Aero

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AIRCRAFT DESIGN AND SYSTEMS GROUP (AERO)

The Future of Aviation

(as seen from the results of AERO)

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Mercedes me Store Hamburg, Ballindamm 17

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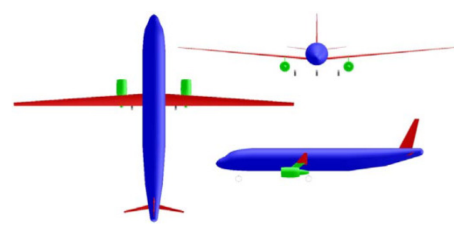

Motivation for this Presentation

o My research interest in **aircraft design**

o Aircraft are the **only means** of transportation to connect people **between continents**
o Aircraft are the **only feasible means** of transportation in areas with **underdeveloped infrastructure of roads and rails**
o Aircraft are the **fastest means** of transportation for other **long distance connections**

o Aircraft **do not need infrastructure** between airports (besides ATC)
o But: Aircraft have **fundamentally twice the drag** compared to surface transport,
o But: Aircraft do well in comparison due to their **lightweight and efficient design**

o Aircraft face the **challenge**
to **safe fossil fuels**, to **limit pollution**
to get operated with **regenerative fuels** (drop in fuel or hydrogen)

=> A task for **aircraft design** to find **promising configurations** and to **integrate new technologies**

Content [1]

Aviation History – Further / Faster / Higher → Economic

Aviation Law – Unlimited Freedom?

Aviation Growth – Uncontrolled & Booming?

Aviation Off-Course? – Eco-Efficiency / Sustainability

Introduction to Aircraft Design

Blended Wing Body (BWB)

Box Wing Aircraft (BWA)

Smart Turboprop

"The Rebel"

Hydrogen Powered Aircraft

Outlook: Synthetic Fuel --- Drop-in Fuel

Overall Conclusions

[1] The content of this lecture at the „Mercedes me Store Hamburg" takes care of participants in the lecture without any prior knowledge of aviation.

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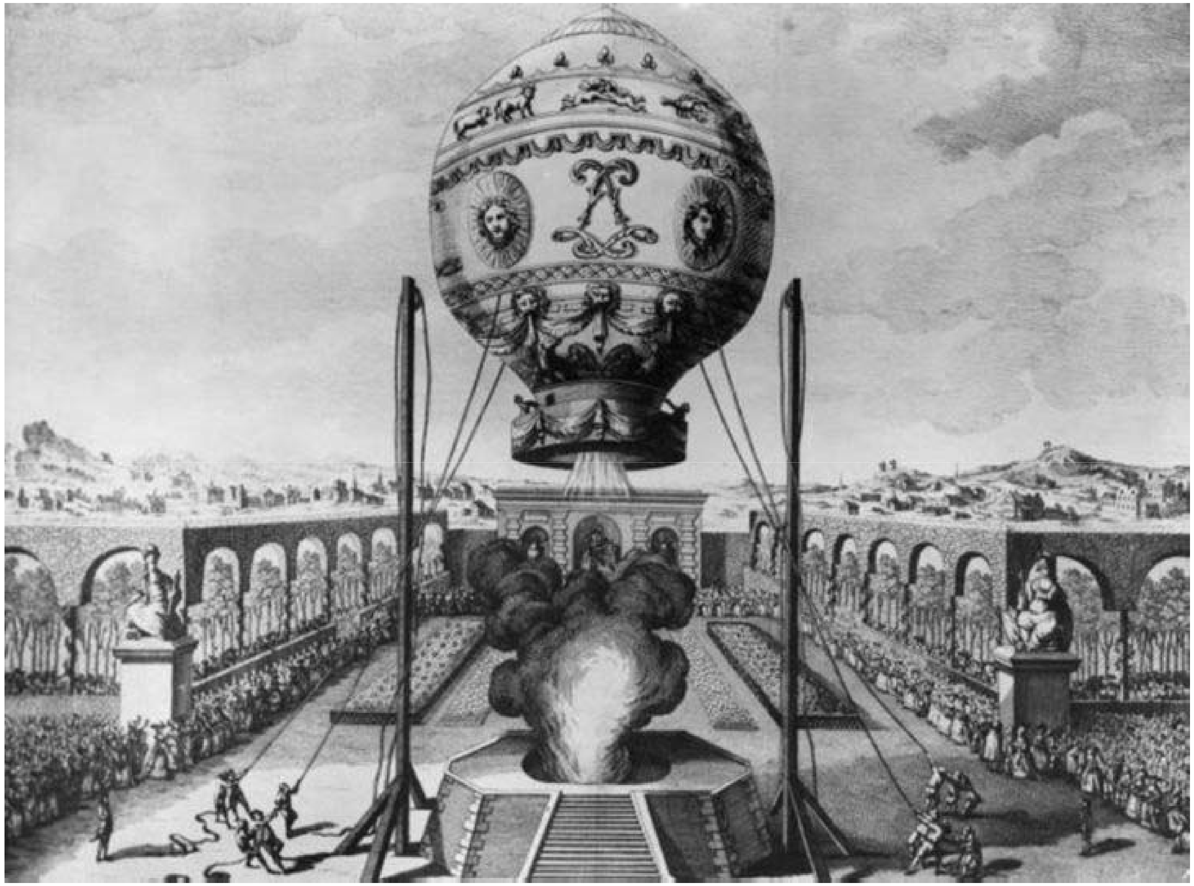
Montgolfière is the name of the hot air balloon (flight principle „lighter than air“), named after the French inventor **Joseph Michel a**nd **Jacques Etienne Montgolfier**.

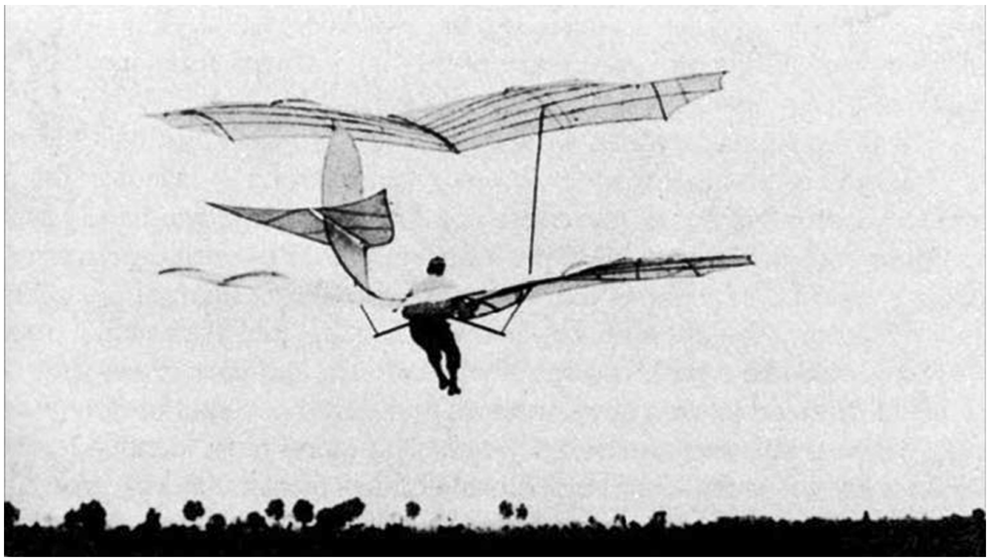
On 21. November 1783
take-off in the garden of castle
La Muette near Paris.
Jean-François Pilâtre de Rozier
and
François d’Arlandes
undertake the first free air balloon
flight in human history.



Karl Wilhelm **Otto Lilienthal**
*23. May 1848 in Anklam; † 10. August 1896 in Berlin

He was probably the first human
to successfully achieve repeated gliding flights.
Lilienthal helped as such the
flight principle „heavier than air“ to succeed.

