Runway Length Calculations
For Commercial Aircraft (MTOW > 60,000 lbs)

CEE 4674 - Airport Planning and Design

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Runway Length for Regional Jets and Aircraft with MTOW > 60,000 lb (27,200 kg)

- Inputs to the procedure:
  - Critical aircraft
  - Maximum certificated takeoff weight (MTOW)
  - Maximum landing weight (MALW)
  - Airport elevation (above mean sea level)
  - Mean daily maximum temperature of the hottest month of the year
  - Runway gradient
  - Airport Planning Manual (APM)
  - Payload-range diagram (optional)

Runway Length for Regional Jets and Aircraft with MTOW > 60,000 lb (27,200 kg)

- Determine takeoff runway length
- Determine landing runway length
- Apply adjustments to obtained runway length
- The longest runway length becomes the recommended runway length for airport design

Temperature Effects in Runway Length Charts

- All design charts have a temperature parameters (be careful)
- While determining runway length for airport design, we need to use the temperature that closely matches the mean daily maximum temperature of the hottest month of the year
- When a temperature values in the chart is “no more than 3° F (1.7° C) lower than the recorded value for the mean daily maximum temperature of the hottest month at the airport” the chart is set to apply
- If the design temperature is too high consult with the aircraft manufacturer

Landing Procedure (FAA)

a) Use the landing chart with the highest landing flap setting (if more than one flap setting is offer), zero wind, and zero effective runway gradient.

b) Enter the horizontal weight axis with the operating landing weight equal to the maximum certificated landing weight. Linear interpolation along the weight axis is allowed. Do not exceed any indicated limitations on the chart.

c) Proceed vertically to the airport elevation curve, sometimes labeled “pressure altitude.” Interpolation between curves is allowed. Use the wet pavement charts. Otherwise use 15% above the dry condition

d) Read the runway length. Linear interpolation along the length axis is allowed.

e) Increase the obtained landing length for “dry runway” condition by 15 percent for those cases noted in paragraph 508. No landing length adjustment is necessary by regulation for non-zero effective runway gradients for any airplane type.

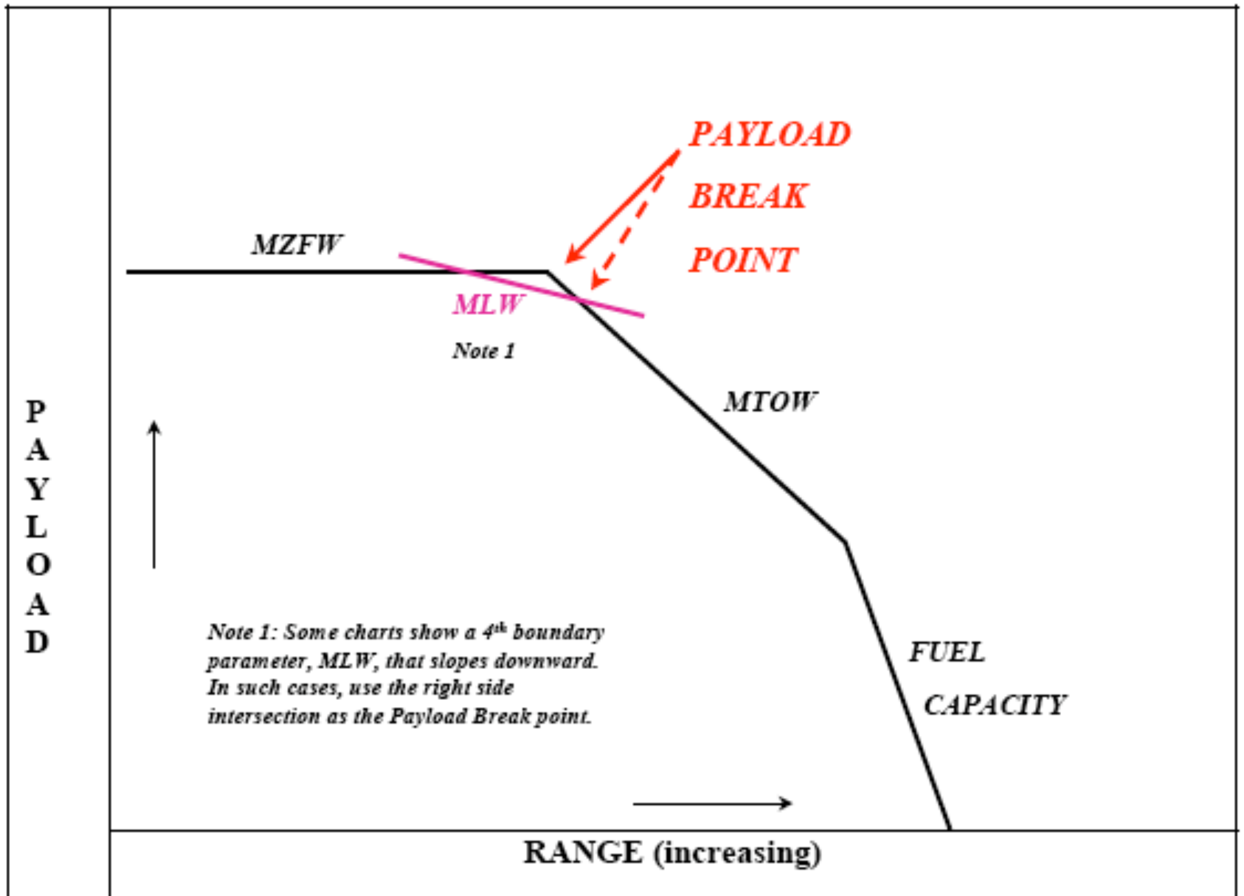
Takeoff Runway Length Procedure (FAA)

Select the correct **aircraft-engine combination** of runway length design charts

Two possible ways to calculate runway length:

- **No stage length provided**: use the MTOW value from the payload-range diagram (near payload-break point – see diagram in next page)
- **For actual routes expected to be flown** (and used as design point) use the actual takeoff (or Desired Takeoff Weight – DTW)
- The design operating takeoff weight (DTW) equals the actual operating takeoff weight for the given route length.
- *"Consult with AC 120-27D, Aircraft Weight and Balance Control, provides average weight values for passengers and baggage for payload calculations for short-haul routes"*

Hypothetical Payload-Range Diagram



MLW maximum design landing weight
MTOW maximum design takeoff weight (some APMs label it Brake Release)
MZFW maximum design zero fuel weight (some APMs label it Maximum Design Payload)

Weights Authorized by FAA (source: *AC 120-27E)*

Standard Average Passenger Weight	**Weight Per Passenger**
Summer Weights	
Average adult passenger weight	190 lb
Average adult male passenger weight	200 lb
Average adult female passenger weight	179 lb
Child weight (2 years to less than 13 years of age)	82 lb
Winter Weights	
Average adult passenger weight	195 lb
Average adult male passenger weight	205 lb
Average adult female passenger weight	184 lb
Child weight (2 years to less than 13 years of age)	87 lb

- Summer weights apply from May 1 to October 31
- Allowance of 16 lb per person for carry-out items in table above
- Average weight of a bag is 30 lb
- Heavy bags are 60 lbs
- Use 220 lb/passenger (190 + 30) for airport design

Weights Authorized by FAA (source: *AC 120-27E)*

- Some operators do surveys of passenger and luggage item weights
- If an operator conducts a survey and finds that the 16 lb allowance is small, it will be necessary to increase the weight allowance
- A recommended random sample is necessary:

Survey Subject	Minimum Sample Size	Tolerable Error
Adult (standard adult/male/female)	2,700	1%
Child	2,700	2%
Checked bags	1,400	2%
Heavy bag	1,400	2%
Plane-side loaded bags	1,400	2%
Personal items and carry-on bags	1,400	2%
Personal items only (for operators with a no carry-on bag program)	1,400	2%

Final Notes on Runway Length Calculations

- Read the runway length requirement by entering the desired takeoff weight and airport elevation
- Linear interpolation along the runway length axis is allowed
- Adjust the takeoff runway length for non-zero effective runway gradients
- Increase the runway length by 10 feet (3 m) per foot (0.3m) of difference in runway centerline elevations between the high and low points of the runway centerline
- Final runway length is the most demanding of the landing and the takeoff

Example Calculation
No Stage Length Defined

Unresticted Takeoff Condition

Boeing 737-900 per FAA AC
Example 1 in FAA AC Appendix 3

- Airplane Boeing 737-900 (CFM56-7B27 Engines)
- Mean daily maximum temperature of hottest month at the airport 84° Fahrenheit (28.9° C)
- Airport elevation 1,000 feet
- Maximum design landing weight (see table A3-1-1) 146,300 pounds
- Maximum design takeoff weight 174,200 pounds
- Maximum difference in runway centerline elevations 20 feet

Boeing 737-900 Example (per FAA AC) Landing Analysis

Step 1 – the Boeing 737-900 APM provides three landing charts for flap settings of 40-degrees, 30-degrees, and 15-degrees. **The 40-degree flap setting landing chart**, figure A3-1-1, is chosen since, it results in the shortest landing runway length requirement.

Steps 2 and 3 – Enter the horizontal weight axis at 146,300 pounds and proceed vertically and interpolate between the airport elevations "wet" curves of sea level and 2,000 feet for the 1,000-foot wet value. Wet curves are selected because the airplane is a turbo-jet powered airplane (see paragraph 508). Interpolation is allowed for both design parameters.

Step 4 – Proceed horizontally to the length axis to read 6,600 feet. Interpolation is allowed for this design parameter.

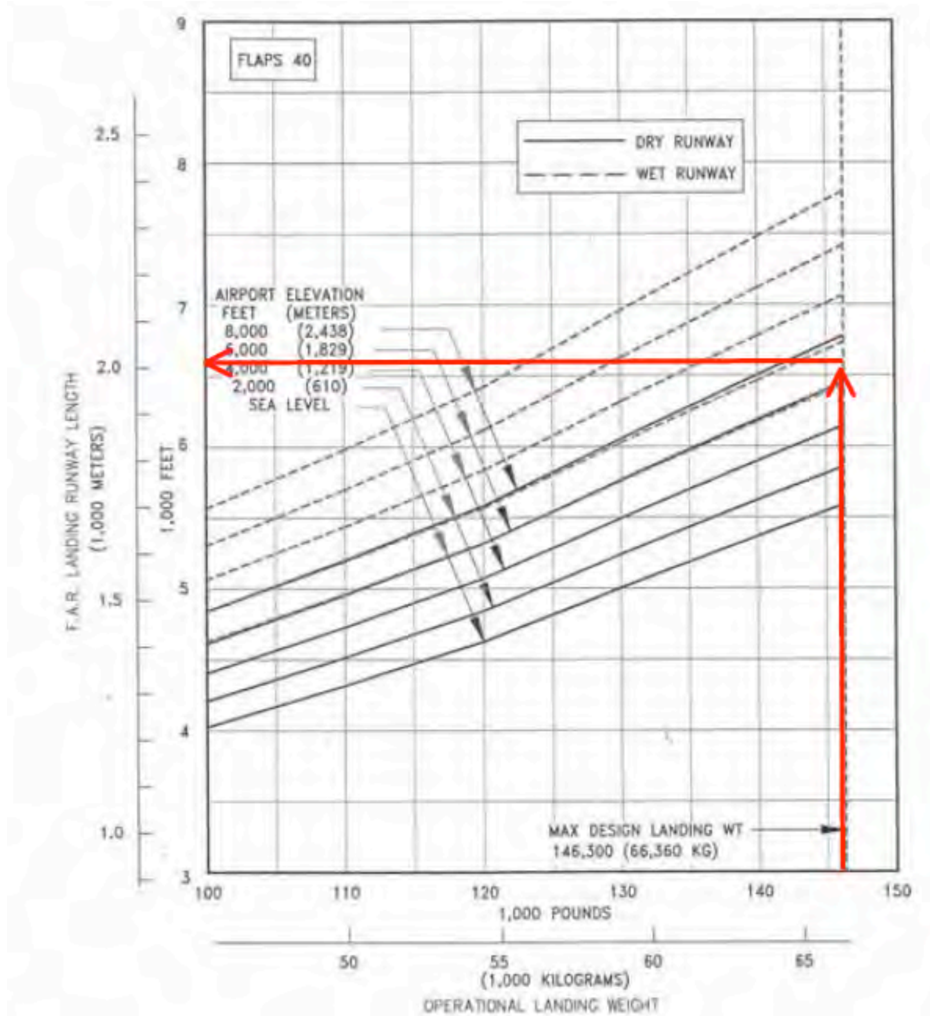
Step 5 – Do not adjust the obtained length since the "Wet Runway" curve was used. See paragraph 508 if only "dry" curves are provided.

The length requirement is 6,600 feet. Note: Round lengths of 30 feet and over to the next 100-foot interval. Thus, the landing length for design is **6,600 feet.**

Boeing 737-900 Example (per FAA AC) Landing Analysis (Chart)

Note:

Highest flap
Setting selected
According to
FAA procedure



Boeing 737-900 Example (per FAA AC) Takeoff Analysis

Step 1 – The Boeing 737-900 APM provides a takeoff chart at the standard day + 27°F (SDT + 15° C) temperature applicable to the various flap settings. Notice that this chart can be used for airports whose mean daily maximum temperature of the hottest month at the airport is equal to or less than 85.4° F (29.7° C). Since the given temperature for this example is 84° F (28.9° C) falls within this range, select this chart.

Steps 2 and 3 – Enter the horizontal weight axis at 174,200 pounds and proceed vertically and interpolate between the airport elevation curves of sea level and 2,000 feet for the 1,000-foot value. Interpolation is allowed for both design parameters.

Note: As observed in this example, a takeoff chart may contain under the "Notes" section the condition that linear interpolation between elevations is invalid. Because the application of the takeoff chart is for airport design and not for flight operations, interpolation is allowed.

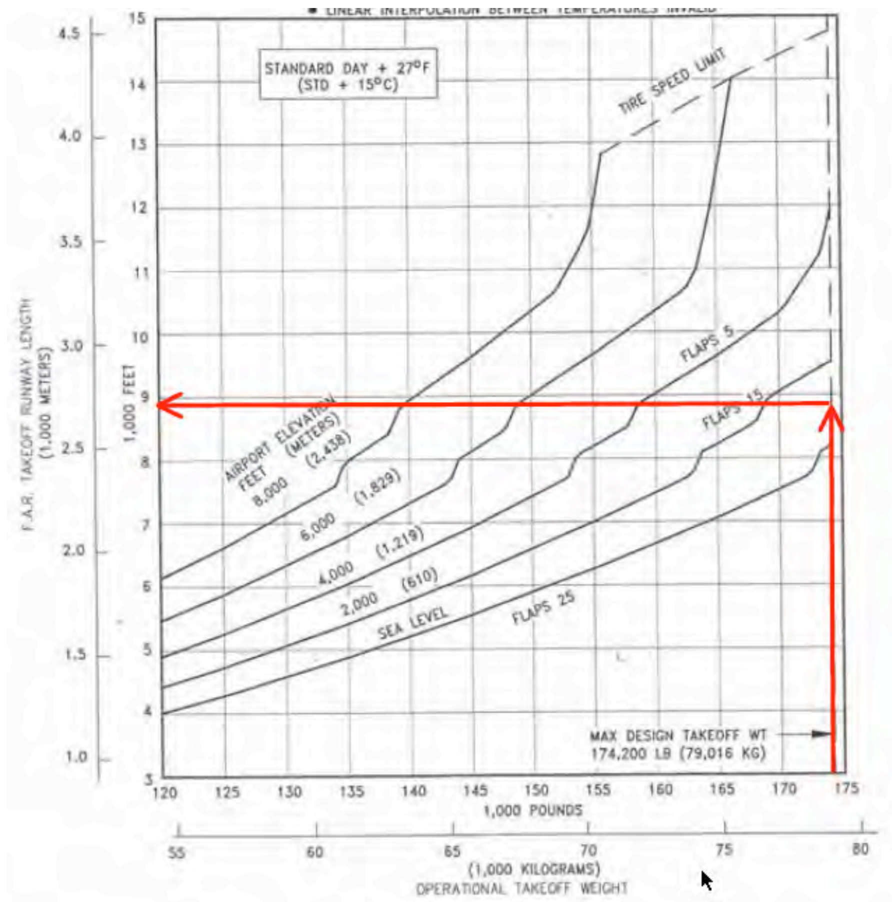
Boeing 737-900 Example (per FAA AC) Takeoff Analysis (Chart)

Step 4 – Proceed horizontally to the length axis to read 8,800 feet. Interpolation is allowed for this design parameter.

Step 5 – Adjust for non-zero effective runway gradient (see paragraph 509).

8,800 + (20 x 10) = 8,800 + 200 = 9,000 feet

The takeoff length requirement is 9,000 feet. Note: Round lengths of 30 feet and over to the next 100-foot interval. Thus, the takeoff length for design is 9,000 feet.



Boeing 737-900 Example (per FAA AC) Recommended Runway Length

- The recommended runway length is 9,000 feet
- The takeoff runway length is dominant

Max. Landing Design Weight	146,300 pounds
Max. Takeoff Design Weight	174,200 pounds
Landing Length	6,600 feet
Takeoff Length	9,000 feet

Example Calculation
With Stage Length Defined

Boeing 777-200 HGW Example

- Boeing 777-200 High Gross Weight Estimate the runway length to operate a Boeing 777-200 High Gross Weight (HGW) from Washington Dulles to Sao Paulo Guarulhos airport in Brazil (a stage length of 4,200 nm) at Mach .84. After consultation with the airline you learned that their B777s have a gross weight of 592,000 lb. (HGW option) and have a standard three-class seating arrangement
- The airline has B 777-200 HGW with General Electric engines
- Assume hot day conditions.

Aircraft Basic Information

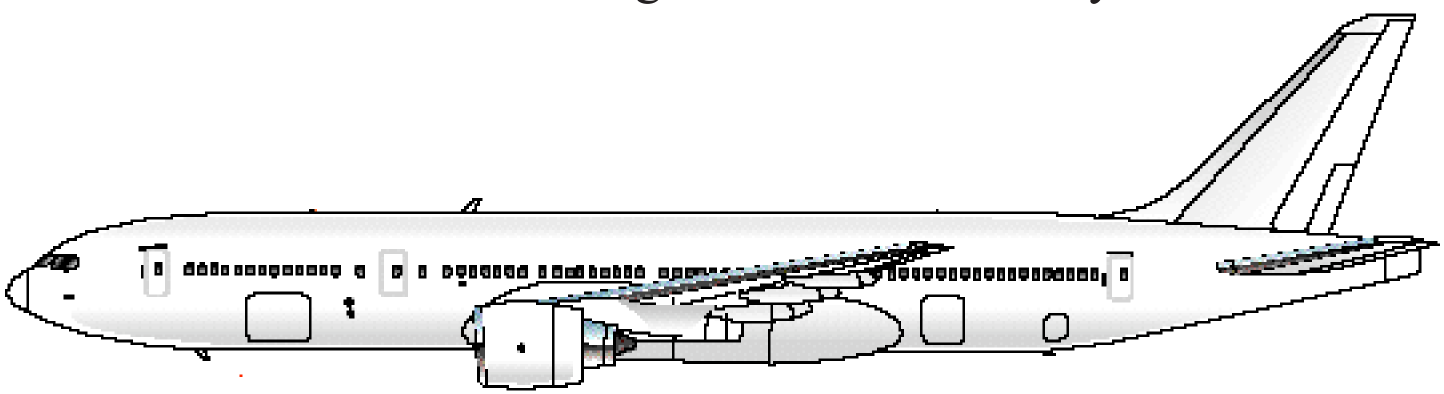
Boeing Document D6-58329

CHARACTERISTICS	UNITS	BASELINE AIRPLANE			HIGH GROSS WEIGHT OPTION		
MAX DESIGN TAXI WEIGHT	POUNDS	508,000	517,000	537,000	582,000	592,000	634,500
	KILOGRAMS	230,450	234,500	243,500	263,640	268,480	287,800
MAX DESIGN TAKEOFF WEIGHT	POUNDS	506,000	515,000	535,000	580,000	590,000	632,500
	KILOGRAMS	229,500	233,600	242,630	263,030	267,500	286,900
MAX DESIGN LANDING WEIGHT	POUNDS	441,000	445,000	445,000	460,000	460,000	460,000
	KILOGRAMS	200,050	201,800	201,800	208,700	208,700	208,700
MAX DESIGN ZERO FUEL WEIGHT	POUNDS	420,000	420,000	420,000	430,000	430,000	430,000
	KILOGRAMS	190,470	190,470	190,470	195,000	195,000	195,000
SPEC OPERATING EMPTY WEIGHT (1)	POUNDS	298,900	298,900	299,550	304,500	304,500	304,500
	KILOGRAMS	135,550	135,550	135,850	138,100	138,100	138,100
MAX STRUCTURAL PAYLOAD	POUNDS	121,100	121,100	120,450	125,550	125,550	125,550
	KILOGRAMS	54,920	54,920	54,620	56,940	56,940	56,940
SEATING CAPACITY (1)	TWO-CLASS	375 - 30 FIRST + 345 ECONOMY					
	THREE-CLASS	305 - 24 FIRST + 54 BUSINESS + 227 ECONOMY					
MAX CARGO - LOWER DECK	CUBIC FEET	5,656(2)	5,656(2)	5,656(2)	5,656(2)	5,656( )	5,656(2)
	CUBIC METERS	160.3 (2)	160.3 (2)	160.3 (2)	160.3 (2)	160.3 (2)	160.3 (2)
USABLE FUEL	US GALLONS	31,000	31,000	31,000	45,220	45,220	45,220
	LITERS	117,300	117,300	117,300	171,100	171,100	171,100
	POUNDS	207,700	207,700	207,700	302,270	302,270	302,270
	KILOGRAMS	94,240	94,240	94,240	137,460	137,460	137,460

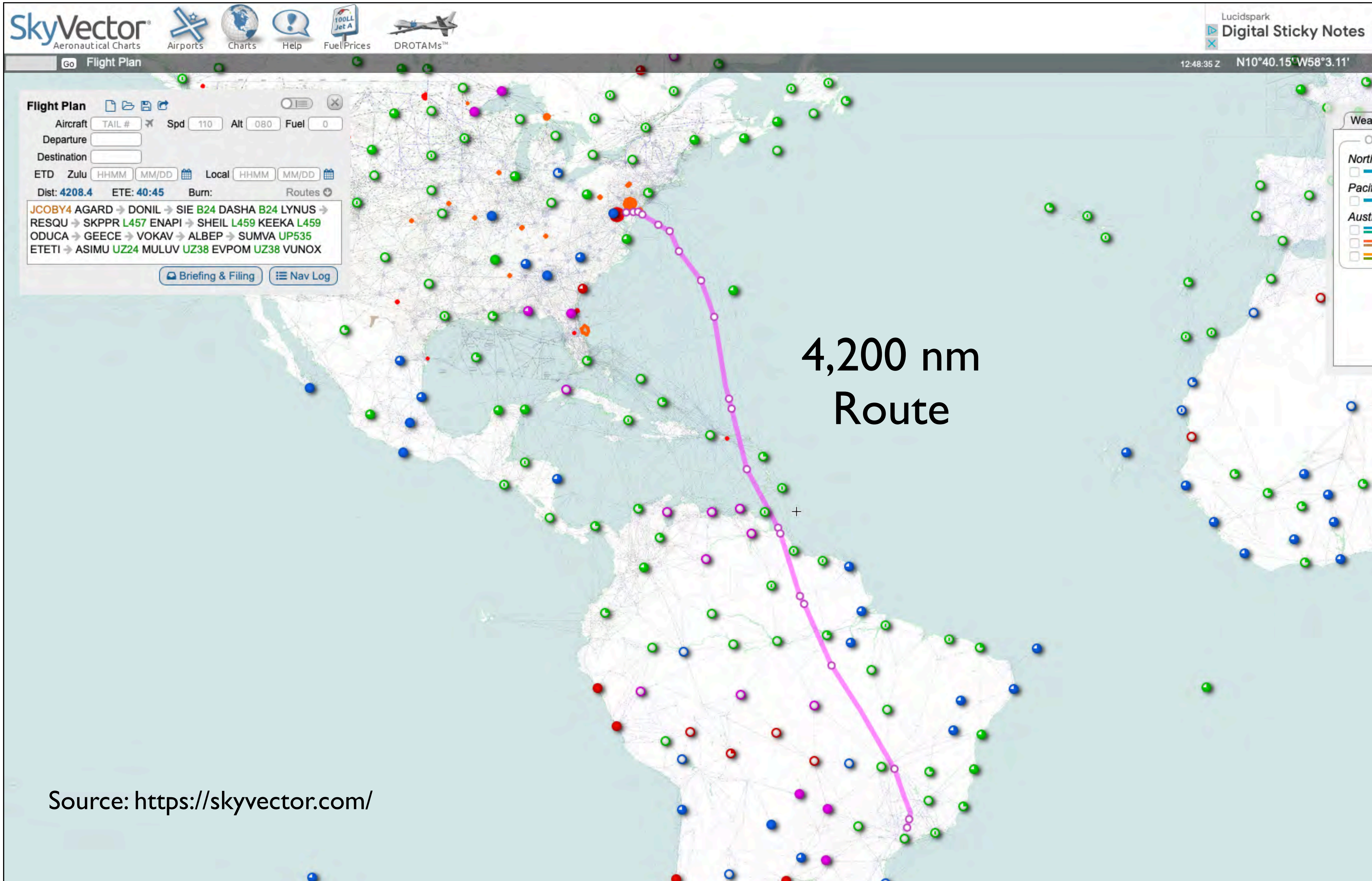
Boeing 777-200 High Gross Weight

Estimate the runway length to operate a Boeing 777-200 High Gross Weight (HGW) from Washington Dulles to Sao Paulo Guarulhos airport in Brasil (a stage length of 4,200 nm) at Mach .84.

After consultation with the airline you learned that their B777s have a gross weight of 592,000 lb. (HGW option) and have a standard three-class seating arrangement.The airline has B 777-200 HGW with General Electric engines. Assume hot day conditions.



Typical Flight Route from IAD (Washington, Dulles) to GRU (Sao Paulo, Brazil)



Discussion of Computations

1) Estimation of Desired Takeoff Weight (DTW)

$$DTW = PYL + OEW + FW$$

where:

PYL is the payload carried (passengers and cargo)

OEW is the operating empty weight

FW is the fuel weight to be carried (usually includes reserve fuel)

Note: PYL and OEW can be easily computed

Boeing 777-200 (GE Engines)

CHARACTERISTICS	UNITS	BASELINE AIRPLANE			HIGH GROSS WEIGHT OPTION		
MAX DESIGN TAXI WEIGHT	POUNDS	508,000	517,000	537,000	582,000	592,000	634,500
	KILOGRAMS	230,450	234,500	243,500	263,640	268,480	287,800
MAX DESIGN TAKEOFF WEIGHT	POUNDS	506,000	515,000	535,000	580,000	590,000	632,500
	KILOGRAMS	229,500	233,600	242,630	263,030	267,500	286,900
MAX DESIGN LANDING WEIGHT	POUNDS	441,000	445,000	445,000	460,000	460,000	460,000
	KILOGRAMS	200,050	201,800	201,800	208,700	208,700	208,700
MAX DESIGN ZERO FUEL WEIGHT	POUNDS	420,000	420,000	420,000	430,000	430,000	430,000
	KILOGRAMS	190,470	190,470	190,470	195,000	195,000	195,000
SPEC OPERATING EMPTY WEIGHT (1)	POUNDS	298,900	298,900	299,550	304,500	304,500	304,500
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MAX STRUCTURAL PAYLOAD	POUNDS	121,100	121,100	120,450	125,550	125,550	125,550
	KILOGRAMS	54,920	54,920	54,620	56,940	56,940	56,940
SEATING CAPACITY (1)	TWO-CLASS	375 - 30 FIRST + 345 ECONOMY					
	THREE-CLASS	305 - 24 FIRST + 54 BUSINESS + 227 ECON MY					
MAX CARGO - LOWER DECK	CUBIC FEET	5,656(2)	5,656(2)	5,656(2)	5,656(2)	5,656( )	5,656(2)
	CUBIC METERS	160.3 (2)	160.3 (2)	160.3 (2)	160.3 (2)	160.3 (2)	160.3 (2)
USABLE FUEL	US GALLONS	31,000	31,000	31,000	45,220	45,220	45,220
	LITERS	117,300	117,300	117,300	171,100	171,100	171,100
	POUNDS	207,700	207,700	207,700	302,270	302,270	302,270
	KILOGRAMS	94,240	94,240	94,240	137,460	137,460	137,460

Computation of Payload and OEW

- OEW = 304,500 lb (138,100 kg)
- PYL = (305 passengers) (100 kg/passenger)
    - PYL = 30,500 kg (67,100 lb)
    - OEW + PYL = 168,600 kg (370,920 lb)
- NOTE: We used the standard weight of 100 kg per passengers in this solution

SPEC OPERATING	POUNDS	298,900	298,900	299,550	304,500	304,500	304,500
EMPTY WEIGHT (1)	KILOGRAMS	135,550	135,550	135,850	138,100	138,100	138,100

Computation of Fuel Weight

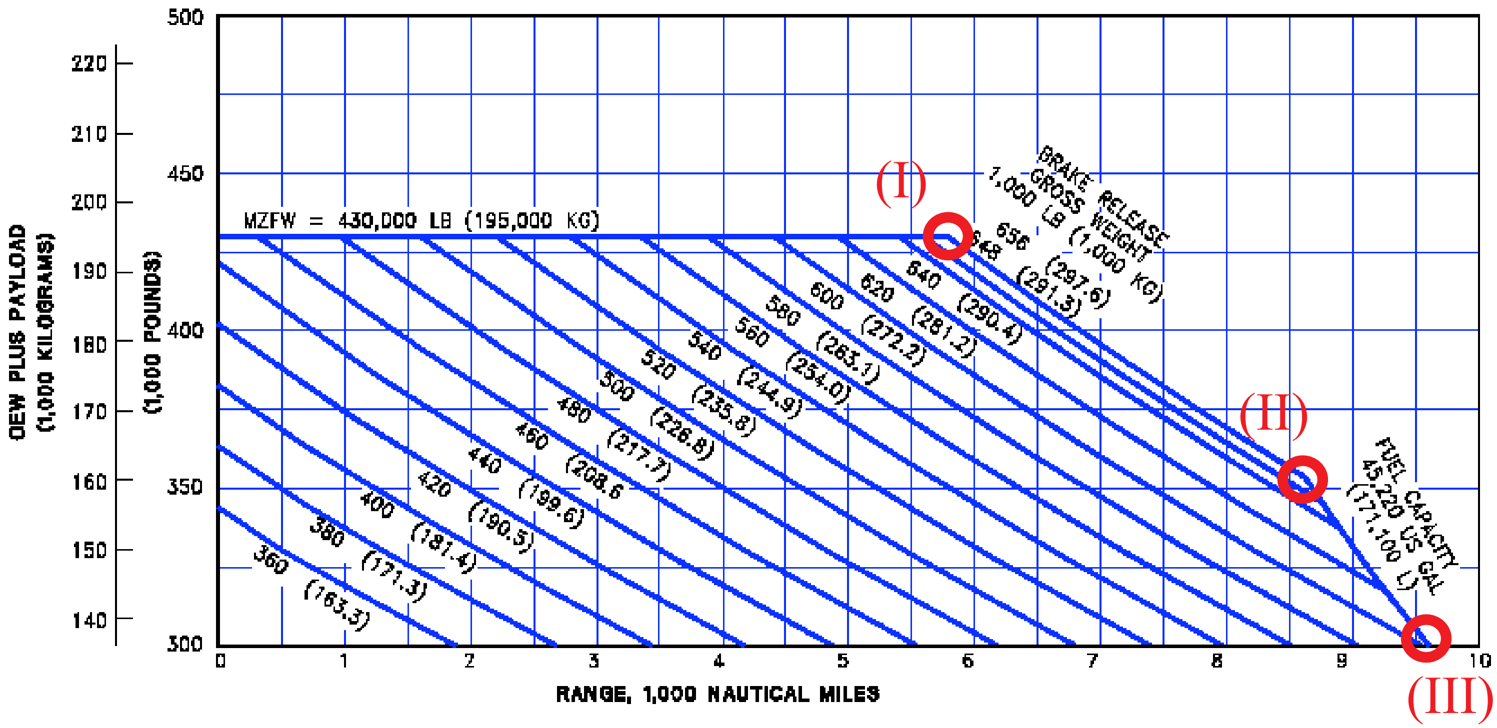
This analysis requires information on fuel consumption for this aircraft flying at a specific cruising condition. Use the payload range diagram of the aircraft to estimate the average fuel consumption in the trip.

The Payload-Range Diagram is a composite plot that shows the operational tradeoffs to carry fuel and payload.

- As the payload carried increases the amount of fuel to conduct a flight might be decreased thus reducing the actual range (distance) of the mission
- P-R diagrams consider operational weight limits such as MZFW, MTOW and MSPL

Range-Payload Diagram for Boeing 777-200

NOTES:
* STANDARD DAY, ZERO WIND
* 0.84 MACH STEP CRUISE
* TYPICAL MISSION RULES
* NORMAL POWER EXTRACTION AND AIR CONDITIONING BLEED
* CONSULT USING AIRLINE FOR SPECIFIC OPERATING PROCEDURE AND OEW PRIOR TO FACILITY DESIGN



Expalantion of P-R Diagram Boundaries

From this diagram three corner points representing combinations of range and payload are labeled with roman numerals (I-III). An explanation of these points follows.

Operating point (I) represents an operational point where the aircraft carries its maximum payload at departs the origin airport at maximum takeoff gross weight (note the brake release gross weight boundary) of 297.6 metric tons.

The corresponding range for condition (I) is a little less than 5,900 nautical miles. Note that under this conditions the aircraft can carry its maximum useful payload limit of 56,900 kg (subtract 195,000 kg. from 138,100 kg. which is the OEW for this aircraft).

Payload-Range Diagrams Explanations

Operating Point (II) illustrates a range-payload compromise when the fuel tanks of the aircraft are full (note the fuel capacity limit boundary).

Under this condition the aircraft travels 8,600 nm but can only carry 20,900 kg of payload (includes cargo and passengers), and a fuel complement of fuel (171,100 liters or 137,460 kg.).

The total brake release gross weight is still 297.6 metric tons for condition (II).

Payload-Range Diagrams Explanations

Operating Point (III) represents the ferry range condition where the aircraft departs with maximum fuel on board and zero payload. This condition is typically used when the aircraft is delivered to its customer (i.e., the airline) or when a non-critical malfunction precludes the carrying of passengers.

This operating point would allow this aircraft to cover 9,600 nautical miles with 137,460 kg.of fuel on board and zero payload for a brake release gross weight of 275,560 kg. (137,460 + 138,100 kg.) or below MTOW.

Limitations of P-R Diagram Information

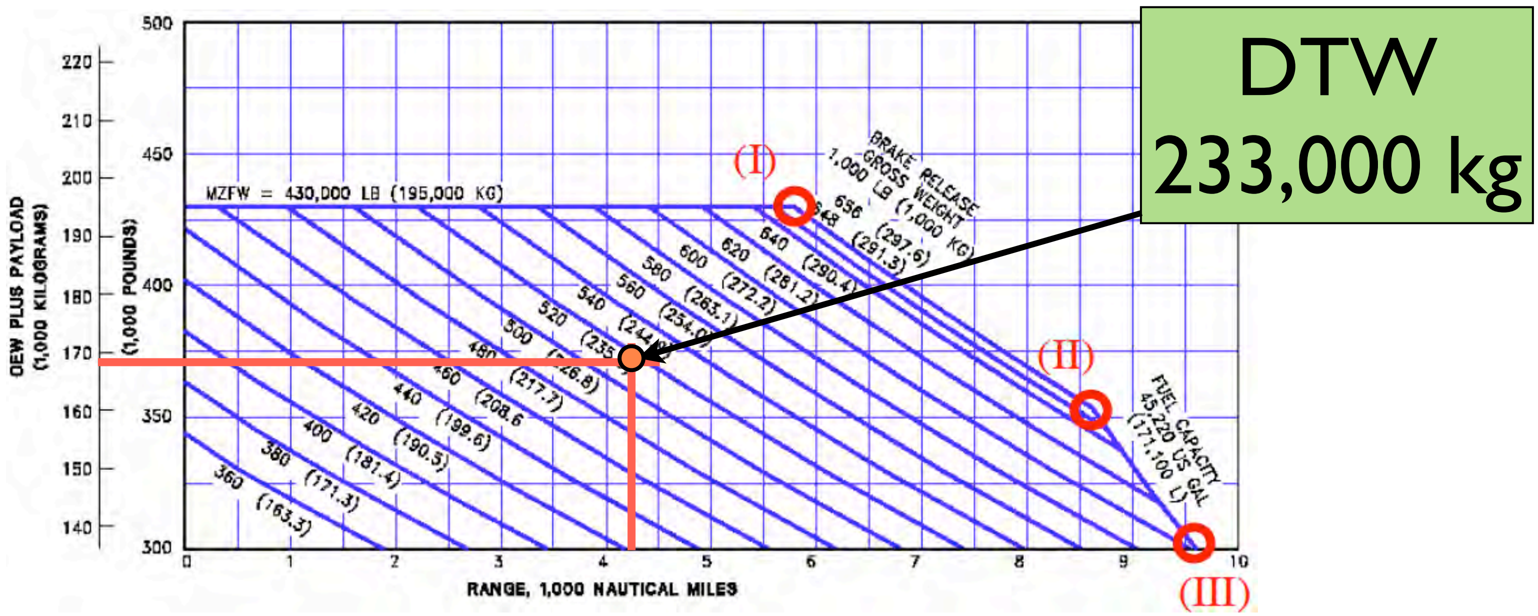
A note of caution about payload range diagrams is that they only apply to a given set of flight conditions.

