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Hamburger Bezirksverein e.V.
Arbeitskreis Luft- und Raumfahrt

Invitation to an RAeS lecture in cooperation with the DGLR and VDI

21st Century Challenges for the Design of Passenger Aircraft

Prof. Jeff Jupp FREng, FRAeS,
RAeS Greener By Design Group,
former Technical Director Airbus UK

With thanks to NASA

Lecture followed by discussion

Entry free ! No registration required !

Download: http://hamburg.dglr.de

Date: Thursday, 30th May 2013, 18:00
Location: HAW Hamburg
Berliner Tor 5, (Neubau), Hörsaal 01.12

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Praxis Seminar Luftfahrt

21^{ST} CENTURY CHALLENGES FOR THE DESIGN OF PASSENGER AIRCRAFT

Professor Jeff Jupp FREng FRAeS

Chairman – RAeS Greener By Design Group

Hamburg 30th May 2013

Designed to meet Requirements

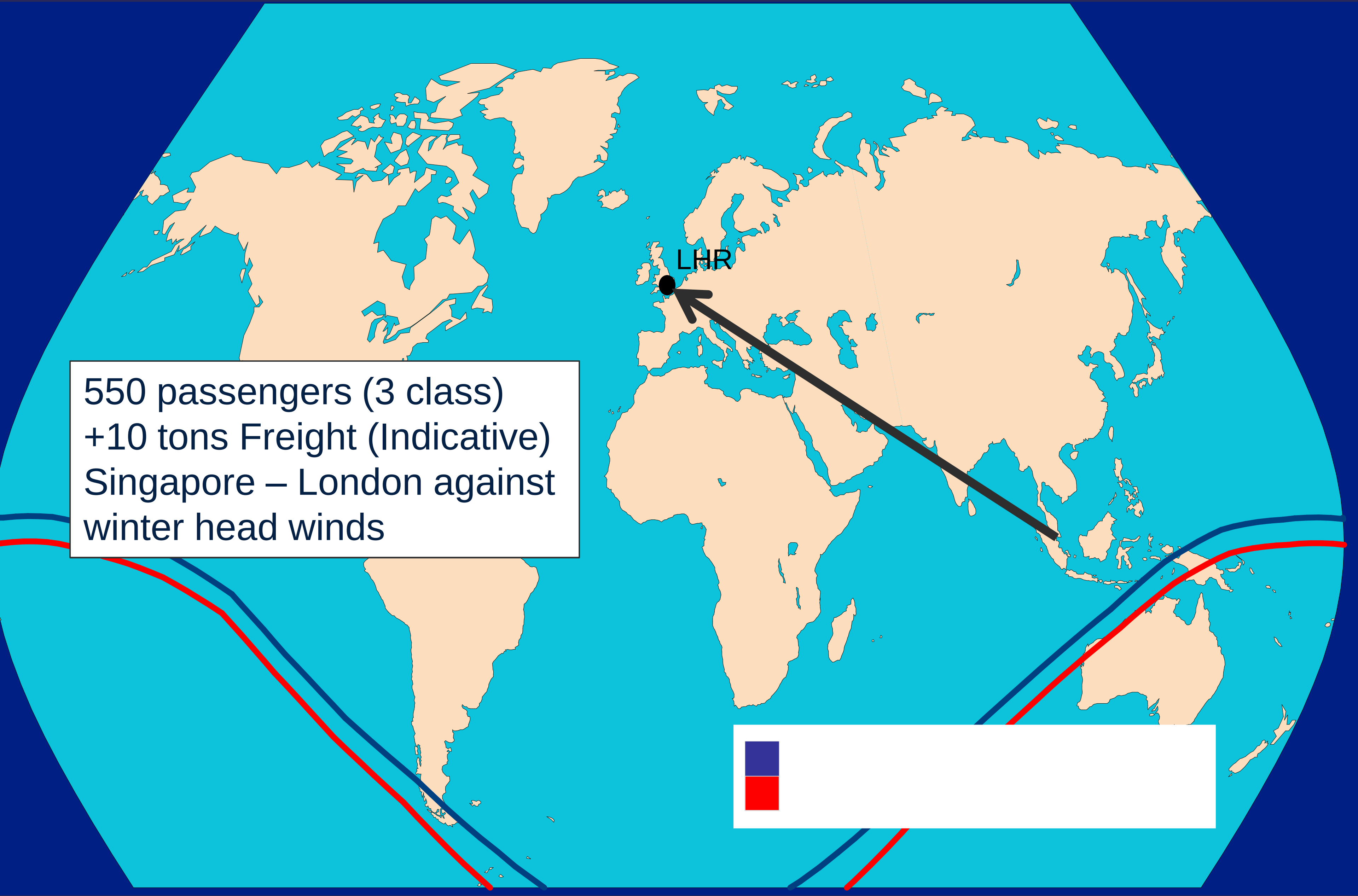
- Aircraft design starts with the customer requirements, of which there will be many.