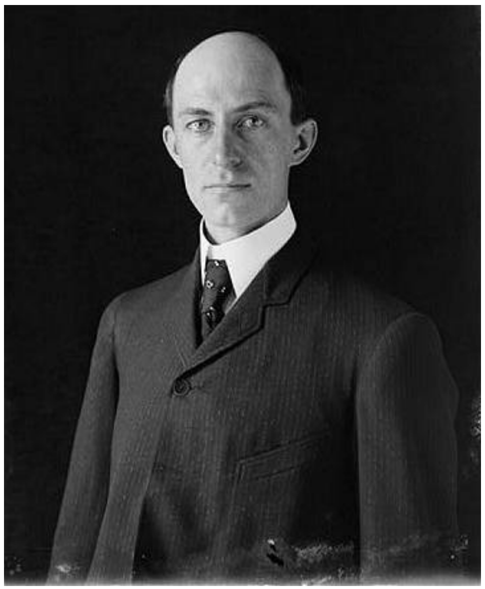
Initial experimental studies started in 1891.

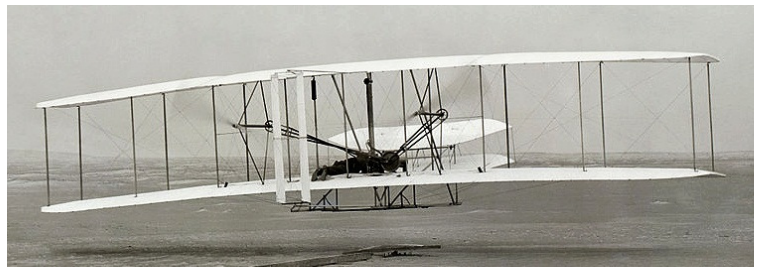


The Wright brothers,
Wilbur Wright (* 16. April 1867 in Millville, Indiana; † 30. May 1912 in Dayton, Ohio) and
Orville Wright (* 19. August 1871 in Dayton; † 30. Januar 1948 in Dayton)
US-american aviation pioneers,
achieved in the beginning of the 20th century flights with gliders and went to
controlled flights of an aircraft powered by an engine.

The flight from 17. December 1903, is (according to Orville) the first time in history,
for „a machine with a human on board to get airborne into free flight by its own force,
to fly on a horizontal path, and to land without being destroyed".

Although not the first to build and fly experimental aircraft, the Wright brothers were the first
to invent aircraft controls that made fixed-wing powered flight possible.





Wilbur (links) und Orville Wright

Gustav Albin **Weißkopf**
*1. Januar 1874 in Leutershausen, Bavaria; † 10. October 1927 in Bridgeport (Connecticut), USA
was a German-American pioneer of powered flights. In the USA he named himself Gustave Whitehead.
He is said to have undertaken a first powered flight already in 1899.
Several newspapers report a powered flight on 14th August 1901 with an aircraft he called No 21
The flight reached a hight of 50 feet and covered a distance of 1/2 mile.

Karl Jatho
*3. February 1873 in Hannover; † 8. December 1933 in Hannover
was a German public official and aviation pioneer.
He is said to be the first human
to undertake a powered flight.
„On 18. August 1903 the first jump in
calm weather. Length 18 m at a hight of 0.75 m."

Karl Jatho

Gustav Weißkopf

Charles Augustus **Lindbergh**, jr.
*4. Februar 1902 in Detroit, Michigan; † 26. August 1974 in Kipahulu, Maui,Hawaii
was a US-american pilot.

He achieved from 20. to 21. May 1927 a non-stop flight from New York to Paris.
This was the first solo crossing of the Atlantic.

This flight made Lindbergh to one of the most known persons in aviation history.

The first non-stop Atlantic crossing from America to Europa with an aircraft was achieved already in Juni 1919 by **John Alcock** and **Arthur Whitten Brown**.
The flight was done from St. Johns / Newfoundland to Irland.

The first nons-top Atlantic crossing from the European mainland to (North-)America was achieved by Ehrenfried Günther **Freiherr von Hünefeld**, **Hermann Köhl**, and **James Fitzmaurice** in 1928.

First in Flight ?

Kitty Hawk is a small village in the US-American state North Carolina, known for "the first powered flights in history" made by the Wright brothers. --- Really?

https://de.wikipedia.org/wiki/Kitty_Hawk

Chicago Convention (1944)

- today 187 member states have signed the convention
- **International Civil Aviation Organisation (ICAO)** established
- today 18 annexes to Chicago Convention (e.g.):

  Annex 2: Rules of the Air
  Annex 6: Operation of Aircraft
  Annex 8: Airworthiness of Aircraft
  Annex 11: Air Traffic Services
  Annex 14: Aerodromes
  Annex 16: Aircraft Noise
  Annex 17: Security

- 5 "freedoms of the air" defined (later extended to 8)

European Aviation Organisations

- European Civil Aviation Conference (ECAC)
- Association of European Airlines (AEA)
- European Regional Airlines Association (ERA)
- Eurocontrol
  - route charges
  - Air Traffic Flow Management, ATFM
- European Aviation Safety Agency (EASA)

  The agency will assist EU legislators in the development of common rules for
  - the certification of aeronautical products and parts
  - the approval of maintenance organizations and air operations
  - the licensing of air crew and the safety oversight of airports and air traffic services
- European Association of Aerospace Industries (AECMA)

German Aviation Organisations – Organe der deutschen Luftverwaltung

Bundesministerium
für Verkehr und
digitale Infrastruktur

Abteilung *Luftfahrt*

- Luftfahrt-Bundesamt (LBA)
  - Verkehrszulassung von Luftfahrzeugen
  - Erteilung von Erlaubnissen an luftfahrttechnisches Pesonal
  - Überwachung von Luftfahrtunternehmen
  - Musterprüfung von Luftfahrtgerät (zusammen mit JAA)
- Bundesstelle für Flugunfalluntersuchung (BFU)
- Deutscher Wetterdienst (DWD)

Organe der deutschen Luftverwaltung (Fortsetzung)

- Deutsche Flugsicherung GmbH (DFS)
  - Flugverkehrskontrolle (**Air Traffic Control, ATC**)
  - Verkehrsflußregelung (Air Traffic Flow Management, ATFM)
  - Luftraummanagement (Airspace Management, ASM)
  - Flugberatung (Aeronautical Information Service, AIS)
  - Fluginformationsdienst (Flight Information Service, FIS)
  - Flugalarmdienst zur Benachrichtigung der Such- und Rettungsdienste (SAR)
  - Flugfernmeldedienst
  - Herausgabe von Veröffentlichungen:
    - Nachrichten für Luftfahrer (NfL)
    - Notice to Airmen (NOTAM)
    - Aeronautical Information Publication (AIP):

