Example of Runway Length Analysis

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Runway Length Estimation Example

A new airport will be constructed at a site located 3,500 feet above sea level. Temperature data collected at the site shows the mean daily maximum temperature of the hottest month to be **26 degrees Celsius**. The table below shows the critical design aircraft information. Figure 1 shows a picture of the design aircraft.

Aircraft	Engine	Remarks
Boeing 747-8 (passenger version) 987,000 Maximum Takeoff Weight	GEnx 2B engines	Passenger configuration with a total of 515 seats

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Figure 1. Boeing 747-8 Passenger Version (A.A. Trani).

Typical Questions

1. Find the runway length required to satisfy FAA and EASA regulations to operate the critical aircraft **without takeoff restrictions**. This implies the airline will be able to depart at the maximum takeoff gross weight from the airport.

2. Find the amount of belly cargo the aircraft can carry while using the runway design of part (1).

3. Estimate how far can the aircraft fly without refueling for the runway design in part (1)?

4. Find the Specific Air Range (SAR) of the aircraft in part (3).

Answers

1. Find the runway length required to satisfy FAA and EASA regulations to operate the critical aircraft without takeoff restrictions from the new airport. This implies the airline will be able to depart at the maximum takeoff gross weight from the airport.

ISA Temperature at 3,500ft is 8.1C (temperature is linear with altitude).

Temperature offset = 26 - 8.1 deg. C = 17.9 deg. C.

Use ISA + 17.9 deg.C

Conclusion:

ISA + 17.9 deg. C is more than 1.7 deg. C from ISA + 15 deg. C

1.7 deg. C. Is the margin allowed by the FAA to use to the closest chart.

Use the takeoff figures for **ISA+25C**.

