Air Transportation 2050 – A holistic View

Guest Lecture at Royal Melbourne Institute of Technology

Melbourne, September 14th, 2012

Prof. Dr.-Ing. Volker Gollnick, Director

AGENDA

- Introduction of the Institute
    - The Way of Thinking
    - The Way of Working
- Scenarios of Future Air Transportation
- Some Examples of holistic Air Transportation Concepts design and Analysis
    - Climate Optimized Air Transportation
    - Intermediate Stop Operations
    - Laminar Flow Aircraft
- How does the Aircraft look tomorrow?

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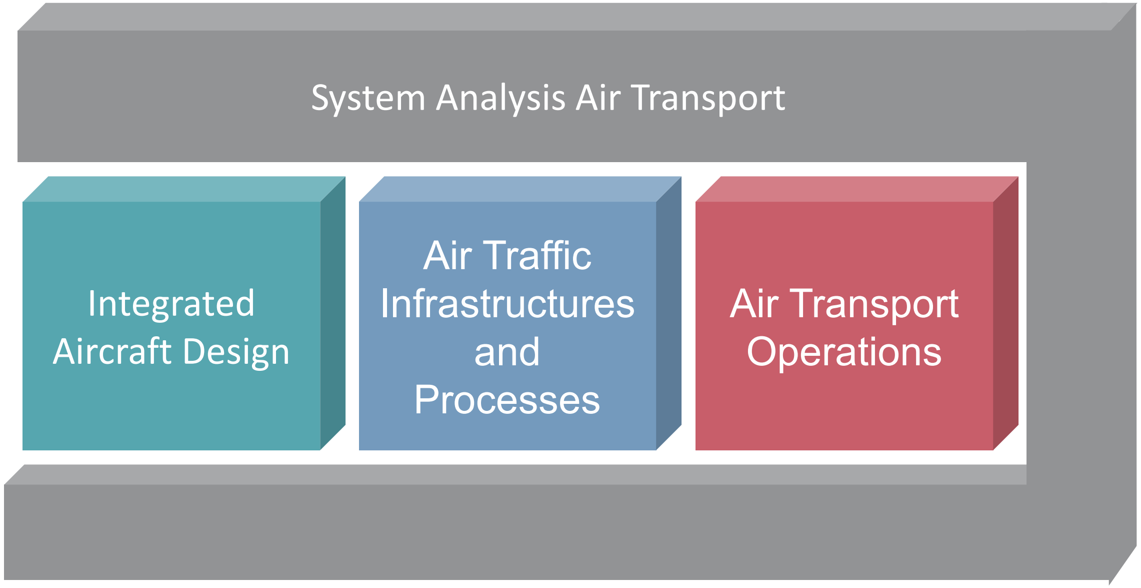
Representation of the main system elements within the institute


System Analysis Air Transport

Integrated Aircraft Design

Air Traffic Infrastructures and Processes

Air Transport Operations

Three system related **departments** provide technical and procedural basic competencies for conceptual technical developments and integration ➔ interfaces to further disciplinary institutes

Covered by a **department** for **system analysis and assessment**

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The Way of Thinking

- **System hierarchy**
  - The System – *Air Transportation System*
  - Sub structure – Airport, *Aircraft*, Airline, ATM
  - Subsystem – Terminal, *Wing*, MRO, Surveillance
  - Component – CheckIn, *FlightControl*, LineMaintenance, Radar

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The Way of Thinking

- **Integration**
  - **„Intellectual Integration“** - Understanding of functional relations and interactions
  - **Modelling** - Functional definition and composition of systems on functional level
  - IT oriented **SW-system integration** - Integration of calculation and simulation tools
  - **Physical integration** of components to systems

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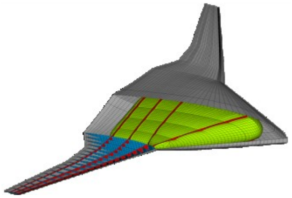
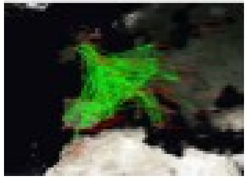
The Way of Thinking

- **Technology**
  - A **physical principle** or technique to realise a function, form concept



  - A new rule based **procedure** like continious descent approach

  - A new **process** to improve an operation or production like point to point airline network



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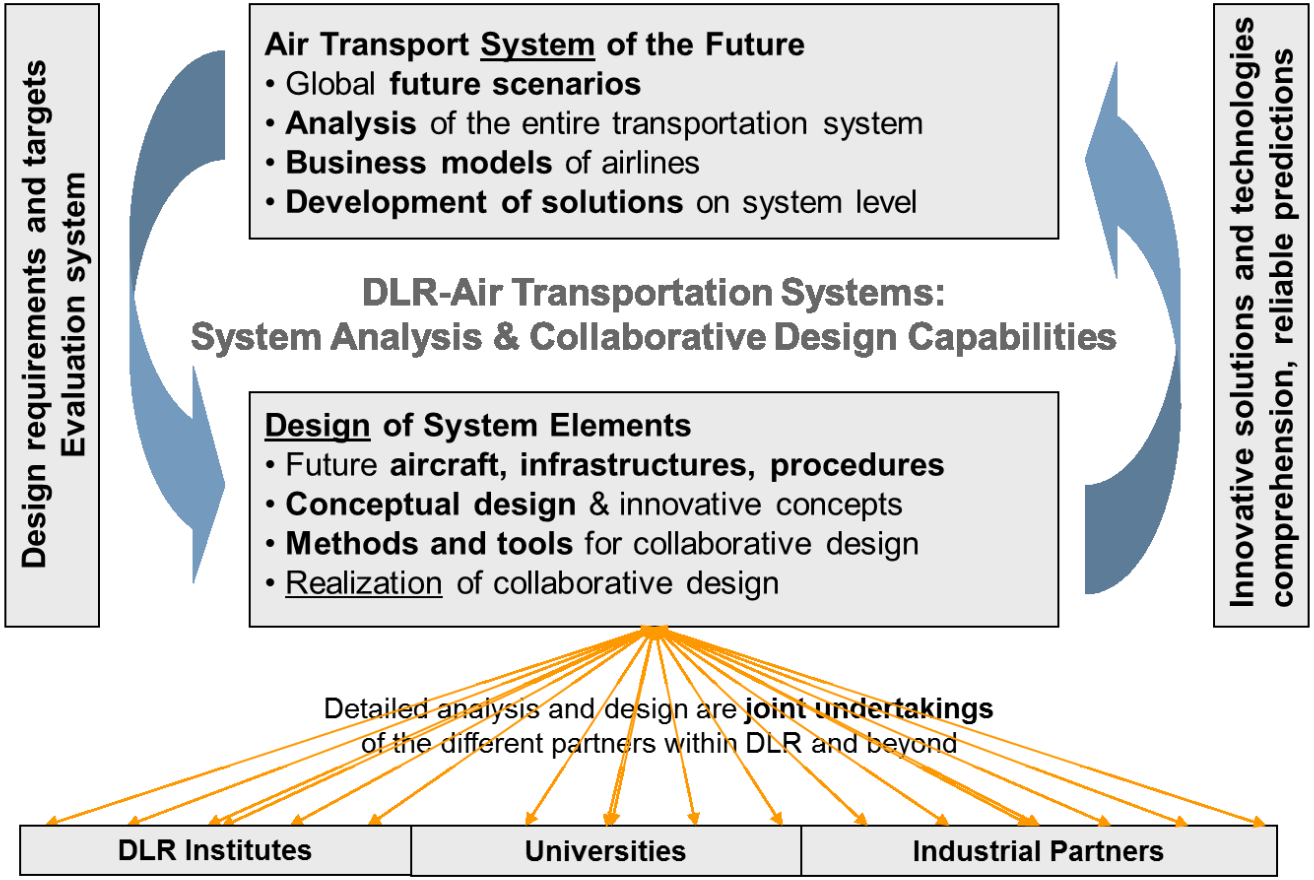
The Way of Working



Design requirements and targets
Evaluation system

Air Transport System of the Future
- Global **future scenarios**
- **Analysis** of the entire transportation system
- **Business models** of airlines
- **Development of solutions** on system level

DLR-Air Transportation Systems:
System Analysis & Collaborative Design Capabilities

Design of System Elements
- Future **aircraft, infrastructures, procedures**
- **Conceptual design** & innovative concepts
- **Methods and tools** for collaborative design
- Realization of collaborative design

Innovative solutions and technologies
comprehension, reliable predictions

Detailed analysis and design are **joint undertakings**
of the different partners within DLR and beyond

DLR Institutes | **Universities** | **Industrial Partners**

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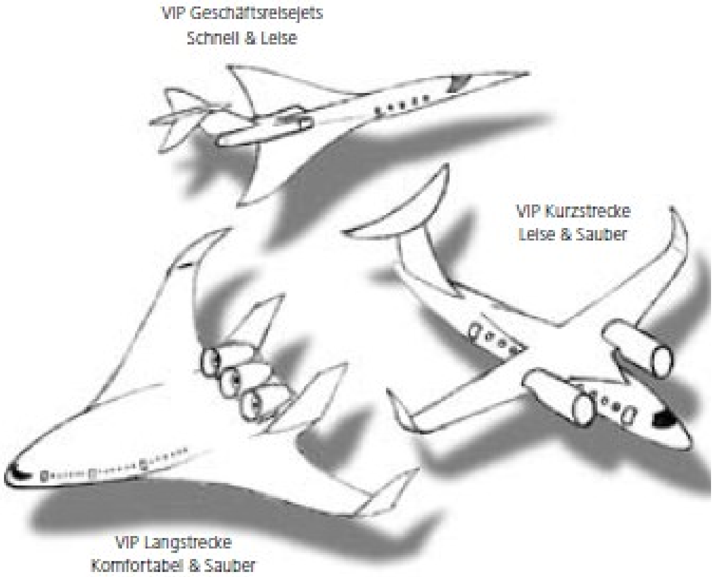
Virtual Integration Platform (VIP):

A method for integrated air transport concepts development:

Overall Air Transportation Concepts for defined air transportation missions composed of the main subsystems (aircraft, airport, air traffic management, airline operations) including transportation and control processes



Three leading concepts:

- Short range air transport
- Long range air transport
- High speed air transport

How to let them become reality?

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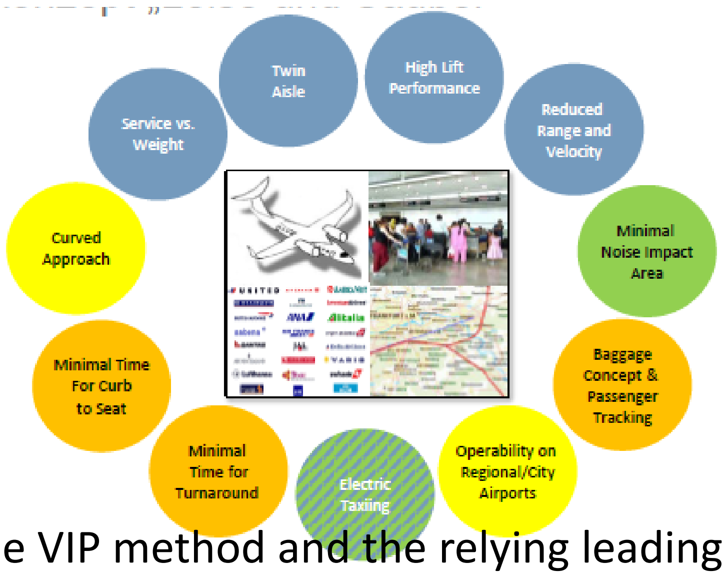
Virtual Integration Platform – How to let them become reality?

Leading Concept Example: Short Range Mission Segment – „Silent and Clean“

Associate Technologies which are of particular but not eclusively interest for this mission



- 🔵 Integr. Aircraft Design
- 🟢 Environmental System Analysis
- 🟡 Air Transport Infrastructure and Processes
- 🟠 Air Transpot Operations

The VIP method and the relying leading concepts **merge different disciplinary research tasks** to a comprehensive **interdisciplinary and integrated research project**

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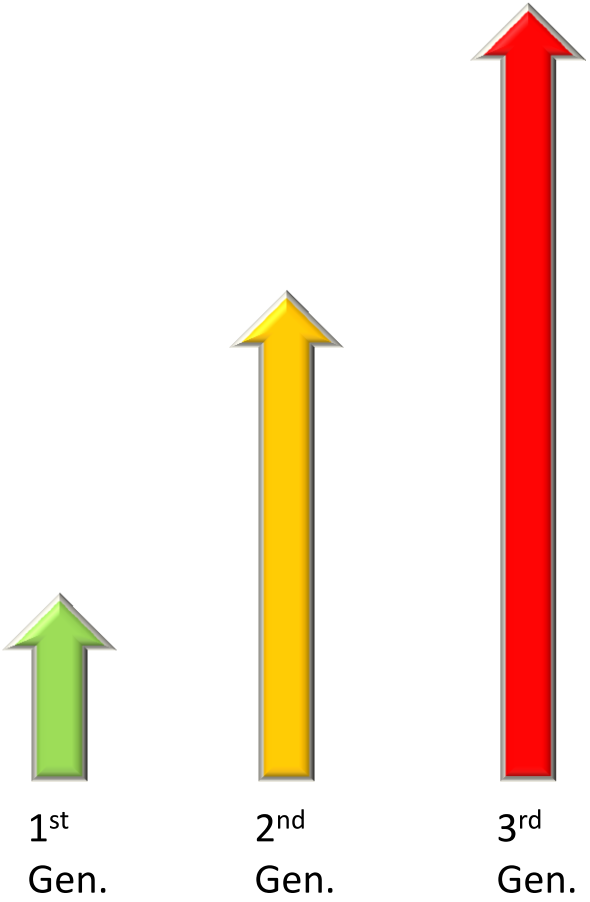
Three Generations of Multi Disciplinary Optimization

Definition according to Prof. Juan Alonso, Stanford University

- **Optimization assisted design in teams**
- Management of knowledge
- Collaboration of engineers and computers

- Workflow management software
- Networked computing, Interfaces
- Complex problems

- Analysis-based design computations
- Optimization algorithms
- Approximation techniques



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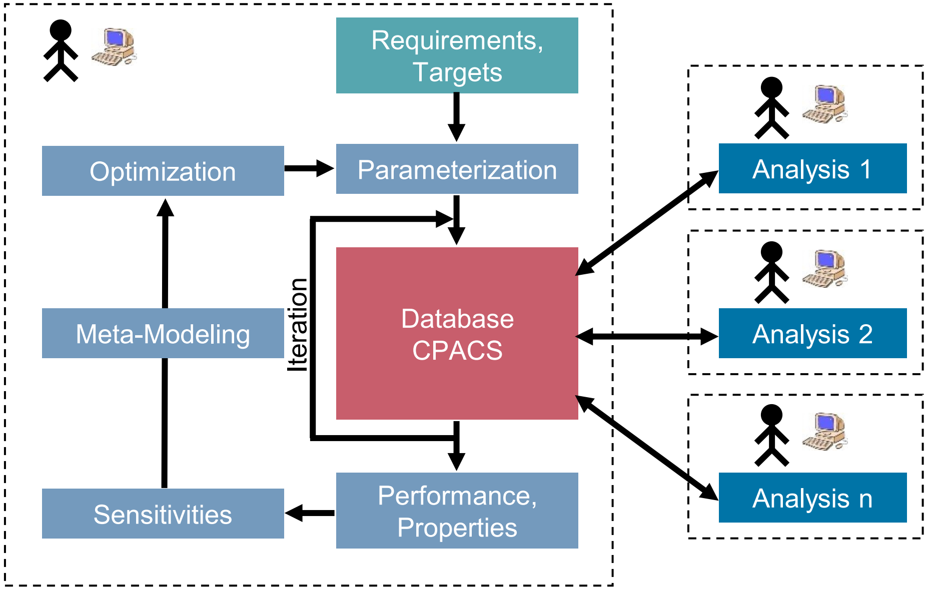
The interdisciplinary way of working



Requirements, Targets

Optimization

Parameterization

Iteration

Database CPACS

Meta-Modeling

Sensitivities

Performance, Properties

Analysis 1

Analysis 2

Analysis n

- Distributed computing system -> tools remain on the specialists’ servers.
- Tools of specialists are wrapped -> tools do not need to be adapted.
- Coupling via central data model CPACS (Common Parametric Aircraft Configuration Schema).

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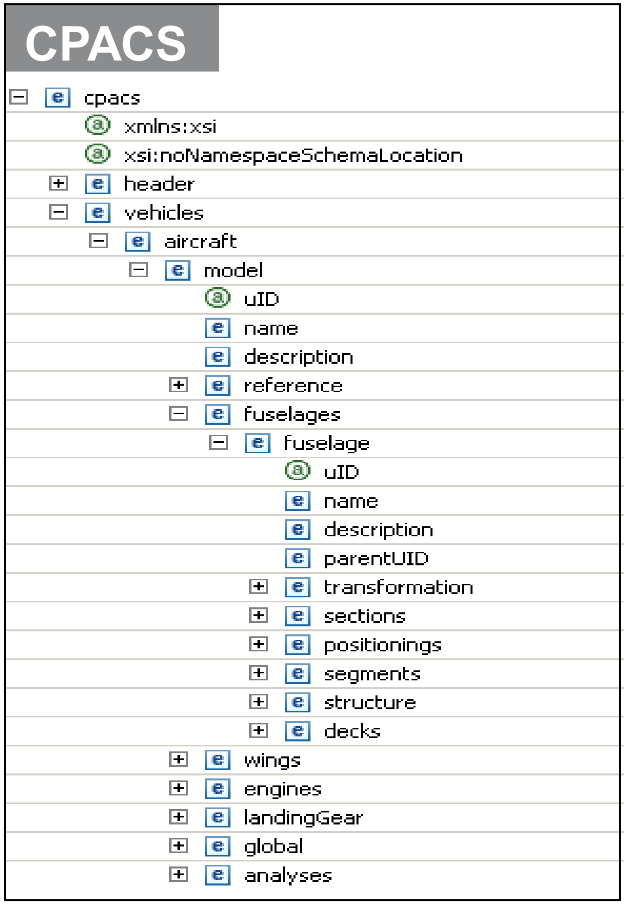
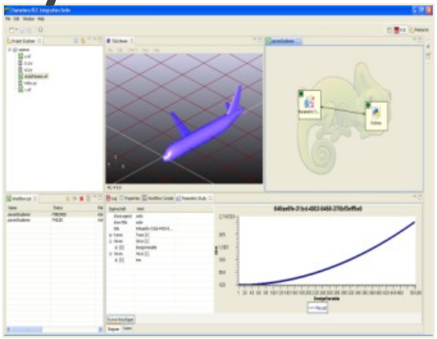
The DLR Framework Concept

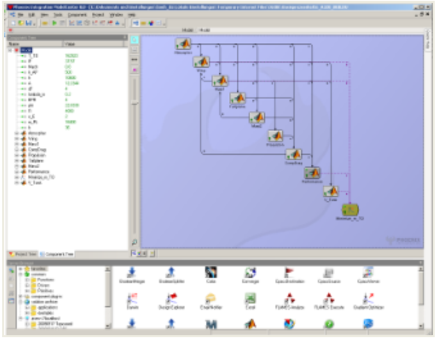


CPACS

- cpacs
  - xmlns:xsi
  - xsi:noNamespaceSchemaLocation
  - header
  - vehicles
    - aircraft
      - model
        - uID
        - name
        - description
        - reference
        - fuselages
          - fuselage
            - uID
            - name
            - description
            - parentUID
            - transformation
            - sections
            - positionings
            - segments
            - structure
            - decks
        - wings
        - engines
        - landingGear
        - global
        - analyses



RCE (ECLIPSE)



ModelCenter

- CPACS is a hierarchic data model based on an XML schema definition.
- CPACS can hold geometry, analysis results and process data.
- Libraries for handling and geometry processing (TIXI/TIGL).
- Compatible to standards like IGES and STEP.
- Wrappers are stand-alone tools.
- Framework independent implementation.