- Two traditional major ones are:-

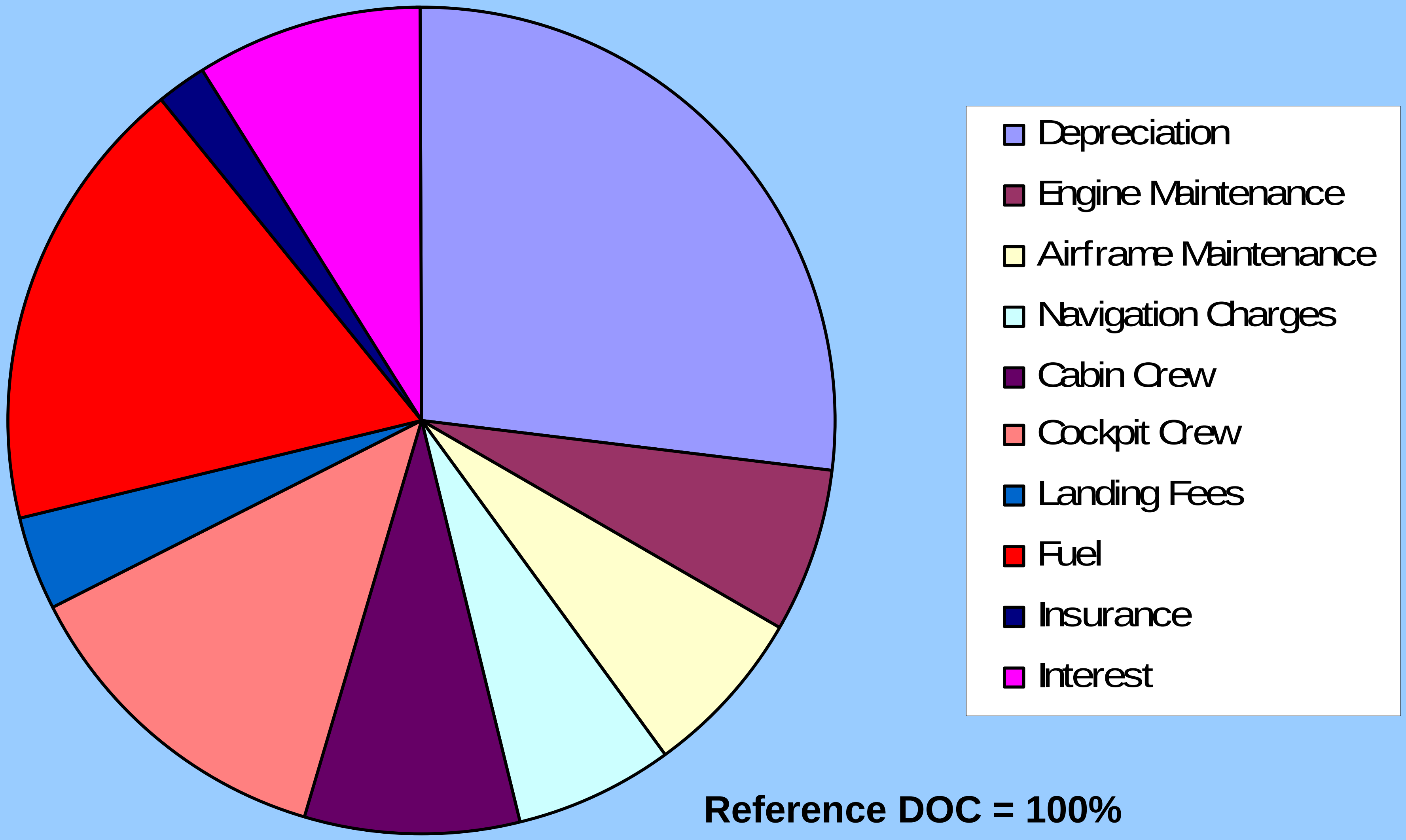
    - The Design Mission - the number of passengers (+ cargo) and range

    - The operating costs including the effect of first price “The Direct Operating Costs”

A380 Design Mission & Range Capability



Typical Direct Operating Cost Breakdown - Fuel Price $0.8



Reference DOC = 100%

So how will traditional requirements be affected by the demands of the 21st Century?