For example, in Figure Boeing claims that this diagram only applies to zero wind conditions, 0.84 Mach, standard day conditions (e.g., standard atmosphere) and Air Transport Association (ATA) domestic fuel reserves (this implies enough fuel to fly 1.25 hours at economy speed at the destination point).

If any of these conditions changes so does the payload-range diagram.

Back to Our Problem

- Our critical aircraft (B777-200 HGW option) is expected to fly 4,200 nm with full passengers
- From the Payload-Range diagram read off the Desired Takeoff Weight (DTW) as ~233,000 kg
- Recall: OEW + PYL = 168,600 kg
- The amount of fuel carried for the trip would be:
  - FW = DTW - OEW - PYL = 64,400 kg.



Presentation of Runway Length Information

For the aircaft in question we have two sets of curves available to compute runway length:

- Takeoff
- Landing

These curves apply to specific airfield consitions so you should always use good judgement in the analysis. Typically two sets of curves are presented by Boeing:

- Standard day conditions
- Standard day + ΔT conditions

where ΔT represents some increment from standard day conditions (typically 15^{o}).

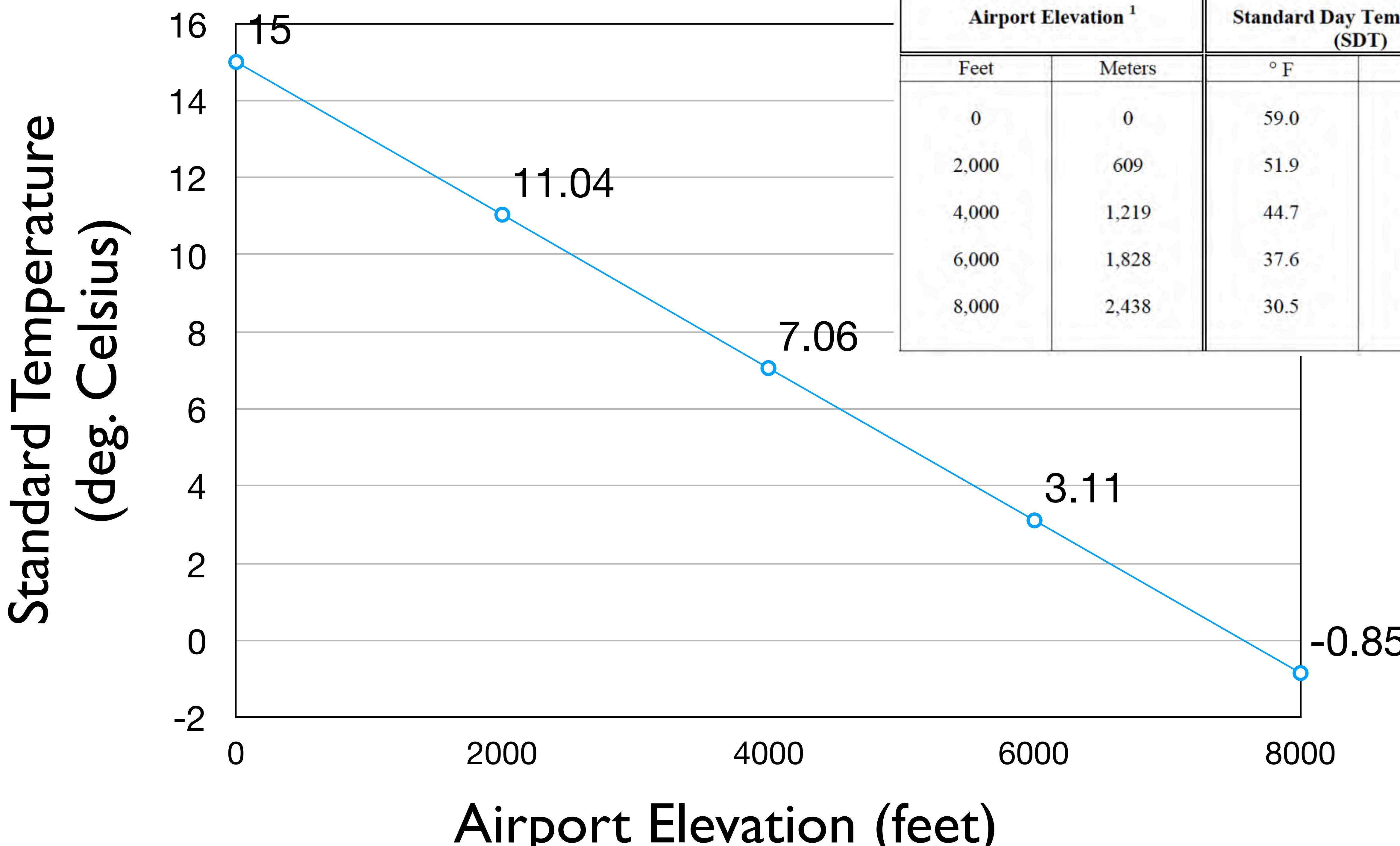
Conversion of Standard Temperatures (Table 4.1 in FAA AC 150/5325-4b)

- Use the table to understand what constitutes standard temperature (ISA) for various airfield elevations

Table 4-1. Relationship Between Airport Elevation and Standard Day Temperature

Airport Elevation [1]		Standard Day Temperature [1] (SDT)	
Feet	Meters	° F	° C
0	0	59.0	15.00
2,000	609	51.9	11.04
4,000	1,219	44.7	7.06
6,000	1,828	37.6	3.11
8,000	2,438	30.5	-0.85

International Standard Atmosphere (ISA) Conditions (Temperature)



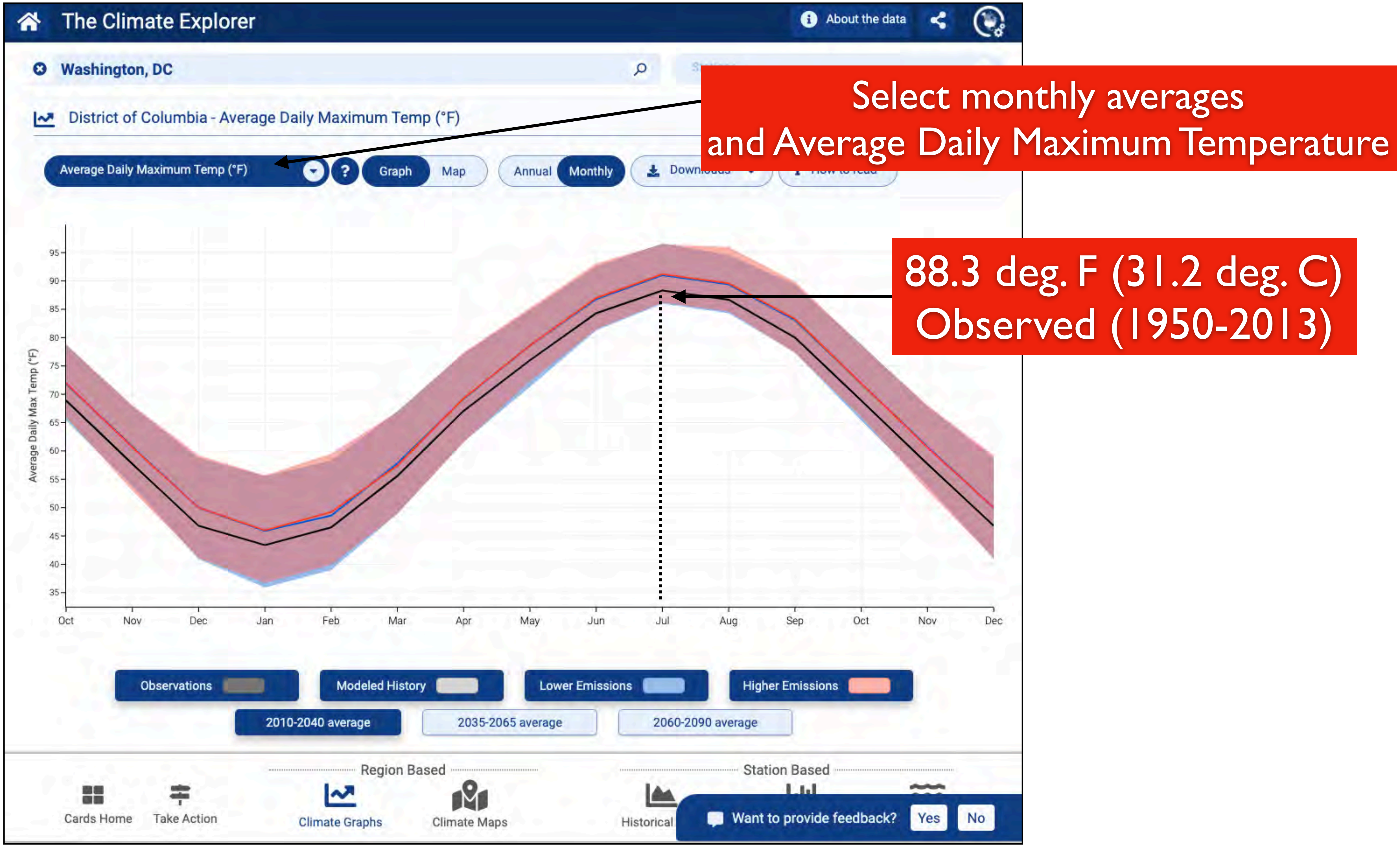
Airport Elevation [1]		Standard Day Temperature [1] (SDT)	
Feet	Meters	° F	° C
0	0	59.0	15.00
2,000	609	51.9	11.04
4,000	1,219	44.7	7.06
6,000	1,828	37.6	3.11
8,000	2,438	30.5	-0.85

Finding Temperature Data for Your Airport

- Temperature information is critical in runway length design
- Various websites plot and contain airport environmental data including temperature and wind
- Temperature:
  - weather.com
  - https://crt-climate-explorer.nemac.org/climate_graphs/

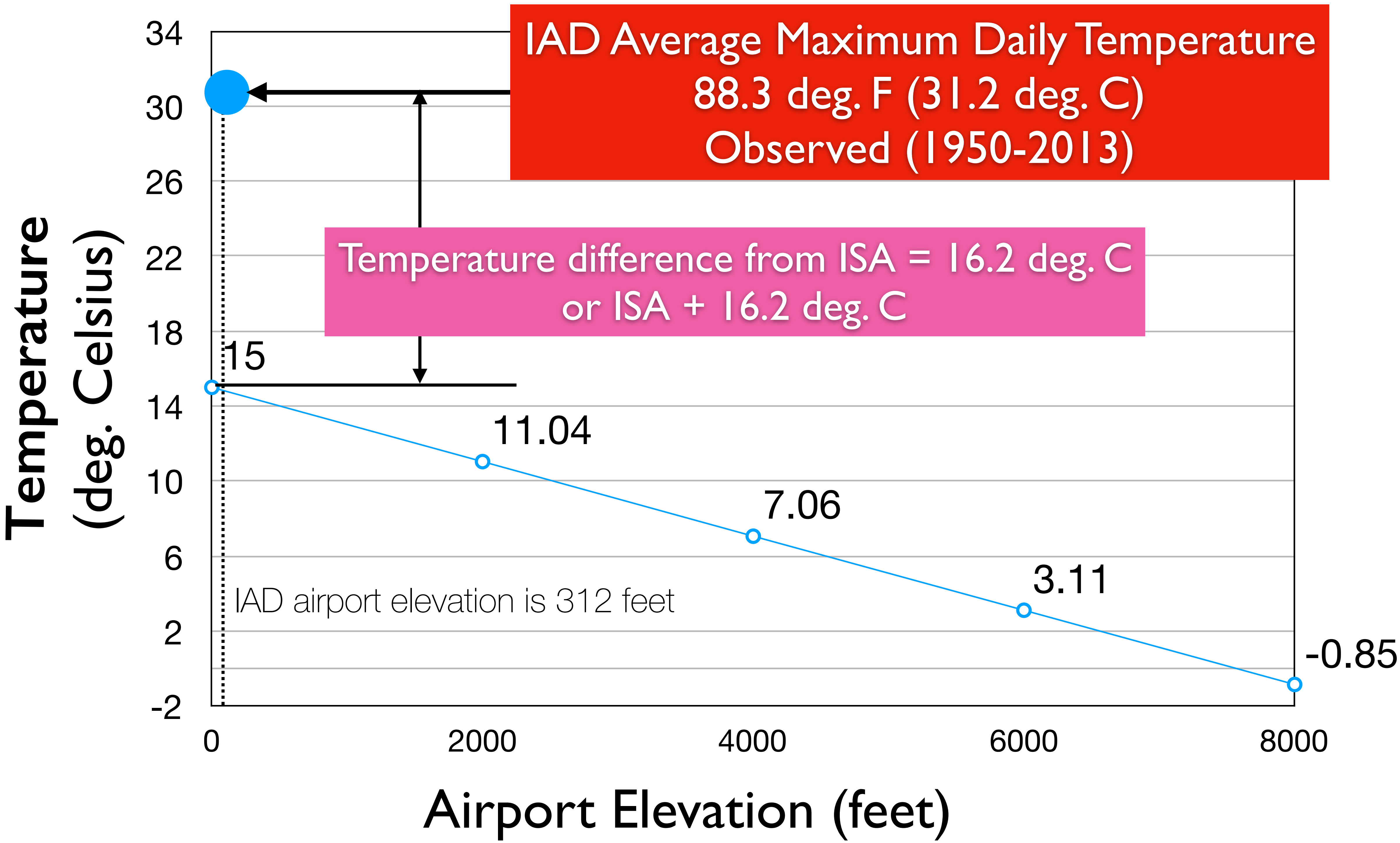
Climate Explorer Website

Monthly average daily maximum temperature

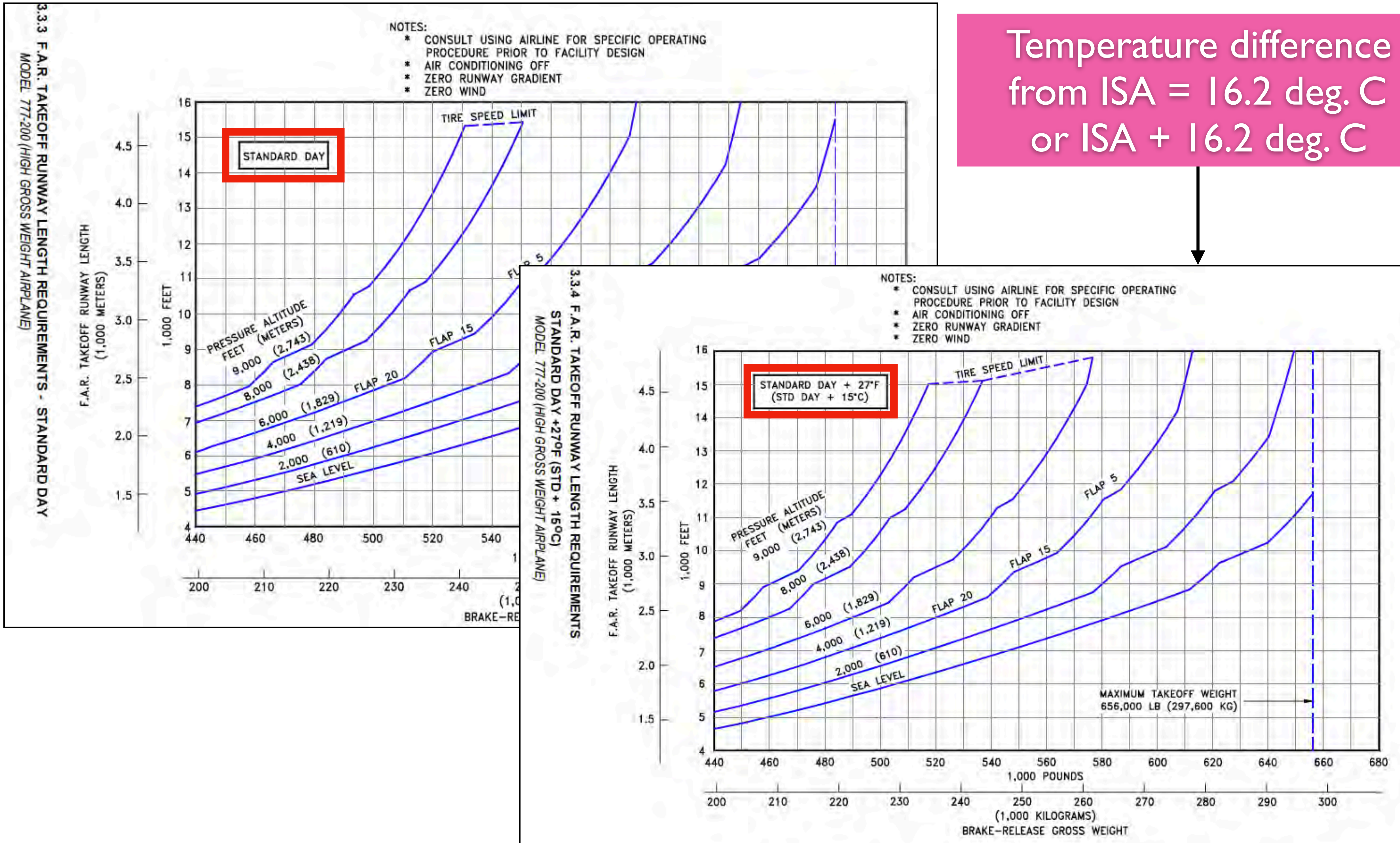


https://crt-climate-explorer.nemac.org/climate_graphs/

Determine the Design Temperature Conditions at IAD

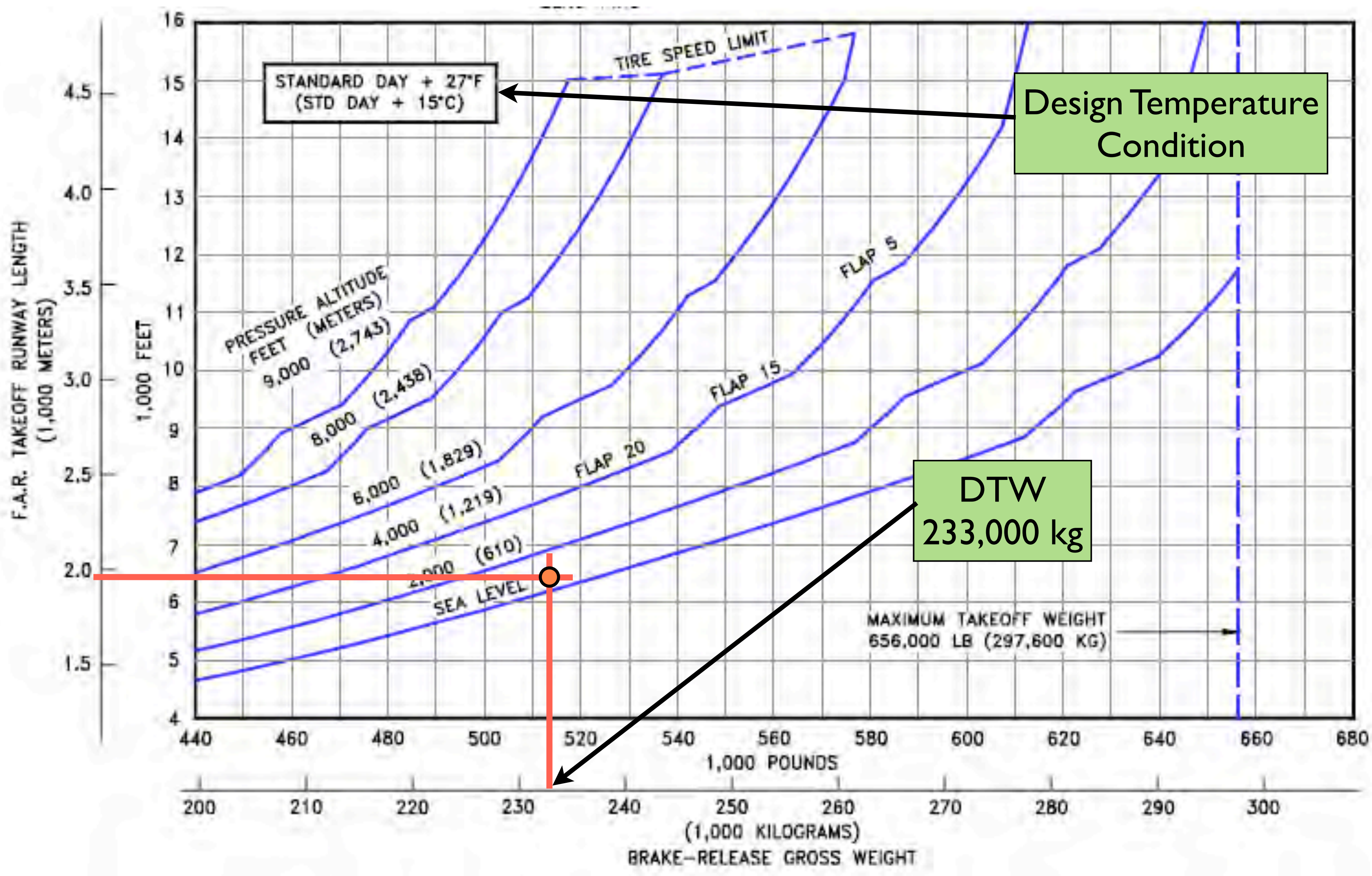


Select the Performance Chart to Use in the Runway Design



Temperature difference from ISA = 16.2 deg. C or ISA + 16.2 deg. C

Takeoff Curves for Boeing 777-200 HGW



Takeoff Runway Length Analysis

From the performance chart we conclude:

- **$RL_{takeoff}$ = 1,950 m.**
- Optimum flap setting = 20 degress for takeoff (see flap setting lines in the diagram)
- DTW is way below the maximum capability for this aircraft.

Landing Analysis (Boeing 777-200 HGW)

- The analysis is similar to that performed under FAA AC 150/5325-4b
- Consider an emergency situation and compute the landing weight at the departing airport
  - DTW = 233,000 kg
- The maximum allowable landing weight for the aircraft is:
  - MALW = 208,700 kg.
- Since DTW > MALW use the Maximum Allowable Landing Weight (MALW)
  - RL_{land} = **1,850 meters** (using wet pavement conditions)

Landing Analysis (Boeing 777-200 HGW)

CHARACTERISTICS	UNITS	BASELINE AIRPLANE			HIGH GROSS WEIGHT OPTION		
MAX DESIGN TAXI WEIGHT	POUNDS	508,000	517,000	537,000	582,000	592,000	634,500
	KILOGRAMS	230,450	234,500	243,500	263,640	268,480	287,800
MAX DESIGN TAKEOFF WEIGHT	POUNDS	506,000	515,000	535,000	580,000	590,000	632,500
	KILOGRAMS	229,500	233,600	242,630	263,030	267,500	286,900
MAX DESIGN LANDING WEIGHT	POUNDS	441,000	445,000	445,000	460,000	460,000	460,000
	KILOGRAMS	200,050	201,800	201,800	208,700	208,700	208,700

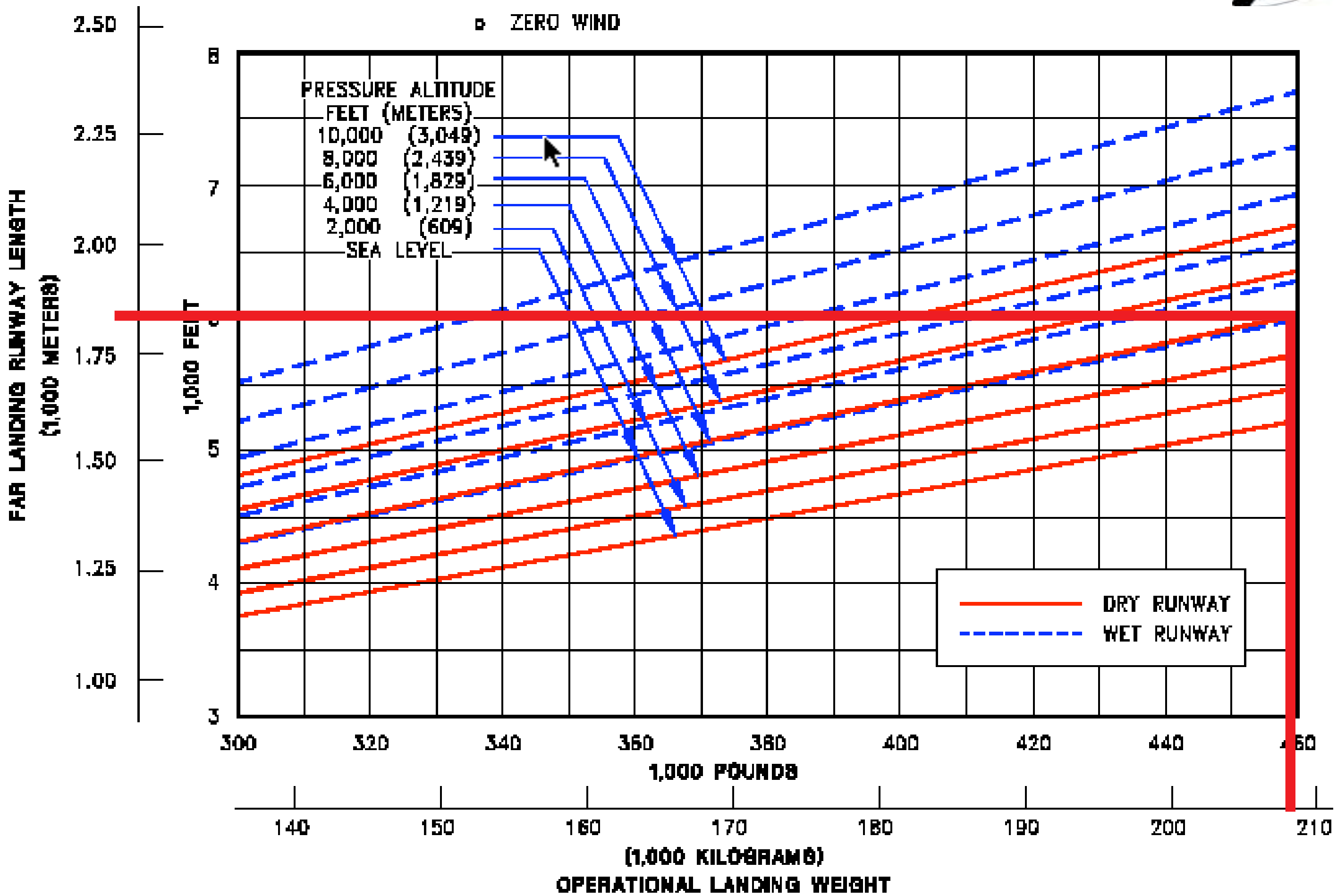
In most emergencies after takeoff, pilots would like to land "legally" at or below the MALW limit (landing gear is designed to withstand landings up to MALW with normal limits)

Maximum Allowable Landing Weight

Example Incident (Source: Aviation Herald)

- United Airlines B772 near Tokyo on July 28th 2010 suffered an engine failure after departure
- Article at: http://avherald.com/h?article=42f0df24/0000&opt=0
- Pilots shut down the bad engine and **dumped fuel**
  - "*The NTSB reported that the crew heard a loud bang from the #2 engine followed by a high pitch grinding noise for about 3-4 seconds".*
  - *Within a few more seconds all instruments of the #2 engine had decreased to 0".*
  - *"90,000 lbs of fuel were dumped before the airplane landed with about 12,000 lbs overweight. The engine failure was contained but metal debris was observed in the tailpipe*".

Boeing 777-200 HGW Landing Performance



3.4.1 FAA LANDING RUNWAY LENGTH REQUIREMENTS
MODEL 777-200

If not given in a chart, for wet conditions increase the landing distance by 15%

Reconcile Takeoff and Landing Cases

Select worst case scenario and use that as runway length requirement.

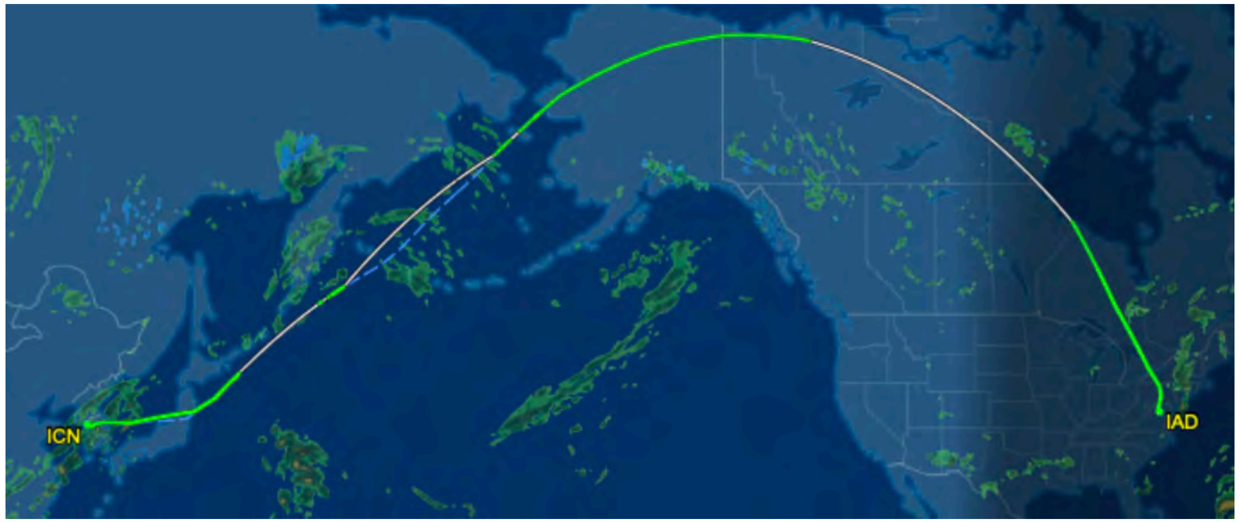
$RL_{takeoff}$ = 1,950 m.

RL_{land} = 1,850 m.

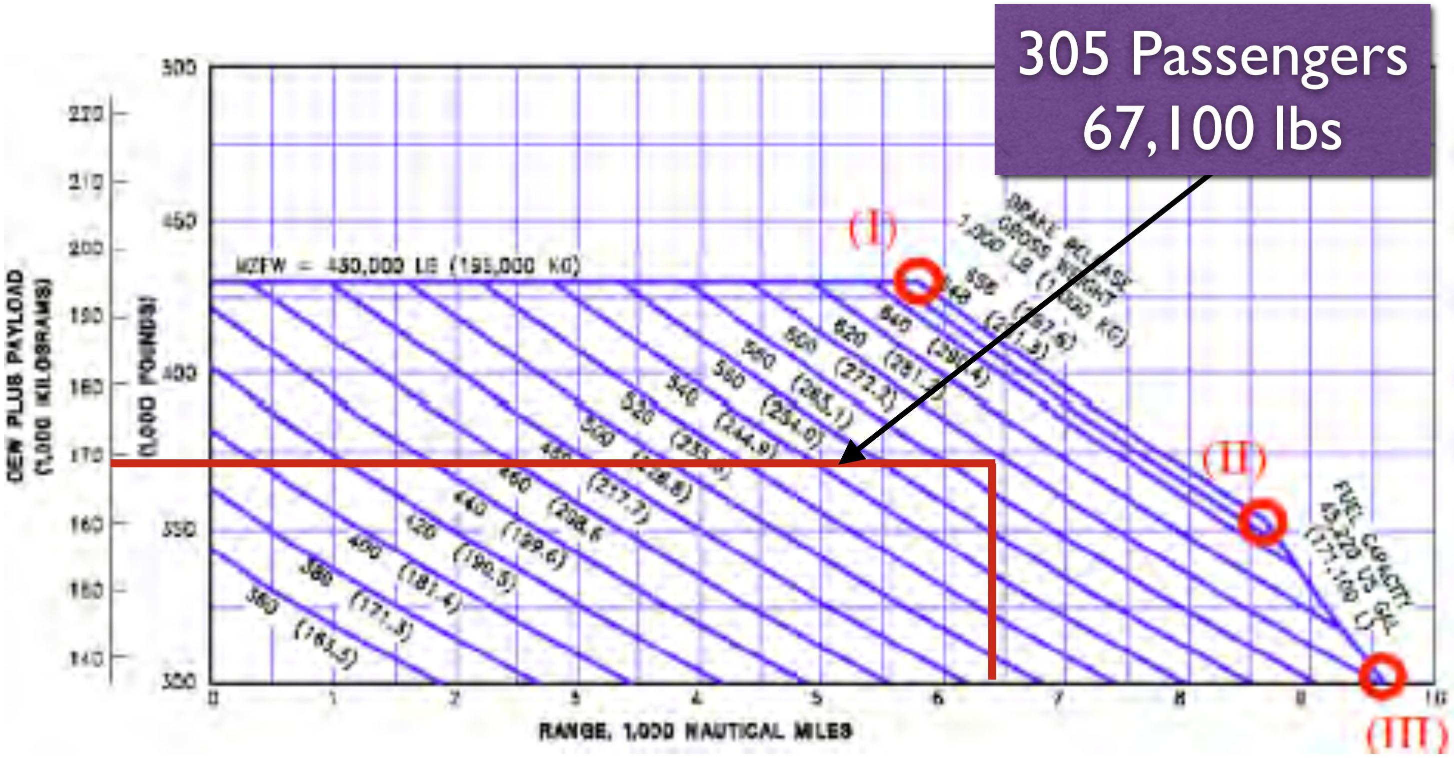
Takeoff dominates so use the $RL_{takeoff}$ as the design number.

Change Route Length to IAD-ICN

- Assume that the airline wants to operate the Boeing 777-200 HGW aircraft in the route Dulles (IAD) to Seoul (ICN)
- Great Circle Distance = 6,046 nm
- Typical distance = 6,409 nm



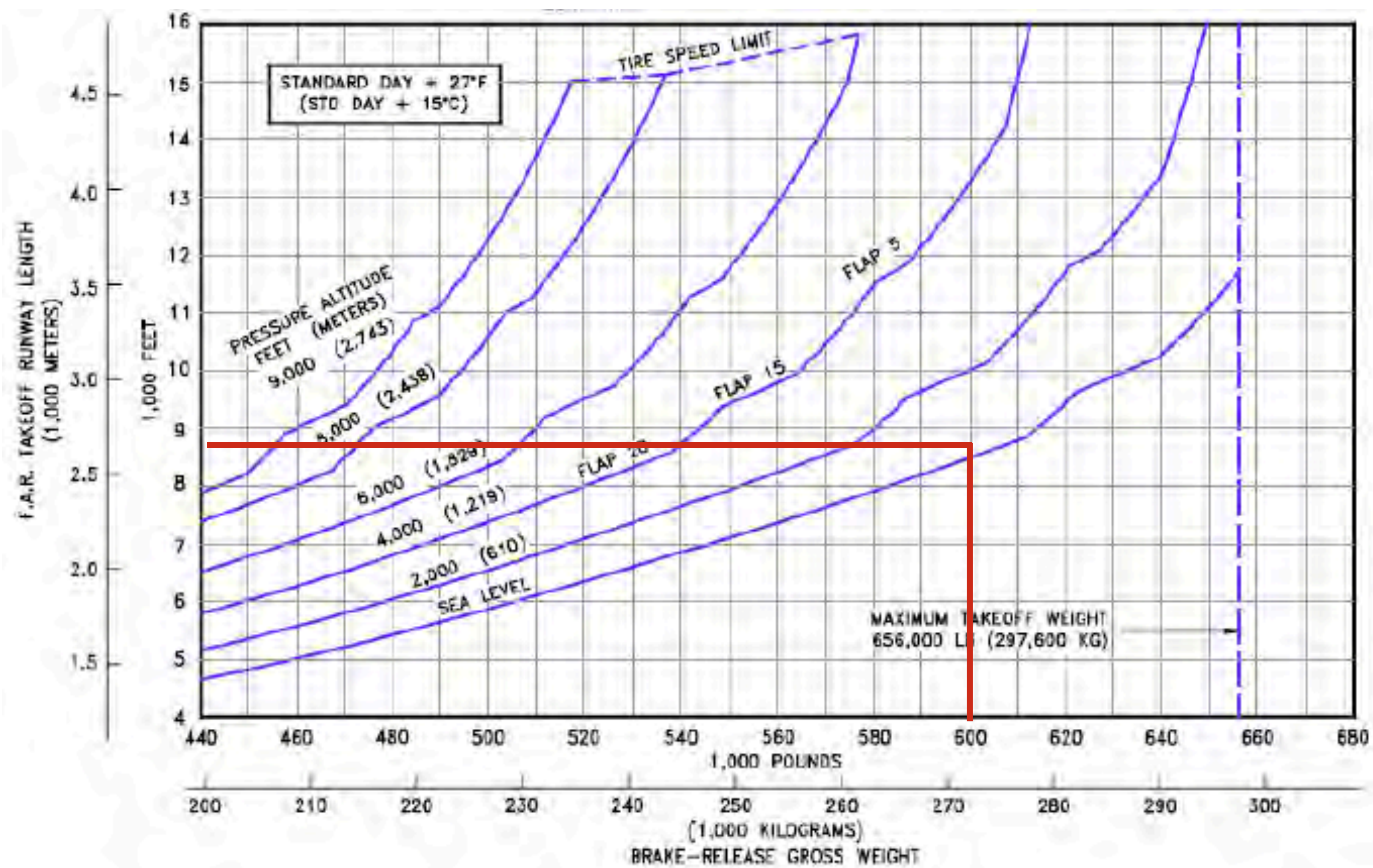
Source: Flightaware



- Use the payload-range diagram to find the Desired Takeoff Weight (DTW)
- New DTW ~600,000 lbs.