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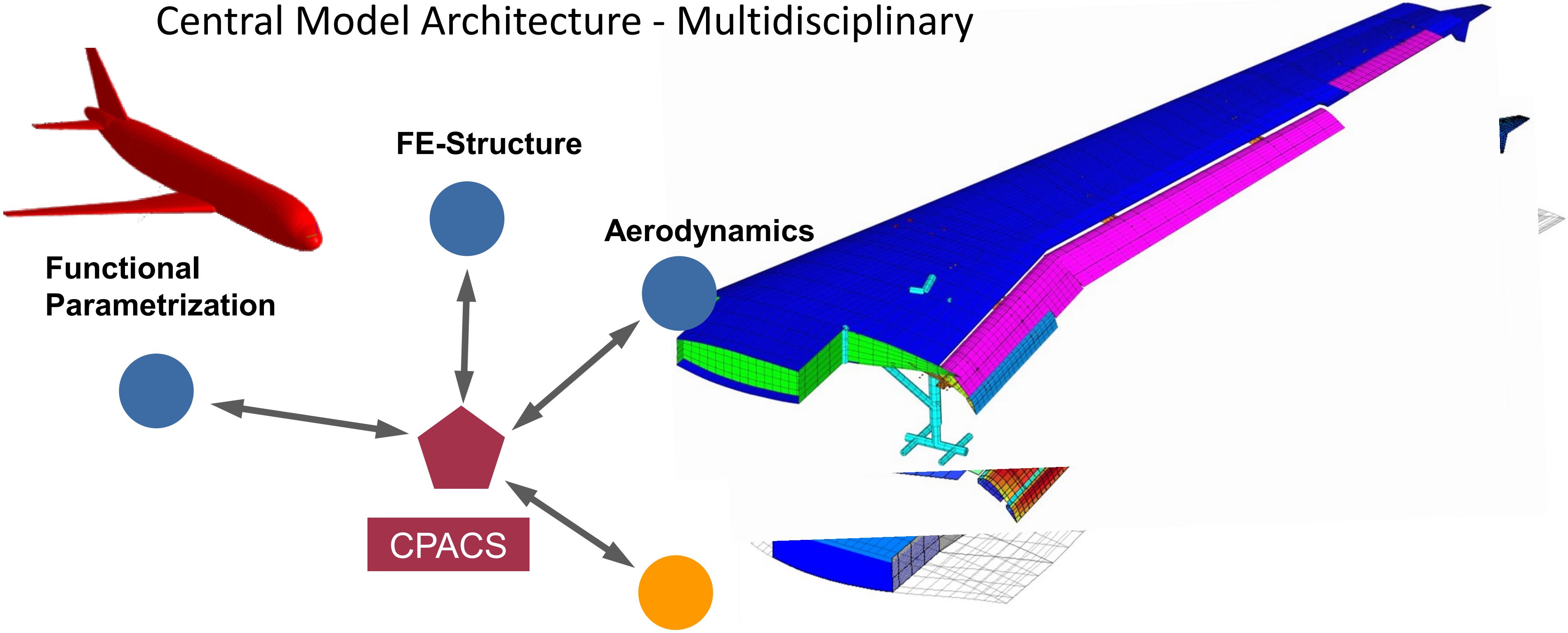
Integrated Aircraft Design

Central Model Architecture - Multidisciplinary



FE-Structure

Aerodynamics

Functional Parametrization

CPACS

Fuel Loads

Different models with different geometric representations can be derived from the global CPACS model using the software libraries.

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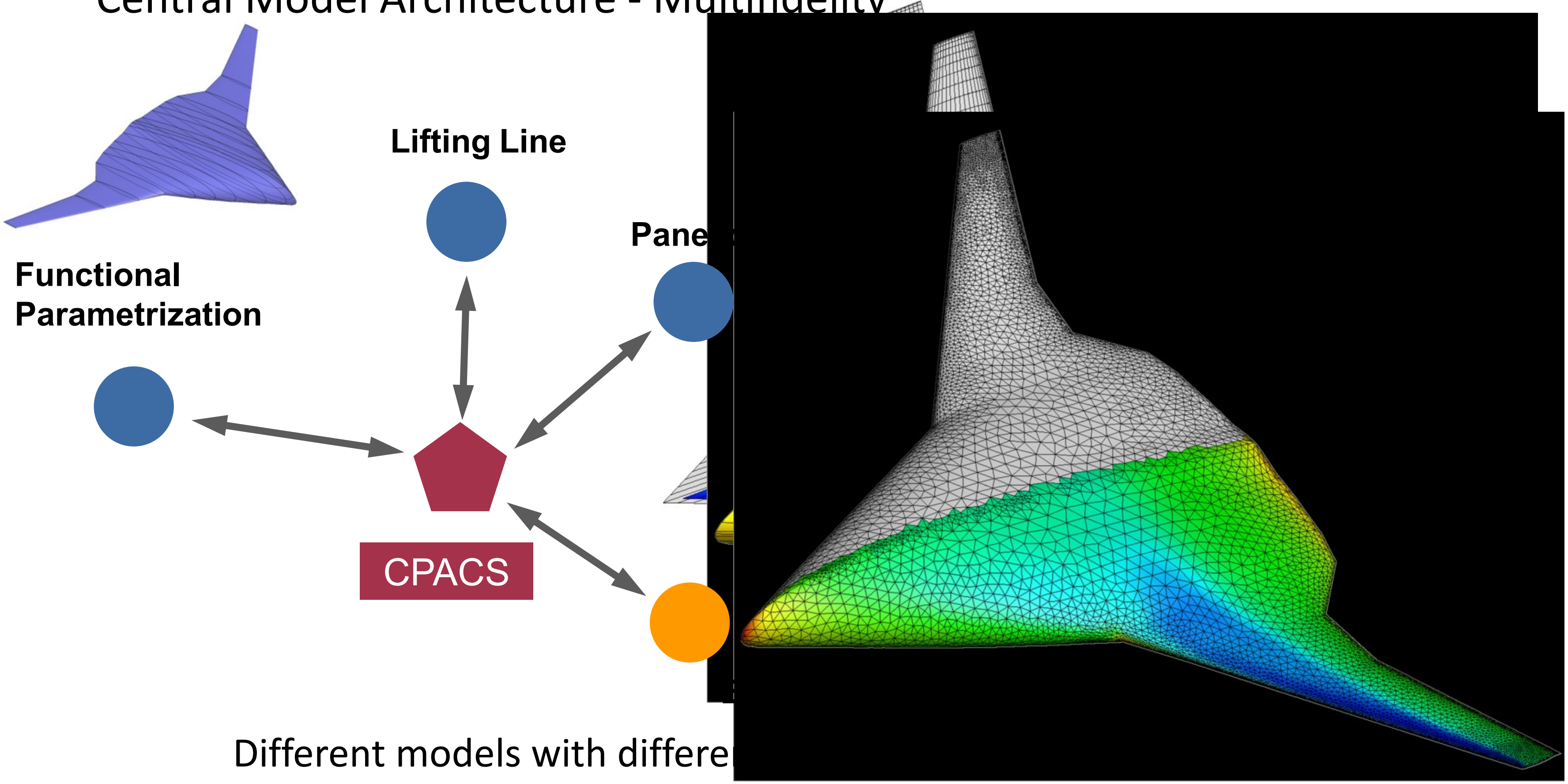
Integrated Aircraft Design

Central Model Architecture - Multifidelity



Different models with differe
derived from the global CPACS model using the software libraries.

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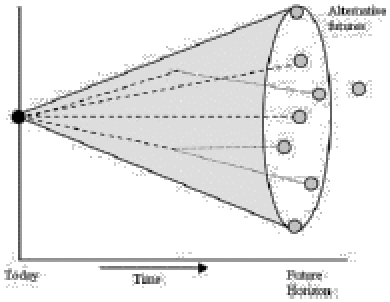
Leading Concept “Comfortable & Clean” – an example for an integrated ATS concept research

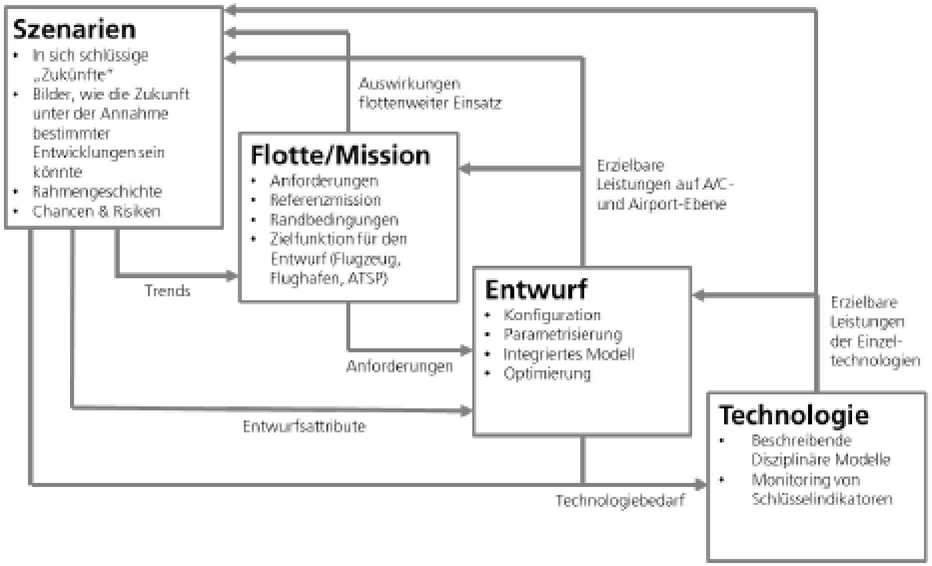
- Comfortable Cabin
- Alternative Fuel
- Climate-Optimized Trajectory
- Applying LFC At Large Bodies
- Avoiding Large Atmospheric Disruptions
- Intermediate Stop Operations
- Avionics For Single Pilot Operation
- Blended Wing Body AC Design
- Container Tracking And Safety
- New Container and Payload Loading Concepts
- Concept of Mega Airports

Scenarios for future Air Transportation Systems

Scenarios for future Air Transportation Systems

Integration of research of the future into an integrated design process





Szenarien
- In sich schlüssige „Zukünfte"
- Bilder, wie die Zukunft unter der Annahme bestimmter Entwicklungen sein könnte
- Rahmengeschichte
- Chancen & Risiken

Flotte/Mission
- Anforderungen
- Referenzmission
- Randbedingungen
- Zielfunktion für den Entwurf (Flugzeug, Flughafen, ATSP)

Entwurf
- Konfiguration
- Parametrisierung
- Integriertes Modell
- Optimierung

Technologie
- Beschreibende Disziplinäre Modelle
- Monitoring von Schlüsselindikatoren

Auswirkungen flottenweiter Einsatz

Erzielbare Leistungen auf A/C- und Airport-Ebene

Erzielbare Leistungen der Einzeltechnologien

Trends

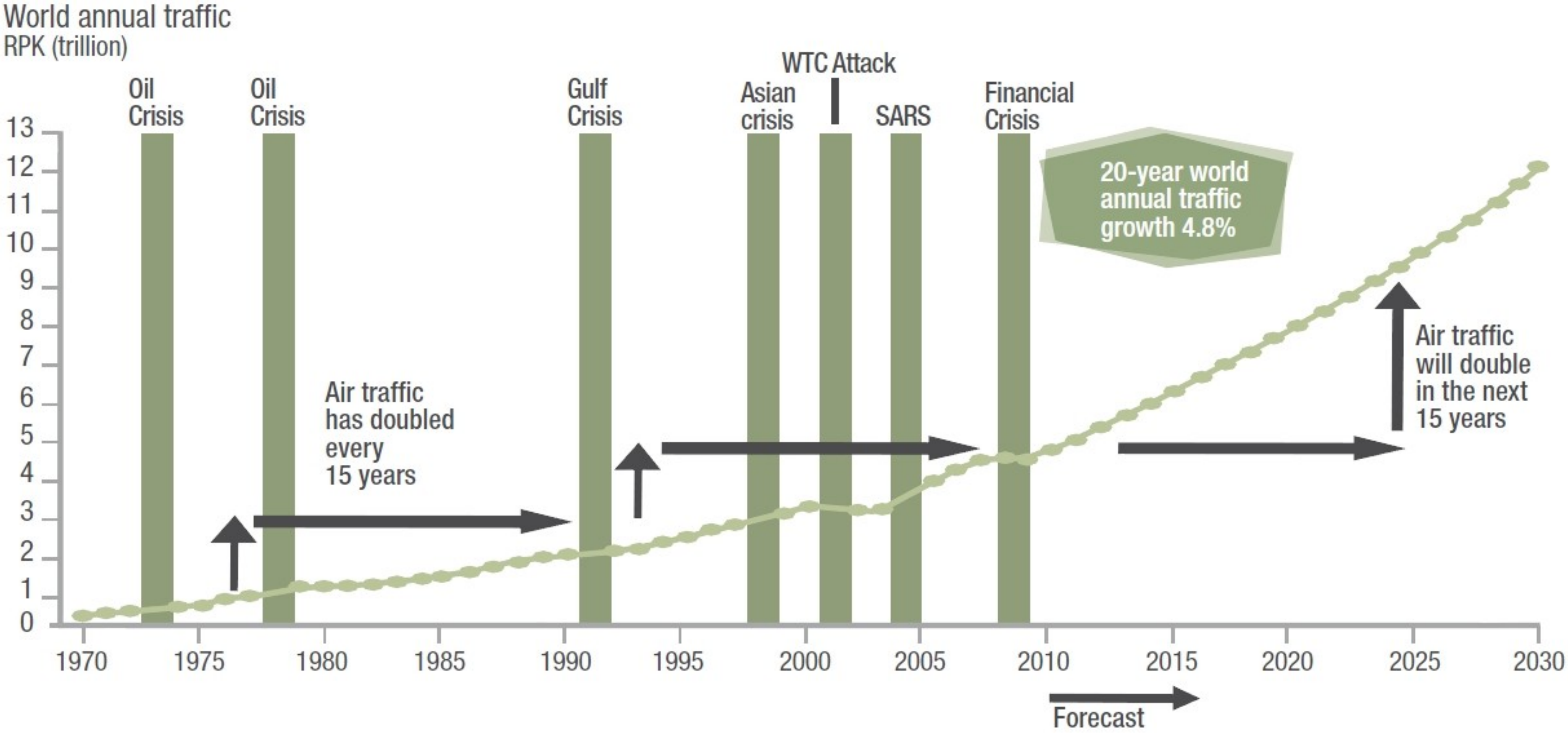
Anforderungen

Entwurfsattribute

Technologiebedarf

Boundaries for Future Developments

Perspectives in Aviation (1/3)

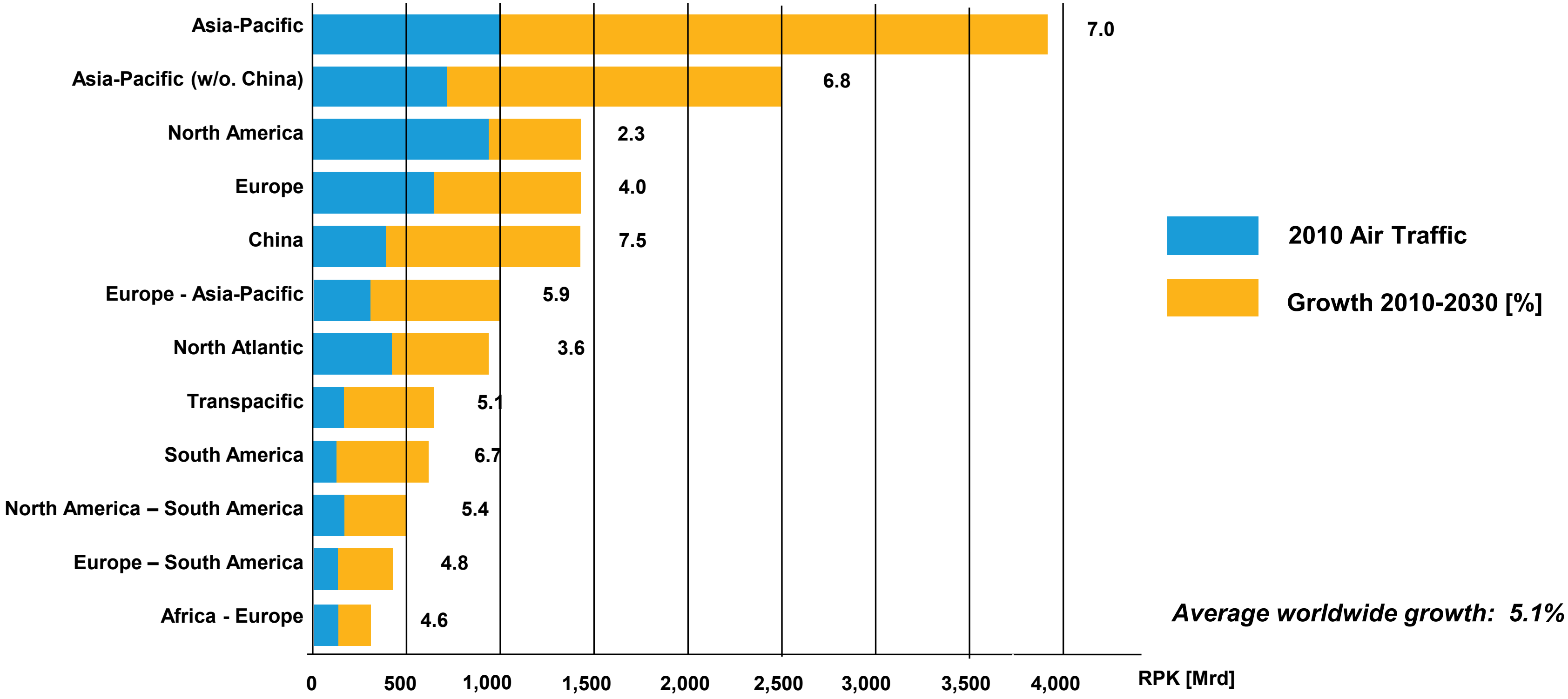


➔ Despite any disturbancies aviation industry is still expecting **4.8% global annual growth** in terms of growing passenger movements

