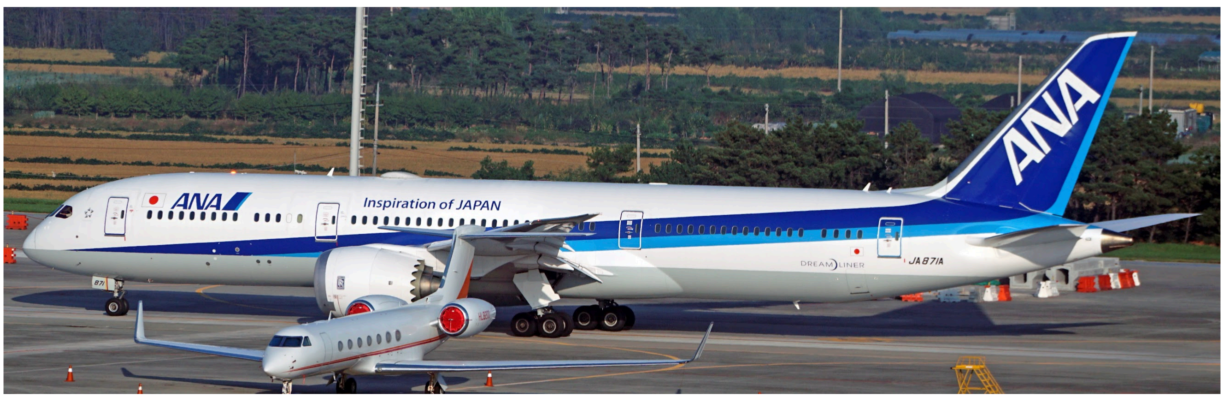
Assignment 3: Aircraft Performance Calculations

Solution Instructor: TraniProblem 2

An airline is evaluating two aircraft to operate flights from Colorado Springs Airport (COS) Airport. The following table shows the aircraft proposed by Boeing. The airline would like to fly with the selected aircraft to Narita International Airport in Japan (NRT). In your analysis use the latest version of the Boeing documents.

Table 1. Boeing 787-9 and Boeing 787-10 Considered in the Airline Evaluation.

Aircraft Considered
Boeing 787-9 with High-Thrust Rolls-Royce engines (see picture below). The aircraft has a maximum design takeoff weight of 561,500 lb. With 290 seats in a two-class layout. See other characteristics in the Boeing documents for airport planning and design.

Boeing 787-10 with High-Thrust Rolls-Royce engines. Aircraft maximum design takeoff weight is 560,000 lb. 330 seats in a two-class layout. See other characteristics in the Boeing documents for airport planning and design.

Use the Climate Explorer website (https://crt-climate-explorer.nemac.org/climate_graphs) to find the mean maximum temperature of the hottest month of the year. More detailed information about the airport can be found at the AIRNAV database available on the web at: http://www.airnav.com/airports/ or visit the airport site.

Historical temperature = 84 deg. F

Higher emissions = 86.9 deg. F.

COS airport elevation is 6,187 feet (1886 meters)

Longest runway is 13,500 feet

ISA temperature at COS = 36.93 degrees F.

Design condition is ISA + 47.1 deg. F. Use ISA + 45 deg. F.

a) Find if the proposed route can be flown with both aircraft considered. In your analysis use the Great Circle Flight Path mapper link provided in our interesting web sites. Add 6% to the distances calculated to account for real Air Traffic route conditions and to account for possible weather deviations from the optimal Great Circle flight path.

Trip distance = 5,373 nm (adjusted from 5,071 nm). Table 1 shows a summary of the calculations for the Boeing 787-9.

Table 1. Boeing 787-9 Analysis with 100% Load Factor. Maximum design takeoff weight of 561,500 lb (254,692). With 290 seats in a two-class layout.		
Parameter	Kilograms	Pounds
OEW	127,300	280,060
PYL	29,000	63,800
OEW + PYL	156,300	343,860
DTW	222,000	488,400
FW	65,700	144,540
Passengers	290	
Fuel/passenger	227	498
Runway Length (takeoff)	**13,700 feet**	**13,700 feet**
Runway Length (Landing)	8,000 feet	8,000 feet
Route Distance	5375	
Average SAR (nm/kg)	0.0818	

b) Find the runway length needed for each one of the aircraft flying the COS-NRT route. Determine if Colorado Springs has enough runway length to support flights with all seats full.

The runway is 13,500 feet. 13,700 feet is needed (see Figure 3) for the Boeing 787-9 to operate from Colorado Springs. Technically, a runway extension would be needed if the airline wants to operate such service.