Change Route Length to IAD-ICN

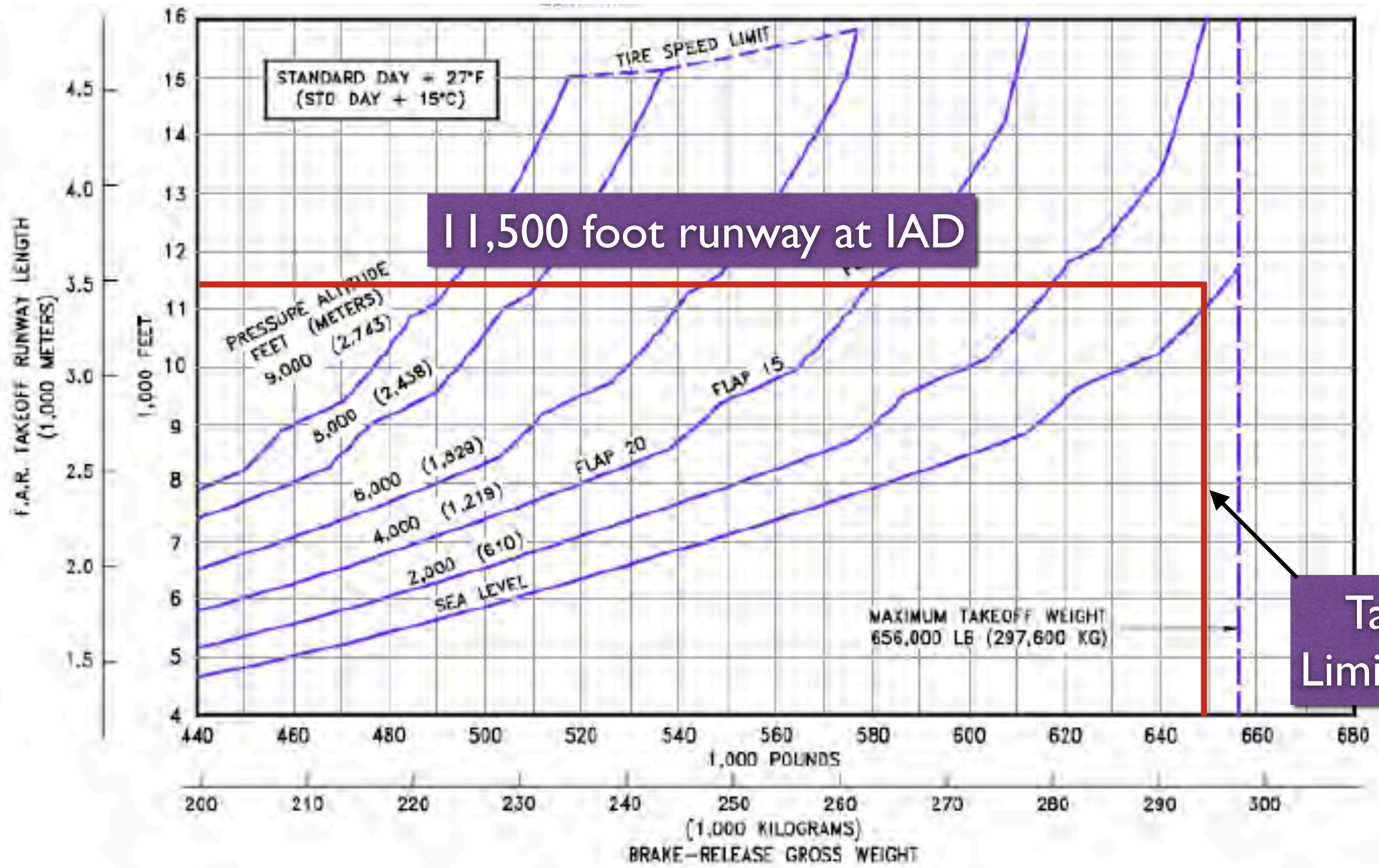
- Use the payload-range diagram to find the Desired Takeoff Weight (DTW) for the new route
- New DTW ~600,000 lbs.



- The takeoff runway length required is now 8,800 feet
- IAD longest runways are 11,500 feet
- The aircraft can easily fly the route and still carry additional cargo

Maximum Takeoff Weight Limit Departing IAD

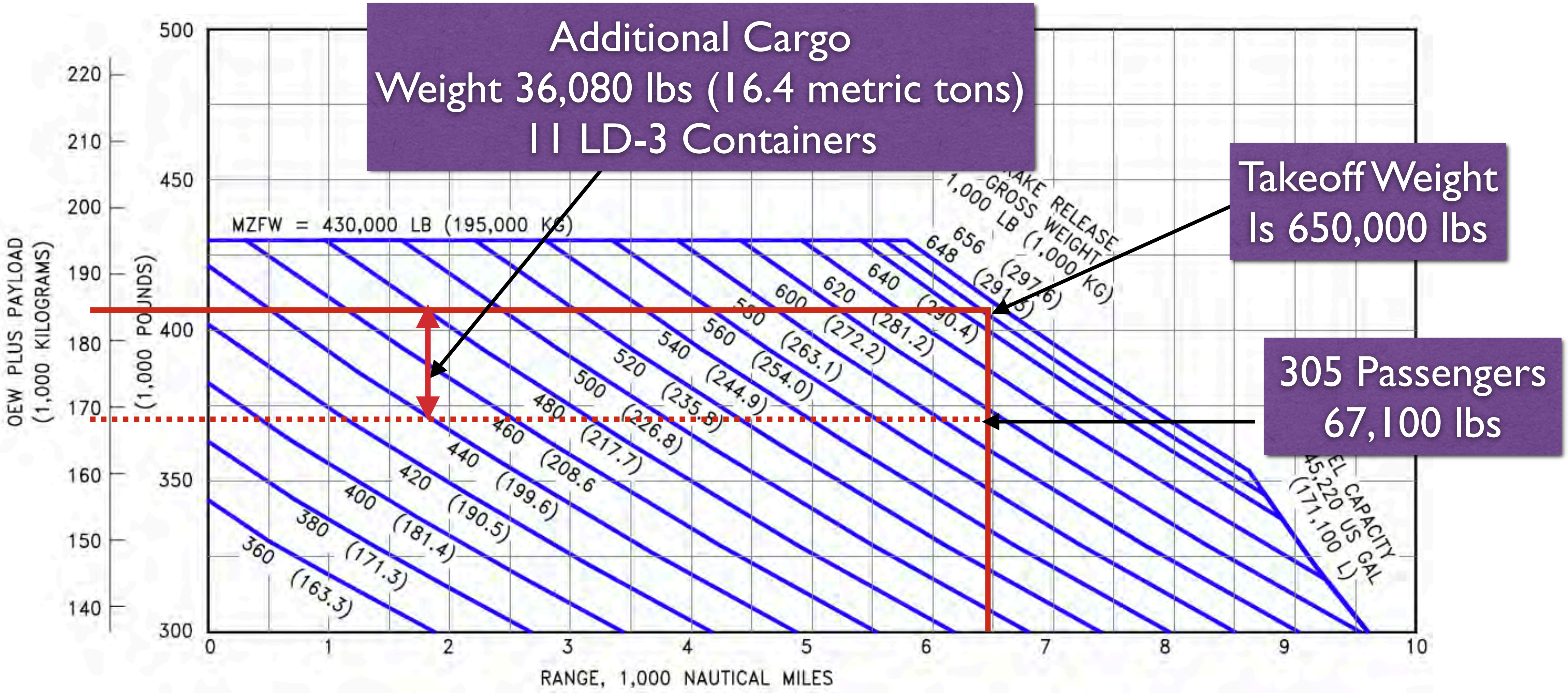
- Use the takeoff performance chart to estimate the maximum takeoff weight from IAD with the existing runway length (11,500 feet)



- Maximum takeoff weight is 650,000 lbs

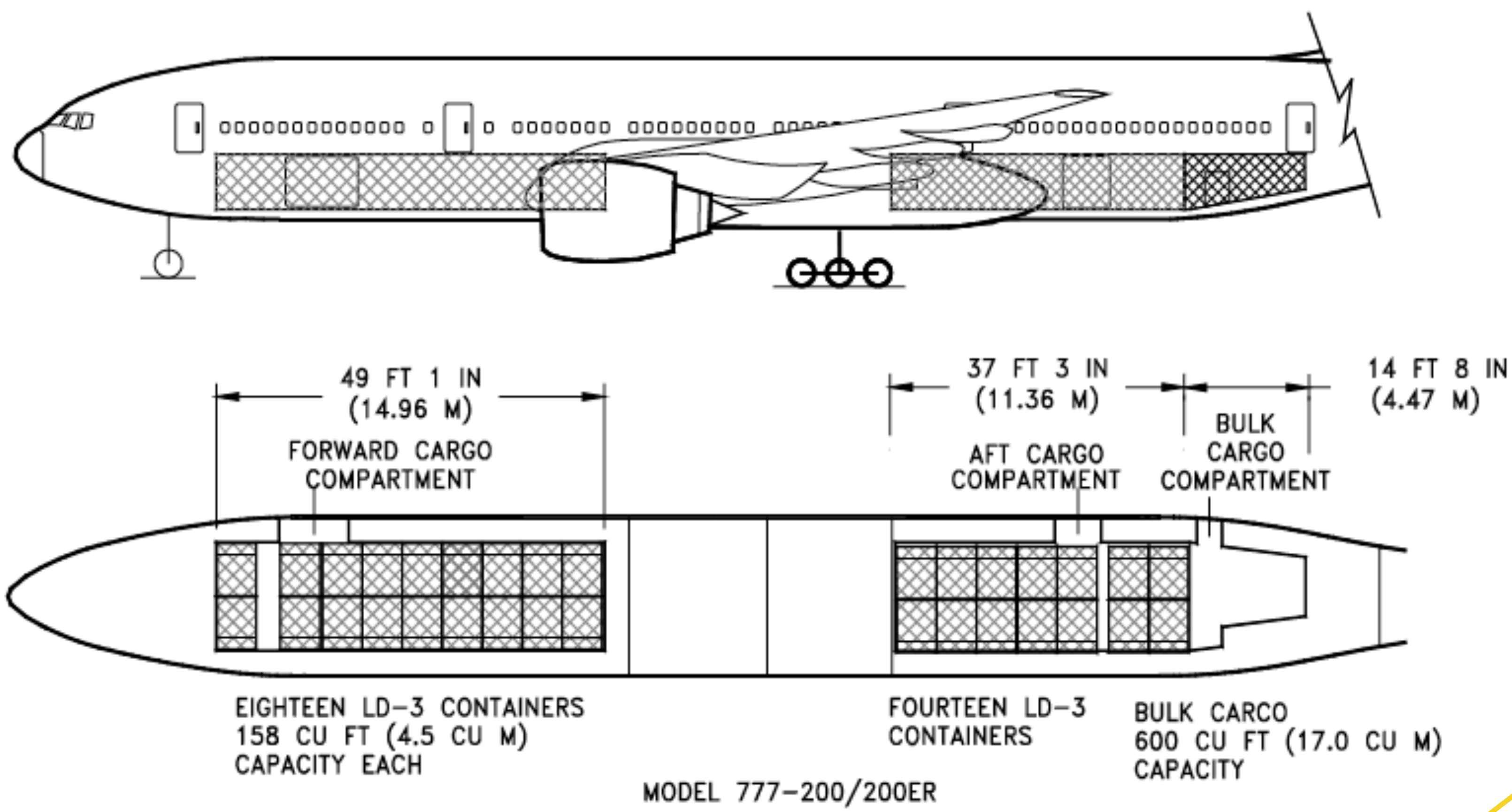
Maximum Takeoff Weight Limit Departing IAD

- Use the takeoff performance chart to estimate the maximum takeoff weight from IAD with the existing runway length (11,500 feet)
- Recall: the maximum takeoff weight is 650,000 lbs
- The flight can carry 36,080 lbs. of cargo in the cargo compartment



Conclusions

- A Boeing 777-200 HGW can operate from IAD in the original route (IAD-GRU) with a full passenger load
- The same aircraft can fly long routes to Asia (IAD-ICN) with all seats full and additional 36,080 lbs in the cargo compartment
- Cargo is a very important source of revenue for airlines



Source: Boeing

LD-3 container
Weight limit is 3,500 lbs

Source: A. Trani

Observed Trends in Takeoff Performance Charts

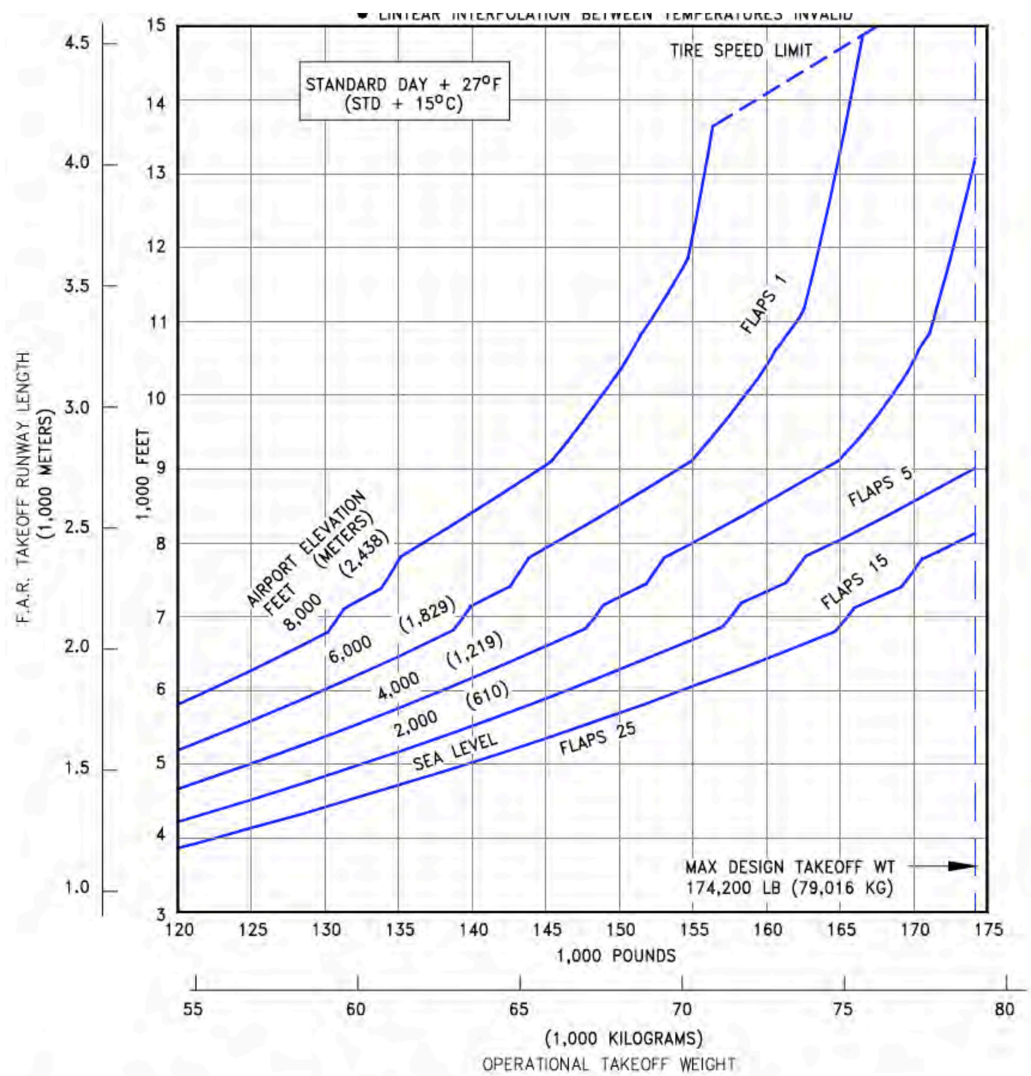
- If DTW increases the RL values increase non-linearly (explain using the fundamental aircraft acceleration equation)
- As field elevation increases (pressure altitude) the RL values increase as well (temperature effect on air density)
- As DTW and field elevation increase the optimum flap setting for takeoff decreases
  - This is consistent with our knowledge of C_d and C_L. Hot and high airfield elevations require very low flap settings during takeoff to reduce the drag of the aircraft.
- High airfield elevations (and large to moderate DTWs) could hit a tire speed limit boundary. Aircraft tires are cretified to this limit and thus an airline would never dare to depart beyond this physical boundary.

Runway Surface Conditions in APM (Aircraft Performance Manual for Airport Design and Planning)

- Until recently, most aircraft manufacturers provided takeoff runway length data for both dry and wet pavement conditions
- In recent publications, some aircraft airport design information only provides dry takeoff performance charts
- Paragraph 508 in AC 150/5325-4b states:
  - *Many airplane manufacturers' APMs for turbojet-powered airplanes provide both dry runway and wet runway landing curves.* ***If an APM provides only the dry runway condition, then increase the obtained dry runway length by 15 percent (for landing analysis).***

Example: Boeing 737-800 with CFM56-7B26 Engines

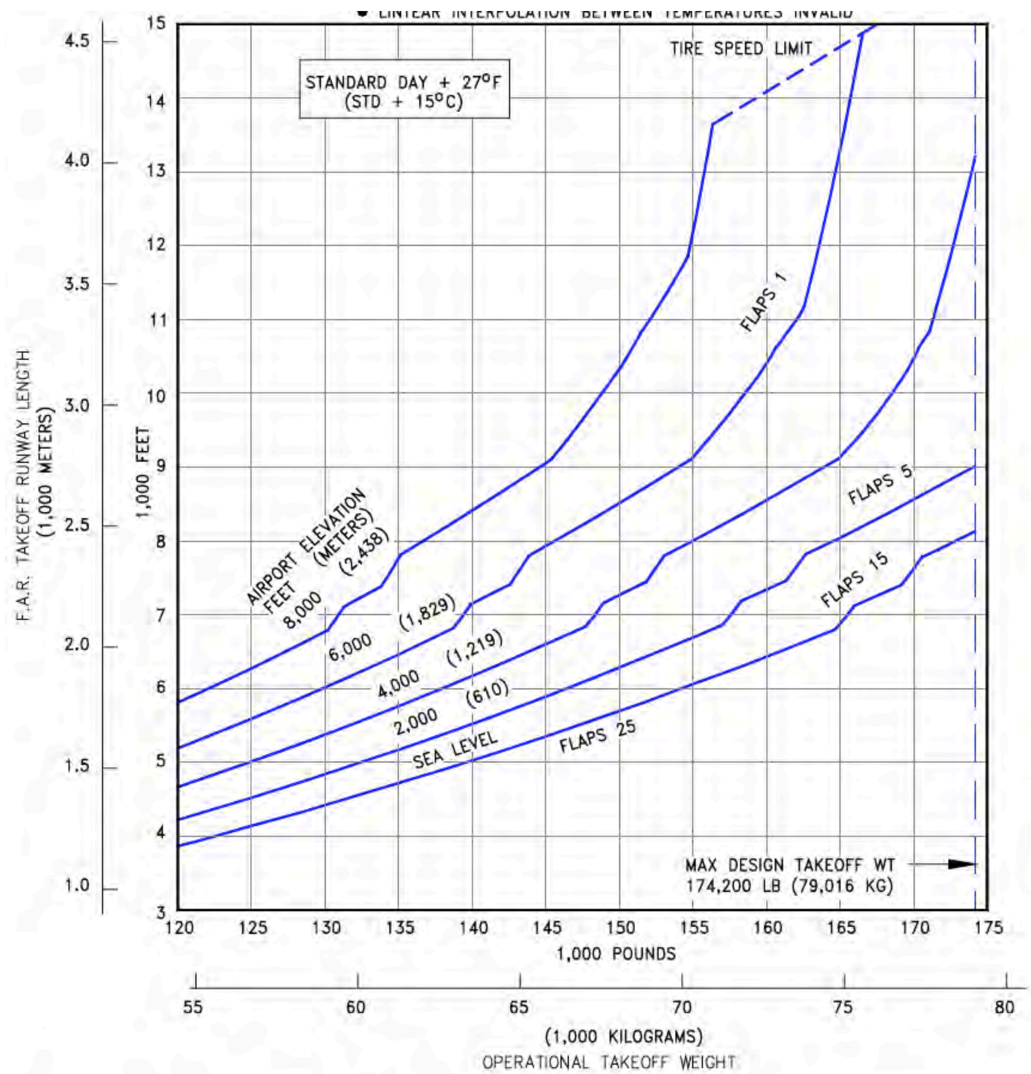
- Old Boeing 737-800 takeoff performance chart (December 2001)
- Engines CFM56-7B26
- Rated at 26,300 lb of thrust at sea level
- ISA + 15 deg. C



3.3.30 F.A.R. TAKEOFF RUNWAY LENGTH REQUIREMENTS
STANDARD DAY +27°F (STD + 15°C), DRY RUNWAY
MODEL 737-800 (CFM56-7B26 ENGINES AT 26,300 LB SLST)

Example: Boeing 737-800 with CFM56-7B26 Engines (APM circa 2001)

- Takeoff mass = 75,000 kg
- 4000 feet airport elevation
- ISA + 15 deg. C
- Dry Runway
- FAR Takeoff length is **9,100 feet**



3.3.30 F.A.R. TAKEOFF RUNWAY LENGTH REQUIREMENTS
STANDARD DAY +27°F (STD + 15°C), DRY RUNWAY
MODEL 737-800 (CFM56-7B26 ENGINES AT 26,300 LB SLST)

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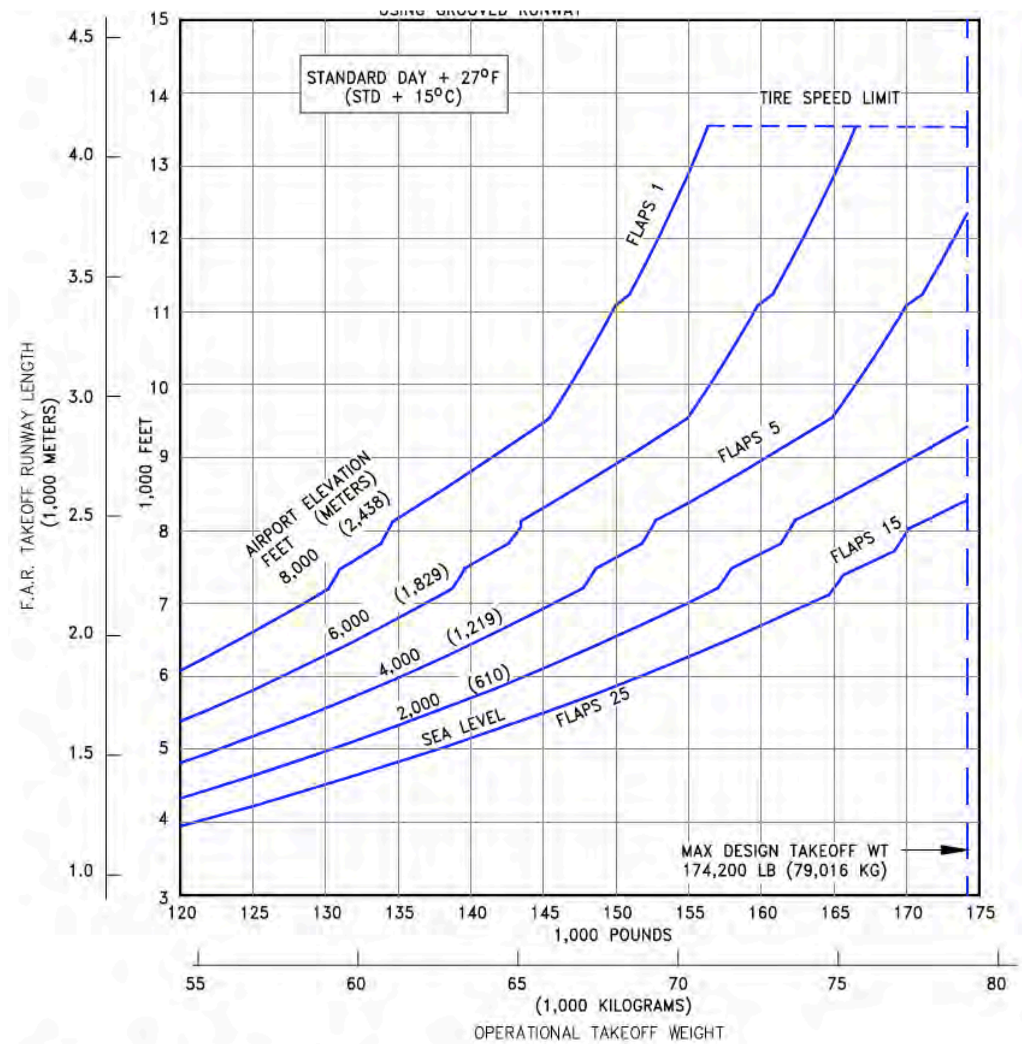
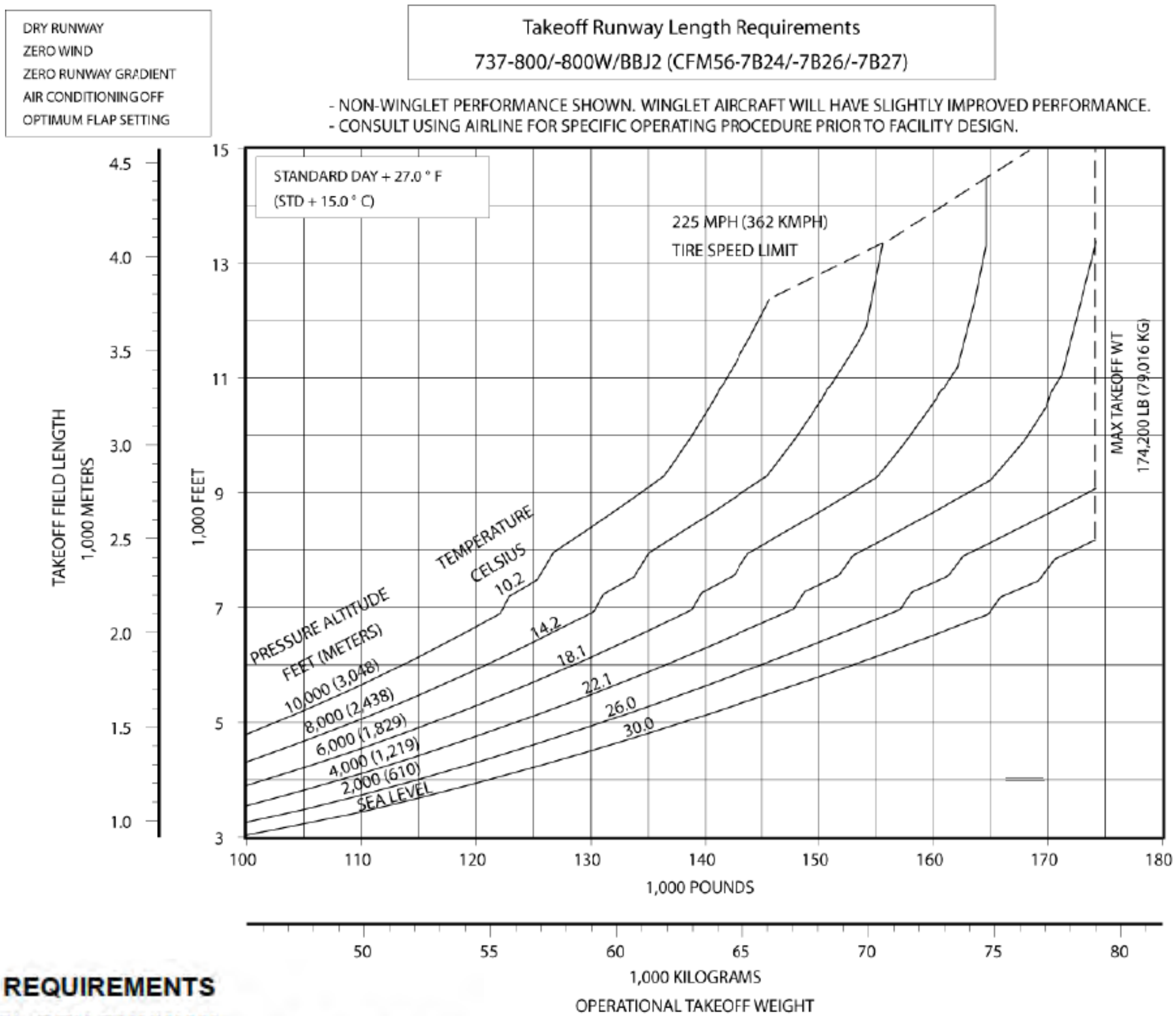
Example: Boeing 737-800 with CFM56-7B26 Engines (APM circa 2001)

- Takeoff mass = 75,000 kg
- 4000 feet airport elevation
- ISA + 15 deg. C
- **Wet Runway**
- FAR Takeoff length is 9,600 feet



3.3.32 J.A.A. TAKEOFF RUNWAY LENGTH REQUIREMENTS
STANDARD DAY +27°F (STD + 15°C), WET RUNWAY
MODEL 737-800 (CFM56-7B26 ENGINES AT 26,300 LB SLST)

Example: Boeing 737-800 with CFM56-7B26 Engines (APM circa 2010)



F.A.R. TAKEOFF RUNWAY LENGTH REQUIREMENTS

STANDARD DAY +27°F (STD + 15°C), DRY RUNWAY

MODEL 737-800/-800W/BBJ2 (CFM56-7B24/-7B26/-7B27 ENGINES AT 26,000 LB SLST)

Example: Boeing 737-800 with CFM56-7B26 Engines (APM circa 2010)

- Takeoff mass = 75,000 kg
- 4000 feet airport elevation
- ISA + 15 deg. C
- **Dry Runway** (only chart provided in the new document)
- FAR Takeoff length is **9,100** feet
- 15% adjustment for wet runway yields **10,465 feet**
- **This is a substantial increase in runway length compared to previous Boeing manuals**

Final Notes on Takeoff Runway Length Distance Adjustments in Wet Runways

- Boeing and Airbus do not provide takeoff performance charts under wet runway conditions in their latest Airport Planning Manuals (APM)
- Use these charts (without correction) to estimate runway length performance
- Boeing provides wet pavement performance charts for landing
- Airbus does not provide wet pavement performance charts for landing
- According to FAA AC 150/5325-4B, the dry performance charts need to be adjusted by 15%

Final Notes on Takeoff Runway Length Distance Adjustments in Wet Runways (2)

- The use of performance charts without correction for operations from wet pavement conditions can be justified according to the following:
- FAA and EASA (European Safety Agency) allow **thrust reverser use** in the estimation of Accelerate and Stop Distance in the calculation of takeoff performance
- **Thrust reverser use is not allowed** in the calculation of takeoff performance in dry runways
- This implies an additional safety factor added in the estimation of runway performance under dry pavement conditions

Runway Elements Considered in Other Analyses

Important Runway Design Safety Elements

The following are some definitions of terms employed in the declared distance concept analysis.

- Runway Protection Zone (RPZ)
- Runway Object Free Area (ROFA)
- Runway Safety Area (RSA)
- Obstacle Free Zone (OFZ)

Critical runway areas are defined in Chapter 3 of the FAA AC 150/5300-13B.

3/31/2022 AC 150/5300-13B

CHAPTER 3. Runway Design

Runway Protection Zone (RPZ)

Trapezoidal shape area at the end of every runway and centered with the runway centerline

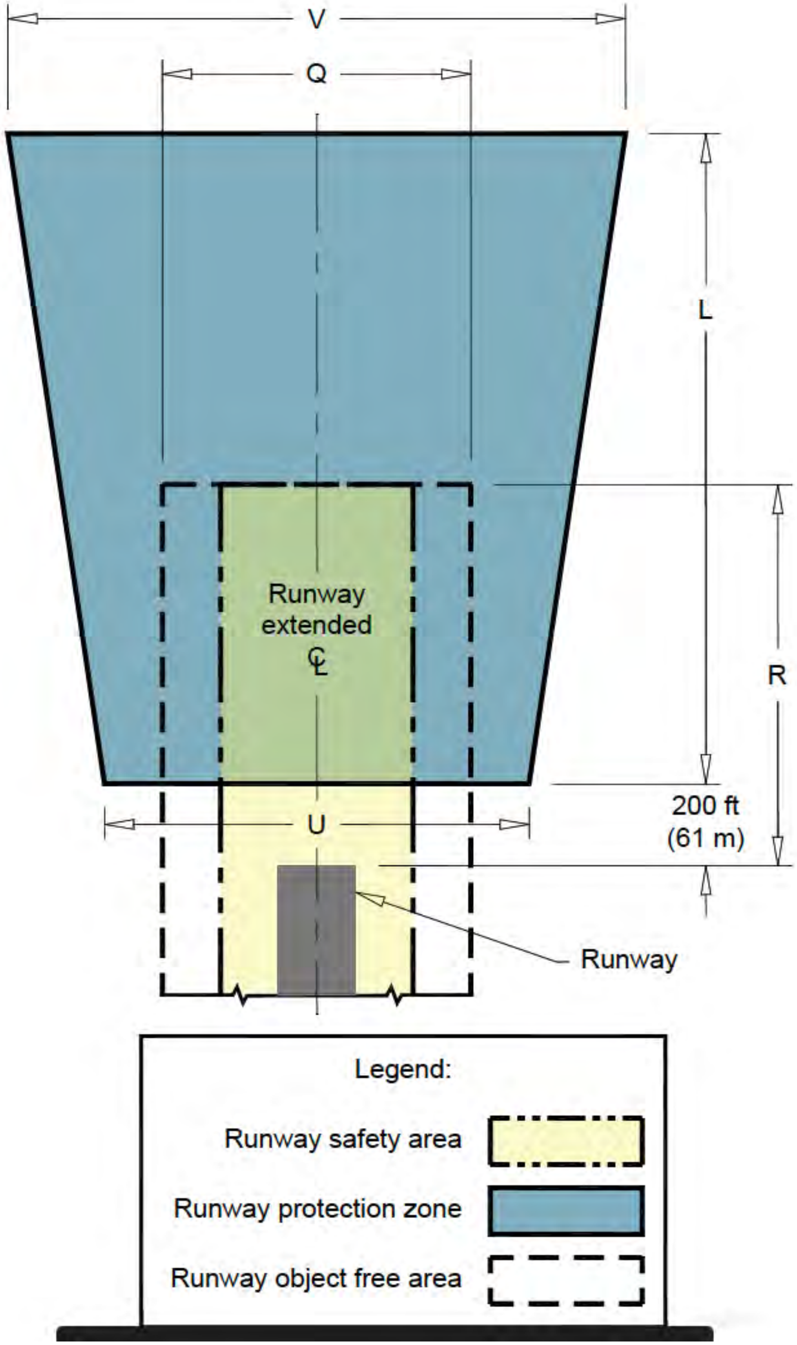
Two components make up the PRZ:

- Controlled activity area
- A portion of the Runway Object Free Area (ROFA)

According to the FAA AC 5300-13 the function of the RPZ is to "enhance the protection of people and property on the ground."

- Ideally, the airport should control the RPZ area
- RPZs should be clear of incompatible objects
- Ideally the control is exercised by buying the land of the RPZ

Runway Protection Zone Definitions



Dimensions of the RPZ distances are provided in Appendix **G** of the FAA AC 150/5300-13B

source:
FAA AC 150/5300-13B

FAA Requires two RPZ Zones: One for Approach and one for Departures

3.13.1 Standards.

The RPZ is trapezoidal in shape and centered about the extended runway centerline. Two different components comprise the RPZ: the approach and departure RPZ, which normally overlap. Discontinuity may occur when the approach or departure RPZ begins at a location other than 200 feet (61 m) beyond the end of the runway (refer to Figure 3-26 and Figure 3-28).

3.13.1.1 **Approach RPZ.**

The approach RPZ extends from a point 200 feet (61 m) from the runway threshold, as shown in Figure 3-26, for a distance as prescribed in Appendix G or the online Runway Design Standards Matrix Tool.

