

**Assignment 3: Runway Aircraft Performance Calculations**

Solution

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**Problem 1**

A new airline is evaluating two aircraft to operate flights from Phoenix International (PHX) Airport. The following table shows the aircraft proposed by airline executives. Two long-haul, origin-destination pairs the airline would like to fly with the selected aircraft are: a) PHX-LHR and b) PHX-FCO.

*Table 1. Aircraft Considered in the Airline Evaluation.*

Aircraft Considered
Below: Boeing 787-9 with Typical Rolls-Royce engines. Aircraft maximum design takeoff weight is 561,500 lb. 290 seats in a two-class layout.
 A photograph of an ANA Boeing 787-9 Dreamliner aircraft on a tarmac. The aircraft is white with blue and red accents. The tail features the ANA logo. The fuselage has "Inspiration of JAPAN" and "DREAMLINER" written on it. The registration number "JA871A" is visible on the rear fuselage. A smaller aircraft is visible in the foreground.
Below: Boeing 787-8 with Typical Rolls-Royce engines. Aircraft maximum design takeoff weight is 502,500 lb. 242 seats in a two-class layout.
 A photograph of an American Airlines Boeing 787-8 aircraft on a runway. The aircraft is white with red and blue stripes on the tail. The word "American" is written on the fuselage. The registration number "N809AA" is visible on the rear fuselage.

The design airport temperature used should be the average of the maximum daily temperatures 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 Boeing documents for airport design.

- a) Find the average stage length to be flown between each one of the critical OD airport pairs. 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.

PHX-LHR GCD distance = 4,580 nm or 4,855 nm with 6% additional distance

PHX-FCO GCD distance = 5,357 nm or 5,678 nm with 6% additional distance

- b) Find the runway length needed for each of the aircraft operating the critical route. Determine if PHX has enough runway length to support these flights with all seats full.

Use the Boeing 787 document dated October 2025 (787\_ACAP\_Rev\_Q).

Critical route is PHX-FCO (5,678 nm planned)

Historical temperature = 104.7 deg. F

Higher emissions = 107.4 deg. F.

PHX airport elevation is 1,135 feet (Arnav)

Longest runway is 11,489 feet

ISA temperature at PHX = 54.95 degrees F.

Design condition is ISA + 49.75 deg. F.

**Use ISA + 61 deg. F. runway design curves**

Trip distance is 5,678 nm (planned). Table 1 shows a summary of the calculations for the Boeing 787-9.

Below: Boeing 787-9 with Typical Rolls-Royce engines. Aircraft maximum design takeoff weight is 561,500 lb. 290 seats in a two-class layout.



CHARACTERISTICS	UNITS	MODEL 787-9 *[1]	
MAX DESIGN TAXI WEIGHT	POUNDS	563,000	573,000
	KILOGRAMS	255,372	259,908
MAX DESIGN TAKEOFF WEIGHT	POUNDS	561,500	571,500
	KILOGRAMS	254,692	259,228
MAX DESIGN LANDING WEIGHT	POUNDS	425,000	425,000
	KILOGRAMS	192,776	192,776
MAX DESIGN ZERO FUEL WEIGHT	POUNDS	400,000	400,000
	KILOGRAMS	181,436	181,436
SEATING CAPACITY	ONE CLASS	406 ALL-ECONOMY SEATS; FAA EXIT LIMIT = 420 SEATS	
	MIXED CLASS	290 DUAL-CLASS; 28 BUSINESS CLASS, 262 ECONOMY CLASS (SEE SEC 2.4)	
MAX CARGO - LOWER DECK *[2]	CUBIC FEET	6,090	6,090
	CUBIC METERS	172.4	172.4
USABLE FUEL *[3]	U.S. GALLONS	33,399	33,399
	LITERS	126,429	126,429
	POUNDS	223,773	223,773
	KILOGRAMS	101,522	101,522

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	225,000	495,000
FW	68,700	151,140
Passengers	290	

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
Fuel/passenger	237	521
Required runway Length (takeoff) at ISA + 61 deg. F (feet)	12500	12500
Runway gradient (%)	0.20	0.20
Difference in runway threshold elevation (feet)	23	23
Runway required corrected for gradient	12730	12730
Longest runway available (feet)	11489	11489
Wet pavement runway length (Landing) (Feet)	7200	7200
Route Distance	5678	5678
Average SAR (nm/kg) and (nm/lb)	0.0826	0.0376