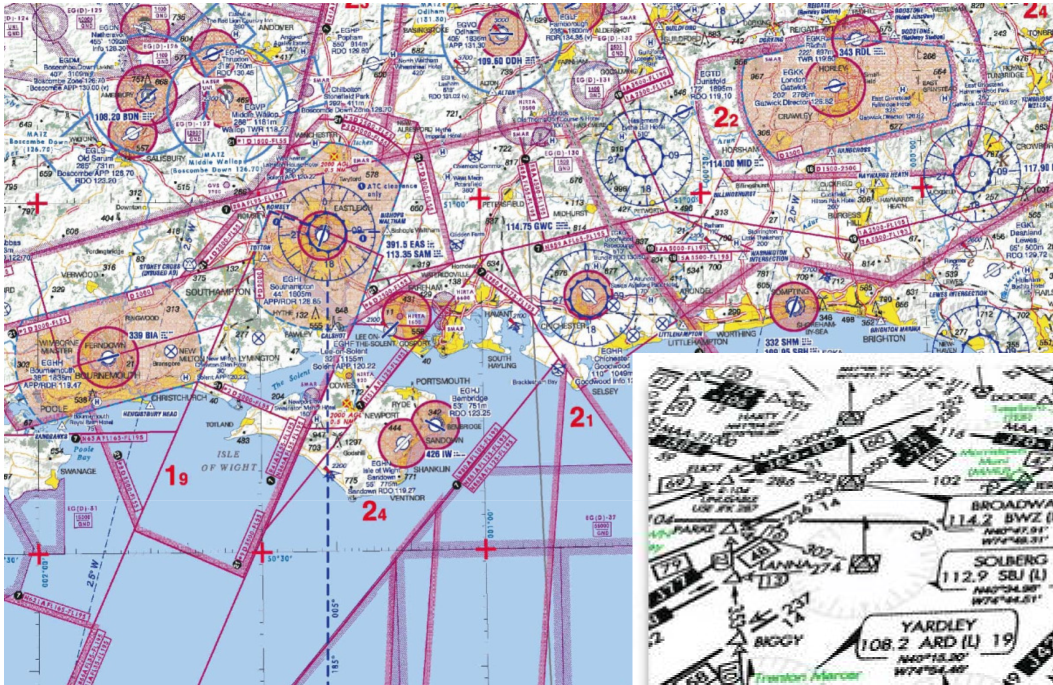
      Band I: GEN, AGA, COM, MET, RAC, FAL, SAR

      Band II: IFR-Karten ENROUTE und TERMINAL (SID und STAR)

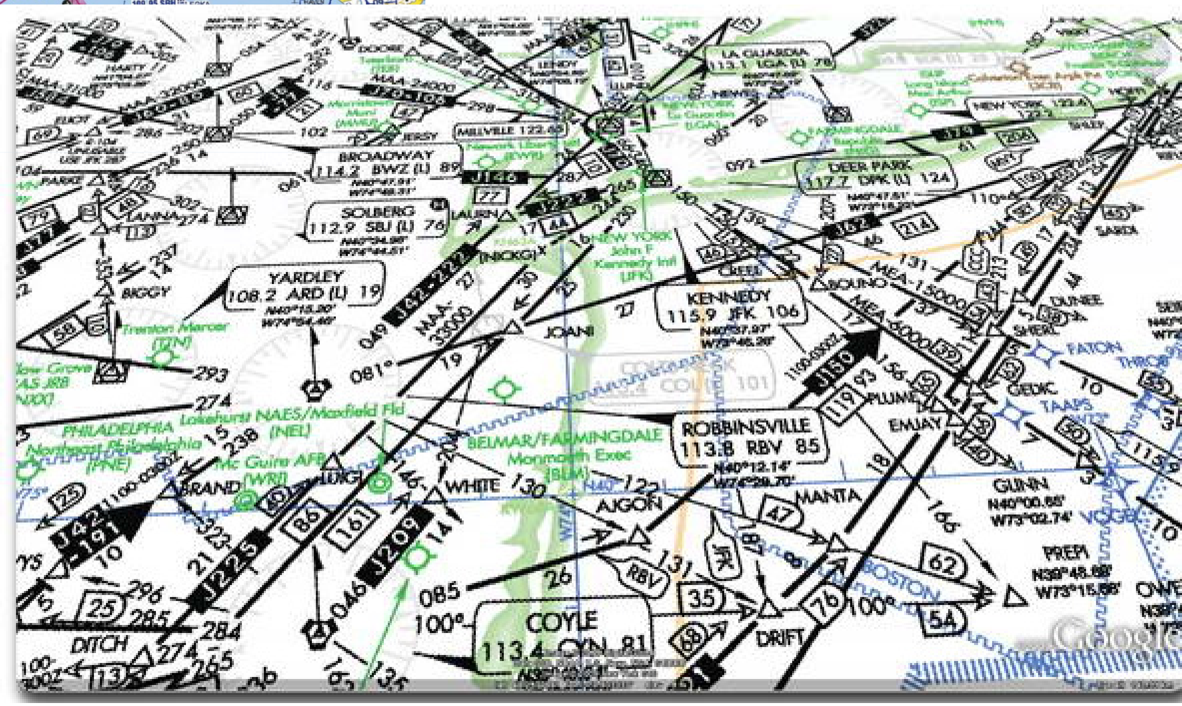
      Band III: VFR-Informationen (GEN, COM MET RAC) und Flugplätze

