Assignment 7: Imaginary Surfaces and Airport Geometric Design Standards

Solution Key
Instructor: Trani

Problem 1

This problem analyzes possible FAR Part 77 imaginary surface violations. The single runway airport has a **9,200-foot precision runway** (see Figure 1). The objects identified near the runway are proposed by two developers and a telecommunications company.

a) Study the objects shown in Figure 1 and check if they violate any Part 77 imaginary surface. State the critical FAR Part 77 imaginary surface applicable to each object. Also, state if the objects are obstacles to navigation. Show your calculations.

Figure 1.1 shows the imaginary surfaces as they apply to the problem.

The 138-foot tall building is not an obstacle to navigation because it lies inside the horizontal surface with a height of 150 feet.

The 67-foot data center is located 5,256 feet from the primary surface (i.e., start of the approach surface) inside the approach surface (see Figure 1.1). At that location the height of the approach surface is 105.12 feet (5256/50). Therefore, the data center does not violate the approach surface.

The antenna is located in the transitional surface. The antenna is located 3,267 feet from the primary surface (I.e., start of the approach surface. At the location of the antenna, the approach surface height is 65.34 feet. The semi-width of the approach surface (measured from the extended centerline of the runway) is 990.05 feet. The distance to the antenna is (1233 - 990.05) 242.95 feet. The transitional surface follows from that point at a slope 7:1. Hence the height of the transition surface at the location of the antenna is (242.95/7 + 65.34) 100.47 feet. The antenna is not in violation of the transitional surface.

The communications tower is located 225 feet beyond the 10,000-foot arc of the horizontal surface and inside the approach surface (see Figure 1.1). The approach surface has a slope of 50:1 up to 10,000 feet and 40:1 beyond that point. The hight of the approach surface at the location of the communications tower is 205.65 feet (10000/50 + 225/40). The tower is not in violation of the approach surface.

b) Find if the communications tower, the data center or the antenna meet the instrument departure surface criteria. Show your calculations.

The 67-foot data center is located 5,456 feet from the runway and inside Section 1 of the departure surface (see Figure 1.2). At that location the height of the departure surface is 136.34 feet (5256/40). Therefore, the data center does not violate the departure surface.

The communications tower is located 10,425 feet from the runway end point (see Figure 1.3). The departure surface has a slope of 40:1. The height of Section 1 of the departure surface at the location of the communications tower is 260.63 feet (10425/40). The tower is not in violation of the departure surface.

*The antenna is located in Section 2 of the departure surface (see Figures 1.2 and 1.3). The antenna is located 3,467 feet from the runway end point. The transverse angle (θ) for Section 2 of the departure surface is 19.4 degrees (transverse slope is 2.83:1). At a location 3,467 feet from the runway end, the height of the departure surface is 86.67 feet (3467/40). The perpendicular distance from the extended centerline of the runway to the edge of Section 1 of the departure surface is 972.3 feet (3457*sin(15) + 150/2). The Section 2 of the departure surface rises 85.6 feet (1233-972.3)*sin(19.4)) above the Section 1 height (86.67 feet) for a total height of 173.3 feet. Clearly, the antenna does not violate Section 2 of the departure surface.*

c) State the main difference between the Part 77 approach surface and the instrument departure surface for the precision runway.

The differences can be summarized as follows:

1. The Part 77 approach surface starts 200 feet from the end of the runway. The departure surface starts at the runway end point.
2. The slopes are different. Part 77 is 50:1 and the departure surface is 40:1.
3. The Part 77 approach surface extends to 50,000 feet. The departure surface extends 12,152 feet.
4. Part 77 surfaces include a transitional surface that is substantially wider than Section 2 of the departure surface.

