Progettazione di veicoli aerospaziali (AA-LZ)

E1. Conceptual Design of subsonic commercial aircraft

3. Payload-Range Diagram

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Take-off weight

$$m_{TO} = \frac{m_{crew} + \overbrace{m_{payload}}^{f(n_{pax})}}{1 - \underbrace{\left(\frac{m_{fuel}}{m_{TO}}\right)}_{f(R, V, sfc, E)} - \underbrace{\left(\frac{m_{empty}}{m_{TO}}\right)}_{f(m_{TO}, C, A)}}$$

1. Variations of **payload mass** and **maximum range** are the most influential on $\boldsymbol{m_{TO}}$

2. Sensitivity analyses are used to understand the impact of a variation of one of these parameters on to the m_{TO}.

3. Trade studies are then used to see the effect of the combined variation of a set of parameters onto m_{TO}, thus allowing to trade-off the best set of parameters. In this case, the best set of parameters should maximize performance requirements while minimizing the m_{TO}.

Sensitivity analysis

$$m_{TO} = \frac{m_{crew} + m_{payload}}{1 - \left(\frac{m_{fuel}}{m_{TO}}\right) - \left(\frac{m_{empty}}{m_{TO}}\right)}$$

During conceptual design phase, the evaluation and refinement of requirements, involving stakeholders, represent a fundamental part. Typical examples are “Range Trade” and “Payload Trade”.

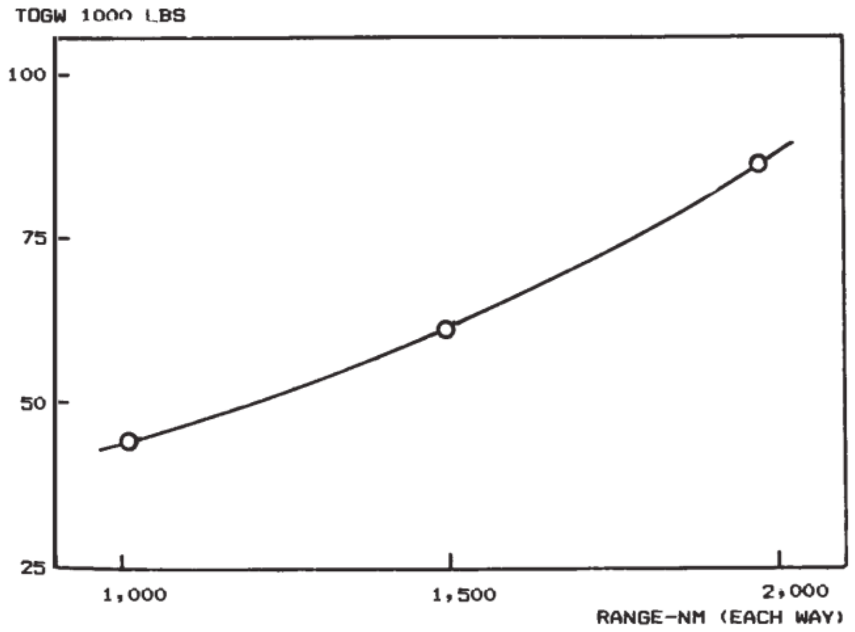


Fig. 3.11 Range trade.

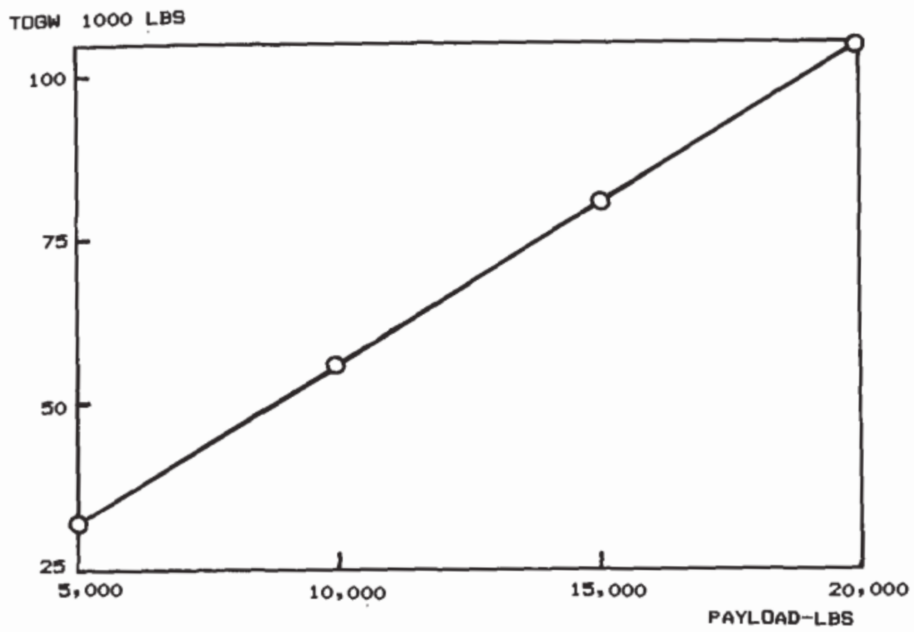
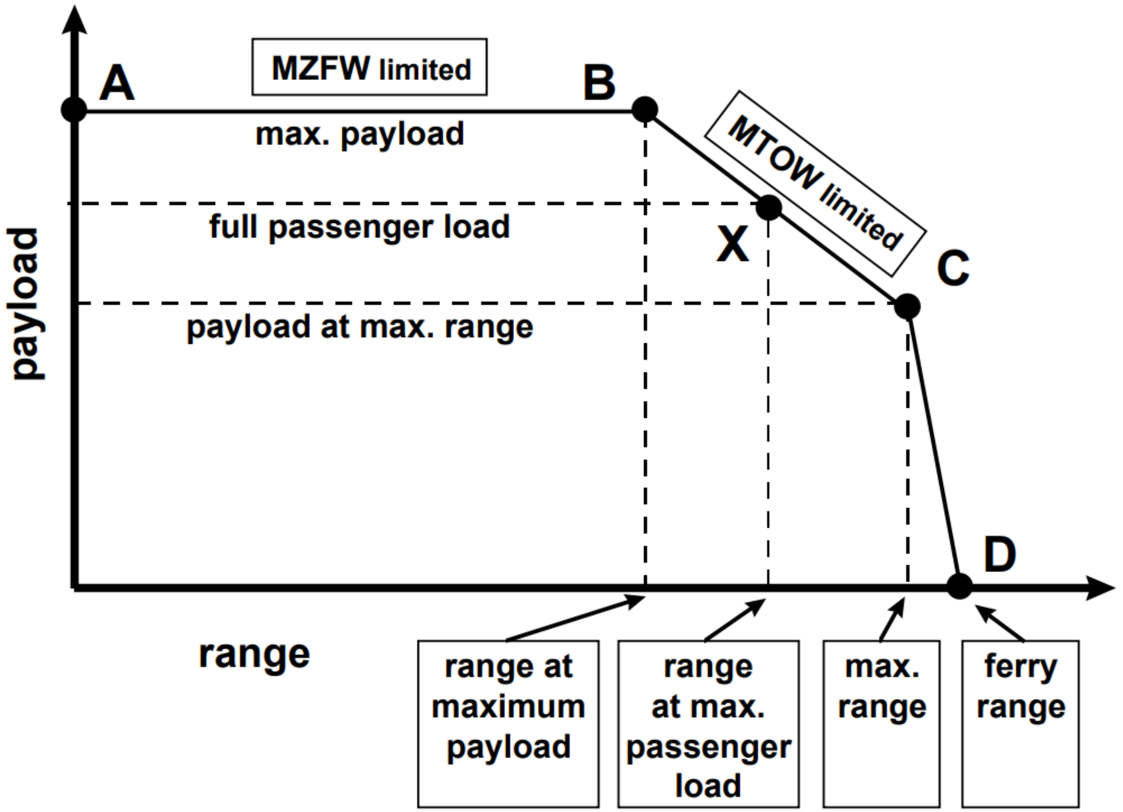


Fig. 3.12 Payload trade.