3.13.1.2 **Departure RPZ.**

The departure RPZ begins 200 feet (61 m) beyond the runway end. If the end of the TORA and the runway end are not the same, it is 200 feet (61 m) beyond the far end of the TORA. Refer to Appendix G or the online Runway Design Standards Matrix Tool for dimensional standards.

source:

FAA AC 150/5300-13B

Table **G-11** Runway Eesign Standard Matrix for Aircraft Design Groups C/D/E and V

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Table G-11. Runway Design Standards Matrix, C/D/E-V

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		C/D/E – V			
ITEM	DIM [1]	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
RUNWAY DESIGN					
Runway Length	A	*Refer to paragraphs 3.3 and 3.7.1*			
Runway Width	B	150 ft	150 ft	150 ft	150 ft
Shoulder Width		35 ft	35 ft	35 ft	35 ft
Blast Pad Width		220 ft	220 ft	220 ft	220 ft
Blast Pad Length		400 ft	400 ft	400 ft	400 ft
Crosswind Component		20 knots	20 knots	20 knots	20 knots
RUNWAY PROTECTION					
Runway Safety Area (RSA)					
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
Runway Object Free Area (ROFA)					
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
Obstacle Free Zone (OFZ)					
Runway, Inner-approach, Inner-Transitional		*Refer to paragraph 3.11*			
Precision Obstacle Free Zone (POFZ)					
Length		N/A	N/A	N/A	200 ft
Width		N/A	N/A	N/A	800 ft
Approach Runway Protection Zone (RPZ)					
Length	L	1,700 ft	1,700 ft	1,700 ft	2,500 ft
Inner Width	U	500 ft	500 ft	1,000 ft	1,000 ft
Outer Width	V	1,010 ft	1,010 ft	1,510 ft	1,750 ft
Departure Runway Protection Zone (RPZ)					
Length	L	1,700 ft	1,700 ft	1,700 ft	1,700 ft
Inner Width	U	500 ft	500 ft	500 ft	500 ft
Outer Width	V	1,010 ft	1,010 ft	1,010 ft	1,010 ft

source: FAA AC 150/5300-13**B**

RPZ Dimensions

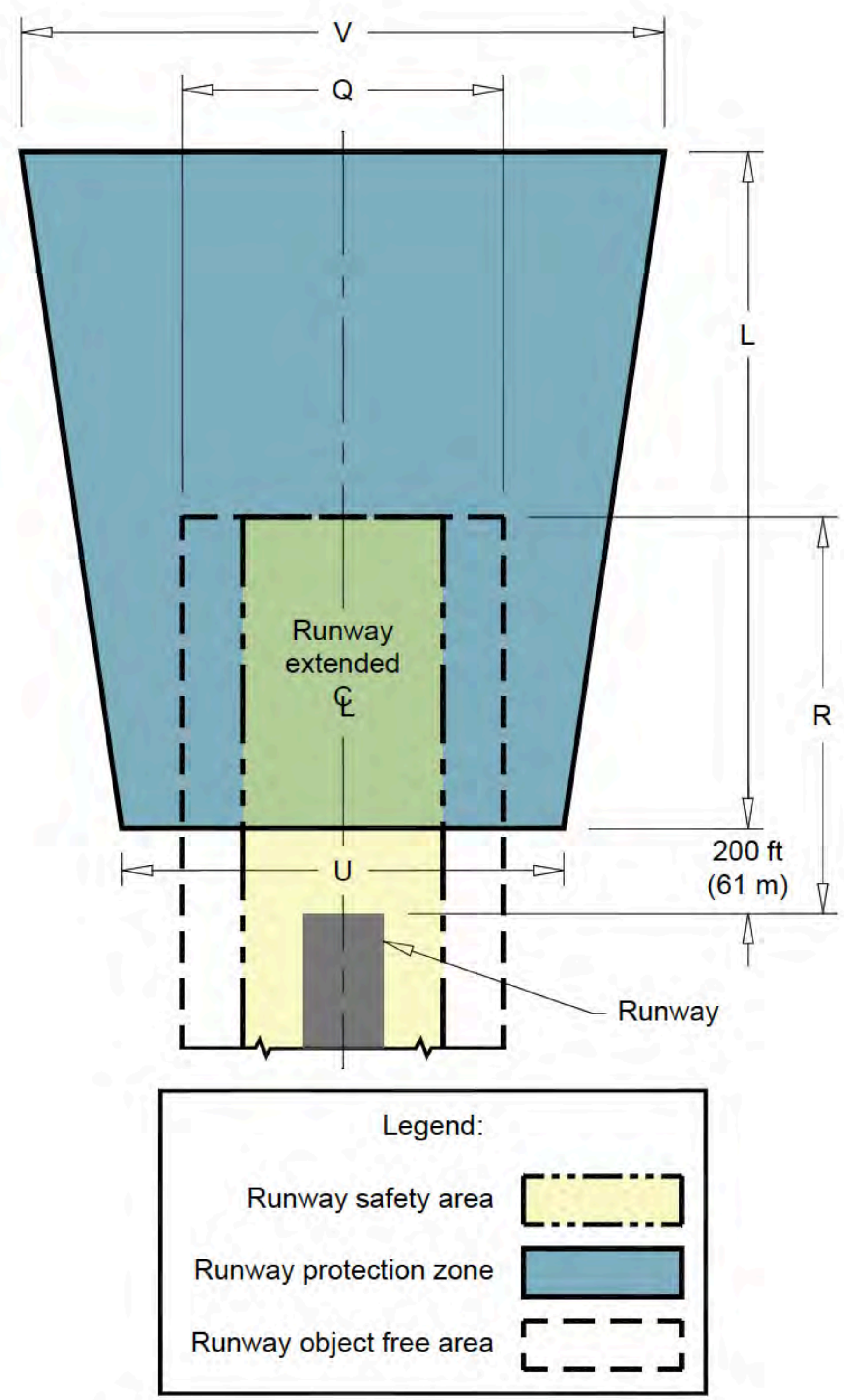
Runway Object Free Area (ROFA)

- Read Section 3.12 in the FAA Advisory Circular 150/5300-13B

"*ROFA is a clear area limited to equipment necessary for air and ground navigation, and provides wingtip protection in the event of an aircraft excursion from the runway.*"

- Dimensions of the ROFA are contained in Appendix G of the FAA AC 150/5300-13B
- Alternatively, consult the new FAA Runway Design Standards Matrix Tool available at:

https://www.faa.gov/airports/engineering/airport_design/rdsm/



ROFA Design Rationale (Section 3.12.1)

"ROFA provides a clear area of above-ground objects protruding above the elevation of the nearest point of the RSA:"

- *"Ensure terrain is no higher than the nearest point of the RSA within a distance from the edge of the RSA equal to half the most demanding wingspan of the RDC."*
- *"Design area clear of parked aircraft, agricultural operations, and other non-aeronautical activities."*
- *"Equipment necessary for air navigation and aircraft ground maneuvering and fixed-by-function, per Table 6-1, may reside within the ROFA, except as precluded by other clearing standards (e.g., NAVAID critical areas)."*

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ROFA Dimensions in the FAA Runway Design Standards Matrix Tool

Runway Design Standards Matrices Form

Instructions: Choose to view data for a single Aircraft Approach Category (AAC) and Airplane Design Group (ADG) or compare two. If you compare two, the differences between the first and second option will be highlighted in yellow.

Main Category (required):	C/D/E - III
Compare Category (optional):	- Not Selected -
Submit	Reset

Airbus A320neo landing at ATL runway 8L

ADG - III

AAC - C

C/D/E - III

ROFA Dim.	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

Source: FAA Runway Design Matrix https://www.faa.gov/airports/engineering/airport_design/rdsm

ROFA Dimensions for Small Aircraft (A/B - I) in Appendix G of FAA AC 150/5300-13B

Beechcraft Baron 58
ADG - I
AAC - B

Table G-1. Runway Design Standards Matrix, A/B-I

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		A/B – I Small Aircraft			
ITEM	DIM [1]	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
RUNWAY DESIGN					
Runway Length	A	*Refer to paragraphs 3.3 and 3.7.1*			
Runway Width	B	60 ft	60 ft	60 ft	75 ft
Shoulder Width		10 ft	10 ft	10 ft	10 ft
Blast Pad Width		80 ft	80 ft	80 ft	95 ft
Blast Pad Length		60 ft	60 ft	60 ft	60 ft
Crosswind Component		10.5 knots	10.5 knots	10.5 knots	10.5 knots
RUNWAY PROTECTION					
Runway Safety Area (RSA)					
Length beyond departure end [9, 10]	R	240 ft	240 ft		
Length prior to threshold	P	240 ft	240 ft		
Width	C	120 ft	120 ft	120 ft	300 ft
Runway Object Free Area (ROFA)					
Length beyond runway end	R	240 ft	240 ft	240 ft	600 ft
Length prior to threshold	P	240 ft	240 ft	240 ft	600 ft
Width	Q	250 ft	250 ft	250 ft	800 ft

ROFA Dimensions

ROFA Dimensions for Large Aircraft (C/D/E - V) in Appendix G of FAA AC 150/5300-13B

Boeing 787-8
ADG - V
AAC - D

Table G-11. Runway Design Standards

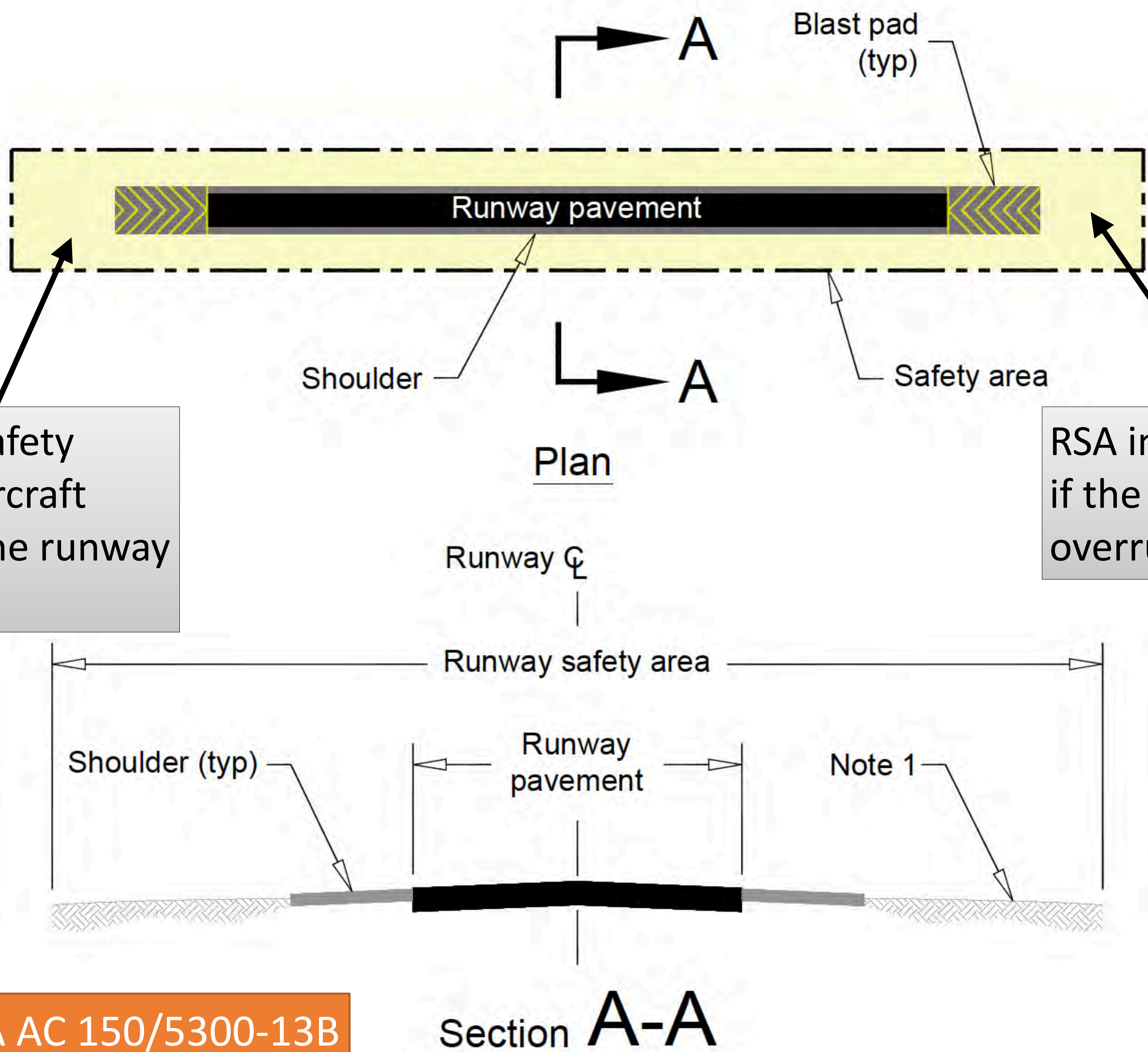
Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		C/D/E – V			
ITEM	DIM [1]	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
RUNWAY DESIGN					
Runway Length	A	*Refer to paragraphs 3.3 and 3.7.1*			
Runway Width	B	150 ft	150 ft	150 ft	150 ft
Shoulder Width		35 ft	35 ft	35 ft	35 ft
Blast Pad Width		220 ft	220 ft	220 ft	220 ft
Blast Pad Length		400 ft	400 ft	400 ft	400 ft
Crosswind Component		20 knots	20 knots	20 knots	20 knots
RUNWAY PROTECTION					
Runway Safety Area (RSA)					
Length beyond departure end [9, 10]	R	1,000 ft	1,000 ft	[illegible]	[illegible]
Length prior to threshold [11]	P	600 ft	600 ft	[illegible]	[illegible]
Width	C	500 ft	500 ft	[illegible]	[illegible]
Runway Object Free Area (ROFA)					
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

ROFA Dimensions

Runway Safety Area (RSA)

- *Area surrounding the runway that should be clear of objects, except for objects that need to be located in the runway or taxiway safety area because of their function (i.e., navigation equipment on frangible structures)*
  - *Cleared and graded and have no hazardous ruts, humps or depressions*
  - *Objects higher than 3 inches (7.6 cm) should be mounted on frangible structures*
  - *Manholes should be constructed at grade (or 7.6 cm. in height at most)*
  - *No underground fuel storage facilities are allowed inside RSA (or taxiway safety areas)*
- **Tables in Appendix G of the FAA AC 150/5300-13B provide the RSA dimensional standards**

Runway Safety Area (RSA)



RSA improves safety if the landing aircraft lands short of the runway (undershoot)

RSA improves safety if the landing aircraft overruns the runway

Figure 3-16 in FAA AC 150/5300-13B

RSA Dimensions in the FAA Runway Design Standards Matrix Tool

Runway Design Standards Matrices Form

Instructions: Choose to view data for a single Aircraft Approach Category (AAC) and Airplane Design Group (ADG) or compare two. If you compare two, the differences between the first and second option will be highlighted in yellow.

Main Category (required):	C/D/E - III
Compare Category (optional):	- Not Selected -
Submit	Reset

C/D/E - III

RSA Dim.	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

Airbus A320neo landing at ATL runway 8L
ADG III and AAC C

Source: FAA Runway Design Matrix
https://www.faa.gov/airports/engineering/airport_design/rdsm

RSA Dimensions in the FAA AC 150/5300-13B

Table G-9. Runway Design Standards Matrix, C/D/E-III

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		**C/D/E – III**			
ITEM	DIM [1]	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
RUNWAY DESIGN					
Runway Length	A	*Refer to paragraphs 3.3 and 3.7.1*			
Runway Width [12]	B	100 ft	100 ft	100 ft	100 ft
Shoulder Width [12]		20 ft	20 ft	20 ft	20 ft
Blast Pad Width [12]		140 ft	140 ft	140 ft	140 ft
Blast Pad Length		200 ft	200 ft	200 ft	200 ft
Crosswind Component		16 knots	16 knots	16 knots	16 knots
RUNWAY PROTECTION					
Runway Safety Area (RSA)					
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
Runway Object Free Area (ROFA)					
Length beyond runway end	R	1,000 ft	1,000 ft	[illegible]	[illegible]
Length prior to threshold [11]	P	600 ft	600 ft		
Width	Q	800 ft	800 ft		

Airbus A320neo
ADG III and AAC C

Runway Safety Area: Design Rationale

- According to FAA, the RSA "The runway safety area enhances the safety of airplanes which undershoot, overrun, or veer off the runway, and it provides greater accessibility for firefighting and rescue equipment during such incidents."
- Studies suggest that in the majority of aircraft accidents , aircraft stay within 1,000 ft. of the end of the runway (see the plot presented on the next page)"
- RSA length beyond the runway end standards may be met by provision of an Engineered Materials Arresting System or other **FAA approved arresting system providing the ability to stop the critical aircraft using the runway exiting the end of the runway at 70 knots** (consult FAA AC 150/5220-22).

Runway Safety Area Design Rationale

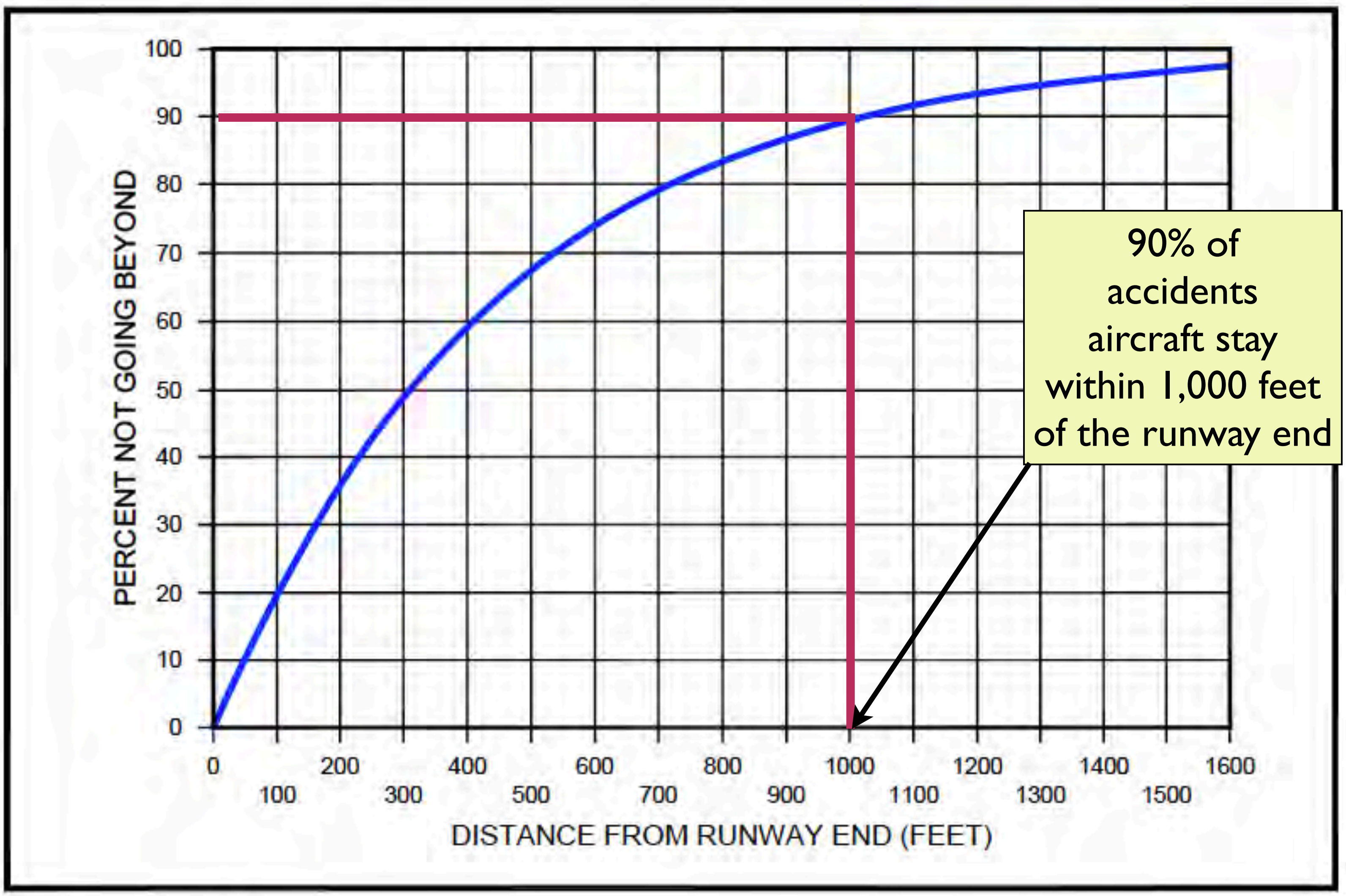


Figure 3-8. Percent of aircraft overrun versus distance beyond the runway end

source: FAA AC 150/5300-13a

Table G-12 Runway Eesign Standard Matrix for Aircraft Design Groups C/D/E and VI

Table G-12. Runway Design Standards Matrix, C/D/E-VI

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		**C/D/E – VI**			
ITEM	DIM [1]	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
RUNWAY DESIGN					
Runway Length	A	*Refer to paragraphs 3.3 and 3.7.1*			
Runway Width	B	200 ft	200 ft	200 ft	200 ft
Shoulder Width		40 ft	[illegible]	[illegible]	[illegible]
Blast Pad Width		280 ft	[illegible]	[illegible]	[illegible]
Blast Pad Length		400 ft	400 ft	400 ft	400 ft
Crosswind Component		20 knots	20 knots	20 knots	20 knots
RUNWAY PROTECTION					
Runway Safety Area (RSA)					
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

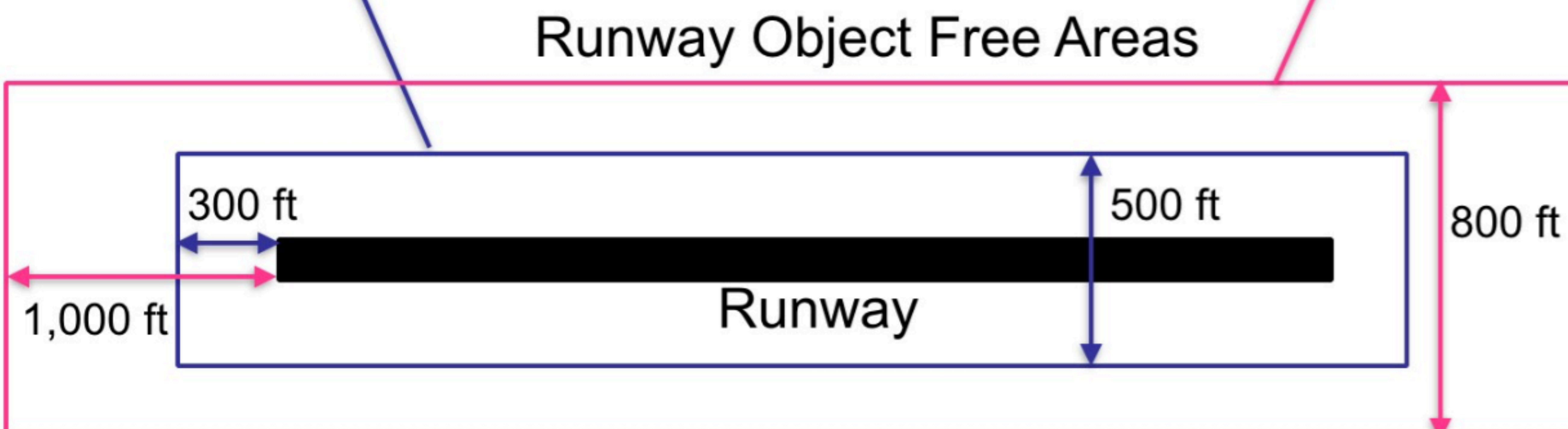
RSA Dimensions

source: FAA AC 150/5300-13

Virginia Tech Montgomery Executive Airport

2018 (before runway extension)

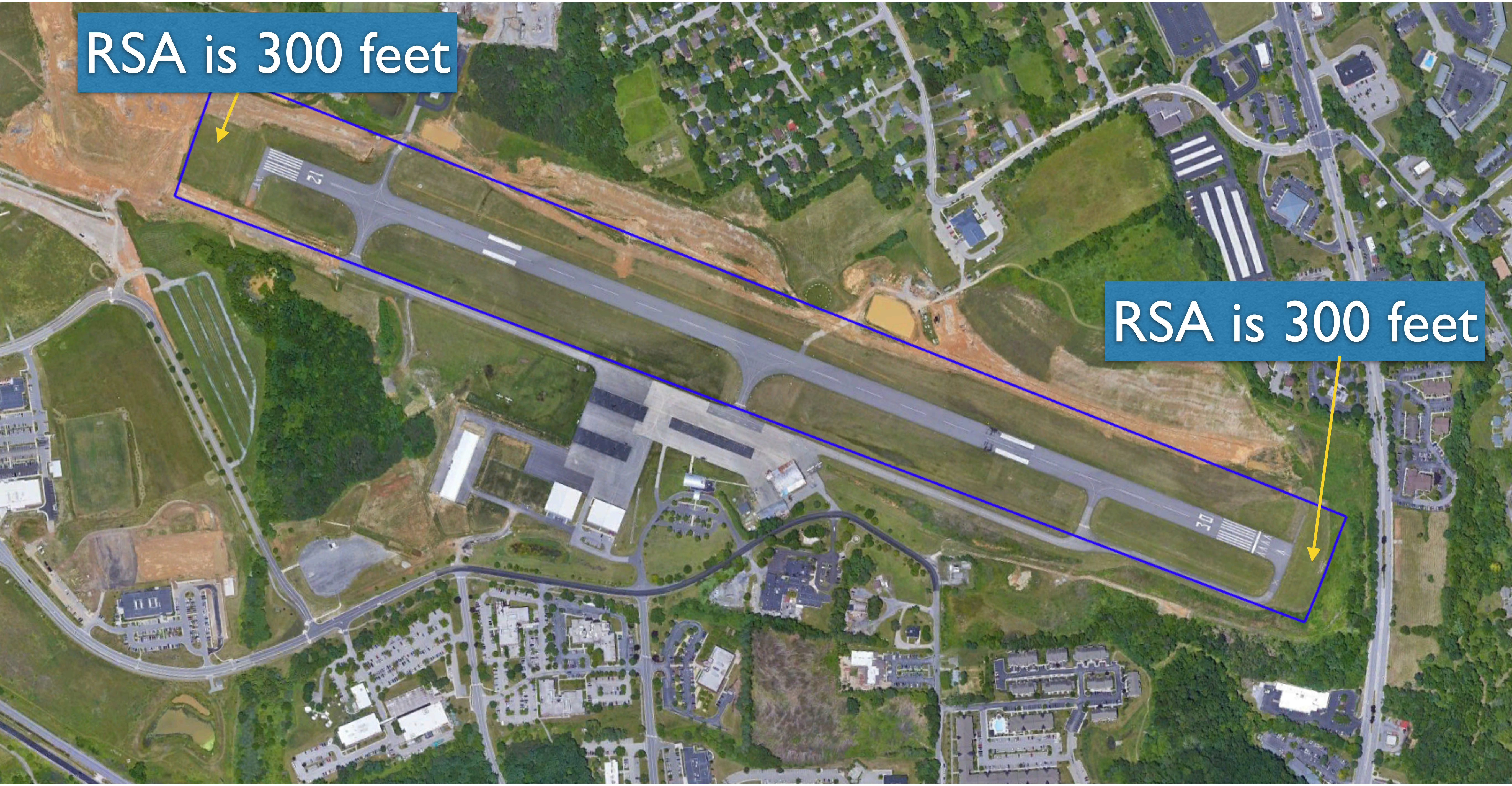
2021 (after runway extension)



Virginia Tech Montgomery Executive Airport

2018 (before runway extension)

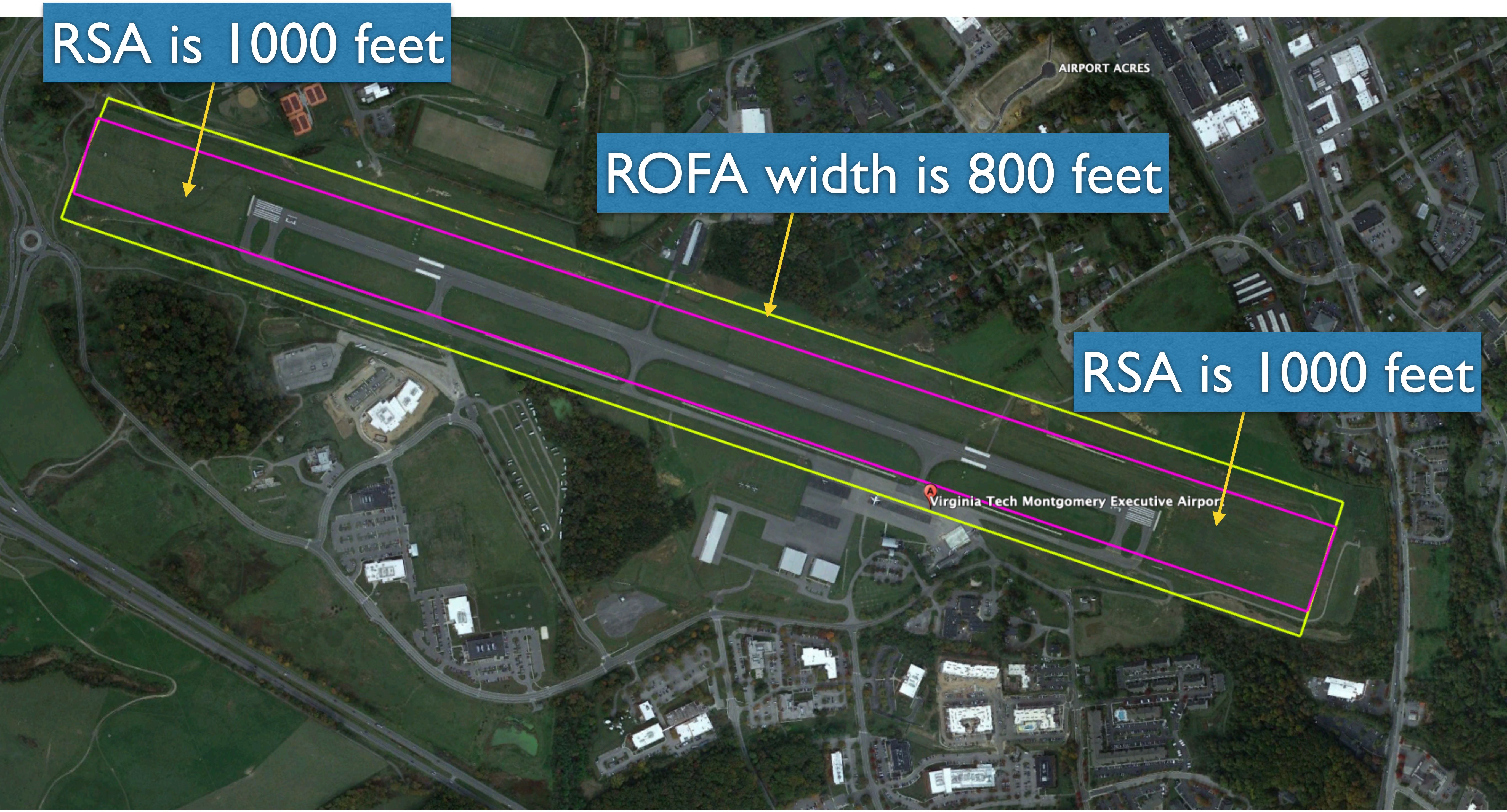
Critical Aircraft : B - II



Virginia Tech Montgomery Executive Airport

2021 (after runway extension)

Critical Aircraft : C - II

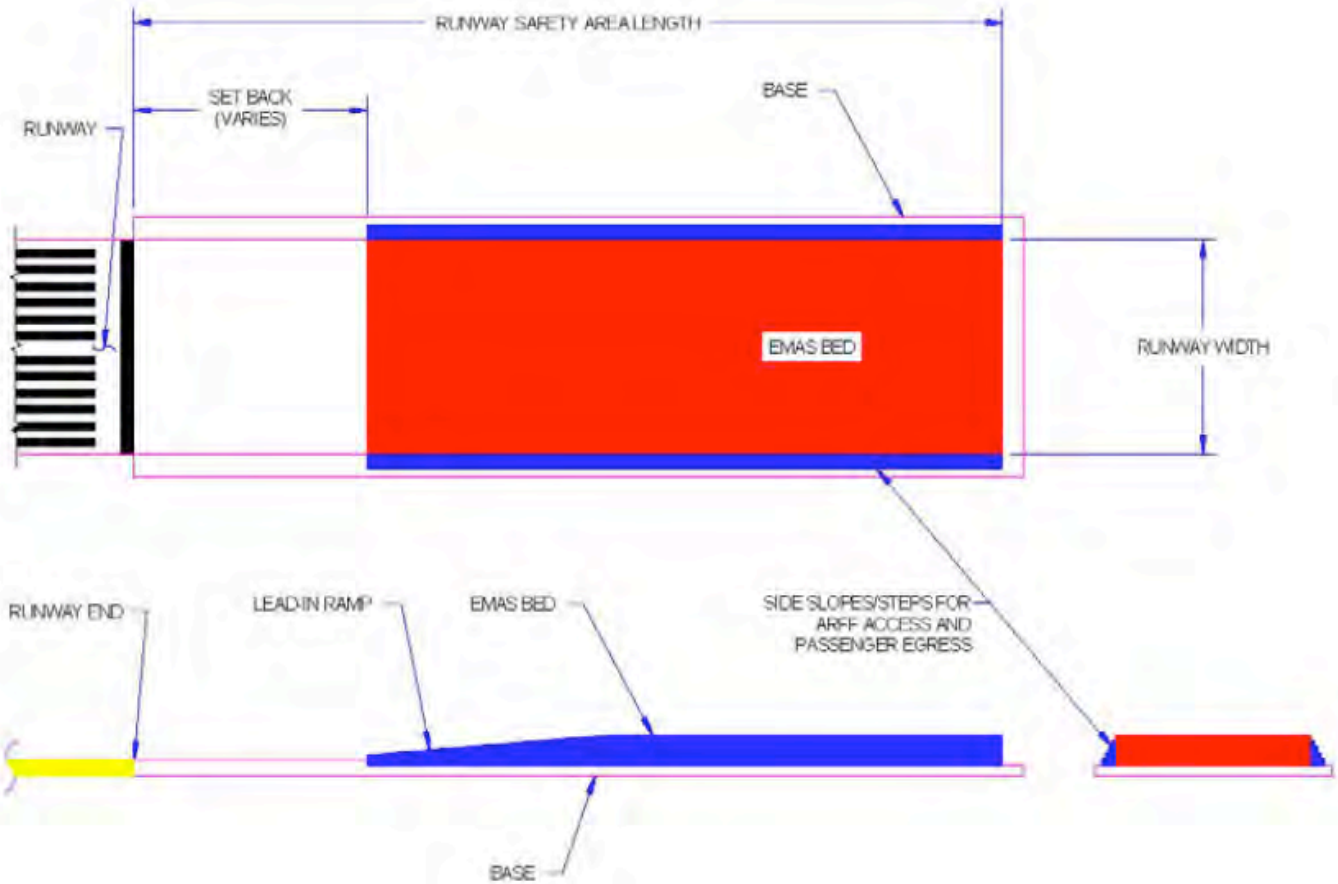


Airports without enough RSA Area

- Many airports do not have enough space to provide a full RSA based on the design criteria of the FAA
- In such cases the FAA allows an **Engineered Materials Arresting System** - EMAS - system to replace the standard RSA
- The guidance in AC 150/5300-13a states:
- "RSA length beyond the runway end standards may be met by provision of an Engineered Materials Arresting System or other FAA approved arresting system providing the ability to stop the critical aircraft using the runway exiting the end of the runway at **70 knots**. See AC 150/5220-22a."