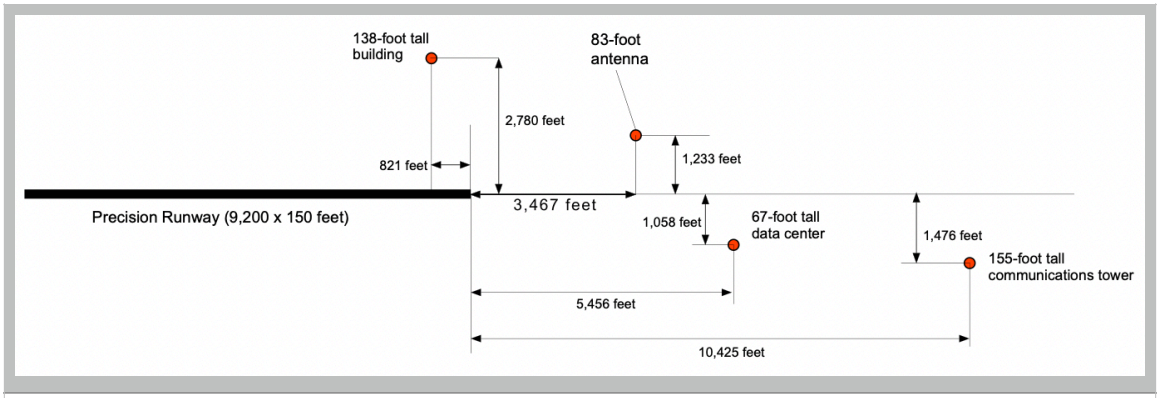


Figure 1. Objects Identified Near the Existing Runway. Drawing to Scale.

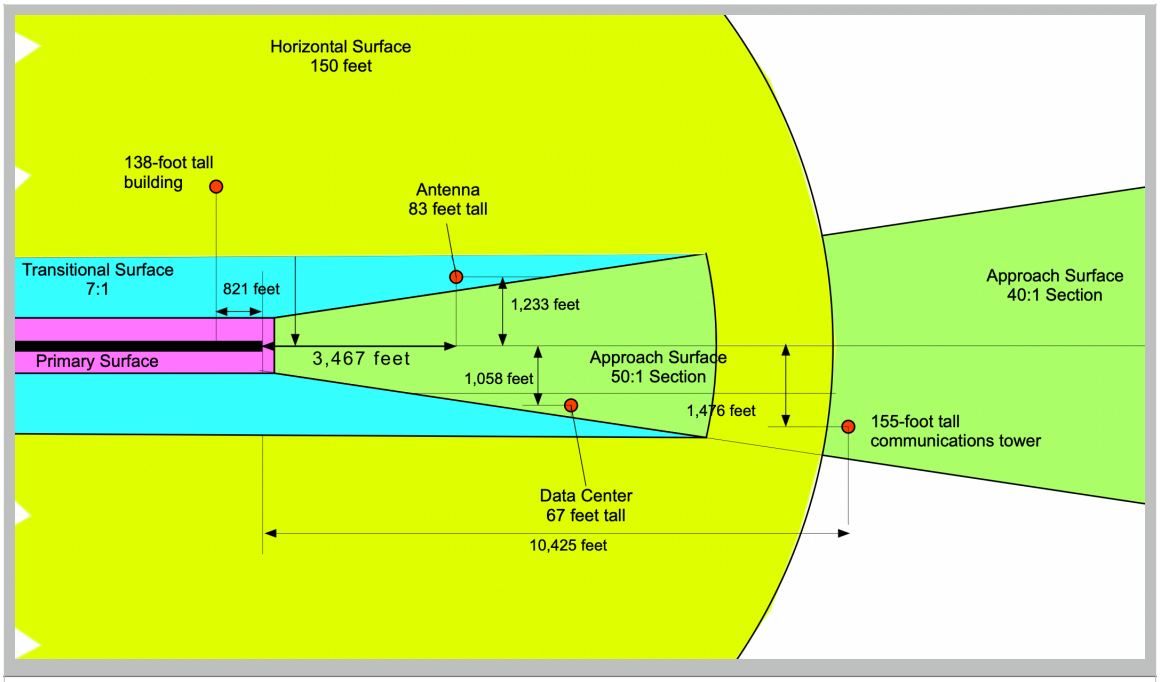
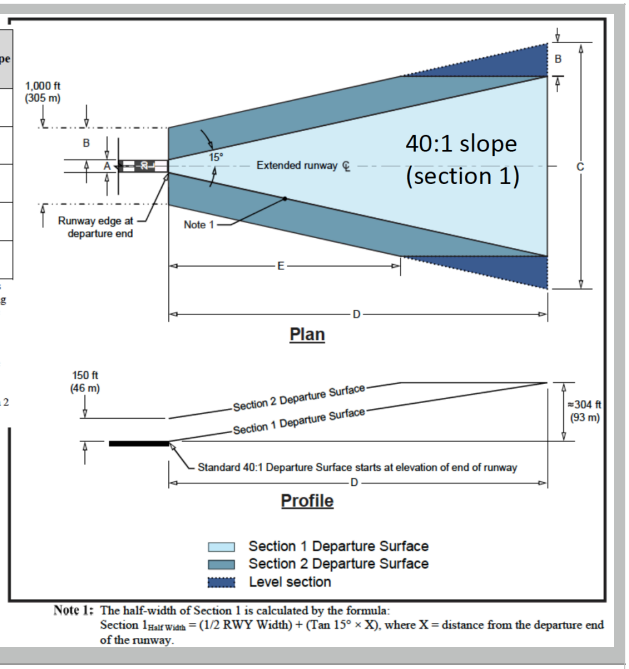