Source: Airbus GMF 2011

Boundaries for Future Developments

Perspectives in Aviation (2/3)



Average worldwide growth: 5.1%

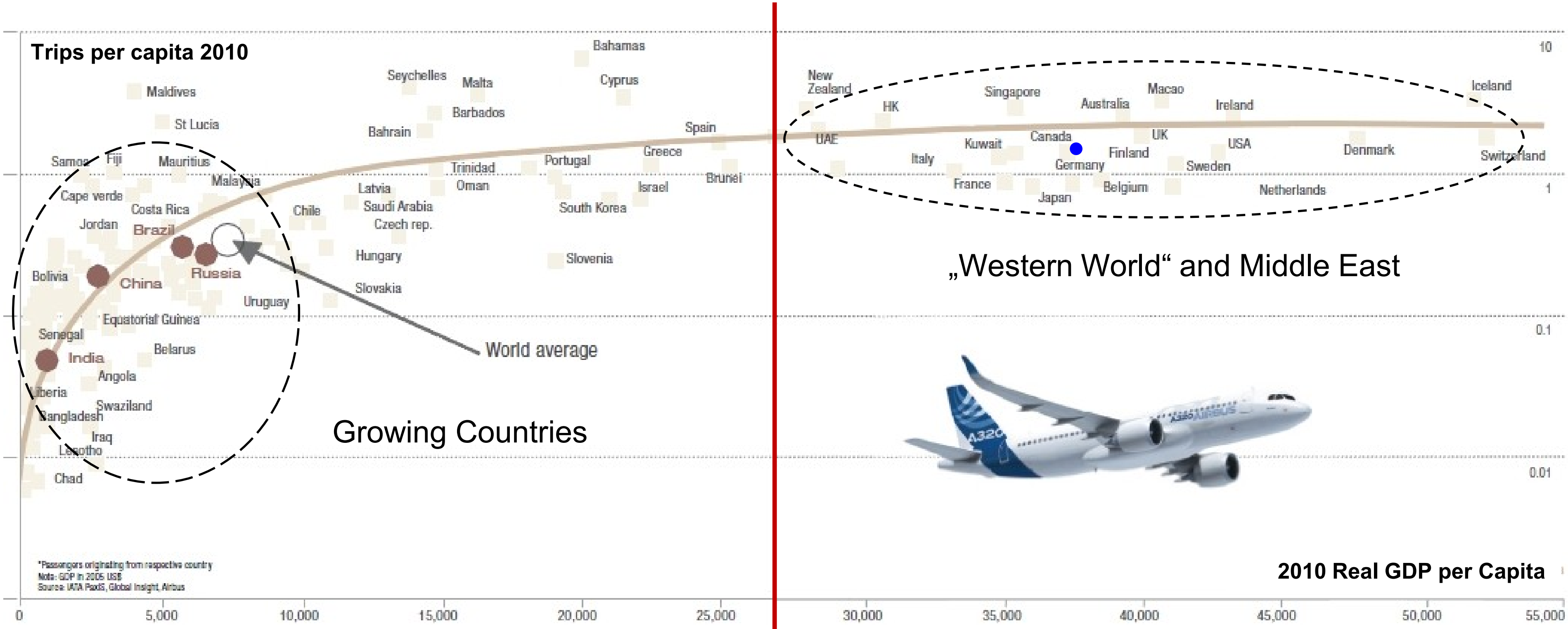
➔ Remarkable growth on long range

➔ Growth on short range is depending on regions

Source: Boeing Market Qutlook 2011

Boundaries for Future Developments

Perspectives in Aviation (3/3)



Growing Countries

„Western World“ and Middle East

*Passengers originating from respective country
Note: GDP in 2005 US$
Source: IATA PaxIS, Global Insight, Airbus

Mobility steep increasing function of the economic growth

Mobility nearly independent from economic growth and static

➔ Short range transport will increase in growing countries with own manufacturing industry

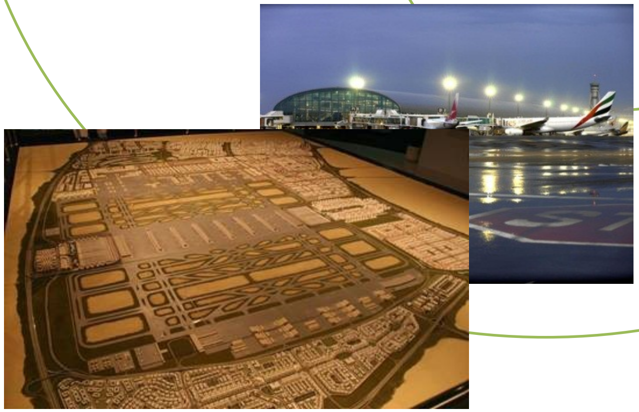
➔ Long range transport will grow between „Western World, Middle East and Growing Countries

Source: Airbus GMF 2011

Boundaries for Future Developments

Change of global traffic flow

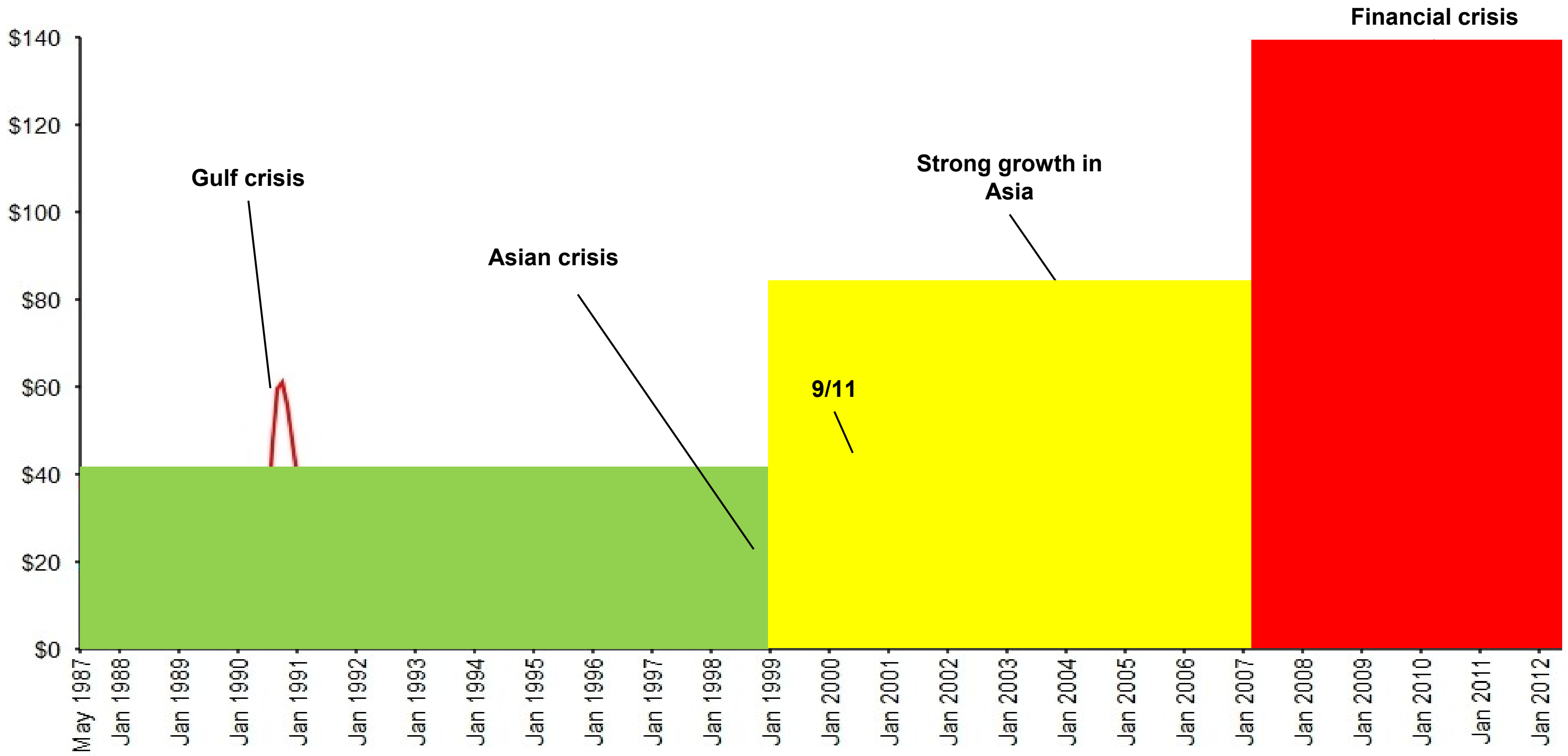
- **Middle East reaches 2/3 of global population** within 8 hours flight
- **Mega airport turntables** provide significant long range transport capacities
- **Air transport flows will change** resulting in a changing relevance of the acutal airport hubs and spokes in Europe
- **European Airlines will benefit but also change** their business models due to the Middle East and Asian developments



Dubai World Central Airport

Boundaries for Future Developments

Development of oil price 1987 - 2012



➔ Oil price is constantly growing with increasing gradient, which leads to a highly sensitive and destabilizing development

Source: EIA

A Paradigm Shift in Aviation

Trade Off between Mobility and Green Transportation

- **Mobility is a major pillar** of high life style and prosperity
- Increasing energy/oil cost and ecological responsibility **argue against quantitative traffic growth**
- Ensure **mobility with less energy effort**, materials, emissions and noise **requests for less traffic ➔ less aircraft, less airport, airspace capacity**
- **Passenger mobility** can be achieved with **less aircraft movements**
- **Cost and emissions** per flight are **to be shared** by more people per trip

➔ from **quantitative to qualitative** air transport growth

Source: U. Becker, TU Dresden, V. Gollnick, DLR

The Paradigm Shift of Flying

Changes

Qualitative Growth of Aviation

- Balance of time, cost, emissions, effort
    - **Less traffic, less aircraft, consolidated capacities**
    - **Less** noise and **emissions**
    - **More** potential for robustness, and reliability in the transportation processes

- **Increased level of service**
    - **More comfort** and relaxed **travel experience**
    - Air transport is **more attractive**
    - **More** potential for **punctuality** (door to door)

- **Common Vision**
    - Joint targets and common goals

- **Integrated ATS**
    - Understanding of systems dependencies

Flightpath 2050
Europe's Vision
for Aviation

From Air Transport System 2050 Vision
to Planning for Research and Innovation

EREA

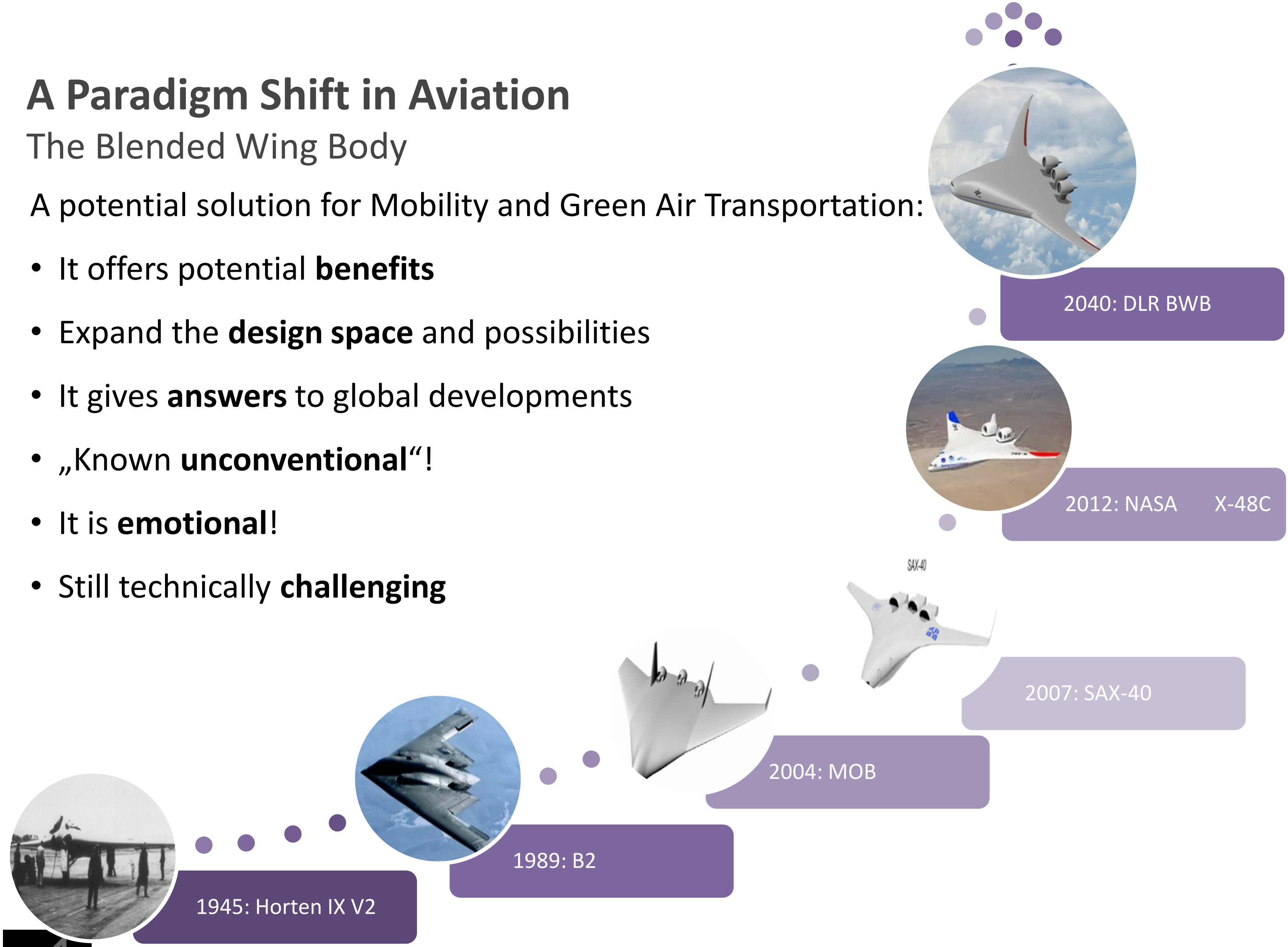
Source: U. Becker, TU Dresden, V. Gollnick, DLR

A Paradigm Shift in Aviation

The Blended Wing Body

A potential solution for Mobility and Green Air Transportation:

- It offers potential **benefits**
- Expand the **design space** and possibilities
- It gives **answers** to global developments
- „Known **unconventional**“!
- It is **emotional**!
- Still technically **challenging**



1945: Horten IX V2

1989: B2

2004: MOB

2007: SAX-40

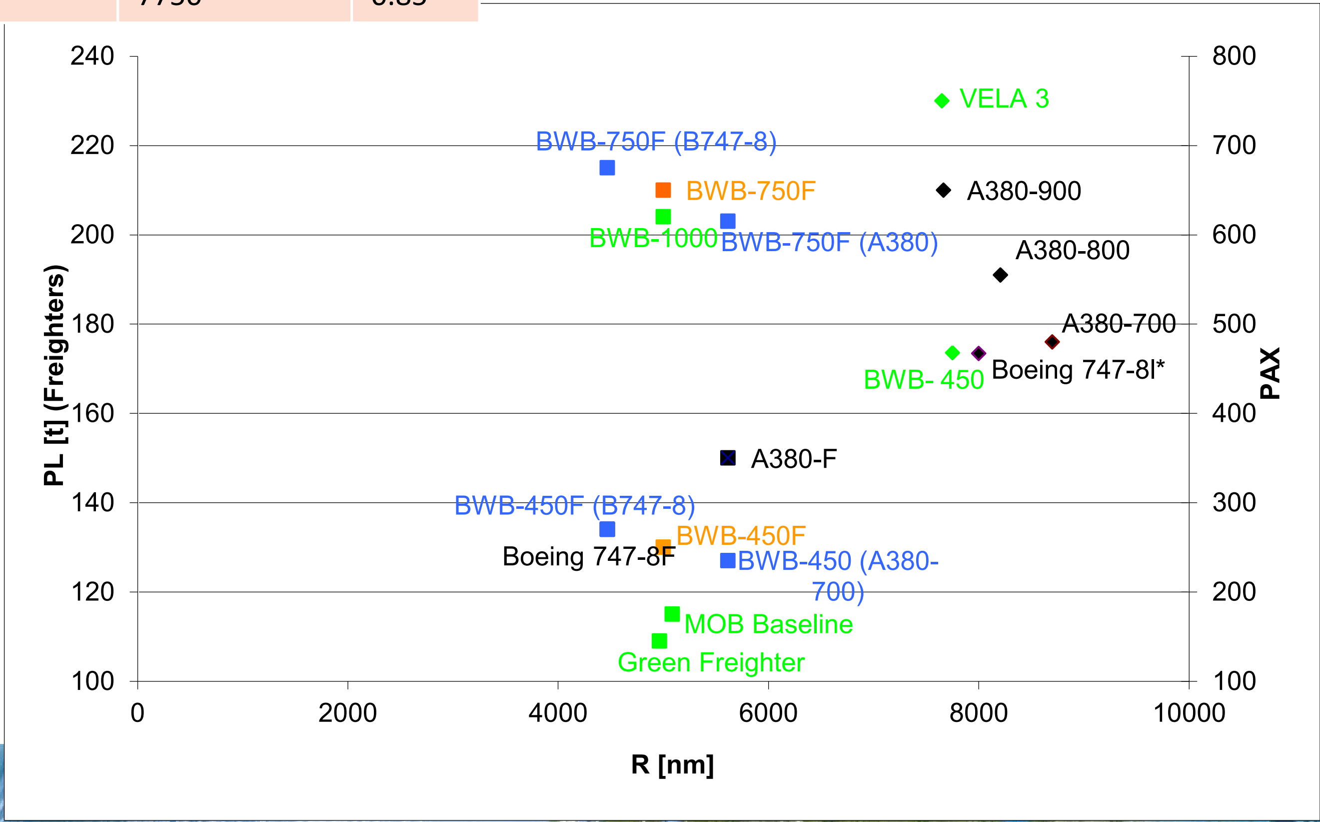
2012: NASA X-48C

2040: DLR BWB

The Blended Wing Body

A potential solution for Green Air Transportation

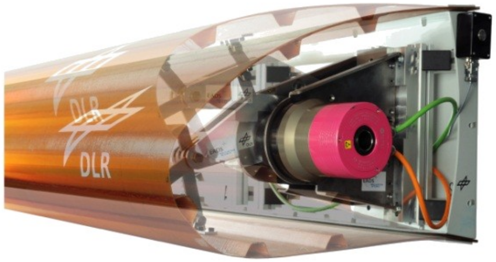
Concepts	Payload - Cabin	Range [nm]	Mach
BWB 450	468 PAX	7750	0.85
VELA 3	750 PAX	7650	0.85
MOB	115 [t]	5087	0.85
SAX 40	215 PAX	5000	0.8
DLR BWB	500 PAX	7750	0.85



