

# RANGE PAYLOAD DIAGRAM

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## Sources:

Fielding, J. P., *Introduction to Aircraft Design*, Cambridge Aerospace Series 11, 1999

Ackert, S., *Aircraft Payload-Range Analysis for Financiers*, *Aircraft Monitor*, 2013

# Definitions

- Range
  - Distance that an a/c can cover during flight
- Payload:
  - Total weight for which airline gets “paid”
    - Passengers, Baggage, Cargo
- Trade-off between Range & Payload
  - Range-Payload Diagram

Depends on perspective !

# AIRCRAFT WEIGHT BREAKDOWN

# Manufacturer's Perspective

- ❑ Maximum Ramp Weight (MRW)
- ❑ Maximum Takeoff Weight (MTOW)
- ❑ Maximum Landing Weight (MLW)
- ❑ Maximum Zero Fuel Weight (MZFW)
- ❑ Authorized Limit v/s Structural Limit



# Operator's Perspective

- Manufacturer's Empty Weight (MEW)
- Standard Items (SI)
  - Unusable fuel, Engine oil, Toilet fluids & Chemicals
  - Fire extinguishers & emergency O<sub>2</sub> equipment
  - Galley structures & Supplementary electronic eqpt.
- Operator Items (OI)
  - Crew + Baggage, Documents, Seats, Life Rafts & Vests
  - Food and Beverages
- Operating Empty Weight (OEW)
  - $OEW = MEW + SI + OI$
- Maximum Payload
  - Passengers + Baggage + Cargo

# Boeing 737-800

Certified Weight	Operational Max. (1000 lb)	Structural Max. (1000 lb)
MRW	156.2	174.9
MTOW	155.5	174.2
MLW	144.0	146.3
MZFW	136.0	138.3



# Typical Aircraft weight build-up

- $W_{\text{ramp}} = W_{\text{warmup}} + W_{\text{taxi}} + W_{\text{TORun}} + W_{\text{TO}}$
- $W_{\text{TO}} = W_{\text{pay}} + W_{\text{fuel}} + W_{\text{Ops-empty}}$
- $W_{\text{Ops-empty}} = W_{\text{str}} + W_{\text{crew}} + W_{\text{Ops. Items}}$
- $W_{\text{Ops. Items}} = W_{\text{F\&B}} + W_{\text{mags}} + W_{\text{.....}}$
- $W_{\text{fuel}} = \text{Mission Fuel} + \text{Reserve Fuel}$
- $W_{\text{pay}} = W_{\text{pax}} + W_{\text{baggage}} + W_{\text{cargo}}$
- Limitations on  $W_{\text{pay}}$ 
  - Volume
  - Structural strength of Cargo bay





Source: <http://i.ytimg.com/vi/ZJYHwnV-nO4/maxresdefault.jpg>

# Example of Weight Build-up

## *Avro-RJ 100 Whisperjet*

### Regional Jet Transport Aircraft



# Weight Build-up

## □ Specs

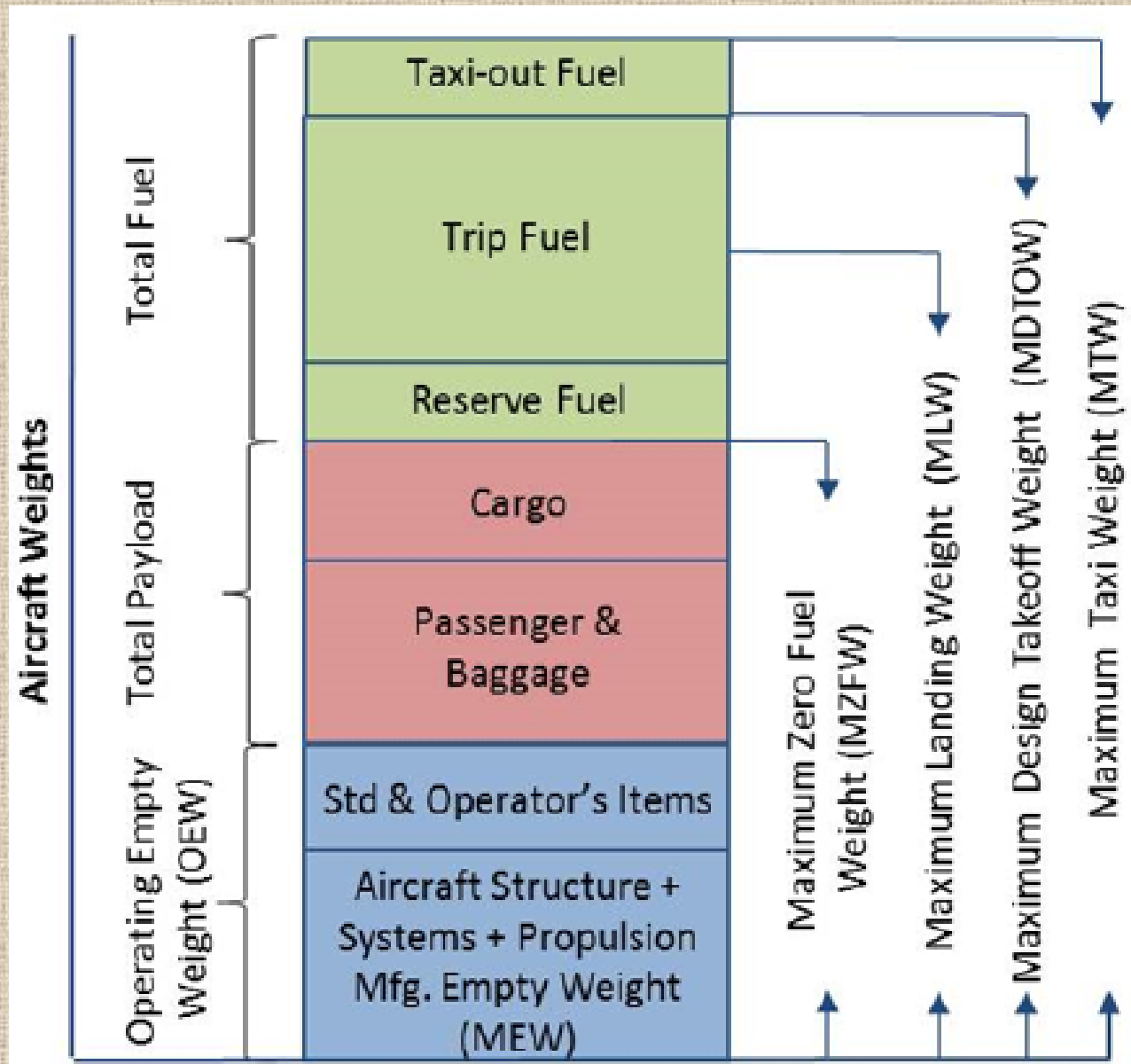
▪ Max Takeoff Weight	MTOW	44226
▪ Max Landing Weight	MLW	40143
▪ Max Zero Fuel Weight	MZFW	37422
▪ Operating Empty Weight	OEW	25600
▪ Max Fuel Capacity = 11728 liters		
▪ Max. no of Passengers	$n_{\text{pax}}$	112

## □ Calculated Values

▪ Max Payload Weight = (MZFW-OEW)	MPW	11822
▪ Max Fuel Weight	MFW	9242

□ Payload + Fuel = MTOW-OEW 18626

# Aircraft Weight Buildup



# Maneuver Allowances

□ Engine start & Pre-taxi checks	18 kg
□ Taxi (all engines)	89 kg
□ Takeoff (estimate)	50 kg
□ Approach & Land	143 kg
□ WARMUP + TAXI + TAKEOFF	300kg