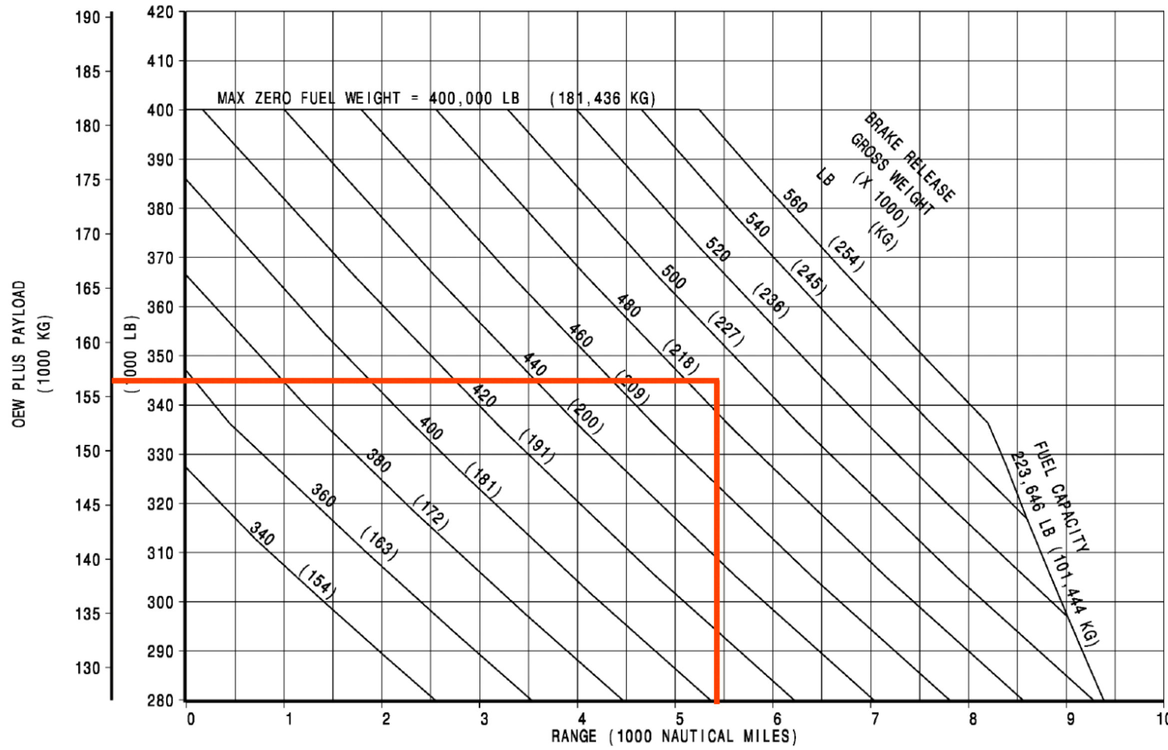


Figure 2. Payload-Range Diagram Boeing 787-9. DTW ~ 222,000 kilograms.

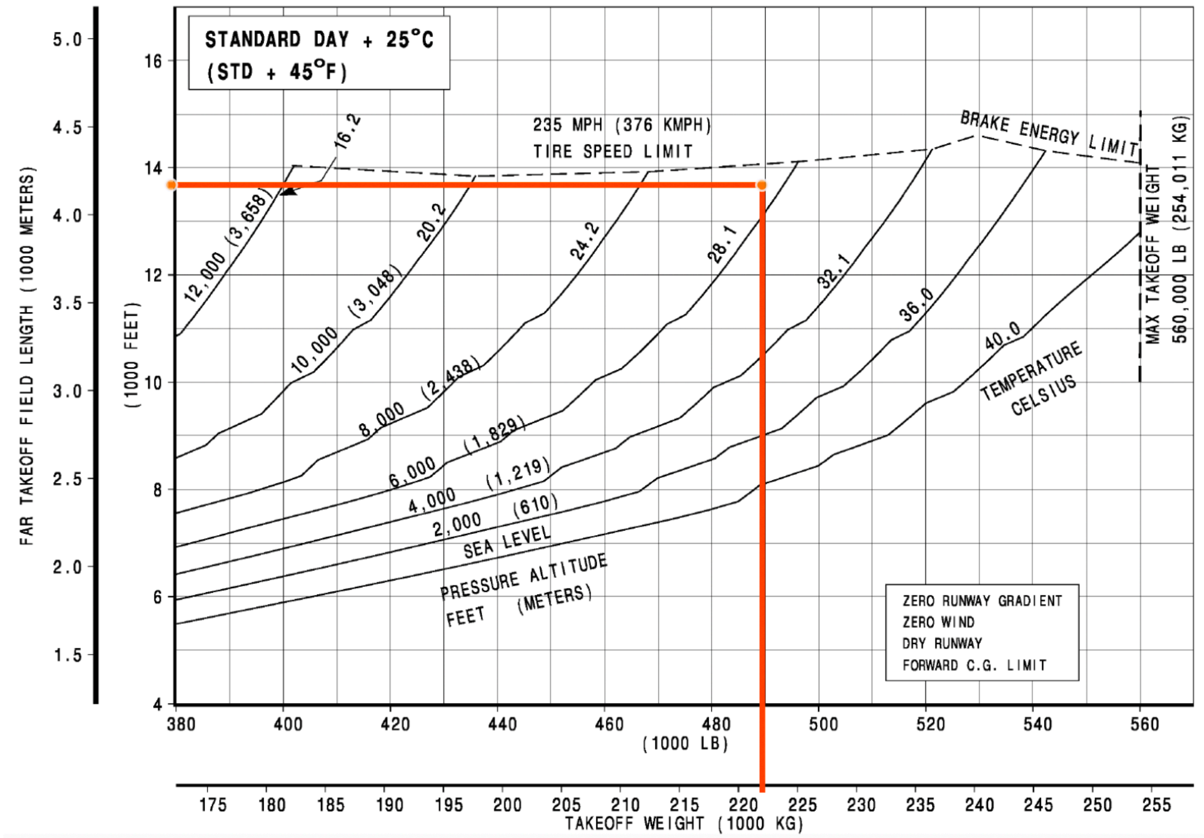


Figure 3. Takeoff Field Length for Boeing 787-9. ISA + 45 deg. F. Performance Chart. High-Thrust Engines. Takeoff from Colorado Springs at 222,000 kilograms.