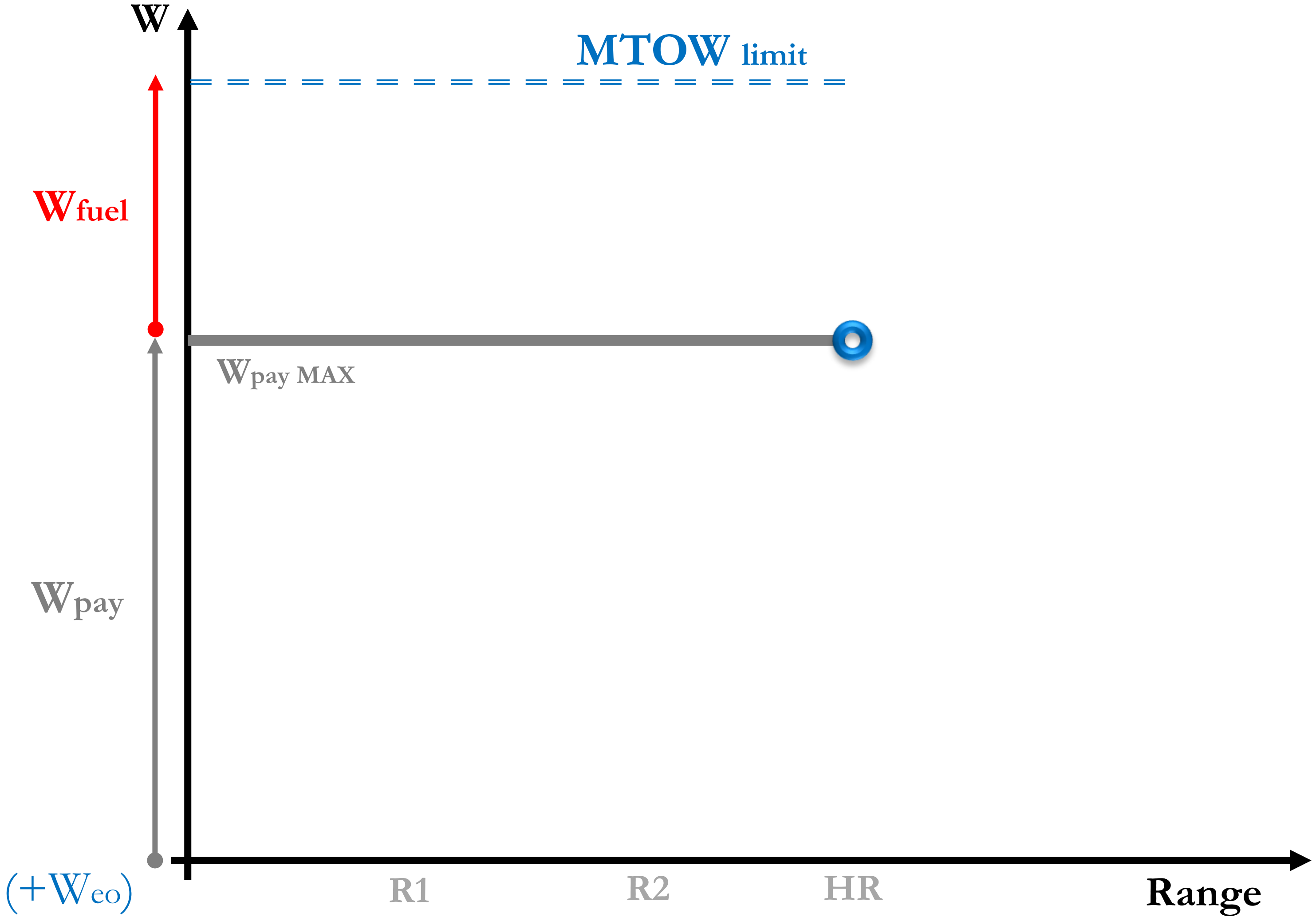
Payload-range diagram



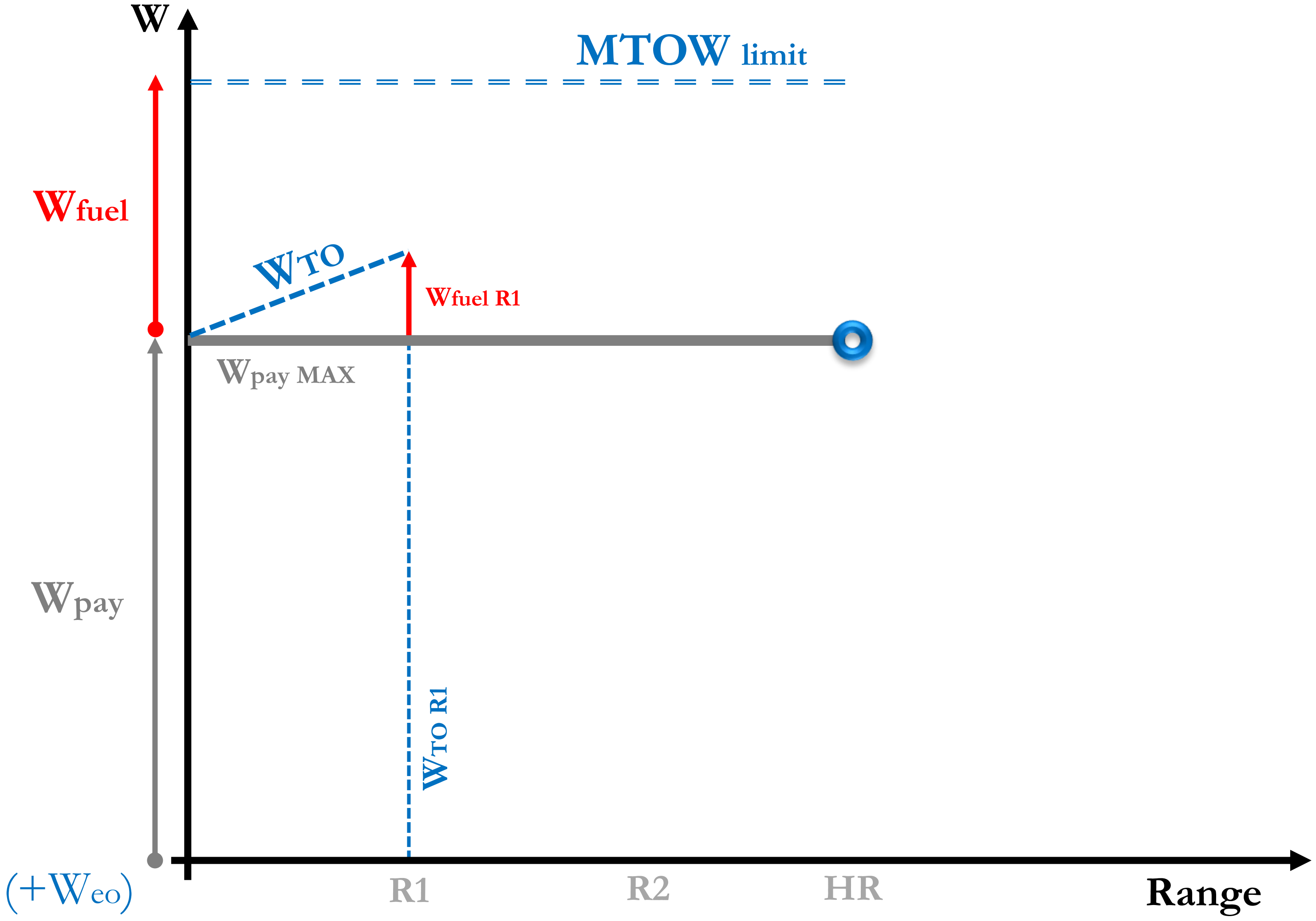
We will now examine how the weight of the aircraft is built-up with reference to its **payload-range diagram**. The payload-range diagram is useful for operators: **a)** comparing payload range capabilities of various aircraft types; **b)** determining how much payload can be flown over what distances according to a set of operational limitations.

The specific shape of the aircraft's payload-range diagram is affected by its aerodynamic design, structural efficiency, engine technology, fuel capacity, and passenger/cargo capacity. Each aircraft has its own corresponding payload-range diagram, with different limitations depending on the engine type installed.