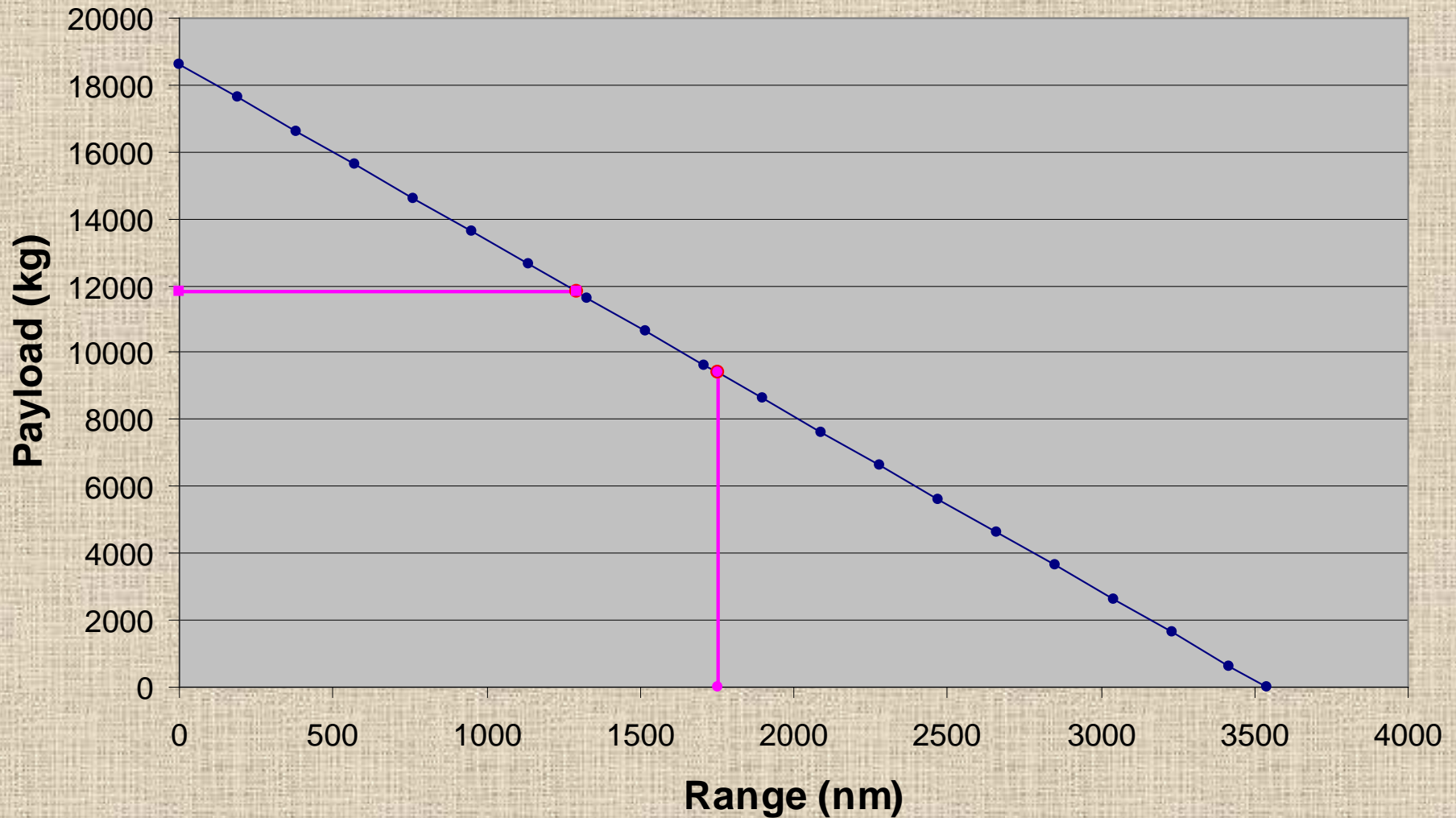
# Weight Breakdown @ Max Payload

□ Ramp Weight	44526
▪ Warmup + Taxi + Takeoff	300
□ Takeoff Weight	44226
▪ Payload	11822
◦ 112 Pax @ 95 kg each	10640
◦ Cargo	1182
▪ Fuel	6804
◦ Reserve Fuel (assumed 0.85* Fuel)	1021
□ Operating Empty Weight	25600
▪ Structure	23925
▪ Crew	375
▪ Ops Items	1300

# Range-Payload Diagram

## Avro-RJ-100 aircraft

(Assuming Payload + Fuel = 18626 kg, and 0.19 nm/kg)



# Two important points

## ❑ All Fuel is not useable !

- Missed Approach, Diversion & Hold 3.5%
- Navigational errors and en Route weather 10.0%
- Trapped Fuel 1.5%