Table 2. Boeing 787-10 Analysis with 100% Load Factor. High-Thrust Rolls-Royce engines. Aircraft maximum design takeoff weight is 560,000 lb. 330 seats in a two-class layout.		
Parameter	Kilograms	Pounds
OEW	136,364	300,000
PYL	33,000	72,600
OEW + PYL	169,364	372,600
DTW	240,000	528,000
FW	70,636	155,400

Table 2. Boeing 787-10 Analysis with 100% Load Factor. High-Thrust Rolls-Royce engines. Aircraft maximum design takeoff weight is 560,000 lb. 330 seats in a two-class layout.		
Parameter	Kilograms	Pounds
Passengers	330	
Fuel/passenger	214	471
Runway Length (takeoff)	**Cannot operate at 240,000 kgs. At any condition**	**Cannot operate at 240,000 kgs. At any condition**
Runway Length (Landing)	8,300 feet	8,300 feet
Route Distance	5375	
Average SAR (nm/kg)	0.0761	

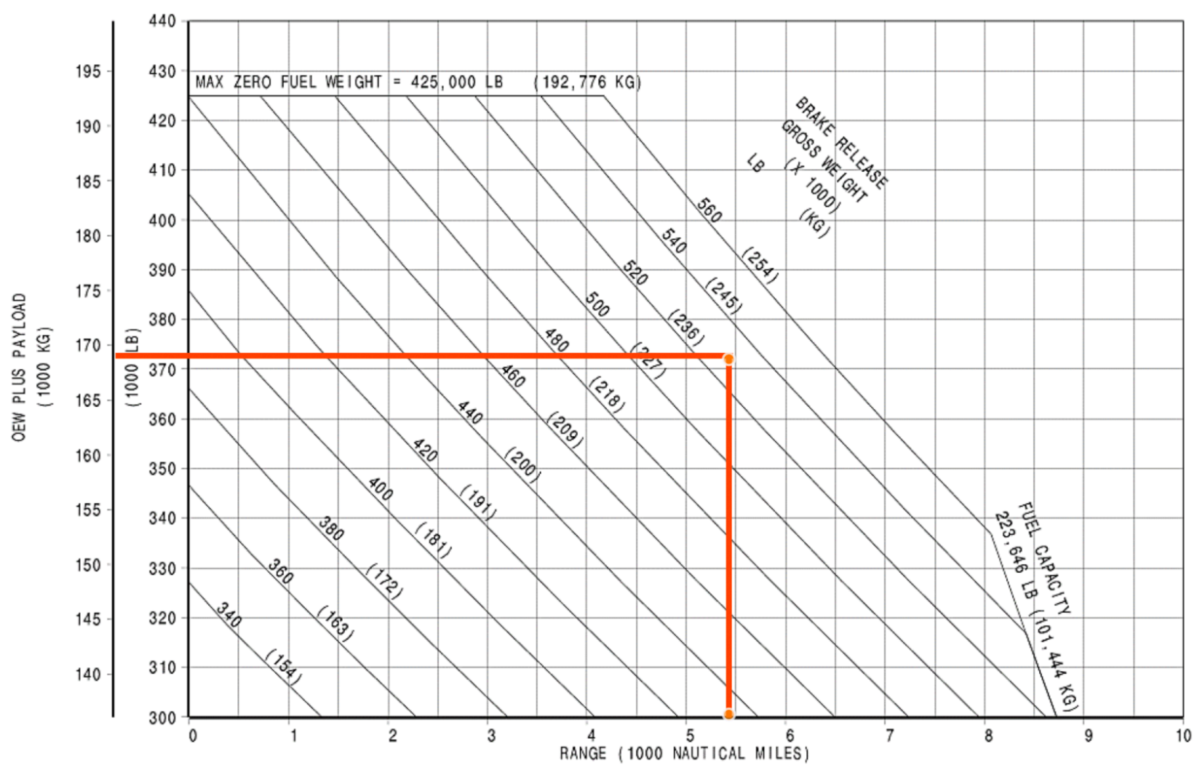


Figure 4. Payload-Range Diagram Boeing 787-10. Estimated Desired Takeoff Weight is 240,000 kilograms.