DFS Deutsche Flugsicherung

Air Space

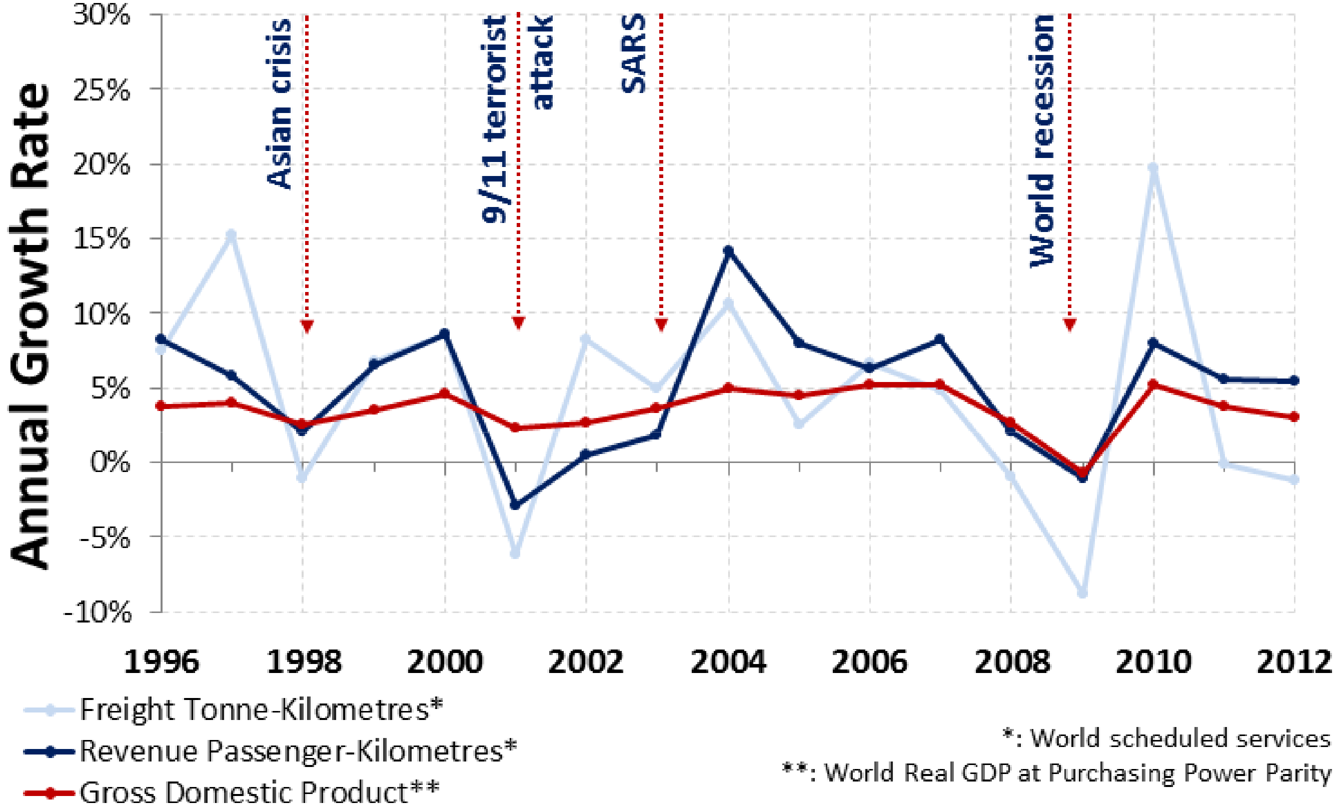


Visual Flight Rules
VFR Map



Instrument Flight Rules
IFR Map

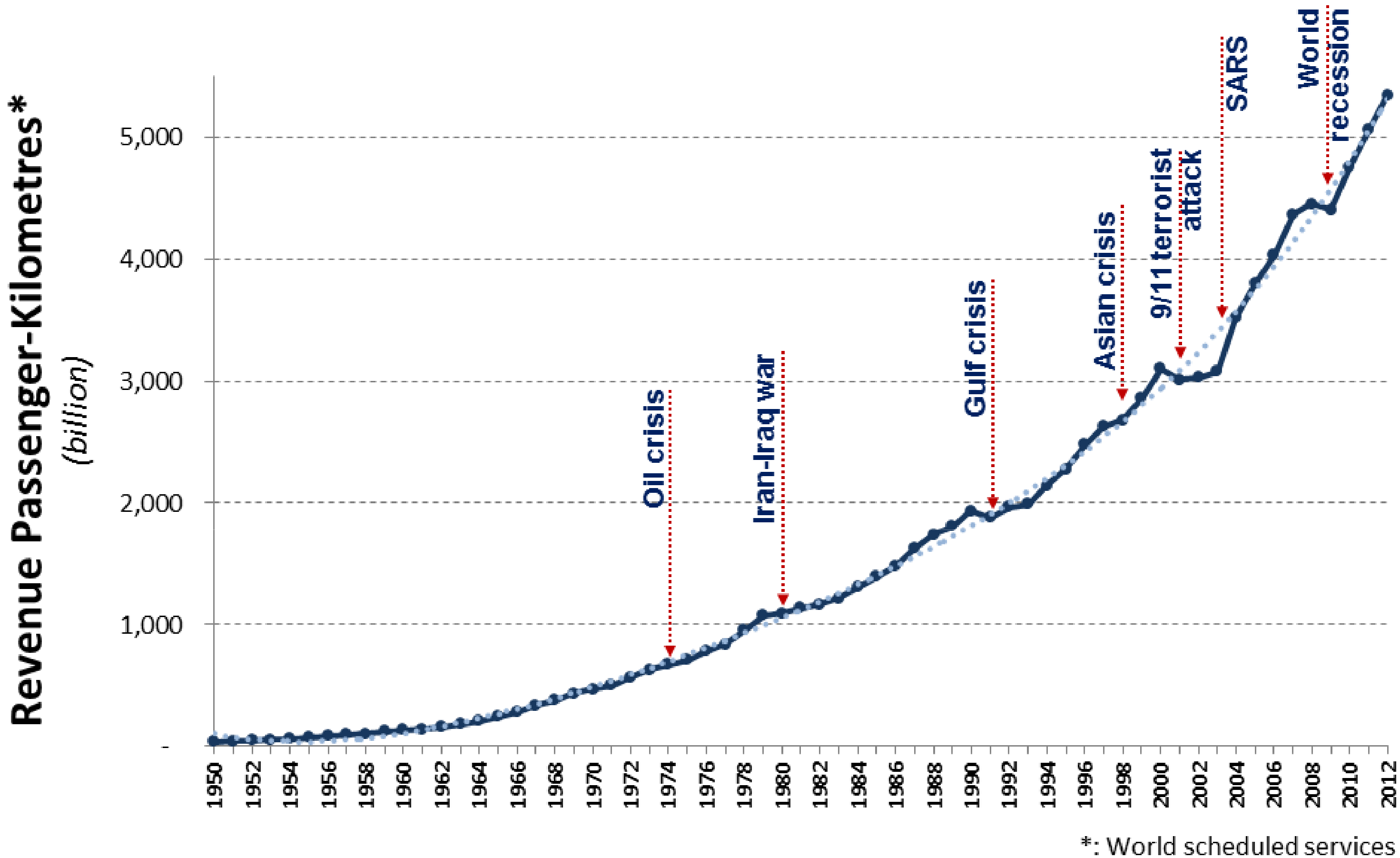
World economic growth *vs.* air traffic growth (passenger and freight)



*: World scheduled services
**: World Real GDP at Purchasing Power Parity

http://www.icao.int/sustainability/Pages/Facts-Figures_WorldEconomyData.aspx

The world aviation - 1950 to 2012



http://www.icao.int/sustainability/Pages/Facts-Figures_WorldEconomyData.aspx


19. Jahrgang
01|12
ZIRKULAR
Ausgabe 01, 31. Januar 2012, 19. Jahrgang
Die Ökoeffizienz des Luftverkehrs

some
have
a different
view …

Definition: **Eco-efficiency** (Ökoeffizienz)

Eco-efficiency is based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution.

World Business Council for Sustainable Development (WBCSD): "Changing Course", 1992

The term has become synonymous with a management philosophy geared towards *sustainability*.

The **eco-efficiency strategy** has the following characteristics:

- Technological innovation the main solution
- Business as the principal actor of transformation
- Trust in markets (if they are functioning well)
- "cradle-to-cradle" (essentially waste free) growth is conducive.

Boulanger, P.M. (2010) "Three strategies for sustainable consumption". S.A.P.I.EN.S. 3 (2)

Definition: **Sustainability** (Nachhaltigkeit)

A sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

United Nations General Assembly: "Report of the World Commission on Environment and Development: Our Common Future; Transmitted to the General Assembly as an Annex to document A/42/427 – Development and International Co-operation: Environment; Our Common Future, Chapter 2: Towards Sustainable Development; Paragraph 1". March 20, 1987. - http://www.un-documents.net/ocf-02.htm

Since the 1980s sustainability has been used especially in the sense of human sustainability on planet earth.