Aircraft Characteristics
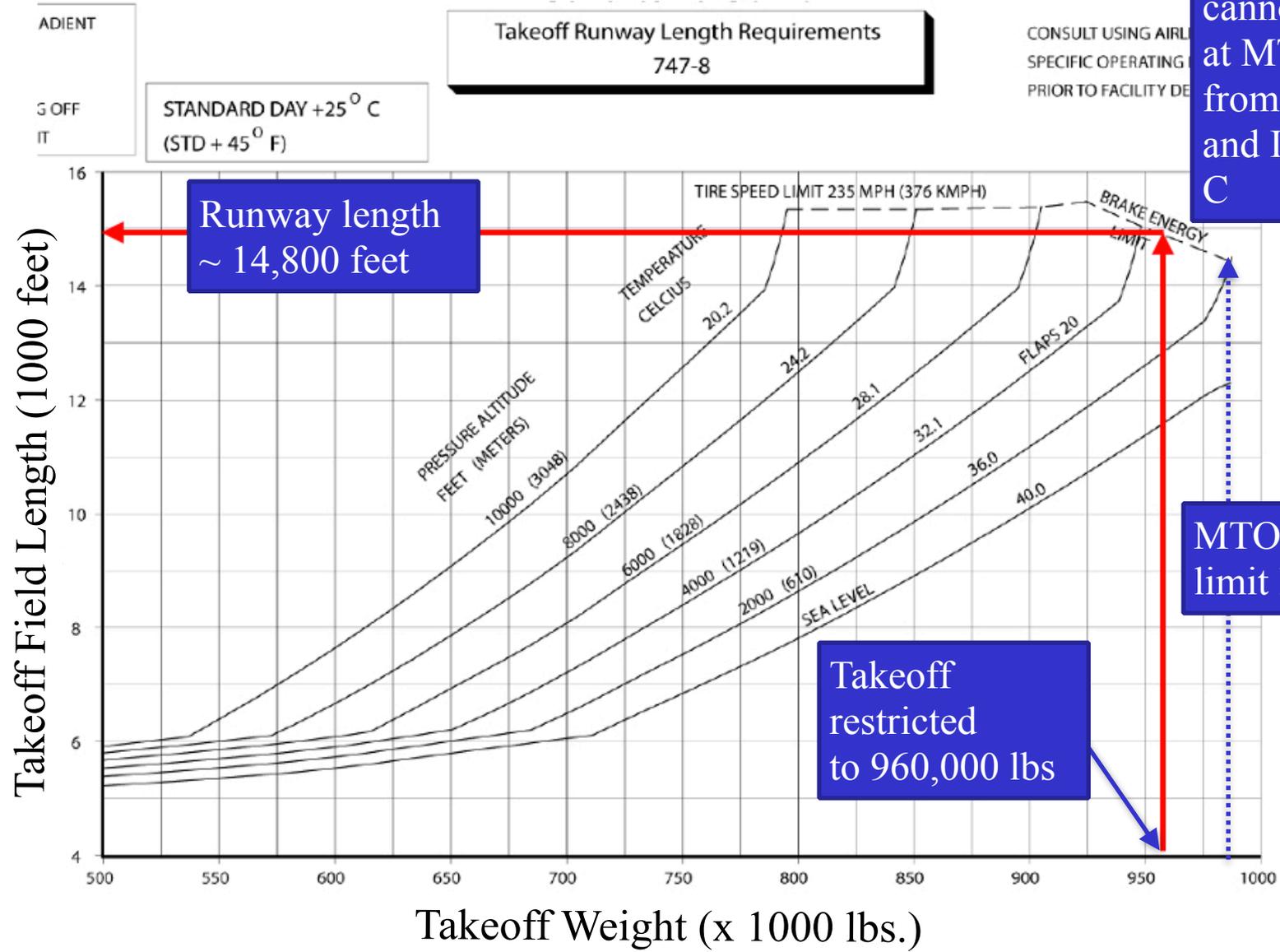

747-8
Airplane Characteristics for Airport Planning

Consult the Boeing documentation to solve the problem

CHARACTERISTICS	UNITS	747-8
MAX DESIGN TAXI WEIGHT	POUNDS	990,000
	KILOGRAMS	449,056
MAX DESIGN TAKEOFF WEIGHT	POUNDS	987,000
	KILOGRAMS	447,696
MAX DESIGN LANDING WEIGHT	POUNDS	688,000
	KILOGRAMS	312,072
MAX DESIGN ZERO FUEL WEIGHT	POUNDS	651,000
	KILOGRAMS	295,289
OPERATING EMPTY WEIGHT (1)	POUNDS	485,300
	KILOGRAMS	220,128
MAX STRUCTURAL PAYLOAD	POUNDS	167,700
	KILOGRAMS	76,067
TYPICAL SEATING CAPACITY (INCLUDES UPPER DECK)	UPPER DECK	48 BUSINESS CLASS
	MAIN DECK	19 FIRST, 96 BUSINESS, 352 ECONOMY
MAX CARGO - LOWER DECK CONTAINERS (LD-1)	CUBIC FEET	5,705
	CUBIC METERS	162
MAX CARGO - LOWER DECK BULK CARGO	CUBIC FEET	640
	CUBIC METERS	18.1
USABLE FUEL CAPACITY	U.S. GALLONS	63,034 (2)
	LITERS	238,610
	POUNDS	426,109
	KILOGRAMS	193,280

Answer to Question 1

Aircraft cannot operate at MTOW from 3,500 feet and ISA + 25 deg. C

ADIENT

G OFF
IT

STANDARD DAY +25° C
(STD + 45° F)

Takeoff Runway Length Requirements
747-8

CONSULT USING AIRL
SPECIFIC OPERATING
PRIOR TO FACILITY DE

Runway length ~ 14,800 feet

TIRE SPEED LIMIT 235 MPH (376 KMPH)

BRAKE ENERGY LIMIT

TEMPERATURE CELCIUS

20.2

24.2

28.1

FLAPS 20

32.1

36.0

40.0

PRESSURE ALTITUDE FEET (METERS)

10000 (3048)

8000 (2438)

6000 (1828)

4000 (1219)

2000 (610)

SEA LEVEL

MTOW limit line

Takeoff restricted to 960,000 lbs

Takeoff Field Length (1000 feet)

Takeoff Weight (x 1000 lbs.)

Answer to Question 1

Note: Maximum allowable landing weights for freighter and passenger versions are not the same.

Use the MALW of the passenger version since the problem involves a passenger Boeing 747-8.

FAA Landing Field Length ~ 8,200 feet

Takeoff distance is greater than landing distance. The airport needs a runway 14,800 feet long.