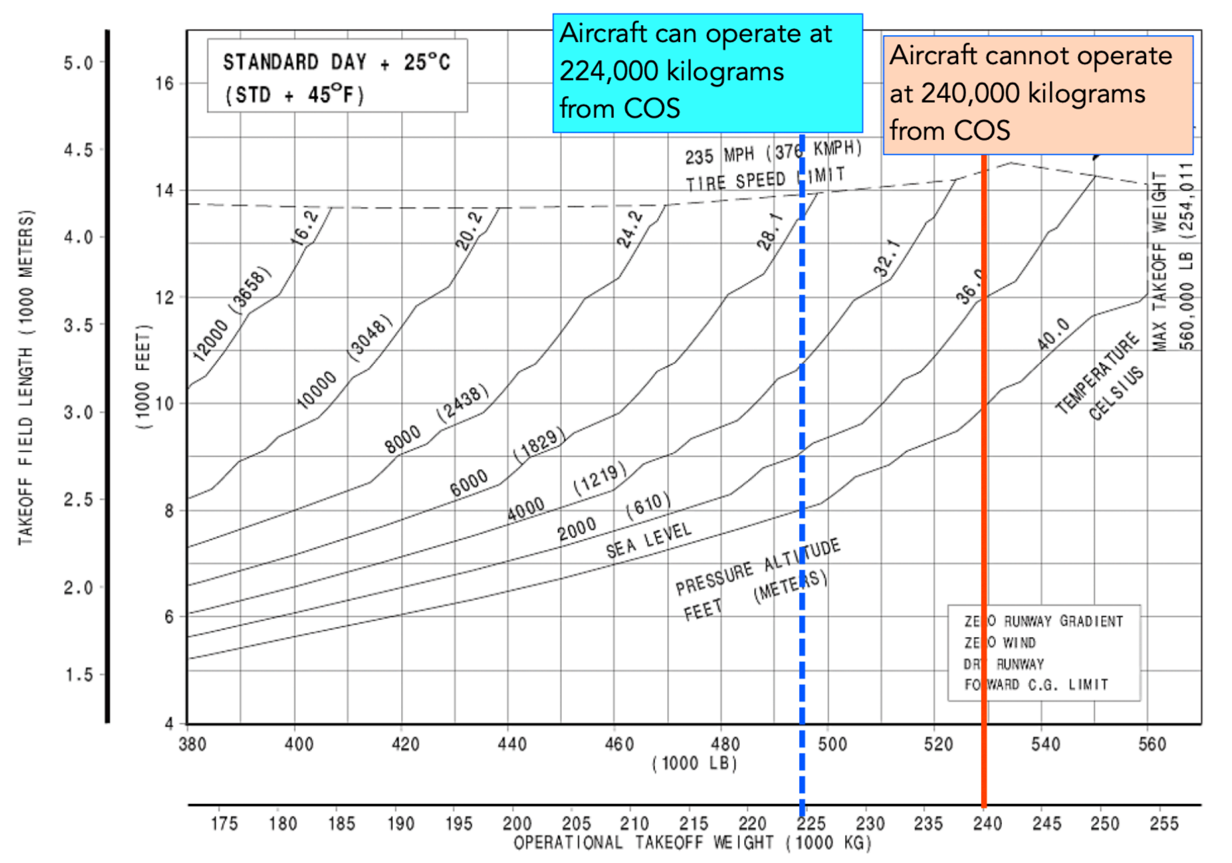


Figure 5. Takeoff Field Length for Boeing 787-10. ISA + 45 deg. F. Performance Chart. High-Thrust Engines.

c) Repeat part (b) assuming a load factor of 0.85 (85% of the seats used).

The Boeing 787-9 can execute the flight with 85% load factor from COS. The runway needed is estimated to be 11,800 feet (see Table 3).

Table 3. Boeing 787-9 Analysis with 85% Load Factor. Maximum design takeoff weight of 561,500 lb (254,692). With 247 Passengers.

Parameter	Kilograms	Pounds
OEW	127,300	280,060
PYL	24,650	54,230
OEW + PYL	151,950	334,290
DTW	216,000	475,200

Table 3. Boeing 787-9 Analysis with 85% Load Factor. Maximum design takeoff weight of 561,500 lb (254,692). With 247 Passengers.		
Parameter	Kilograms	Pounds
FW	64,050	140,910
Passengers	247	
Fuel/passenger	260	572
Runway Length (takeoff)	**11,800 feet**	**11,800 feet**
Runway Length (Landing)	8,000 feet	8,000 feet
Route Distance	5375	
Average SAR (nm/kg)	0.0839	

Table 4. Boeing 787-10 Analysis with 85% Load Factor. High-Thrust Rolls-Royce engines. Aircraft maximum design takeoff weight is 560,000 lb. 330 seats in a two-class layout. 281 Passengers.		
Parameter	Kilograms	Pounds
OEW	136,364	300,000
PYL	28,050	61,710
OEW + PYL	164,414	361,710
DTW	234,000	514,800
FW	69,586	153,090
Passengers	281	
Fuel/passenger	248	546
Runway Length (takeoff)	**Cannot operate at 234000 kilograms from COS. The tire speed limit is exceeded.**	**Cannot operate at 234000 kilograms from COS. The tire speed limit is exceeded.**

Table 4. Boeing 787-10 Analysis with 85% Load Factor. High-Thrust Rolls-Royce engines. Aircraft maximum design takeoff weight is 560,000 lb. 330 seats in a two-class layout. 281 Passengers.		
Parameter	Kilograms	Pounds
Runway Length (Landing)	8,300 feet	8,300 feet
Route Distance	5375	
Average SAR (nm/kg)	0.0772	

d) If the aircraft carries 85% of the seats full, can the flight carry additional belly cargo as payload from the existing longest runway at COS?