Efficiency Gain - No Sustainability

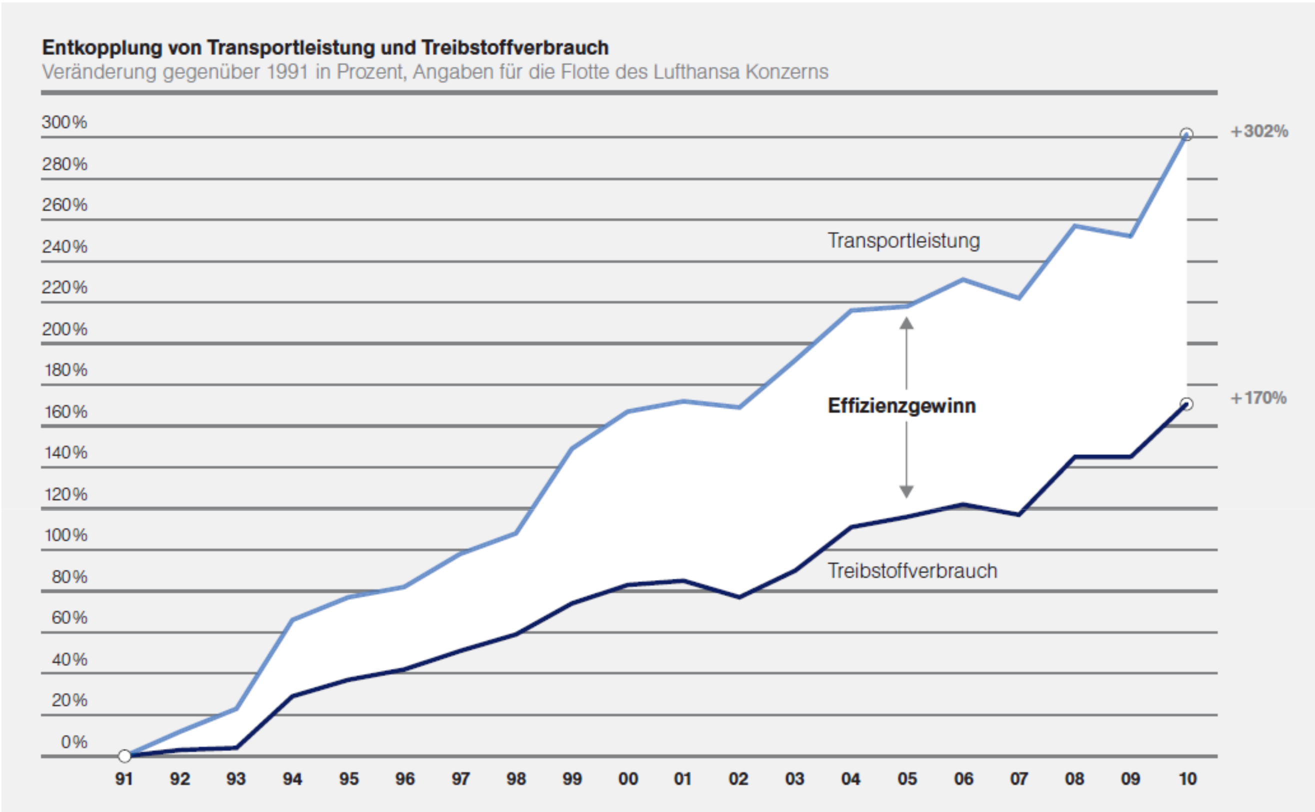


Fig.: Growth of Transport Capacity and Fuel Consumption at Lufthansa

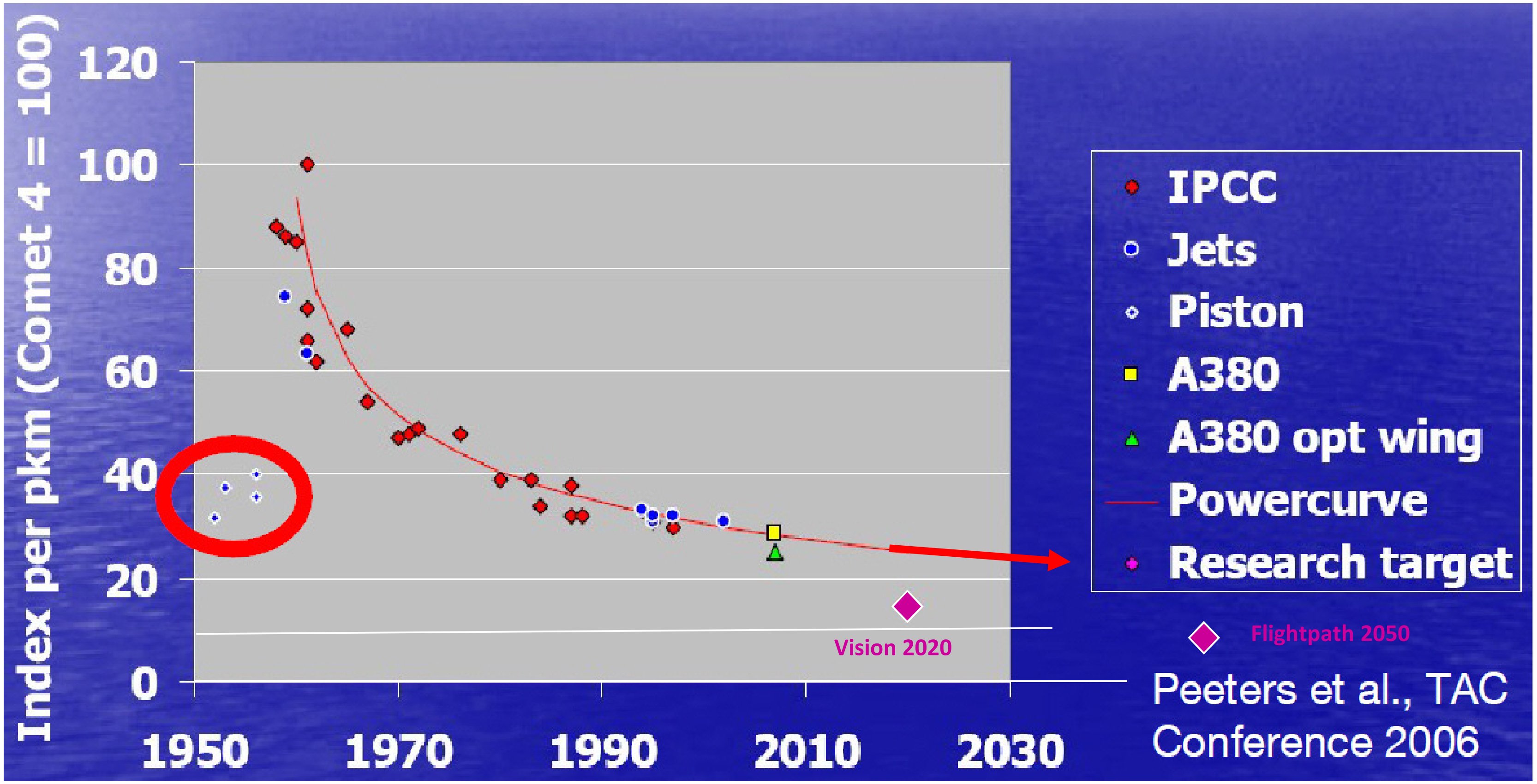
Lufthansa: Balance – Das wichtigste zum Thema Nachhaltigkeit im Lufthansakonzert. 2011

