FACULTY OF AVIATION AND AUTOMOTIVE SYSTEMS (LFS)

Aircraft Fuel Consumption Calculated from the Payload-Range Diagram

Banning short flights for environmental reasons? This tool gives an answer! "Yes, high fuel consumption!"

Passenger aircraft fuel consumption is discussed in society without much detail. Consumption is defined as fuel (mass or volume) per passenger and per 100 km. Different from cars, aircraft show fuel consumption as a function of distance travelled. Why? Fuel is needed for take-off and climb but is not fully recovered during descent and landing. Hence, for very short distances fuel consumption goes towards infinity. Very long distances are only possible with reduced payload (number of passengers) as can be seen from the payload-range diagram. Hence, for ferry range (at zero payload) fuel consumption goes again towards infinity. This results in the bathtub curve. Simple so far, but the calculation is tricky.

PURPOSE

To calculate the fuel consumption as function of flight distance from only a few aircraft parameters. The parameters are: Maximum Take-off Mass (MTOM), Maximum Zero Fuel Mass (MZFM), Mach number in cruise, number of cabin seats, mass of one passenger, distance to alternate, reserves on distance (in %). Notably from the Payload-Range Diagram (Figure 1): maximum payload, payload at maximum range, range at maximum payload, maximum range, ferry range. Rules for fuel reserves are considered. It is distinguished between so-called international reserves and domestic reserves (Figure 2).

METHODOLOGY

Fuel consumption during take-off, climb, descent and landing is estimated from assumed Mission Segment Mass Fractions (MSMF). Reserve fuel is estimated from reserve distance and fuel consumption. This requires an iteration. Possible payload is calculated from required fuel at take-off (considering reserves). As flight distance is increased, payload must be reduced. According to the default strategy, cargo is sacrificed first. As flight distance is increased further, the number of passengers needs to be reduced. This influences fuel mass per distance and number of passengers versus distance. Calculated is also: Fuel mass per distance versus distance, fuel mass versus distance. It is assumed that fuel reserves are not used, are available for the next flight and as such do not count as fuel consumption.

FINDINGS

The aircraft's fuel consumption per passenger and 100 flown kilometers decreases rapidly with distance flown until a near constant level is reached around the aircraft's average flight distance. At longer flight distances, where a reduction of the number of passengers becomes necessary, fuel mass per distance and number of passengers increases significantly. This typical consumption pattern is called the bathtub curve (Figure 3).

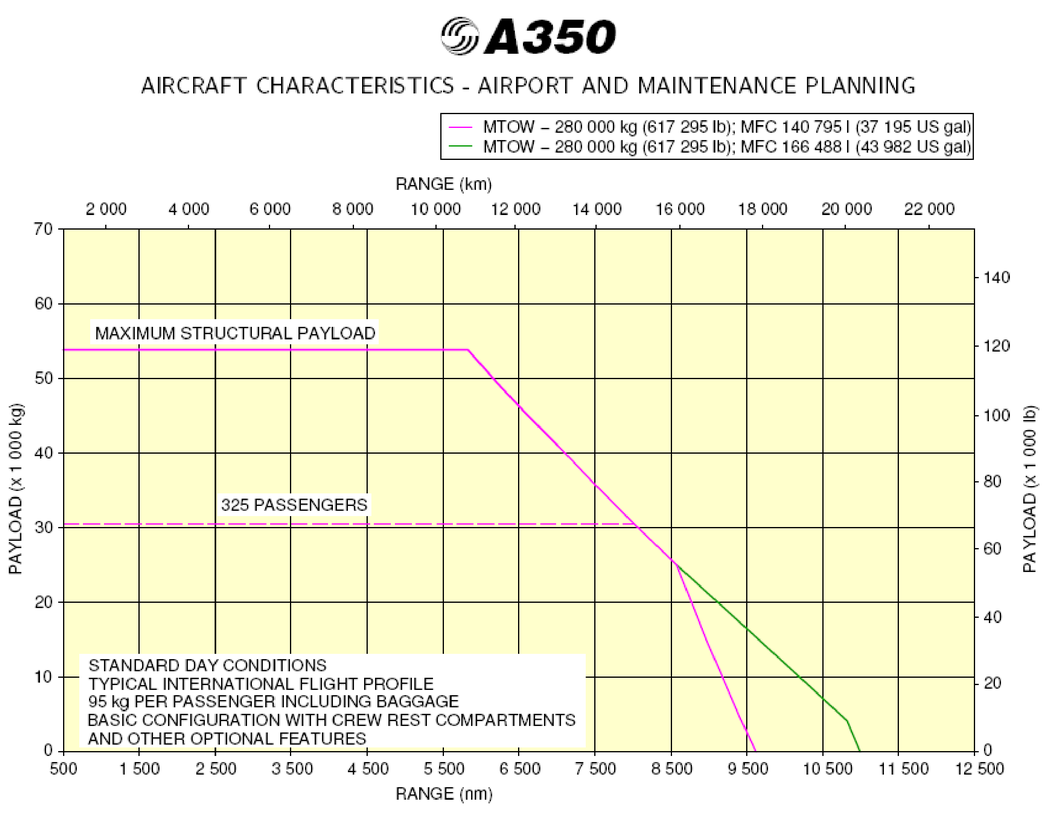

Figure 1: **Major input for the calculation is the payload-range diagram. The diagram is provided by manufacturers on the Internet in the documentation for "Airport and Maintenance Planning".**

RESEARCH LIMITATIONS

The environmental impact of burning fuel is not considered here.