The Boeing 787-9 could ~3500 kilograms in cargo within the 13,500 feet of runway available at COS. The estimated departure weight would be 219,500 kilograms.

e) Using the Payload-Range diagram of each aircraft, to find the fuel needed to fly the route. Find the Specific Air Range (SAR) parameter for each aircraft. Comment on the SAR values calculated.

The SAR values are included in each table.

f) Considering various factors such as payload, fuel economy, and potential of additional belly cargo, which aircraft is the best for this airline? Explain.

The Boeing 787-9 is the only alternative to operate from COS with 85% load factor. The COS runway would have to be extended another 200 feet allowing 100% load factor operations to NRT.

Problem 2

A new low-cost airline is evaluating The Airbus A220-300 to operate flights from a variety of airports including Roanoke-Blacksburg Regional (ROA). The airline would like your help to evaluate the A220-300 with the Pratt and Whitney PW1524G or with the lower thrust PW1521G.

Figure 6. Airbus A220-300 140 seat configuration. Maximum takeoff weight is 149,000 lbs.

The design airport temperature used should be the average of the maximum daily temperatures of the hottest month of the year. Use the Climate Explorer website (https://crt-climate-explorer.nemac.org/climate_graphs) to find the mean maximum temperature of the hottest month of the year. More detailed information about the airport can be found at the AIRNAV database available on the web at: http://www.airnav.com/airports/ or visit the airport site.

In your analysis use the latest version of the Airbus A220-300 documents for airport design (http://128.173.204.63/courses/cee5614/sites_ce_5614.html#Aircraft_Data).

Historical temperature = 84.7 deg. F

Higher emissions = 87.5 deg. F.

ROA airport elevation is 1,175 feet

Longest runway is 6800 feet

ISA temperature at ROA = 54.81 degrees F.

Design condition using historical data is ISA + 27 deg. F. Use ISA + 45 deg. F.

Design condition using climate change conditions is ISA + 29.9 deg. F. Use ISA + 27 deg. F. (ISA + 15 deg. C).

a) Find the maximum range that the airline can fly from ROA airport either at maximum takeoff weight or limited by runway length. Evaluate the departure conditions for both engines and the usual airport design temperature conditions.

Airbus has several documents for the A220-300. Given that the problem refers to the A220-300 I used document BD500-3AB48-32000-00, Issue No. 026 which contains the payload-range diagram for the A220-300 and the full performance specifications.

Figures 7 and 8 shows the runway length performance for the A220-300 with high-thrust and normal thrust engines. The 24,000 lbs thrust engine allows the aircraft to depart at 143,000 lbs. from ROA's 6,800 ft. runway. The normal thrust engine (21,000 lbs) allows a departure weight of 134,000 lbs.

