Quiz 1 - Take Home (Due October 16, via Canvas)

Solution

Instructor: A.A. Trani

Instructions

Create a solution file using the word processor of your choice. Convert to PDF and submit to Canvas. **Include all screen captures of all your work, including aircraft manufacturer's tables and figures, FAA nomographs, and others if you want to receive partial credit**.

Honor Code Pledge

The information provided in this exam is my own work. I have not received information from another person while doing this exam.

_____ (your signature/name)

Problem 1 (40 points)

Perform an assessment of the **future runway length requirements at Roanoke/Blacksburg Regional Airport (ROA)**. A new airline would like to operate from ROA using the Boeing 737-8 (Boeing 737-8 Max) with characteristics shown in Figure 1. The runway assessment considers flying from ROA to Denver (DEN) and Dallas Fort-Worth (DFW) non-stop with 178 passengers. For this analysis, use the latest version of the Boeing documents for airport design.

Aircraft	Engine	Remarks
Boeing 737-8 (Max) equipped with CFM LEAP-1B25 engines. Aircraft maximum design takeoff weight is 179,800 lbs. and 178 seats in a two-class layout. Based on the payload-range diagram, the aircraft operating empty weight is estimated to be 99,000 lbs.		

Figure 1. Aircraft Considered in Problem 1. Picture Source: A.A. Trani.

    a) Find the runway length needed to operate future services from ROA to DEN and DFW. Assume higher emissions in the future (due to climate change). State the design temperature used.

Airport design conditions at Roanoke, Virginia.

Design temperature = 87.5 degrees Fahrenheit (using Climate Explorer higher emissions scenario).

ISA Temperature at 1175.2 feet = 54.8 degrees. F.

Temperature difference = 32.7 degrees. F.

Boeing provides data for takeoff distance at ISA + 27 deg.F. and ISA + 45 deg.F.

32.7 degrees. F. Requires the use of ISA + 45 deg. F.

The Roanoke airport elevation is 1175.2 feet

The longest runway length available (runway 06/24) = 6,800 feet (150 feet wide)

Runway end 06 elevation is 1152 ft. (source: airnav.com)

Runway end 24 elevation is 1151 ft. (source: airnav.com)

The elevation difference is 1 feet.

The effective gradient is negligible 0.015%.

ROA-DEN Great Circle Distance (GCD) is 1168 nm. The route distance is 1238 nm.

ROA-DFW Great Circle Distance (GCD) is 879 nm. The route distance is 932 nm.

The Roanoke-Denver is the critical route. The table below illustrates the calculations for the problem.

Table 1. Takeoff Analysis with 178 Passengers.

Parameter	Value (lbs.)
Operating Empty Weight (OEW)	99000
Payload (PYL)	39160
OEW + PYL	138160
Desired Takeoff Weight (DTW)	159000
Fuel Used	20840
Fuel Used by Passenger	117.1

CHARACTERISTICS	UNITS	MODEL 737-8		
MAX DESIGN TAXI WEIGHT	POUNDS	159,900	180,300	182,700
	KILOGRAMS	72,529	81,782	82,871
MAX DESIGN TAKEOFF WEIGHT	POUNDS	159,400	179,800	182,200
	KILOGRAMS	72,302	81,555	82,644
MAX DESIGN LANDING WEIGHT	POUNDS	150,300	150,300	152,800
	KILOGRAMS	68,174	68,174	69,308
MAX DESIGN ZERO FUEL WEIGHT	POUNDS	142,900	142,900	145,400
	KILOGRAMS	64,818	64,818	65,952
SEATING CAPACITY	TWO-CLASS	178	178	178
	SINGLE-CLASS	189	189	189
MAX CARGO VOLUME LOWER DECK	CUBIC FEET	1,540	1,540	1,540
	CUBIC METERS	43.6	43.6	43.6
USABLE FUEL *[1]	US GALLONS	6,820	6,820	6,820
	LITERS	25,817	25,817	25,817
	POUNDS	45,694	45,694	45,694
	KILOGRAMS	20,730	20,730	20,730

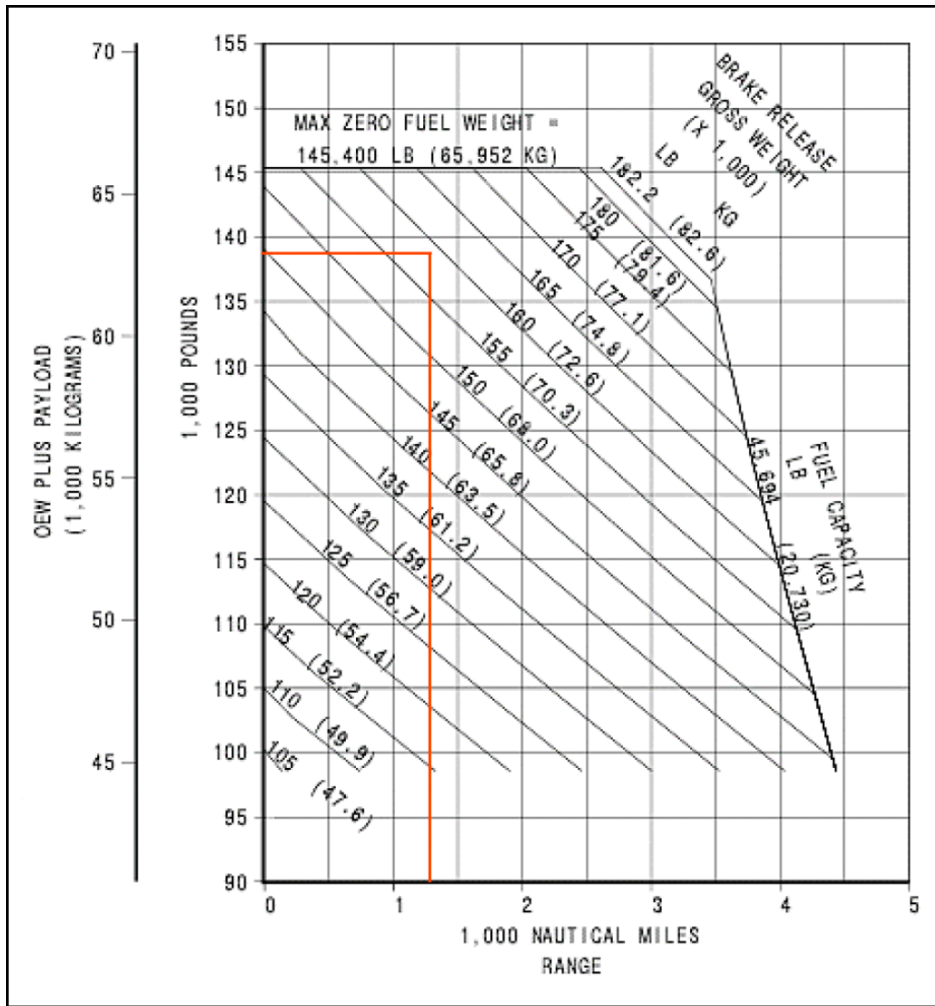*Figure 1.1 Boeing 737-8Max Data. Source: Boeing.*

***Figure 1.2 Boeing 737-8Max Payload-Range Diagram for ROA-DEN Route.
Source: Boeing.***

The runway length for takeoff is **7900 feet** (see Figure 1.3).

