Exam 2 - Take Home

Open Notes and Internet

Instructor: A.A. Trani

Solution

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 used, FAA tables used, and others. You will be penalized if you do not include the graphics of the information used to answer the question.

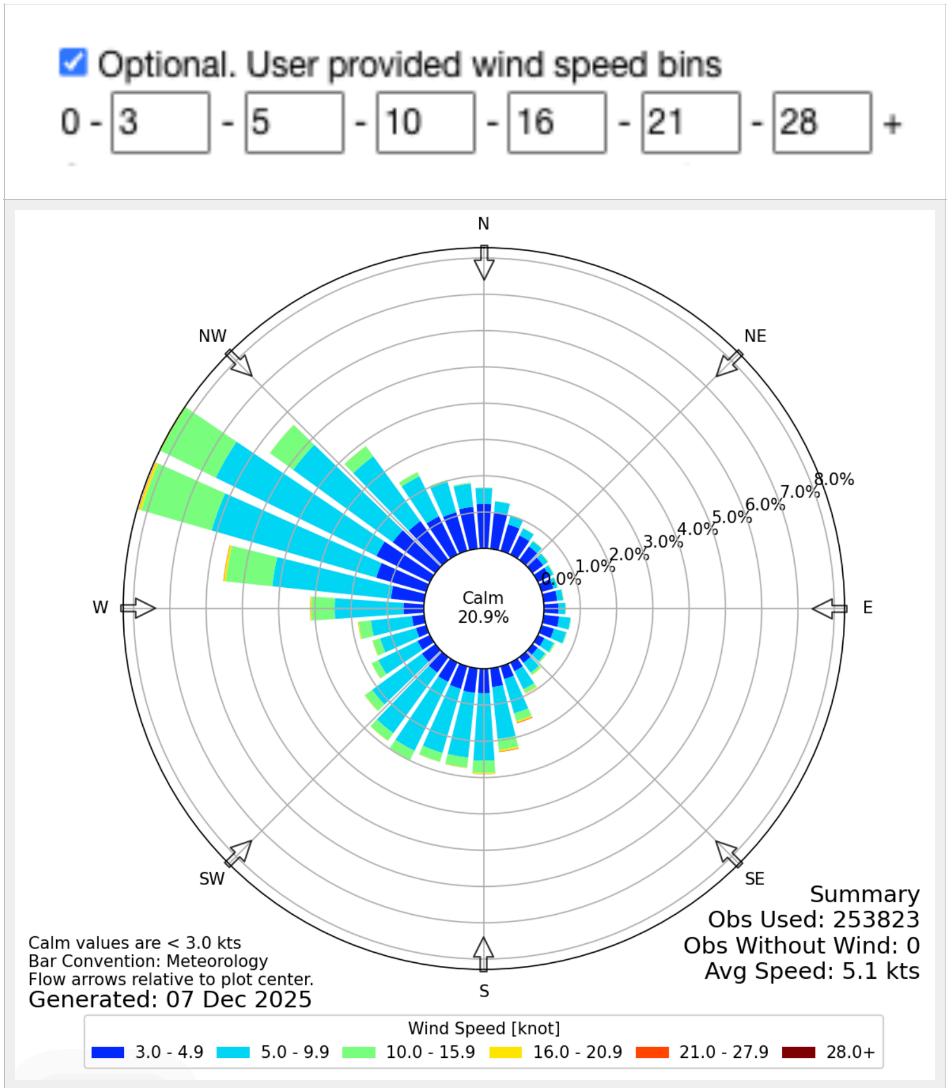
Honor Code Pledge

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 (30 Points)

a) Obtain the San Diego International Airport Wind Data using the Mesonet website.



Azimuth	Calm	0-2.9 Knots	3-4.9 Knots	5-9.9 Knots	10-15.9 Knots	16-20.9 Knots	21-28 Knots
355-004	20.9	1.224	0.443	0.01	0	0	0
005-014		0.998	0.316	0.007	0	0	0
015-024		0.754	0.26	0.006	0	0	0
025-034		0.584	0.217	0.011	0	0.001	0
035-044		0.461	0.177	0.015	0.002	0	0
045-054		0.367	0.156	0.013	0.003	0	0
055-064		0.354	0.124	0.014	0.002	0	0
065-074		0.336	0.118	0.013	0.002	0	0
075-084		0.375	0.164	0.01	0.003	0	0

Figure 1.1 Mesonet Data. Jan/1/1994 to Jan/1/2024.

b) Perform a wind rose analysis for the airport and determine the wind coverage operating both runways ends (09 and 27). The critical aircraft at SAN is the Airbus A350-1000 (see Figure 1). State the design crosswind component.

Design crosswind is 20 knots

Obtain the runway headings using Arnav.com.