The demand to meet required missions at minimum costs, whilst satisfying the requirements of the passengers (for safety, reliability etc.), will still exist.

But this will now be with the extra constraints due to –

- The effects of Aviation on the Environment and particularly Global Warming

  - Although Aviation only contributes 2-4% of man's impact today, it is due to become 10-15% or more without major improvements.

- The price and availability of Fossil Oil

Persistent contrail induced cirrus cloud

Reducing NOx – the lean-burn premixed combustor

Premixed flame does not pass through stochiometric mixture, avoiding peak NOx production.

Direct injection, lean-burn single annular combustor

Staged injector

40% CAEP/2 NOx

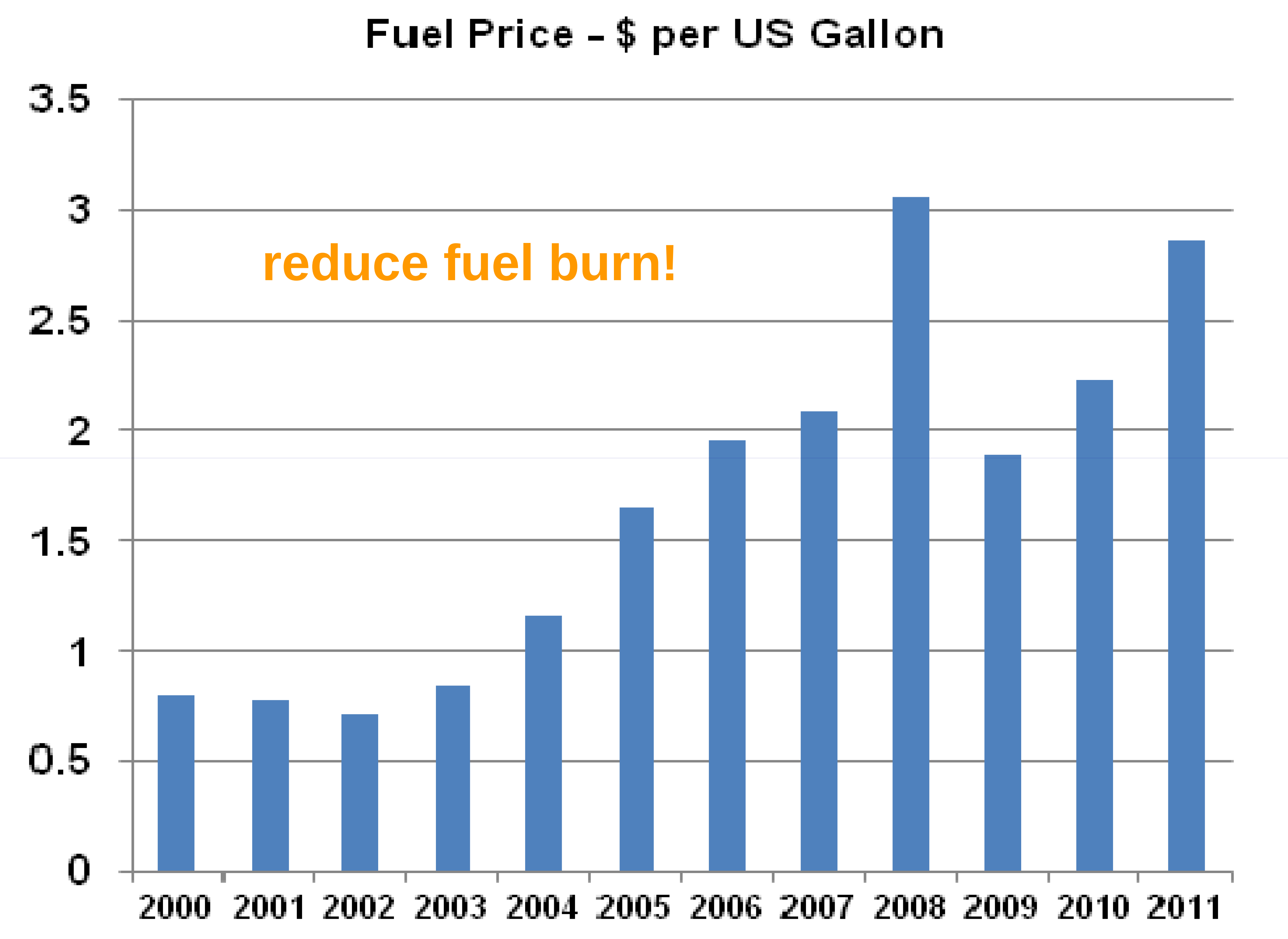
Source Rolls-Royce

Aviation chief contributors to Climate Change (after TRADEOFF, 2003)

• CO_2	100%
• NO_X (net effect of O_3 – CH_4)	45%
• Contrails plus Contrail Cirrus	79 – 355%

Total compared with CO_2 alone:- 224% to 500%

To reduce the impact, the most significant improvement will be to reduce fuel burn


Fuel Price – $ per US Gallon
reduce fuel burn!
3.5
3
2.5
2
1.5
1
0.5
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

What about Bio-fuels?

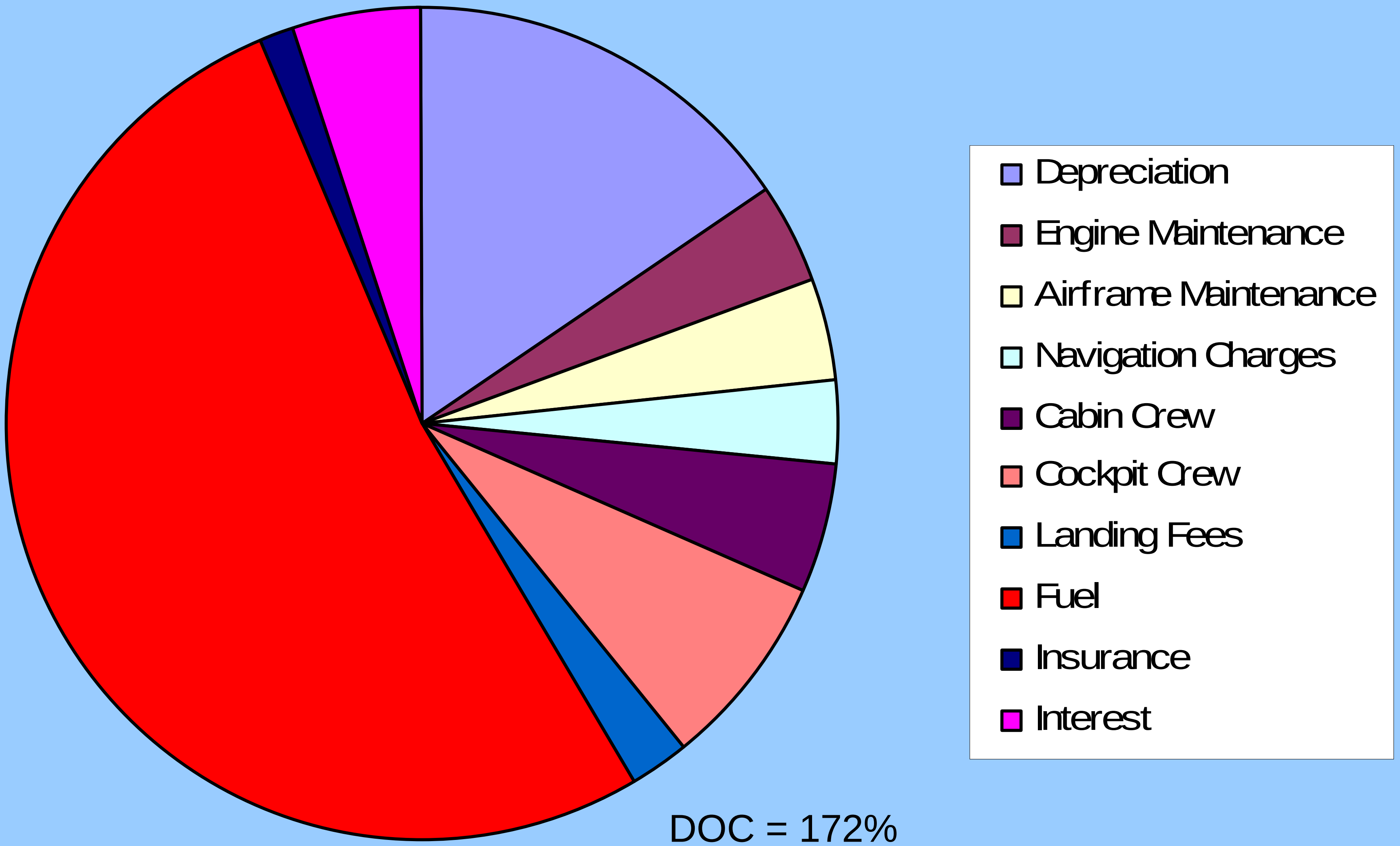
- It is fundamental that production must be sustainable, without prejudice to land and water resources for food production