The runway length needed for landing is 5,800 feet (see Figure 1.4).

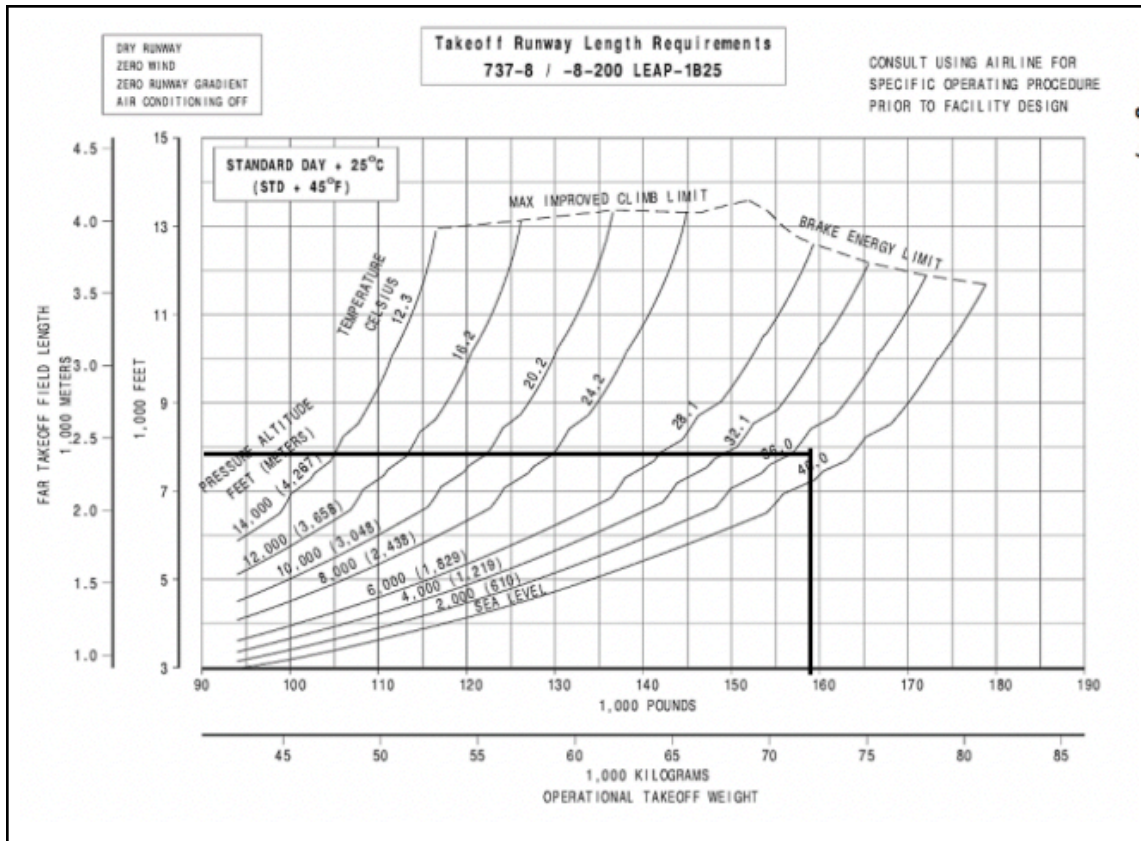**The runway must be extended to 7,900 feet to serve the ROA-DEN route.**

Figure 1.3 Boeing 737-8Max Takeoff Distance Data. ISA + 45 deg. Fahrenheit. ROA-DEN Route with 178 Passengers. Source: Boeing.
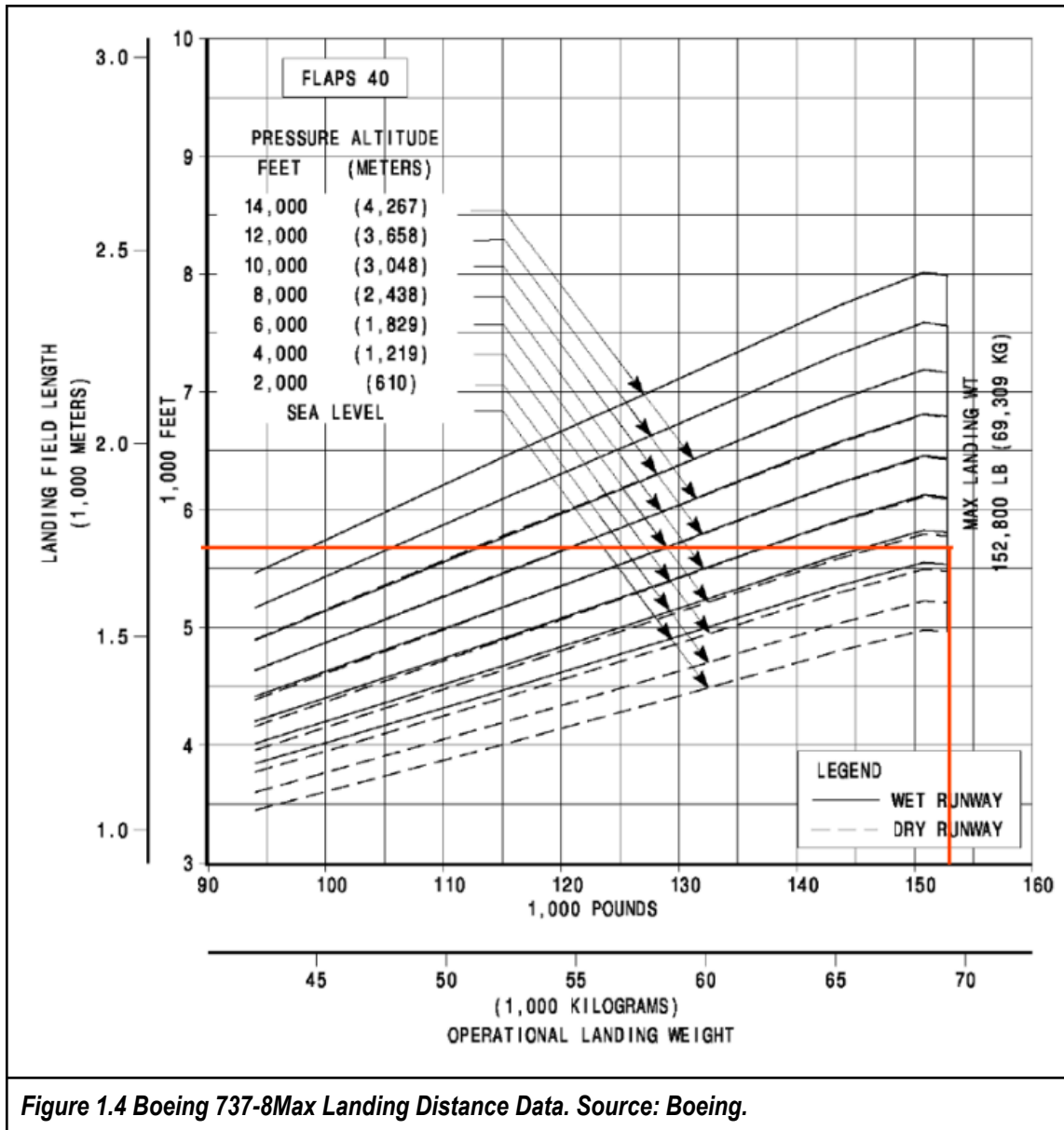
Figure 1.4 Boeing 737-8Max Landing Distance Data. Source: Boeing.