Figure 1.1. Objects Identified Near the Existing Runway and the Corresponding Imaginary Surfaces (Drawn to Scale).

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 m²
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.

Figure 1.2. Surface 7 - Departure Obstacle Criteria.

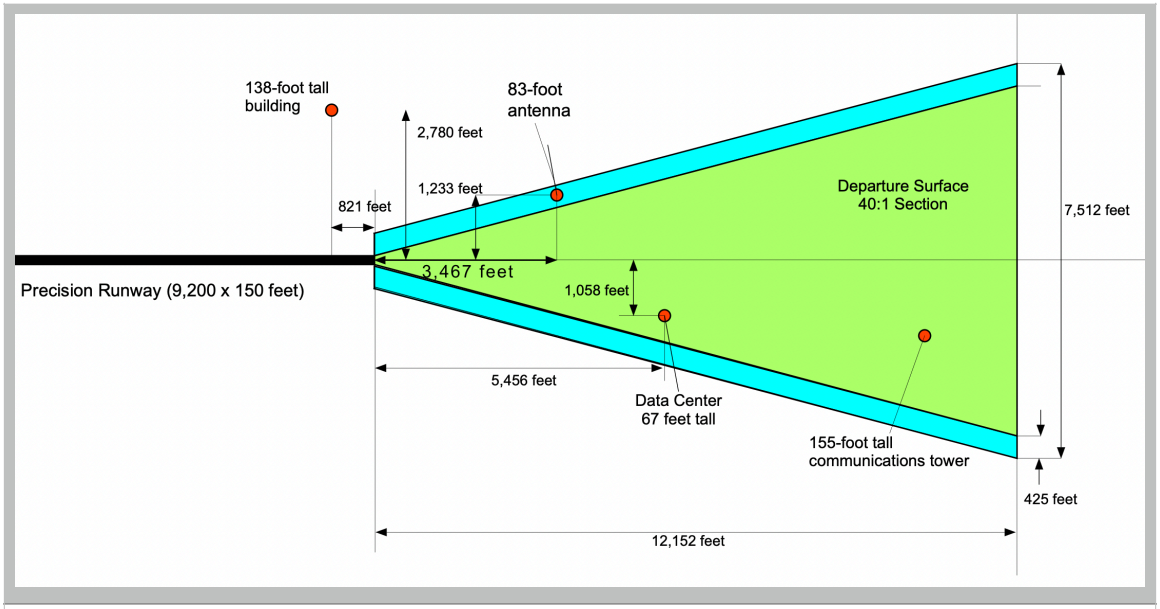


Figure 1.3. Application of Departure Surface Criteria.