Runway 09 - **Runway heading: 095 magnetic, 106 true**

Runway 27 - **Runway heading: 275 magnetic, 286 true**

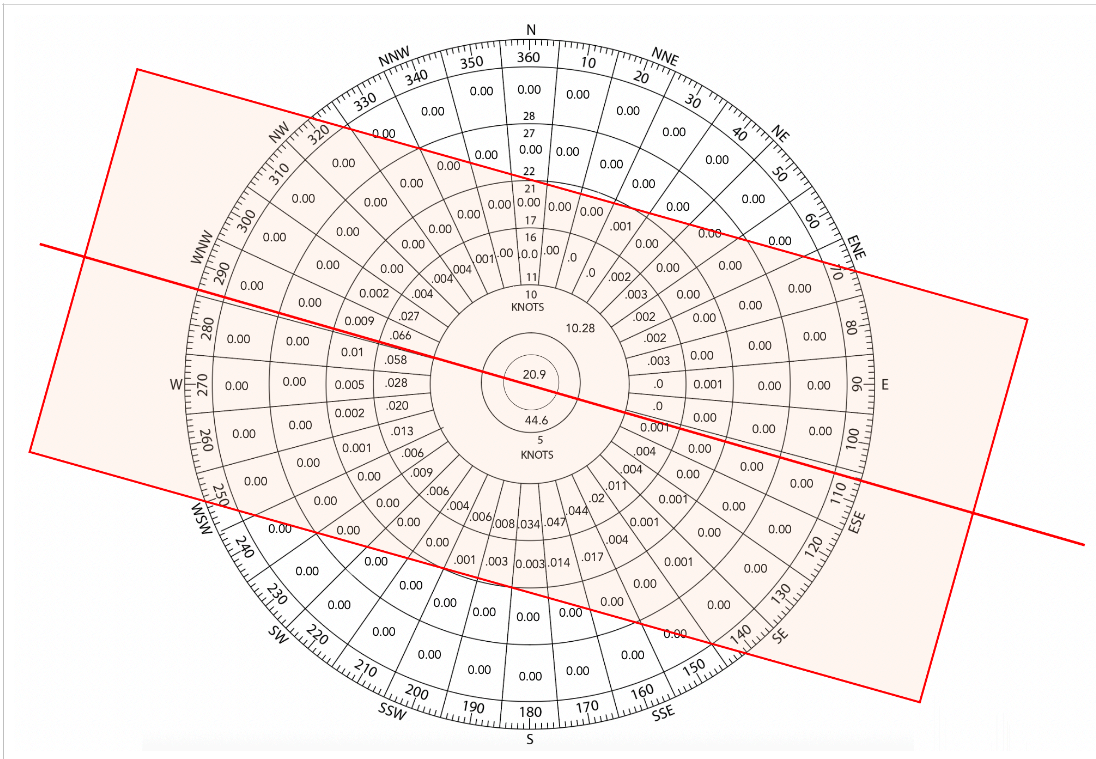


Figure 1.2 Wind Rose Analysis. Runway Headings are 106 and 286 True. Crosswind Component is 20 knots. The Coverage from Both Directions is 99.99%.

c) Find the percent of time operations land and depart on runway 27 at SAN based on wind conditions. Assume zero tailwind allowance.

Refer to Figure 1.3 for the calculation of the coverage for runway 27.

Table 1. Calculation of Crosswind Coverage for runway 27 at San Diego International Airport.

Wind Component	Percent (%)
100% of the calm winds (0-3 knots)	20.90
Winds from 355 to 014 degrees	3.00
Winds from 195 to 355 degrees	57.27
Total Coverage (counting half of calm winds) (%)	**81.17**

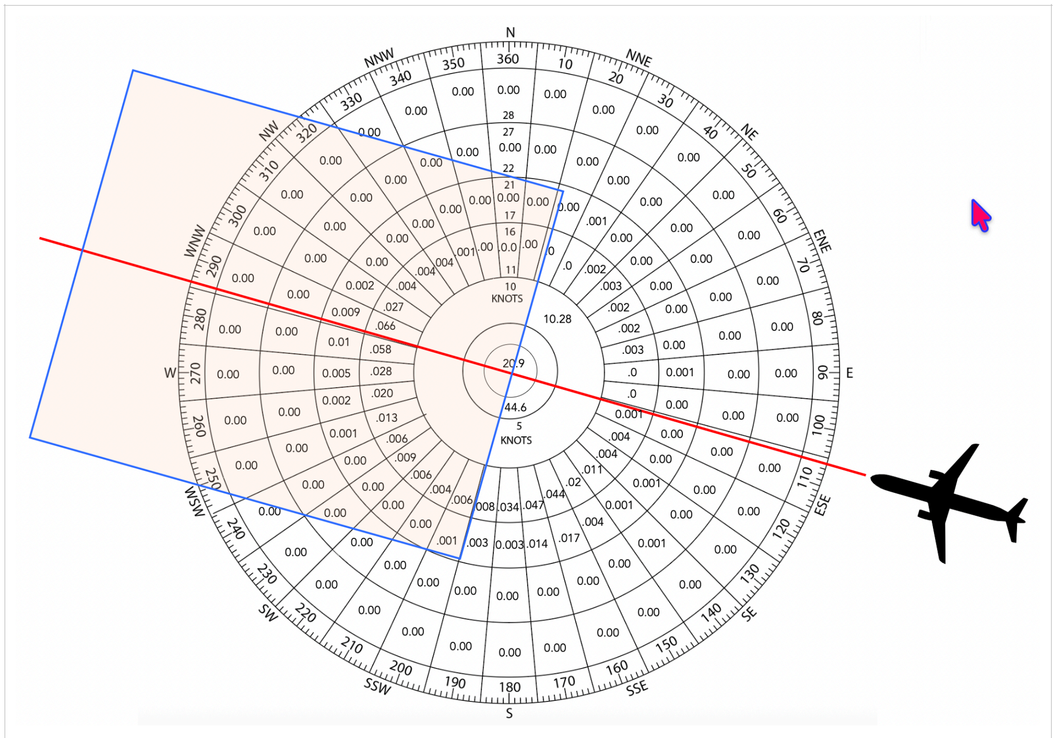


Figure 1.3 Wind Rose Analysis. Runway Heading is 286 True. Crosswind Component is 20 knots. The Coverage on Runway 27 with Zero Tailwind and 100% Allowance for Calm Winds is 81.17%.