b) Considering the existing condition at ROA, what is the runway improvement needed?

A 1,100-foot runway extension is recommended. **The runway length must be 7,900 feet long.**

c) Use Google Earth to draw a polygon representing the required runway calculated in part (a). Assume any runway extension will be done on runway threshold 06.
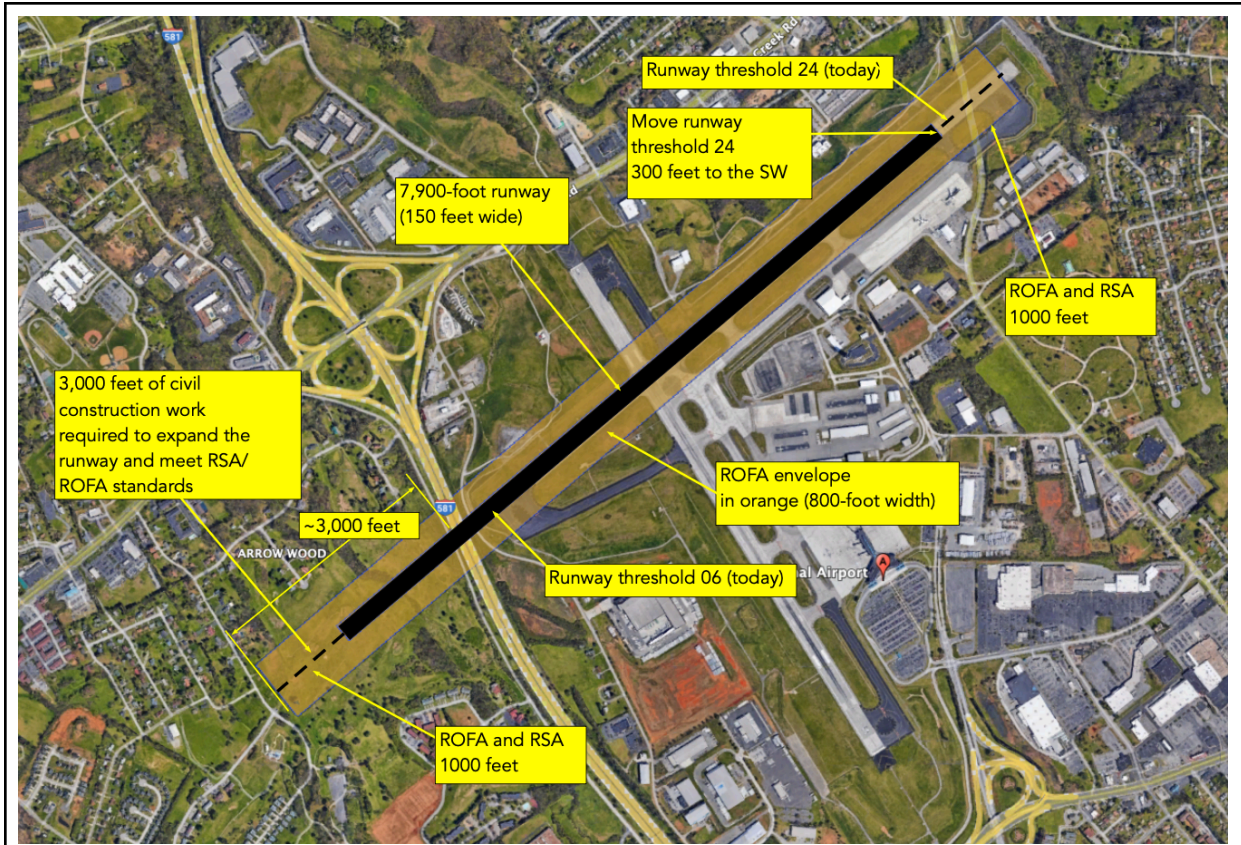
Figure 1.5 ROA Airport Runway Extension Project.

d) If the runway safety areas are to be protected on runway 06-24 at ROA after the improvement, estimate the size of the additional area required on the runway. Draw your solution using Google Earth to show the extra area to be impacted by the project.

The critical aircraft operating at ROA are the Airbus A300-600 and the Boeing 757-200 (both operated by cargo carriers). Use C/D-IV and 5000-foot design conditions. Figure 1.6 illustrates a runway extension project for ROA. A 3,000-foot civil works project is anticipated, requiring an elevated runway above highway I-581.

Table 2. FAA RSA and ROFA Standards for ADG IV and AAC C/D.