Find the Belly Cargo Capacity of the Aircraft

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OEW = 485,300 lbs

Passenger load = 515 * (220 lbs/passenger) lbs = 121,000 lbs

OEW + Passenger Payload = 485,300 lbs + 121,000 lbs = **606,300 lbs**

Maximum Design Zero Fuel Weight is the maximum weight before fuel is added

Maximum Design Zero Fuel (MDZF) = 651,000 lbs

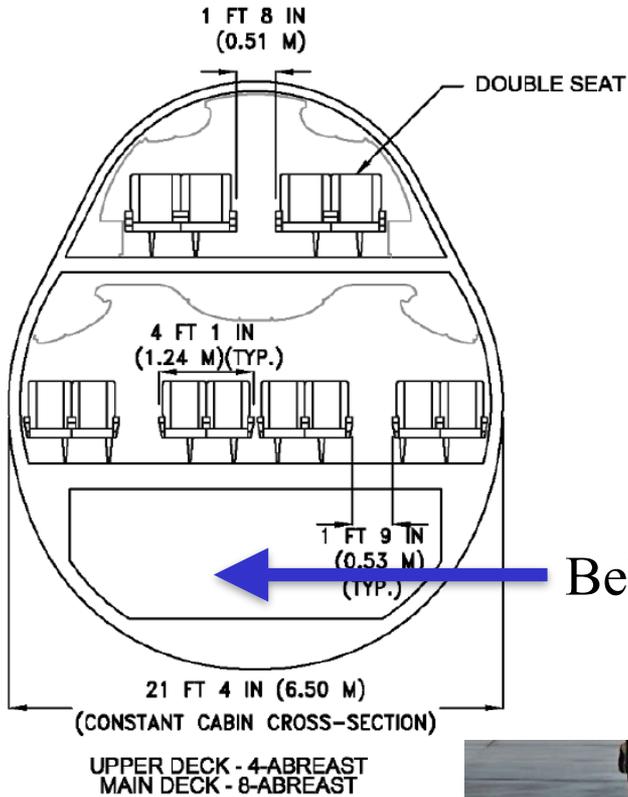Restricted takeoff weight limit is 960,000 lbs.

Maximum Belly Cargo = 651,000 lbs - 606,300 lbs = 44,700 lbs.