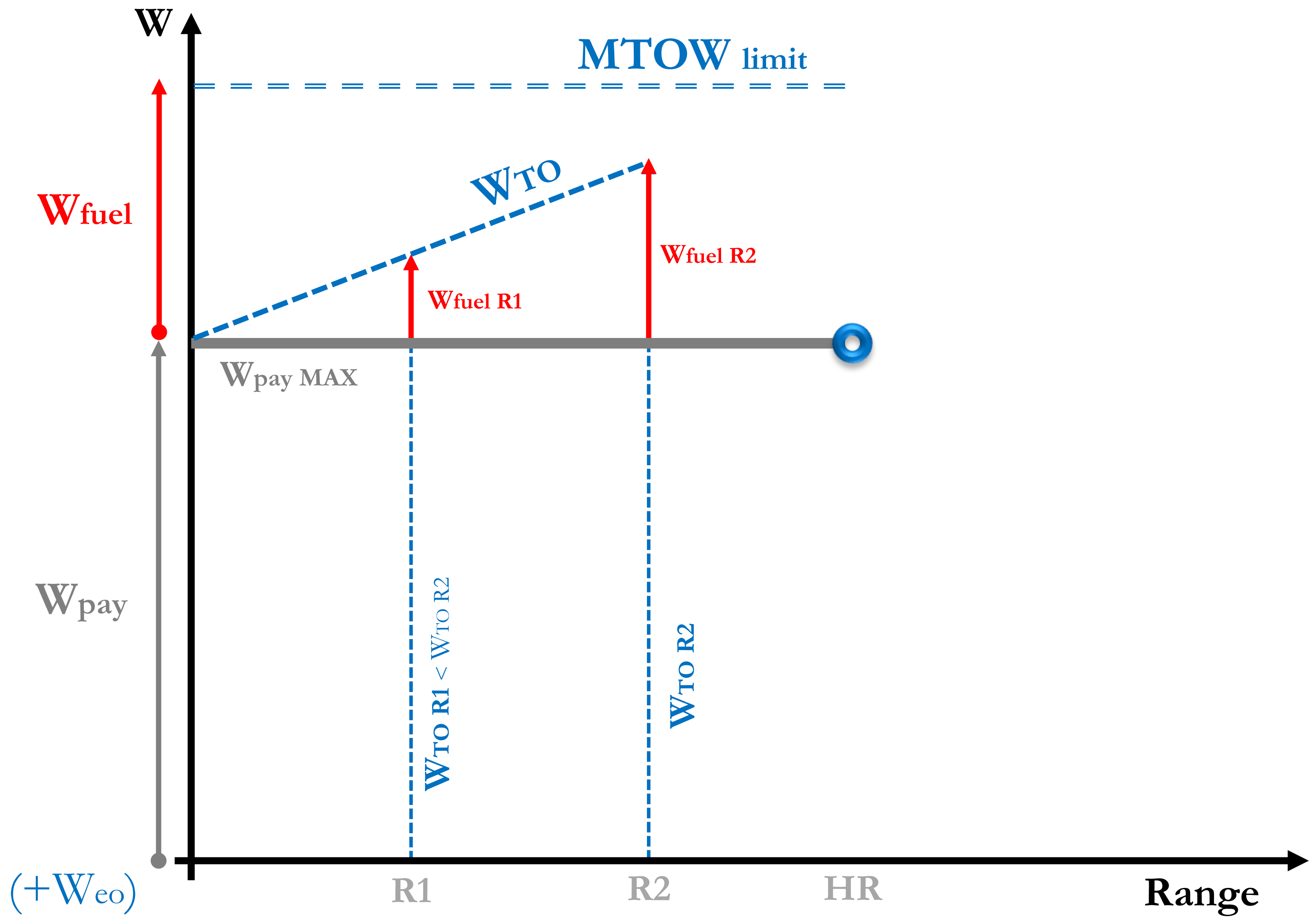
Payload-range diagram



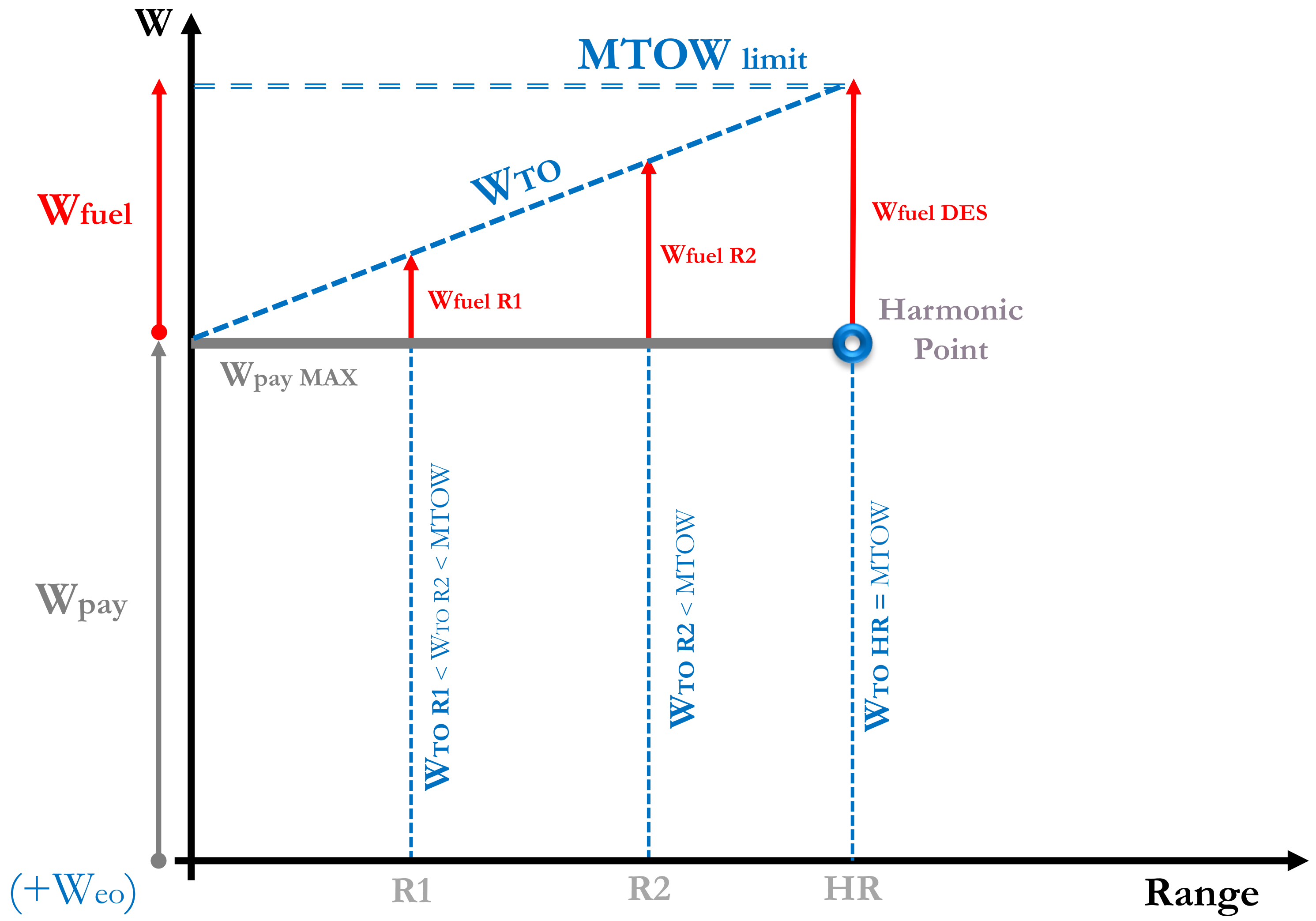
Payload-range diagram



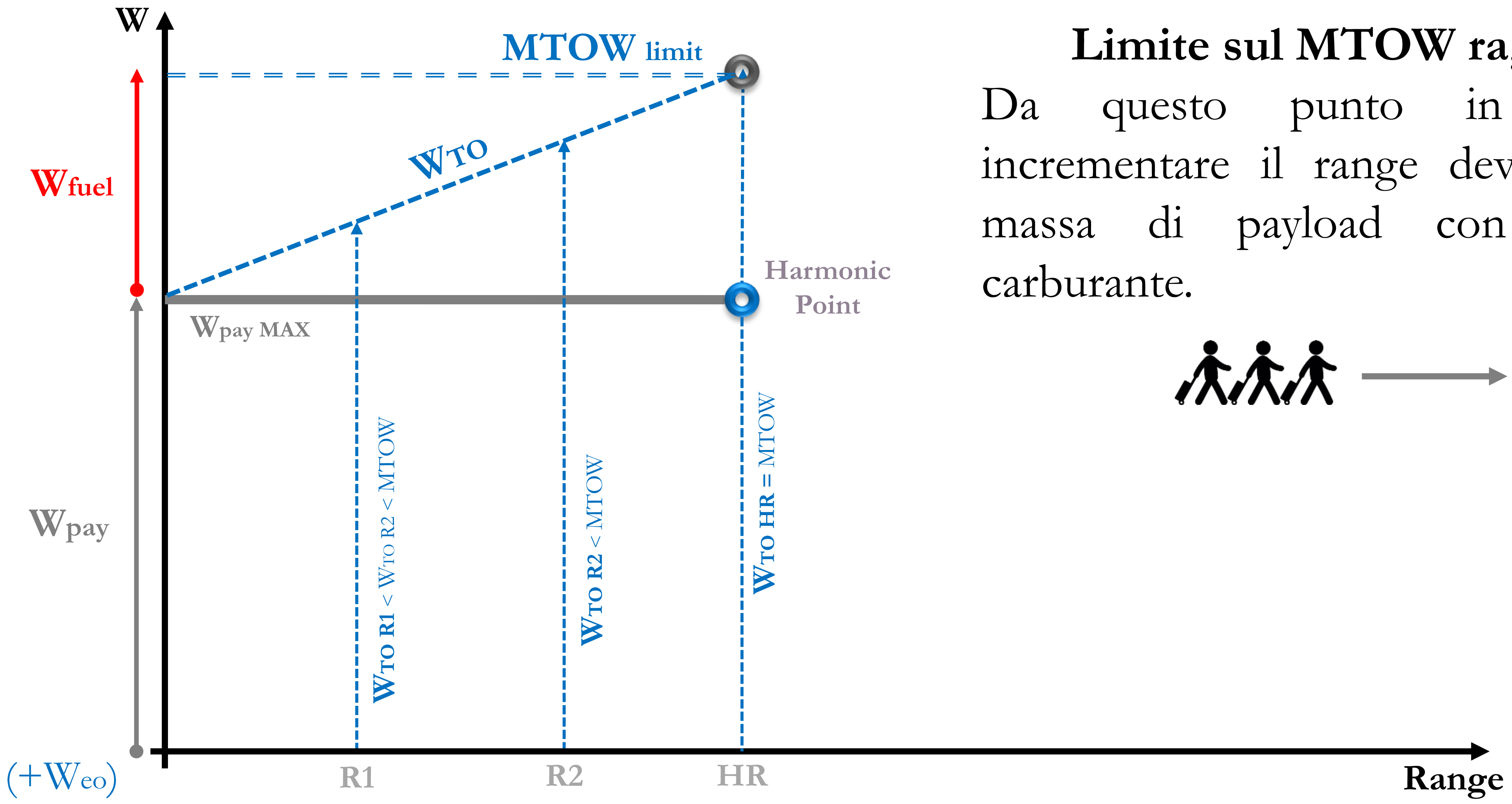
Payload-range diagram



Payload-range diagram



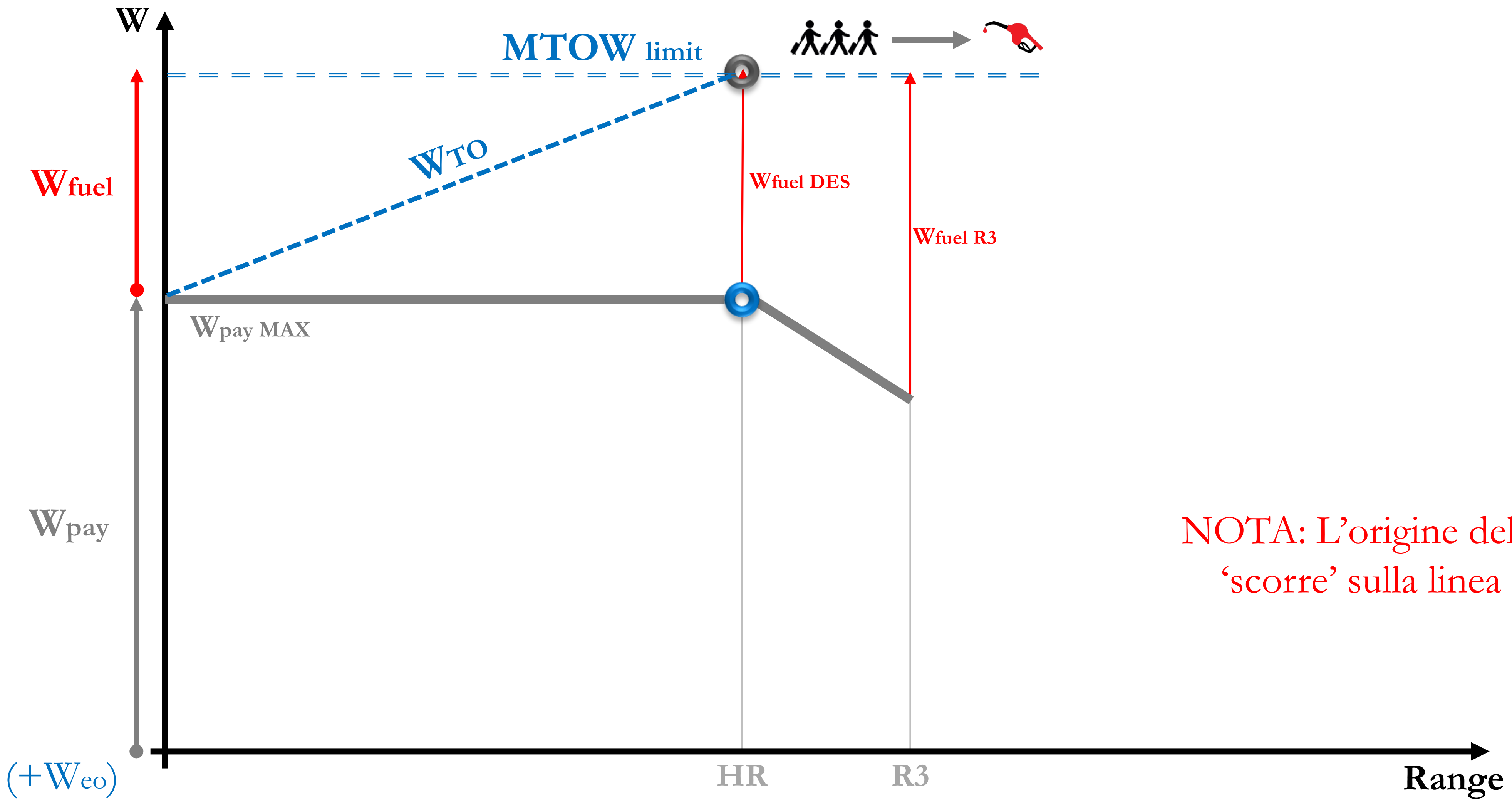
Payload-range diagram



Limite sul MTOW raggiunto

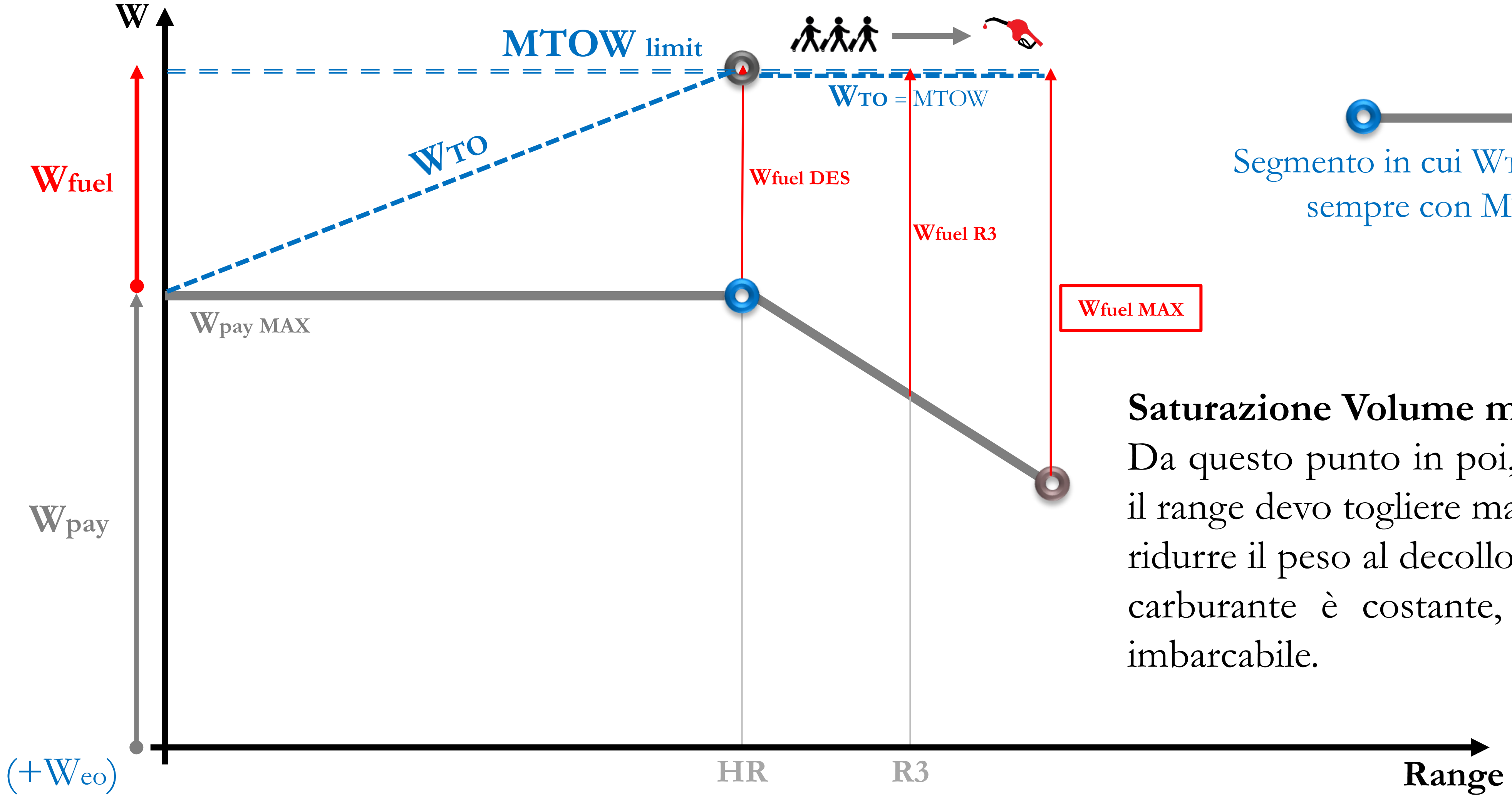
Da questo punto in poi, per incrementare il range devo scambiare massa di payload con massa di carburante.