Main: C/D/E - IV					
RSA Dimension	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	C	500 ft	500 ft	500 ft	500 ft

ROFA Dimension	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

POFZ Dimension	DIM (1)	Visual	Not Lower than 1 Mile	Not Lower than 3/4 Mile	Lower than 3/4 Mile
Length		N/A	N/A	N/A	200 ft
Width		N/A	N/A	N/A	800 ft

Figure 1.6 RSA and ROFA Dimensions for C/D-IV Groups.

e) Explain some of the challenges to completing a runway improvement at ROA.

The challenge is to build an elevated runway extension. This has been done (at a cost) in Atlanta and Madeira's airports.

f) Considering the runway improvement estimated in part (a), if the aircraft is loaded with 83% of the passengers (average load factor in US domestic flights), can the future airport support flights from ROA to Los Angeles?

The GCD distance is 1878 nm. The route distance is 1990 nm.

Table 3 illustrates the calculations. Figure 1.7 shows that the ROA-LAX route requires a takeoff weight of 158,000 lbs (with 148 passengers) and a takeoff field length of 7,600 feet. The route can be operated with a load factor of 83%.

Table 3. Takeoff Analysis with 148 Passengers (ROA-LAX Route).

Parameter	Value (lbs.)
Operating Empty Weight (OEW)	99000
Payload (PYL)	32560
OEW + PYL	131560
Desired Takeoff Weight (DTW)	158000
Fuel Used	26440
Fuel Used by Passenger	148.5
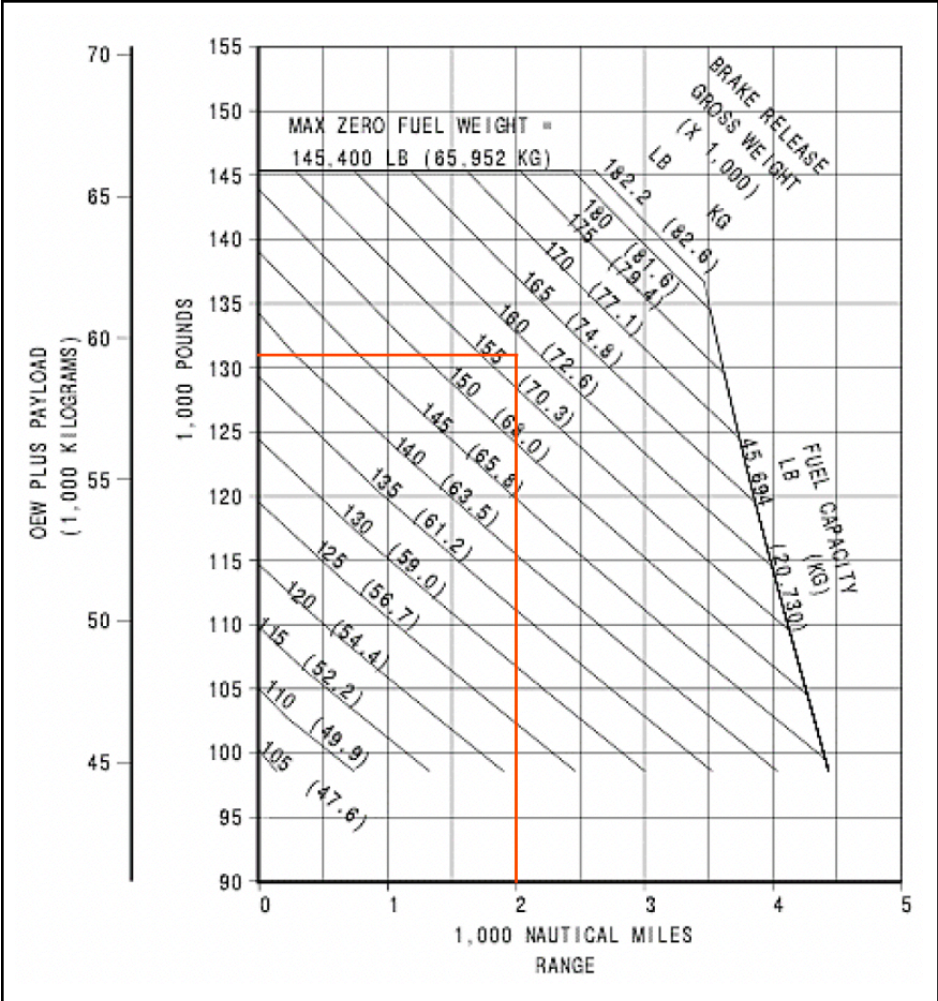
Figure 1.7 Boeing 737-8Max Payload-Range Diagram for ROA-LAX Route. Source: Boeing.

Figure 1.8 Boeing 737-8Max Takeoff Distance Data. ISA + 45 deg. Fahrenheit. ROA-LAX Route with 148 passengers. Source: Boeing.
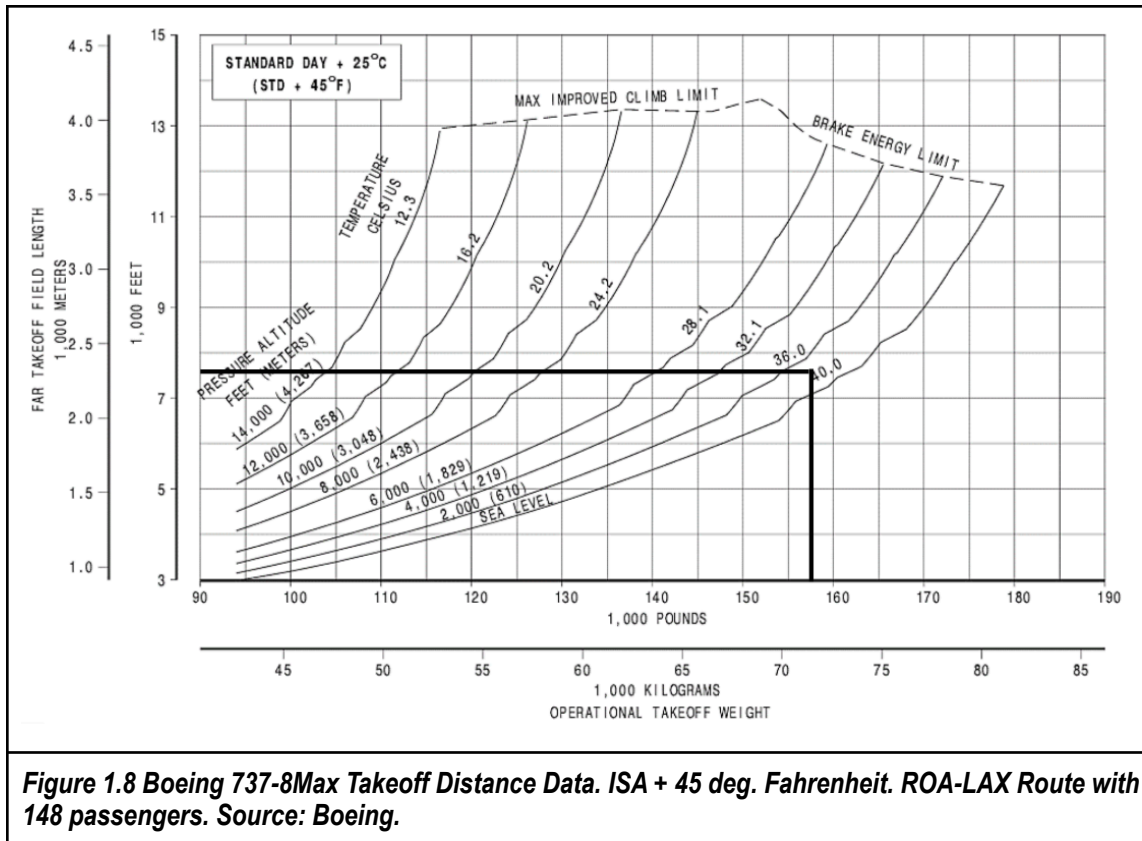
g) With the runway improvement of part (a), can a Gulfstream 450 fly from ROA to London Heathrow airport nons-stop? Explain.