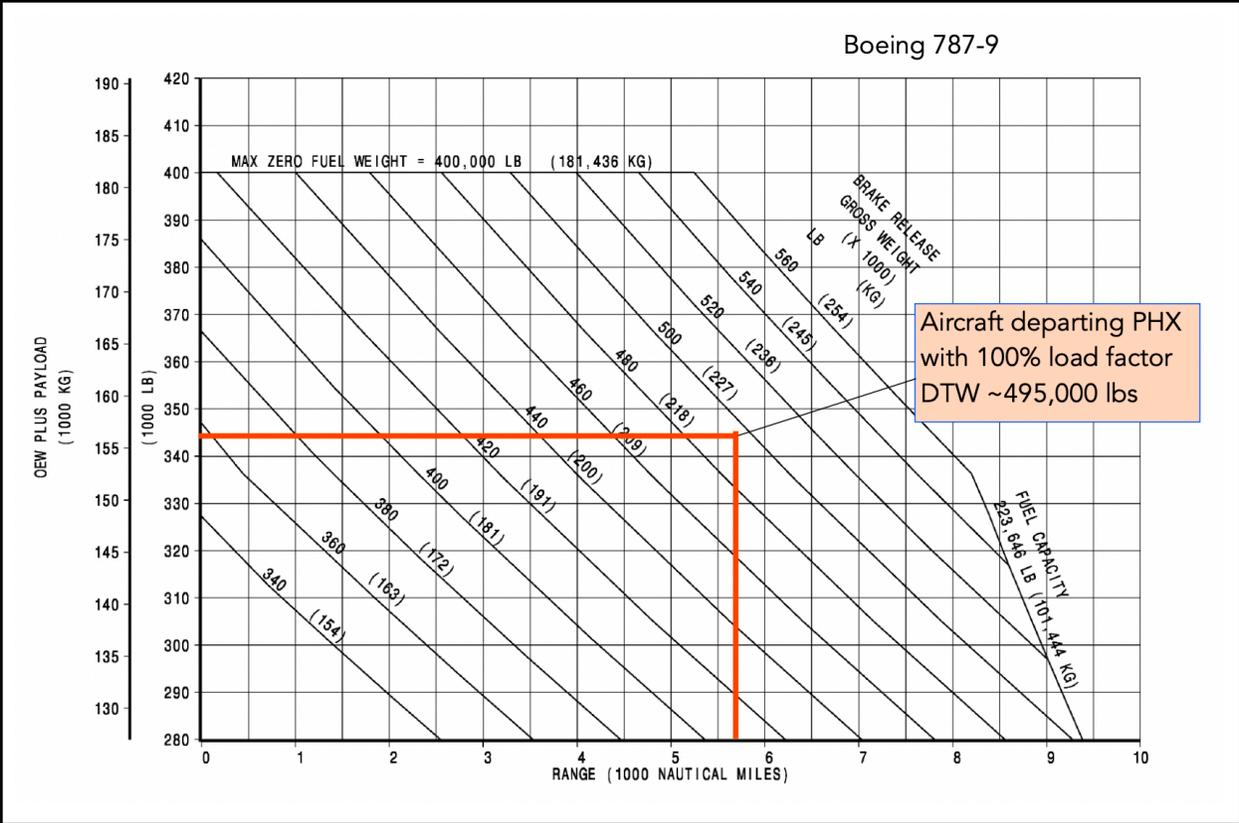


Figure 2. Payload-Range Diagram Boeing 787-9. DTW ~ 495,000 lbs.