Summary of Goals for the Reduction of Fuel Burn or CO2

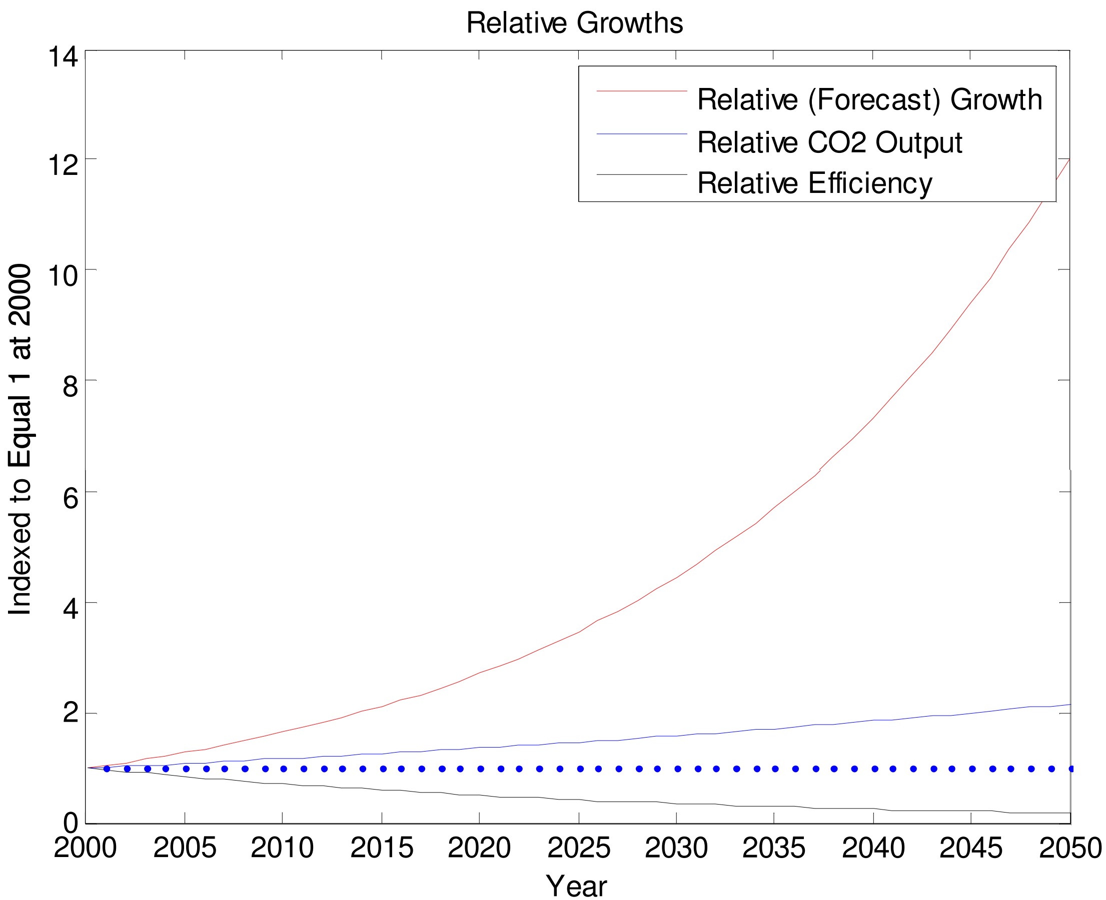
organization	goal	from	to	per year	level	source
ACARE	50,0%	2000	2020	2,05%	A/C	ACARE: *Vision 2020*. Luxembourg, EU, 2001 (deleted from www)
ACARE	75,0%	2000	2050	1,13%	A/C	ACARE: *Flightpath 2050*. Luxembourg, EU, 2011
ATAG	19,6%	2008	2020	1,50%	A/C	ATAG: *Towards sustainable Aviation. Summit Declaration*. Geneva, ATAG, 2012
ATAG/Airbus	0,0%	2020			fleet	ATAG: *Towards sustainable Aviation. Summit Declaration*. Geneva, ATAG, 2012
ATAG/Airbus	50,0%	2020	2050	1,36%	fleet	ATAG: *Towards sustainable Aviation. Summit Declaration*. Geneva, ATAG, 2012
IATA	zero emmission	2007	2050	1,63%	fleet	Bisignani, Vancouver, 2007. - www.iata.org (2012-09-10) (not valid anymore)
IATA	build A/C zero emission	---	2062	---	---	www.iata.org (2012-09-10)
IATA	25,0%	2005	2020	1,50%	fleet	www.iata.org (2012-09-10)
historic data	70,0%	1960	2010	1,07%		www.atag.org (2012-09-10)

- Goals are quite diverse
- Goals have been withdrawn over the years (ACARE, IATA)
- Some goals are not well defined
- Some goals may not be reached …

Fuel Efficiency Improvements of Transport Aircraft Compared with ACARE Goals



Working with Growth and Fuel Efficiency Increases: Exponential Growth



Example

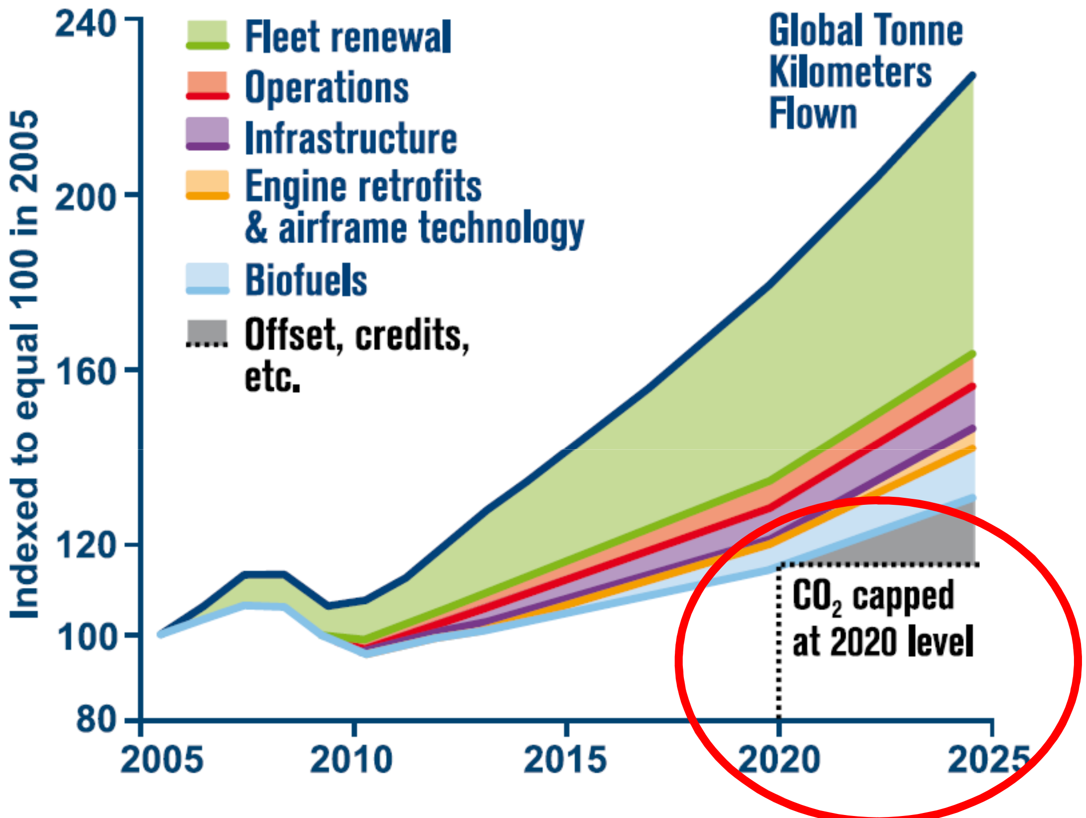
5,1 % Growth (p.a.)

3,6 % Effciency Increase (p.a.)

Resulting in:

1,5 % Net Growth (p.a.)

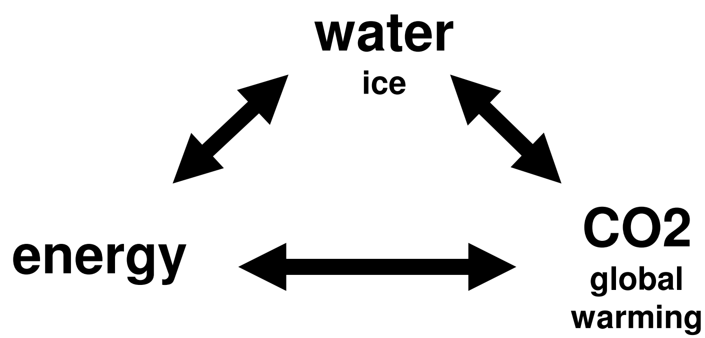
Making up for what is Missing: Introducing Compensation Schemes



There is no real reason to start with compensation in 2020. Compensation could as well start today. If the level of CO2 concentration in the atmosphere is not considered high enough jet, it may not warrant to start with compensation now.

IATA (and ATAG) want to achieve zero emission growth from 2020 onwards. This is only possible with carbon offset schemes.

We have not One but Three Issues!



E => CO2 :	Burning Energy produces CO2
CO2 => E :	Splitting CO2 gives kerosene (some day): Sun-to-Liquid (STL) or Power-to-Liquid (PTL)
E => W:	Sea water is converted to drinking water with help of energy
W => E:	Water is needed for BTL (exception: algae)
CO2 => W:	global worming means melting of glaciers the drinking water storage
W => CO2:	melting of glaciers and polar caps means more global worming

So what is of importance?