Problem 2

a) Use the **FAA Taxiway Fillet Design Tool** to design an odd 145-degree taxiway-taxiway connector for the Airbus A220-300 (see Figure 3). Your design should include all dimensions needed to construct the taxiway fillet (three segment lengths L-1, L-2, L-3; three taxiway widths W-0, W-1, W-2, W-3; and two radii dimensions R-Fillet and R-Outer. **Select a centerline radius to produce a maximum steering angle of 40 degrees.**

The Airbus A220-300 is designated as BCS3 in the Aircraft Characteristic Database. The aircraft belongs to TDG 3 and ADG III. Figure 2.1 shows the design of the 145-degree taxiway junction that produces a steering angle of 40 degrees. The centerline radius is 97.25 feet. Table 1 shows the changes in steering angle for various radii ranging from 78 to 120 feet.

b) For the design aircraft, find the minimum centerline radius on the 145-deg. if the maximum steering angle is 50 degrees.

The minimum centerline radius is 78 feet

c) Use the **FAA FAA Taxiway Fillet Design Tool** to produce a simple CAD drawing of the taxiway-taxiway connector design in part (a). Show the detailed geometry in the CAD software with dimensions (no hand sketches accepted). You can export the DXF file produced by the FAA Taxiway Design Tool.



Figure 2. Airbus A220-300 at Atlanta Hartsfield-Jackson International Airport (A. Trani).

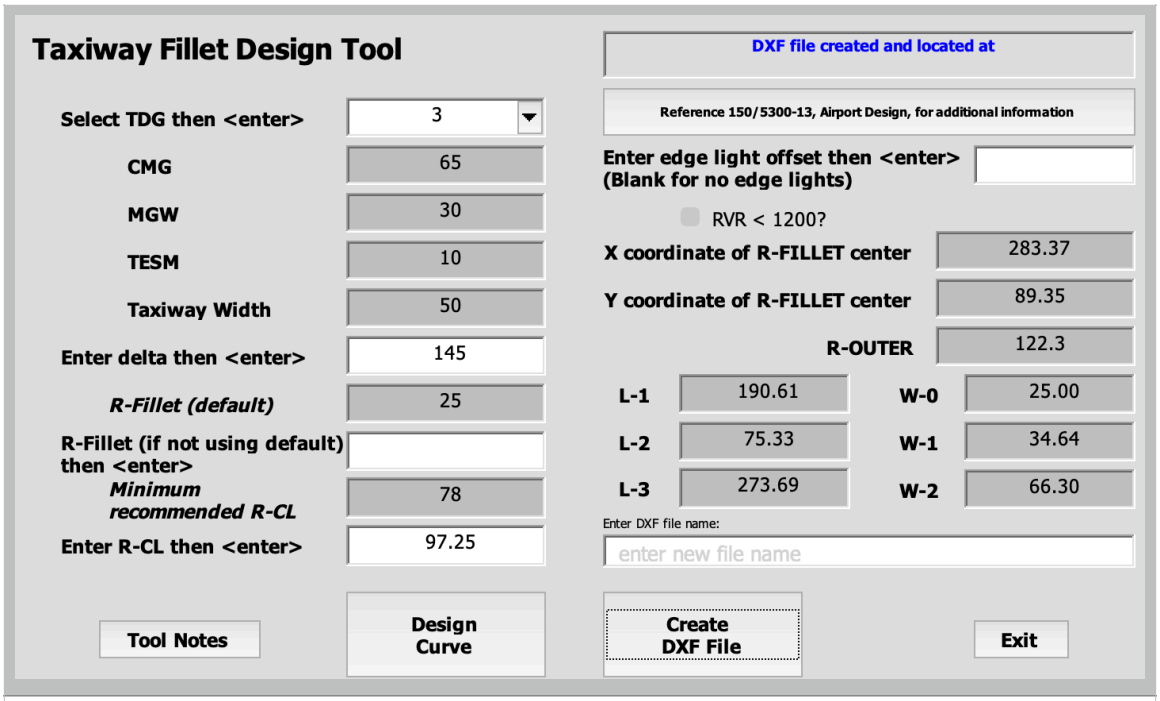


Figure 2.1 Inputs and Output to the Fillet Taxiway Design Tool Using 40-deg Steering Angle.