Payload-range diagram



NOTA: L'origine dell'ordinata W_{fuel} 'scorre' sulla linea del $W_{pay\ MAX}$

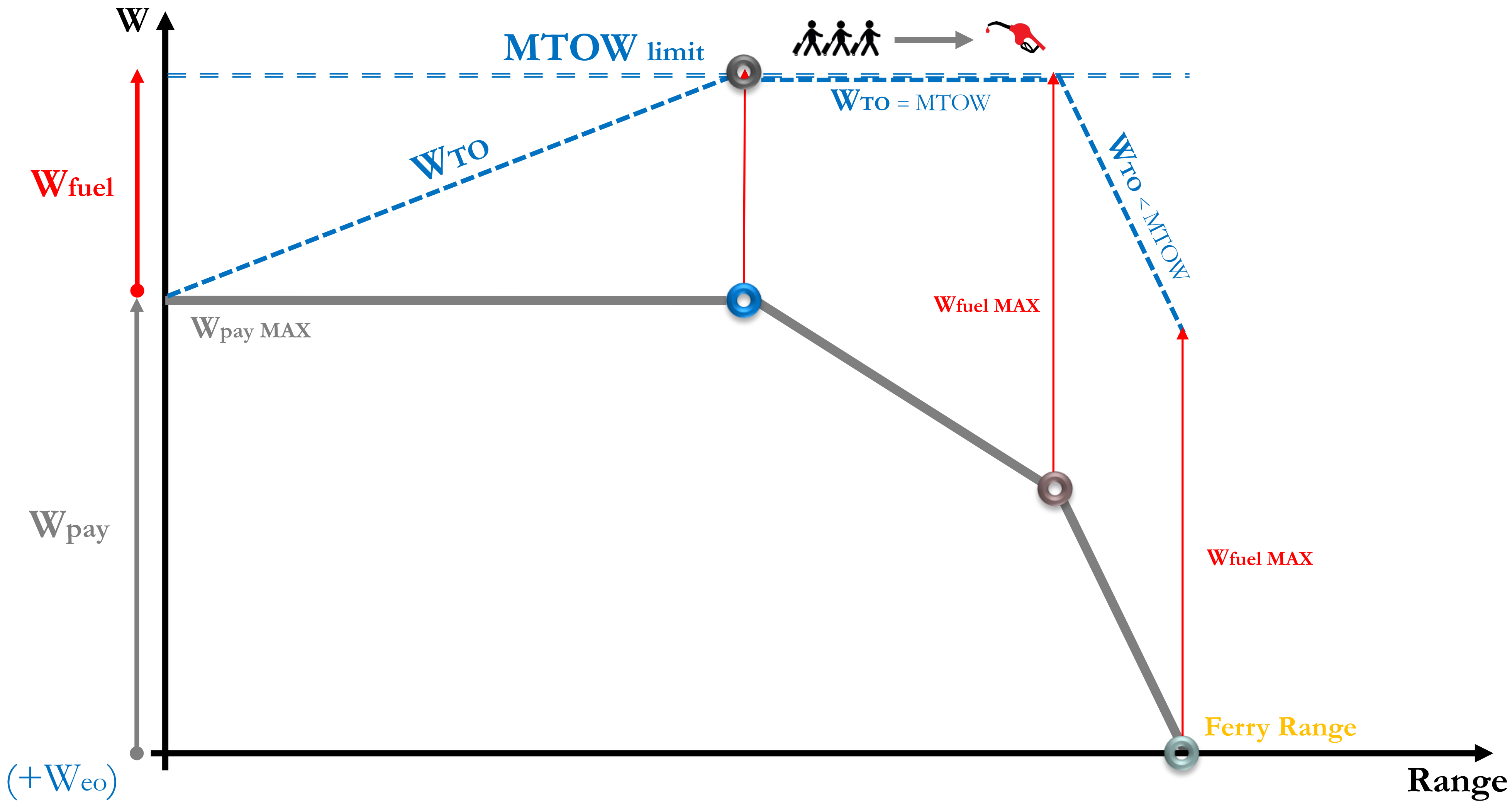
Payload-range diagram



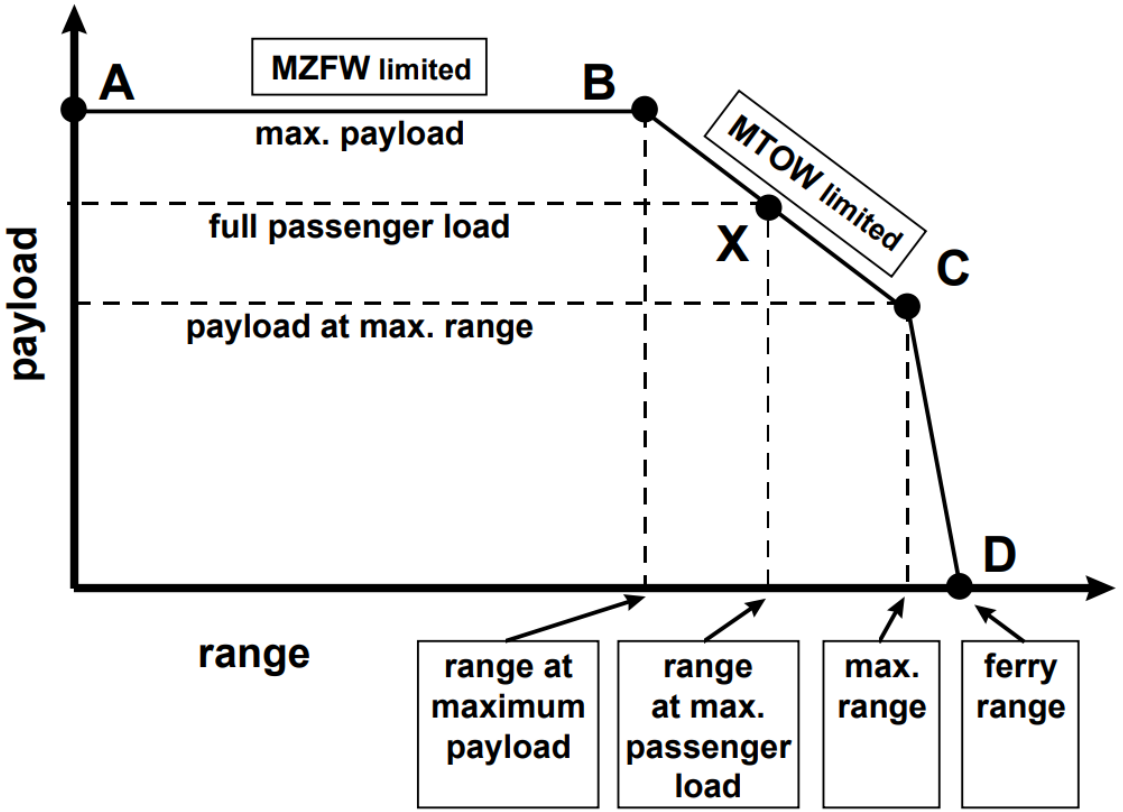
Segmento in cui W_{TO} coincide sempre con MTOW

Saturazione Volume massimo serbatoi.
Da questo punto in poi, per incrementare il range devo togliere massa di payload per ridurre il peso al decollo, mentre il peso di carburante è costante, pari al massimo imbarcabile.

