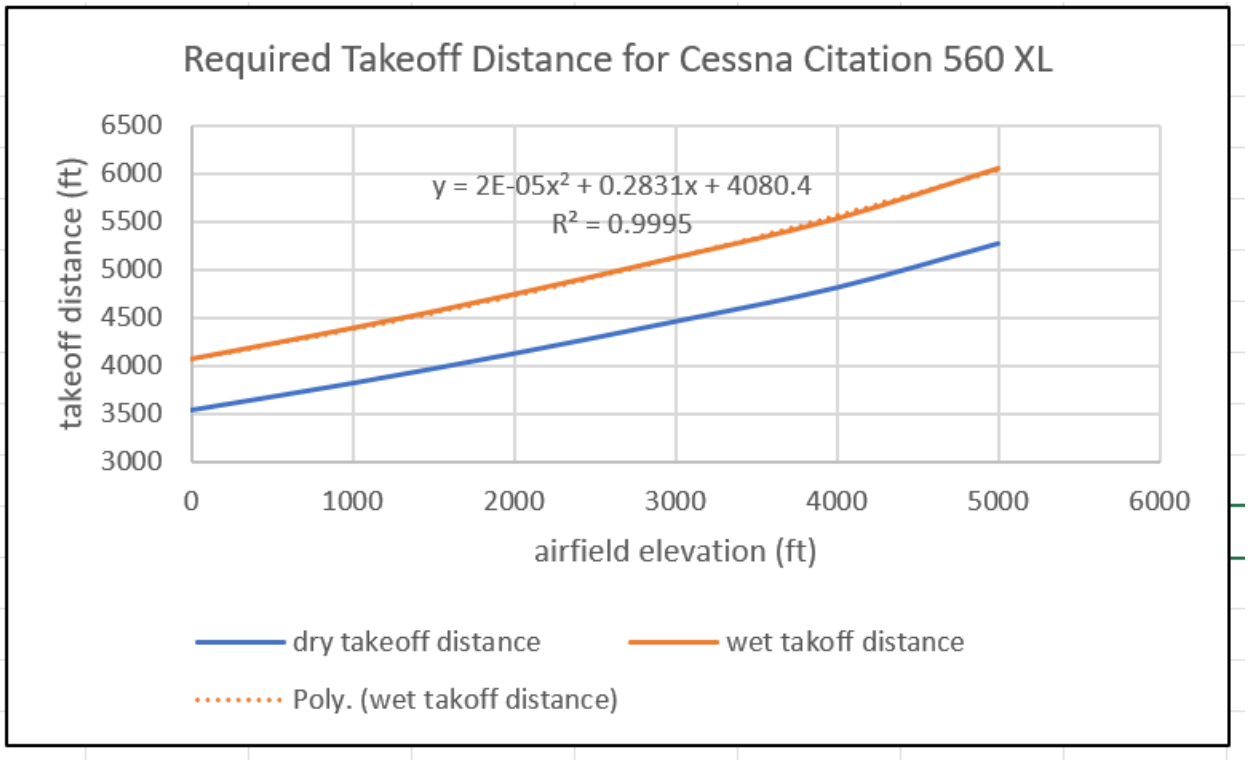
airfield elevation (ft)	dry takeoff distance (ft)	wet takeoff distance (ft)
0	3541	4072
1000	3820	4393
2000	4127	4746
3000	4460	5129
4000	4811	5533
5000	5268	6058

c) Make a plot to show the airport elevation (x-axis) versus the takeoff runway length required (y-axis).



d) What conclusion can you make about the takeoff runway length as a function of airport elevation for a turbofan-powered aircraft. Is the variation of takeoff runway length linear with airport elevation?

Figure 1. Cessna Citation 560 XL. The Other Hokie Bird.



From the trendline equation in the Figure, the relationship between airfield elevation and takeoff distance is quadratic.