Azimuth	Calm	0-2.9 Knots	3-4.9 Knots	5-9.9 Knots	10-15.9 Knot	16-20.9 Knot	21-28 Knots	
355-004	20.9	1.224	0.443	0.01	0	0	0	
005-014		0.998	0.316	0.007	0	0	0	
015-024		0.754	0.26	0.006	0	0	0	
025-034		0.584	0.217	0.011	0	0.001	0	
035-044		0.461	0.177	0.015	0.002	0	0	
045-054		0.367	0.156	0.013	0.003	0	0	
055-064		0.354	0.124	0.014	0.002	0	0	
065-074		0.336	0.118	0.013	0.002	0	0	
075-084		0.375	0.164	0.01	0.003	0	0	
085-094		0.4	0.188	0.011	0	0.001	0	
095-104		0.427	0.319	0.012	0	0	0	
105-114		0.351	0.352	0.021	0.001	0	0	
115-124		0.201	0.288	0.035	0.004	0	0	
125-134		0.177	0.261	0.041	0.004	0.001	0	
135-144		0.196	0.334	0.069	0.011	0.001	0	
145-154		0.264	0.556	0.111	0.02	0.004	0	
155-164		0.367	0.983	0.221	0.044	0.017	0	
165-174		0.519	1.44	0.299	0.047	0.014	0	
175-184		0.675	1.86	0.336	0.034	0.003	0	
185-194		0.68	1.793	0.277	0.008	0.003	0	
195-204		0.646	1.837	0.253	0.006	0.001	0	
205-214		0.593	2.112	0.275	0.004	0	0	
215-224		0.528	2.061	0.254	0.006	0	0	
225-234		0.458	1.694	0.249		0	0	
235-244		0.378	1.203	0.202	0.006	0	0	
245-254		0.292	1.025	0.214	0.013	0.001	0	
255-264		0.338	1.137	0.336	0.02	0.002	0	
265-274		0.561	1.899	0.638	0.028	0.005	0	
275-284		0.92	3.291	1.286	0.058	0.01	0	
285-294		1.428	4.724	2.018	0.066	0.009	0	
295-304		1.641	4.927	1.688	0.027	0.002	0	
305-314		1.451	3.392	0.788	0.004	0	0	
315-324		1.322	2.207	0.345	0.004	0	0	
325-334		1.169	1.228	0.125	0.004	0	0	
335-344		1.104	0.872	0.052	0.001	0	0	
345-354		1.162	0.643	0.027	0	0	0	
	20.9	23.701	44.601	10.282	0.432	0.075	0	99.991

Figure 1.3 Wind Rose Analysis. Runway Heading is 286 True. Crosswind Component is 20 knots. Orange Cells Represent the Coverage Operating on Runway 27. The Coverage on Runway 27 with Zero Tailwind and 100% Allowance for Calm Winds is 81.17%.

d) Do you agree with the runway orientation at SAN? Comment.

Yes, the prevailing winds at San Diego come from the West-North-West.

Figure 1. Airbus A350-1000 landing at San Diego International Airport (A. Trani).

Problem 2 (35 Points)

This problem analyzes the runway capacity for San Diego International Airport when landing and departure operations use runway 27. The airport fleet mix is shown in Table 1. For this analysis, we use the following technical parameters: a) in-trail delivery error of 18 seconds under IMC conditions, b) probability of violation is 5%. Arriving aircraft are "vectored" by ATC to intercept the extended centerline of runway 27 at a fix (point in space) located 14 miles from the runway threshold.

Use the In-Trail Arrival-Arrival Separation Rules consistent with the Consolidated Wake Turbulence groups provided in class (i.e., FAA Order JO 7110.126B) to solve the problem. Use the departure-departure separations provided in class (taken from FAA JO 7110.126B). Use 10 seconds for departure-departure buffers to model pilot reaction time and jet engine mechanical lags.

Table 1. Runway Operational Parameters and Fleet Mix for Problem 2. Consolidated Wake Turbulence Groups.

Aircraft Consolidated Wake Turbulence Group	Percent Mix (%)	Runway Occupancy Time (s)	Typical Approach Speed (knots) from Final Approach Fix
B	6	62	145
C	5	59	143
F	76	51	136
G	13	52	125
Total	100		

a) Estimate runway 27 arrivals-only capacity in IMC conditions. Please show me a couple of sample calculations for Tij and Bij (one for the opening case and one for the closing case). Also, please show two manual calculations of the gap (G) allowing one and two departures between successive arrivals.

Technical Parameters (inputs)				Parameter	Values
Dep-Arrival Separation (nm)				δ	2
Common Approach Length (nm)				γ	14
Standard deviation of Position Delivery Error (s)				σ	18
Probability of Violation				Pv	5
Cumulative Normal at Pv				qv	1.65
Buffer for departure-departure (seconds)					10
	G	F	C	B	
ROT (s)	52	51	59	62	70
Percent Mix (%)	13	76	5	6.00	0.00
Vapproach (knots)	125	136	143	145.0	150.0

Minimum Separation Matrix (nm)			Arrivals-Arrivals	
		Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	C	B
G	3	3	3	3
F	3	3	3	3
C	3.5	3.5	3	3
B	5	5	4	3

Error Free Separation Matrix				
		Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	C	B
G	86	79	76	74
F	119	79	76	74
C	152	111	76	74
B	200	155	106	74

Pij Matrix				
		Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	C	B
G	0.017	0.099	0.007	0.008
F	0.099	0.578	0.038	0.046
C	0.007	0.038	0.003	0.003
B	0.008	0.046	0.003	0.004

Buffer Matrix (Bij)				
		Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	C	B
G	29.70	29.70	29.70	29.70
F	22.71	29.70	29.70	29.70
C	17.01	25.16	29.70	29.70
B	9.84	21.48	28.31	29.70

Augmented Matrix (Tij + Bij)				
		Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	C	B
G	116	109	105	104
F	142	109	105	104
C	169	136	105	104
B	209	177	134	104
Arrivals Only Capacity (per hour)			30.68	

Figure 2.1 Arrivals-Only Capacity for Single Runway (Problem 2).

b) Estimate the departures-only capacity of runway 27 in IMC conditions.

Departure-Departure Separation Matrix with Buffers (seconds)				
		Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	C	B
G	70	70	70	70
F	70	70	70	70
C	130	130	130	130
B	130	130	130	130

Estimation of Critical Departure Gaps				
			E(ROT)	52.19
Departures		Gap (EΔTij)	E(δ/Vj)	53.22
1		115.41		10.00
2		182.01		
3		248.61		
4		315.21		
5		381.81		

Departures per Gap				
		Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	C	B
G	1	0	0	0
F	1	0	0	0
C	1	1	0	0
B	2	1	1	0

Departures per hour with 100% Arrival Priority							
		Trailing Aircraft (Header Columns)					
Lead (column 1)	G	F	C	B		Sum	
G	0.50	0.00	0.00	0.00	0.00	0.50	
F	2.93	0.00	0.00	0.00	0.00	2.93	
C	0.19	1.13	0.00	0.00	0.00	1.32	
B	0.46	1.35	0.09	0.00	0.00	1.91	
	0.00	0.00	0.00	0.00	0.00	0.00	
						6.66	Total Departures
Summary for Arrival - Departure Diagram							with 100% arrival priority

Figure 2.2 Departure-Only Capacity for Single Runway (Problem 2). Departures with 100% Arrival Priority.

c) Draw the Pareto diagram (i.e., arrival-departure diagram) for the runway at San Diego.