- There are good possibilities - for example Halophytes (salt water tolerant plants eg Salicornia) and Algae

- But all predictions are that the cost will be high (at least the equivalent of 4$/USG) and therefore the demand for reduced fuel burn will remain.

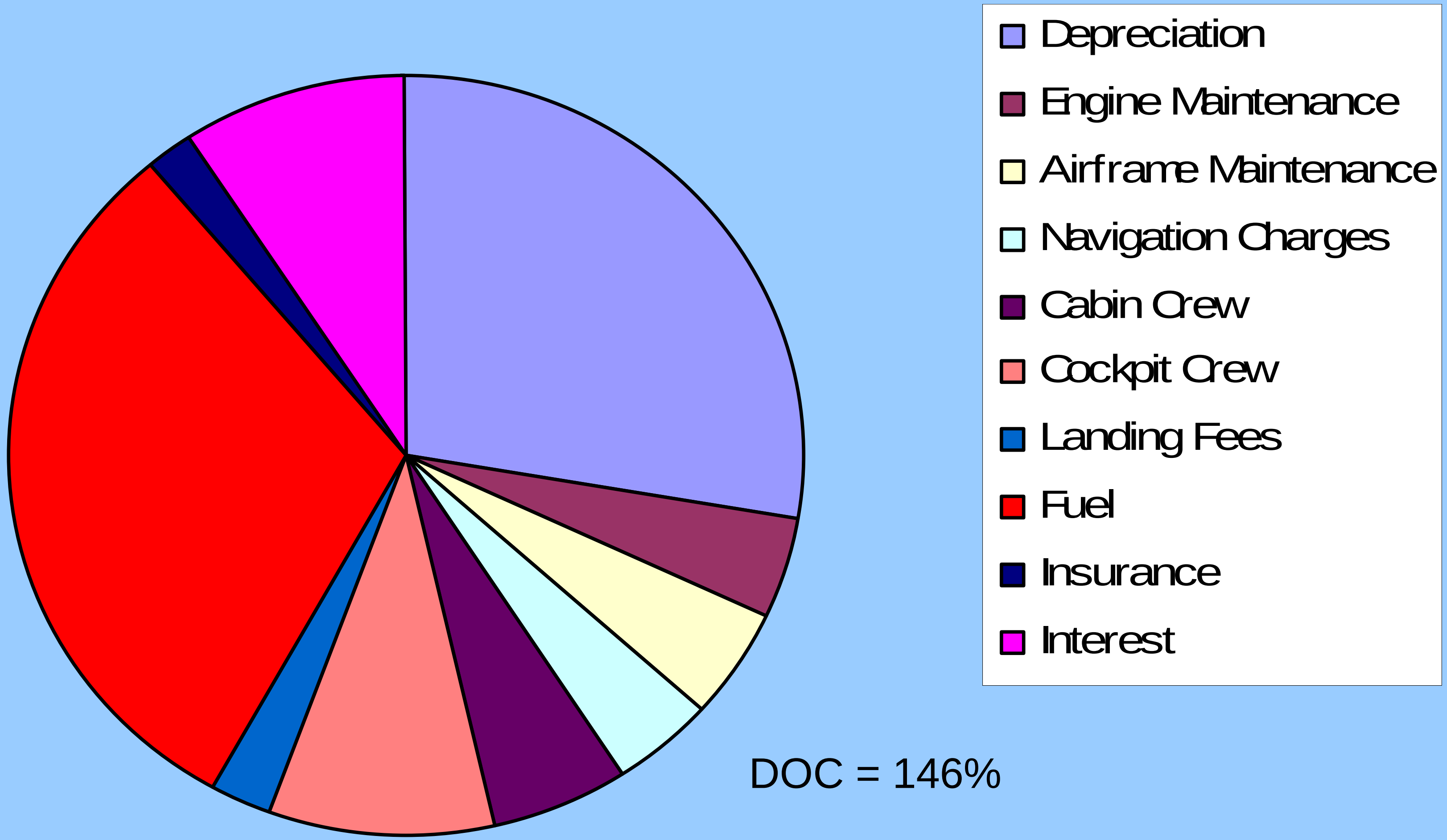
reduce fuel burn!