Table 1. Centerline Radius versus Steering Angle for TDG 3.

Centerline Radius (feet)	Steering Angle (degrees)	Remarks
78.0	50.0	Minimum radius. Does not meet the desired steering angle
97.25	40.0	Meets the desired steering angle
97.5	39.9	Meets the desired steering angle
98.0	39.7	Meets the desired steering angle
100.0	38.9	Meets the desired steering angle
110.0	35.3	Meets the desired steering angle
120.0	32.2	Meets the desired steering angle

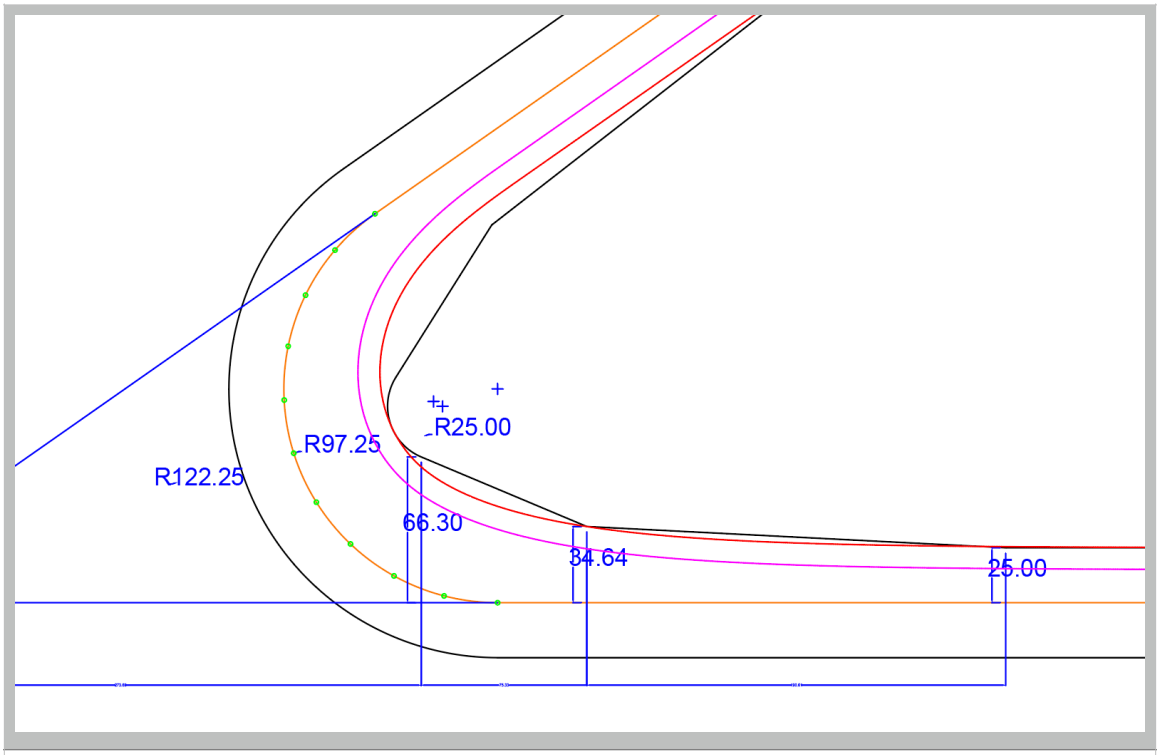


Figure 2.2 CAD Output of the Fillet Design Tool. Centerline Radius is 97.25 feet. The Steering Angle is 40 Degrees. Note that for the design, a fillet radius of 25 feet is required.