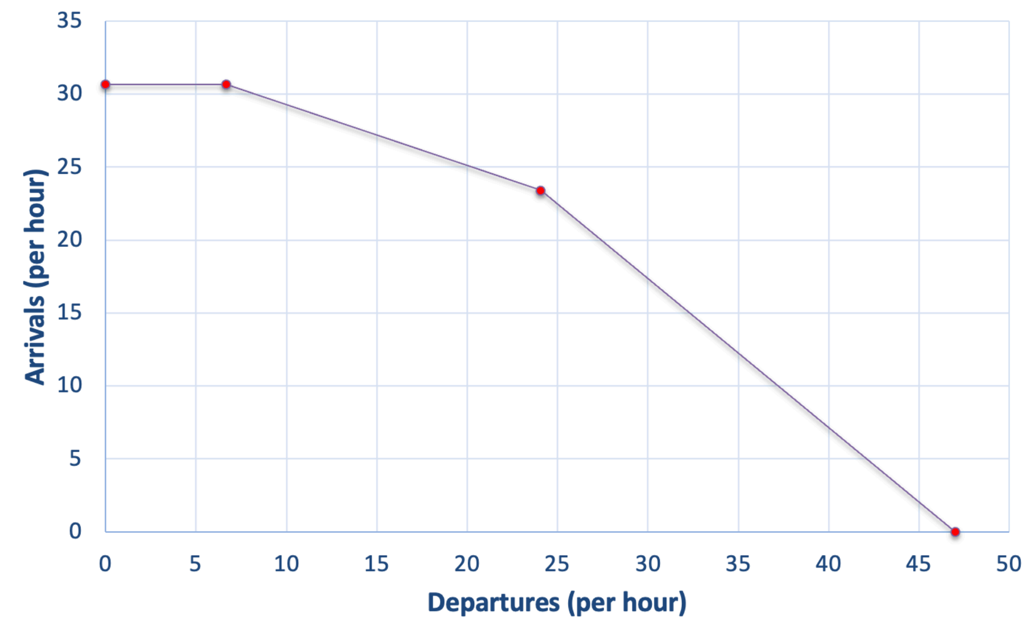


Figure 2.3 Arrival-Departure Pareto Diagram for Single Runway (Problem 2).

d) Compare your answer with the FAA published capacity at San Diego (https://www.faa.gov/sites/faa.gov/files/airports/planning_capacity/profiles/SAN-Airport-Capacity-Profile-2014.pdf). Comment.

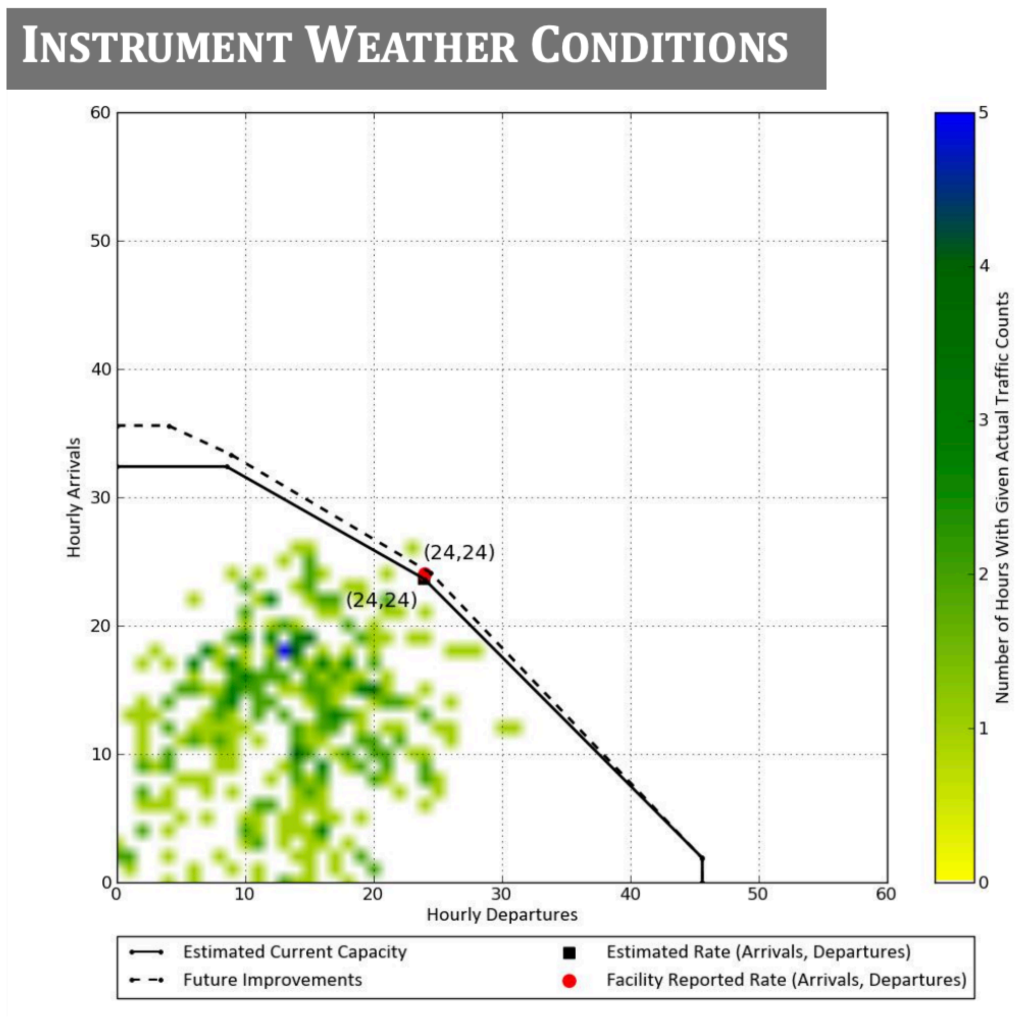


Figure 2.4 Arrival-Departure Pareto Diagram for San Diego (IMC Conditions).