The Blended Wing Body

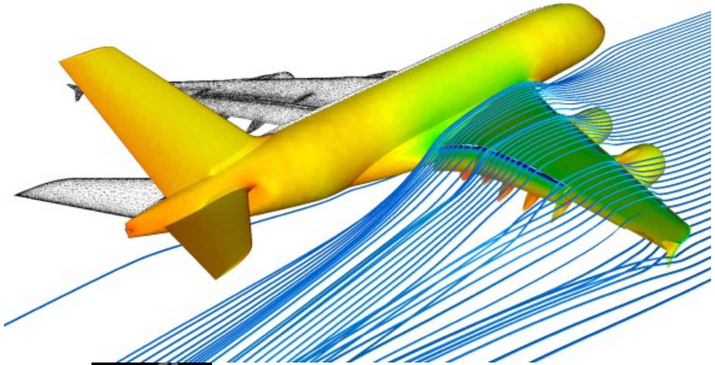
Design for integrated Air Transportation Systems

Airport



Vehicle

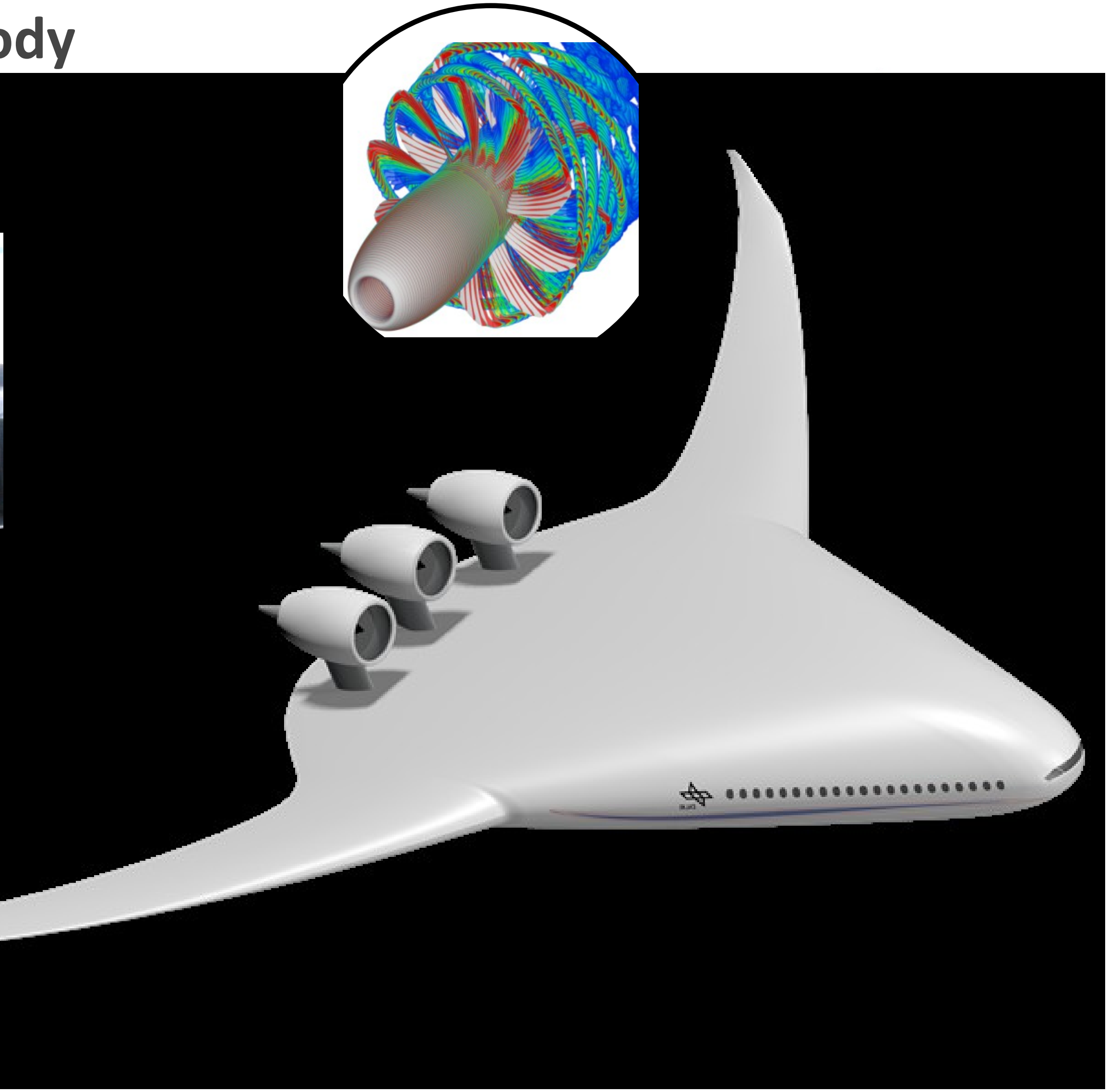
Technologies



Operations

The Blended Wing Body

A Coupled



Concept

Benefit

Challenge

MDO

Integration

Source: DLR, Institute for Air Transportation Systems

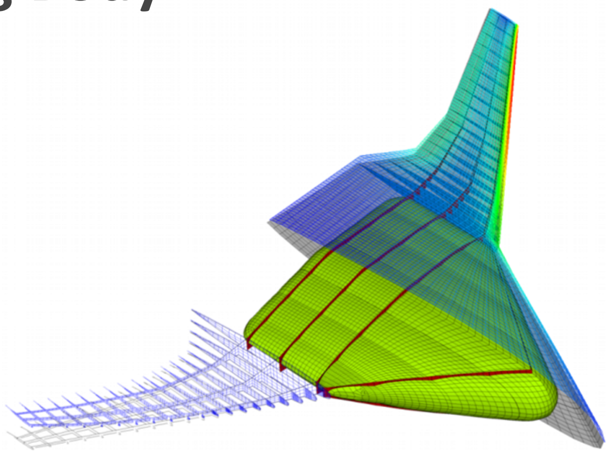
The Blended Wing Body

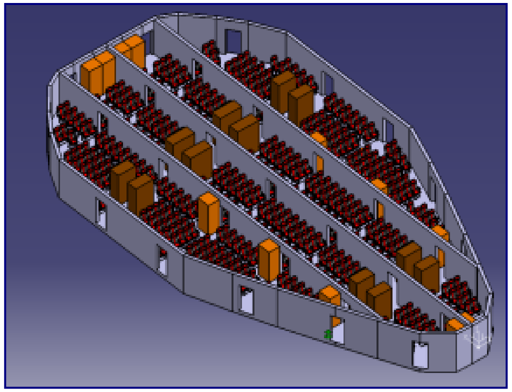
An Overall ATS Design

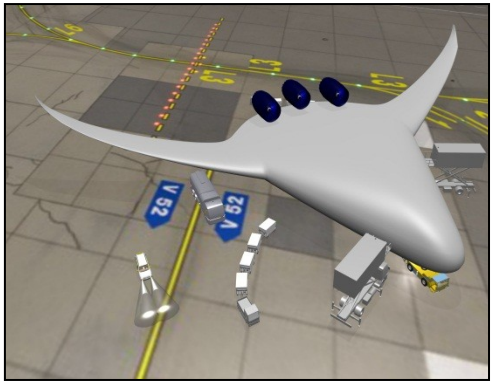
Cabin Design

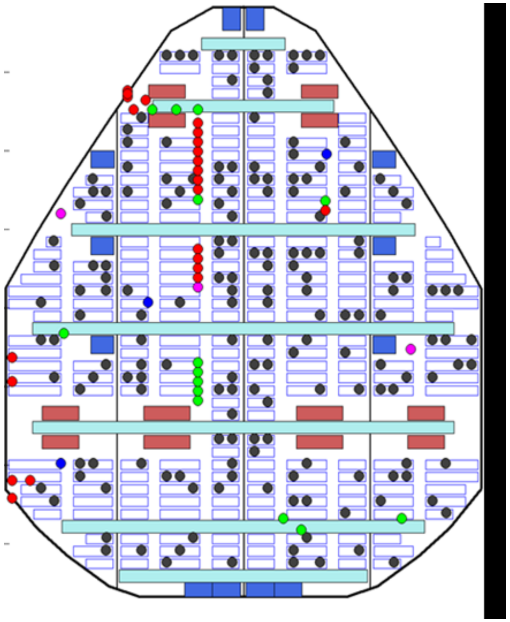
Boarding

Turnaround Operations







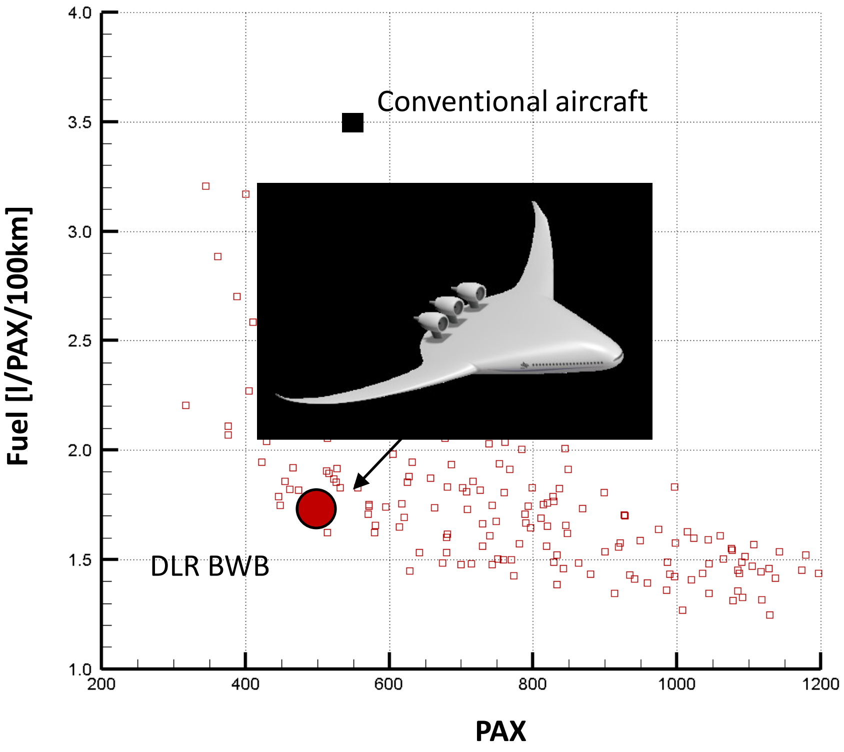


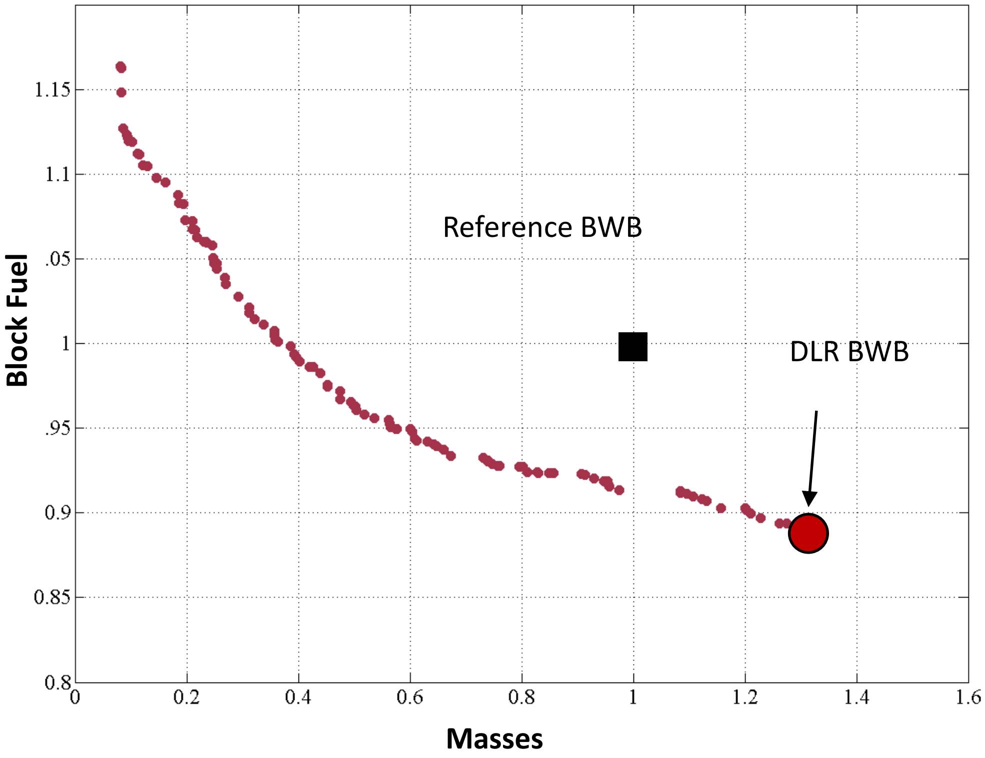
Source: DLR, Institute for Air Transportation Systems, Hamburg

The Blended Wing Body

An Overall ATS Design

Block fuel improvements with respect to conventional configurations

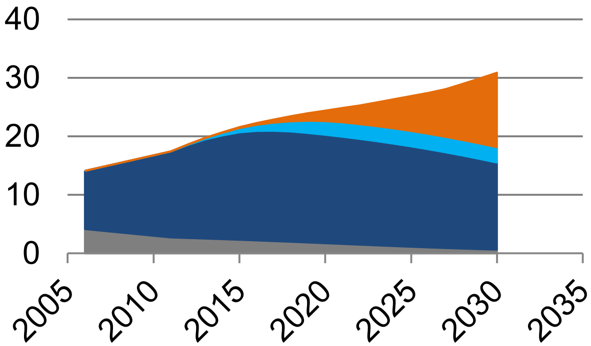




Source: DLR, Institute for Air Transportation Systems, Hamburg

Fast Foreward, FFWD

ATS System Analysis of Global Fuel Burn (CO_2) Forecast



ATS System Analysis of Global Fuel Burn (CO_2) Forecast

1 Problem

- **Environmental Impact of Future Air Traffic Growth (CO_2)**

  Difficult to Estimate the Role of:

  - Single Aircraft Families
  - New Technology

2 Objectives

- **Estimate Future World Fleet of Airliners and their Fuel Burn (CO_2)**
  - On Basis of Individual Aircraft Models
  - New Technology Penetration
  - Growth & Retirements

3 Approach

- **<u>Bottom-Up</u> Fleet and Fuel Burn Forecast**

On the Basis of:

- FESG Forecast Details
- Individual Aircraft Fleets and Order Books
- Eurocontrol BADA Performance DB

4 Results

- **Flexible Forecast Environment:**
  - Fleet and Fuel Burn of Single Aircraft Types: From **today** up to year **2036**
  - Alternative Growth, Market, Technology & Policy Scenarios

IATA

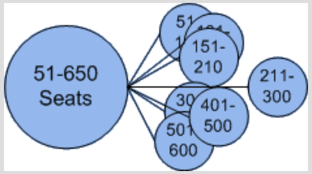
FWD

DLR

ATS System Analysis of Global Fuel Burn (CO_2) Forecast

1 Status quo

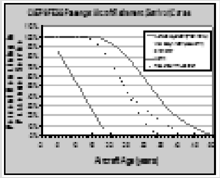
- Today‘s fleet
  - World fleet
  - Sub fleets