The GCD distance is 3,349 nm. The route distance is 3,550 nm.

Steps in the procedure:

1) Use SARLAT to estimate the required useful load to cover the route ROA-LHR (London).

Figure 1.9 shows the range analysis in SARLAT to estimate the useful load required to fly the route ROA-LHR with a Gulfstream 450. The Gulfstream 450 departs ROA with a useful load of 89% to fly 3,550 nm to London.

2) Use SARLAT to estimate the runway requirements of the Gulfstream 450.

Figure 1.10 shows the runway design length analysis in SARLAT to estimate the runway length needed to fly the route ROA-LHR. The Gulfstream 450 departs ROA with a useful load of 89% to fly 3,550 nm to London. The takeoff field length is 5,902 feet for dry pavement conditions and 6,787 feet for wet pavement. A 7,900-foot runway allows the corporate jet to fly six passengers and two pilots to London.
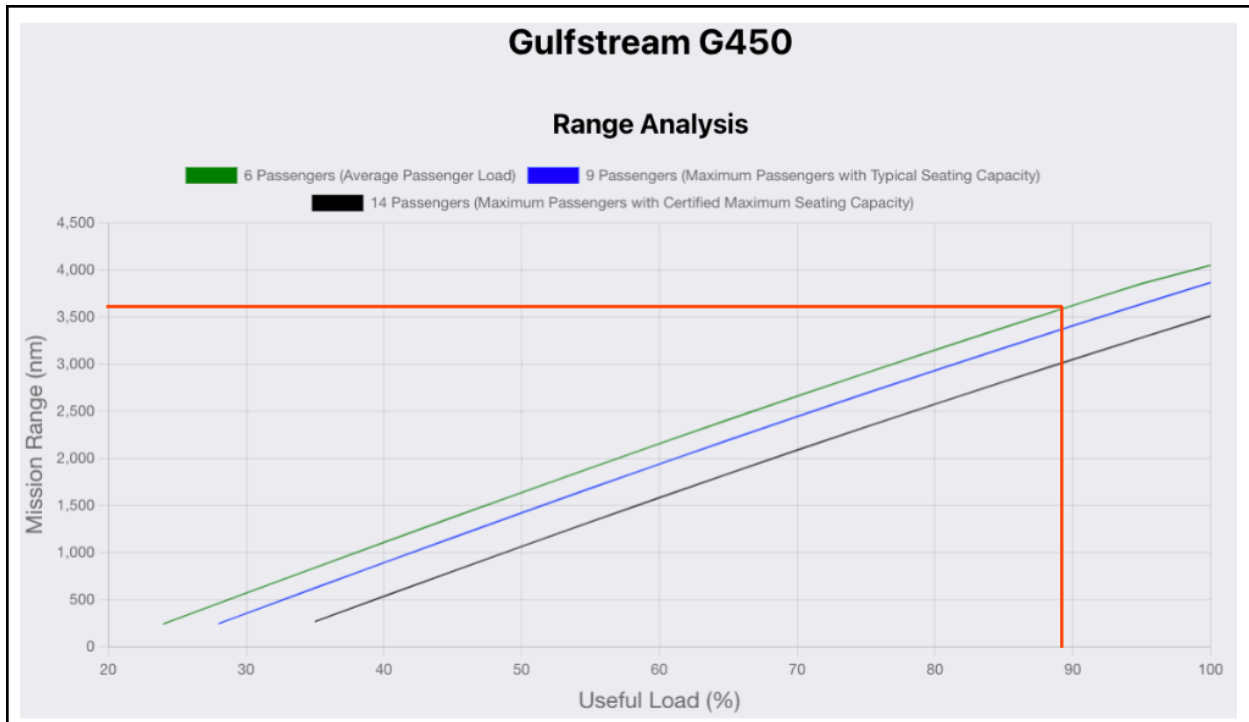
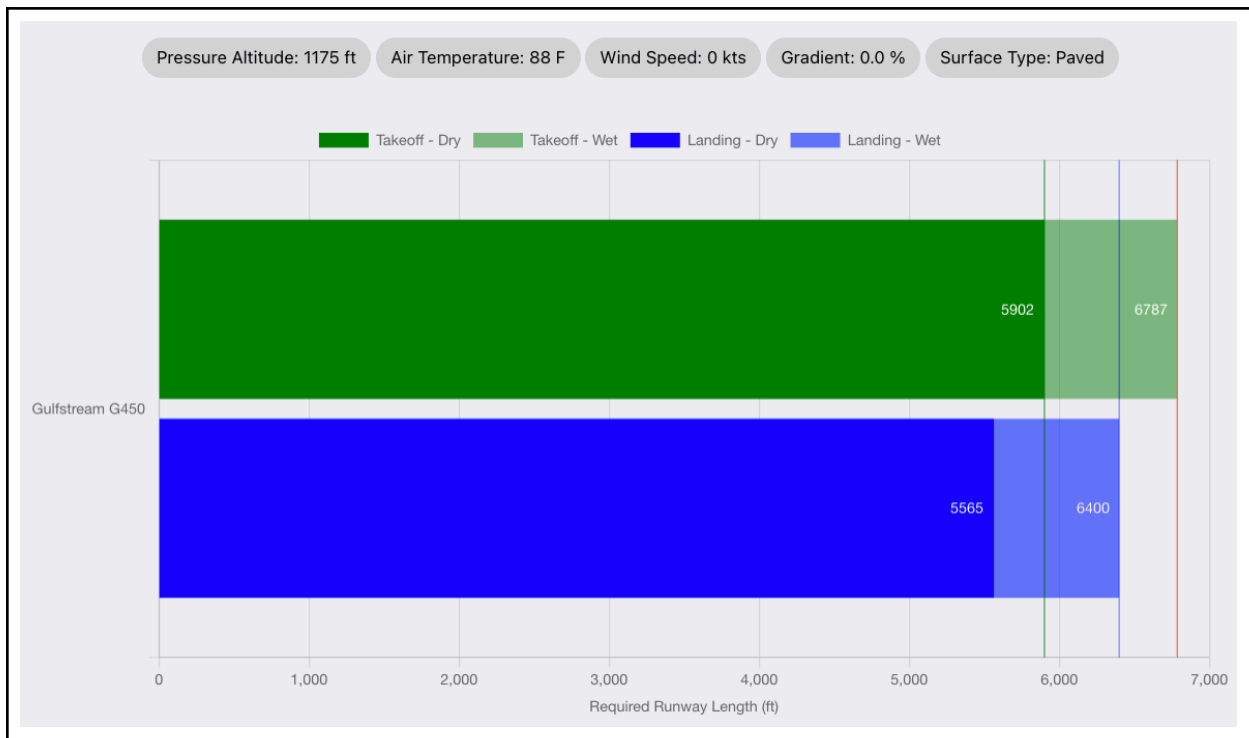Figure 1.9 SARLAT Range Analysis for Gulfstream 450. ROA-LHR Route.