1.) **water**
2.) **energy**
3.) **CO2**

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Outlook: Synthetic Fuel --- Drop-in Fuel

Overall Conclusions

Introduction to Aircraft Design

- o Passenger aircraft carry **passenger** with their **baggage** and often additional **cargo**
- o Passenger, baggage and cargo are called **payload** because they generate revenue for the airline operating the aircraft for **profit**
- o The **payload** is carried over a certain distance. The aircraft allows a certain **range**

- o An aircraft consists of major components. For a **conventional aircraft** these components are: one **fuselage**, one **wing**, a horizontal tail and a vertical tail
- o Horizontal tail and vertical tail are together called **empennage** and are located **aft**
- oThis configuration is called **tail aft**

- o An **unconventional configuration deviates** in one or more aspects **from** the **definition of the conventional configuration**

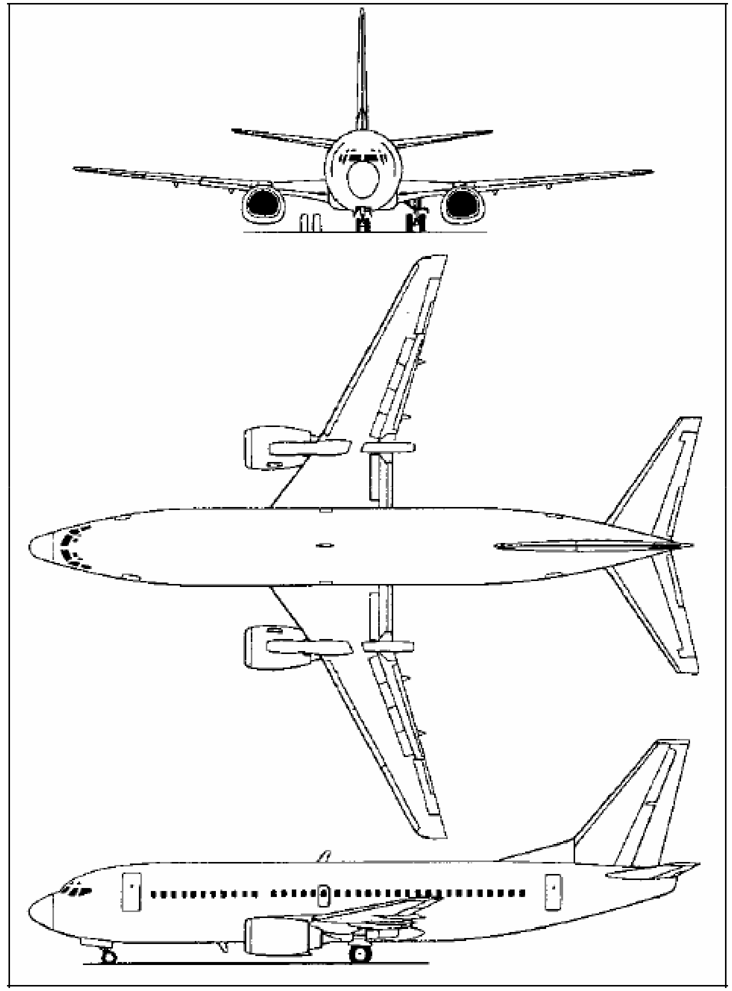
- o A **promising configuration for future passenger aircraft** is
  - a conventional or unconventional **configuration** combining major aircraft components
  - **integrating** also the effects of **new technologies** from other aeronautical disciplines
  - such that **operating costs** are **reduced** by also
  - **reducing fuel burn** considerably **and** hence **pollution**

Conventional Aircraft Configurations

o The dominant configuration is the
  conventional configuration
  (**fuselage**, **wing**, **tail aft**) with
  - **low wing**
  - **engines** in nacelles **under the wing**

o **Configuration** has **evolved / optimized during decades** of
  - aircraft design
  - production
  - operation

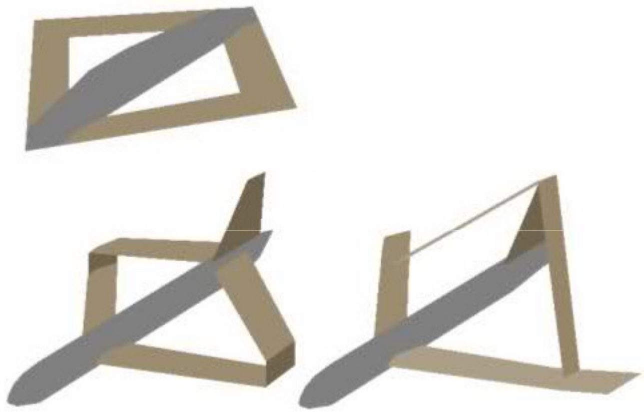
  with the objective **to reduce operating cost:**
  - **depreciation** (of aircraft price)
  - interest
  - insurance costs
  - **fuel** costs
  - **maintenance** costs
  - **crew costs** (cockpit crew, cabin crew)
  - **fees** (landing fees,
    navigation charges, ground handling costs)

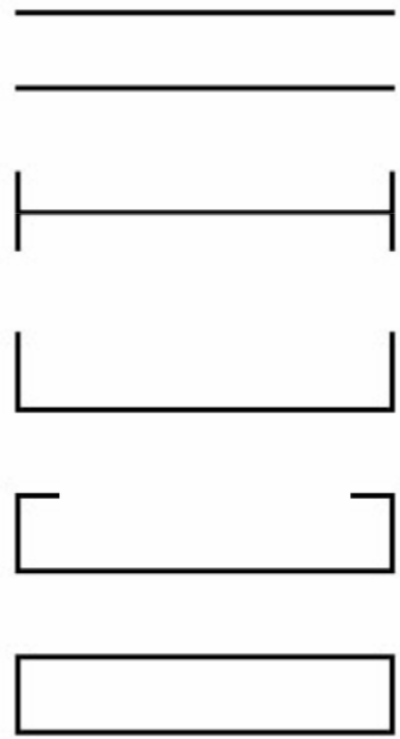


Example: Boeing 737-300

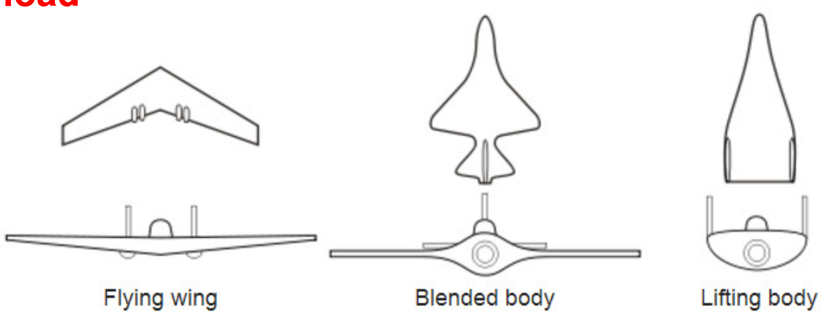
Systematic of Configurations (Hierarchy)

- o **Generation of lift and trim**
  - **single surface**
  - **system of surfaces**
    - # separated surfaces: **canard** + wing, **tandem wing**, wing + tail, canard + wing + tail (**three surface**)
    - # joint surfaces
      - § planar surfaces
      - § nonplanar surfaces
        - => winglets
        - => C-wing
        - => box wing
        - => biplane
  - **fuselage (body)**





- o **Accommodation of payload**
  - **fuselage**
    - # single
    - # twin or triple
  - **fuselage + wing**
  - **wing**