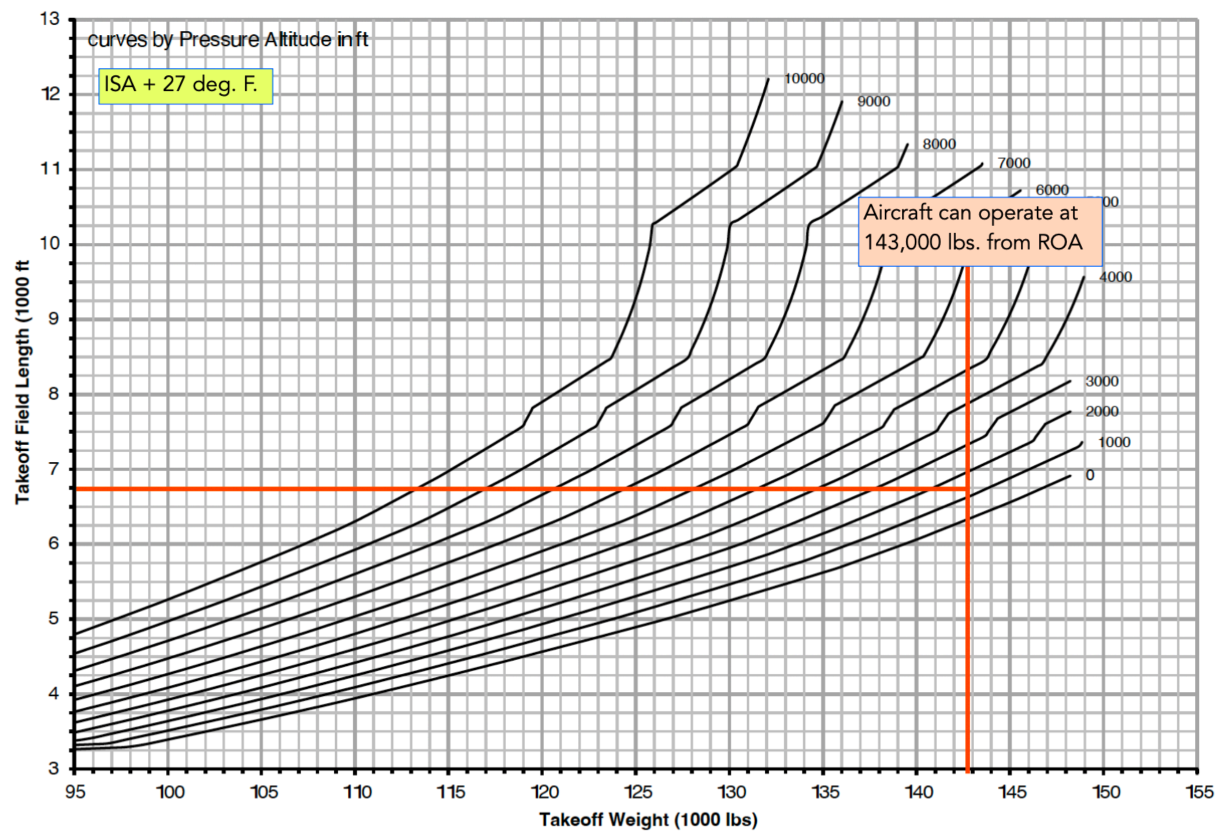


Figure 7. Takeoff Field Length for Airbus A220-300. ISA + 27 deg. F. Performance Chart. High-Thrust Engines (24,000 lbs).

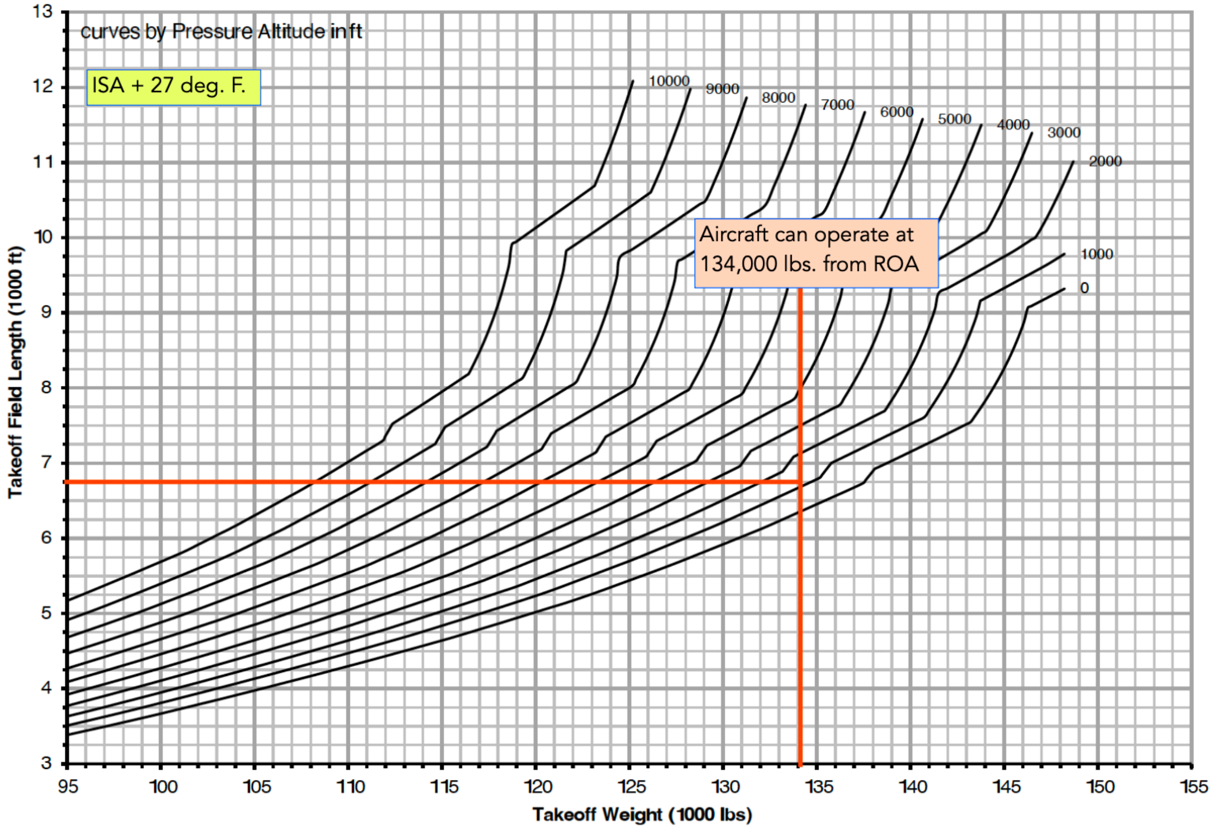


Figure 8. Takeoff Field Length for Airbus A220-300. ISA + 27 deg. F. Performance Chart. Normal Thrust Engines (21,000 lbs).

Figure 9 shows the payload-range diagram for the A220-300. The tradeoff line at MTOGW has a slope of -9.63 lbs/nm. If the takeoff weight from ROA is 143,000 lbs (6,000 lbs below the maximum of 149,000 lbs), then an estimate of the maximum range is:

$$Range = 3100 - 6000/9.23 = 2477 \text{ nm}$$

The calculation assumes that the fuel burn at 143,000 lbs is similar to that at 149,000 lbs. This is a rough approximation but still useful to determine the tradeoff in range departing from a short runway.