Figure 1.10 SARLAT Runwa Design Analysis for Gulfstream 450. ROA-LHR Route. Aircraft Departs at 89% Useful Load.

Problem 2 (30 Points)

Use the Small Aircraft Runway Length Analysis Tool (SARLAT) to evaluate the Perry Stokes Airport (TAD) runway near Trinidad, Colorado. The airport serves single, multi-engine piston, and turboprop aircraft (Table 2). Use a Higher Emissions scenario in your runway evaluation and design scenarios.

Table 2. Aircraft Fleet Mix for Problem 2 (Runway Evaluation).

Aircraft Type	Aircraft	Annual Arrivals	Annual Departures
Piston	Cessna 182	3190	3190
Piston	Cirrus SR20	1830	1830
Piston	Diamond DA40	1450	1450
Piston	Cessna 421C	430	430
Turboprop	Turbo Commander 690B	340	340
Turboprop	Cessna 208 Caravan	305	305
Turboprop	Socata 850	250	250
Jet	Cessna Citation Jet 2	300	300
Total		8095	8095

Airport design conditions at Trinidad, Colorado.

Temperature = 90 degrees. Fahrenheit (using Climate Explorer higher emissions scenario).

Trinidad airport elevation = 5761.6 feet

Runway length available = 5,500 feet (75 feet wide)

Runway end 03 elevation is 5760.4 ft. (source: airnav.com)

Runway end 21 elevation is 5740.3 ft. (source: airnav.com)

The elevation difference is 20.1 feet.

The effective gradient of the runway is 0.37% (rounded to 0.4% in SARLAT)

Note: there is a second runway at TAD (runway 09/27). However, that runway is gravel/turf (see airnav.com).

Perform a **runway evaluation** of the current runway length available at the airport and answer the following questions.

a) Is the runway length available suitable for all aircraft? Explain any issues found.

The runway is sufficient for most aircraft, assuming dry pavement conditions. The Cessna CitationJet 2 is the most limited aircraft operating from the airport (it can only operate at 67% useful load). It can take off at 11,000 lbs and travel 513 nautical miles with four passengers.

Aircraft Name	Aircraft Mix	NBAA IFR Maximum Range		Useful Load (Takeoff Weight)		Landing No Correction	
		Dry	Wet	Dry	Wet	Dry	Wet
Piston							
Cessna 182 Skylane	39%			100 % 2950 lbs	100 % 2950 lbs	✓	✓
Cessna 421 Golden Eagle	5%			100 % 7450 lbs	69 % 6584 lbs	✓	✓
Cirrus SR 20	22%			100 % 3150 lbs	82 % 2966 lbs	✓	✓
Diamond 40 Star	18%			100 % 2646 lbs	100 % 2646 lbs	✓	✓
Turboprop							
Cessna 208 Caravan	4%			100 % 8000 lbs	100 % 8000 lbs	✓	✓
Rockwell Commander 690B	5%			91 % 9939 lbs	20 % 7029 lbs	✓	✓
Socata TBM 850	3%			100 % 7394 lbs	95 % 7263 lbs	✓	✓
Jet							
Cessna CitationJet 2	4%	70 % FLIGHTS IN NAS 513 nm / 4 pax	52 % FLIGHTS IN NAS 363 nm / 4 pax	67 % 11000 lbs	59 % 10640 lbs	✓	✓

Figure 2.1 SARLAT Evaluation Analysis.

b) For the fleet mix in Table 2, state the aircraft with the most significant number of restrictions if the runway is wet at TAD.

Cessna Citation Jet 2 is a critical aircraft under dry conditions.