Payload-range diagram



Payload-range diagram



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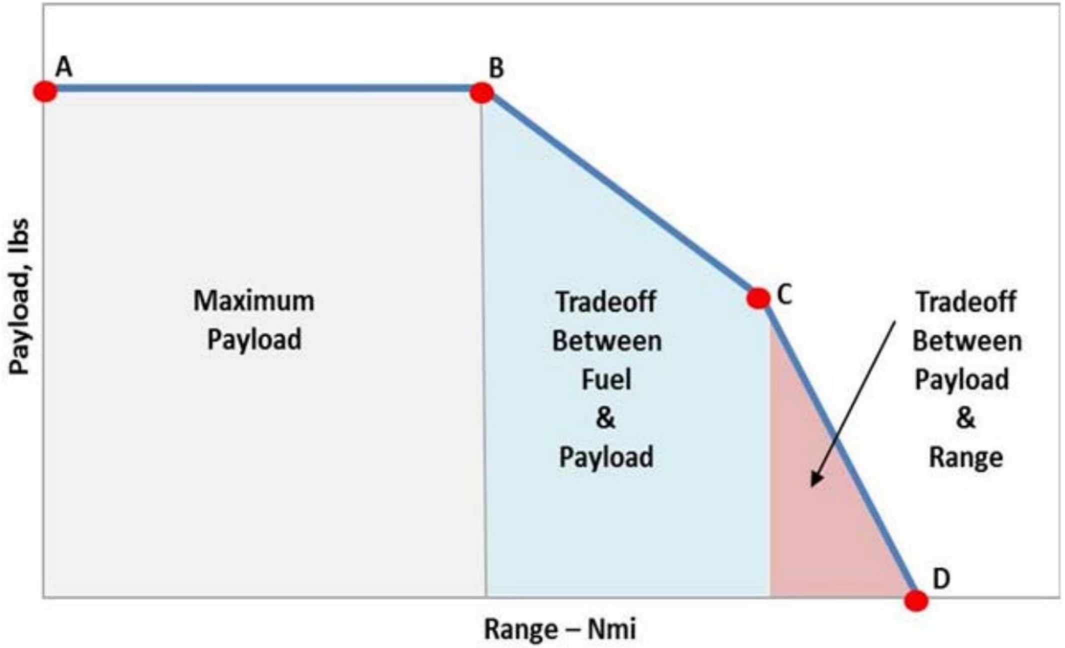
Payload-range diagram

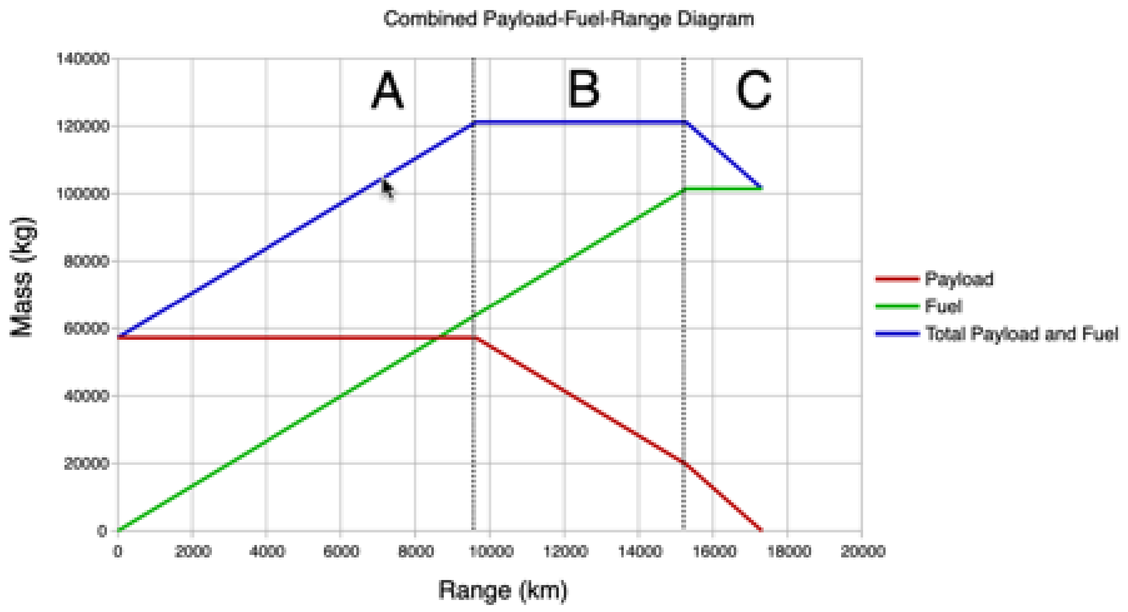
$$m_{TO} = m_{crew} + m_{payload} + m_{fuel} + m_{empty}$$



- At Point A the aircraft is at maximum payload with no fuel on-board.
- Along Points A to B – maximum payload range; fuel is added so that a certain range can be flown.
- Point B represents the maximum range the aircraft can fly with maximum payload.
- Along Points B to C – payload limited by MTOW; payload is traded for fuel to attain greater range.
- At Point C the maximum fuel volume capacity has been reached, and represents the maximum range with full fuel tanks where a reasonable payload can be carried.
- Along Points C to D – payload limited by fuel; only payload can be offloaded to make the aircraft lighter, thereby improving its range capability.
- Point D the aircraft is theoretically at the Operator's Empty Weight (OEW), and range flown at this point is considered the maximum ferry-range.

[1] Ackert, Shannon. "Aircraft payload-range analysis for financiers." Aircraft Monitor: San Francisco, CA, USA (2013).

Payload-range diagram



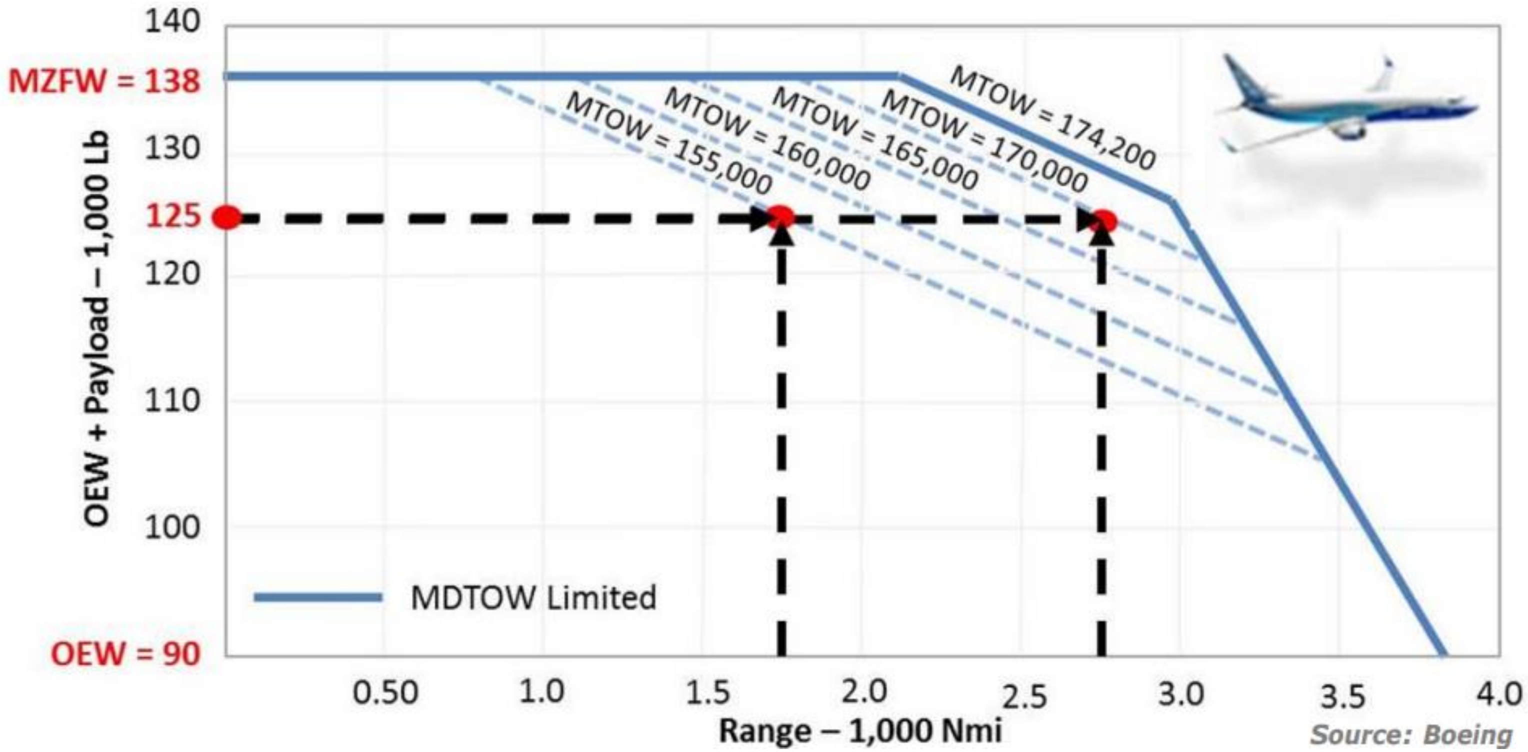
A: Fuel can be added as needed to reach any range needed in this area, but payload cannot exceed the certified or physical maximum possible for the aircraft. *MTOM increases*

B: There is still space in the fuel tanks to add more fuel, but the maximum take-off weight of the aircraft has been reached (pt.2). In order to fly further, some payload must be offloaded in order to allow more fuel to be loaded. *MTOM is reached and kept constant*

C: The aircraft fuel tanks are full, so the only way to fly further is to reduce the total weight of the aircraft by reducing the payload further. Due to the reduced total aircraft weight, the aircraft is then able to fly further, even with the same amount of fuel. *MTOM decreases*

[1] Ackert, Shannon. "Aircraft payload-range analysis for financiers." Aircraft Monitor: San Francisco, CA, USA (2013).

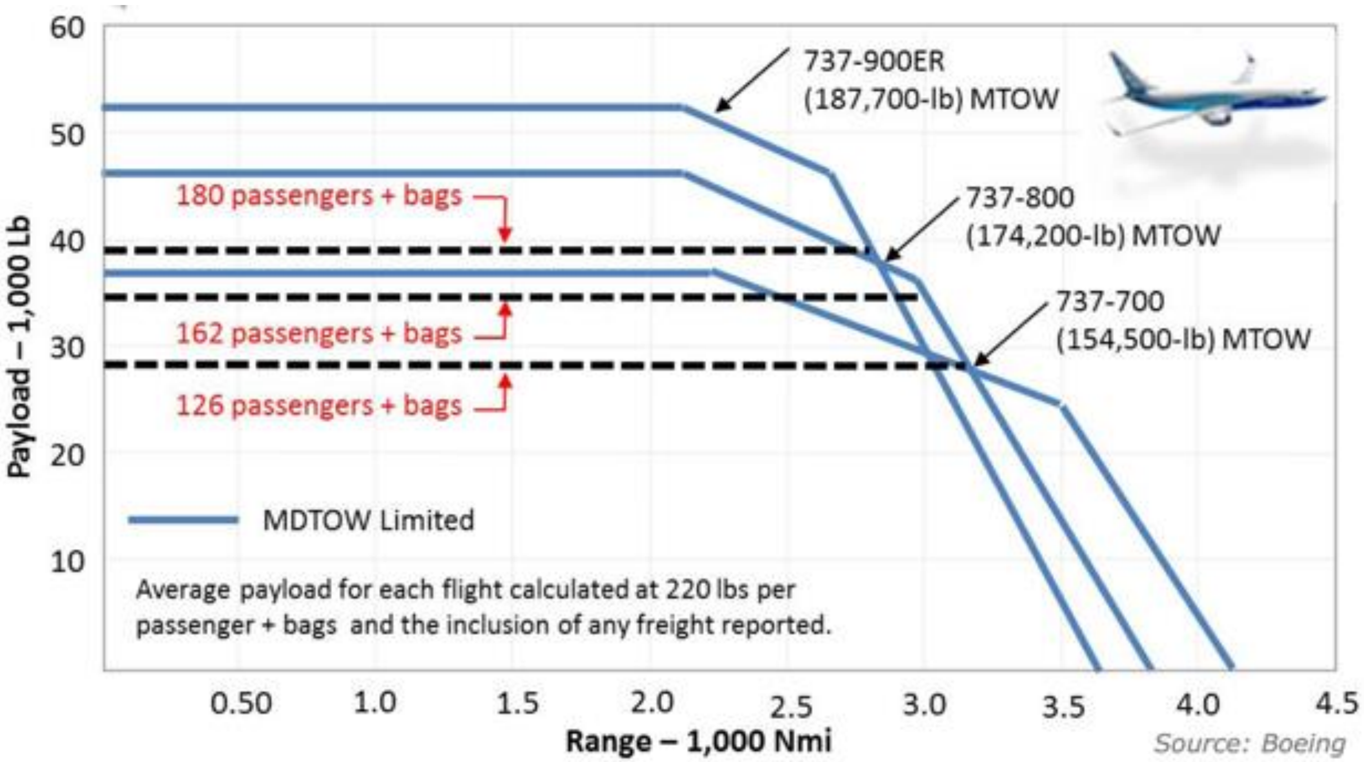
Payload-range diagram



The region inside of the boundary represents feasible combinations of payload and range missions. A contour line inside of the boundary and parallel with the MTOW boundary represents lines of alternative, authorized MTOWs. The authorized weight limits are chosen by the airline and often referred to as the purchased weights.