The FAA San Diego diagram shows slightly higher arrivals-only capacity (32 /hour). The 50/50 arrivals/departure point is the same in both diagrams at 24,24. The FAA San Diego diagram truncates the arrival capacity at 46/hr. Our analysis shows 47/hour. Overall, the time-space diagram model shows good similarity with the simulation-based approach used by the FAA (MITRE).

Problem 3 (35 Points)

Answer the following questions briefly.

a) Can Honolulu International Airport do simultaneous independent approaches in bad weather conditions? Comment on the FAA rule used and the state the runways that could be used for independent landing operations (if that is possible).

HNL can do independent approaches in IMC conditions. For example, runways 8L and 8R centerlines are 6,700 feet apart. The reciprocal runways (26R and 26L) can also support independent arrivals.

b) During some periods of time, the Dallas-Fort Worth international Airport operates arrivals on runway 31R and departures on runway 35L. Is the configuration subject to Converging Runway Operations (CRO)? Explain the condition for CRO operations.

The ends of runways 31R and 35L are separated diagonally by 2400 feet. Therefore, they are subject to CRO rules. CRO requires the runway thresholds to be separated by 1 nm or more.

c) Find the **maximum payload that can be carried by a** Boeing 747-8F (freighter with GEnx-2B67 engines) with maximum takeoff gross weight of 975,000 lbs. (see Figure 2) using runway 31R at DFW. Use the DFW temperature design conditions. Consider 2035-2065 climate change temperature projections.

Figure 2. Boeing 747-8F (freighter) Departing Atlanta Hartsfield-Jackson International Airport (A. Trani).

The DFW design conditions using Climate Explorer predicts 101.6 deg. Fahrenheit. Using high-emissions in the period 2035-2065. DFW is located at 606.4 feet above mean sea level conditions.

The ISA temperature condition at DFW is 56.8 deg. Fahrenheit.

The difference in temperature is (101.6 -56.8) 44.8 deg. Fahrenheit. Use ISA + 45 deg. Fahrenheit if Bo

Runway 13L/31R is 9,000 feet long.

Elevation difference is (553.1 - 508.4) 44.7 feet using data in Arnav. This means, the effective runway for takeoff is:

$R_{eff} = 9000 - 447$ = 8,553 feet

The maximum takeoff weight using runway 31R is 820,000 lbs. (see Figure 3.1).

Operating empty weight is 434,600 lbs.

Table

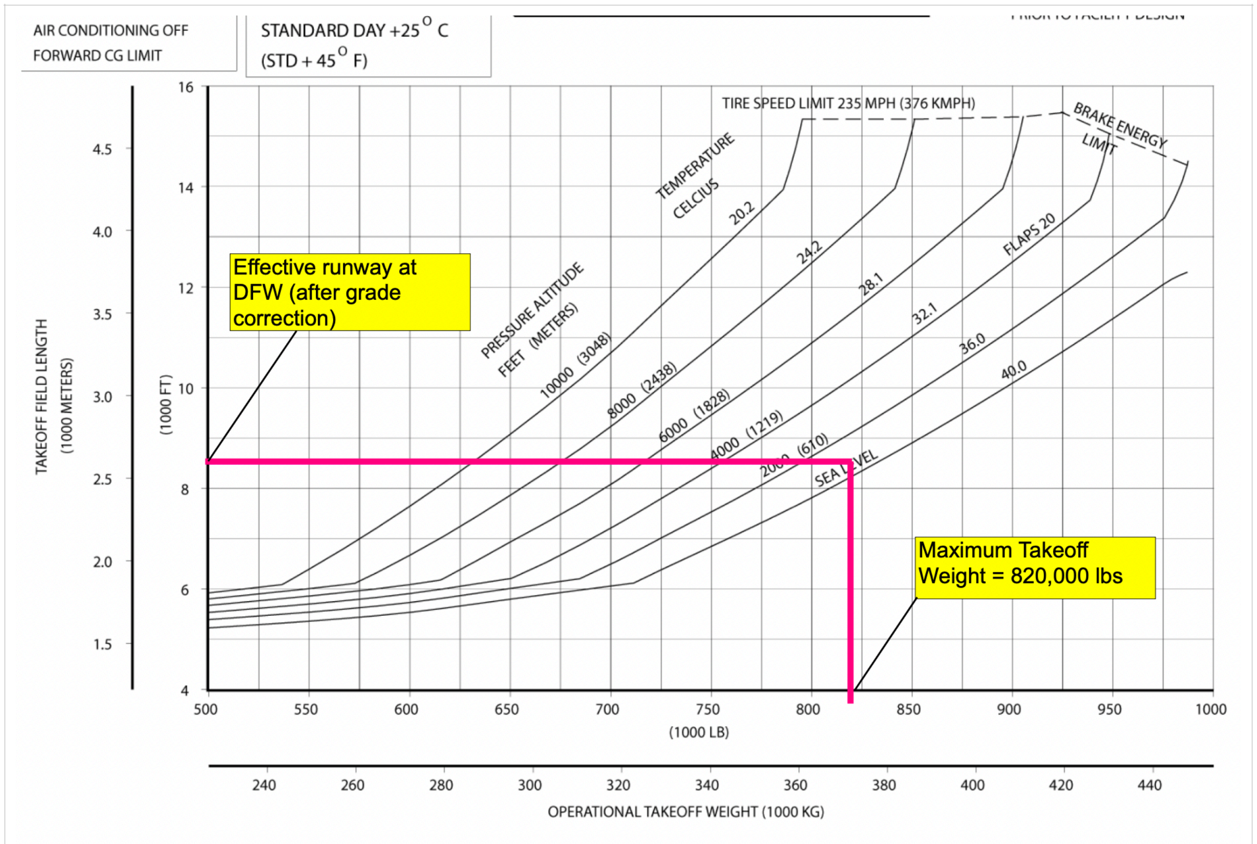


Figure 3.1 Boeing 747-8F (freighter) Takeoff Field Length Performance from DFW Airport Using Runway 31R.