The Rockwell Commander 690 has more restrictions under wet pavement conditions (only 20% useful load).
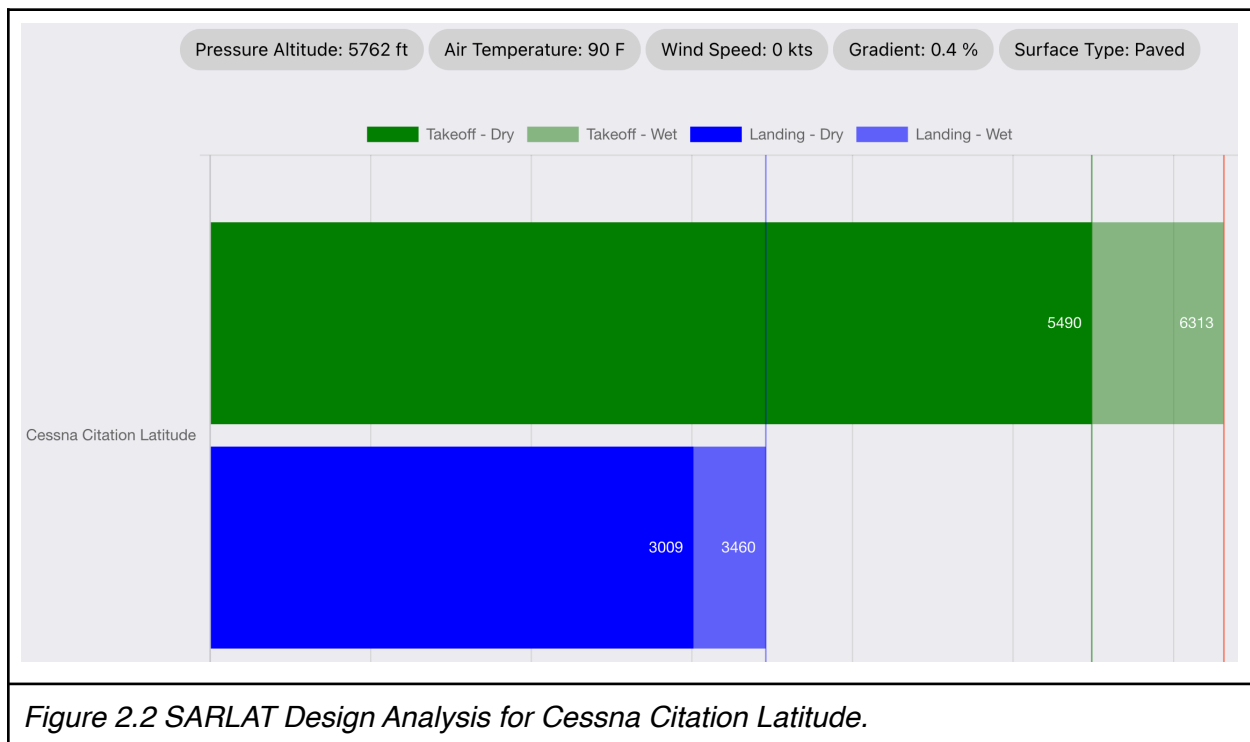
c) How far can the Cessna Citation Jet 2 fly on a rainy day with four passengers and the flight crew?

The Cessna Citation Jet 2 can fly four passengers 363 nautical miles with a wet runway at TAD.

Runway improvement scenario

d) Calculate a runway length improvement as part of a new airport master plan study. **This would allow mid-size jets like the Cessna Citation Latitude to operate with 70% useful load from the airport with a wet runway**.

Use the SARLAT design mode to estimate the runway length needed to operate a Cessna Citation Latitude with 70% useful load with a wet runway. Figure 2.2 shows the results obtained for the mid-size jet. The runway needed to operate at 70% of useful load is 6313 feet (**round to 6300 feet**). The new master plan could specify an 800-foot runway extension.

| Pressure Altitude: 5762 ft | Air Temperature: 90 F | Wind Speed: 0 kts | Gradient: 0.4 % | Surface Type: Paved |

Takeoff - Dry   Takeoff - Wet   Landing - Dry   Landing - Wet

Cessna Citation Latitude

5490   6313

3009   3460

Figure 2.2 SARLAT Design Analysis for Cessna Citation Latitude.

e) Can the Cessna Citation Latitude fly from TAD to SEA (Seattle-Tacoma International Airport) with a wet runway with your proposal of part (d).

Use the Great Circle mapper to estimate the distance between TAD and SEA. The Great Circle Distance is 1,002 nautical miles. The route distance is estimated to be 1,062 nautical miles. Figure 2.3 illustrates the range analysis for the Cessna Citation Latitude departing with the 70% useful load constraint.

The aircraft can fly four passengers at a distance of 1,200 nm. Therefore, the extended runway would allow such an operation.
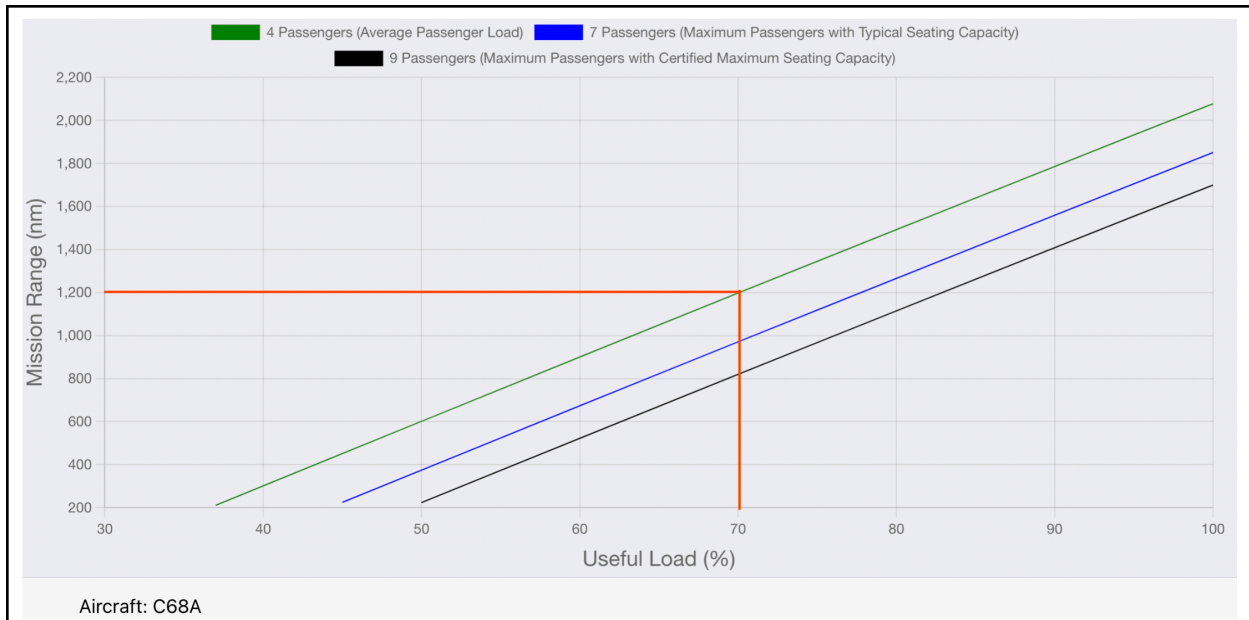
Figure 2.3 SARLAT Range Analysis for Cessna Citation Latitude.

f)   With your proposed runway length improvement in part (a), can the Cessna Citation Jet 2 operate at a higher takeoff weight? Explain.