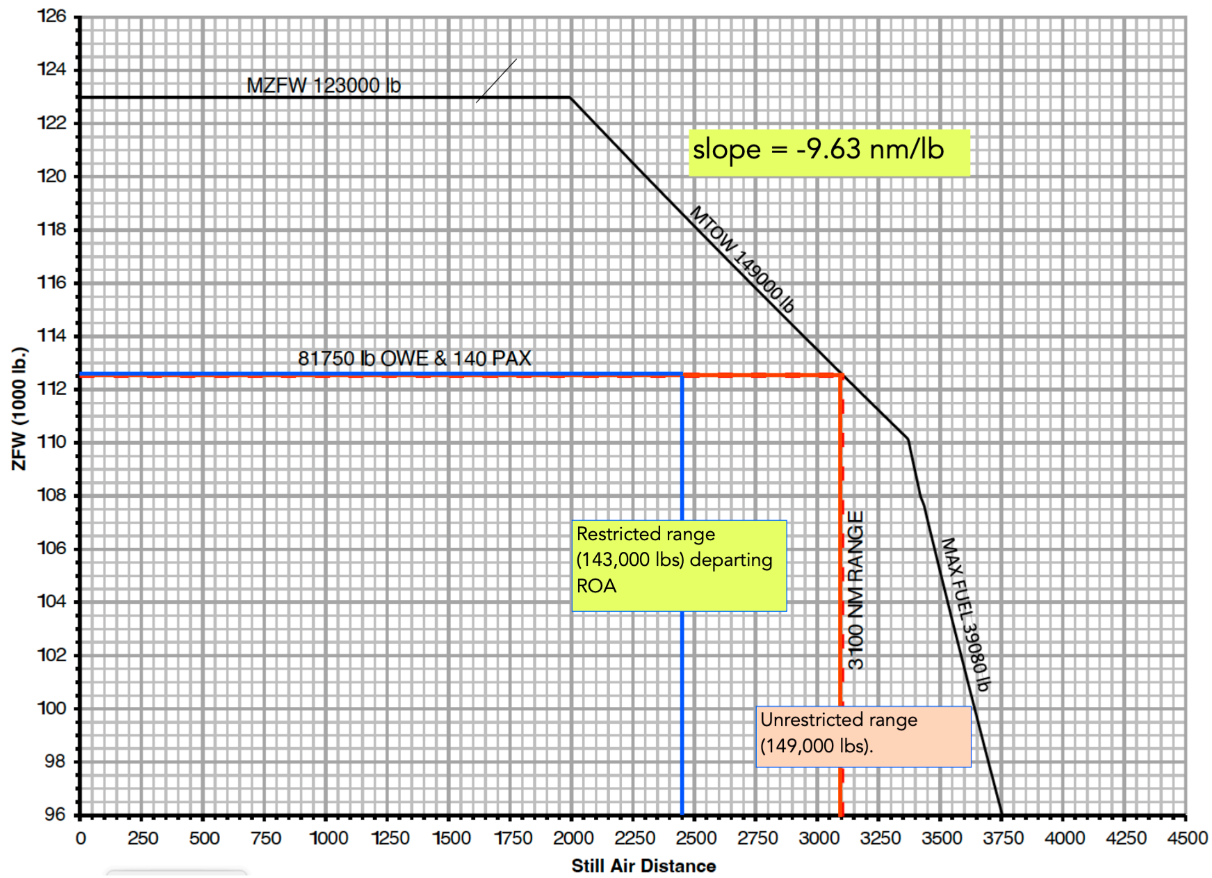


Figure 9. Payload-Range Diagram for Airbus A220-300. ISA Conditions. The slope of the MTOGW Line is -9.63 lb/nm.

b) Does ROA have enough runway to support maximum takeoff weight departure operations?

No. Only 143,000 lbs for the high-thrust engine version (24,000 lbs) and 134,000 lbs for normal thrust engine (21,000 lbs).

c) Estimate the average fuel per passenger on a 1,200 nm (includes detour factor) for the aircraft.

For a 1,200 nm trip, the aircraft has an estimated DTW of:

$$DTW = OEW + PYL + FW$$

$FW = 9.23 * 1200 + 0.20 * (9.23 * 1200) = 13291$ lbs (adding 20% fuel reserve)

$DTW = 81750 + 13291 + 30800 = 125841$ lbs.

Fuel per passenger ~ $1200 * 9.23/140$ = 79.11 lbs. (only the fuel used is employed in the estimate)

d) Find the SAR for the same 1,200 nm trip.

SAR = $1200/11076$ = 0.1083 nm/lbs

e) Considering the runway length and the environmental conditions at ROA airport which aircraft engine would you recommend?

The lower thrust engine provides more fuel efficiency and yet allows MTOGW at 134,000 lbs. The Airbus A220-300 with MTOGW of 149,000 lbs would probably require the 24,000 lbs engine (higher thrust).