◦ Mission Fuel = Total Fuel - Reserve Fuel =  $0.85 \times \text{Total Fuel}$

## ❑ Specific Range is not constant !

- Increases as aircraft becomes lighter

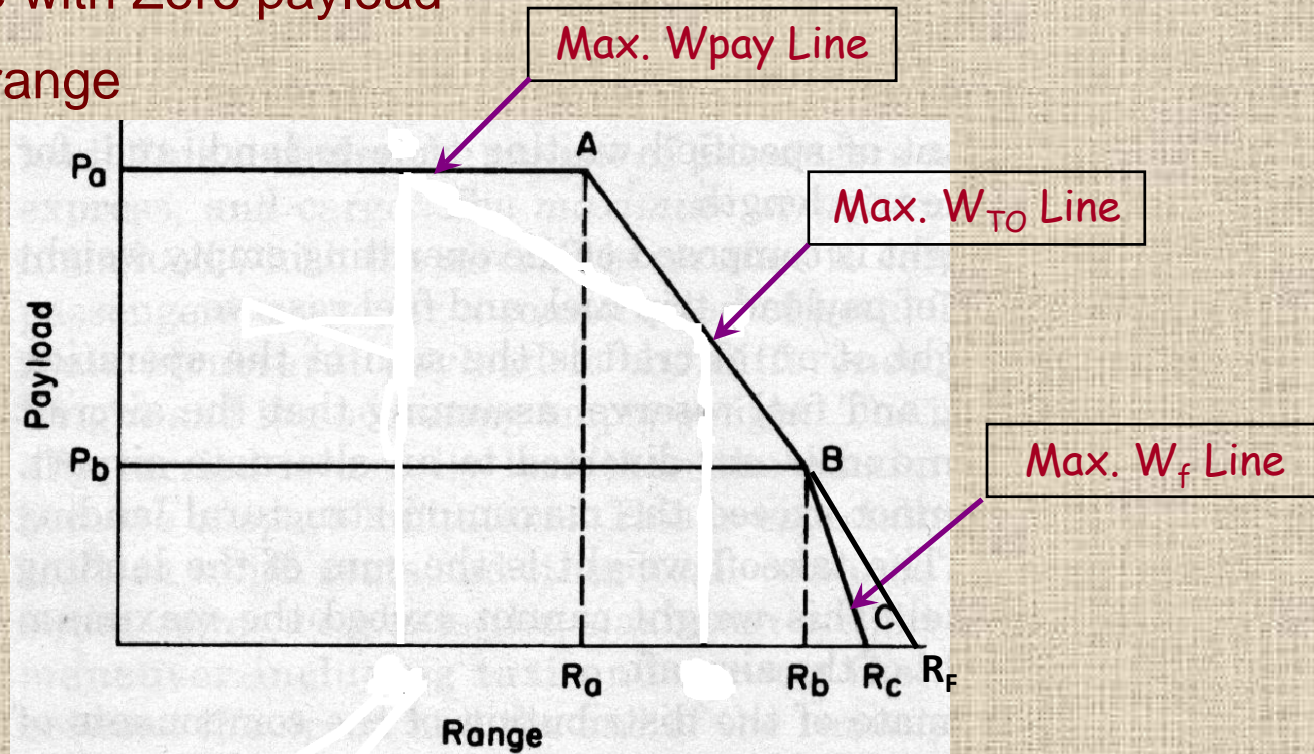


# Three types of Range

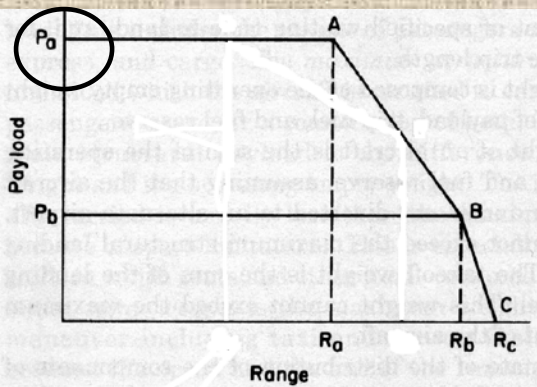
- Harmonic Range
  - Range with maximum possible payload
- Ferry Range
  - Range with zero payload, and including reserve fuel
- Gross Still Air Range
  - Range assuming all the mission fuel is utilized for cruise flight alone

# RPD calculation

- $P_a$  = MPW &  $R_a$  = Harmonic Range = max Range @  $P_a$
- If we need Range  $> R_a$ , Tradeoff between  $W_{\text{pay}}$  &  $W_{\text{fuel}}$ 
  - $R_b$  = Range with Max Fuel &  $W_{\text{pay}}$  of  $P_b$
- If we need more Range than  $R_b$ , Reduce  $W_{\text{payload}}$
- $R_c$  = Range with Zero payload
- $R_F$  = Ferry range



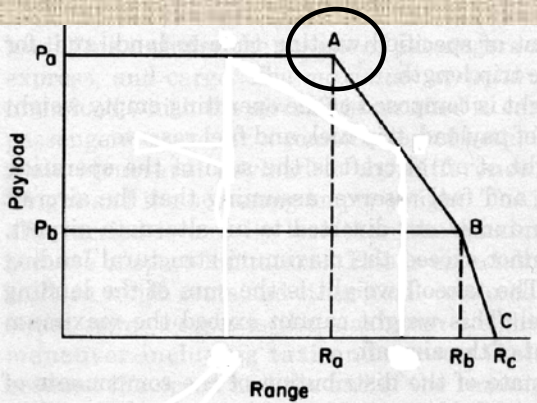
# RPD Calculation Point - $P_a$



Pt.	Payload	TOW	FW	Range
$P_a$	MPW	MZFW	Zero	Zero

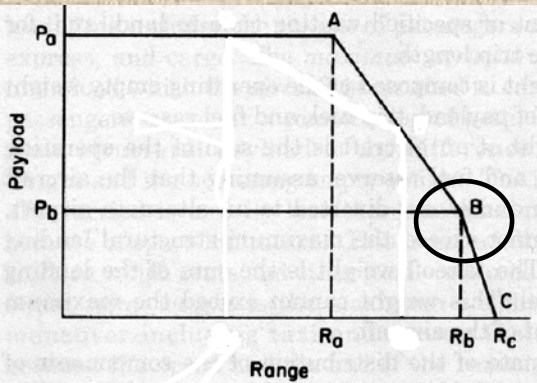


# RPD Calculation Point A



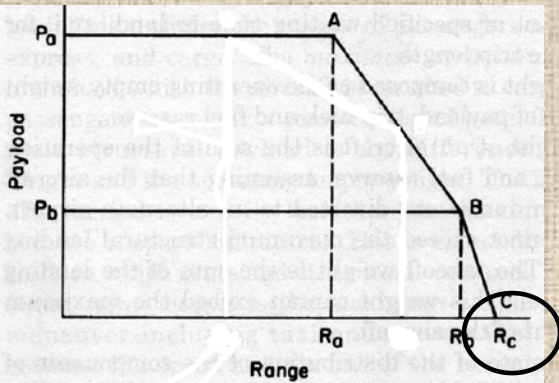
Pt.	Payload	TOW	FW	Range
A	MPW	MTOW	MTOW- MPW -OEW	$(FW-RF)*SR$

# RPD Calculation Point B



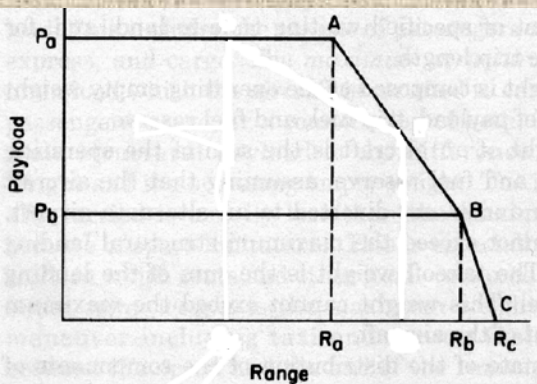
Pt.	Payload	TOW	FW	Range
B	MTOW -OEW -MFW	MTOW	MFW	(MFW-RF)*SR

# RPD Calculation Point C



Pt.	Payload	TOW	FW	Range
C	Zero	OEW+MFW	MFW	FW*SR





# RPD Calculation Table

Pt.	Payload	TOW	FW	Range
$P_a$	MPW	MZFW	Zero	Zero
A	MPW	MTOW	MTOW- MPW -OEW	$(FW-RF)*SR$
B	MTOW -OEW -MFW	MTOW	MFW	$(MFW-RF)*SR$
C	Zero	OEW+MFW	MFW	$FW*SR$

# RPD calculation for Avro RJ-100

Note: Assuming  $SR = 0.19 \text{ nm/kg}$

MTOW = 44226    MPW = 11822    MFW = 9242

OEW = 25600    RF = 1386    MZFW = 37422

Pt.	Payload	TOW	FW	Range
$P_a$				
A				
B				
C				

# RPD calculation for Avro RJ-100

Note: Assuming  $SR = 0.19 \text{ nm/kg}$

MTOW = 44226    MPW = 11822    MFW = 9242

OEW = 25600    RF = 1386    MZFW = 37422

Pt.	Payload	TOW	FW	Range
$P_a$	11822		Zero	Zero
A	11822	44226		
B		44226	9242	
C	Zero		9242	