ASCEND Fleet Data

2 Aircraft Classifications

- Traffic Shares
- Retirement curves



ICAO FESG Forecast

3 Growth Scenarios

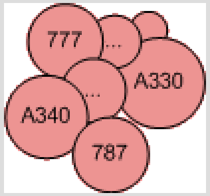
- Traffic Growth

- Market Shares

Case specific Information

4 Prediction

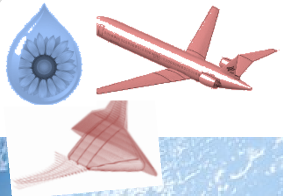
- Next years‘ deliveries

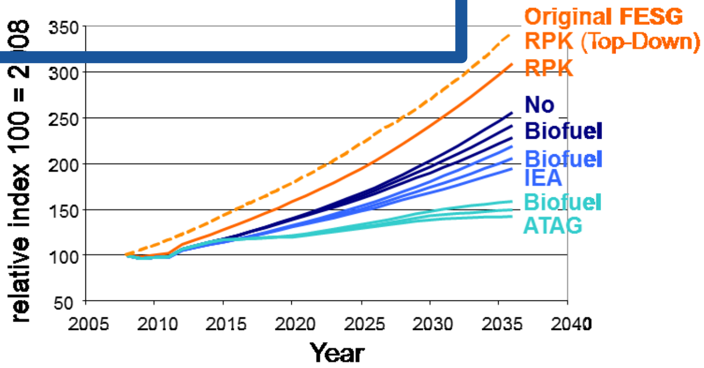


Aircraft specific performance data

Aircraft-specific operation data

New aircraft programs, timelines



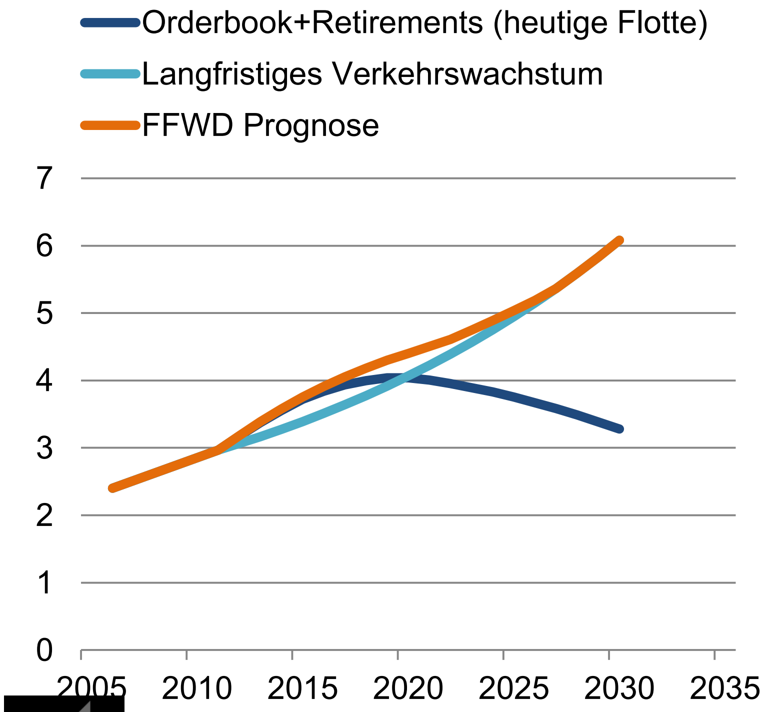


ATS System Analysis of Global Fuel Burn (CO_2) Forecast

Future Horizons - Short and long term developments

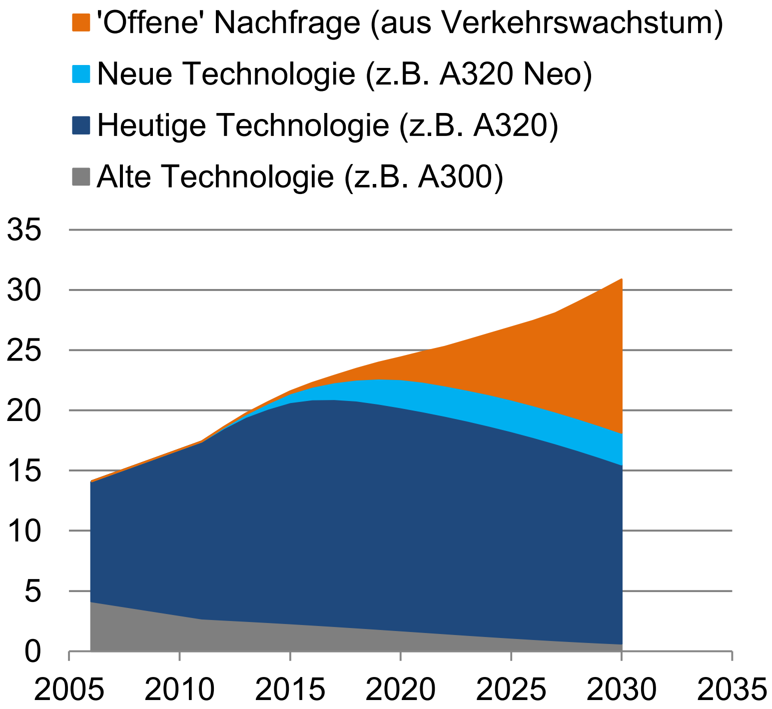
Development of traffic

Offered seat capacity of world fleet [Mio]



Development of technologies

Operational world fleet aircraft [Tsd]



ATS System Analysis of Global Fuel Burn (CO_2) Forecast

Fuel Consumption and CO2 Emissions related to aircraft level and technology scenarios

Operational A/C types

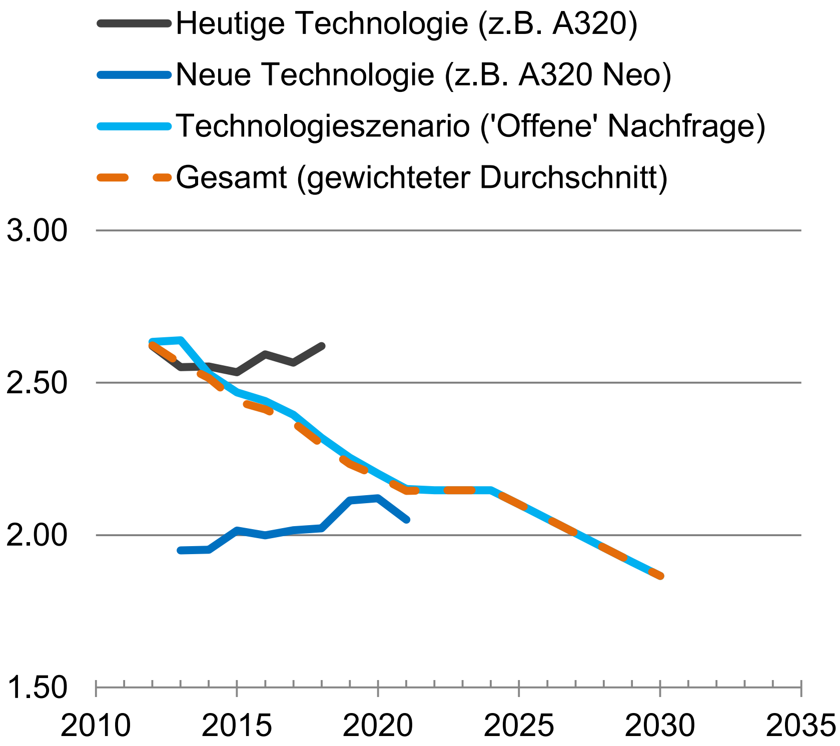
- Fuel flow calculation based on Eurocontrol BADA performance data
- Performance data available for 76 A/C

Future demand

- Technology scenarios based on acutal A/C development references, typical production cycles, longterm potentials

Fuel consumption of new A/C

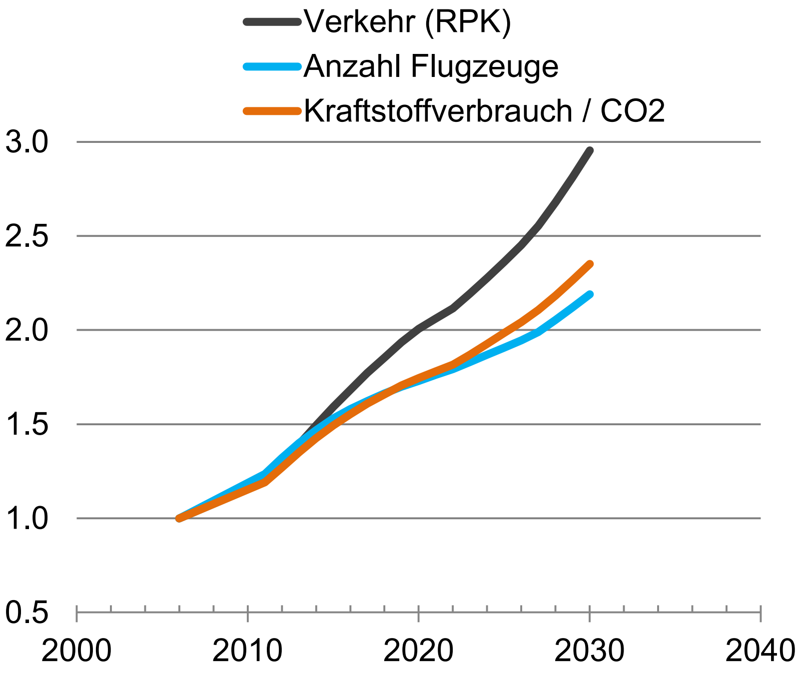
in [litre/Seat/100 km]
seat class 101-150



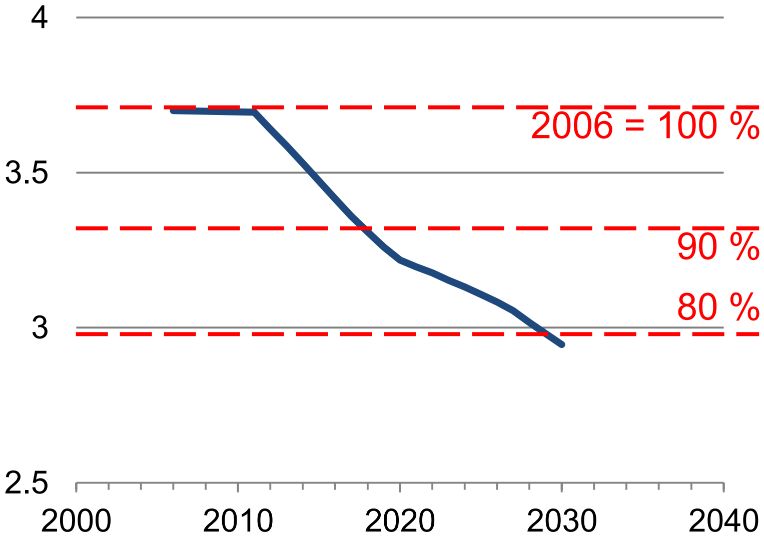
ATS System Analysis of Global Fuel Burn (CO_2) Forecast

Estimation of global effect of A/C families and technologies

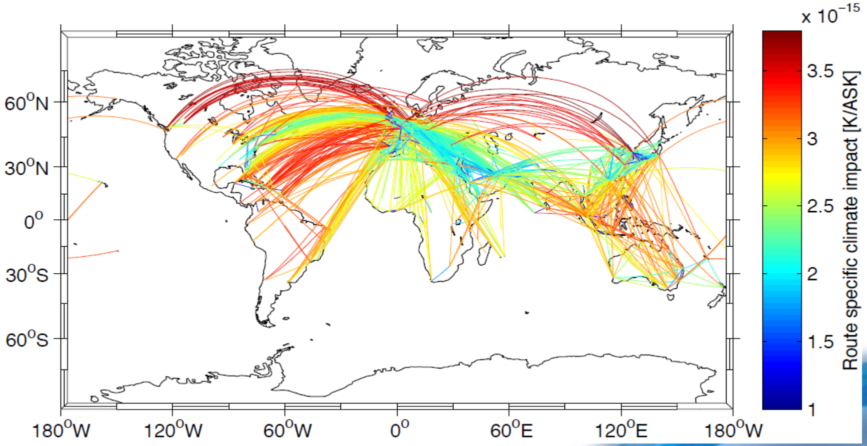
Future development of air transport, A/C, fuel consumption/CO2



Average fuel consumption of world A/C fleet [litre/pax/100 km]



Climate Optimized Air Transportation, CATS



Knowledge for Tomorrow

Climate Optimized Air Transportation

Goals

Identify potential for **climate impact reduction** by reducing flight altitude and speed for

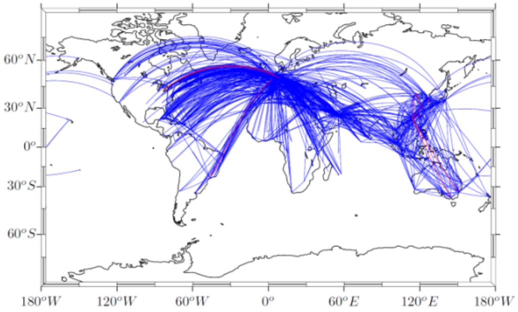
- ➔ actual aircraft
- ➔ re-designed aircraft

using

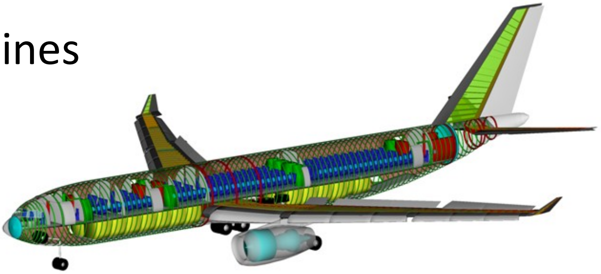
- a **world fleet** of a representative long range aircraft
- typical **real flight tracks as references** for assessment
- **Average Temperature Response** (ATR) und **Direct Operating Costs** (DOC) as metrices
- Assessment ATR und DOC Änderung **relativ zu heutigen Flugverfahren**
- **Value trade off** ATR vs. DOC

Climate Optimized Air Transportation

Boundary Conditions



Leg network	**1178 Routes** with annual frequency in **2006** based on OAG data
Vertical profile	**ICA** 13-41 kft (step size 1kft) **Mach** 0.4-0.85 (step size 0.001) *Continuous climb cruise*
Aircraft	**A330-200** with CF6-80E1A3 engines calibrated on real data
Cost assessment	Only **Cash Operating Costs**, Staff and fuel cost basis **2006**
Climate assessment	32 years continous emissions average ATR over 100 years including **CO_2**, **O_3**, **CH_4**, **H_2O**, **contrails**, **contrail-cirrus**



$$ATR_{100} = \frac{1}{100}\int_{2006}^{2106} \Delta T(t)dt$$

Climate Optimized Air Transportation

Design and Analysis Chain based on CPACS and Collaboration

Propulsion

engine performance

Aircraft design

aerodynamics, weights

Route network

mission profile

Atmosphere

atmospheric data

Fuel estimation

mission fuel

Trajectory calculation

4D trajectories, emission distribution

Flight Envelope

feasible trajectories

DOC

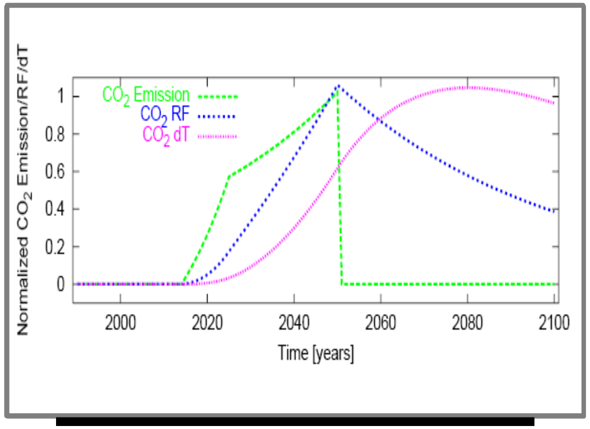
direct operating costs

Climate impact

climate impact

Process Control

iteration of routes



AirClim

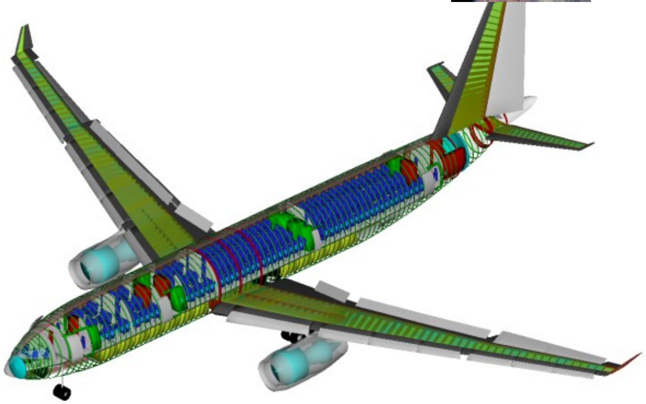
- Linearized response based on DLR E39/CA
- CO_2, CO, O_3, CH_4, H_2O contrails, contrial-cirrus

Climate Optimized Air Transportation

Adaption of A/C Design

Cruise conditions for **DOCrel = 1.1**

ICA (mean) 7947 m → **Design ICA** 8000 m
Ma_cr (mean) 0.717 → **Design Ma** 0.72

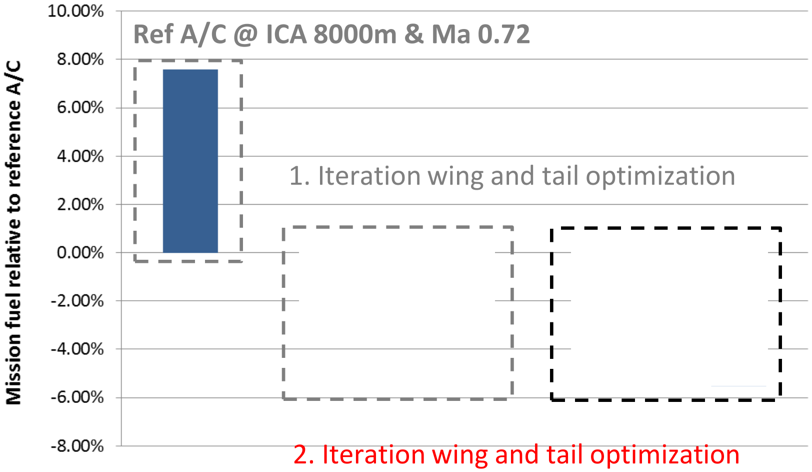


Redesign for climate compatible cruise conditions

Design steps

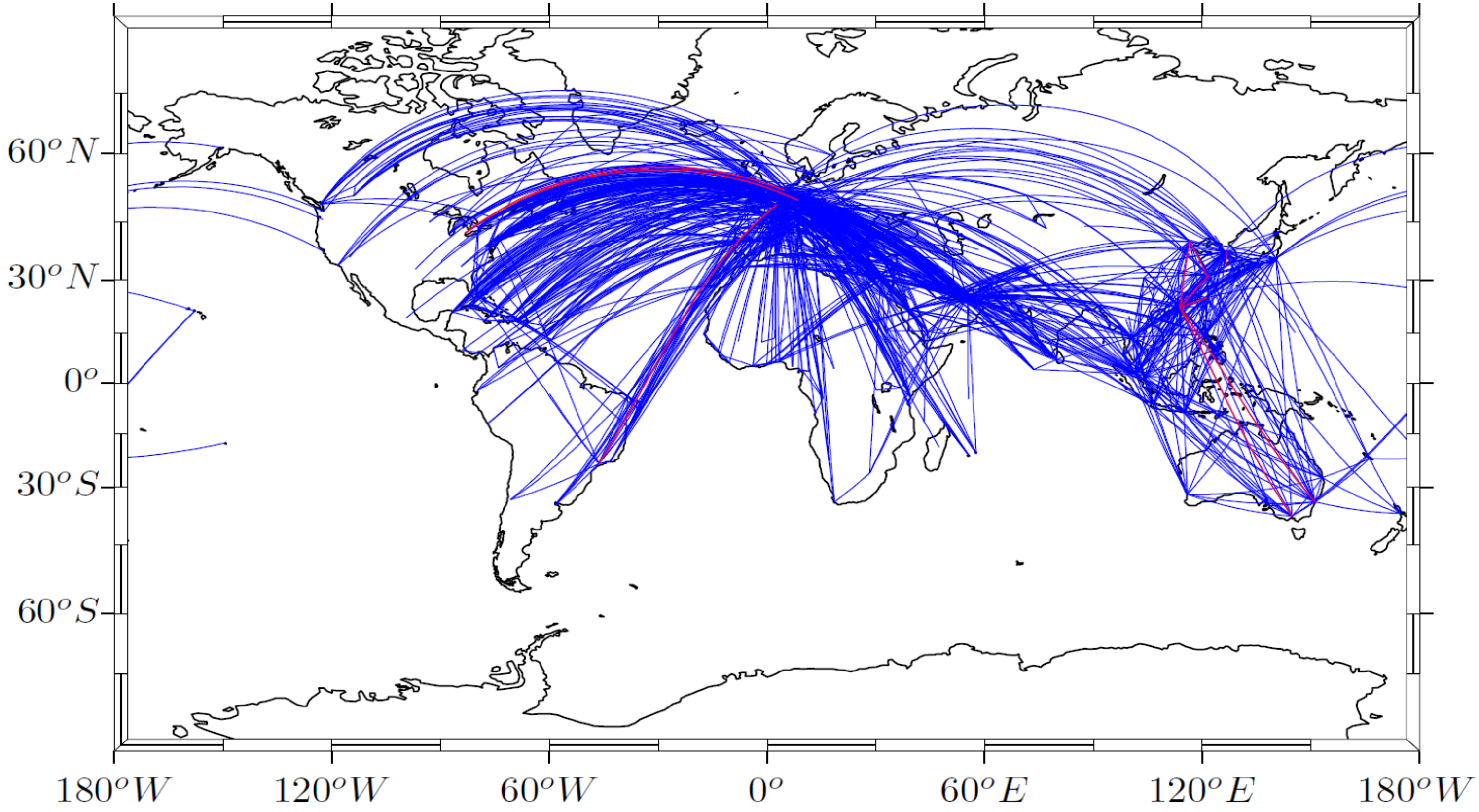
Wing optimization		Ref.	1. It.	**2. It.**
- Wing LE sweep	[deg]	32	23	22
- Wing area	[m2]	361	366	360
- Wing aspect ratio		9.3	12.6	13
- Wing position (x/LF)		0.341	0.337	0.344
Empenage definition				
- HTP LE sweep	[deg]	34	24	24
- HTP area	[m2]	71	57	55
- VTP LE sweep	[deg]	44.4	32	31
- VTP area	[m2]	53	60	59