Problem 3

Perform geometric design calculations for a new international airport (see Figure 3). The idea is to provide eight gates that can accommodate aircraft up to the size of a Boeing 787-9 (see Figure 3).

a) Find the dimensions A through R in Figure 3. Make sure that your design allows pilots entering the gate position to maneuver with steering angles no more than 50 degrees. Assume the service roads have 12-foot wide lanes. Use the new design criteria to satisfy the taxilane object-free areas on the dual taxi lane. For dimension D, use the distance between the nose of the aircraft and the terminal building of a modern terminal like the LAX Tom Bradley International Terminal. For each dimension in your solution, state the criteria used.

The Boeing 787-9 belongs to ADG V and TDG 5. The total length of the aircraft is 203.4 feet and the wingspan is 197.3 feet. Note the ACD lists the length at 206 feet. Hence the dimensions may change slightly. In the solution I used 204 feet of length.

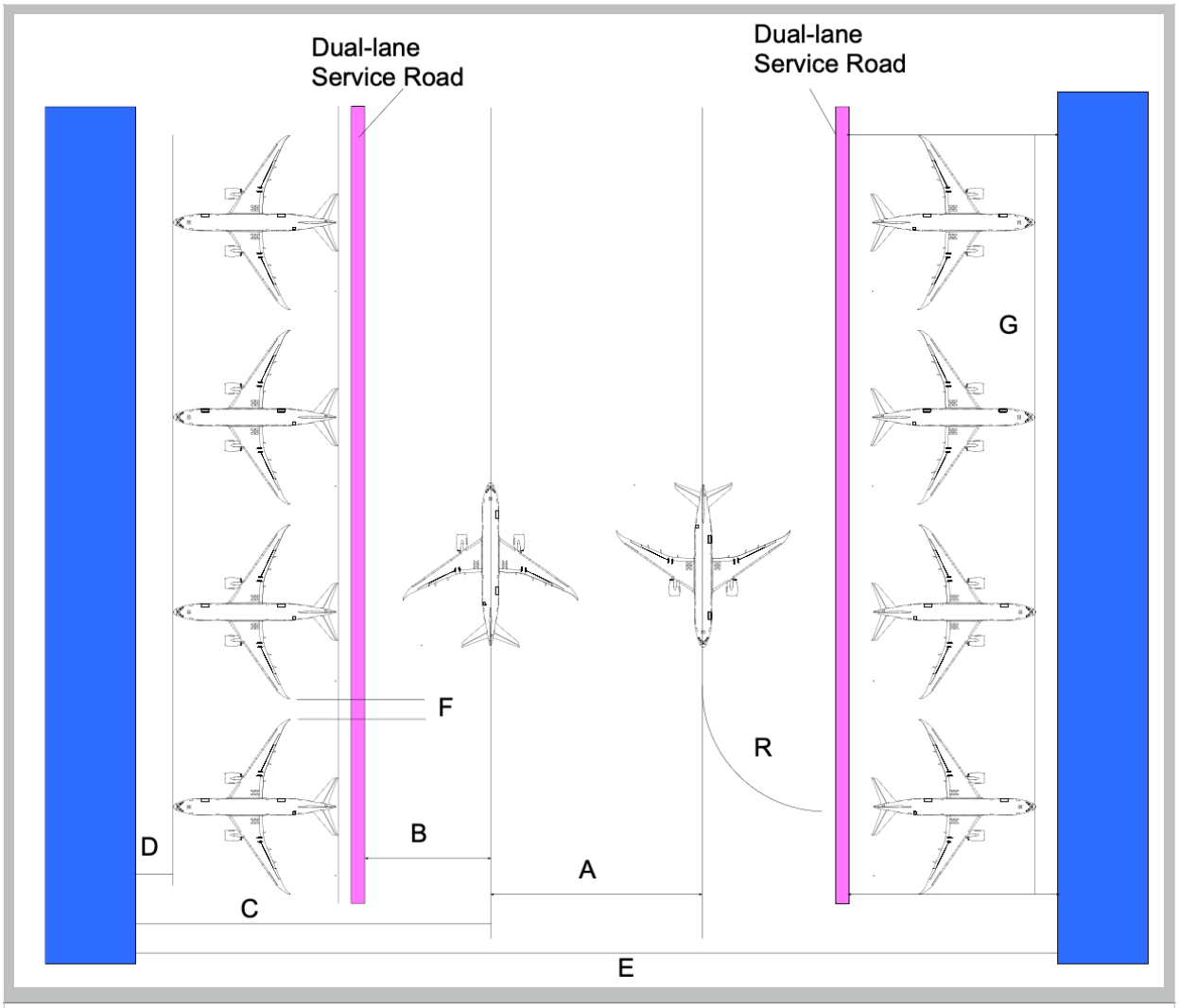


Figure 3. Airport Terminal Configuration for Problem 3.

Item	Dimension (feet)	Reference
A	242	Table 4-1 Distance between parallel taxi lanes

Item	Dimension (feet)	Reference
B	135	Table 4-1 Distance to a fix or movable object
C	412	Sum of B+D + 2(14 ft) 28 feet wide dual service road
D	40-45	LAX Distance to Terminal Building (TBT terminal)
E	1,066	2C+ A
F	25-28	Taxilane wingtip clearance of dimensions provided in geometric design handout page 37
G	864-873	Range changes when applying 25-28 feet in wingtip clearance
R	126	Boeing document. Steering angle is 50 degrees.

b) Estimate the steering angle and wingtip radius of the Boeing 787-9 for the centerline radius R selected in part (a) of the problem. Consult Section 4 of the corresponding Boeing airport design and planning document.

Nose gear (centerline radius) is 126 feet (R3) as suggested by Boeing for a steering angle of 50 degrees.

c) Use the FAA taxiway design tool to track the centerline radius selected in parts (a-b) and the main gear of the Boeing 787-9 as it maneuvers to enter the gate. Export the CAD drawing and show me the nose gear and main gear tracks.



Figure 4. Boeing 787-9 at Atlanta International Airport (A. Trani).