# RPD calculation for Avro RJ-100

Note: Assuming  $SR = 0.19 \text{ nm/kg}$

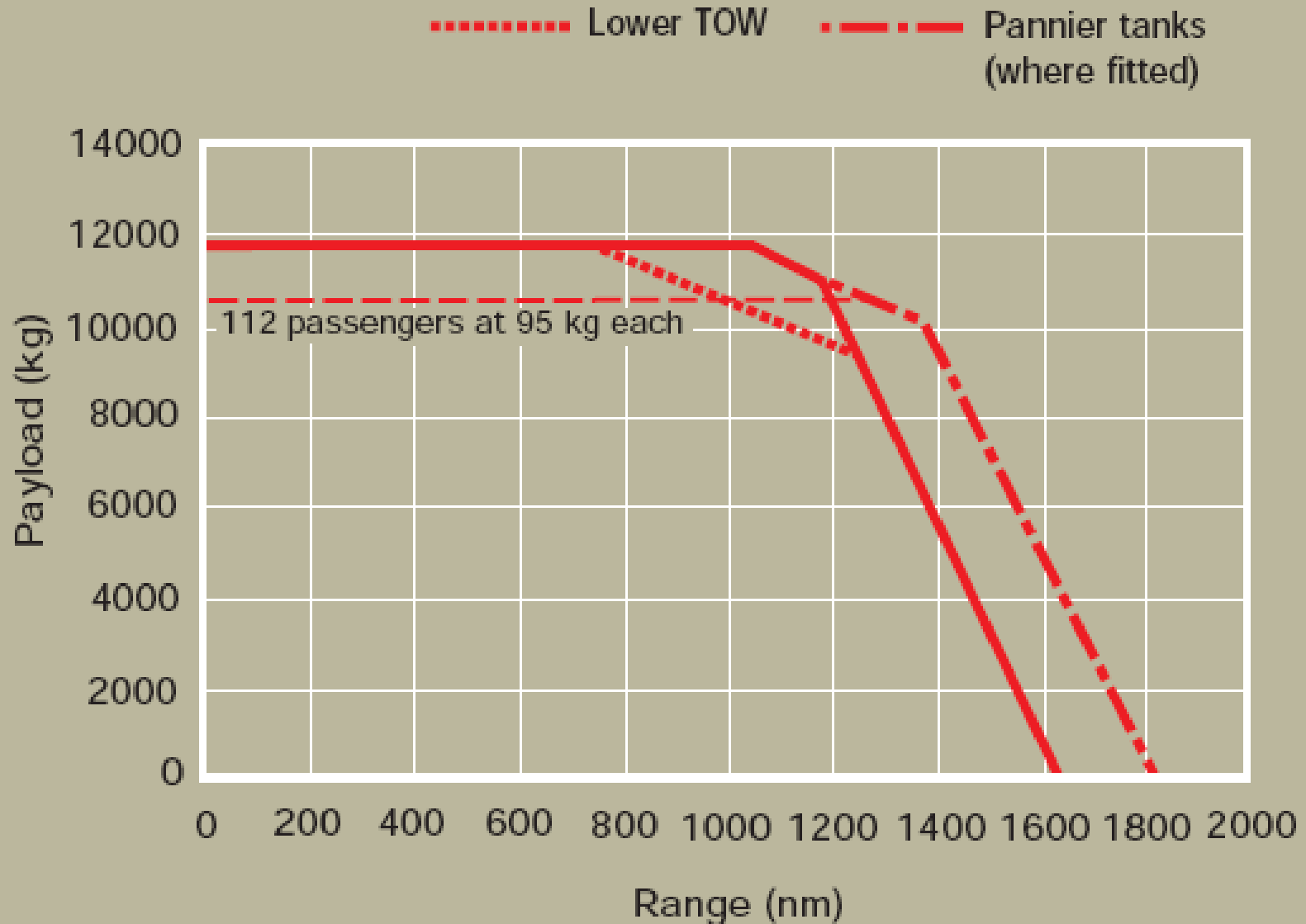
MTOW = 44226    MPW = 11822    MFW = 9242

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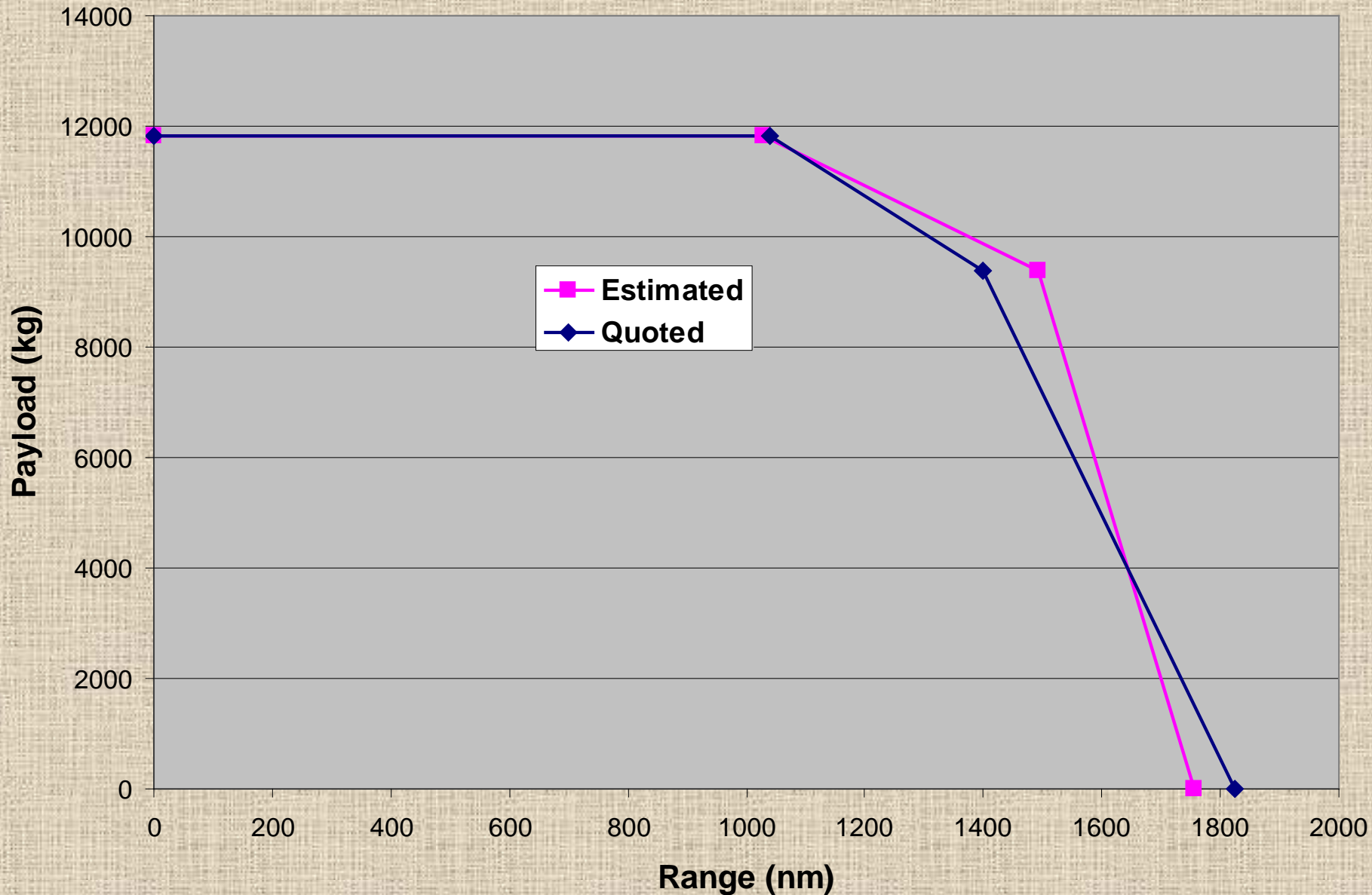
Pt.	Payload	TOW	FW	Range
$P_a$	11822	37422	Zero	Zero
A	11822	44226	6804	1029
B	9384	44226	9242	1493
C	Zero	34842	9242	1756