Ref. cruise conditions @ 10000m & Ma 0.82



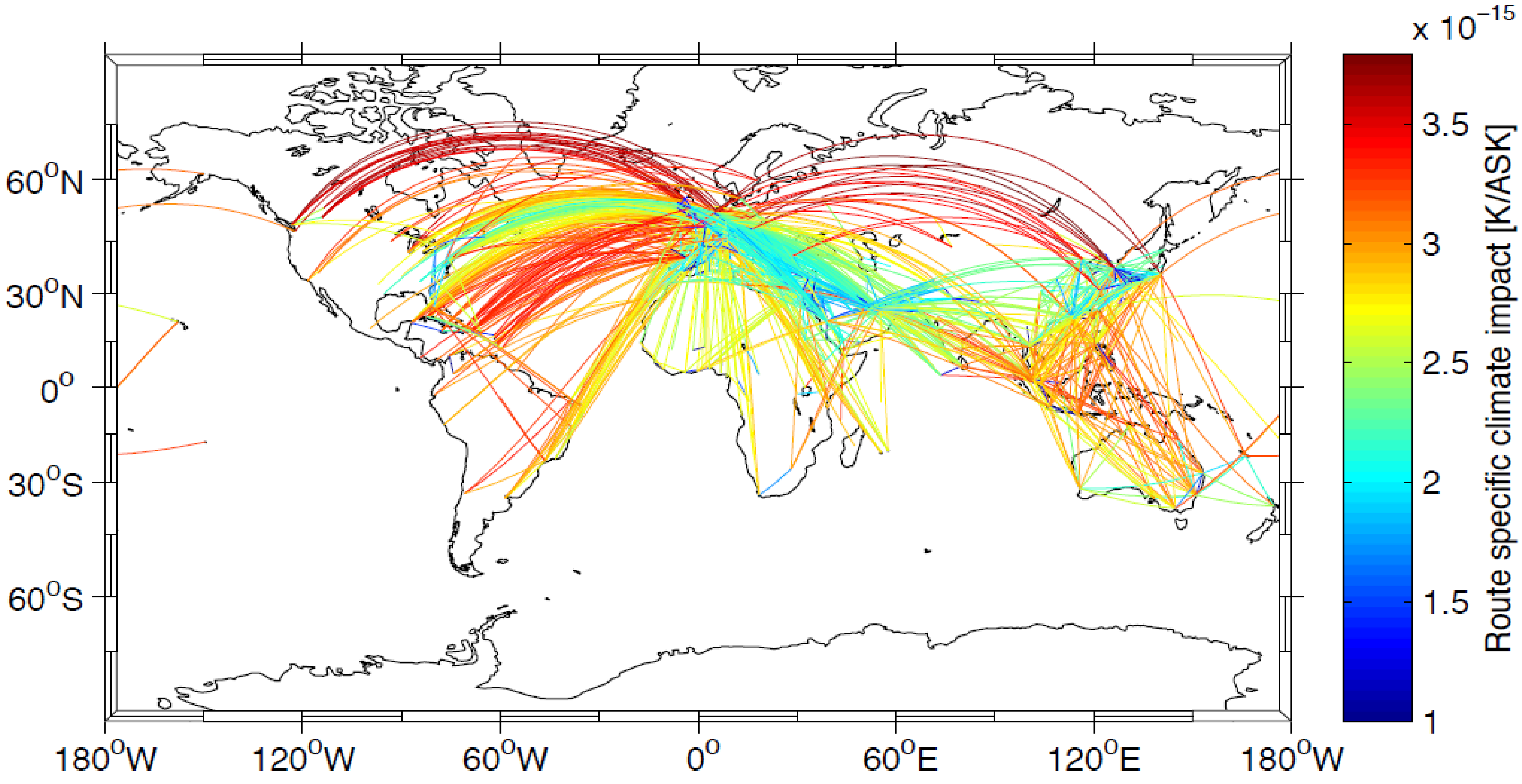
Climate Optimized Air Transportation

Reference: Global leg net of all A330 flight in 2006



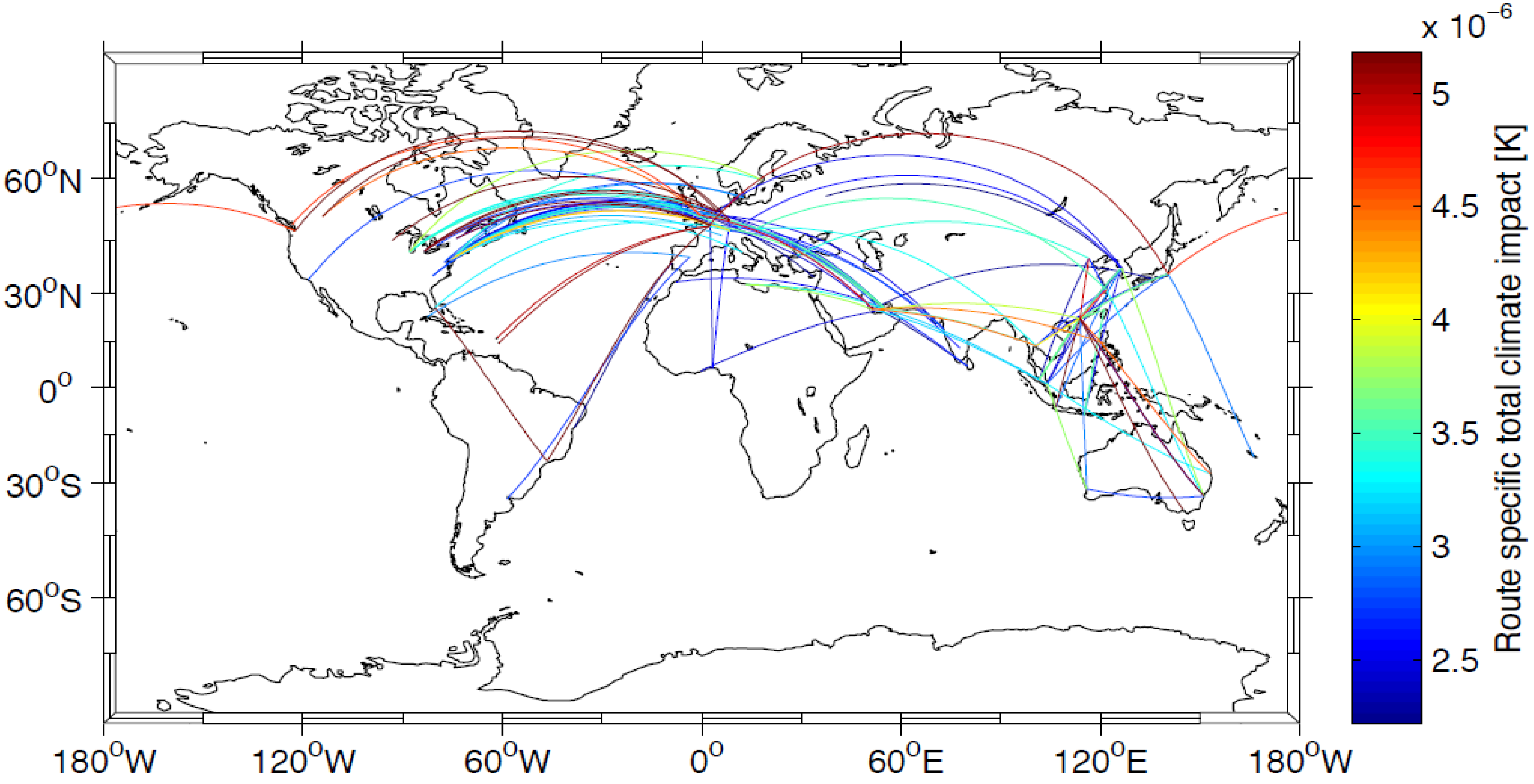
Climate Optimized Air Transportation

Reference: Climate impact of actual scenario per route and annual ASK



Climate Optimized Air Transportation

Reference: Climate impact of top 112 routes representing 50% of impact of A330 fleet



Climate Optimized Air Transportation

Results: Trade off between DOC and ATR climate impact

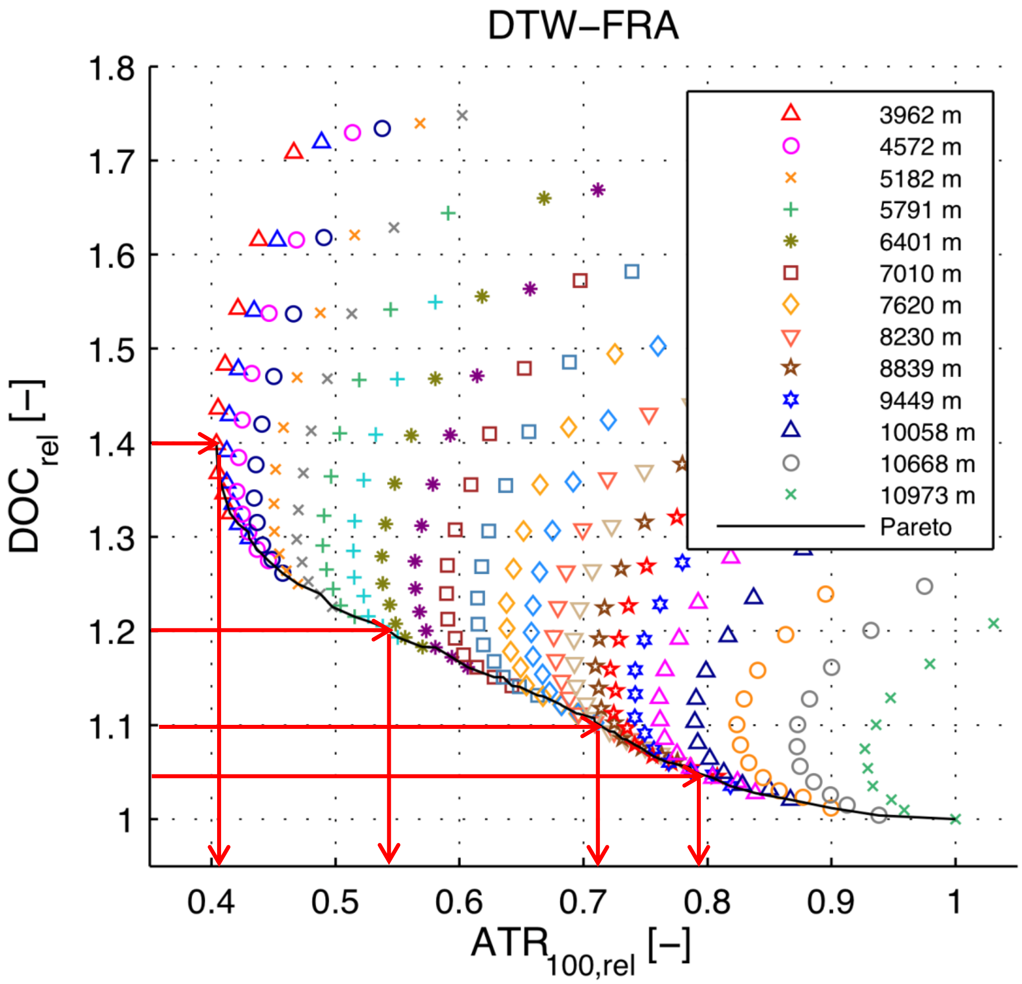
- Trade-off for exemplary mission depicted (-> Pareto frontier)
- Mission: DTW-FRA
- Climate impact reduction of

  59 %

  requires

  40 %

  DOC increase wrt. minimum DOC operations!
- Identification of ideal trade-o for whole route network allov for the derivation of a new de point for a more climate-frien aircraft



Climate Optimized Air Transportation

Value Analysis theory

DOC and ATR change of each individual trajectory relative to reference profile

Relative **DOC change**

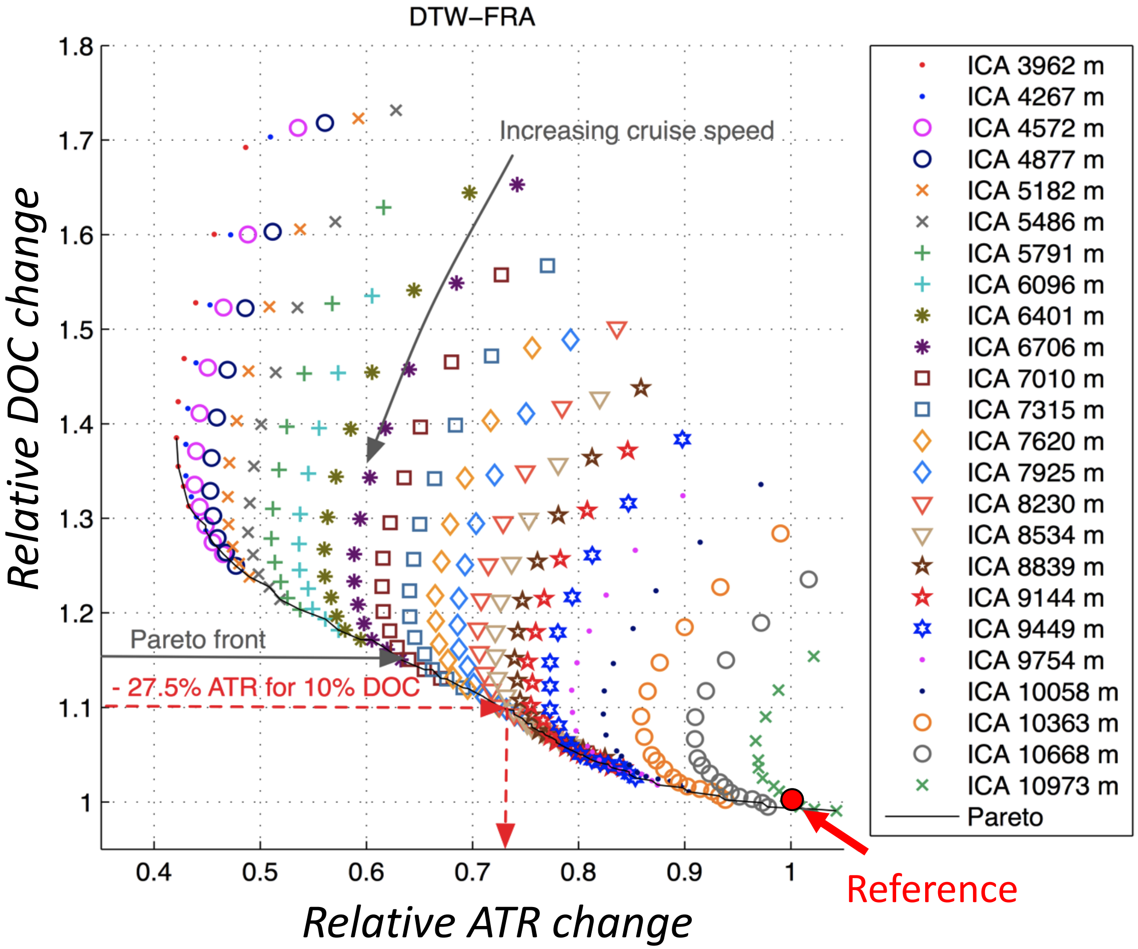
$$DOC_{rel,i,k} = \frac{DOC_{i,k}}{DOC_{i,ref}}$$