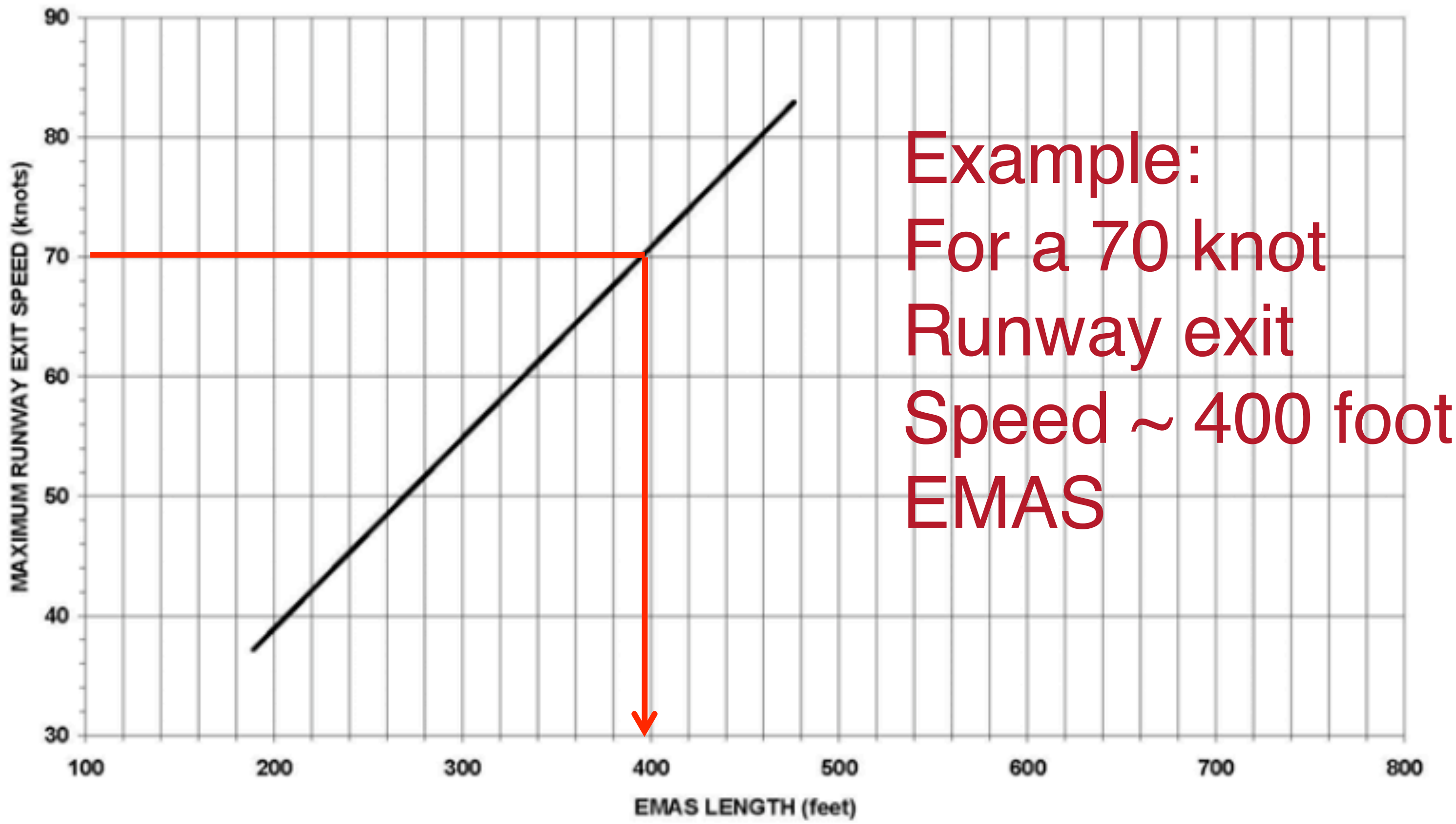
Basic Layout of EMAS System

- Information about EMAS systems is contained in FAA AC 150/5220-22a



Sample Design of Chart of EMAS System

- Boeing 737-400 at 150,000 lb
- Poor braking and no reverse thrust



Accidents that Employed the EMAS System

EMAS Arrestments

Date	Crew and Passengers	Incident
May 1999	30	A Saab 340 commuter aircraft overran the runway at JFK Airport in New York
May 2003	3	A Gemini Cargo MD-11 overran the runway at JFK Airport in New York
January 2005	3	A Boeing 747 overran the runway at JFK Airport in New York
July 2006	5	A Mystere Falcon 900 overran the runway at Greenville Downtown Airport in South Carolina
July 2008	145	An Airbus A320 overran the runway at Chicago O'Hare Airport in Chicago, IL
January 2010	34	A Bombardier CRJ-200 regional jet overran the runway at Yeager Airport in Charleston, WVA
October 2010	10	A G-4 Gulfstream overran the runway at Teterboro Airport in Teterboro, NJ
November 2011	5	A Cessna Citation II overran the runway at Key West International Airport in Key West, FL
October 2013	8	A Cessna 680 Citation overran the runway at Palm Beach International in West Palm Beach, FL
January 2016	2	A Falcon 20 overran the runway at Chicago Executive Airport in Chicago, IL
October 2016	37	A Boeing 737 overran the runway in Flushing, NY
April 2017	2	A Cessna 750 Citation overran the runway at Burbank Airport in Burbank, CA

source: FAA (2017 - https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=13754)

Sample Accidents saved by the EMAS

- Read more: http://www.flightsafety.org/asw/aug06/asw_aug06_p13-19

EMAS Installations(source:FAA)

EMAS Installations

Airport	Location	# of Systems	Installation Date(s)
JFK International	Jamaica, NY	2	1996(1999)/2007 (2014)
Minneapolis St. Paul	Minneapolis, MN	1	1999(2008)
Little Rock	Little Rock, AR	2	2000/2003
Rochester International	Rochester, NY	1	2001
Burbank	Burbank, CA	1	2002* (2017)
Baton Rouge Metropolitan	Baton Rouge, LA	1	2002
Greater Binghamton	Binghamton, NY	2	2002 (2012)/2009***
Greenville Downtown	Greenville, SC	1	2003**/2010***
Barnstable Municipal	Hyannis, MA	1	2003
Roanoke Regional	Roanoke, VA	1	2004
Fort Lauderdale International	Fort Lauderdale, FL	4	2004, 2014
Dutchess County	Poughkeepsie, NY	1	2004**
LaGuardia	Flushing, NY	4	2005 (2014)/2015
Boston Logan	Boston, MA	2	2005/2006 (2012) (2014)
Laredo International	Laredo, TX	1	2006/2012***
San Diego International	San Diego, CA	1	2006
Teterboro	Teterboro, NJ	3	2006+/2011/2013
Chicago Midway	Chicago, IL	2	2006/2007****
Merle K (Mudhole) Smith	Cordova, AK	1	2007
Charleston Yeager	Charleston, WV	1	2007
Manchester	Manchester, NH	1	2007
Cleveland Hopkins	Cleveland, OH	2	2011
Groton	Groton-New London, CT	2	2011
Augusta State	Augusta, ME	2	2011
Elmira-Corning	Elmira, NY	1	2012
Trenton-Mercer	Trenton, NJ	4	2012/2013
New Bern	New Bern, NC	1	2012
Memphis	Memphis, TN	1	2013
Burke Lakefront	Cleveland, OH	1	2013
San Francisco	San Francisco, CA	4	2014
T.F. Green	Providence, RI	3	2014/2015/2017
Addison	Addison, TX	1	2014
Chicago Executive	Wheeling, IL	2	2014/2015
Reagan National	Washington, DC	3	2014/2015
Monterey	Monterey, CA	2	2015
Oakland International	Oakland, CA	1	2015
Nome	Nome, AK	1	2015
Lehigh Valley	Allentown, PA	2	2015
John Tune	Nashville, TN	1	2015
Kodiak	Kodiak, AK	2	2015
Rutland	Rutland, VT	1	fall 2015
Sikorsky	Bridgeport, CT	1	fall 2015
McAllen International	McAllen, TX	1	fall 2015
Sandiford	Louisville, KY	1	fall 2015
Venice	Venice, FL	1	2016
Boca Raton	Boca Raton, FL	2	2017

EMAS Designed for a large corporate jet

Obstacle Free Zone (OFZ)

- Read Section 3.11 in the FAA Advisory Circular 150/5300-13B

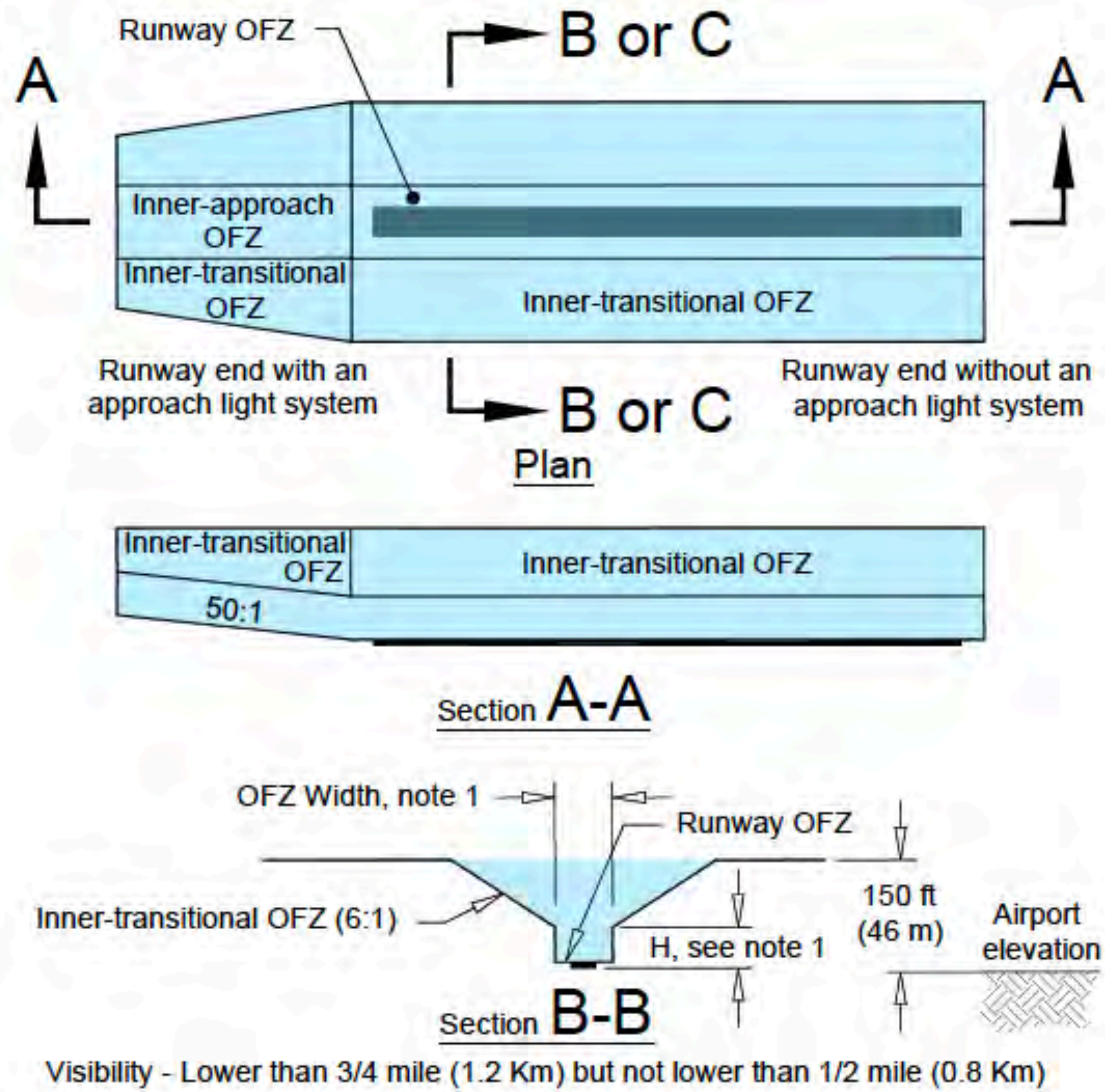
"*OFZ is a design and operational surface kept clear during aircraft operations*"

  - No other aircraft allowed
  - No object penetrations
  - Frangible Navigational Aids (NAVAIDS) allowed

- Appendix G of the FAA AC 150/5300-13B provides dimensions of the OFZ
- Alternatively, consult the new FAA Runway Design Standards Matrix Tool available at:
- https://www.faa.gov/airports/engineering/airport_design/rdsm/

Obstacle Free Zone (OFZ) Components

- Four components made the OFZ:
  - Runway OFZ
  - Precision Obstacle Free Zone (POFZ)
  - Inner Approach OFZ (IA-OFZ)
  - Inner Transitional OFZ (IT-OFZ)



Source: FAA 150/5300-13B

Runway Obstacle Free Zone (ROFZ)

- **Volume of airspace above the runway surface** used to protect penetrations by parked aircraft or other moveable objects
- Runway OFZ **extends 200 feet beyond the runway end**
- Runway OFZ widths are:

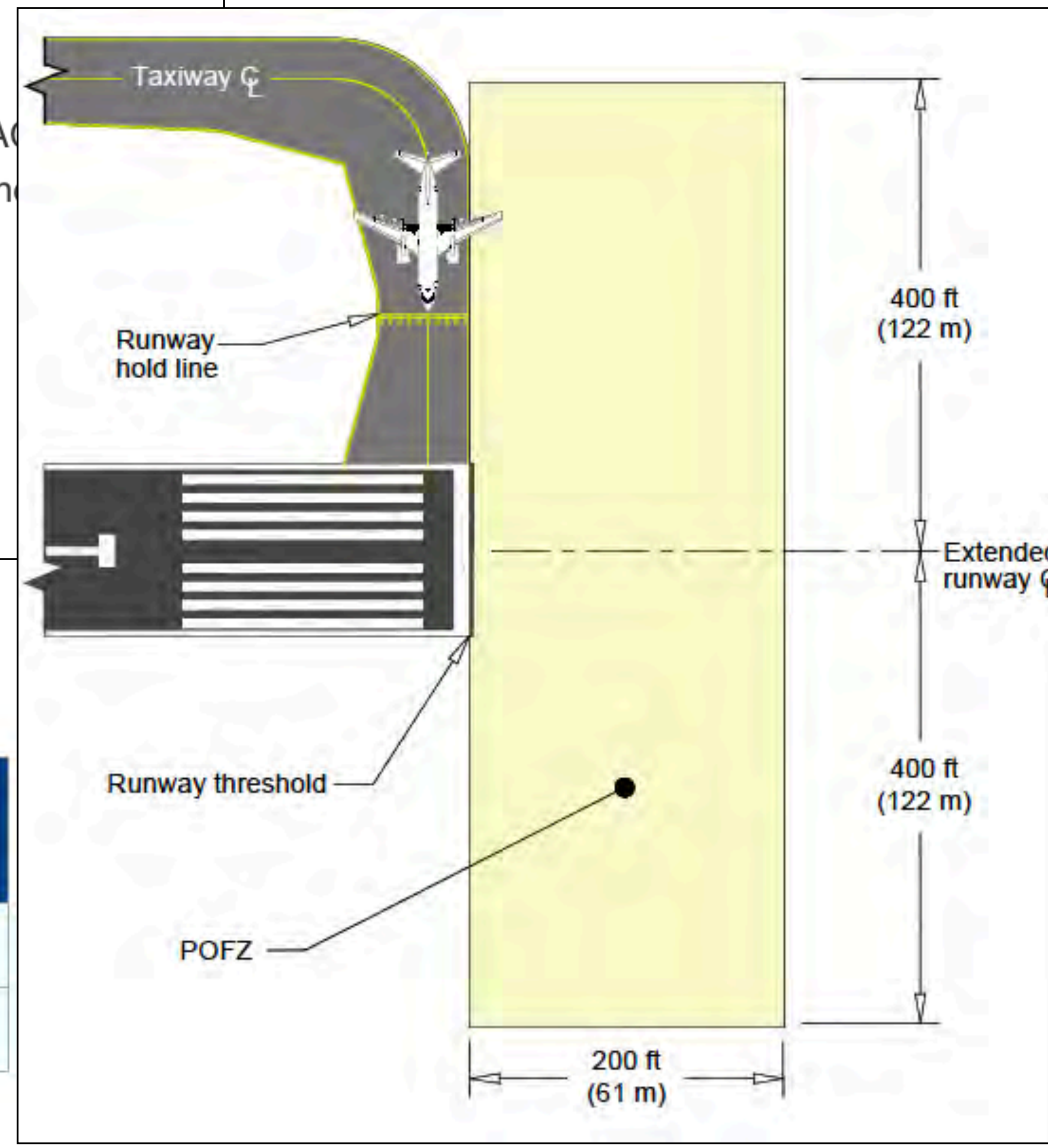
Aircraft Type	*Runway OFZ Width*	*Other Criteria*
Small (=< 12,500 lbs)	*300 ft (90 m.)*	*Visibility < 3/4 mile (1200 m.)*
Small (=< 12,500 lbs)	*250 ft (75 m.)*	*Approach speed >= 50 knots*
Small (=< 12,500 lbs)	*120 ft (36 m.)*	*Approach speeds < 50 knots*
Large (>12,500 lbs)	*400 ft (120 m.)*	*Applies to all*

Precision Obstacle Free Zone (POFZ) Dimensions in the FAA Runway Design Standards Matrix Tool

Runway Design Standards Matrices Form

Instructions: Choose to view data for a single Aircraft Approach Category (AA(
Airplane Design Group (ADG) or compare two. If you compare two, the differen
the first and second option will be highlighted in yellow.

Main Category (required):	C/D/E - III
Compare Category (optional):	- Not Selected -
Submit	Reset



C/D/E - III

POFZ Dim.	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

Source: FAA 150/5300-13B (Fig. 3-24)

POFZ Dimensions for Large Aircraft (C/D/E - V) in Appendix G of FAA AC 150/5300-13B

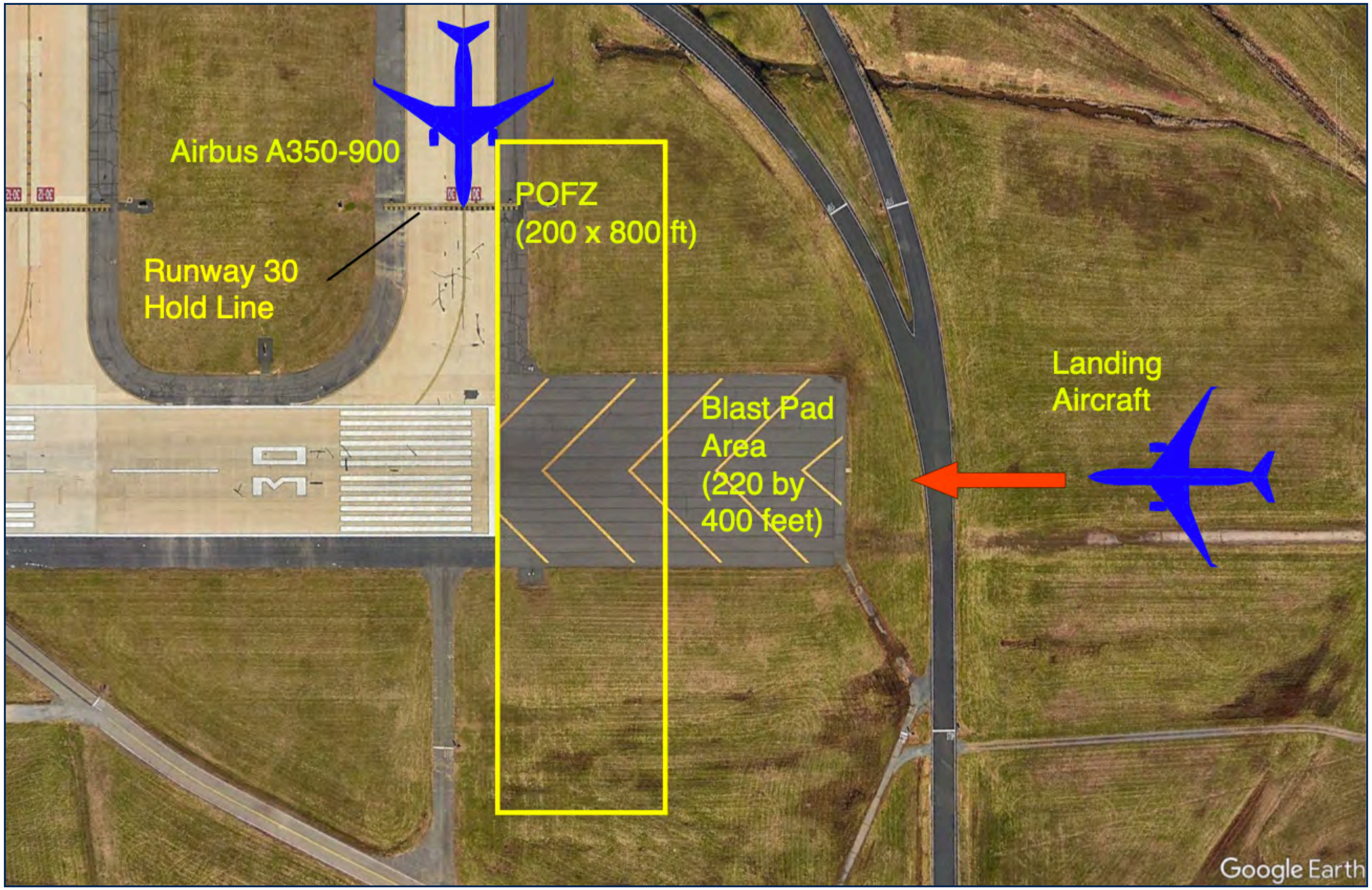
Boeing 787-8
ADG - V
AAC - D

Table G-11. Runway Design Standards Matrix, C/D/E-V

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		C/D/E – V			
ITEM	DIM [1]	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
RUNWAY DESIGN					
Runway Length	A	*Refer to paragraphs 3.3 and 3.7.1*			
Runway Width	B	150 ft	150 ft	150 ft	150 ft
Shoulder Width		35 ft	35 ft	35 ft	35 ft
Blast Pad Width		220 ft	220 ft	220 ft	220 ft
Blast Pad Length		400 ft	400 ft	400 ft	400 ft
Crosswind Component		20 knots	20 knots	20 knots	20 knots
RUNWAY PROTECTION					
Runway Safety Area (RSA)					
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
Runway Object Free Area (ROFA)					
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
Obstacle Free Zone (OFZ)					
Runway, Inner-approach, Inner-Transitional		*Refer to paragraph 3.11*			
Precision Obstacle Free Zone (POFZ)					
Length		N/A	N/A	N/A	200 ft
Width		N/A	N/A	N/A	800 ft

Example of POFZ (IAD Airport)

- Dulles International Airport Runway 30 threshold
- The objective of POFZ is to keep objects clear of areas that may interfere with sensitive Instrument Landing Systems (ILS)



Source: Google Earth

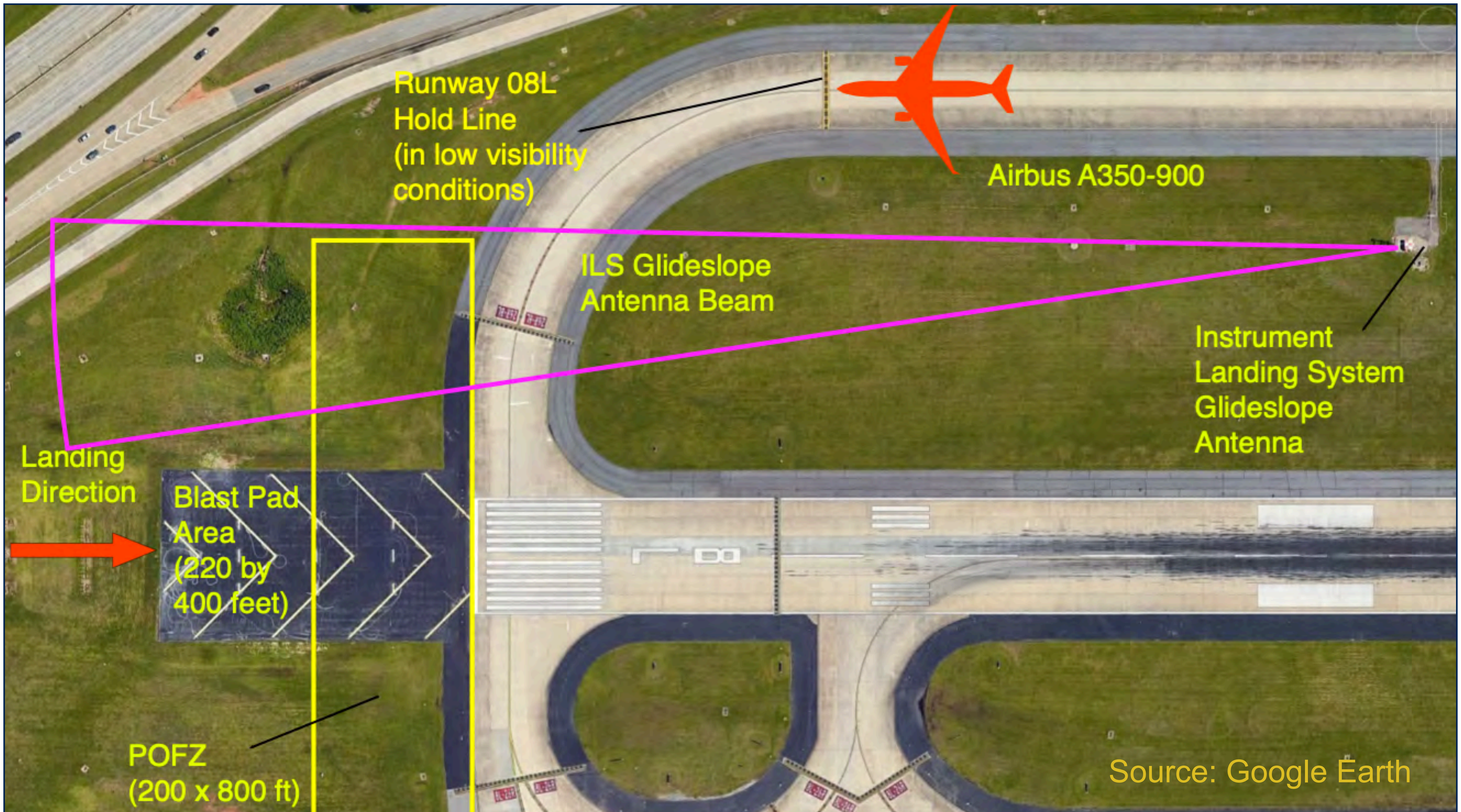
Example of POFZ (IAD Airport)

- Dulles International Airport Runway 1C threshold
- The objective of POFZ is to keep objects clear of areas that may interfere with sensitive Instrument Landing Systems (ILS)

Source: Google Earth

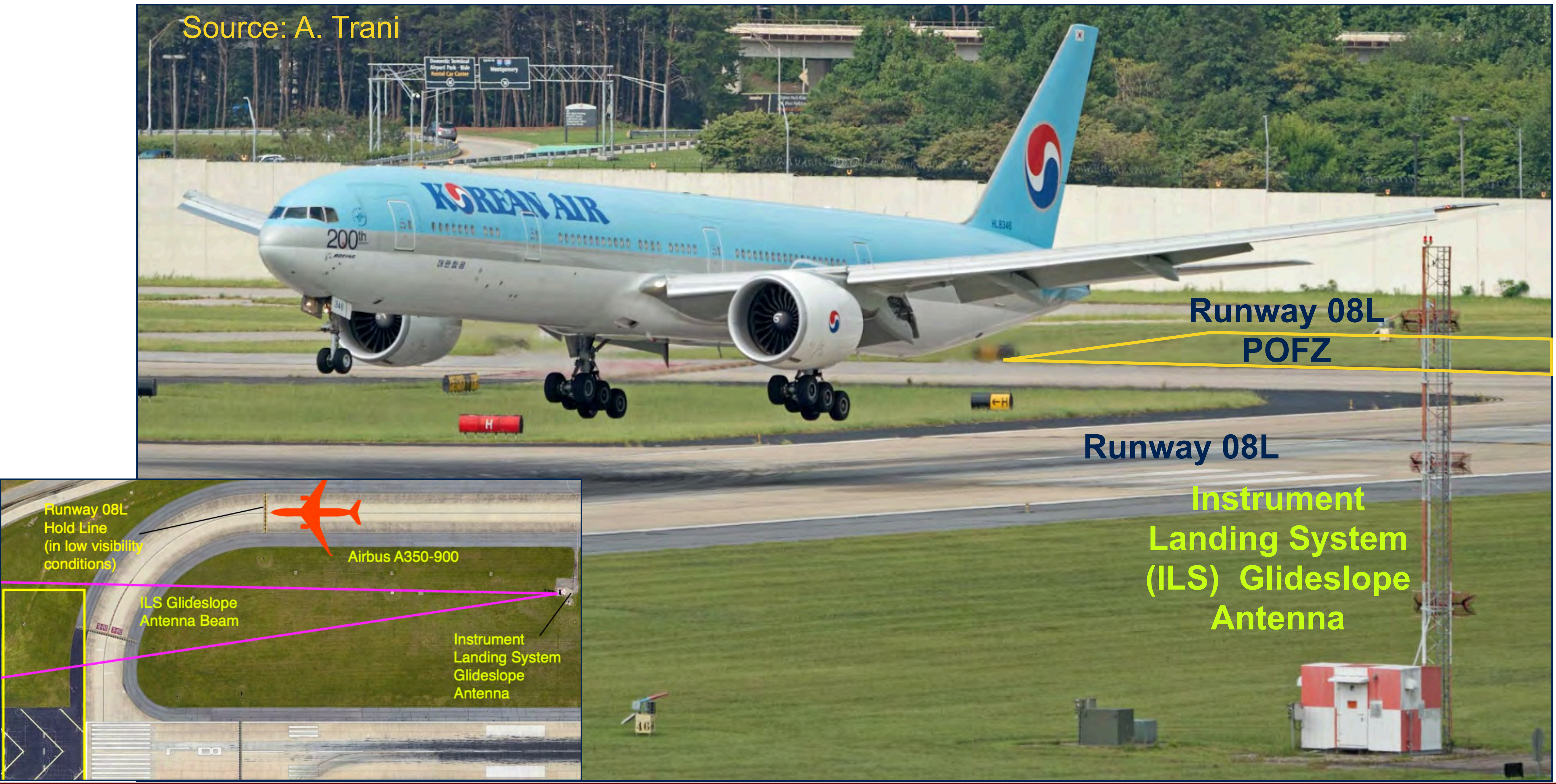
Example of POFZ (ATL Airport) and an offset ILS Hold Line

- Atlanta International Airport Runway 08L threshold
- The objective of POFZ is to keep objects clear of areas that may interfere with sensitive Instrument Landing Systems (ILS)



Example of POFZ and Offset ILS Hold Line (ATL Airport)

- Atlanta International Airport Runway 08L threshold
- The offset ILS hold line exists to avoid having aircraft interfere with ILS glide slope antenna beam in low visibility conditions



Inner-Approach OFZ

- Applies to runway with an Airport Lighting System (ALS)
- Starts 200 feet (61 m.) from runway end
- Ends 200 feet (61 m.) after the last light element of the ALS system
- Similar width as the Runway OFZ
- Slope 50:1 (horizontal : vertical)

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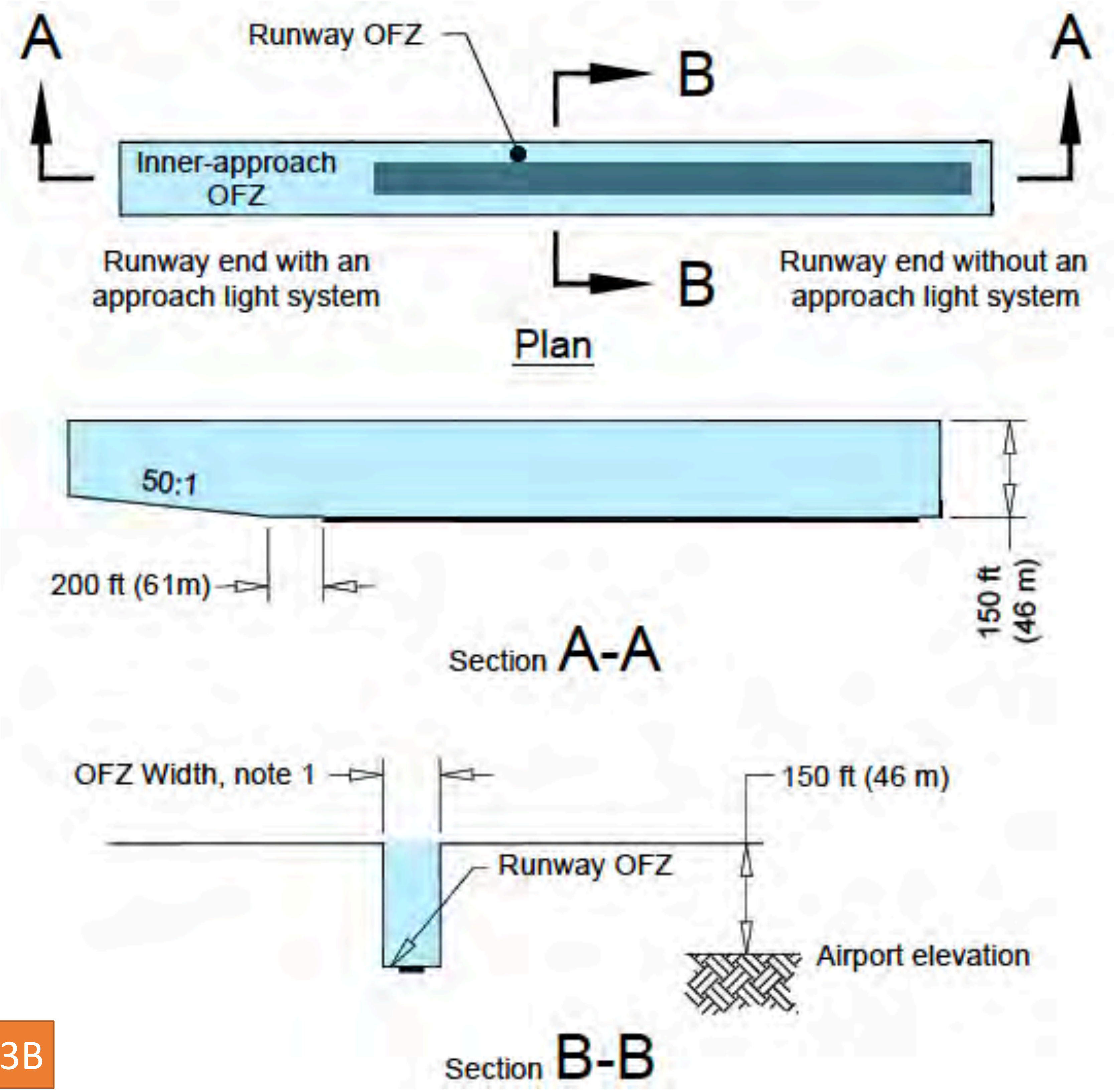
Inner-Approach OFZ

Visual runways

Runways with not lower than 3/4 mile (1200 m.) approach visibility minima

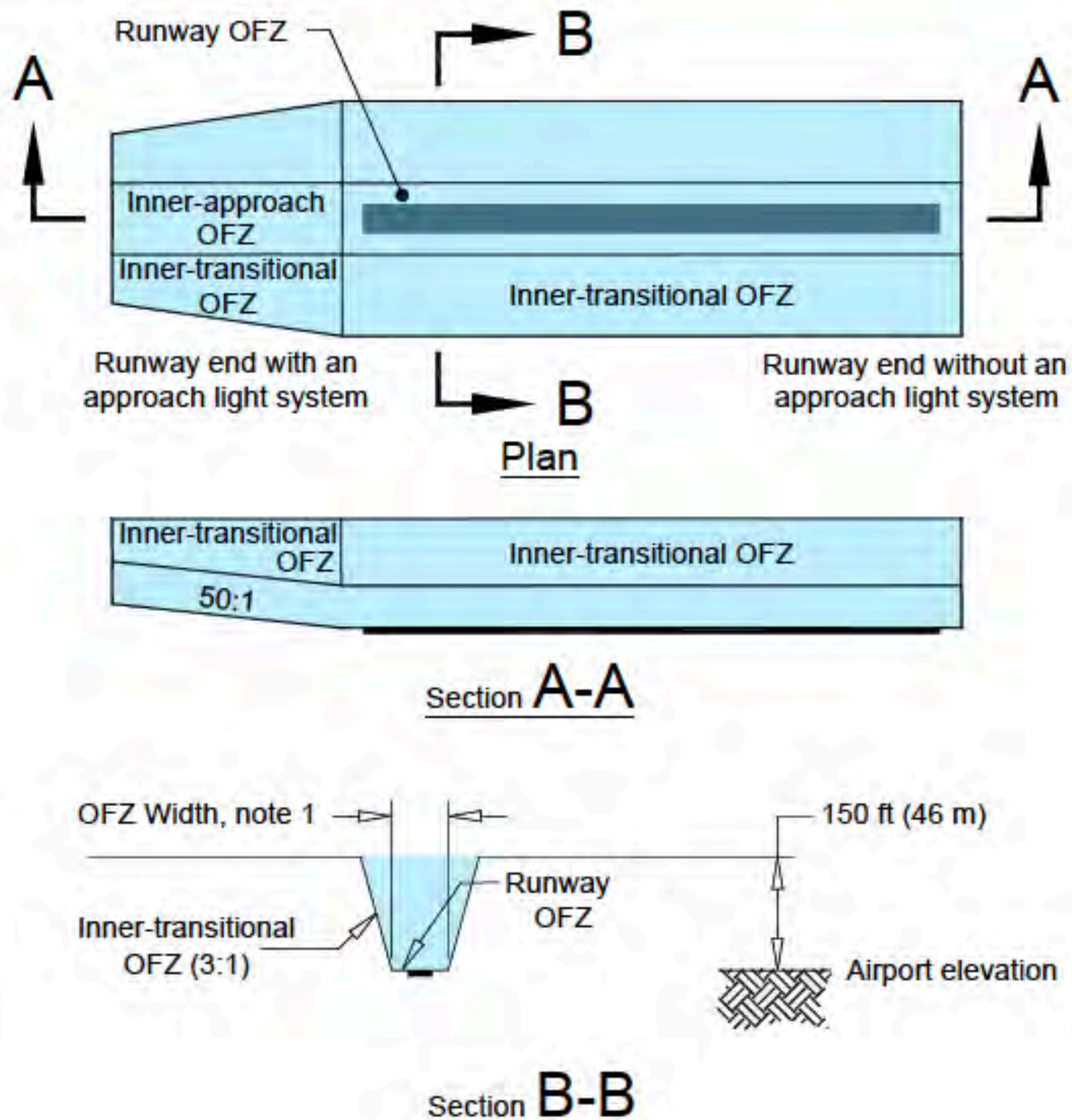


Source: FAA 150/5300-13B

Inner-Approach OFZ
Inner-Transitional OFZ

Small aircraft (<=12,500 lbs)

Runways with lower than 3/4 mile (1200 m.) approach visibility minima



Source: FAA 150/5300-13B

Inner-Transitional OFZ

Large aircraft (>12,500 lbs) Runways with lower than 3/4 mile (1200 m.) approach visibility minima

a. In U.S. customary units,

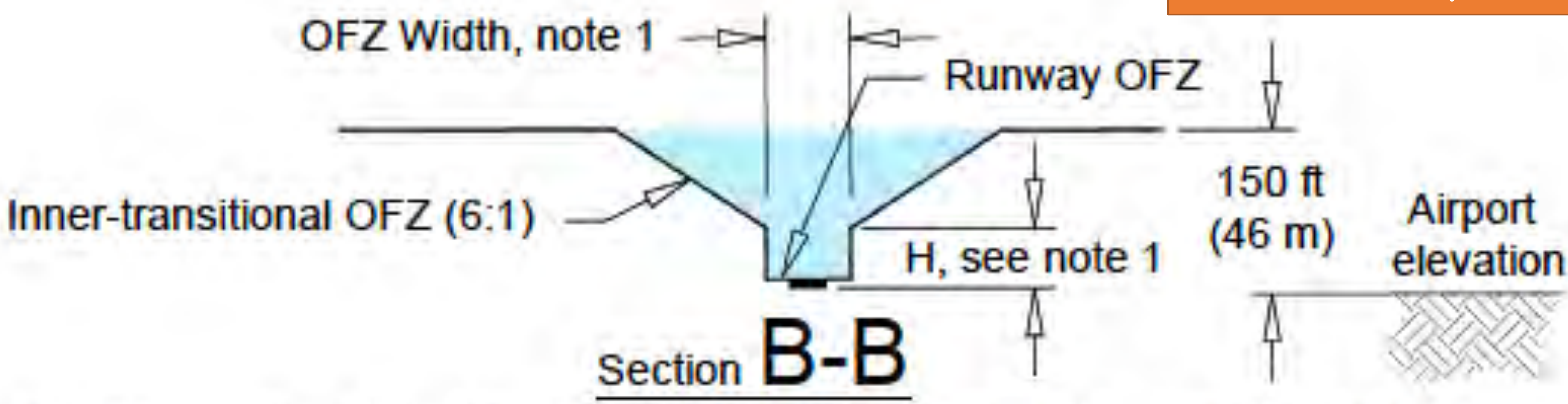
$$H_{feet} = 61 - 0.094(S_{feet}) - 0.003(E_{feet}).$$

b. In the International System of Units (SI),

$$H_{meters} = 18.4 - 0.094(S_{meters}) - 0.003(E_{meters}).$$

c. S is equal to the most demanding wingspan of the RDC of the runway, and E is equal to the runway threshold elevation above sea level.