# Actual RPD of Avro-RJ-100



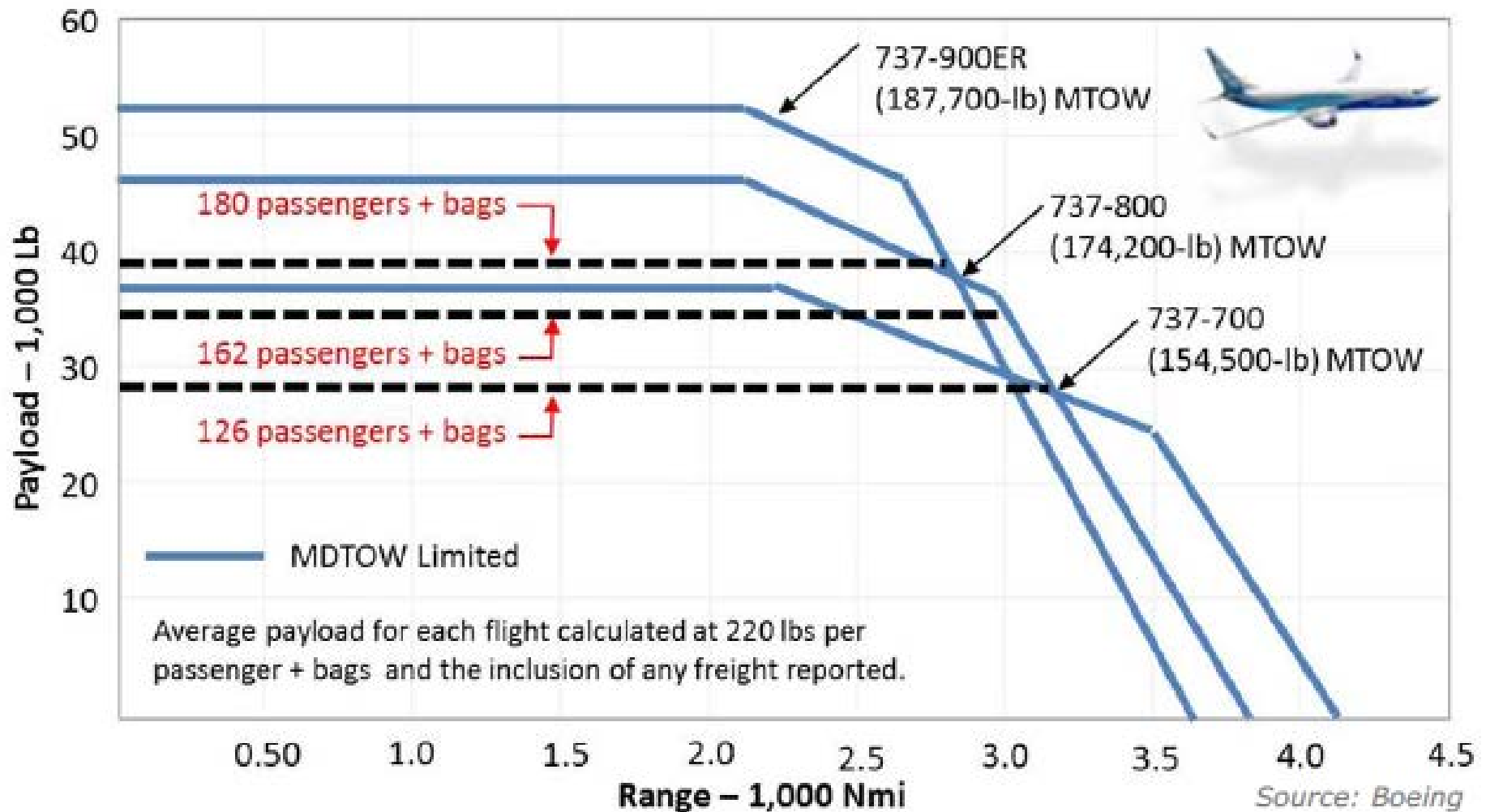
# Quoted v/s Estimated RPD for Avro-RJ-100



# Factors affecting RPD

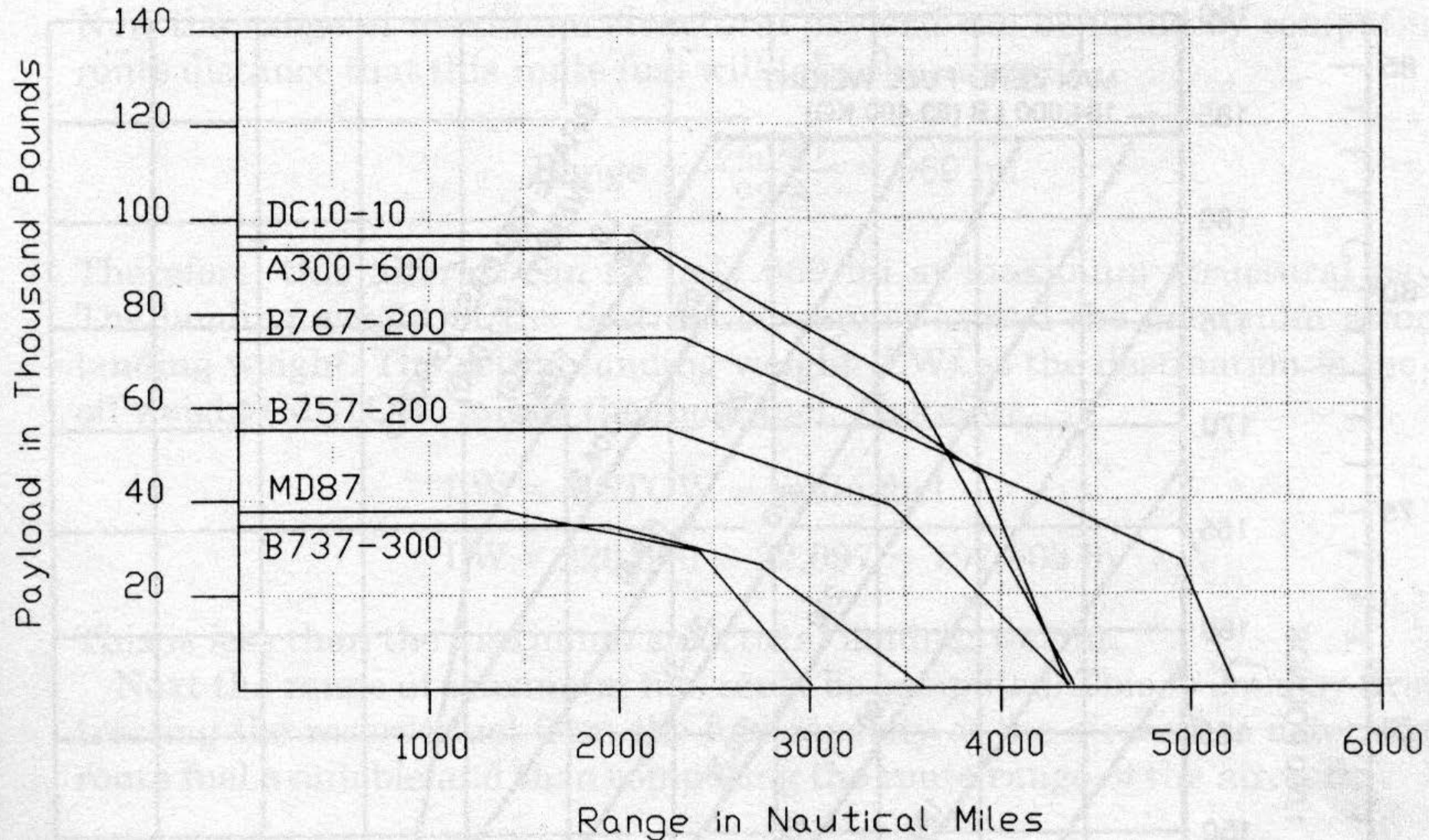
- ❑ Flight altitude
- ❑ Speed
- ❑ Powerplant
- ❑ Fuel
- ❑ Amount of reserve fuel to be carried
- ❑ En-route Meteorological conditions
  - For comparison of different aircraft, Payload range curves are usually shown for a standard day, no wind and long range cruise conditions