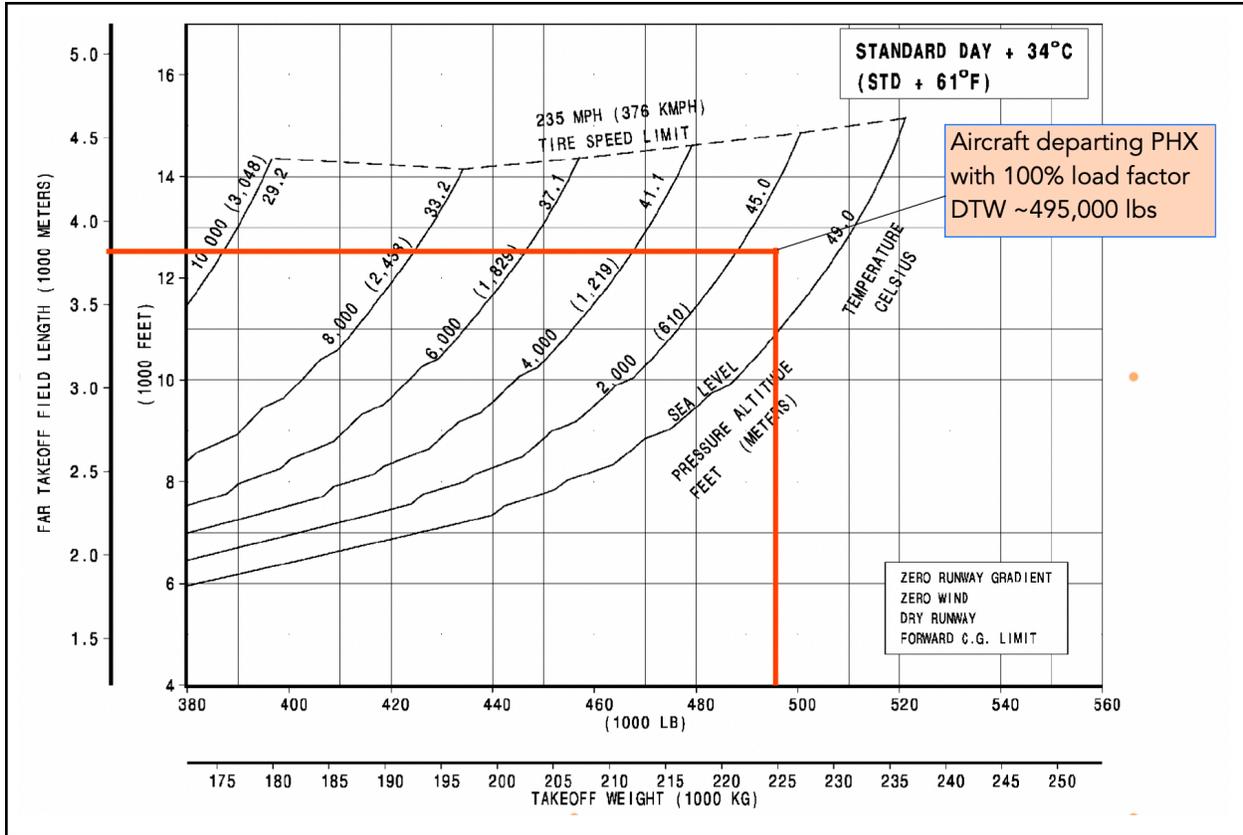


Figure 3. Takeoff Field Length for Boeing 787-9. ISA + 61 deg. F. Performance Chart. High-Thrust Engines. Takeoff from Phoenix at 495,000 lbs.

- c) Estimate the average fuel per passenger assuming a full passenger load on both routes. Can the airline achieve good fuel savings using the Boeing 787-9?
- d) Using the Payload-Range diagram of each aircraft, and using the longest flight of the two routes, find the Specific Air Range (SAR) parameter for each aircraft. Comment on the SAR values calculated.
- e) Considering various factors which aircraft is the best for this airline? Explain.

The Boeing 787-9 is more economical per passenger.

## Problem 2

An airline is evaluating the Boeing 737-9 Max aircraft to operate flights Ronald Reagan National Airport (DCA) to San Diego (SAN) and Denver (DEN). The following table shows the aircraft in question.

Table 1. Aircraft Considered in the Airline Evaluation.

Aircraft Considered
Below: Boeing 737-9 Max with CFM LEAP-1B28 engines. Aircraft maximum design takeoff weight is 194,700 lb. 193 seats in a two-class layout.

## Aircraft Considered



The design airport temperature used should be the average of the maximum daily temperatures 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 Boeing documents for airport design.

- a) Find if the flight to San Diego is possible from DCA with a full load of passengers considering the airport elevation and runway length constraints today. State any limits found in your analysis.
- b) Find if the flight from Denver to DCA with a full load of passengers is possible considering the airport elevation and runway length constraints at Denver. State any limits found in your analysis.
- c) Considering the analysis above, explain the effect of airport elevation on runway length.
- d) What is the maximum thrust rating for the CFM LEAP-1B28 engine at sea level and static conditions?