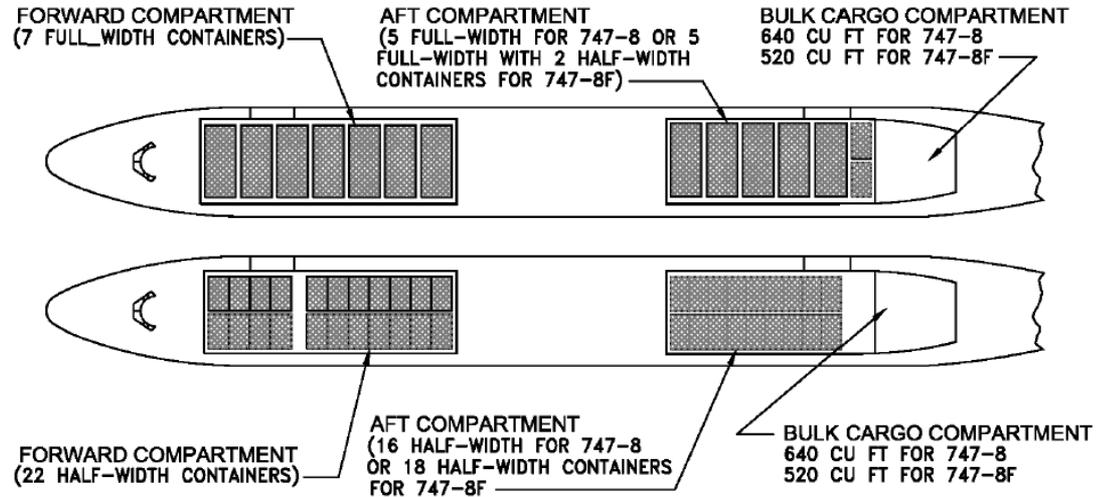# Belly Cargo Capacity for Boeing 747-8I

Belly Cargo Space

Half-width container

Source: Boeing
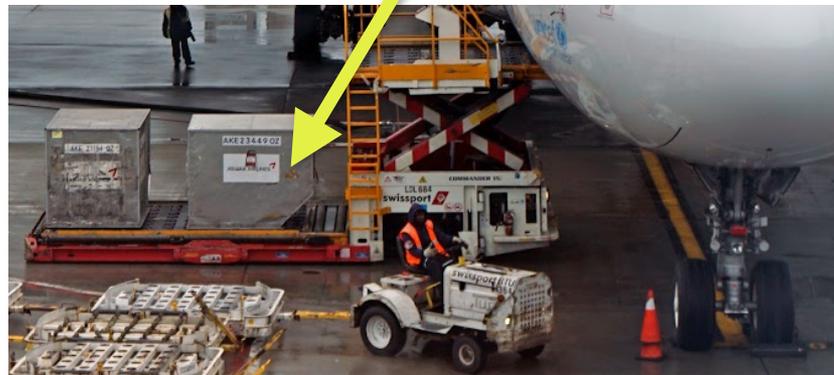
| CONTAINER DATA	HALF-WIDTH	FULL-WIDTH
INTERNAL VOLUME PER CONTAINER	173 CU FT 4.9 CU M	350 CU FT 9.9 CU M
TARE WEIGHT	270 LB 123 KG	470 LB 213 KG
MAXIMUM CARGO WEIGHT PER CONTAINER	3,230 LB 1,465 KG	6,530 LB 2,962 KG
MAXIMUM GROSS WEIGHT PER CONTAINER	3,500 LB 1,588 KG	7,000 LB 3,175 KG
TOTAL VOLUME OF 12 FULL-WIDTH PLUS 2 HALF-WIDTH CONTAINERS IS 4,546 CU FT (129 CU M)		
GROSS WEIGHT FOR 12 FULL-WIDTH PLUS 2 HALF-WIDTH CONTAINERS IS 91,000 LB (41,277 KG)		

Estimation of Aircraft Range for Design Conditions

Payload / Range
747-8

STANDARD DAY, ZERO WIND
MACH 0.855 CRUISE
STEP CLIMB AT 2000 FT INCREMENTS
NORMAL POWER EXTRACTION AND AIR CONDITIONING BLEED
TYPICAL MISSION RULES

CONSULT USING AIRLINE FOR SPECIFIC OPERATING
PROCEDURE AND OEW PRIOR TO FACILITY DESIGN
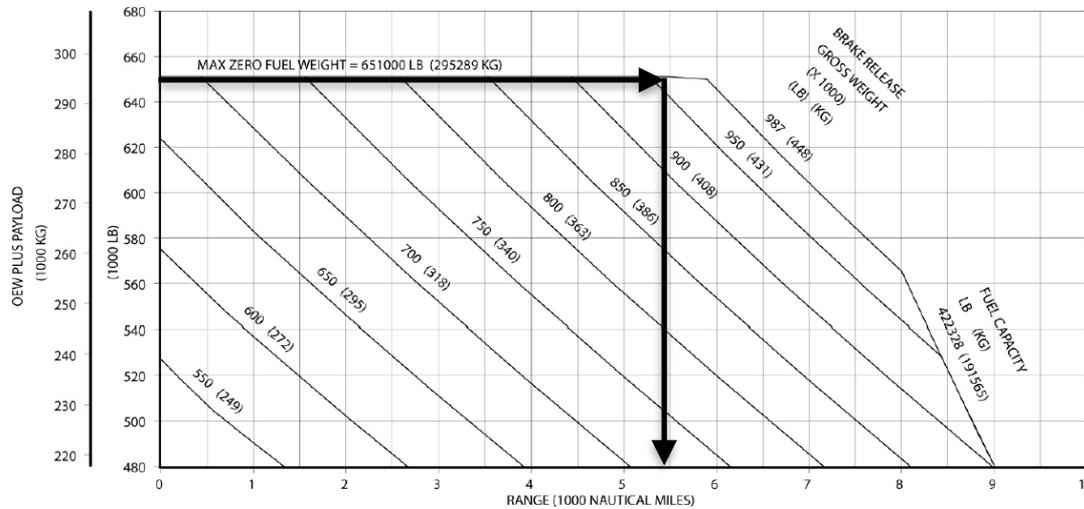
OEW = 485,300 lbs

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Maximum Belly Cargo = 651,000 lbs - 606,300 lbs = 44,700 lbs

Find OEW + Payload
485,300 lbs + 121,000 lbs + 44,700 lbs

Restricted takeoff weight limit is 960,000 lbs.

Aircraft can fly 5,400 nautical miles

OEW + Payload = 651,000 lbs (same as maximum zero fuel weight)

Specific Air Range Calculation

- A useful metric to compare the efficiency of an aircraft
- Similar to a car fuel efficiency.
- SAR is the ratio of the distance traveled divided by the fuel used.
- Example units are nm/lb, nm/kg

OEW = 485,300 lbs.
Passenger load = 121,000 lbs.
Belly cargo = 44,700 lbs
Takeoff weight = 960,000 lbs.

Fuel used = 960,000 - 651,000 lbs.

Fuel used = 309,000 lbs

$$SAR = \frac{d}{f_c}$$ Where:

$$SAR = \frac{5,400}{309,000}$$

$$SAR = 0.017 \quad \text{nm/lb.}$$

SAR is the specific air range (nm/lb)

d is the distance traveled (nm)

f_c is the fuel used (lbs.)