[1] Ackert, Shannon. "Aircraft payload-range analysis for financiers." Aircraft Monitor: San Francisco, CA, USA (2013).

Family concept

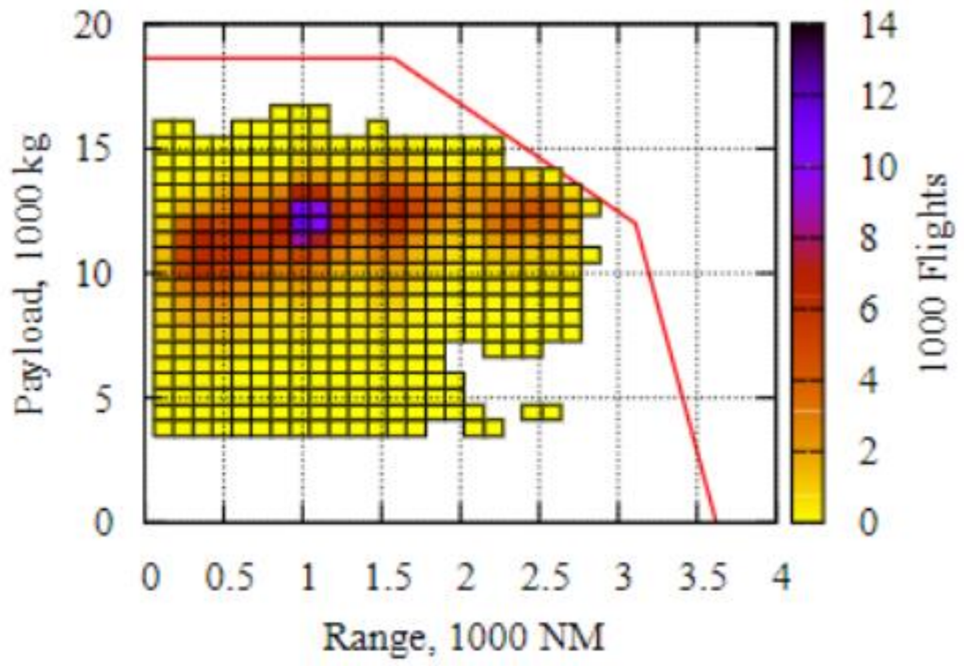


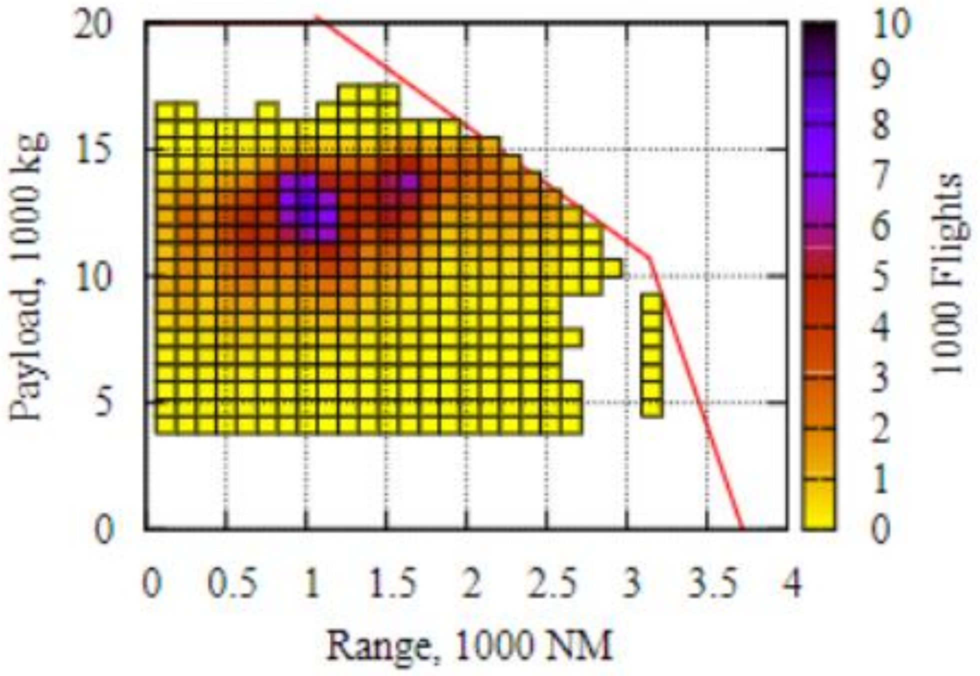
The above example illustrates how the family concept can assist airlines to better match an aircraft model (i.e., 737-700, 737-800, etc.) to specific parts of its network. Operational flexibility becomes especially important in fleet planning as future range and payload requirements can be adjusted more easily by selecting smaller and/or larger-sized variants of an aircraft type you already operate.

[1] Ackert, Shannon. "Aircraft payload-range analysis for financiers." Aircraft Monitor: San Francisco, CA, USA (2013).

Open discussion

Actual aircraft missions deviates from the design point [1]





1. Husemann M. et al. Flexibility within flight operations as an evaluation criterion for preliminary aircraft design. Journal of Air Transport Management, Volume 71, 2018.

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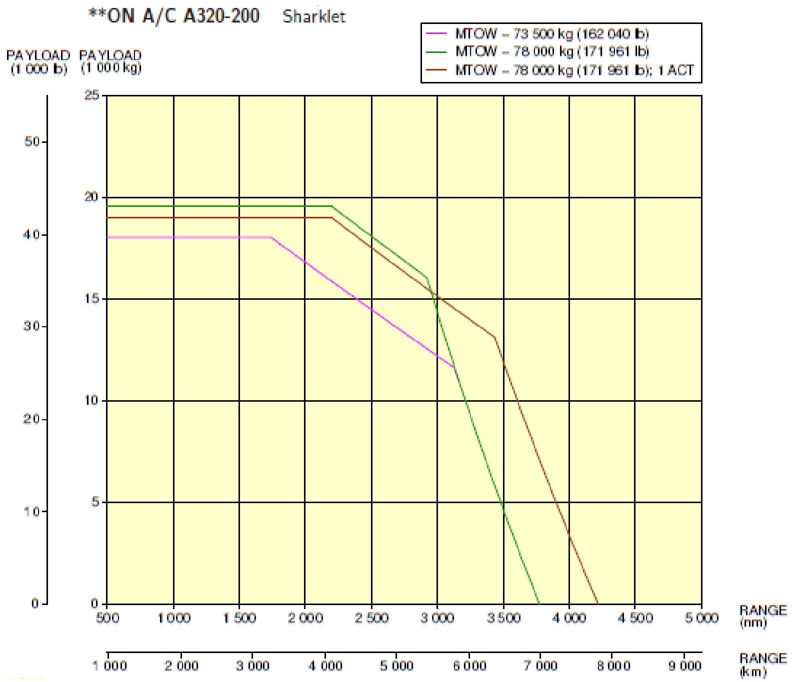