Direct Operating Cost Breakdown - Fuel Price $4



Direct Operating Cost Breakdown

- Fuel Price $4
- First cost 150%
- Fuel burn 50%



New ACARE Vision – "FLIGHTPATH 2050"

In 2050:-

- Technologies and Procedures available to give 75% reduction in CO_2 emissions , 90% reduction in NO_x emissions and 65% reduction in perceived noise (relative to new aircraft delivered in 2000)

- Aircraft are emission free when taxiing

- Air vehicles designed and manufactured to be recyclable

- Europe established as a centre of excellence on sustainable alternative fuels including for Aviation

- Europe leading on atmospheric research and establishment of global environmental standards

NASA's goals for a 2030-era aircraft

- A 71-decibel reduction below current Federal Aviation Administration noise standards – aimed to contain objectionable noise within airport boundaries.

- A greater than 75 percent reduction on the ICAO CAEP/6 standard for nitrogen oxide emissions, to improve air quality around airports.

- A greater than 70 percent reduction in fuel burn to reduce greenhouse gas emissions and the cost of air travel.

(Compared with an aircraft entering service today)

Options for reducing fuel burn per passenger-km

The Bréguet range equation

Fuel burn per tonne-kilometre

$$\frac{W_F}{W_P R} = \frac{1}{X}\left(1 + \frac{W_E}{W_P}\right)\left(\frac{1.022\exp\left(\frac{R}{X}\right) - 1}{\left(\frac{R}{X}\right)}\right)$$