The Cessna Citation Jet 2 can operate from the 6,300-foot runway at 70% for dry and wet pavement conditions. A marginal improvement from the 5,500-foot runway for wet conditions (i.e., 52% useful load). Note that under dry pavement conditions, no improvement is observed compared to the existing runway (both 70% useful load). This is because, at the high elevation of TAD, the aircraft is limited to a maximum takeoff of 11,000 lbs (see Figure 2.4). This is due to weight and temperature limitations. The runway extension cannot be justified for the Cessna CJ2 but needs to be justified if the Cessna Latitude is to operate at the airport.

Runway Takeoff and Landing Restrictions

Pressure Altitude: 5762 ft   Air Temperature: 90 F   Wind Speed: 0 kts   Runway Length: 6300 ft   Gradient: 0.4 %   Surface Type: Pave

Aircraft Name	Aircraft Mix	NBAA IFR Maximum Range		Useful Load (Takeoff Weight)		Landing	
						No Correction	
		Dry	Wet	Dry	Wet	Dry	Wet
Jet							
Cessna CitationJet 2	4%	70 % FLIGHTS IN NAS 513 nm / 4 pax	70 % FLIGHTS IN NAS 513 nm / 4 pax	67 % 11000 lbs	67 % 11000 lbs	✓	✓

Figure 2.4 SARLAT Evaluation Analysis for Cessna Citation Jet 2.

Problem 3 (30 points)

Short answer.

|	Question	Short Answer
1	Roanoke Regional airport has a EMAS able to stop a Gulfstream GIII traveling at 70 knots and overrunning the runway after landing on runway16.	False 300 ft EMAS available 430 feet required
2	The Airbus A321neo taxiway design group.	3
3	The Douglas DC-8 was a successful twin engine, turboprop-powered aircraft.	FALSE
4	Runway 1 at Reagan National Airport is a precision runway with approach lights.	TRUE
5	Increase in RSA longitudinal dimensions when a runway transitions from RDC C-II-5000 to D-V-2400.	No increase (0)
6	Maximum height of an object located 600 feet from the runway centerline. The critical aircraft is the Boeing 747-8 and the airport elevation is 2,400 feet. Only check the Inner transitional OFZ.	~100 feet
7	The AAC group for the Airbus A220-300.	C
8	90% of the aircraft overrun accidents on a runway are contained within 1,000 feet of the runway end.	TRUE
9	Aircraft design group for the Boeing 737-10 Max.	III ~117.8-foot wingspan
10	Length of the inner-approach OFZ area if a runway has a 2,400 foot approach light system.	2600 feet 200 feet beyond the last approach light. (Page 67a in handout)
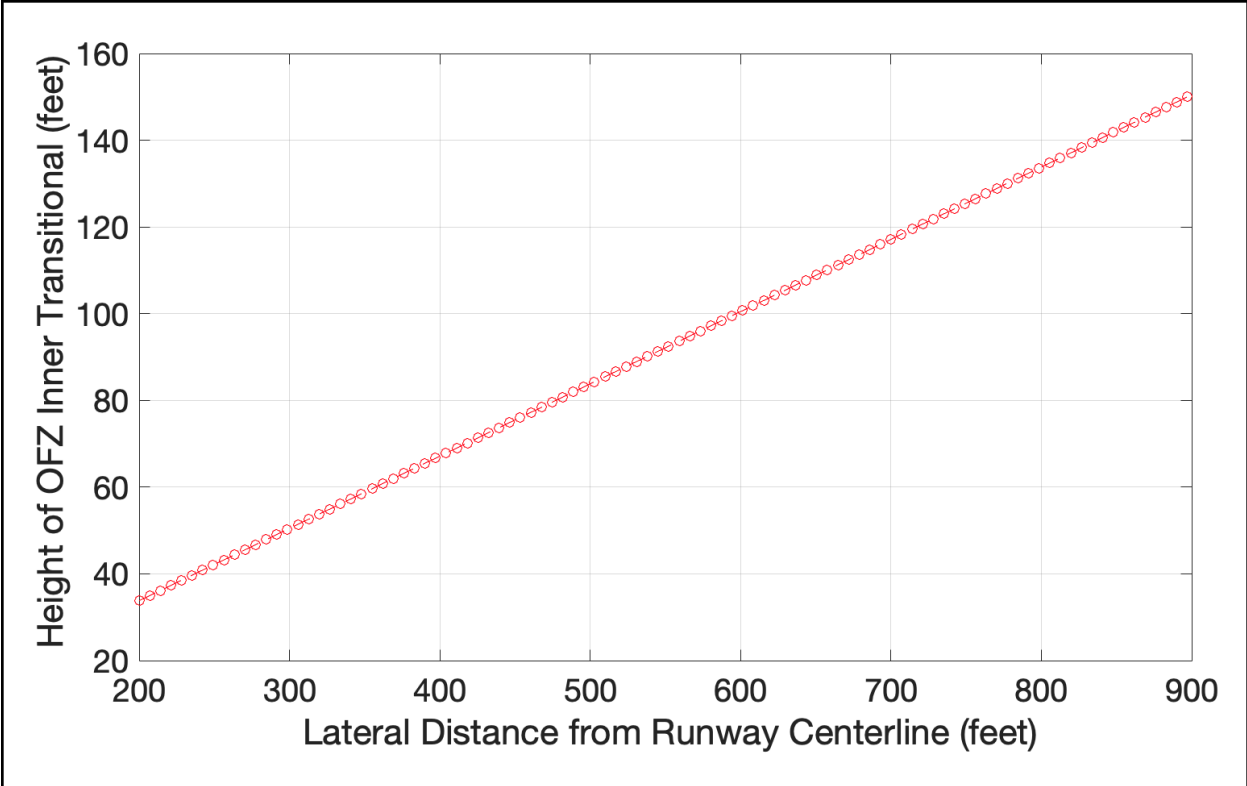
Figure 2.5 Inner Transitional Surface. Category 1 Approach Criteria.