Table 3.1 Payload Conditions at Four Operating Points (A-D).

Operating Point	Payload (lbs)	Range (nm)
A	293,400	1,300
B	215,400	3,000
C	137,400	5,000
D	101,400	6,000

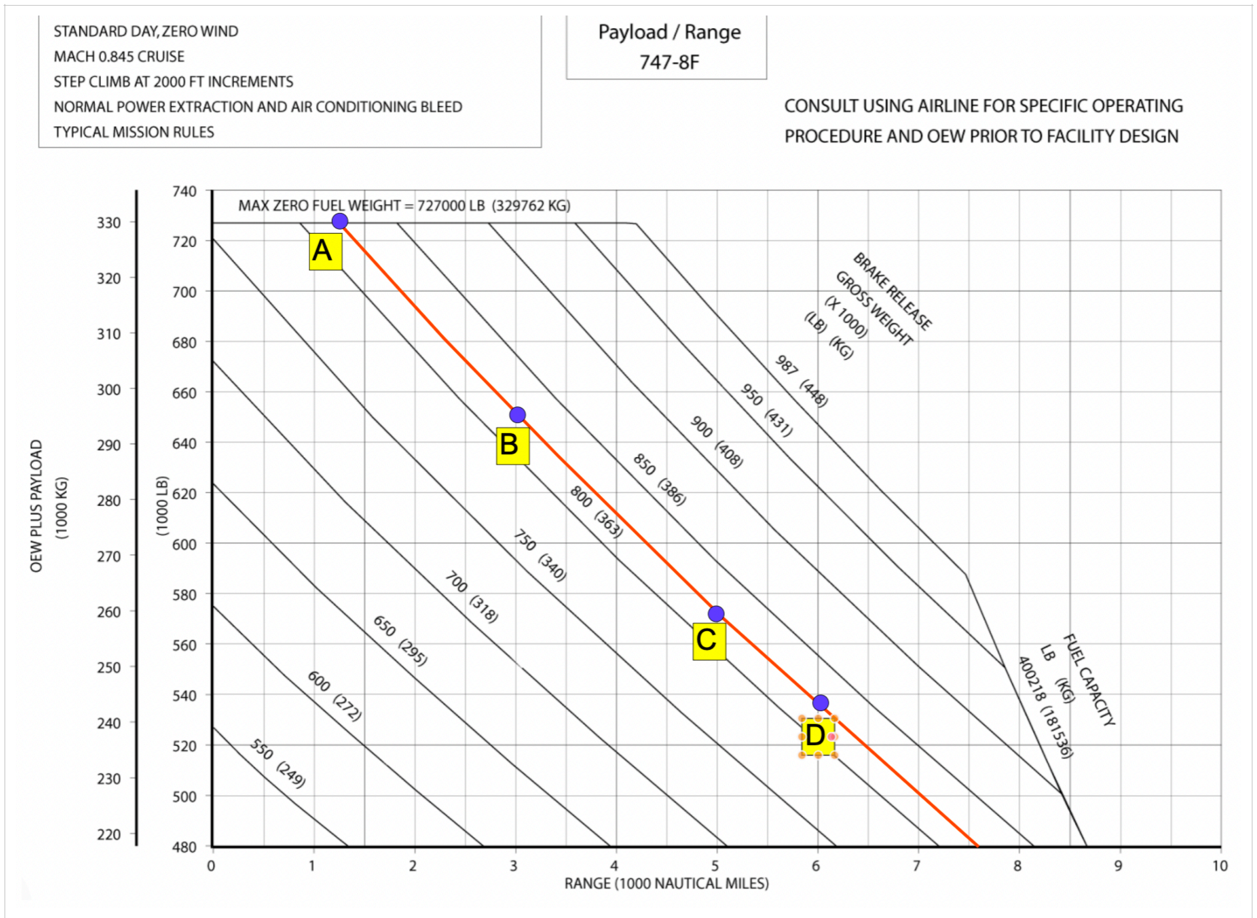


Figure 3.2 Boeing 747-8F (freighter) Payload-Range Diagram. The Orange Line Represents the Maximum Takeoff Weight from DFW Runway 31R. Operating Points A-D Provide Different Payload Conditions.

d) How far can the Boeing 747-8F fly with your payload estimate in part (c)?

Table 3 shows the aircraft range for four operating conditions (A-D).

e) A telecom company proposes to build an antenna at the location shown in Figure 3. The 10,000-foot runway is a precision runway. Is the antenna an obstruction to navigation according to FAR Part 77 standards? Show me the calculations and state the surface in question.

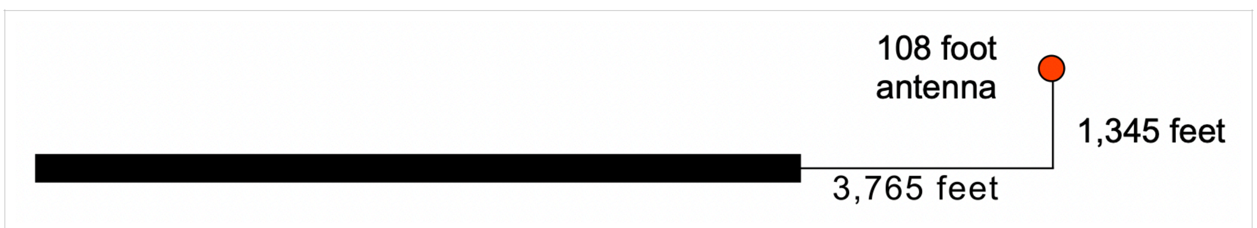


Figure 3. Location of Proposed Antenna near a 10,000-foot Precision Runway.