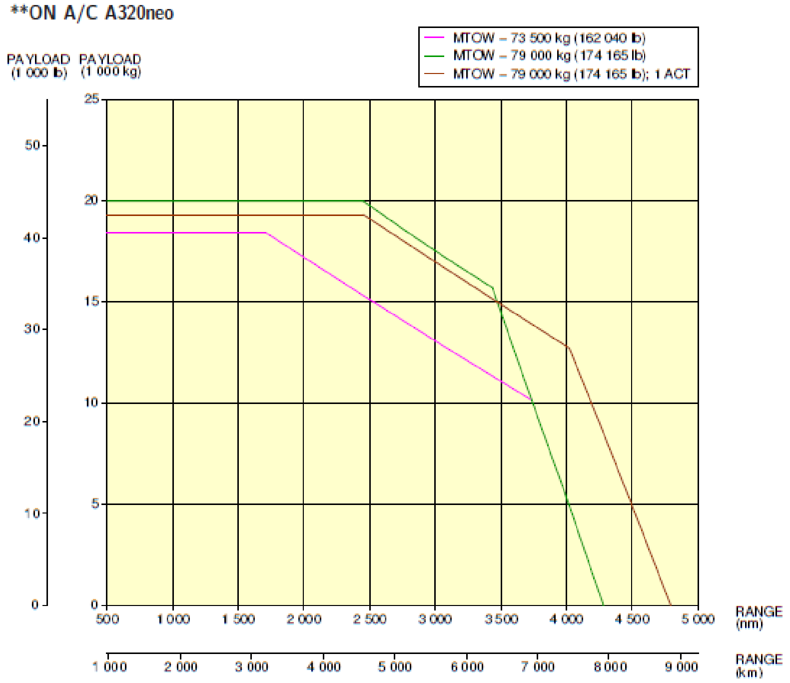

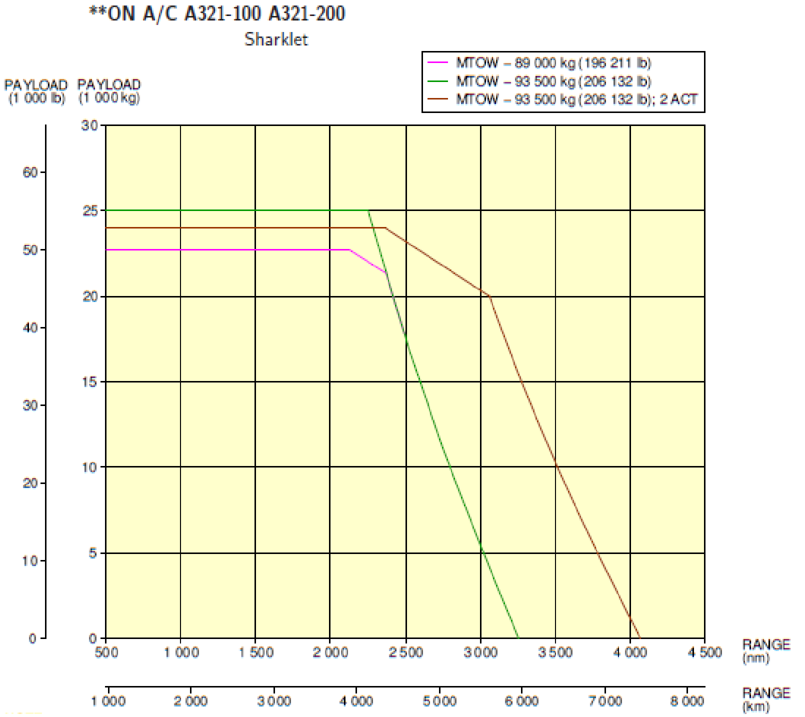

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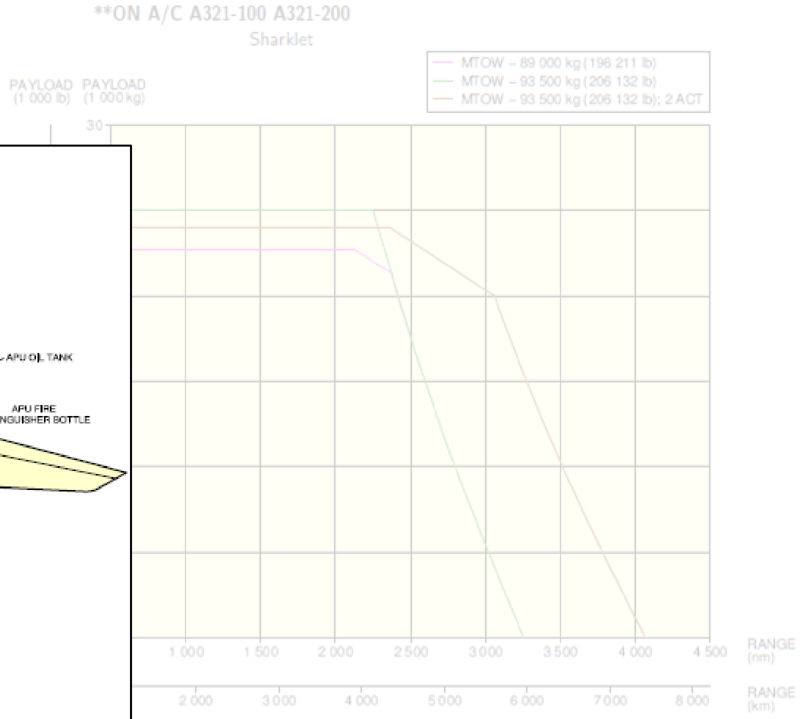

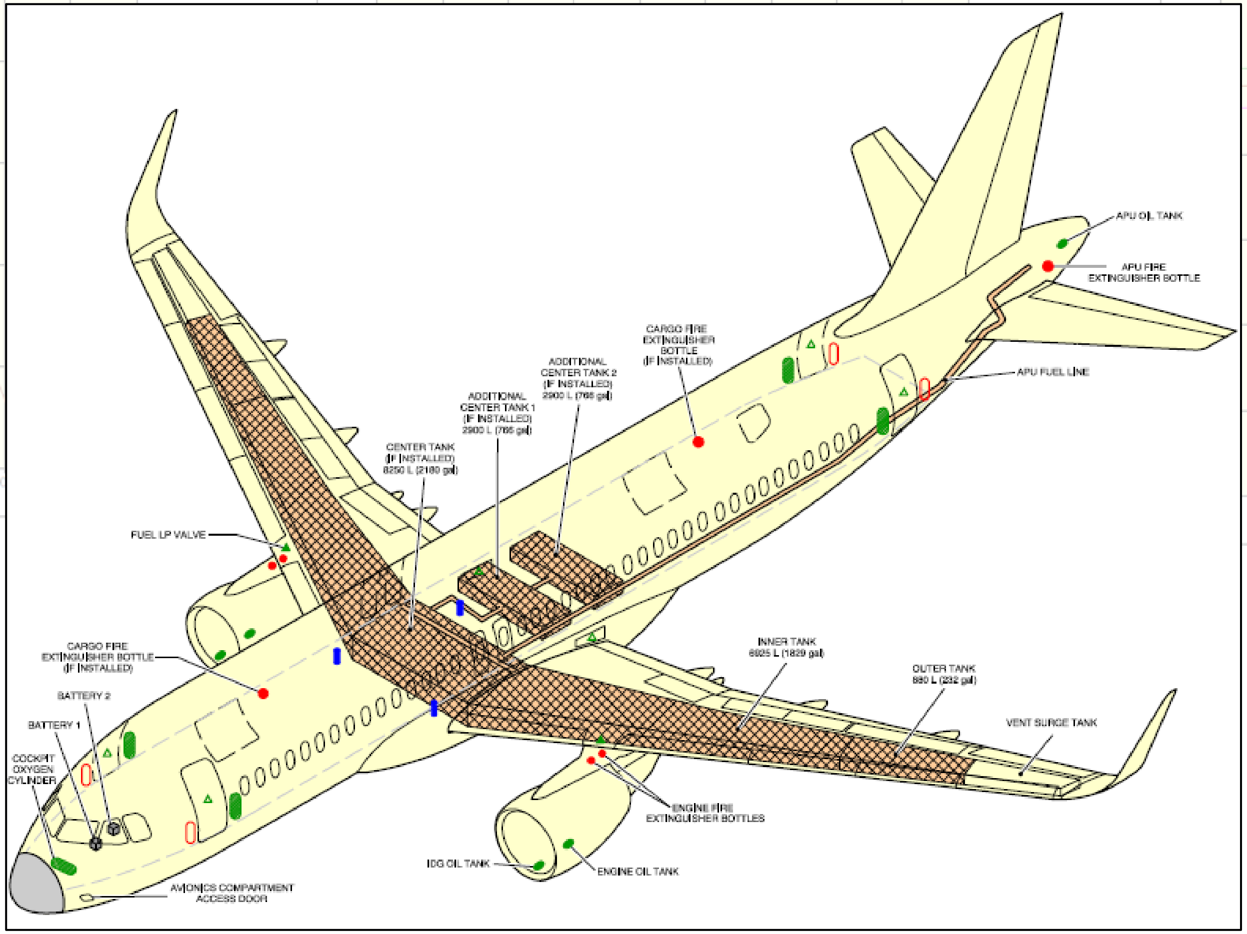

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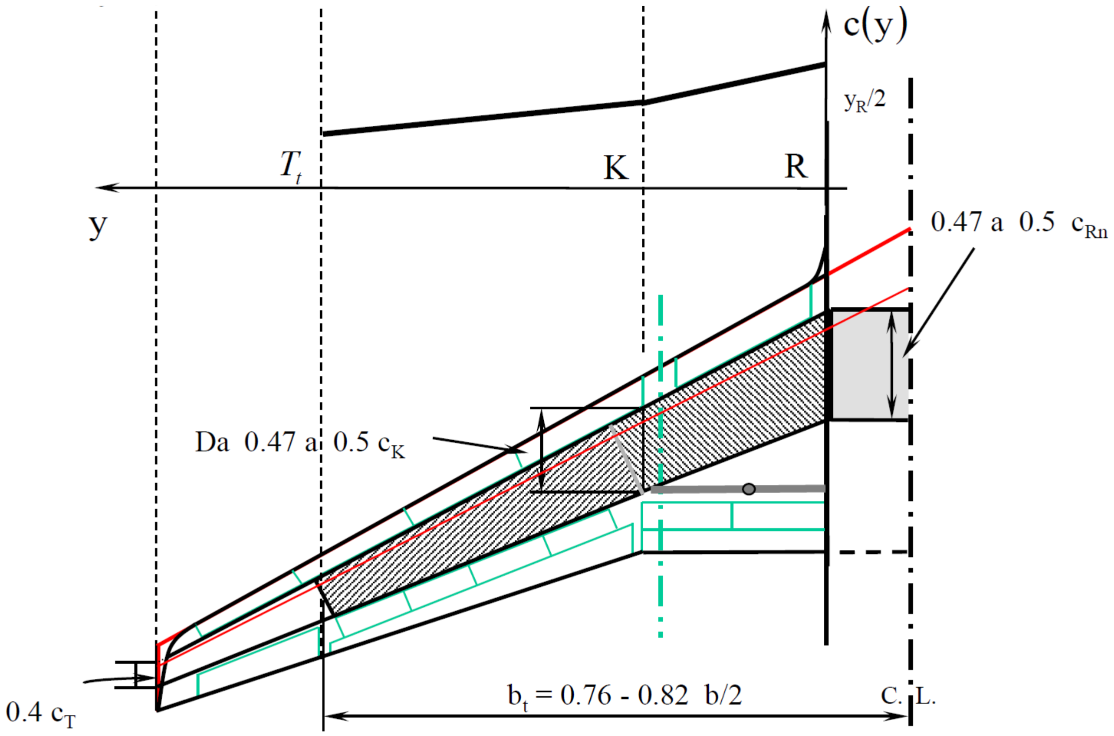