Relative **ATR change**

$$ATR_{rel,i,k} = \frac{ATR_{i,k}}{ATR_{i,ref}}$$

Resulting **Pareto-frontier**

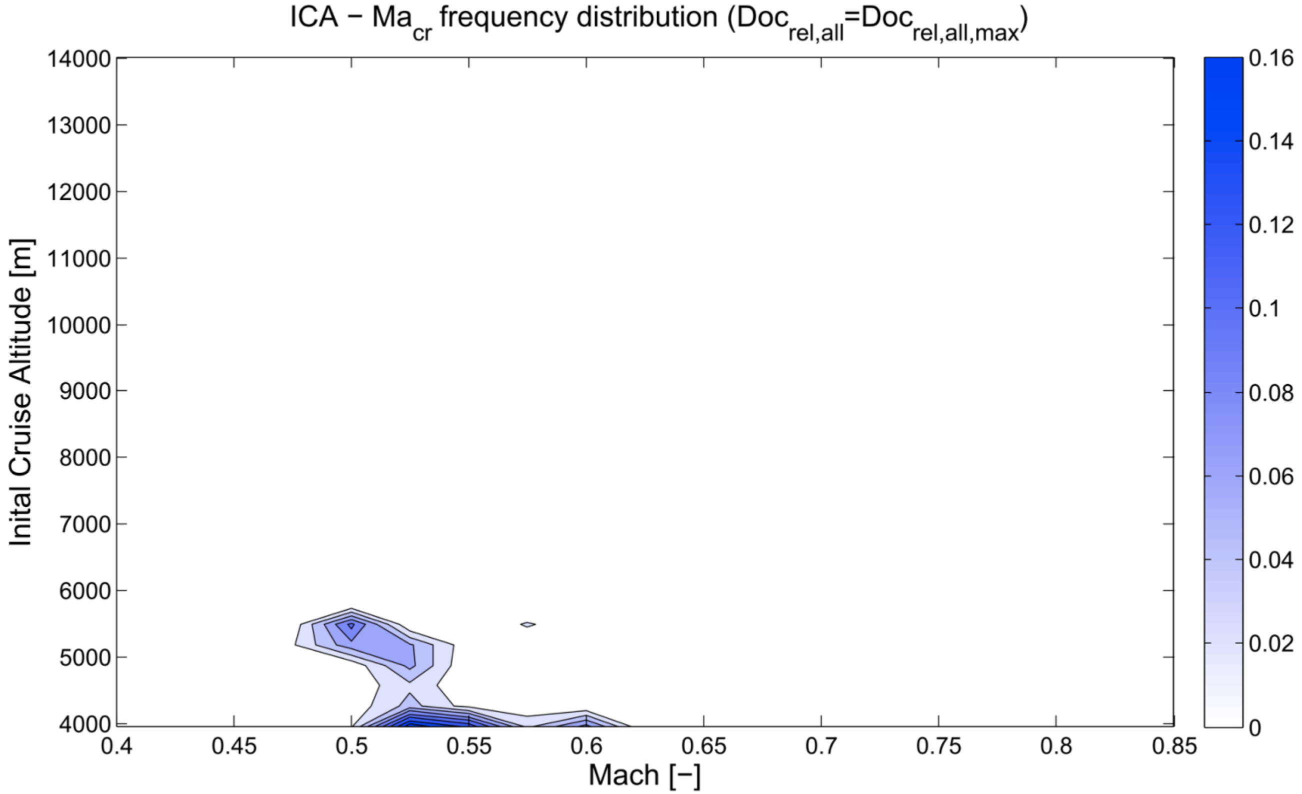
$$Max(ATR_{rel,i,k}) = f(DOC_{rel,i,k})$$



Climate Optimized Air Transportation

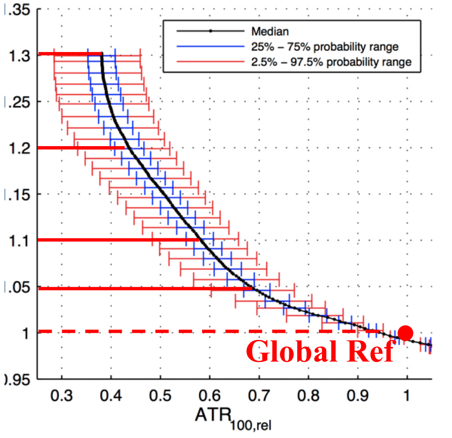
Deriving new A/C design requirements

Probability distribution of cruise conditions (ICA-Ma) for increasing cost



Relative Change in cost **30** %

Relative change in climate impact **62** %



Lower cruise flight and speed conditions for increasing ΔATR_{rel}

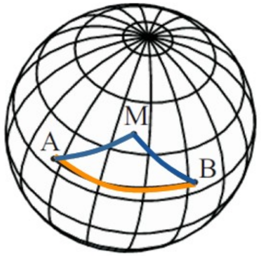
request for A/C redesign to recover off design losses

Intermediate Stop Operations, ISO

Knowledge for Tomorrow

Intermediate Stop Operations

Generic Single Mission Analysis



1 Problem

- Long range aircraft often “over-sized” for average mission lengths
- Payload-Range efficiency (PRE) decreases with very long ranges
- What would be the ATS-impact of refueling an aircraft during a long-haul flight at an intermediate airport?

2 Objectives

- Show the fuel saving potential of ISO
  - Single mission
  - Fleet wide
- Consider given ATS boundary conditions:
  - Routes structure
  - Intermediate airport locations and infrastructure

3 Approach

- Redesign of A330-200 type of aircraft for shorter ranges
- Identification of all A330 and 777 routes in 2009
- Integration of world-airport database

4 Results

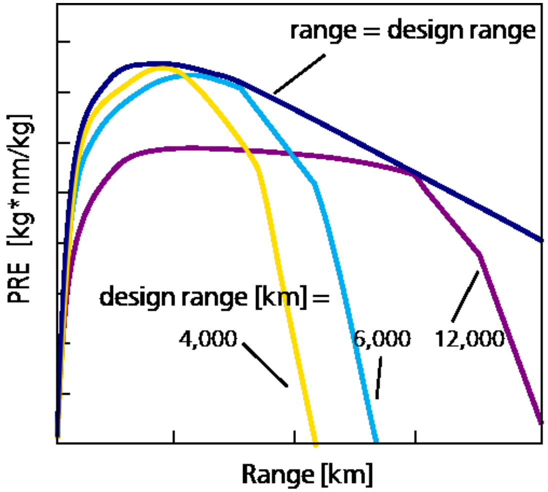
- Ideal mode of operations for each route and ISO airport
- Single flight fuel saving potential
- Global fuel saving potential
- Additional traffic at ISO airports

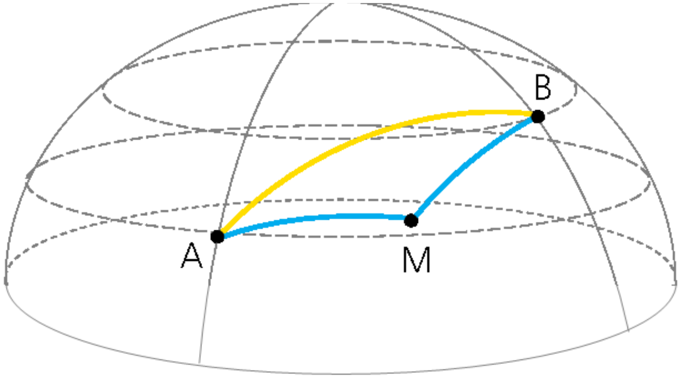
Intermediate Stop Operations

The principle concept

- Long range A/C tend to be oversized in range
- Payload - Range-Efficiency (PRE) decreasing at long range
- Intermediate refueling is an option:
  - In the air: aerial refueling
  - At ground: refuling at airport
- Geographical description of intermediate stop airport (**M**) w.r.t **A** and **B** by:

$$f_{detour} = \frac{\overline{AM} + \overline{MB}}{\overline{AB}} \qquad f_{offset} = \frac{\max\left(\overline{AM}, \overline{MB}\right)}{\overline{AM} + \overline{MB}}$$

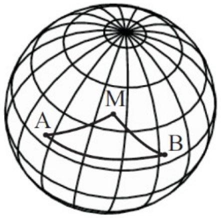


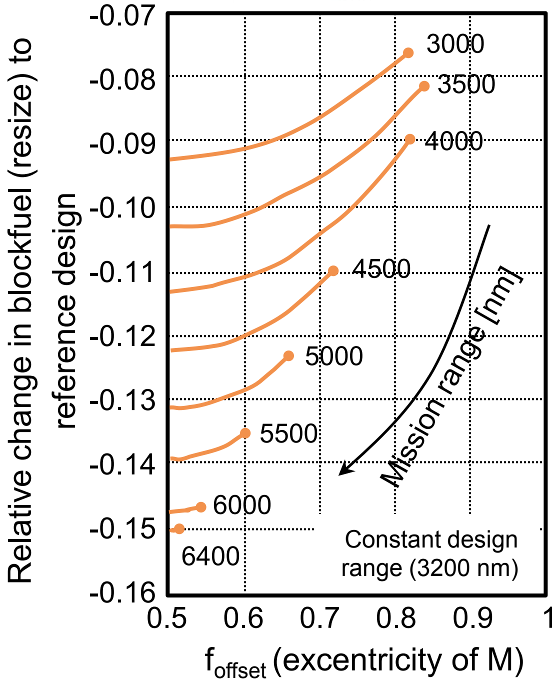


Intermediate Stop Operations

Generic Single Mission Analysis

- A330-200 similar aircraft, re-sized for different design-ranges
- NASA's *Flight Optimization and Performance System* (FLOPS) used for conceptual AC-design
- Fuel burn meta-model for off-design mission calculation
- Reference design range 6400 nm
- ISO with original aircraft yields up to **7%** block fuel savings on a 6400 nm mission
- A/C resized for 3200 nm design range yields up to ~**15.5%** block fuel savings on a 6400 nm mission

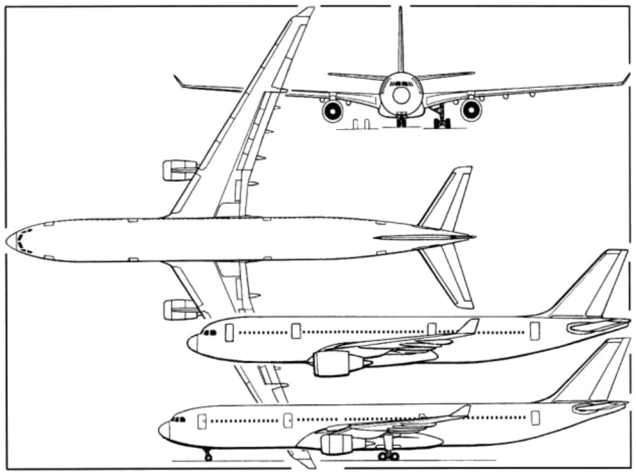




Intermediate Stop Operations

Fuel Saving Potential

- A330-200 like A/C →
- Design adopted to different ranges
- Reference design for 6400 nm compared to ISO-design for 3200 nm range →
- Theoretical potential for fuel saving is about **~ 15 %** für 6400 nm Mission
- About 5% saving possible at given exzentricity f_{offset} for different ranges (→ PRE-Kurve; **~ 5 %**)



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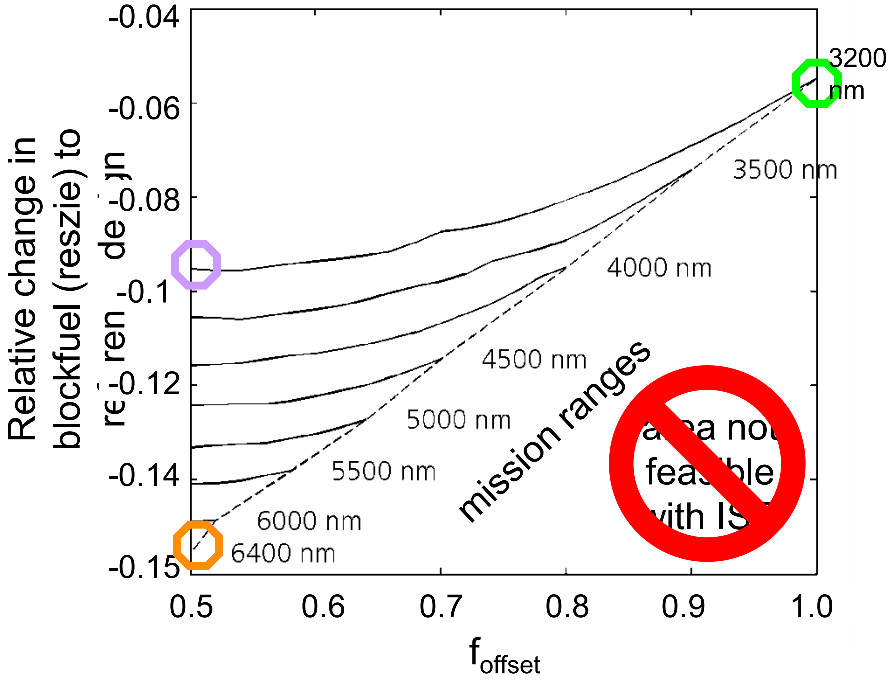
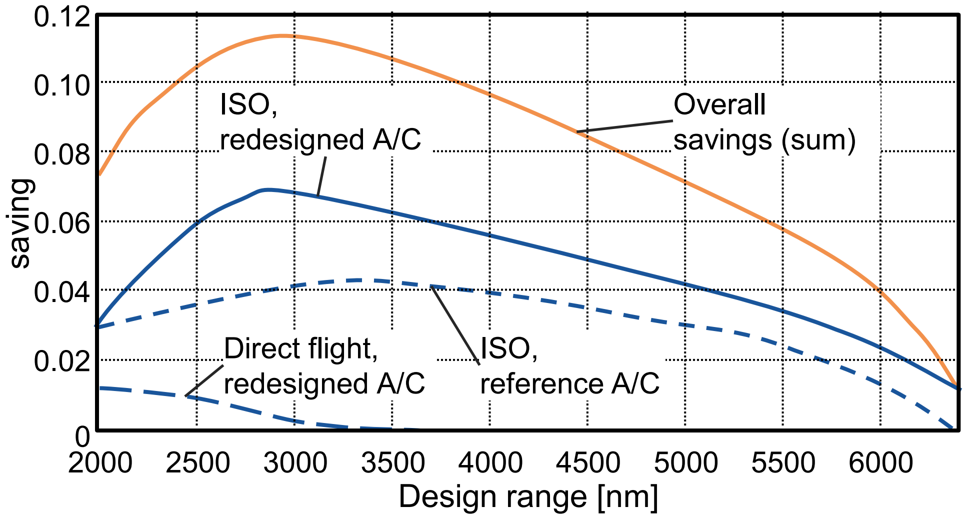


Intermediate Stop Operations

Aircraft Fleet Level Analysis - ISO with resized A/C

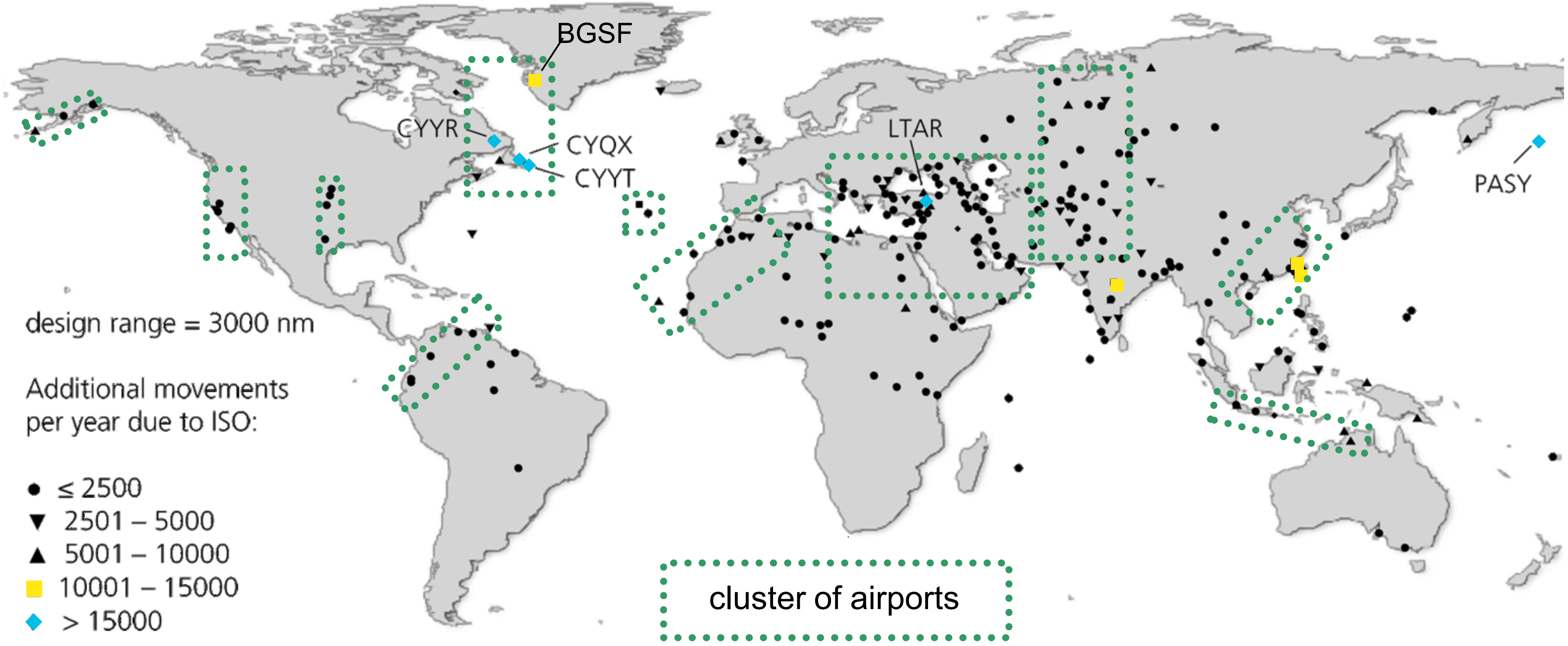
- Global fuel saving potential dependent on A/C design range. Resized aircraft is considered at different design ranges (*x-axis*).
- All A330 and 777 routes of the year 2011
- All airports with runways > 3000m and at least ILS or DME are considered
- 4 different operational modes; For each real route the most fuel efficient alternative is selected.