Source: FAA 150/5300-13B



Visibility - Lower than 3/4 mile (1.2 Km) but not lower than 1/2 mile (0.8 Km)

Inner-Transitional OFZ

Large aircraft (>12,500 lbs)
Runways with lower than 1/2 mile (800 m.) approach visibility minima

Source: FAA 150/5300-13B

a. In U.S. customary units,

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

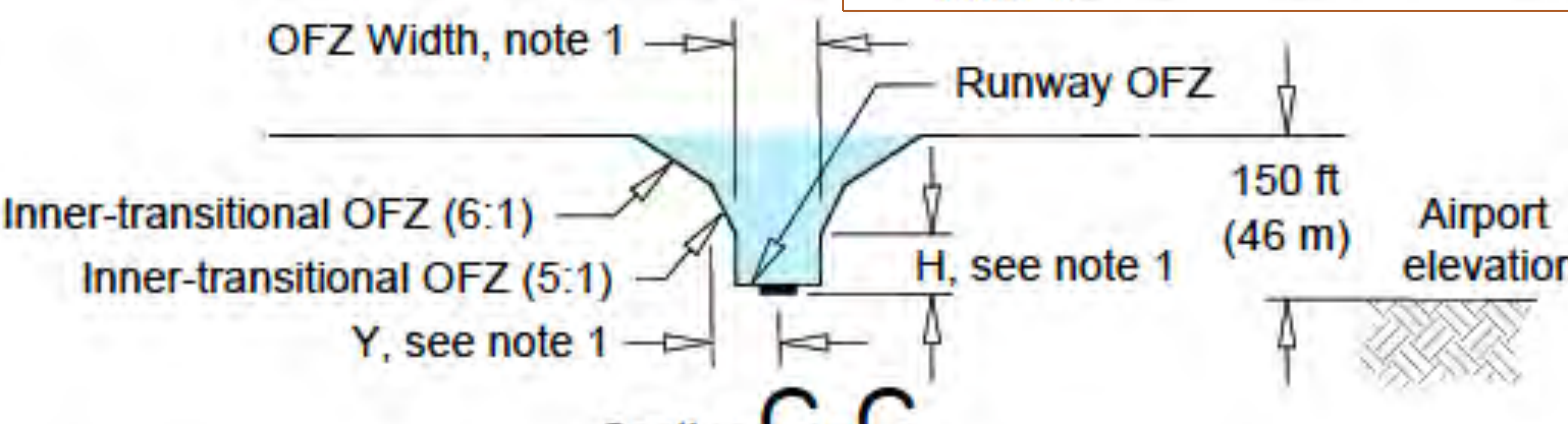
$$Y_{feet} = 440 + 1.08(S_{feet}) - 0.024(E_{feet}).$$

b. In SI units,

$$H_{meters} = 16 - 0.13(S_{meters}) - 0.0022(E_{meters}) \text{ and}$$

$$Y_{meters} = 132 + 1.08(S_{meters}) - 0.024(E_{meters}).$$

c. S is equal to the most demanding wingspan of the RDC of the runway and E is equal to the runway threshold elevation above sea level.



Section C-C

Visibility - Lower than 1/2 mile (0.8 Km)

d. Beyond the distance "Y" from the runway centerline, the CAT-II/III IT-OFZ surface is identical to that for the CAT-I OFZ.

Example Runway Design for Boeing 777-200

Assume a precision approach is needed for Instrument Landing condition operations (called IFR)

Solution:

Identify the design group of the aircraft:

Approach speed = 145 knots

Wingspan = 199.9 ft.

Boeing 777-200 belongs to FAA design group V and Approach Speed class D (see Appendix 13 in AC 150/5300-13)

Use RDC group DV in your analysis (also use visibility < 3/4 mile)

RPZ Design Dimensions for Boeing 777-200

- Runway Protection Zone dimensions found in Appendix G of the FAA 150/5300-13a advisory circular
  - **U** = 1,000 feet (305 meters)
  - **V** = 1,750 feet (534 meters)
  - L = 2,500 feet (762 meters)

Note: FAA now distinguishes between approach and departure Runway Protection Zones

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		C/D/E - V			
ITEM	**DIM** [1]	**VISIBILITY MINIMUMS**			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
Approach Runway Protection Zone (RPZ)					
Length	L	1,700 ft	1,700 ft	1,700 ft	2,500 ft
Inner Width	U	500 ft	500 ft	1,000 ft	1,000 ft
Outer Width	V	1,010 ft	1,010 ft	1,510 ft	1,750 ft
Acres		29.465	29.465	48.978	78.914
Departure Runway Protection Zone (RPZ)					
Length	L	1,700 ft	1,700 ft	1,700 ft	1,700 ft
Inner Width	U	500 ft	500 ft	500 ft	500 ft
Outer Width	V	1,010 ft	1,010 ft	1,010 ft	1,010 ft
Acres		29.465	29.465	29.465	29.465

RSA Design Dimensions for Boeing 777-200

- Runway Safety Area dimensions found in Appendix 7 of the FAA 150/5300-13B advisory circular
  - Width = 500 feet (145 meters)
  - Length prior to landing threshold = 600 feet (183 meters)
  - Length beyond runway end = 1,000 feet (305 meters)

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		C/D/E - V			
ITEM	**DIM** [1]	**VISIBILITY MINIMUMS**			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
RUNWAY PROTECTION					
Runway Safety Area (RSA)					
Length beyond departure end [10, 11]	R	1,000 ft	1,000 ft	1,000 ft	1,000 ft
Length prior to threshold [12]	P	600 ft	600 ft	600 ft	600 ft
Width	C	500 ft	500 ft	500 ft	500 ft

ROFA Design Dimensions for Boeing 777-200

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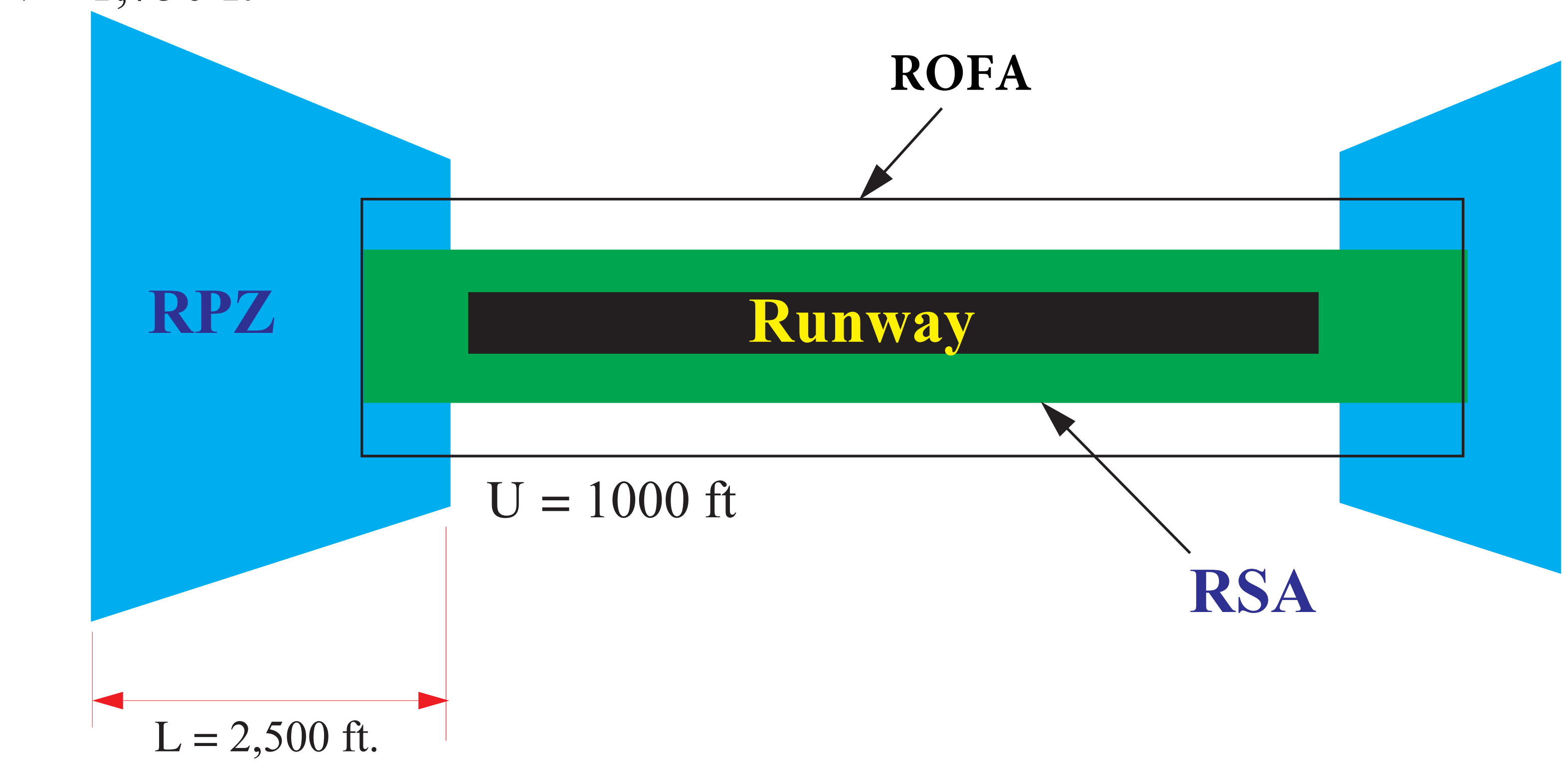
- Runway Object Free Area dimensions found in Appendix G of the FAA 150/5300-13B advisory circular
  - Width = 800 feet (243 meters)
  - ROFA beyond runway end = 1,000 feet (305 meters)
  - ROFA prior to threshold = 600 feet (183 meters)

Aircraft Approach Category (AAC) and Airplane Design Group (ADG):		C/D/E - V			
ITEM	**DIM** [1]	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
Runway Object Free Area (ROFA)					
Length beyond runway end	R	1,000 ft	1,000 ft	1,000 ft	1,000 ft
Length prior to threshold [12]	P	600 ft	600 ft	600 ft	600 ft
Width	Q	800 ft	800 ft	800 ft	800 ft

Example Runway Design for Boeing 777-200

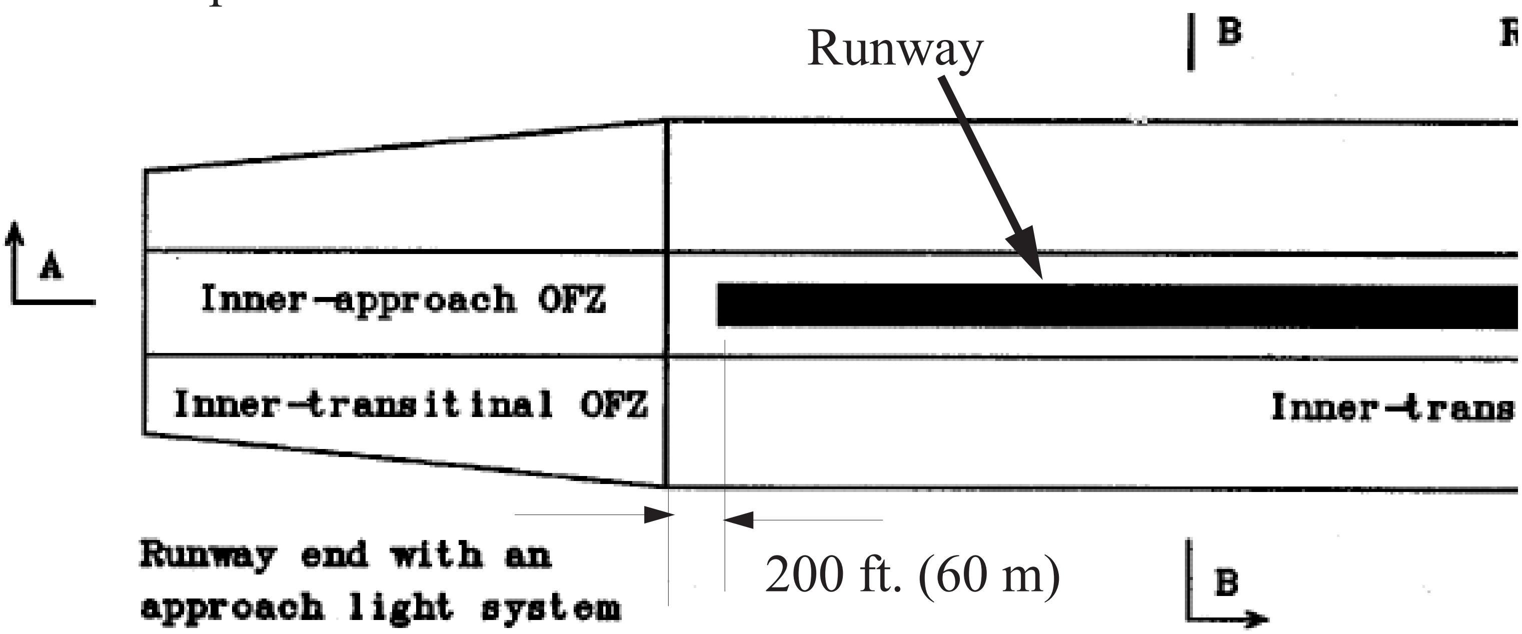
OFA - 800 ft. width, 1000 ft. beyond runway
RSA - 500 ft. width, 1000 ft. beyond runway



Design for Boeing 777-200 OFZ

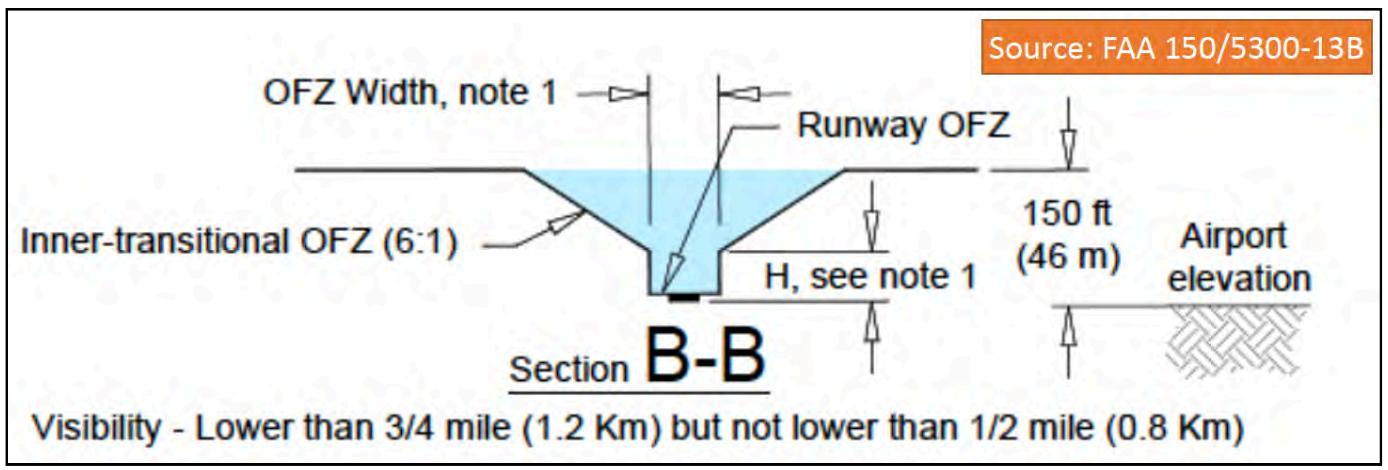
Inner-Approach OFZ surface

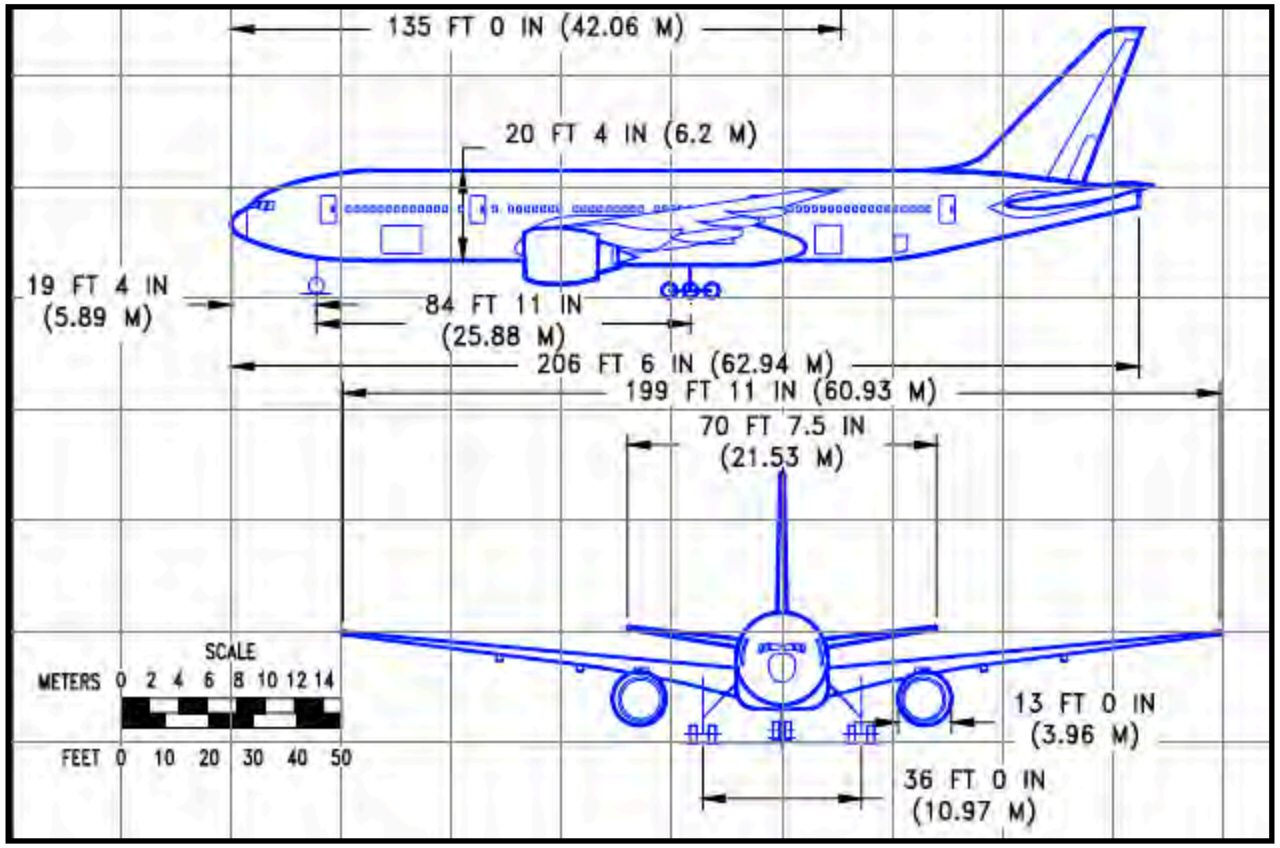
- Starts 200 ft. (60 m) from runway end, Width is 400 ft
- Slope is 50:1



Inner Transitional OFZ Calculation

- Critical aircraft is the Boeing 777-200
- Wingspan is 199.92 feet (see Boeing Data)
- **Instrument Landing System (ILS) Category 1**





S is the critical aircraft wingspan (feet)
E is the airport elevation (feet)

$$H_{feet} = 61 - 0.094(S_{feet}) - 0.003(E_{feet})$$

$$H_{feet} = 61 - 0.094(199.92) - 0.003(0)$$

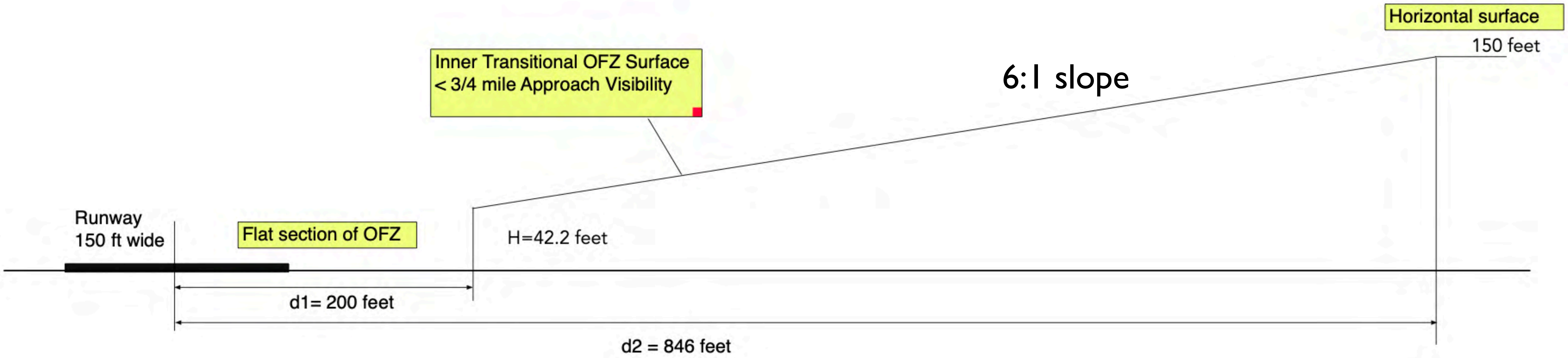
$$H_{feet} = 42.2\ feet$$

Inner Transitional OFZ Calculation

Design parameters:

- Boeing 777-200
- Critical wingspan (S) = 199.92 feet
- Airport elevation (E) = 0 feet

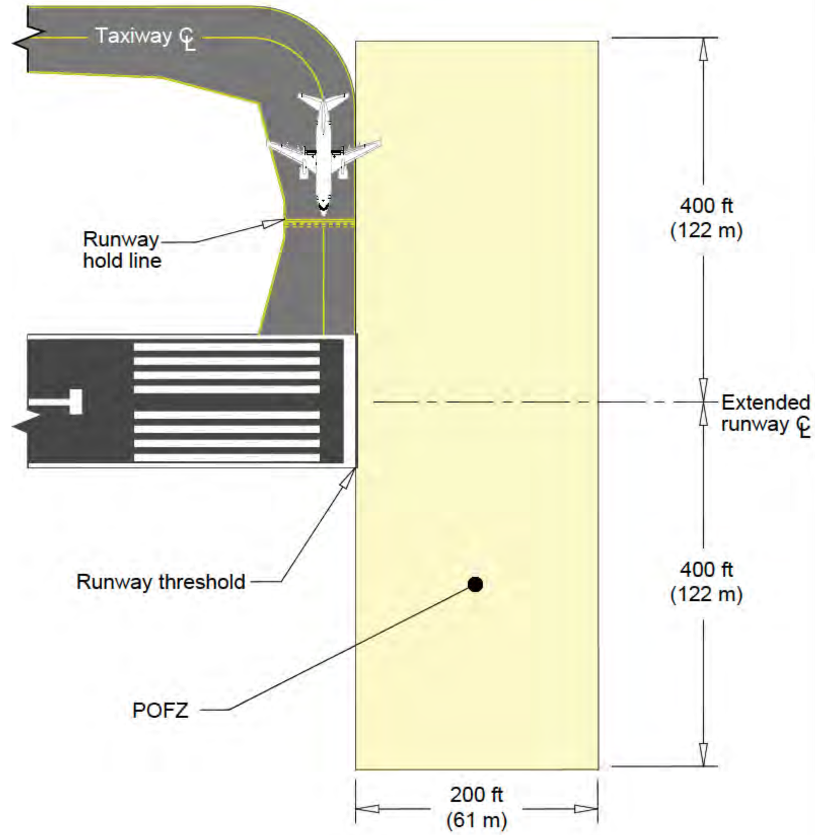
$$H_{feet} = 42.2\ feet$$



Design for Boeing 777-200 OFZ

Precision OFZ

- 200 ft (60 m) long
- 800 ft. (240 m) width



3.11.5 Precision Obstacle Free Zone (POFZ).

The POFZ is a volume of airspace above an area beginning at the threshold, at the threshold elevation. The POFZ extends along the extended runway centerline beyond the runway end for a distance of 200 feet (61 m) at a width of 800 feet (244 m). See Figure 3-24.

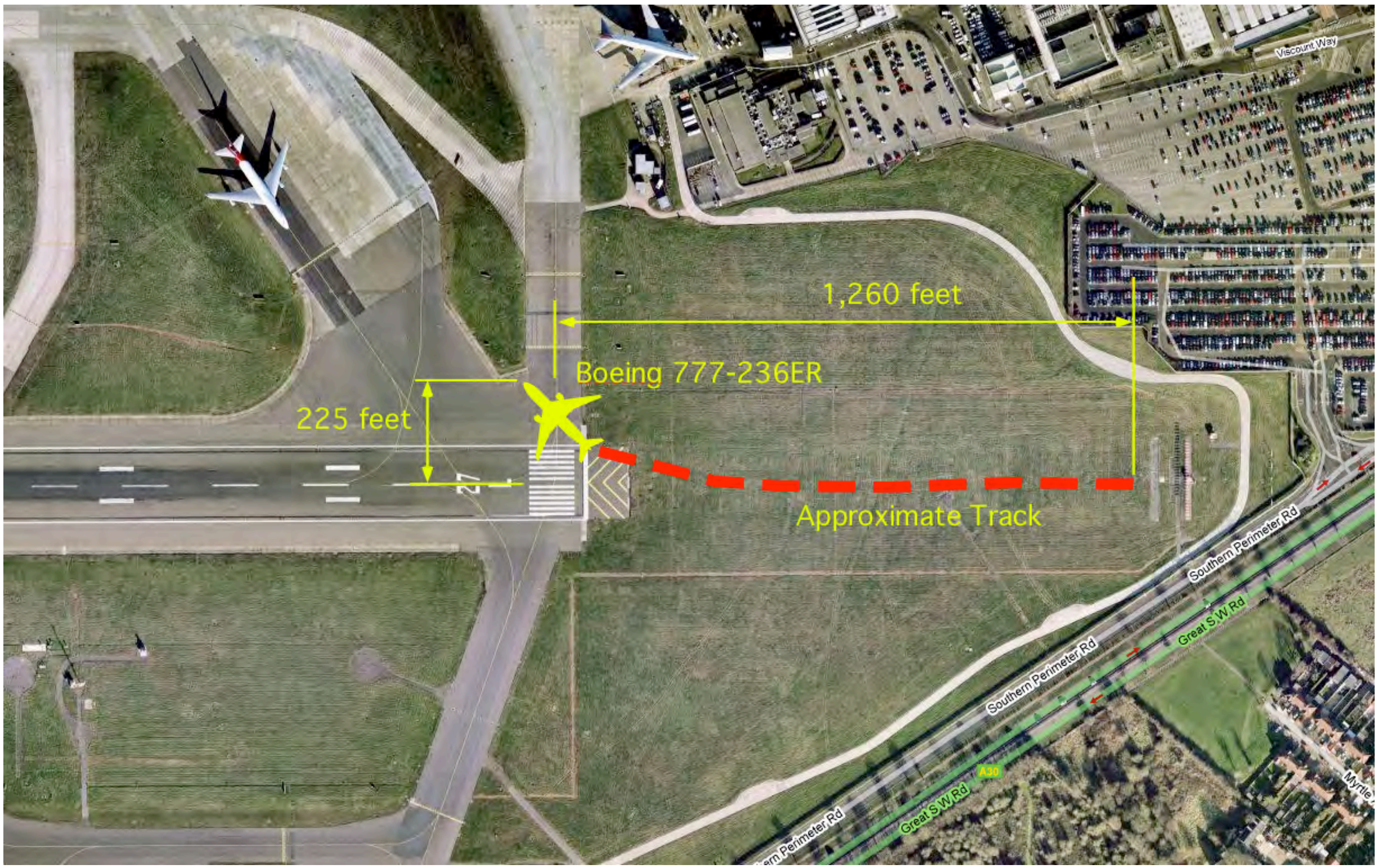
General Slides on Runway Safety

Safety Issues

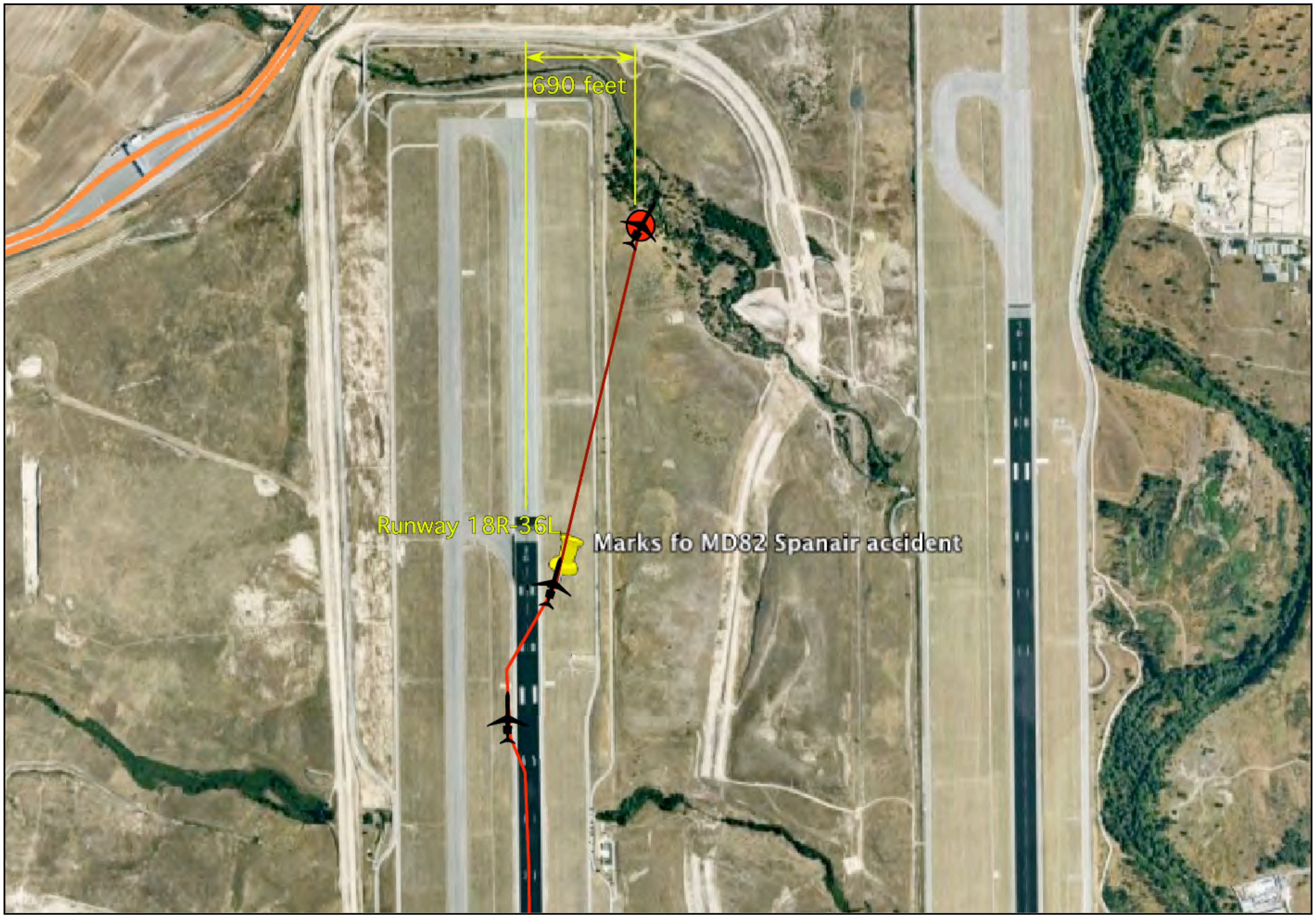
- Runway incursions are not the only reason for runway protection areas
- Runway and taxiway obstacle free zones and safety areas are designed to protect property and people from rare events:
  - Runway collisions with lateral excursions
  - Landing undershoots with lateral excursions
  - Landing overruns with lateral excursions
  - Aborted takeoff and overrun accidents
  - Taxiway wandering (low visibility conditions)

Iberia DC-10-30 Accident at Boston Logan Intl. Airport (Runway 33L)

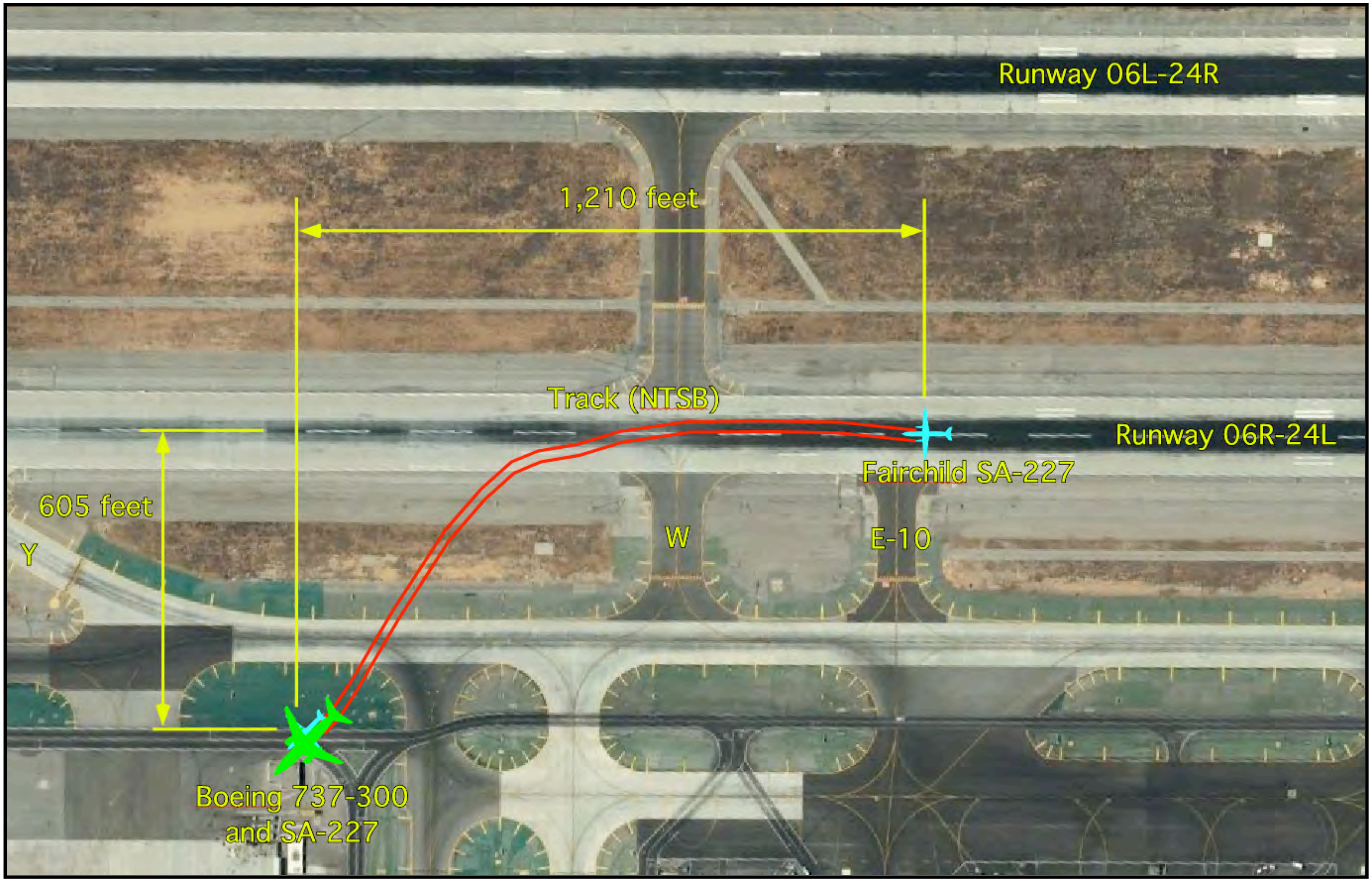
British Airways Boeing 777-236ER Accident at London Heathrow Airport



Boeing-Douglas MD-82 Accident at Madrid, Spain (Runway 36L)



Los Angeles International Runway Collision (Boeing 737-300 and Fairchild SA-227)



Lessons Learned from these Accidents

- Runways need adequate protection from property and other man-made objects
- FAA runway design standards cannot prevent all accidents or their outcomes
- However they can:
  - Reduce the risk of aircraft colliding with others
  - Reduce the risk of property damage
- FAA design standards have evolved with time and respond to new aircraft development

Recent Research in Aircraft Overrun and Undershoot at Airports (ACRP)

- The Airport Cooperative Research program (ACRP) has performed a study to look at issues related to runway safety areas
- Final report has been published (2009)
- Database with 459 accidents and incidents worldwide (overruns, undershoots)
- The panel has access to the safety database of this study (via ACRP)

Displaced Runway Threshold

Many airports cannot meet RSA and OFA criteria

Runways then cannot be used in its complete length requiring **displaced runway thresholds**

Observations for SAN Runway 27

- Interstate highway is elevated with respect to the runway elevation
- This requires aircraft to fly higher than in a normal approach to provide protection against obstacles (the highway is an obstacle)
- The displaced threshold shown in the figure cannot be used by landing aircraft on runway 27
- Shortens the runway available for landing (called landing distance available or LDA)
- The displaced threshold can be used by departing aircraft from Runway 27

Detail of Runway 27 at SAN Airport

San Diego International Airport Runway 27 End Situation

Runway Length Estimation According to the Declared Distance Concept

Other Considerations in Runway Length Analysis

So far the runway length analysis assumed that we have plenty of land to build the runway.