# RPD for B-737 NG Family



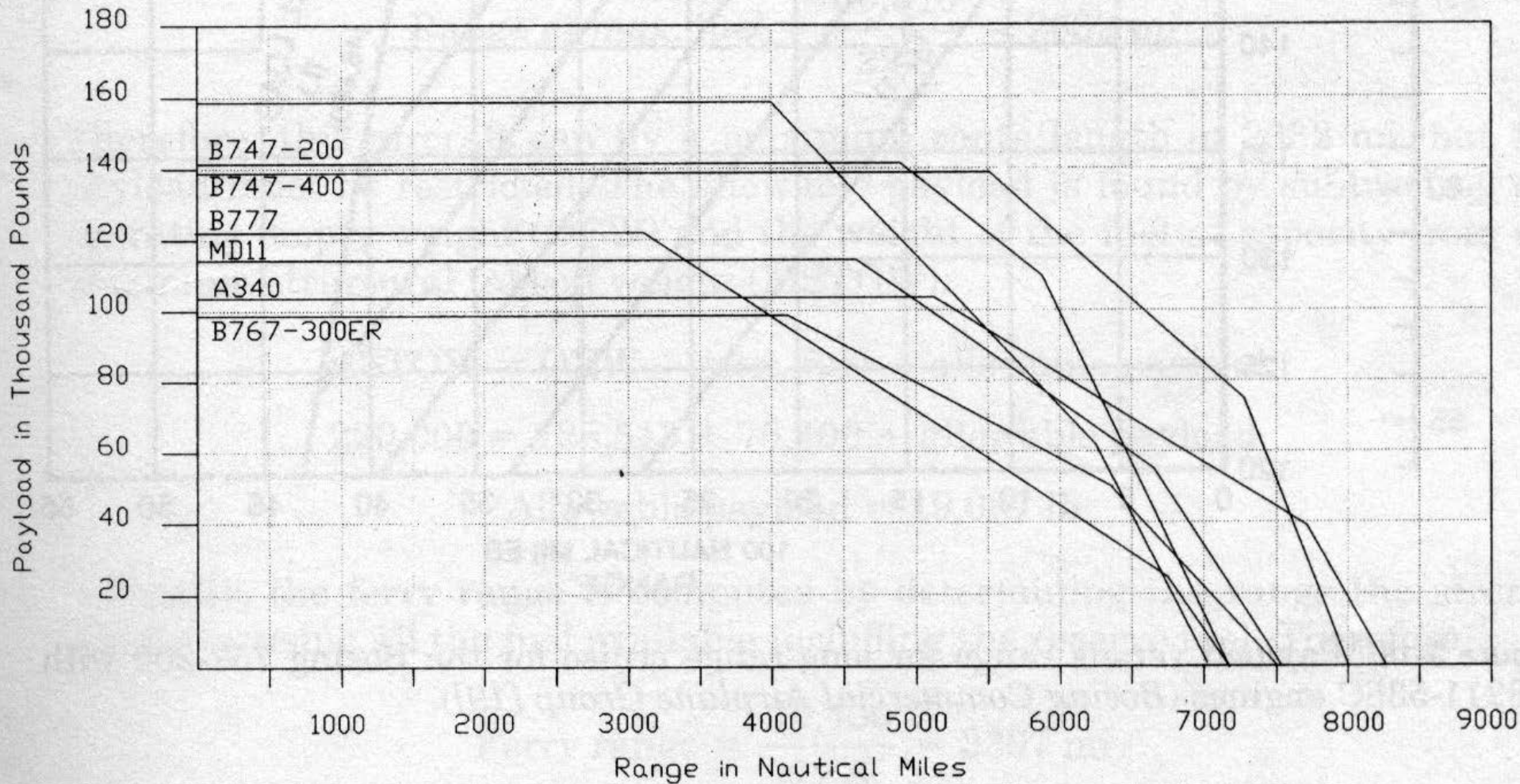


# RPD for some Medium-Range Transport a/c



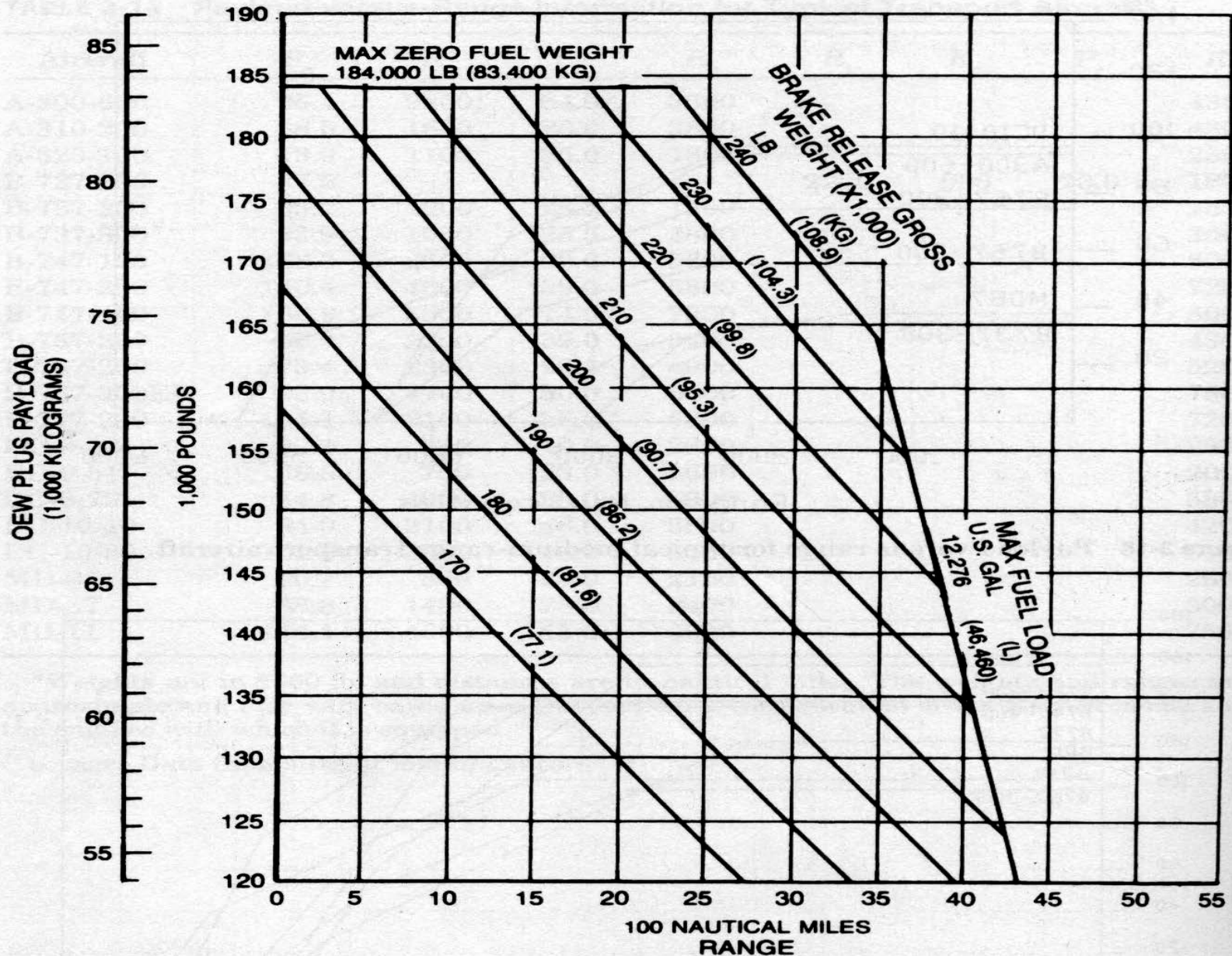


# RPD for some Long-Range Transport a/c

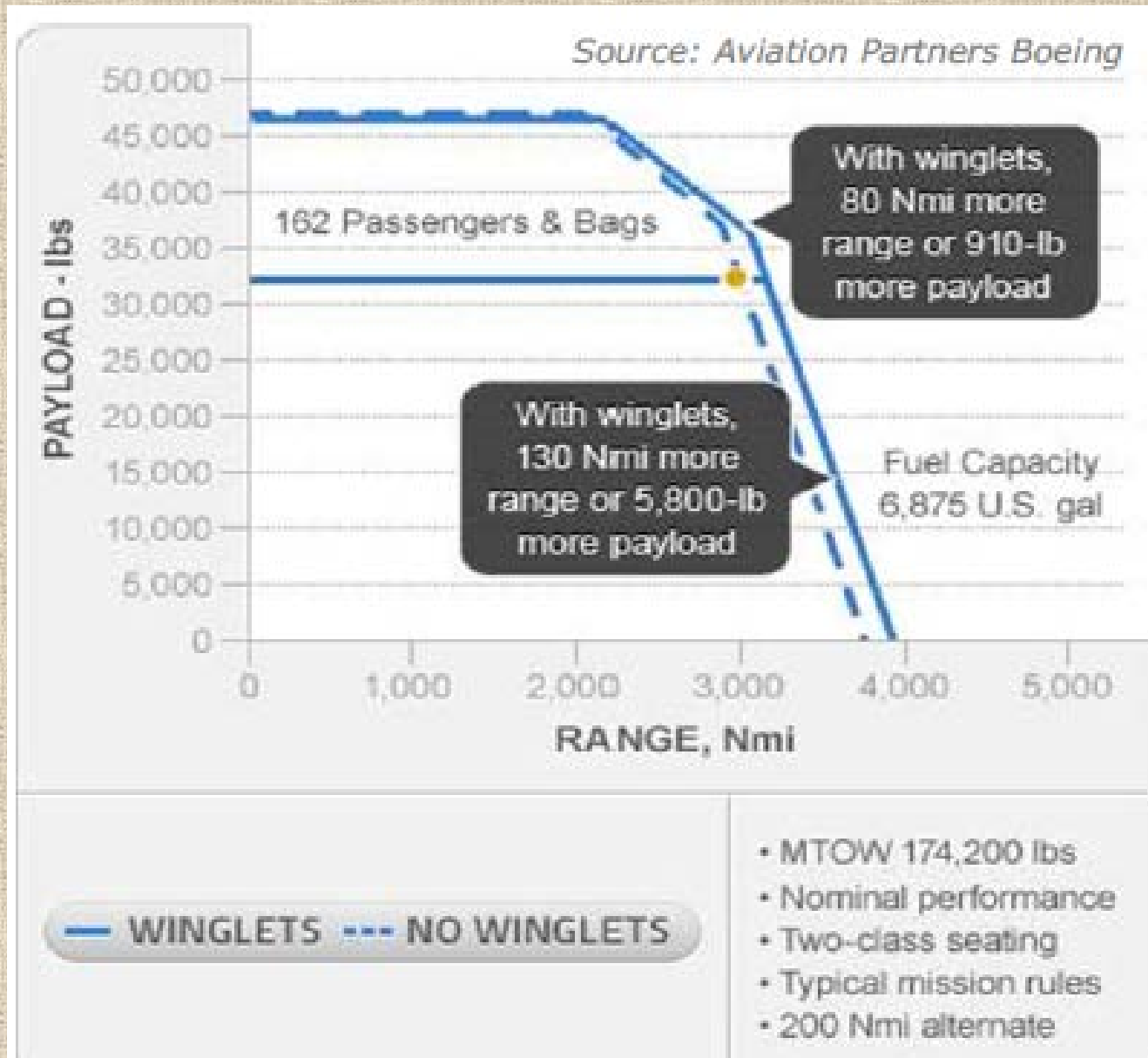




# RPD for B-757-200 with RB-211-535C



# Effect of Winglets on RPD of B737-800





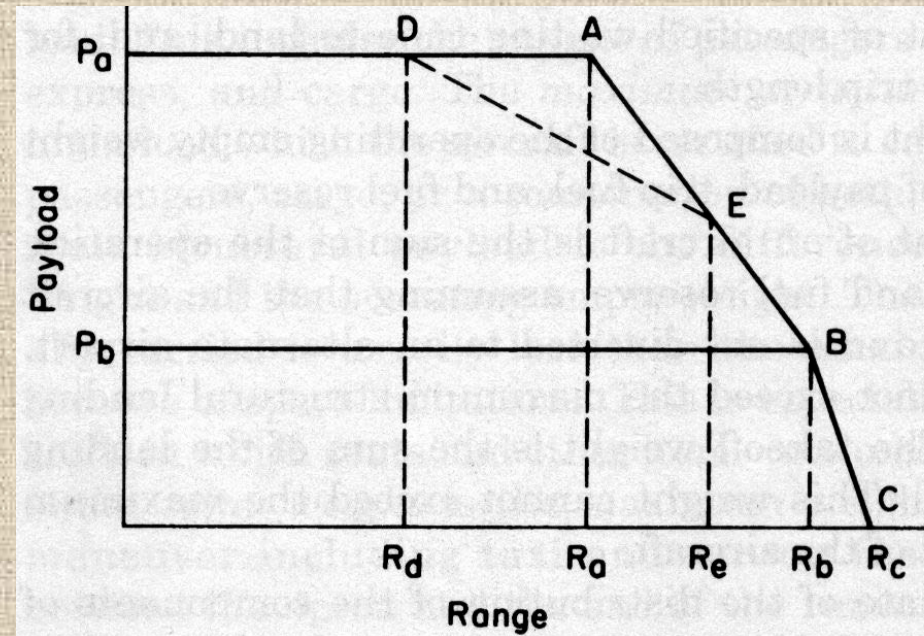
Similar to that due to lower MTOW

# **EFFECT OF MLW ON RPD**

# Effect of MLW on RPD

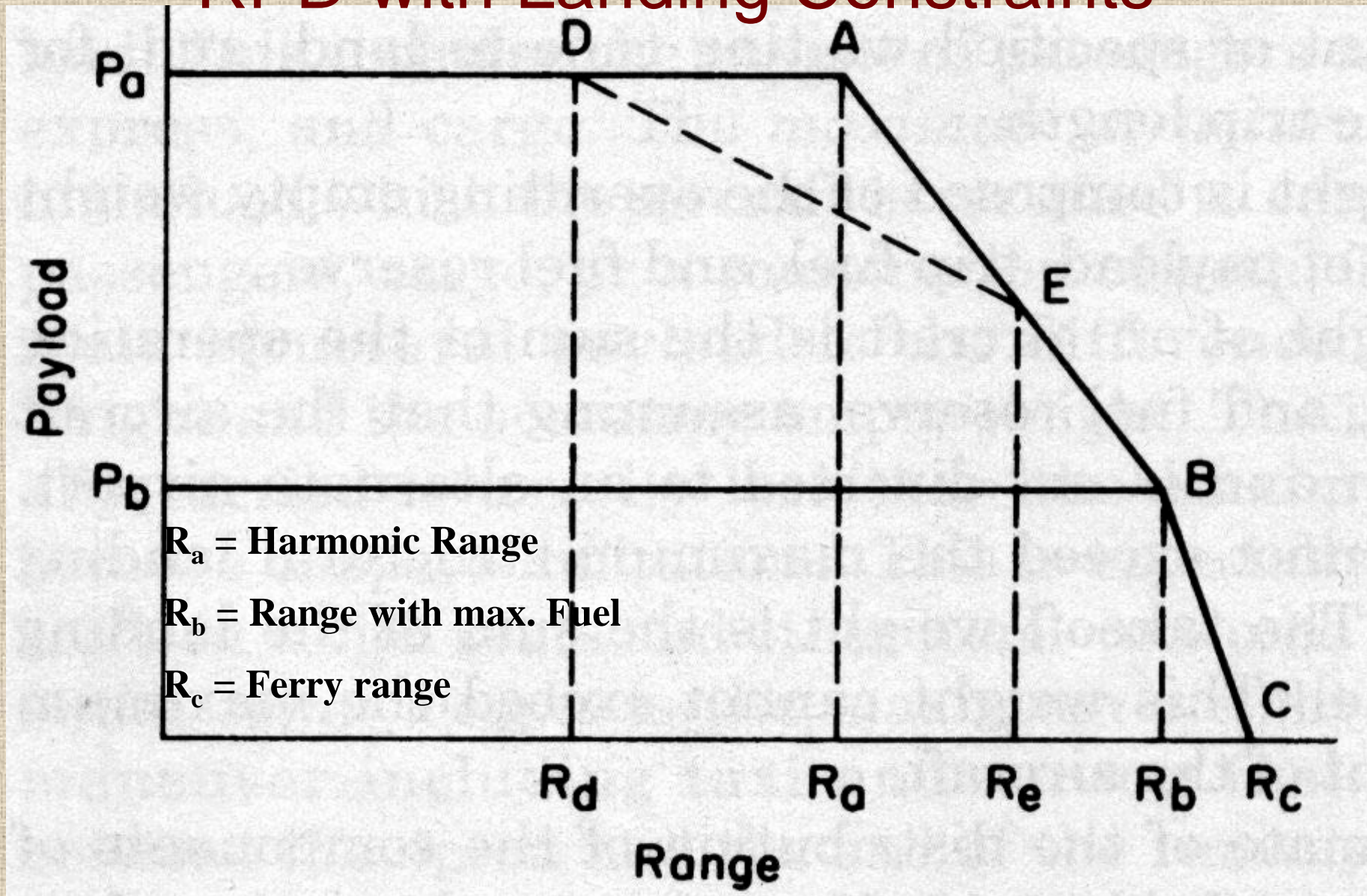
- MLW dictates Range