The proposed antenna is in the transitional surface (see Figure 3.3). At 3,556 feet from the start of the approach surface, the height of the approach surface is:

$$h_{3565} = \frac{3565}{50} = 71.3 \text{ feet}$$

The transition surface starts at the edge of the approach surface and has a slope 7:1. The edge of the approach surface (at th location of the proposed antenna) is 1,034.75 feet from the extended runway centerline. Therefore, the antenna is located 310.25 feet outside the approach surface and into the transition surface (see Figure 3.3). The transition surface rises 44.2 feet in 310.25 feet. The maximum permissible height of the transition surface at the antenna site would be 115.6 feet.

The proposed antenna will not violate the transition surface.

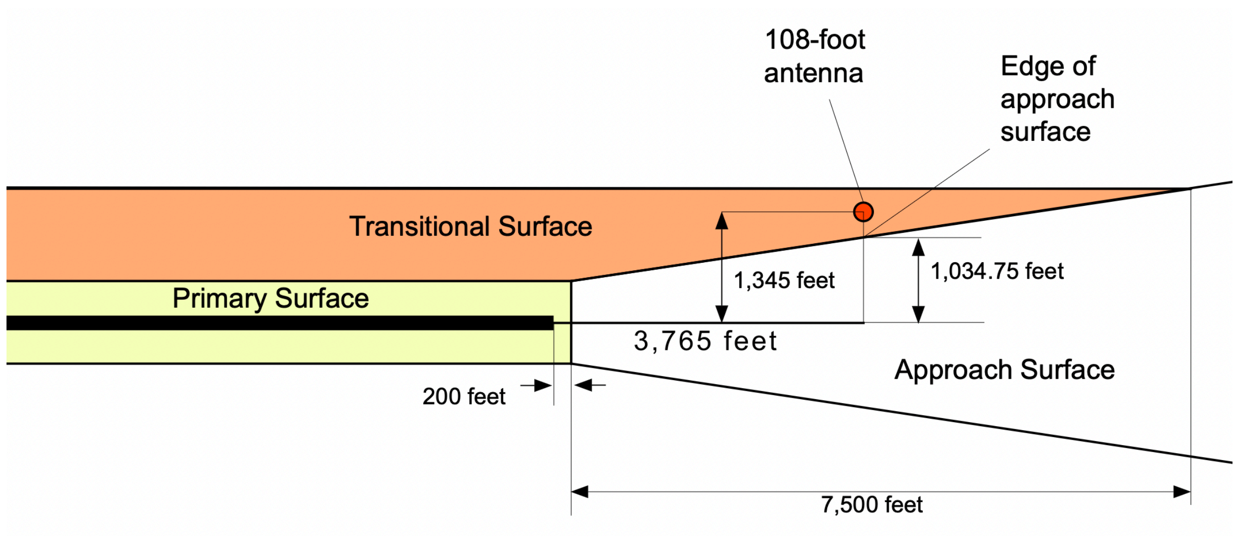


Figure 3.3 The Proposed Antenna is in the Transitional Surface.

f) Check if the antenna referenced in part (e) violates the **new runway siting criteria** considering the runway provides instrument departure operations. Show me the calculations.

The instrument departure surface geometry is depicted in Figure 3.4 per FAA AC 150/5300-13B. The proposed antenna lies outside of surface 1 of the departure surface with a slope 40:1. At 3,765 feet from the runway, the 40:1 slope departure surface rises **94.25 feet** at the departure surface edge (1,056.1 feet from the extended runway centerline).

Surface 2 slopes at an angle 19.4 degrees (2.83:1). The distance from surface 1 edge to the antenna location is 288.9 feet. At a slope 2.83:1, surface 2 rises an additional **102.1 feet** (288.9/2.83). At the location of the antenna, the height of surface 2 is 196.3 feet.

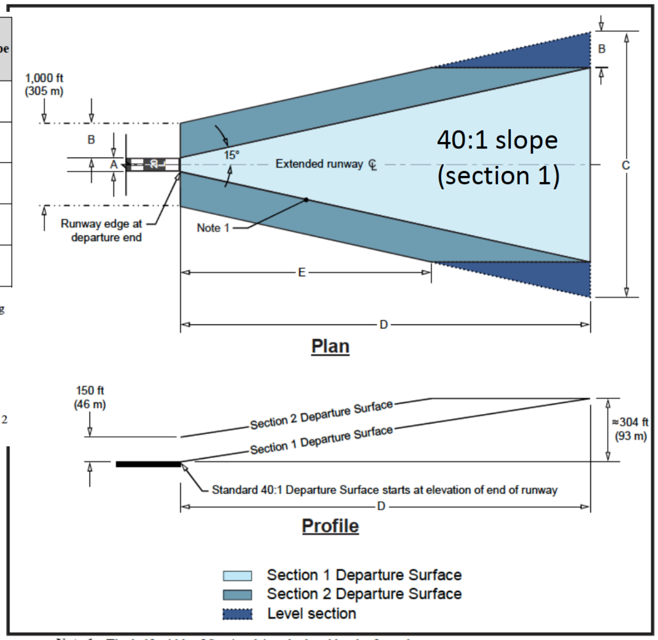
The proposed antenna will not violate surface 2 of the departure surface.

Instrument Runway Departure Surfaces

Surface	Runway Type	A ft (m)	B ft (m)	C ft (m)	D [4] ft (m)	E ft (m)	Section 2 Angle θ [2]	Section 2 Transverse Slope m[2]
Surface 7	Runways providing instrument departure operations	60 (18.3)	470 (143.3)	7,512 (2,290)	12,152 (3,704)	6,152 (1,875)	17:7	3.13:1
		75 (22.9)	462.5 (141.0)				18.0	3.08:1
		100 (30.5)	450 (137.2)				18.4	3.00:1
		150 (45.7)	425 (129.5)				19.4	2.83:1
		200 (61.0)	400 (121.9)				20.6	2.67:1