W_F = Fuel Weight
W_P = Payload
W_E = Aircraft Weight-Empty
R = Range

$X = H\eta L/D$

H = calorific value of fuel

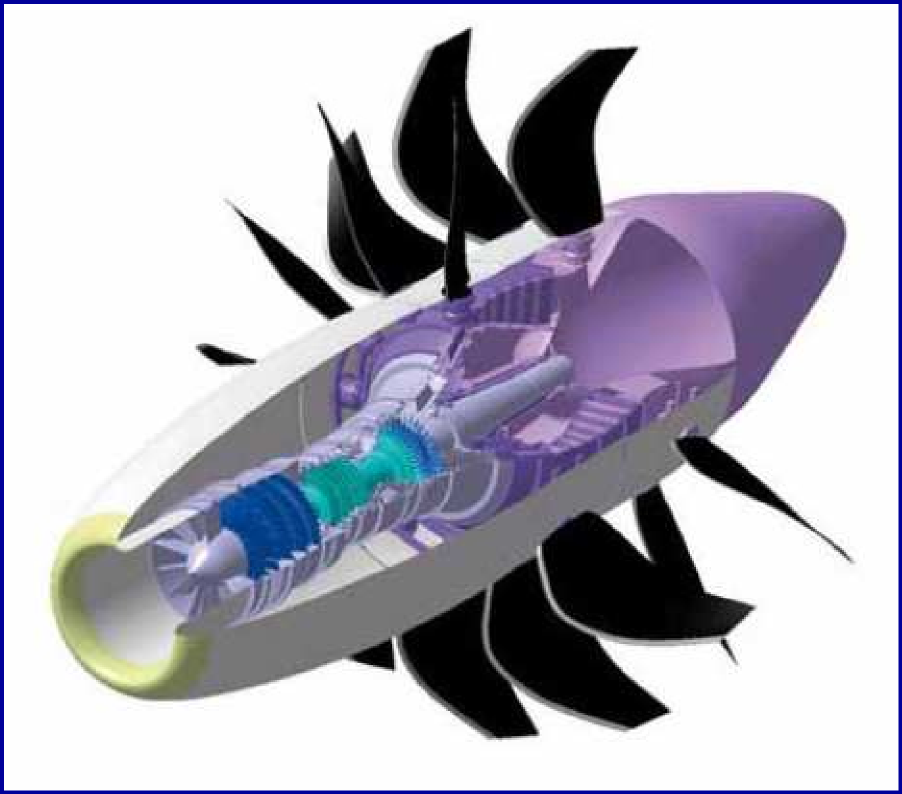
η = overall propulsive efficiency

L/D = lift/drag ratio

Reducing fuel burn by reducing weight – A350 CFRP Fuselage Test Specimen

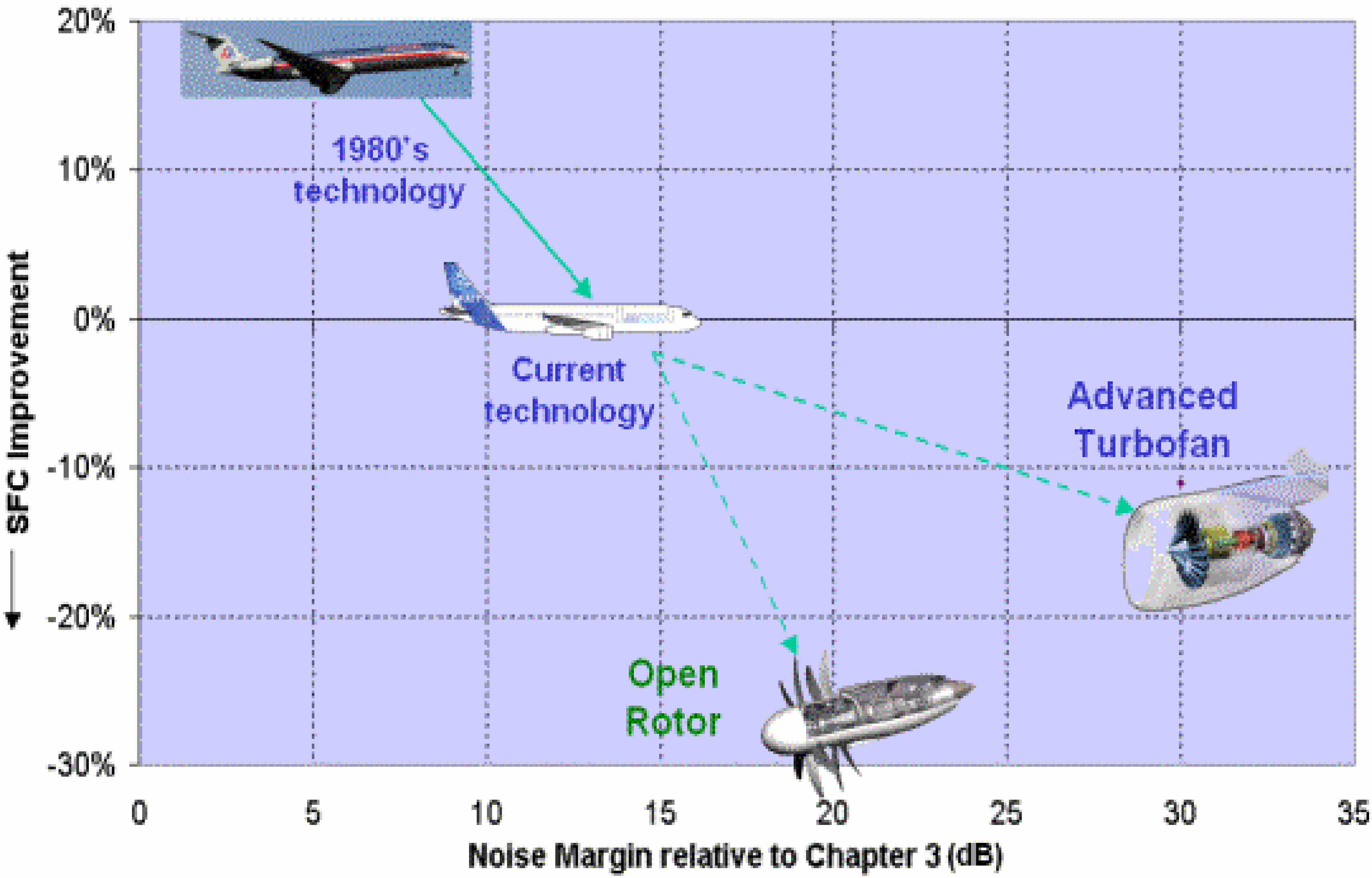
Evolutionary development of current powerplants – Higher bypass ratio etc.