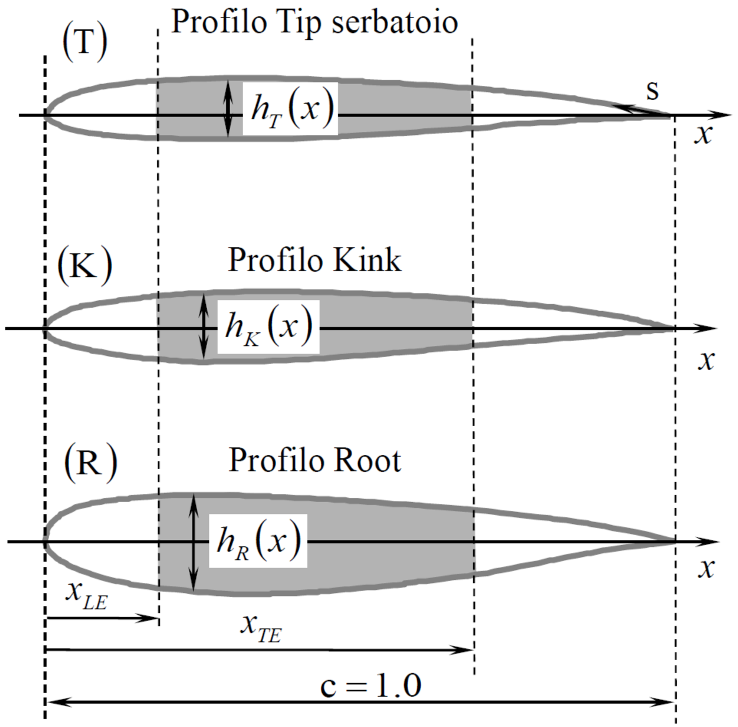

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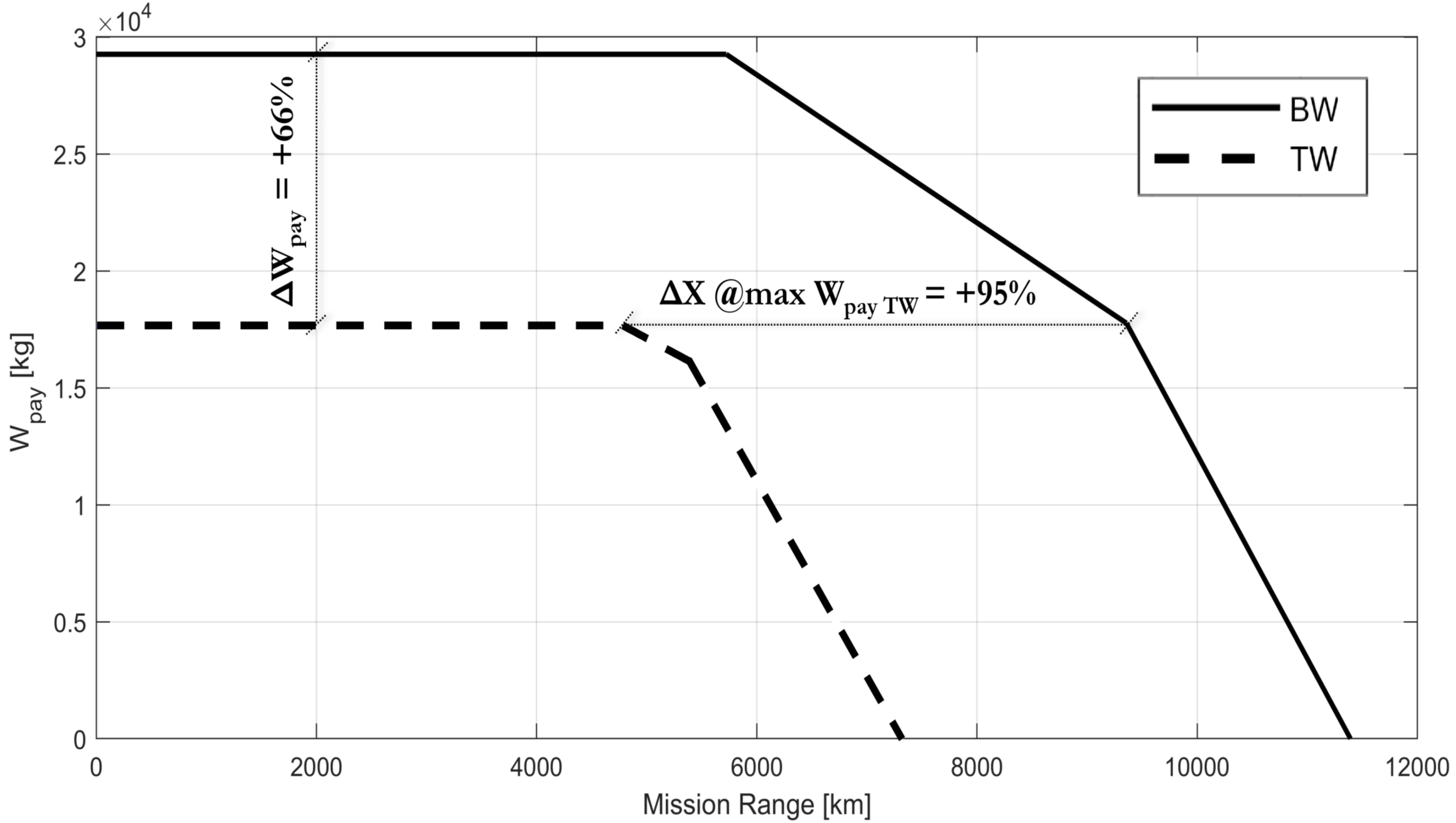

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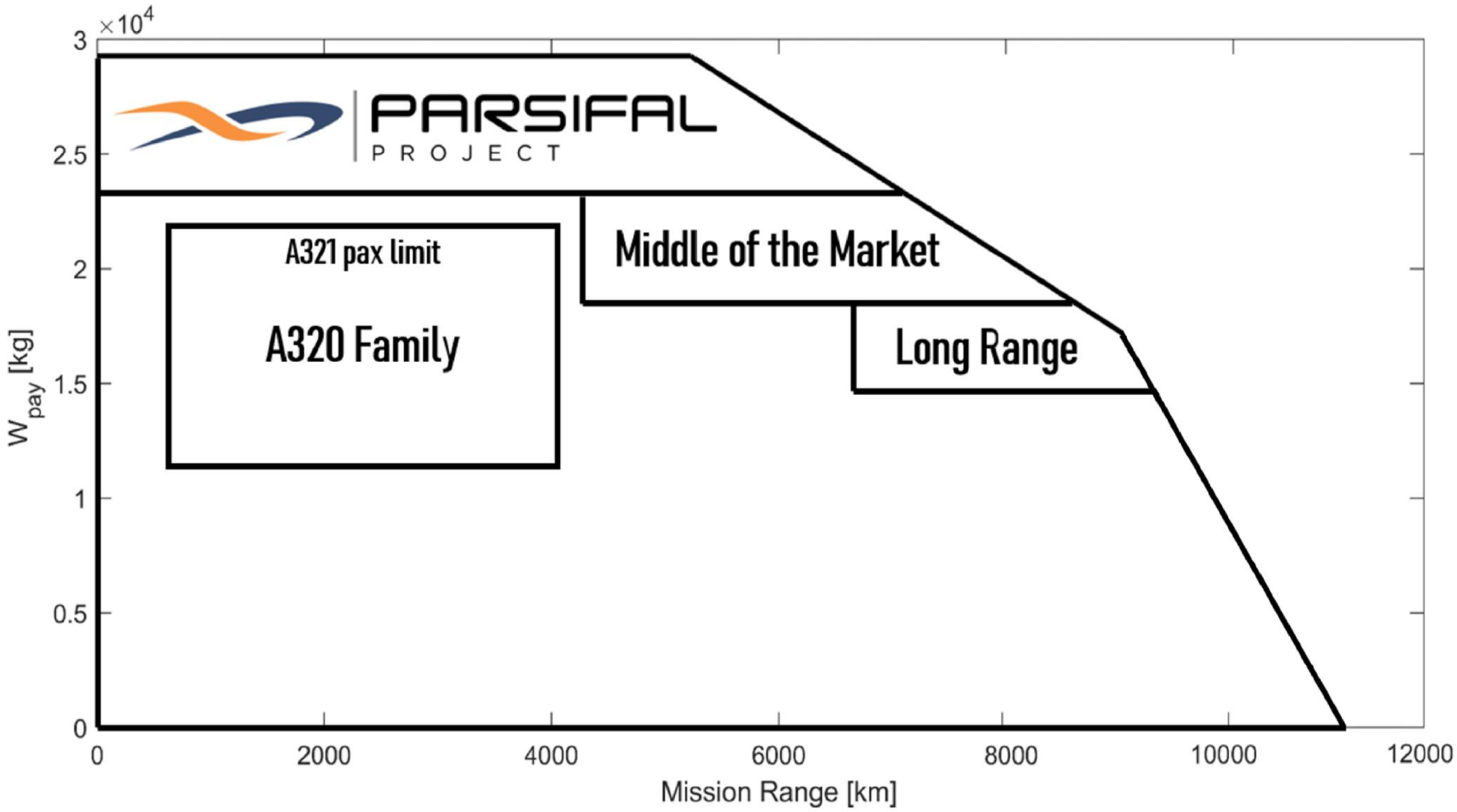

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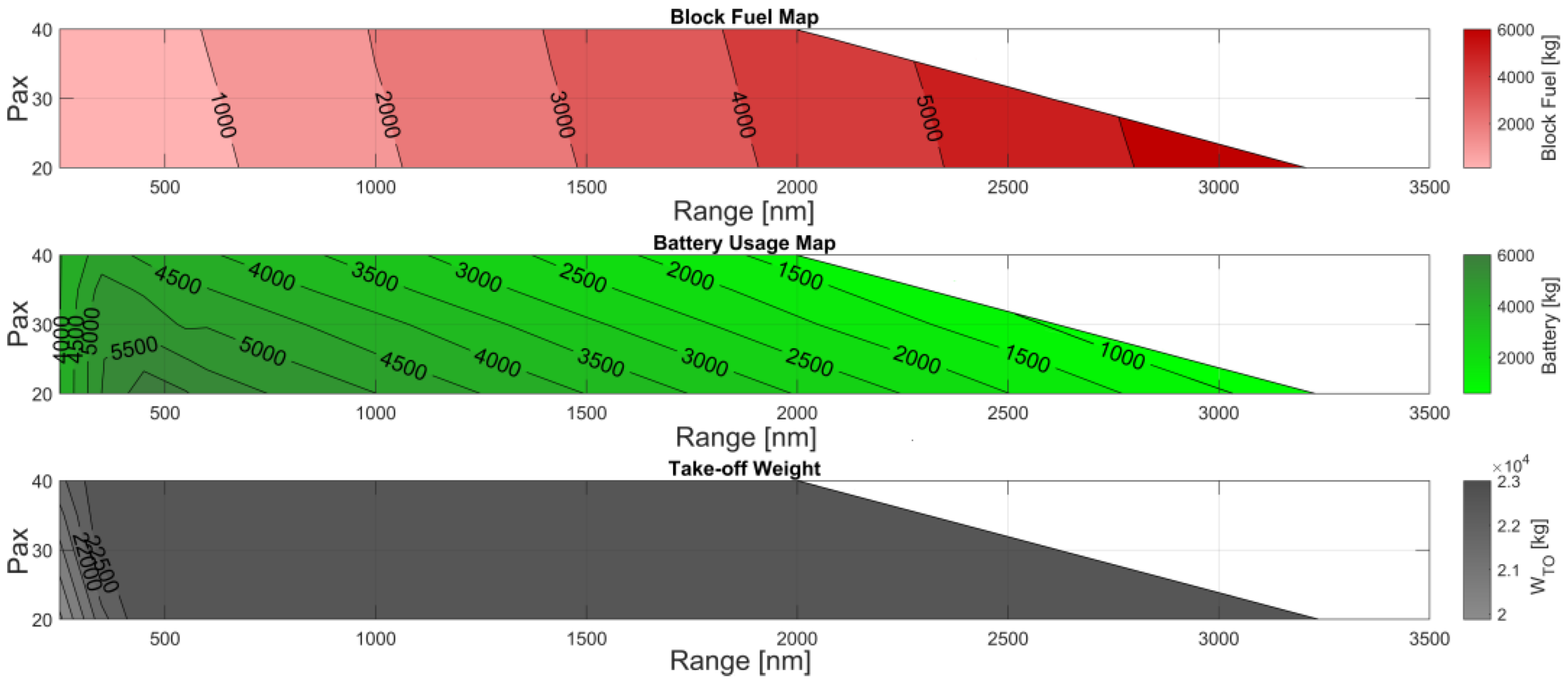

Task 3.1

- **A) Create a Payload-Range Diagram representative of your aircraft concept.**
- **B) On the basis of the results achieved in A), draw different Payload-Range diagrams to explore the possibility to create a family concept**