Relative fuel savings on all routes with regards to direct operations

Intermediate Stop Operations

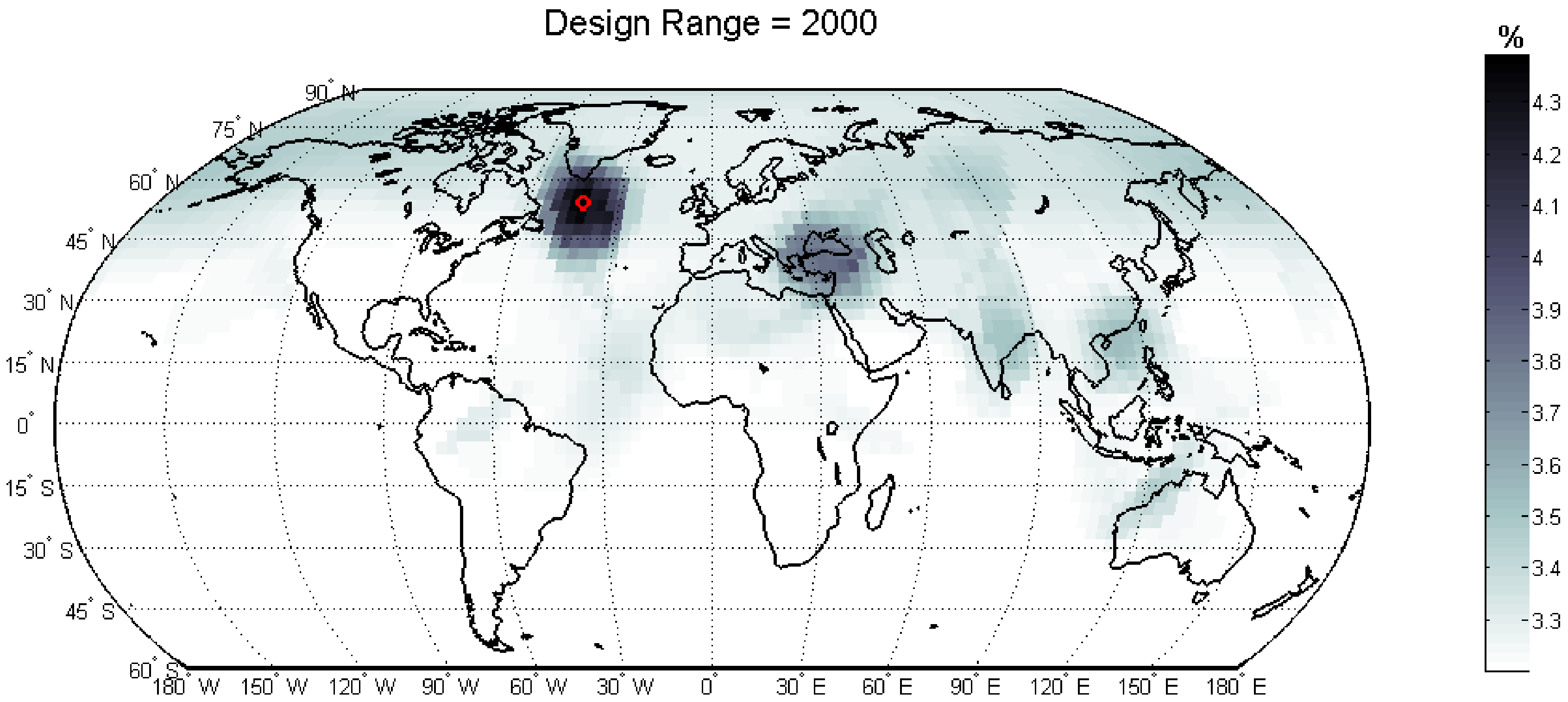
Identification of appropriate intermediate stop airports



- Consideration of
  - typical A330/B777 fligth routes (from OAG, 2007)
  - geographical location of real airport

Intermediate Stop Operations

Optimal position of appropriate airports depending on design range



- Considering variation of design range changes position of “Hot Spots”

Laminar Flow Aircraft Technologies in Operation, LamAiR

Laminar Flow Aircraft Technologies in Operation

Goal: Advance NLF/HLF TRL, find ATS implications

1

Questions

- **Implictions of NLF for an airline?**
  - Net benefit for network-wide ops.? Fuel efficiency on actual routes?
  - Economics: Maintenance, utilization, and aircraft price impact ?
  - Under what boundary conditions does N/HLF make sense?

2

Approach

- **Single flight analysis**
  - Based on high-fidelity DLR aero- and structural models
  - Fuel comparison to A320-200 type aircraft
- **Real-world route network analysis**
  - Based on real flight schedules and route distribution
  - LamAiR A/C gradualy substitutes ref. A/C
- **Cost-benefit analysis**
  - Airline cash-flow modelling (*AirTOBS*)
  - NPV as overall metric for evaluation
  - Parameter variation for maintenance cost, aircraft price and cost of fuel

3

Results

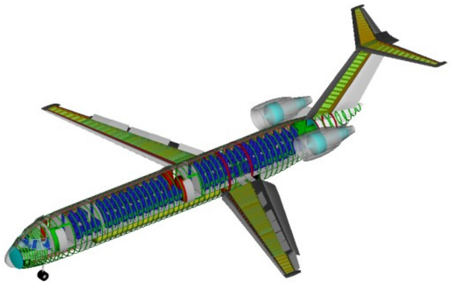
- **Break-even mission range**
- **Net fuel-efficiency benefit on fleet level**
- **Break even fuel price**
- **Definition of targets for e.g. maint. cost**

Laminar Flow Aircraft Technologies in Operation

Chain of Analysis

A/C Design

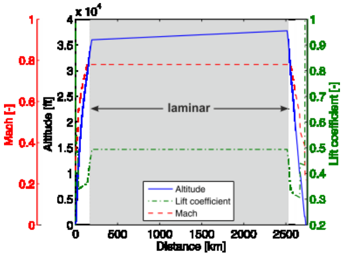
Conceptual Design and Detailed Design
performed by Inst. for Aerodynamics



Aerodynamics- and Engine characteristics
Constraints for operating laminarity

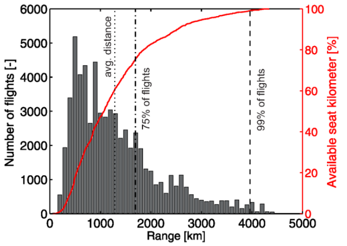
Detailed Analysis

Single flight analysis



Simulation with
TCM (LY-LIP)

Real route analysis

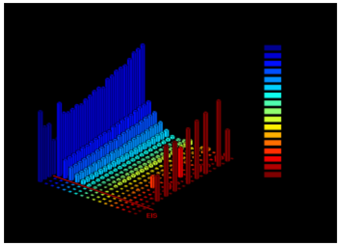


(LY-SLT)

Network analysis

Simulation with
NEMO (LY-LTB)

Economical analysis

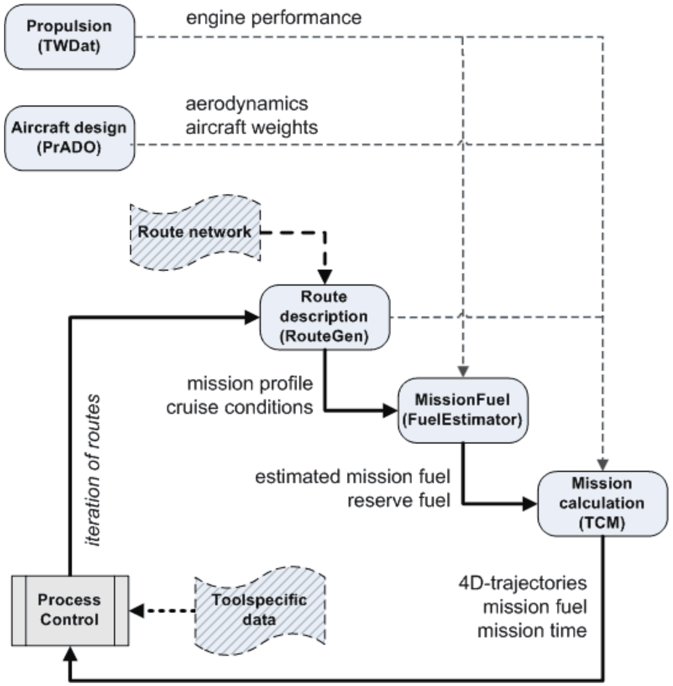


Simulation with
AirTOBS (LY-SLT)

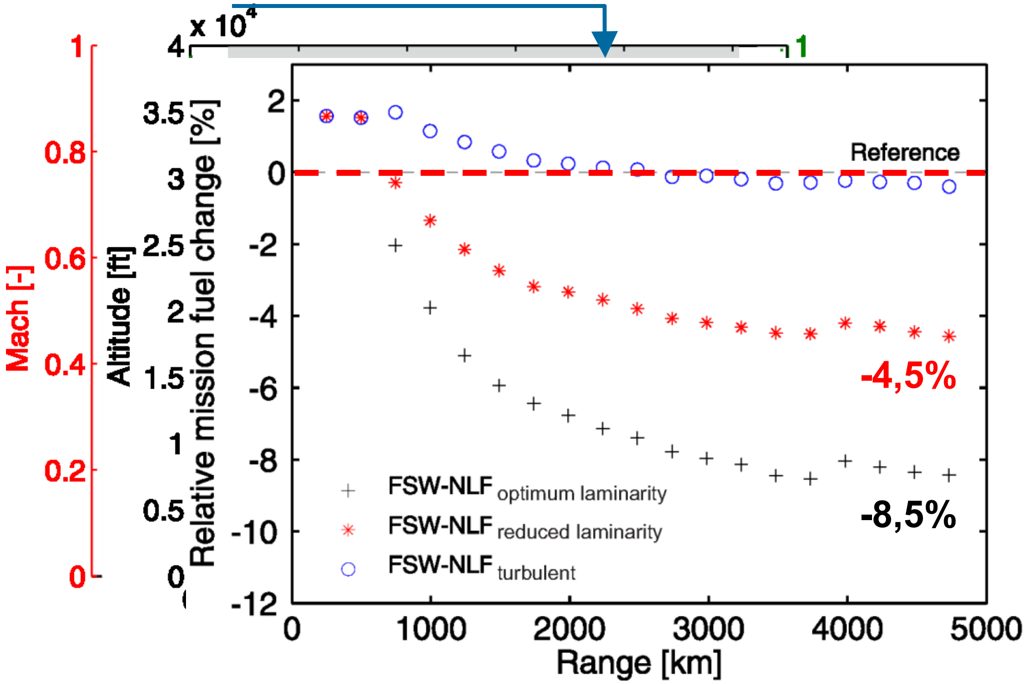
Mission fuel/ time

Laminar Flow Aircraft Technologies in Operation

Single Mission Operation Simulation



Variation Missionslänge

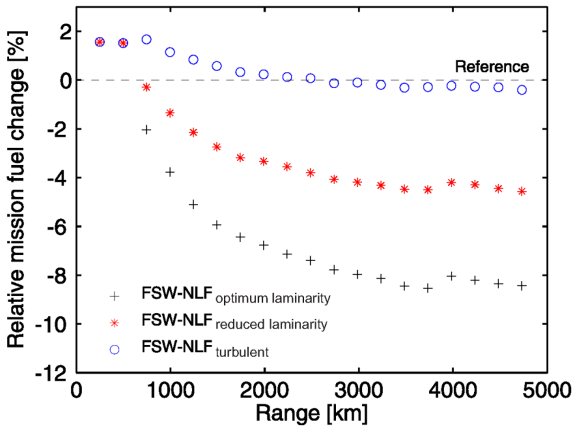


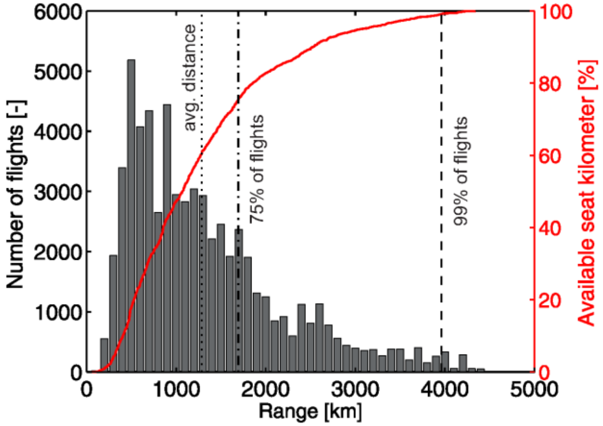
- Determination of mission fuel and time considering operational constraints and real aero and engine characteristics

  ⇨ Relative change of mission fuel requiered

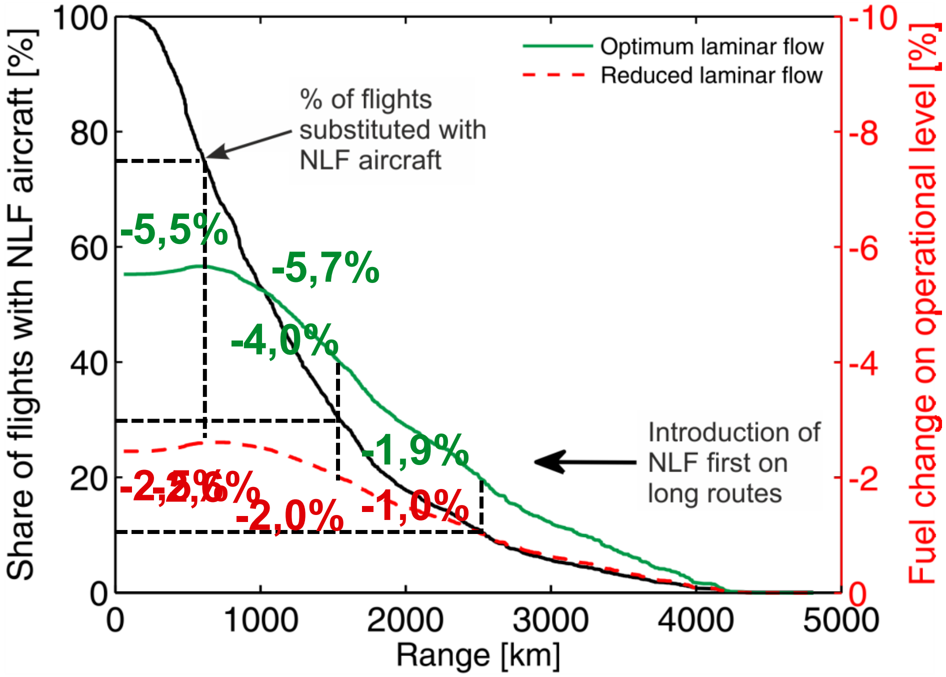
Laminar Flow Aircraft Technologies in Operation

Single Mission Operation vs. Fleet Operation





Fuel saving on operational level



Laminar Flow Aircraft Technologies in Operation

Network Simulation and Analysis

- Netzwerk-Benefit durch Einführung eines NLF Flugzeugs in ein europäisches Routennetz
- Beide Flugzeuge in einem Netz betrieben

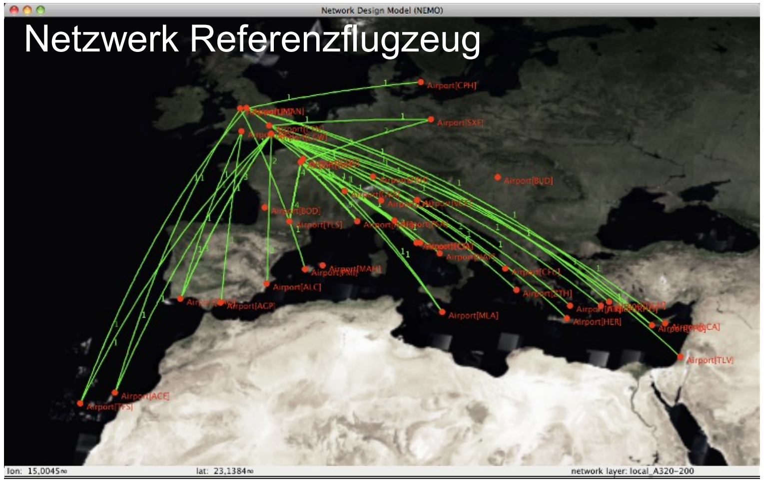
Untersuchung des Einflusses:

- Ø-Laminarität
- Turn-Around-Zeit
- Kraftstoffpreis

auf

- Anteil an angebotenen Sitz-km
- Flottenzusammensetzung
- Änderung Kraftstoffbedarf im Netz
- Airline Profit
- Break-even Sitzladefaktor

Einfluss der Laminarität auf Einsatz im Netz



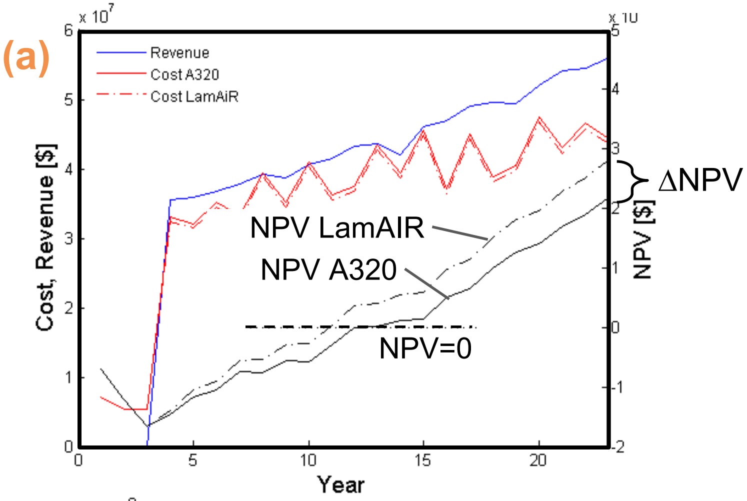
Braun et al.: Analysis of NLF Aircraft based on Airline Network Design and Fleet Assignment, AIAA-2011-6807

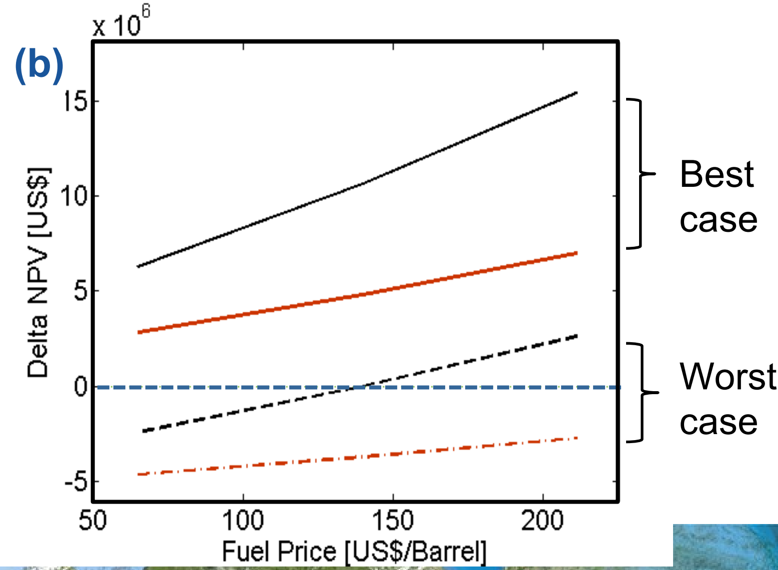
Laminar Flow Aircraft Technologies in Operation

Life Cycle Cost Analysis

- Airline Life Cycle Cost-Benefit Model **AirTOBS**
- Modeling all cost, revenues, and utilization of aircraft operations
- Superior to standard DOC-methods
- **(a)** Cash flow results
  - Main assumptions:

    Fuel price at 80 $/barrel, same aircraft list price and maintenance cost.
- **(b)** Fuel price variation for ΔNPV
  - For design range and representative range distribution
  - Assumptions:
    - *Best case*: +20$/FC maint.; same A/C list price
    - *Worst case*: +500$/FC maint.; +5% A/C list price





Summary

Value of holistic research on disciplinary technologies

- More realism and reliable results by covering all main interfering effects
- Collaboration in interdisciplinary teams is a research field itself
- Look carefully to global developments as an air transport designer to discover the real needs
- Mobility is more important than capacity and movements in a “green transportation system”
- Paradigm shift from quantitative to qualitative growth
- Blended Wing Body is a potential solution for future green air mobility

➔ **Design requirements** and **solutions**
for aircraft and operations

Location

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