PRACTICAL IMPLICATIONS

The presented method allows calculating aircraft type specific fuel consumption based on publicly available information.

SOCIAL IMPLICATIONS

Fuel consumption of every aircraft can be investigated and can be discussed openly.

ORIGINALITY

The method follows from first principles. No other text (including the required software) to present the method was known before 2017.

ACKNOWLEDGMENT

The poster originates from the Bachelor project of Marcus Burzlaff (2017), which was further developed in many ways by other students under the supervision of Prof. Scholz.

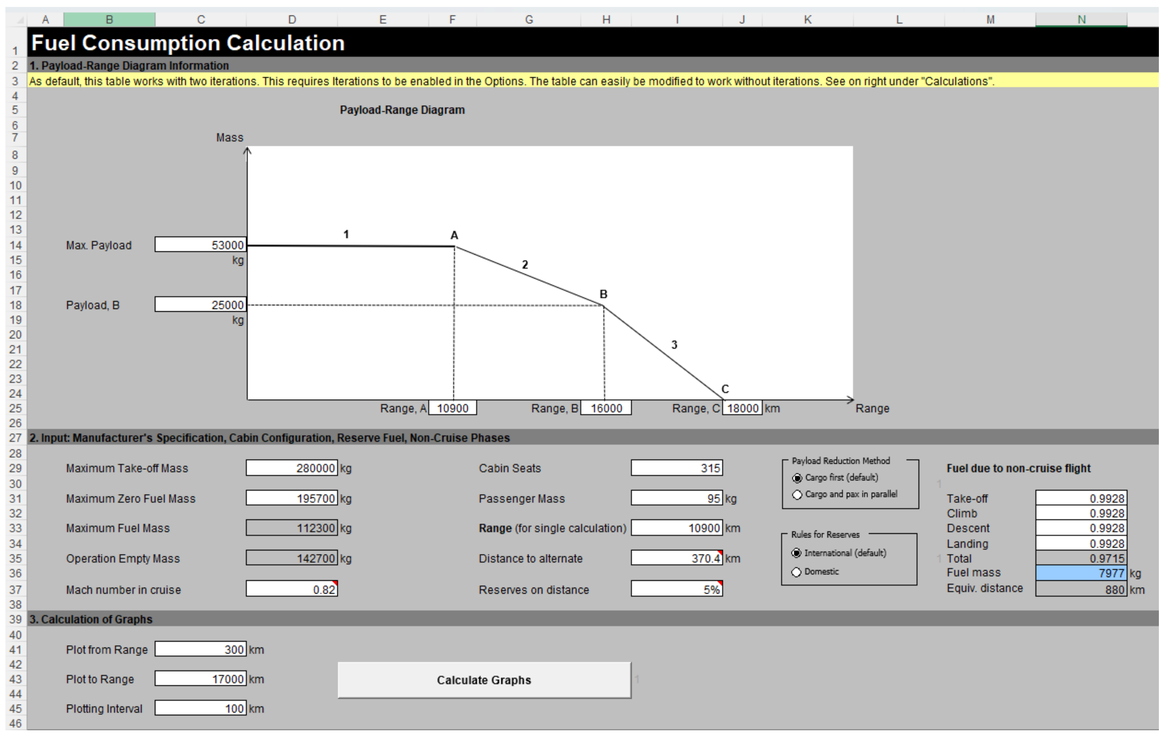

Figure 2: **Input of data using the interface of the Excel tool "FuelCalculation_SLZ.xlsm". Compare, how the input data is mapped from the payload-range diagram of the Airbus A350 (Figure 2).**

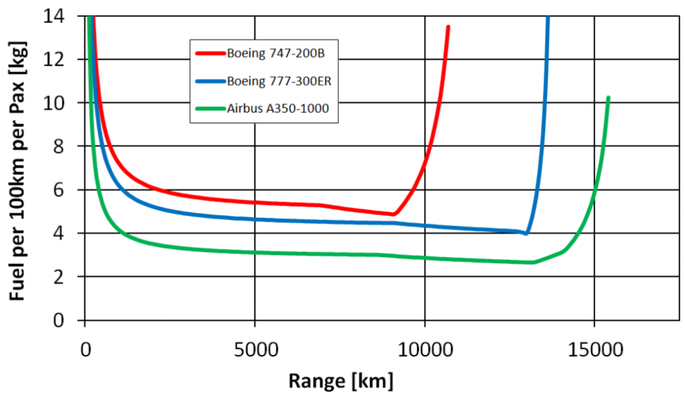

Figure 3: **Results: The aircraft's fuel consumption per passenger and 100 kilometers decreases rapidly with distance flown ("range") until a near constant level is reached. At longer flight distances, fuel mass per distance and number of passengers increases significantly, because payload (and number of passengers) needs to be reduced according to the payload-range diagram.**

More details in the Project of Burzlaff (2017):

https://nbn-resolving.org/urn:nbn:de:gbv:18302-aero2017-12-13.019

Associated research data (Harvard Dataverse):

https://doi.org/10.7910/DVN/2HMEHB

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