Problem 3

Use the data for the large twin-aisle transport aircraft similar to the Boeing 777-200 (http://128.173.204.63/cee5614/cee5614_pub/B777_class.m) to answer the following questions.

a) Calculate total drag produced by the aircraft during a climb profile with an Indicated Airspeed of 270 knots at 3,400 meters above mean sea level conditions. Assume atmospheric conditions to be ISA. The aircraft weight is 320,000 kgs.

Indicated airspeed = 270 knots

Altitude = 3400 meters

Mass of aircraft = 320000 kilograms

Drag = 164935.4 Newtons

Thrust = 567033.2 Newtons

Fuel Burn = 90.73 N/s

Mach Number = 0.480 dimensionless

b) Repeat the process when the aircraft is climbing at 9,500 meters and an indicated Mach number of 0.78.

Indicated airspeed = 322.95 knots

Indicated airspeed = 322.95 knots

Altitude = 9500 meters

Mass of aircraft = 320000 kilograms

Drag = 167424.3 Newtons

Thrust = 244754.1 Newtons

Fuel Burn = 39.16 N/s

Mach Number = 0.780 dimensionless

c) Estimate the instantaneous fuel consumption for each flight condition given in parts (a) and (b).

Fuel burn values are reported above.

d) Comment on the observed trends.

The dark does not change appreciably because at higher altitudes, the density is lower and the speed increase compensates to yield similar drag values/ The fuel burn at 3,400 meters is 2.3 time higher than at 9,500 meters.

Problem 4

Use the SARLAT tool described in class to answer the following:

Use the Small Aircraft Runway Length Analysis Tool (SARLAT) to **design a runway** at a new airport located 3,800 feet above mean sea level conditions. The average of the maximum daily temperature of the hottest month of the year is 80 degrees Fahrenheit. Table 3 shows the representative aircraft at the airport. To obtain the SARLAT tool follow the links in the class notes.

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

See Figure 10.

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

The critical aircraft for dry takeoff is the Cessna Citation Jet 1 (4911 feet). The critical aircraft for landing on wet runway is the CJ1 as well (3,570 feet). A 5,000 foot runway will satisfy both criteria.

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

An additional 650 feet is required to satisfy the wet takeoff condition of the CJ1.

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

Table 3. Aircraft Fleet Mix for Problem 4.

Aircraft Type	Aircraft	Useful Load (%)
Piston	Cirrus SR22	100
Piston	Cessna 421C	100
Jet	Cessna CitationJet 1	90
Jet	Phenom 300	90

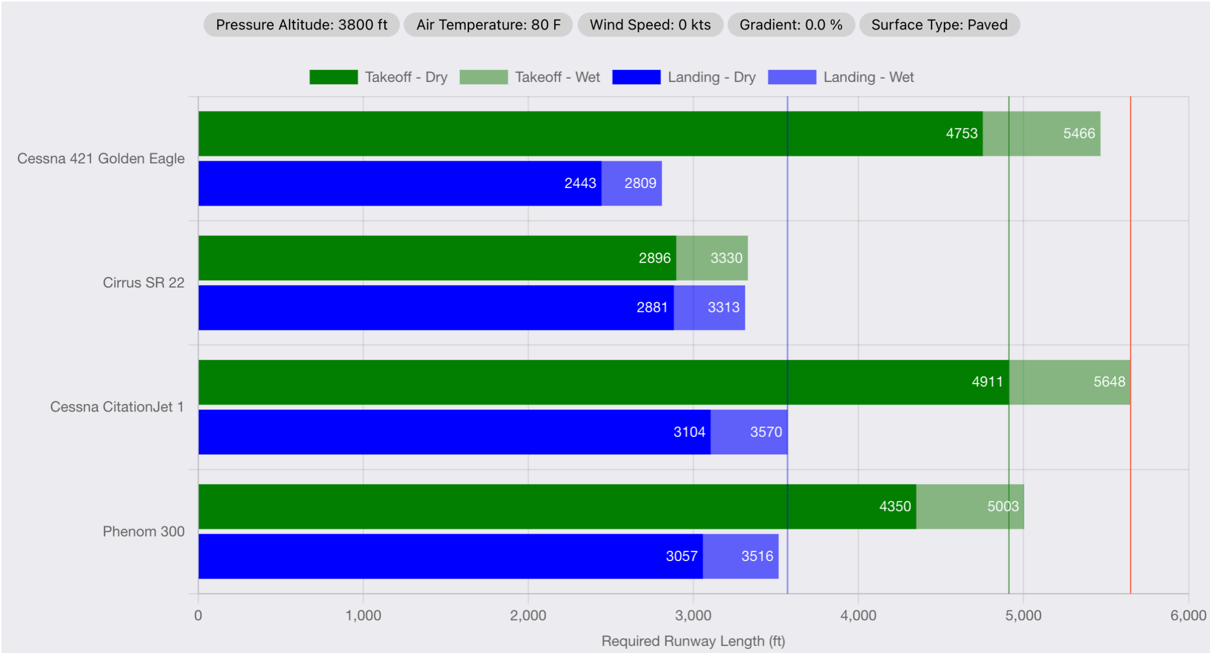


Figure 10. SARLAT Design Case. No Part 135 Operations Considered for Jet Aircraft.