- At D,  $W_{\text{Land}} = \text{permitted } W_{\text{TO}}$
- Range =  $R_d$
- Line DE for payload tradeoff
- Curve DEBC is the RPD

Rather than AEBC

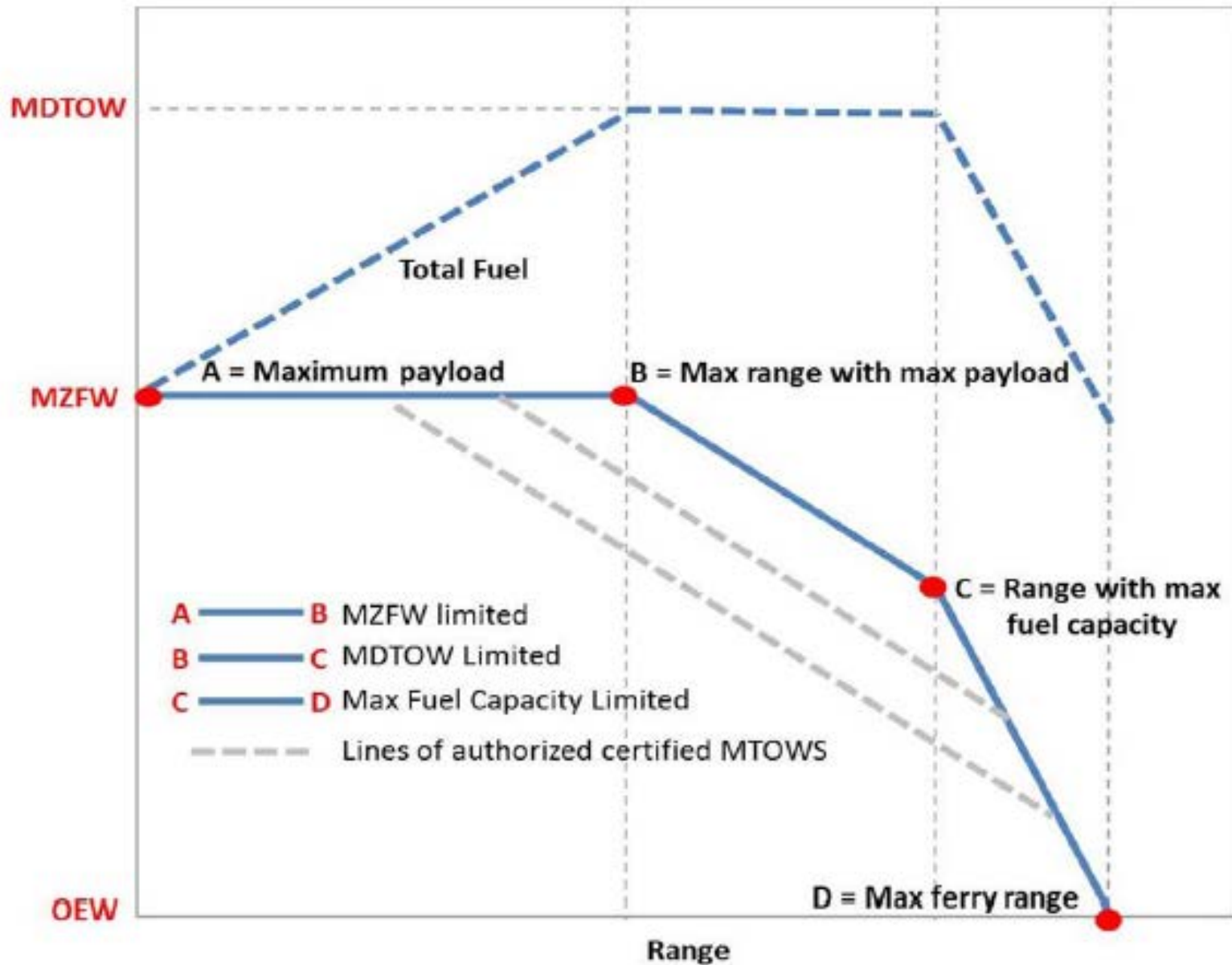




# RPD with Landing Constraints



# Alternate view of RPD





1. Fielding, J. P., *Introduction to Aircraft Design*, Cambridge Aerospace Series 11, 1999.
2. Horonjeff, R., McKelvey, F., Sproule, W., Young, S., *Planning and Design of Airports*, 5<sup>th</sup> edition, McGraw Hill Professional, 2010
3. Ackert, S., Aircraft Payload-Range Analysis for Financiers, *Aircraft Monitor*, April 2013

# ACKNOWLEDGEMENTS

# Self-Study Assignment

## Range Payload Diagram

## Aircraft Data

❖ Maximum structural landing weight	89837 Kg
❖ Maximum structural takeoff weight	99819 Kg
❖ Zero-fuel weight	82810 Kg
❖ Operating empty weight	56948 Kg
❖ Maximum structural payload	25862 Kg
❖ Fuel capacity of the tank	34211 Kg

## Assumptions:

1.25 hour reserve fuel

Average Speed = 869.4 KMPH

Average Fuel Burn = 6.425 kg/km

Plot RPD for the above aircraft