### Problem 3

Use the Small Aircraft Runway Length Analysis Tool (SARLAT 2) to **evaluate the existing runway** at Virginia Tech Montgomery Executive Airport (BCB). Table 2 shows some of the aircraft fleet mix operating at the airport.

a) Use the Climate Explorer website to estimate the design temperature conditions for the airport. The link to the Climate Explorer is on our interesting web site page ([http://128.173.204.63/cee5614/sites\\_ce\\_5614.html#Weather](http://128.173.204.63/cee5614/sites_ce_5614.html#Weather)). Use the temperature profile for Blacksburg or the closest city.

- Consider climate change effects (i.e., higher emissions) and find the future design temperature. Use the future temperature profile for years 2035-2065.

**Table 2. Existing Aircraft Fleet Mix for Problem 3.**

Aircraft Type	Aircraft	Annual Departures / Arrivals	Picture
Jet	Cessna Citation Latitude	650	
Turboprop	King Air B350	1,450	
Jet	Bombardier Challenger 350	560	

Aircraft Type	Aircraft	Annual Departures / Arrivals	Picture
Jet	Embraer Phenom 300	800	

For existing runway length conditions and the historical design temperature answer the following:

- a) Find the critical aircraft operating at BCB using dry and wet runway conditions. Use the historical temperature conditions. Explain.

Aircraft Name	Aircraft Mix	NBAA IFR Maximum Range		Useful Load (Takeoff Weight)	
		Dry	Wet	Dry	Wet
Turboprop					
B350 - Beechcraft King Air 350ER	42%	100 % FLIGHTS IN NAS 1412 nm / 5 pax	78 % FLIGHTS IN NAS 347 nm / 5 pax	76 % 15045 lbs	42 % 12980 lbs
Jet					
CL35 - Bombardier Challenger 350	16%	100 % FLIGHTS IN NAS 1986 nm / 4 pax	92 % FLIGHTS IN NAS 1235 nm / 4 pax	70 % 35921 lbs	51 % 32800 lbs
C68A - Cessna Citation Latitude	19%	100 % FLIGHTS IN NAS 2078 nm / 4 pax	100 % FLIGHTS IN NAS 1816 nm / 4 pax	100 % 30800 lbs	91 % 29726 lbs
E55P - Phenom 300	23%	100 % FLIGHTS IN NAS 1536 nm / 4 pax	100 % FLIGHTS IN NAS 1536 nm / 4 pax	100 % 17968 lbs	100 % 17968 lbs
Evaluation analysis for operations from Blacksburg, VA. Temperature is 86 deg. F. 2120 feet elevation. Runway grade 0.4%.					

- b) For dry runway conditions, find the **takeoff weight** and **useful load** possible for the Bombardier Challenger 350 operating from the existing runway. Use the historical temperature conditions.

Pressure Altitude: 2120 ft

Air Temperature: 86 F

Wind Speed: 0 kts

Runway Length: 5500 ft

Gradient: 0.4 %

Surface Type: Paved

#### Historical temperature data

Takeoff weight (dry) = 36,332 lbs. with 83 deg.F (73% useful load)

Takeoff weight (wet) = 33,542 lbs. with 83 deg.F (55% useful load)

- c) Using the existing runway length at BCB, find the maximum distance that can be flown by a Cessna Citation Latitude with the average passenger load and two pilots?

#### Future climate change

2078 nm / 4 pax (dry)

1816 nm / 4 pax (wet)

#### Historical data

2078 nm / 4 pax (dry)

1903 nm / 4 pax (wet)

- d) Considering climate change future temperature projections and dry runway conditions, find the takeoff weight and useful load possible for the Challenger 350 operating from the existing runway. Comment on any changes compared to part (b).

#### Future climate change

Takeoff weight (dry) = 35,921 lbs. with 86 deg.F (70% useful load)

Takeoff weight (wet) = 32,800 lbs. with 86 deg.F (51% useful load)

A small reduction in useful load compared to historical conditions (from 73% to 70%) under dry conditions.

- e) Find the percent of the flights percent in the US by the Cessna Citation Latitude are covered? Use the historical temperature conditions.

#### Historical data

2078 nm / 4 pax (dry) covers 100% of the flights in the NAS.

1903 nm / 4 pax (wet) covers 100% of the flights in the NAS.