There are many practical situations when this is not true

Under land limited conditions use the Declared Distance Concept for runway length estimation described in Appendix 14 of FAA AC 150/5300-13.

The application of declared distance is done on a case-by-case basis and should be part of the Airport Layout Plan (ALP)

Basic Concept

According to the FAA "by treating the airplane's runway performance distances independently, provides an alternative airport design methodology by declaring distances to satisfy the airplane's takeoff run, takeoff distance, accelerate-stop distance, and landing requirements".

Declared distances are:

- Takeoff Run Available (TORA)
- Takeoff Distance Available (TODA)
- Accelerate to Stop Distance Available (ASDA)
- Landing Distance Available (LDA).

Declared Distance Concept Information

- Paragraph 323 in FAA Advisory Circular 150/5300-13A
- Bottom Line:
  - Declared distances are used when we cannot satisfy all requirements of RSA, ROFA, OFZ and RPZ due to obstacles in the vicinity of the runway

323. Declared distances.

a. Application. Declared distances represent the maximum distances available and suitable for meeting takeoff, rejected takeoff, and landing distances performance requirements for turbine powered aircraft. The declared distances are TORA and TODA, which apply to takeoff; Accelerate Stop Distance Available (ASDA), which applies to a rejected takeoff; and Landing Distance Available (LDA), which applies to landing. A clearway may be included as part of the TODA, and a stopway may be included as part of the ASDA. By treating these distances independently, declared distances is a design methodology that results in declaring and reporting the TORA, TODA ASDA and LDA for each operational direction.

Why Declared Distances?

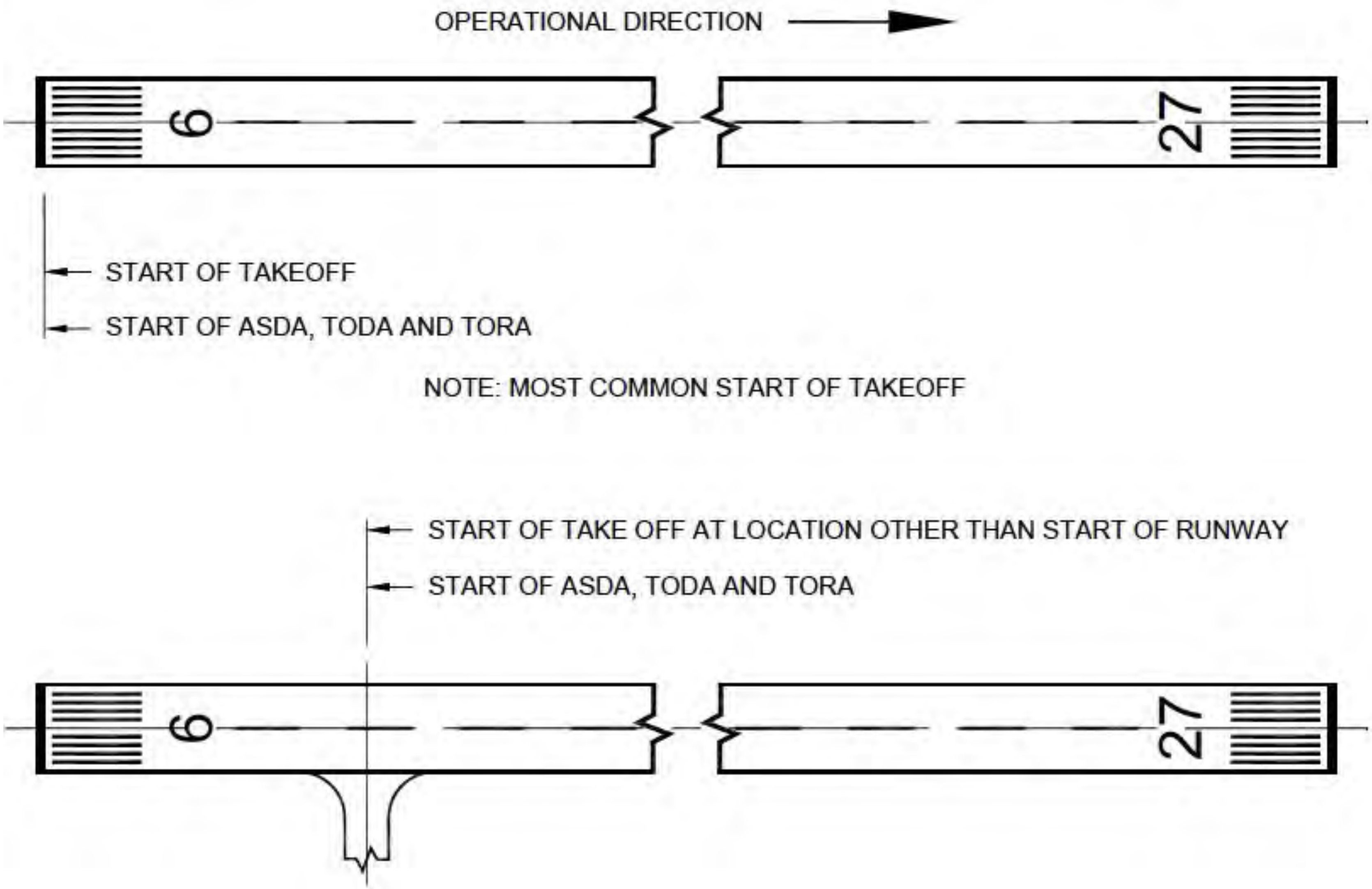
- *“To obtain additional RSA and/or ROFA prior to the runway’s threshold (the start of the LDA) and/or beyond the stop end of the LDA and ASDA”*
- “*To mitigate unacceptable incompatible land uses in the RPZ, to meet runway approach and/or departure surface clearance requirements, in “*
- *“To mitigate environmental impacts”*

Paragraph 323 in FAA AC 150/5300-13A

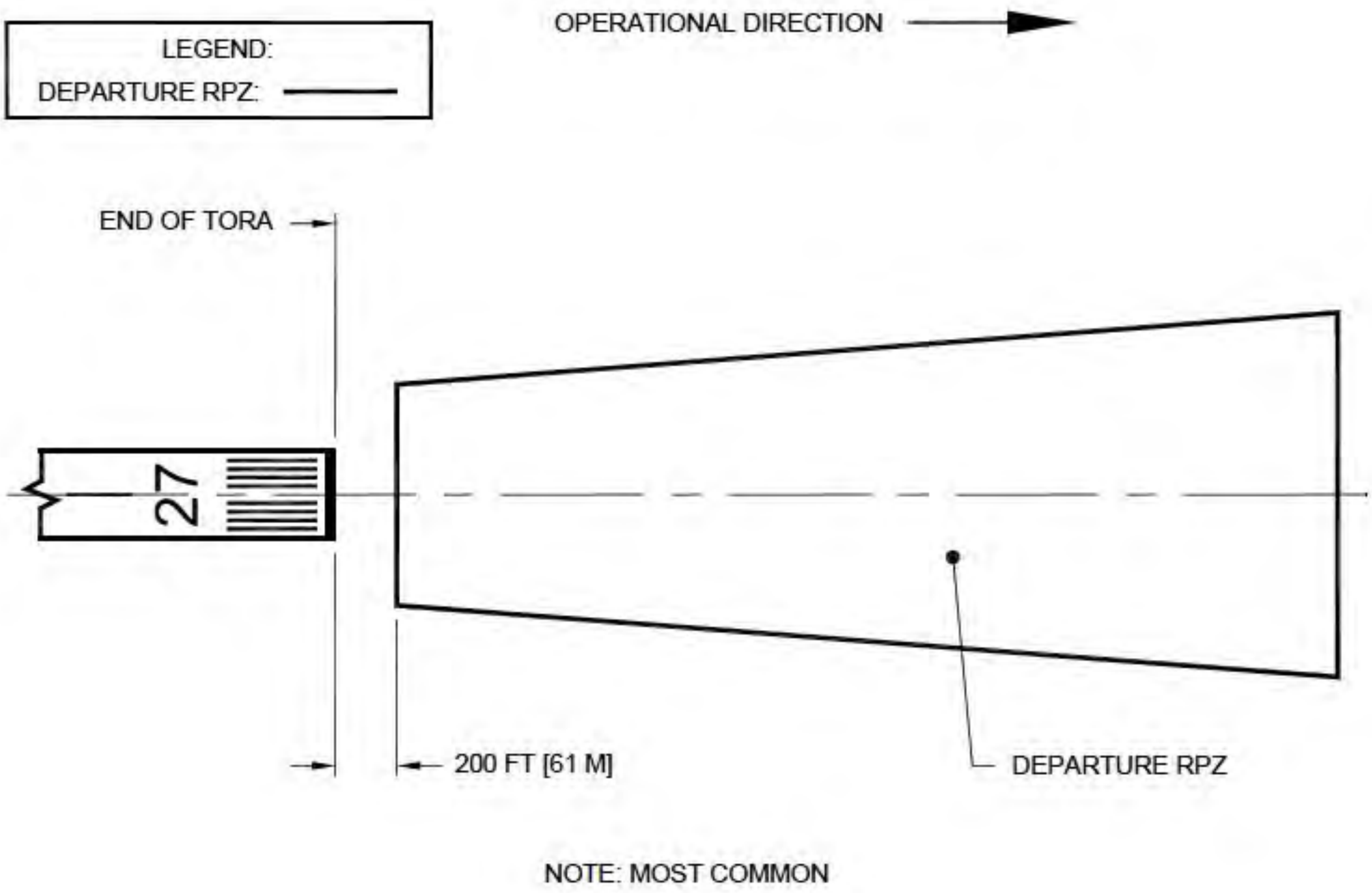
Issues to Consider

- Declared distances may:
  - *"Limit or increase runway use"*
  - *"Result in a displaced runway threshold"*
  - *"May affect the beginning and ending of the RSA, ROFA, and RPZ"*
- *"For runways without published declared distances, the declared distances are equal to the physical length of the runway unless there is a displaced threshold"*

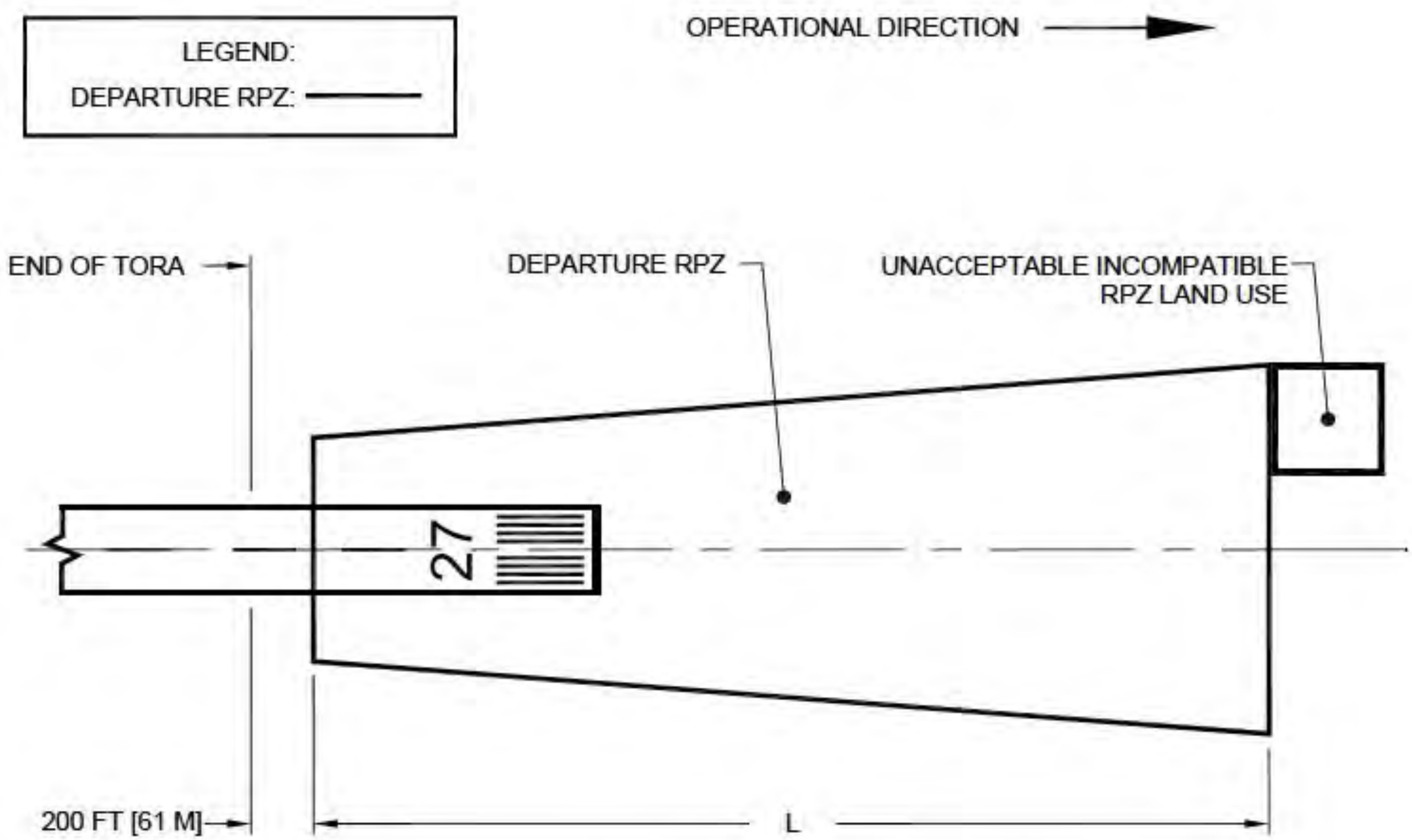
Location of Starting Point of Accelerate-Stop Distance Available (ASDA), TODA, and TORA



Normal Location of Departure End of TORA

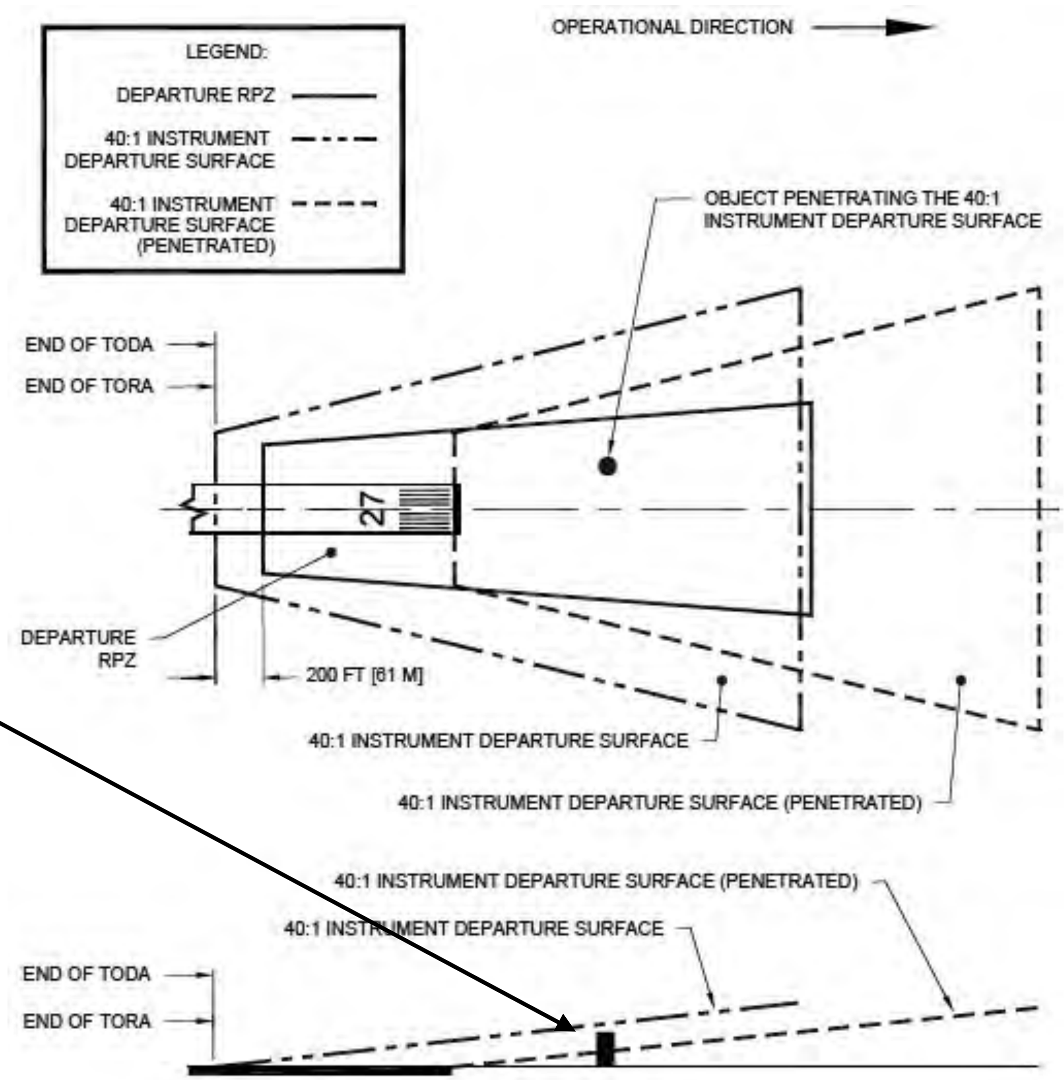


Departure End of TORA Based on Departure RPZ Located to Mitigate Unacceptable Incompatible Land Use

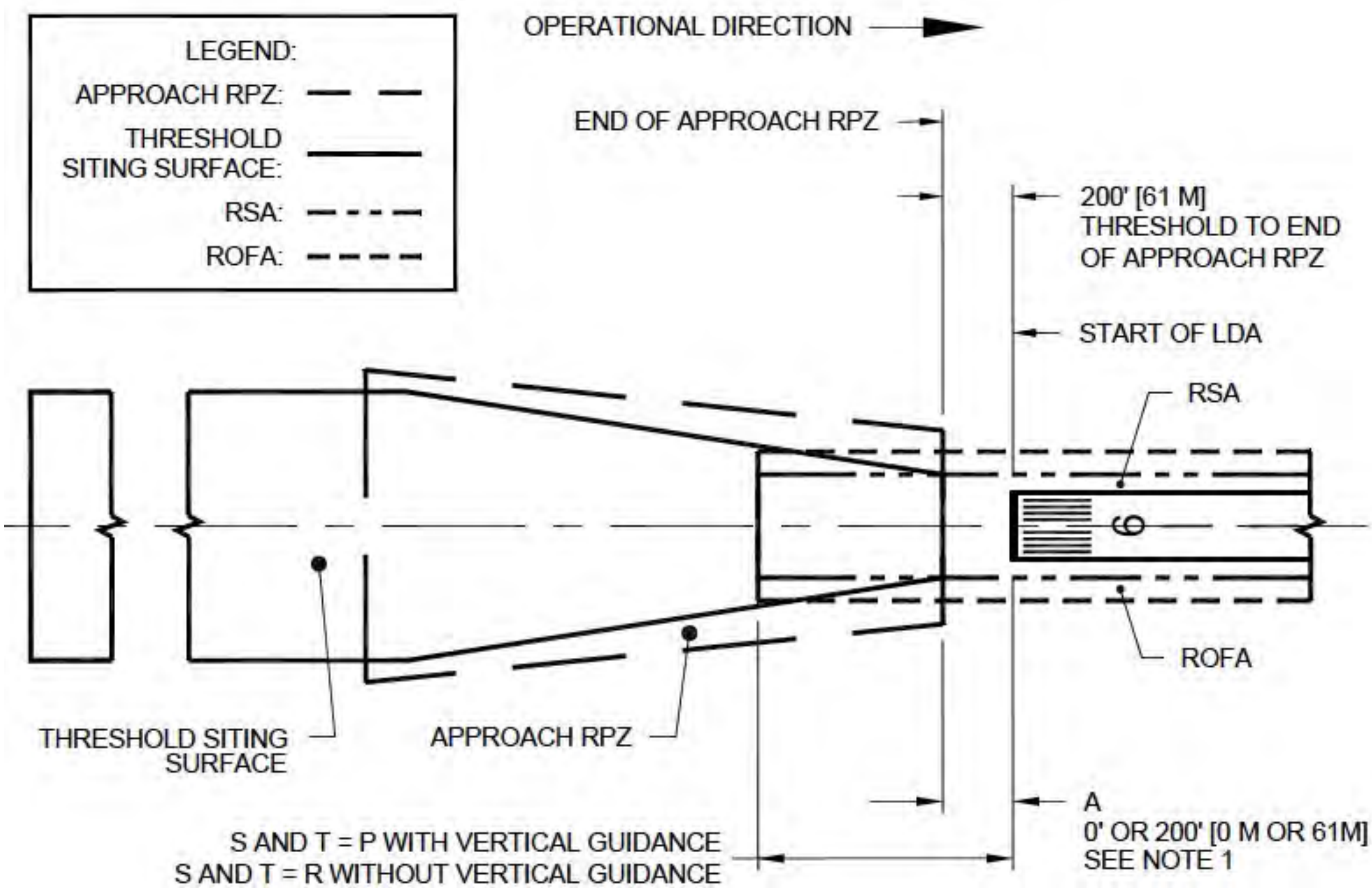


TODA Shortened to Mitigate Penetration to the Departure Surface Resulting in Shortened TORA

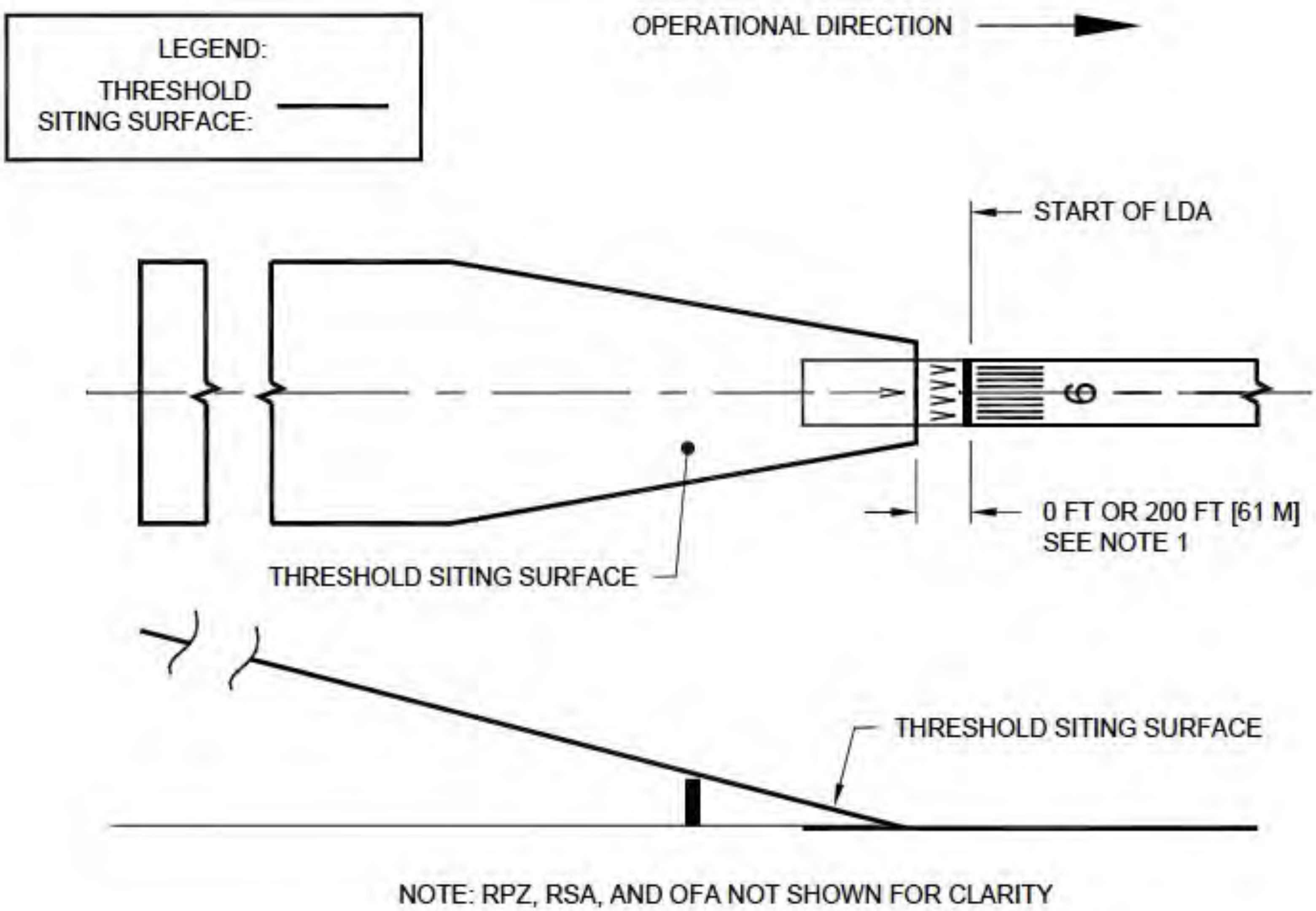
Incompatible item (normally an obstruction)



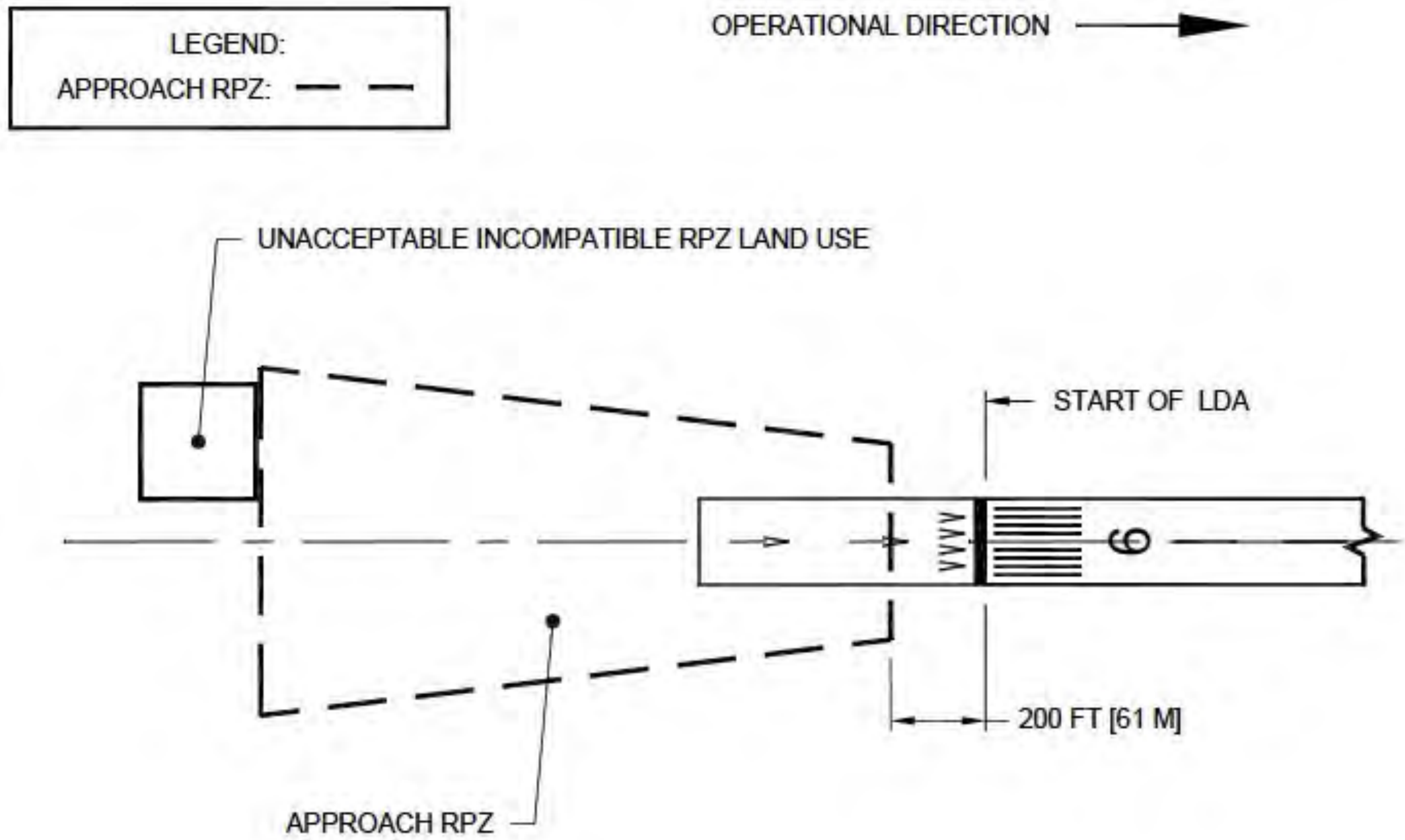
Normal Starting Point of the LDA



Start of LDA at Displaced Threshold Based on Threshold Siting Surface (TSS)

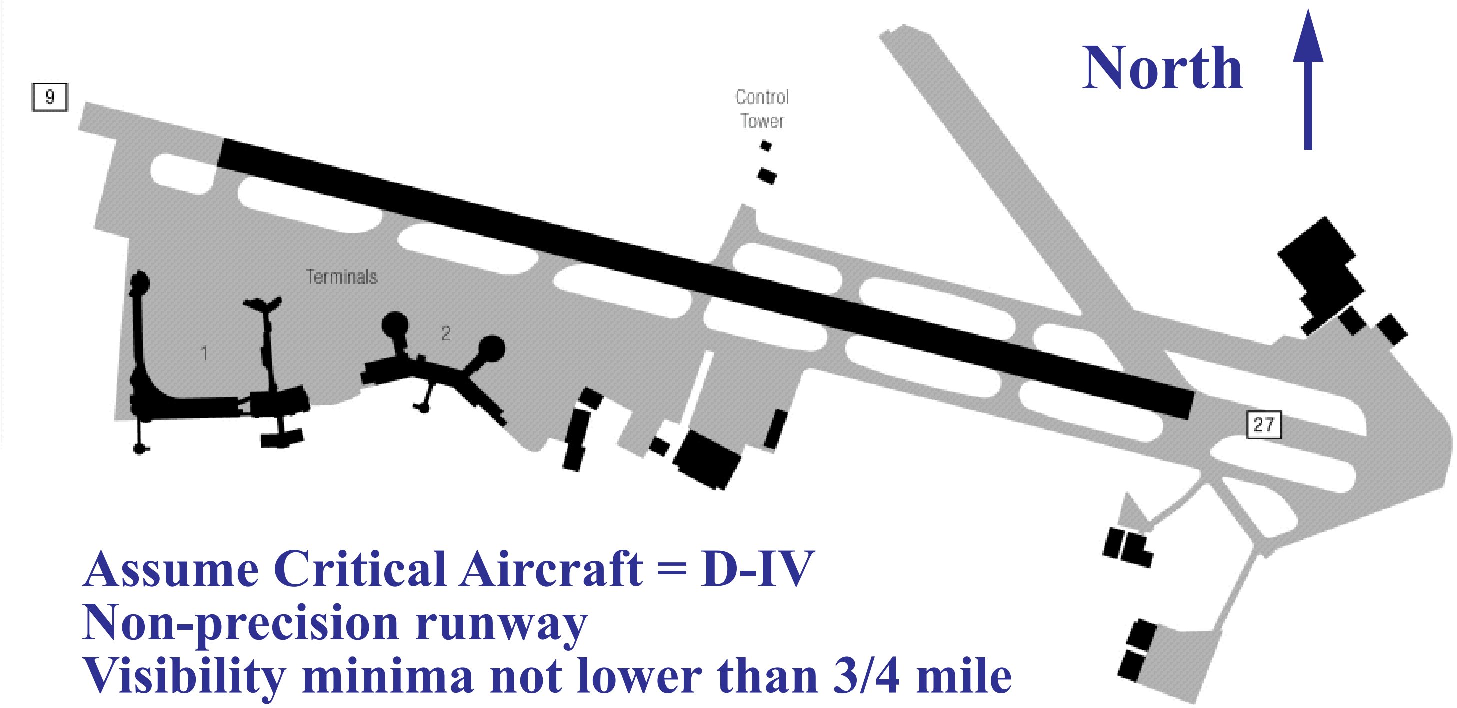


Start of LDA at Displaced Threshold Based on Approach RPZ Located to Mitigate Unacceptable Incompatible Land Use