Open Rotor Configurations



Tu 114 (first flight 1957)

Specific fuel consumption versus noise for open-rotor vs Turbo-fan



Maximising lift-to-drag ratio in cruise

$$\text{Drag} = qS_{DO} + \frac{\kappa}{\pi q}\left(\frac{W}{b}\right)^2 \qquad (C_D = C_{D0} + \kappa C_L{}^2/\pi A)$$

L/D is a maximum when the two components of drag are equal, giving

$$\left(\frac{L}{D}\right)_{MAX} = b\sqrt{\frac{\pi}{4\kappa S_{DO}}}$$

$$\text{when} \quad q = W\sqrt{\frac{\kappa}{\pi b^2 S_{DO}}}$$

$S_{D0} = \sum SC_{D0}$
W = Weight
b = Span
q = dynamic pressure
κ = Induced Drag Factor
L/D = Lift/Drag Ratio

Reducing Vortex Drag – High Span
Reducing C_{D0} – Natural Laminar Flow

NASA - Boeing "SUGAR" Braced Wing Concept

Reducing C_{D0} - Hybrid Laminar Flow

A320 - Hybrid Laminar Flow Fin

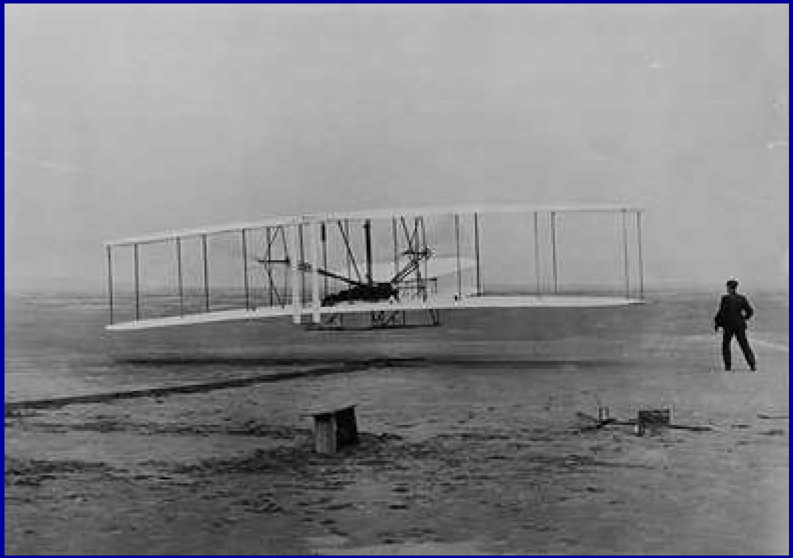
- Flight trials successfully completed
- Up to 50% chord laminarised
- Better than anticipated tolerance to external environment

Reducing C_{D0} – Natural or Hybrid Laminar Flow European "Clean Skies" Research Programme

Minimising Surface Area

Boeing X48-B 1/6 scale test vehicle

(made by Cranfield Aerospace Ltd. UK)



1903

1947

2005


AIRBUS A350
XWB
A350

A350 Painted 13th May 2013

Short range configuration concepts

Future Aircraft Configurations? Unlikely?

Transonic M = 0.9 – 1.2

Supersonic M = 2.2 – 2.4

Options for reducing fuel burn per passenger-km

The Effect of Design Range

The Bréguet range equation

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Effect of design range on fuel burn for long-distance travel

Design range km	Payload tonne	Mission fuel tonne	Reserve fuel tonne	Max TOW tonne	OEW tonne	Fuel for 15,000km tonne
15,000	25.9	120.3	13.5	300.0	140.3	120.3
5,000	25.9	20.4	5.4	120.0	68.4	61.1

Travelling 15,000km in one hop or three

Revision of earlier GBD estimates:

Correction published in August 2006 issue of the Aeronautical Journal

2040 - The Ultra Green Intermediate Range 300 Seater?

With thanks to NASA