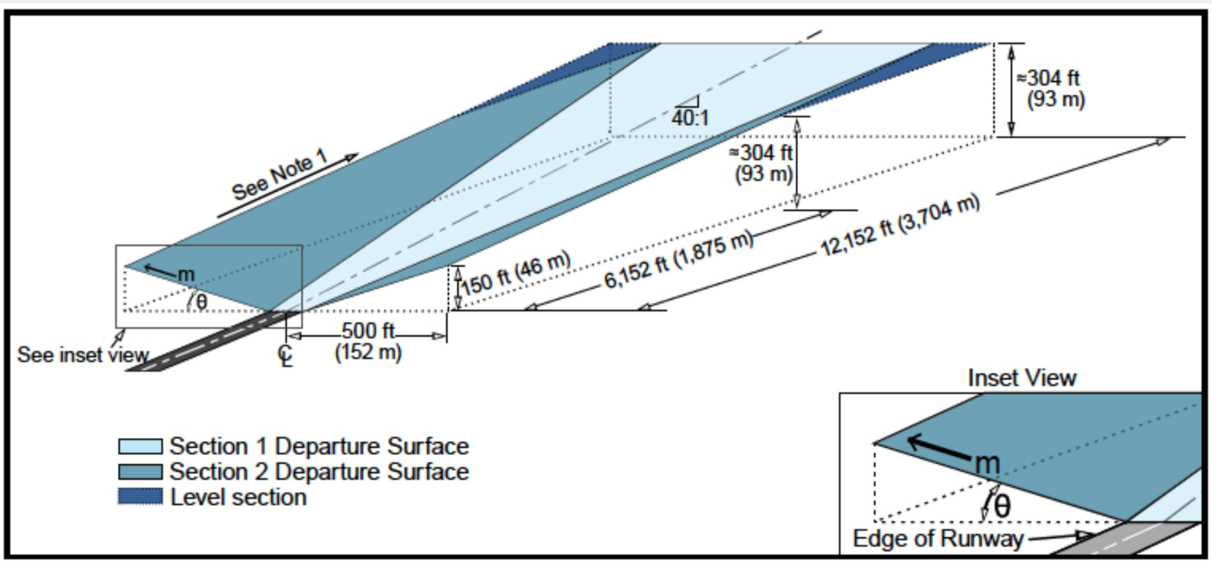
Note 1: Section 1 of the departure surface starts at the DER elevation for the width of the runway and rises along the extended runway centerline at 40:1. Section 2 starts at an equal elevation to the adjoining Section 1. Section 2 continues until reaching 304 ft (92.7 m) and then levels off until reaching the line where Section 1 and Section 2 reach 304 ft (92.7 m) above DER elevation, then that part of Section 2 that leveled off continues at a 40:1 slope.
Note 2: See Figure 3-11 for a graphical depiction of these values.
Note 3: The start of the surface is relative to the DER. For runways with published declared distances, the TODA indicates the beginning of the departure surface. See Figure 3-10.
Note 4: 12,152 feet (3,704 m) represents a 2 nm nominal value for planning purposes.
Note 5: For other runway width values, interpolation is required to determine the value of "B", the Section 2 angle, and the Section transverse slope.

Source: Table 3-5 of FAA AC 150/5300-13B



Note 1: The half-width of Section 1 is calculated by the formula: Section $1_{Half Width}$ = (1/2 RWY Width) + (Tan 15° × X), where X = distance from the departure end of the runway.
Note 2: See Table 3-5 for dimensional values.

Source: Figure 3-9 of FAA AC 150/5300-13B



Note 1: The outer edge of the Section 2 Departure Surface has a slope of 40:1.
Note 2: The 304-foot (93 m) value represents the height above the DER.
Note 3: Refer to paragraph 3.6.2.1 for additional information.

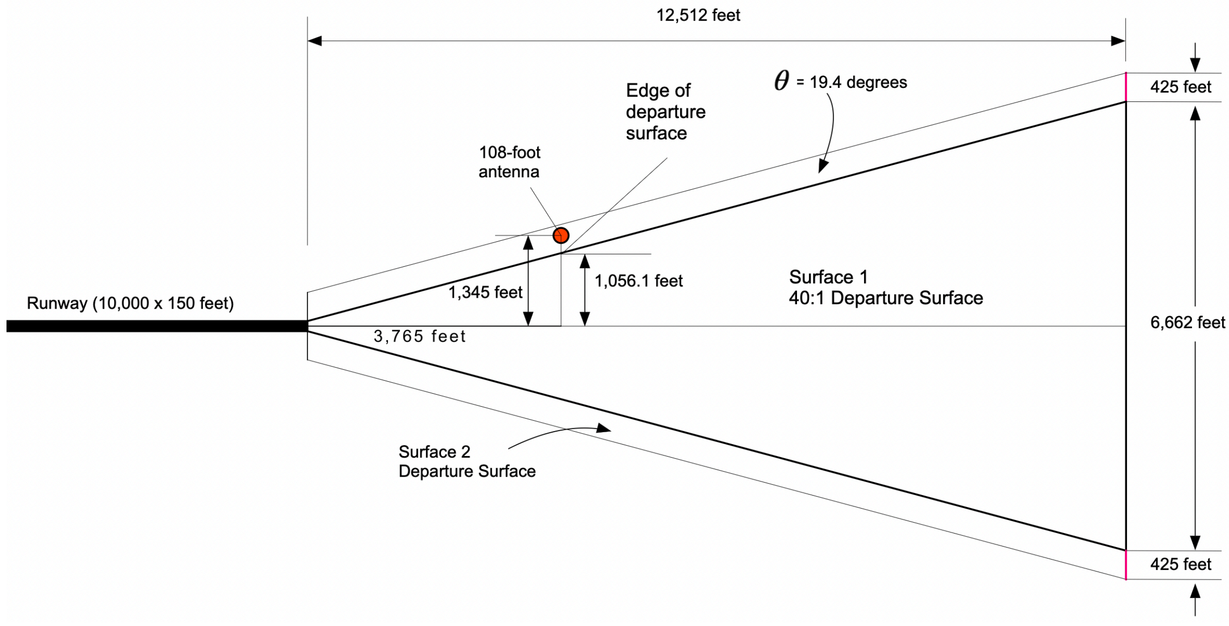


Figure 3.4 Instrument Departure Surface for Instrument Departure Operations.