THRESHOLD SITING SURFACE, OFA AND RSA NOT SHOWN FOR CLARITY

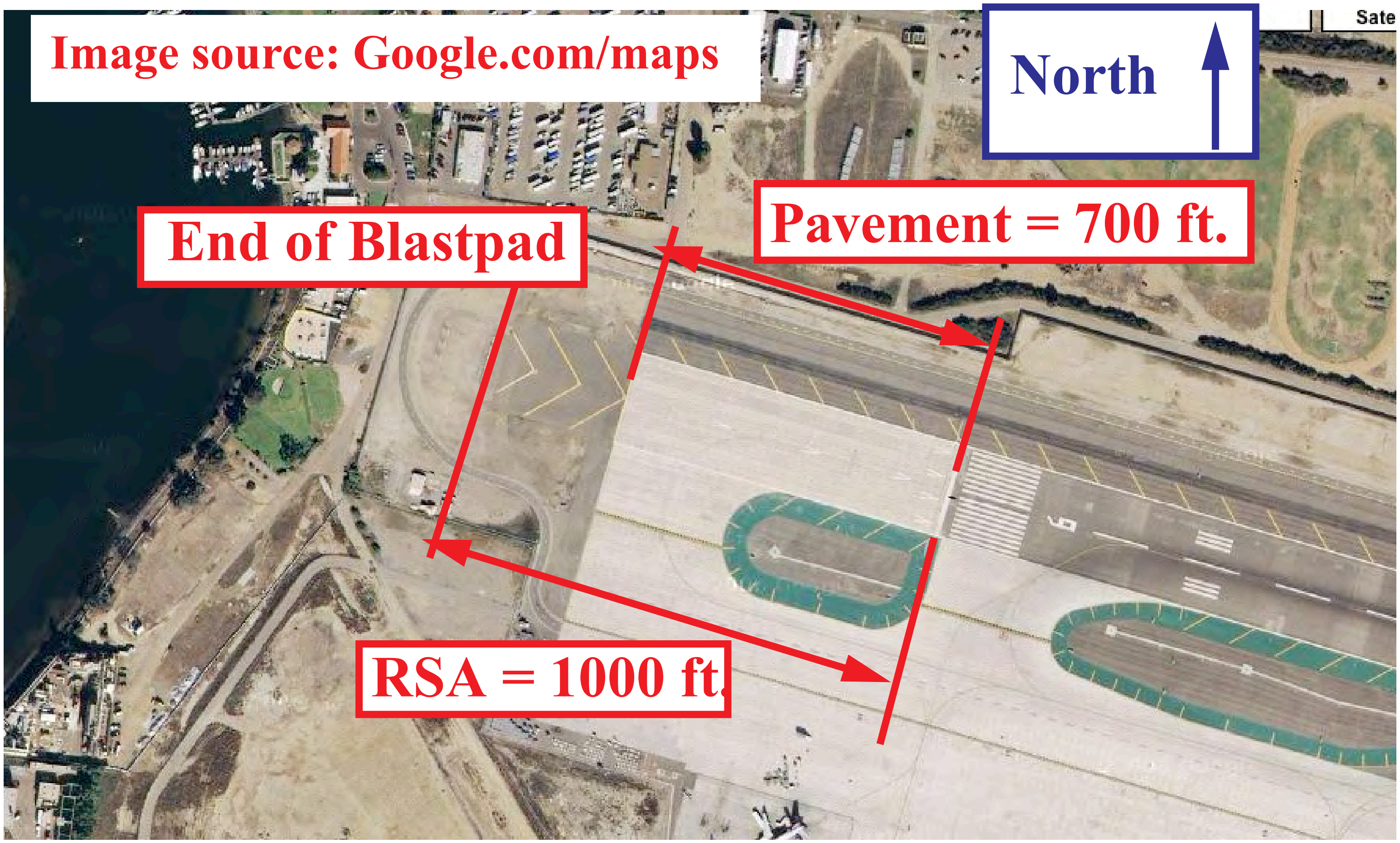
Example - San Diego International Airport



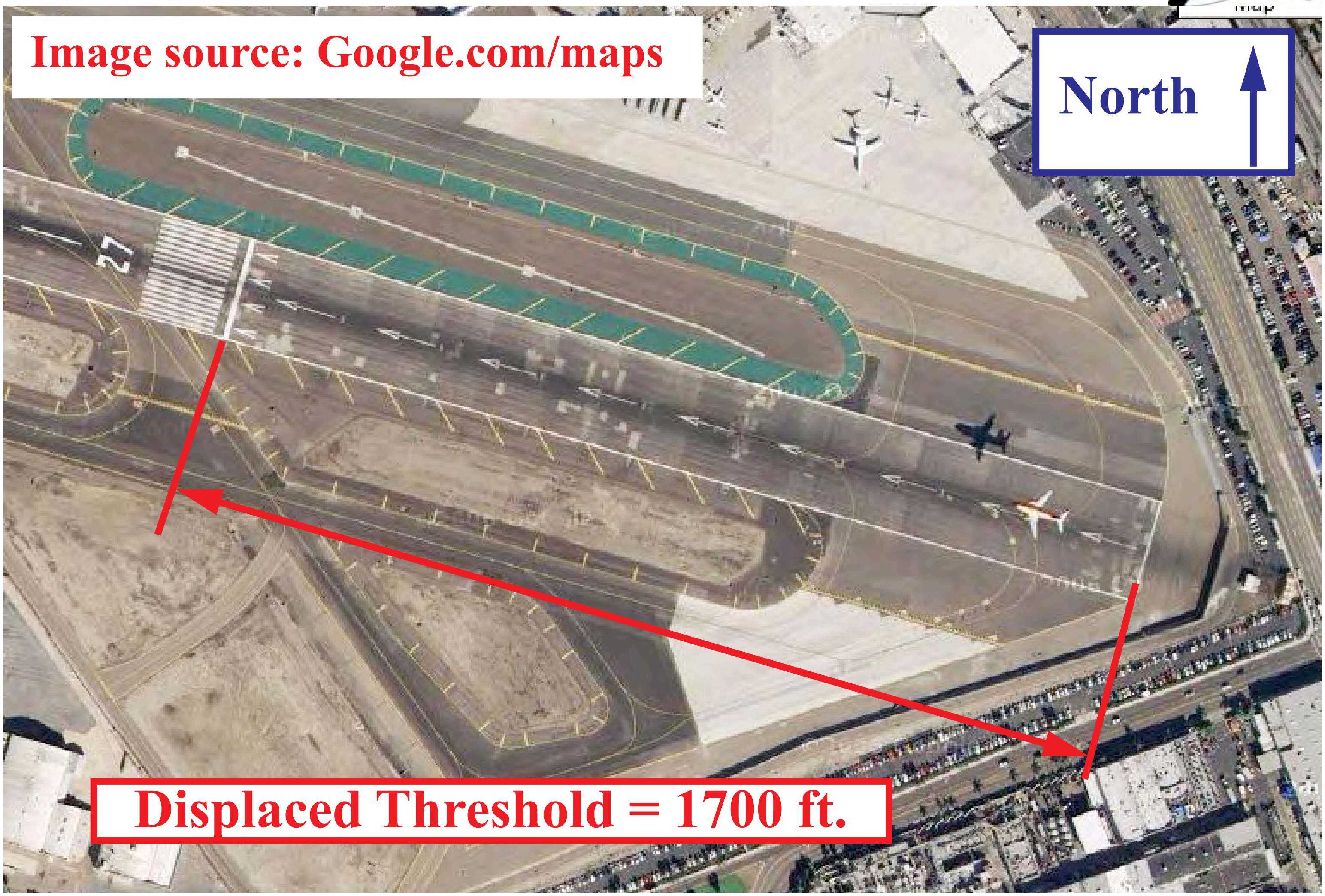
Assume Critical Aircraft = D-IV
Non-precision runway
Visibility minima not lower than 3/4 mile

Runway Length = 9400 ft.
Two displaced thresholds (09 end and 27 end)

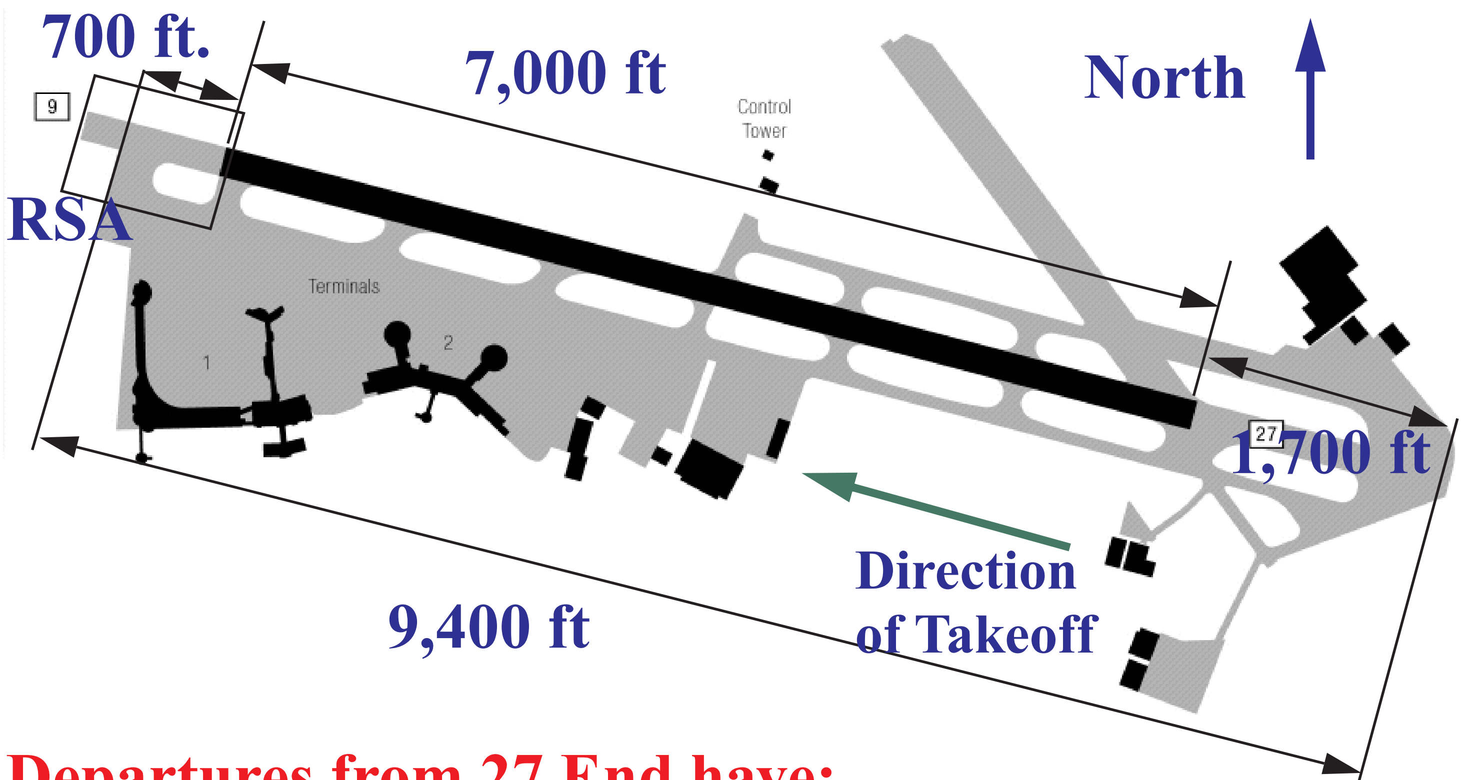
Example - SAN Runway 09 End



Example - SAN Runway 27 End



Example - San Diego International Airport

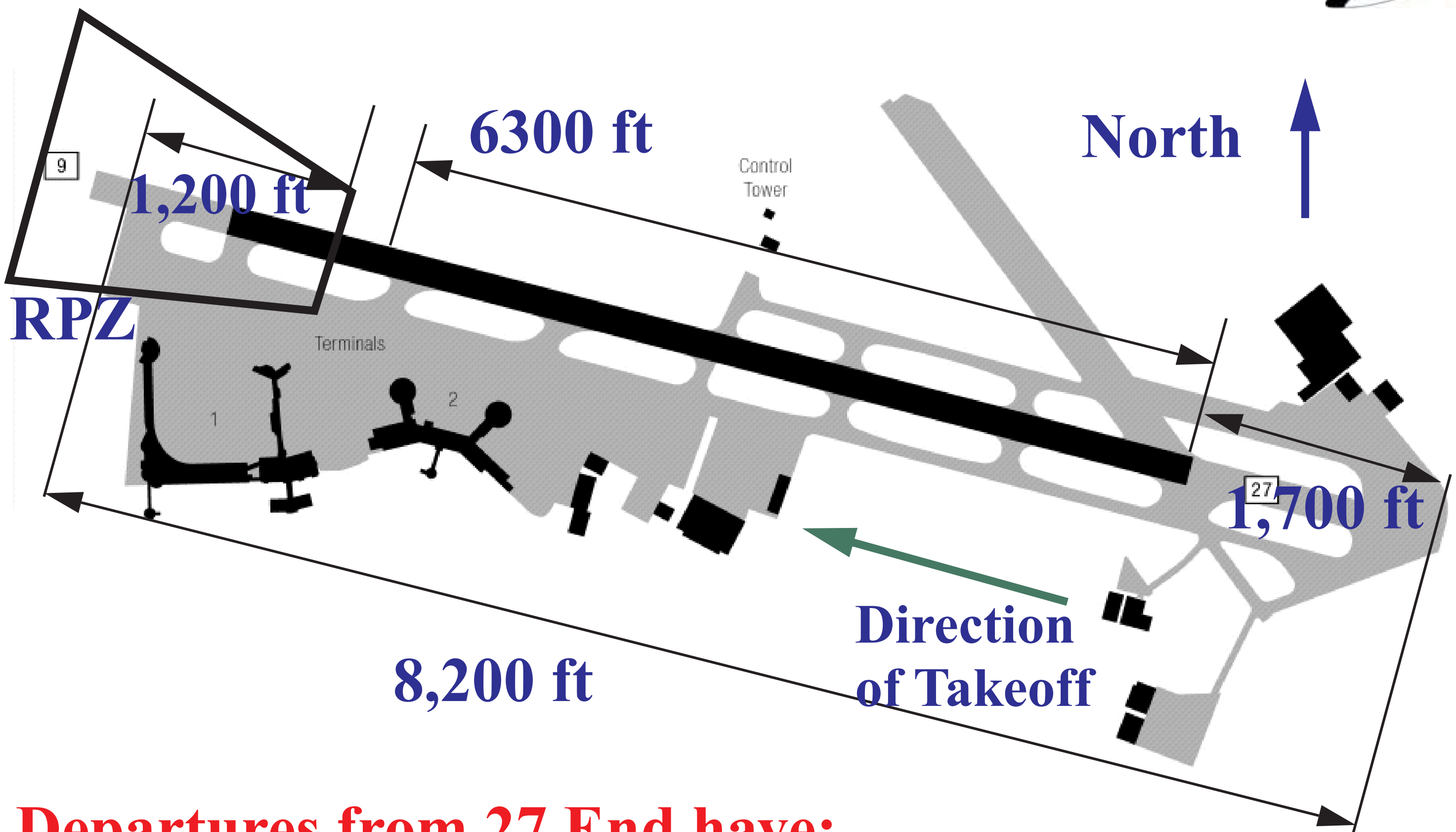


Departures from 27 End have:

Takeoff Distance Available (TODA) = 1700 + 7000 + 700 = 9400 ft.

Accelerate and Stop Distance Available (ASDA) = 8700 ft.

Example - San Diego International Airport

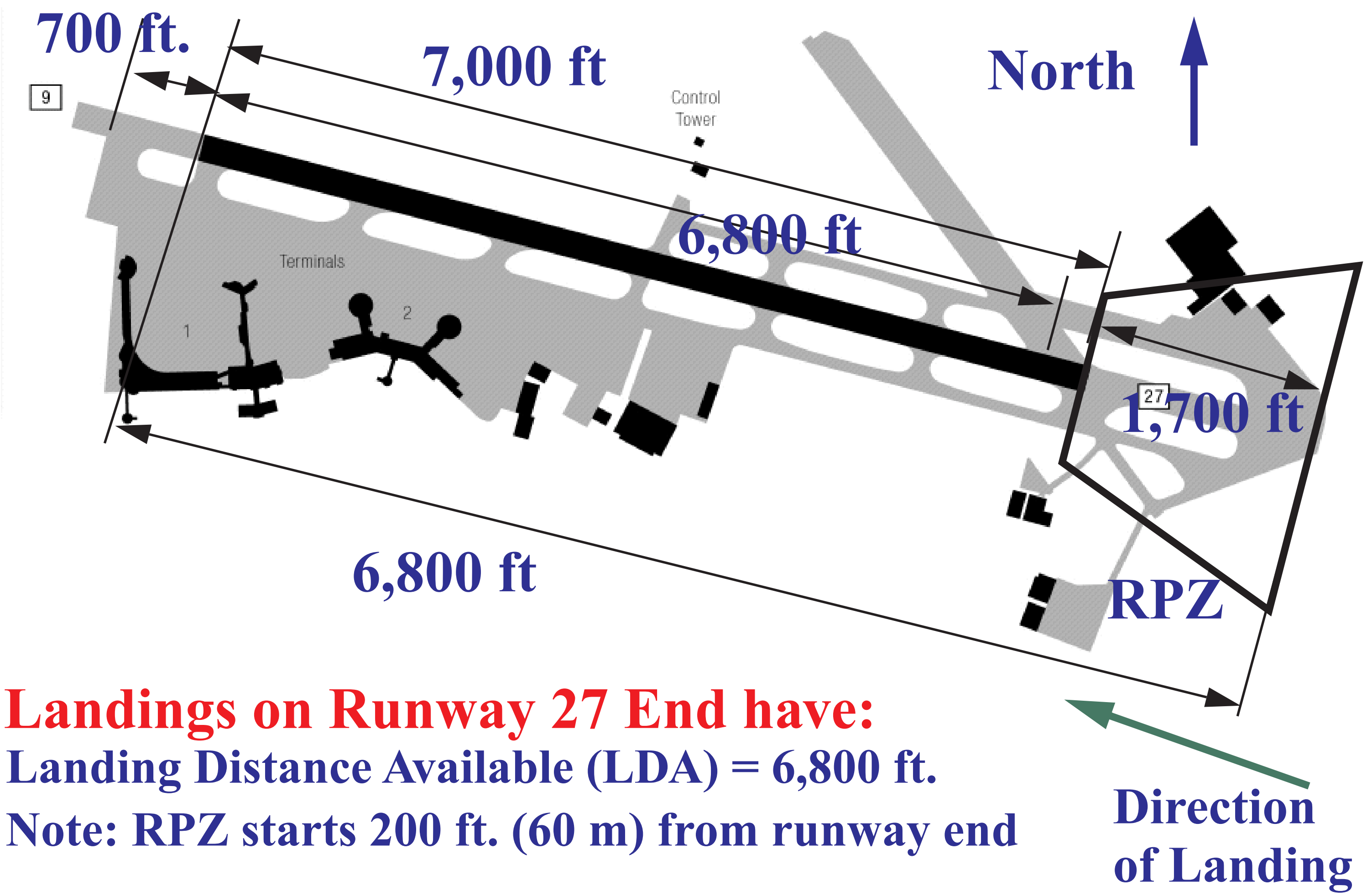


Departures from 27 End have:

Takeoff Run Available (TORA) = 1700 + 6300 = 8000 ft.

Accelerate and Stop Distance Available (ASDA) = 8700 ft.

Example - San Diego International Airport



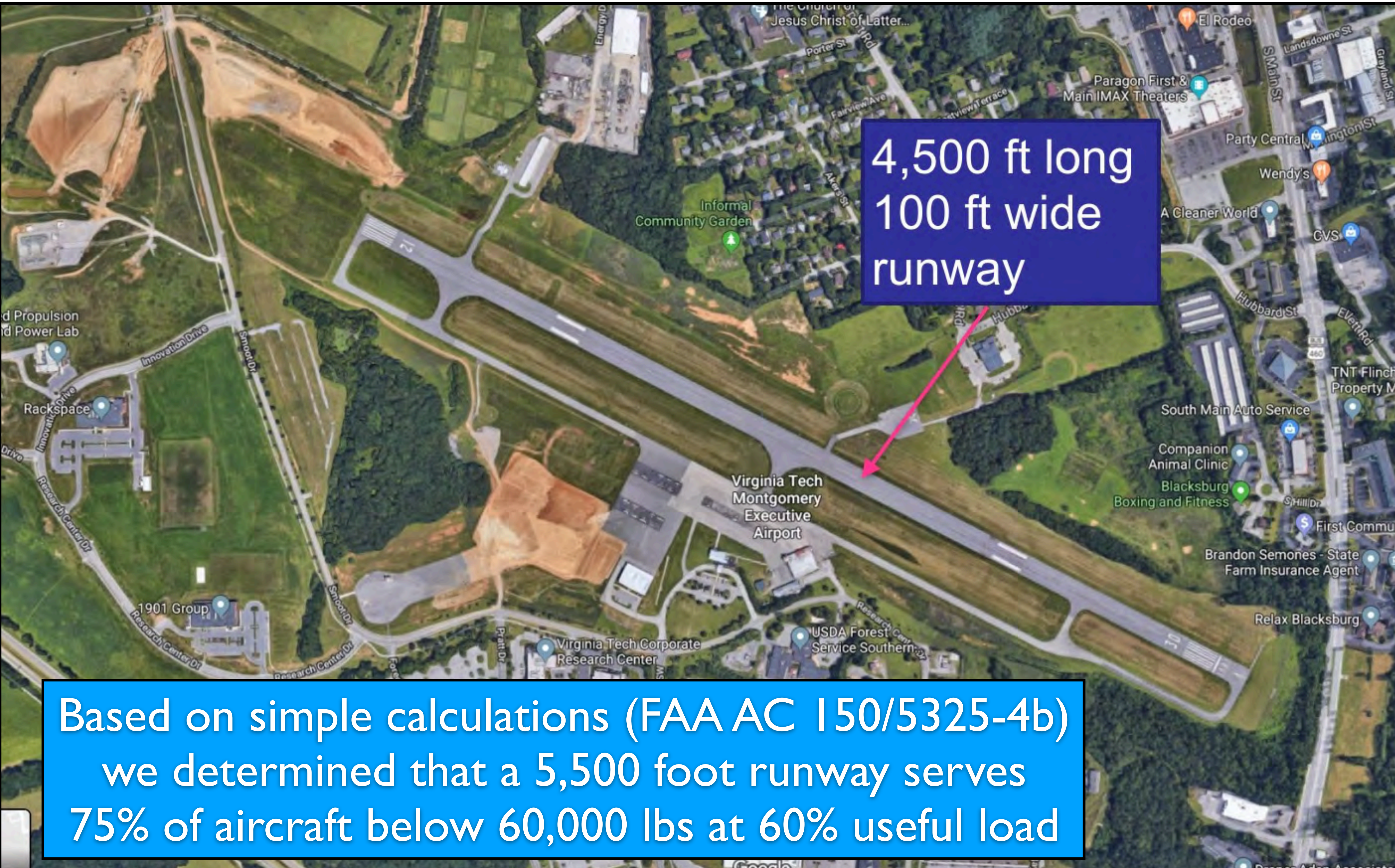
Landings on Runway 27 End have:

Landing Distance Available (LDA) = 6,800 ft.

Note: RPZ starts 200 ft. (60 m) from runway end

Example to Illustrate the Implications of Changing RDC Criteria at an Airport

Old Virginia Tech Airport (BCB)



Based on simple calculations (FAA AC 150/5325-4b) we determined that a 5,500 foot runway serves 75% of aircraft below 60,000 lbs at 60% useful load

Example: BCB Improvements

- Airport: BCB (Blacksburg)
- Issue: Improve the airport to serve 75% of the aircraft population < 60,000 lbs and 60% of useful load
  - Airport elevation = 2,132 feet
  - Mean daily maximum temperature of the hottest month of the year = 83 °F
  - Obtained from average high temperatures on the weather channel (or at NOAA)

Last year BCB extended the runway by 1,000 feet
RDC changed from B-II to C-II

Moving from RDC B-II to C-II

Operating Larger/Faster Business Jets Changes the Runway Safety Standards

Table 3-5. Runway design standards matrix

Aircraft Approach Category (AAC) and Airplane Design Group (ADG): *(select from pull-down menu at right)* — **B – II**

ITEM	DIM[1]	Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
Runway Design					
Runway Length	A		*Refer to paragraphs 302 and 304*		
Runway Width	B	75 ft	75 ft	75 ft	100 ft
Shoulder Width		10 ft	10 ft	10 ft	10 ft
Blast Pad Width		95 ft	95 ft	95 ft	120 ft
Blast Pad Length		150 ft	150 ft	150 ft	150 ft
Crosswind Component		13 knots	13 knots	13 knots	13 knots
Runway Protection					
Runway Safety Area (RSA)					
Length beyond departure end [9, 10]	R	300 ft	300 ft	300 ft	600 ft
Length prior to threshold	P	300 ft	300 ft	300 ft	600 ft
Width	C	150 ft	150 ft	150 ft	300 ft
Runway Object Free Area (ROFA)					
Length beyond runway end	R	300 ft	300 ft	300 ft	600 ft
Length prior to threshold	P	300 ft	300 ft	300 ft	600 ft
Width	Q	500 ft	500 ft	500 ft	800 ft

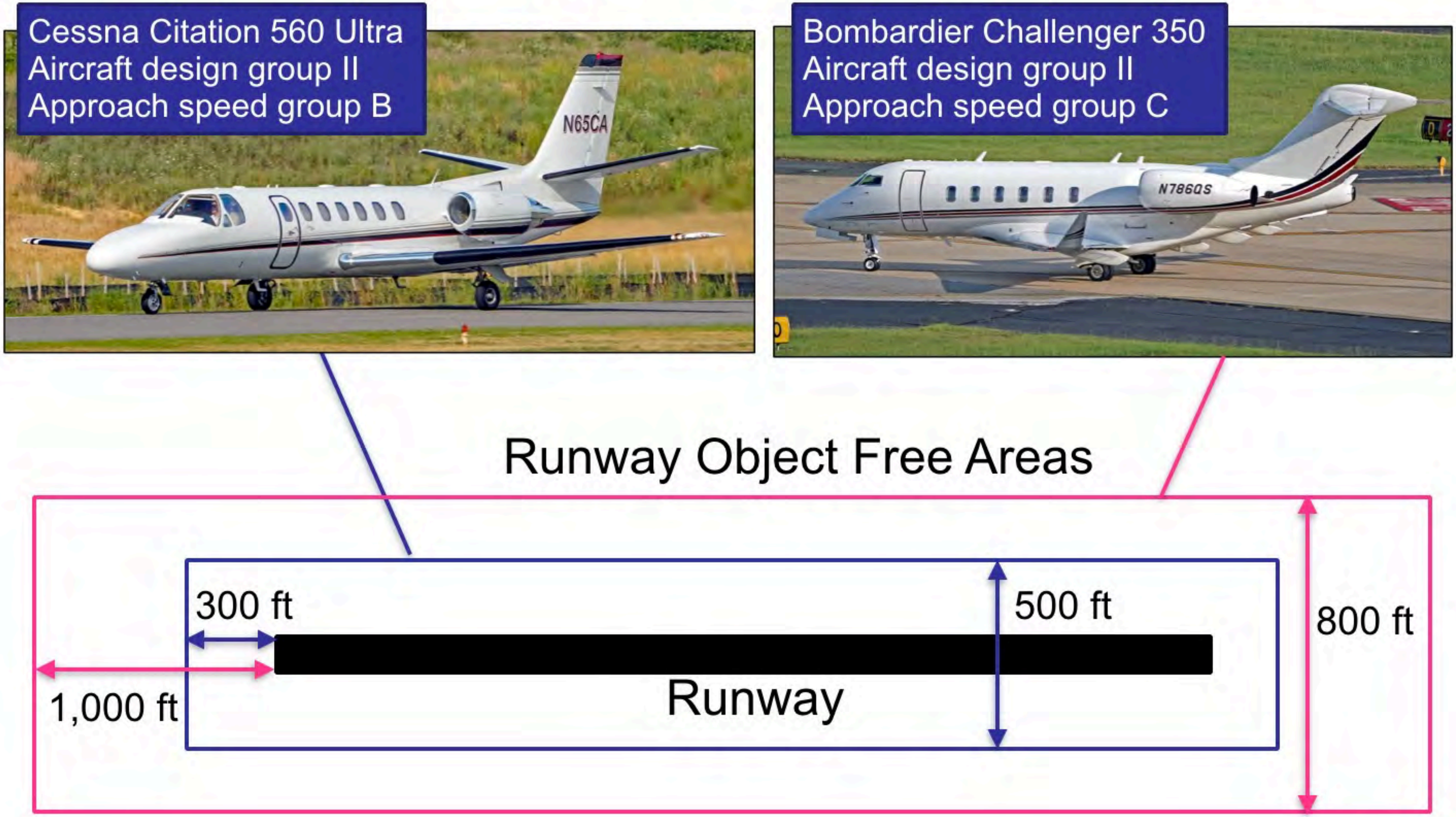
Table 3-5. Runway design standards matrix

Aircraft Approach Category (AAC) and Airplane Design Group (ADG): *(select from pull-down menu at right)* — **C – II**

ITEM	DIM[1]	Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
Runway Design					
Runway Length	A		*Refer to paragraphs 302 and 304*		
Runway Width	B	100 ft	100 ft	100 ft	100 ft
Shoulder Width		10 ft	10 ft	10 ft	10 ft
Blast Pad Width		120 ft	120 ft	120 ft	120 ft
Blast Pad Length		150 ft	150 ft	150 ft	150 ft
Crosswind Component		16 knots	16 knots	16 knots	16 knots
Runway Protection					
Runway Safety Area (RSA)					
Length beyond departure end [9, 10]	R	1000 ft	1000 ft	1000 ft	1000 ft
Length prior to threshold [11]	P	600 ft	600 ft	600 ft	600 ft
Width [13]	C	500 ft	500 ft	500 ft	500 ft
Runway Object Free Area (ROFA)					
Length beyond runway end	R	1000 ft	1000 ft	1000 ft	1000 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

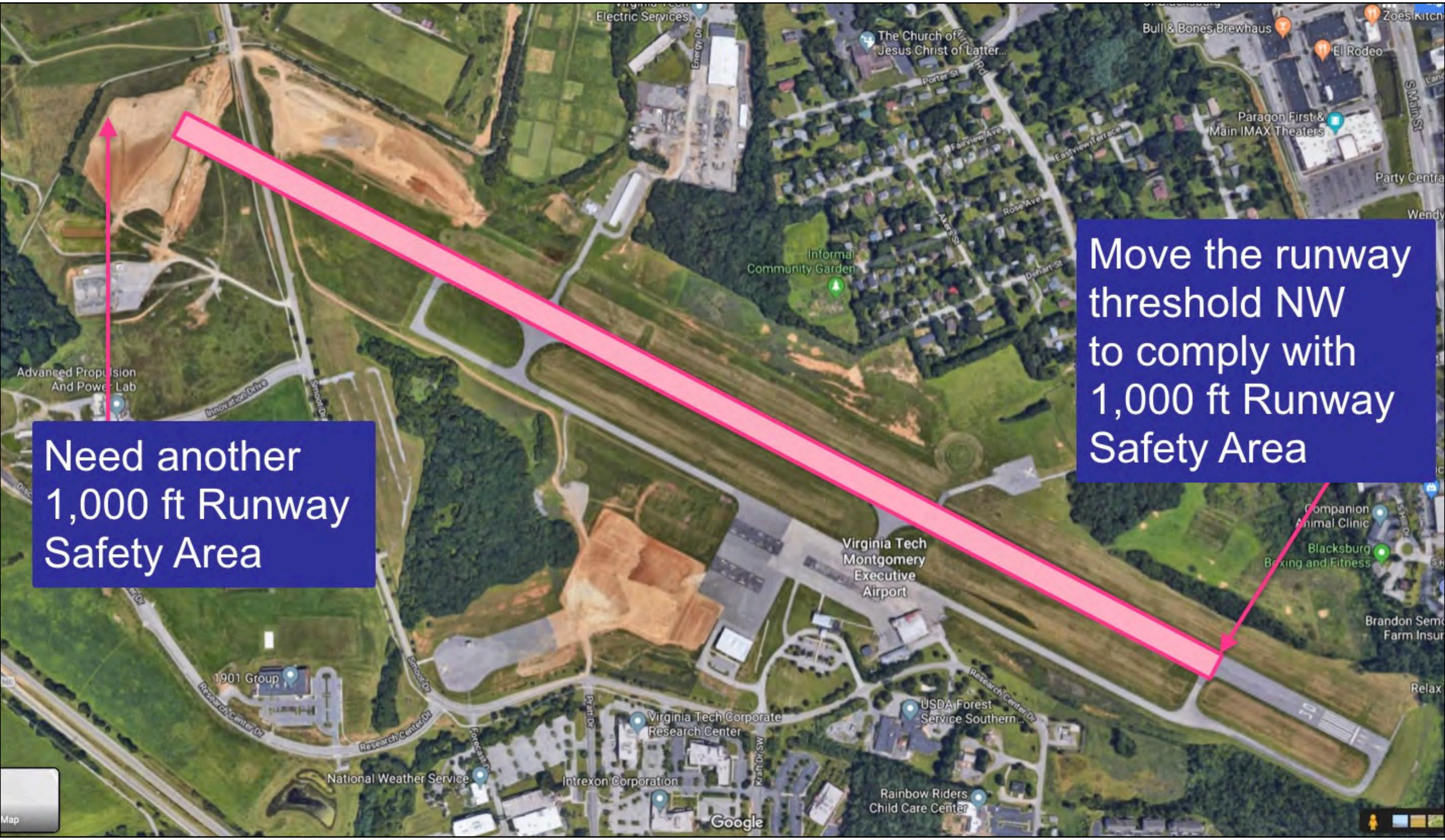
Runway OFZ for RDC B-II and C-II

Larger/Faster Aircraft Require Longer Runway Safety Areas



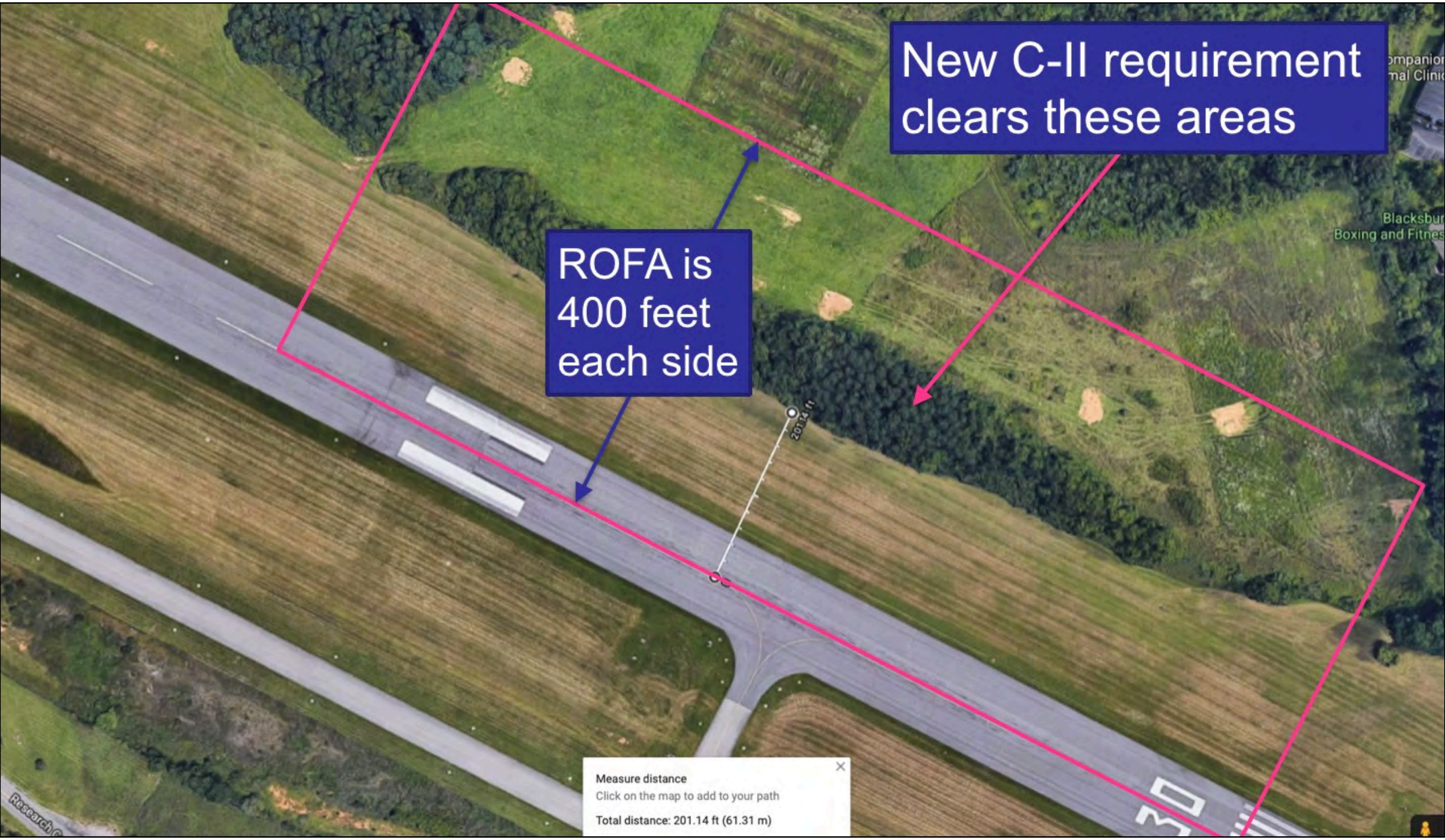
Runway Safety Area (Southeast Side)

Runway Safety Area (Southeast Side)



Runway Object Free Zone Impact

Virginia Tech
Invent the Future



Runway Object Free Zone Impact

Runway Object Free Zone Impact

Runway Object Free Zone Impact

Runway Safety Area Construction

Runway Extension Construction

Challenge: Keep Airport Open during Construction

Challenge: Keep Airport Open during Construction

Airport Closed for two Months in the Final Stage of Construction

Upgrade to Runway Safety Areas

Upgrade to Runway Safety Areas Impacts Others Elements (like Drainage)

Conclusion

- Changes to RDC design criteria can produce large civil construction project at the airport
- Runway extension projects to satisfy new runway design criteria may impact daily operations
  - Taxiway and runway closures
  - Airport closures
- Runway extension programs produce many changes needed to related runway systems
  - Navigational aids
  - New pavement areas
  - Drainage