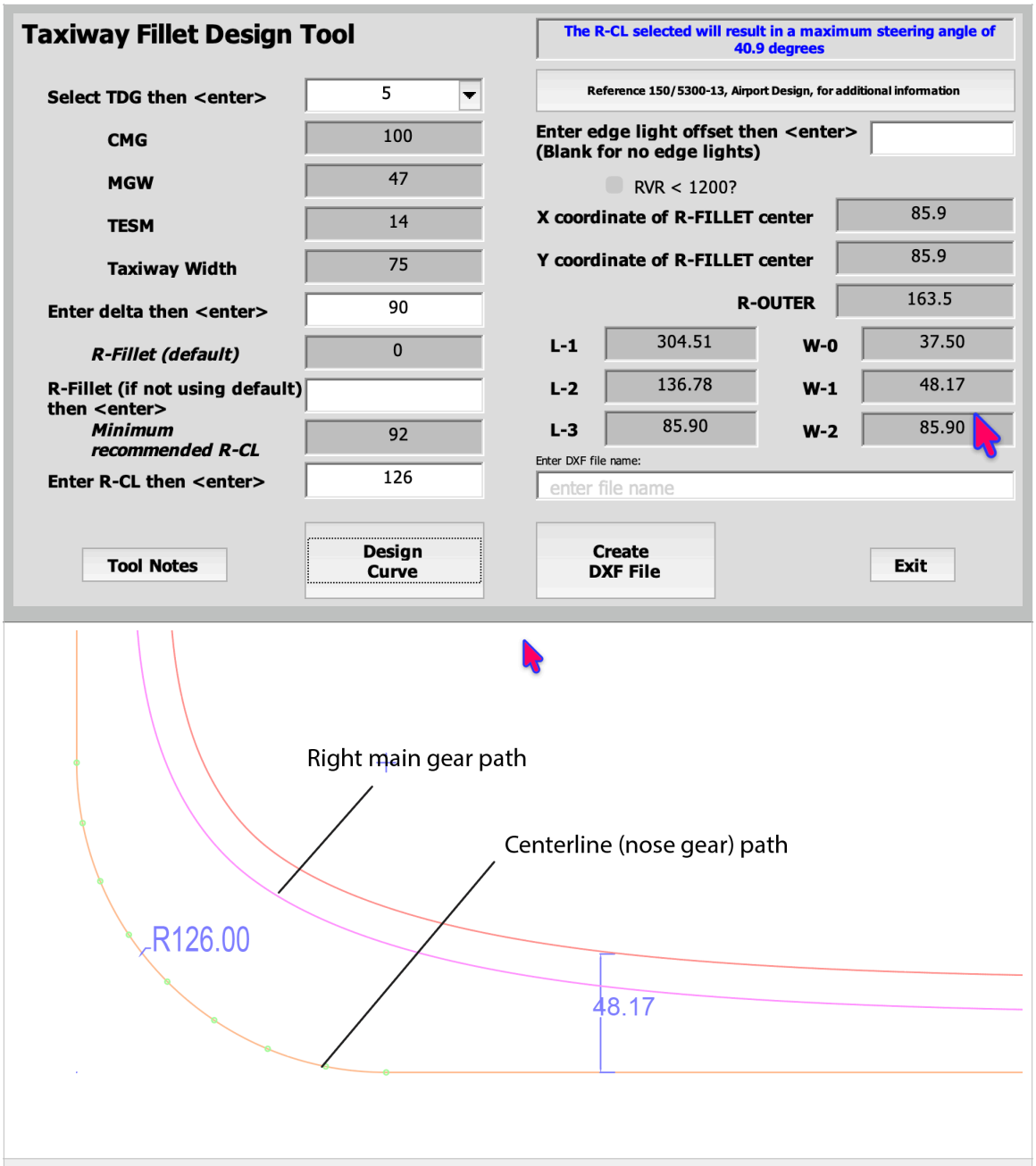


Figure 2.2 CAD Output of the Fillet Design Tool. Centerline Radius is 126 feet. The Steering Angle is 50 Degrees.

Problem 4

An airport is expected to have two parallel taxiways to serve ADG IV aircraft taxiing in opposite directions. The airport is located at 2,300 feet elevation. Specify the following dimensions:

a) Distance between parallel taxiway centerlines.

Use Table 4-1 in FAA AC 150/5300-13B to find 207 feet between parallel taxiways.

b) Find the minimum distance between the taxiway centerline and a fix or movable object.

Use Table 4-1 in FAA AC 150/5300-13B to find 121.5 feet between a taxiway centerline and a fix or movable object.

c) Find the dimension of the taxiway shoulder used in the design.

Aircraft in ADG IV have diverse dimensions of TDG. The figure below shows the TDG classifications for all the aircraft in ADG IV in the ACD.

The typical TDG classes for modern commercial aircraft are 4 and 5. For TDG 4, the soldier width is 20 feet. For TDG 5 the shoulder width increases to 30 feet. Both answers are acceptable.

FAA_Designator	AAC_maximum	ADG	TDG
A400		IV	3
AN12		IV	2B
B703		IV	4
B752		IV	4
B753		IV	4
B762		IV	5
B763		IV	5
B764		IV	5
C130		IV	2B
C160		IV	3
C17		IV	5
C30J		IV	2A
DC10		IV	5
DC87		IV	4
IL76		IV	3
K35R		IV	3
MD11		IV	6

Figure 4.1 TDG Classification for all ADG IV Aircraft in the ACD.

d) Find the taxiway edge safety margin used in the design.

For TDG 4, the safety margin in 10 feet. For TDG 5, the safety margin increases to 14 feet. Both answers are acceptable.

e) State the dimensions of the Taxiway Object Free Area (OFA) and Taxiway Safety Areas (TSA).

TOFA is 243 feet. TSA is 171 feet (the same as the largest wingspan in ADG IV).

f) Find the dimensions (length and width) of the runway blast pad area.

The blast pad area is 200 x 200 feet (width and length) according to Table G-10 in FAA AC 150/5300-13B.