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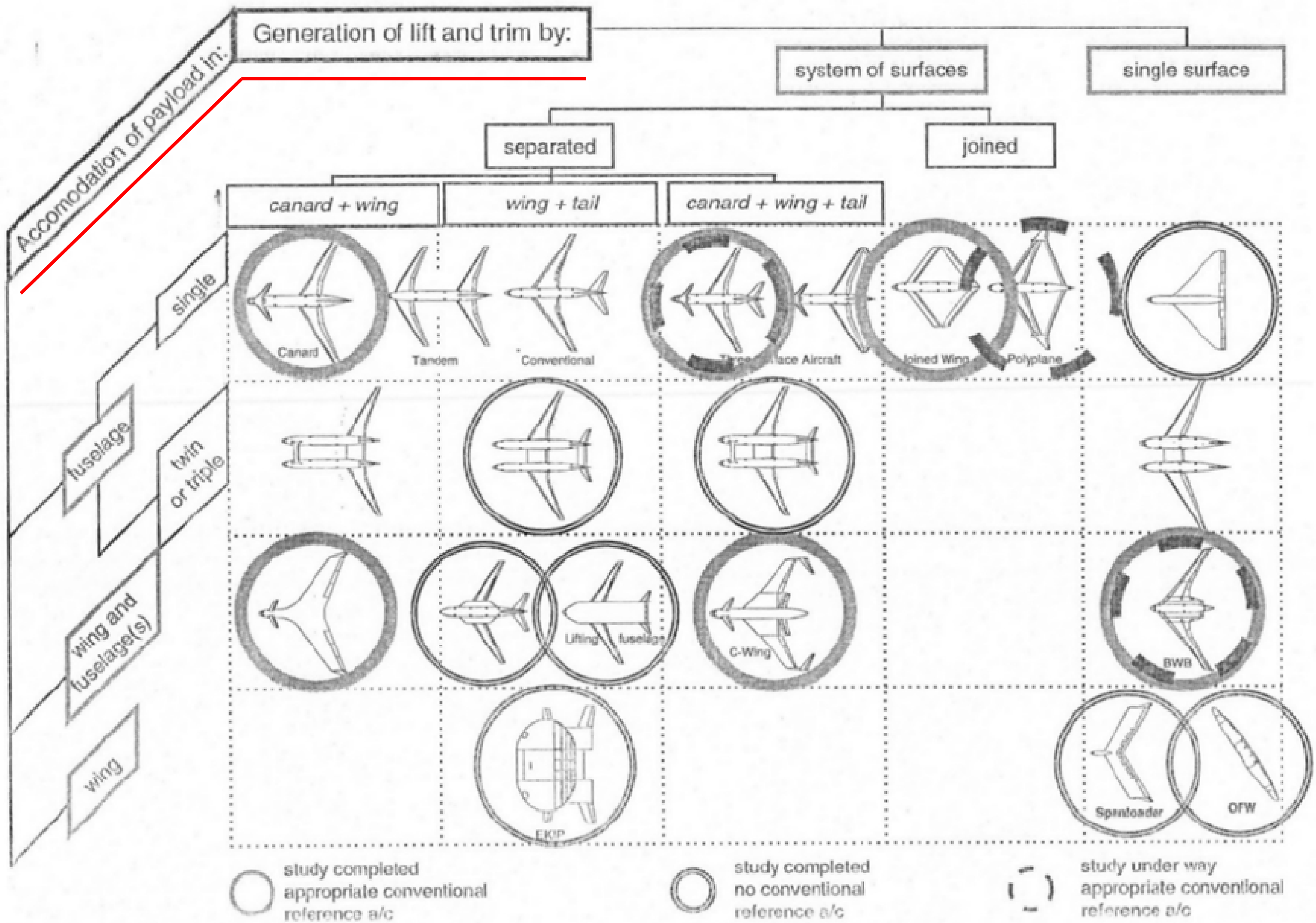
Systematic of Configurations (Matrix)



Source: Airbus 2006

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Selection of Configurations for Discussion

o There are (too) many

- **configurations**
- combinations of configurations
- combinations of configurations with **technologies** from other (aeronautical disciplines):
  # **aerodynamics**
  # **lightweight structures, material scie**nce
  # **engines**
  # **systems**

o There is **not just one** promising aircraft configuration for future passenger aircraft

o **Depending on payload and range requirements different configurations can be proposed**

Selection:

o Blended Wing Body (BWB)

o Box Wing Aircraft (BWA)

o Smart Turboprop

o „The Rebel“

o Hydrogen Powered Aircraft

Blended Wing Body (BWB)

Blended Wing Body (BWB) --- Definition

1) Conventional Configuration: "Tube and Wing" or "Tail Aft" (Drachenflugzeug)
2) Blended Wing Body (BWB)
3) Hybrid Flying Wing
4) Flying Wing

The Blended Wing Body aircraft is a blend of
the tail aft and the flying wing configurations:
A wide lift producing centre body housing the payload
blends into conventional outer wings.

Blended Wing Body (BWB) --- Square-Cube-Law

The BWB configuration is favoured for ultra large aircraft.

Why does physics demand a BWB?

Geometric Scaling: $V \propto l^3$ $\quad m \propto l^3$ $\quad m_{MTO} \propto l^3$

$$S_W \propto l^2$$

Landing Field Length and Approach Speed is limited:

$$\Rightarrow \frac{m_{MTO}}{S_W} = const \;\wedge\; m_{MTO} \propto l^3 \;\Rightarrow\; S_W \propto l^3$$

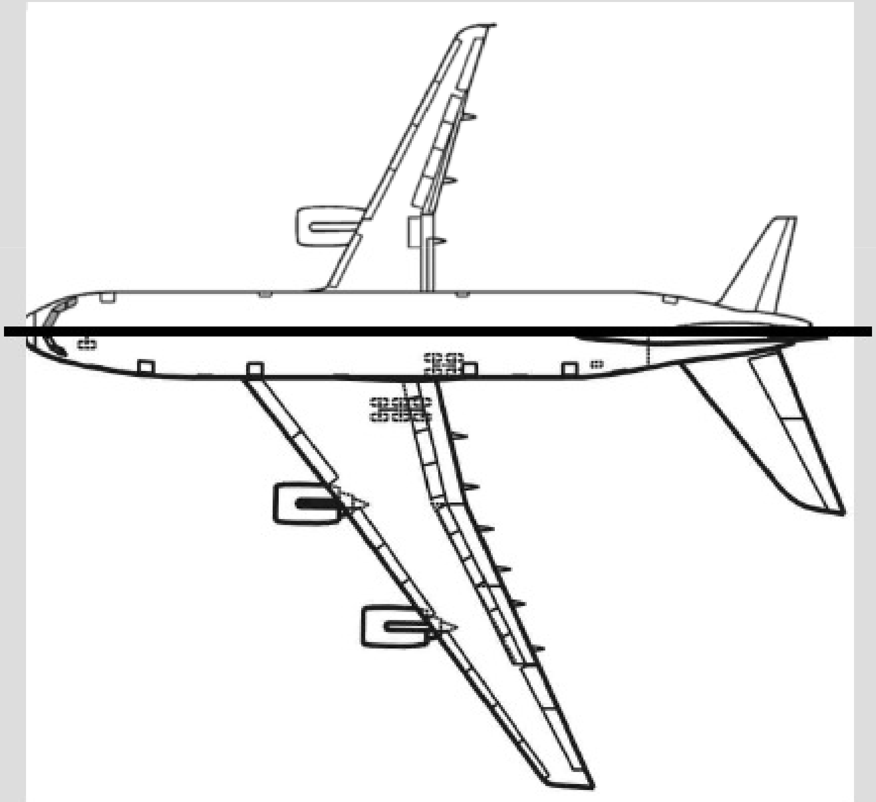
Square-Cube-Law

Blended Wing Body (BWB) --- Square-Cube-Law

The BWB configuration is favoured for ultra large aircraft.

Why does physics demand a BWB?

$$\boxed{S_W \propto l^3}$$



A321 scaled to the same size as the A380.

A321: $$\frac{m_{MTO}}{S_W} = 727\ \mathrm{kg/m^2}$$

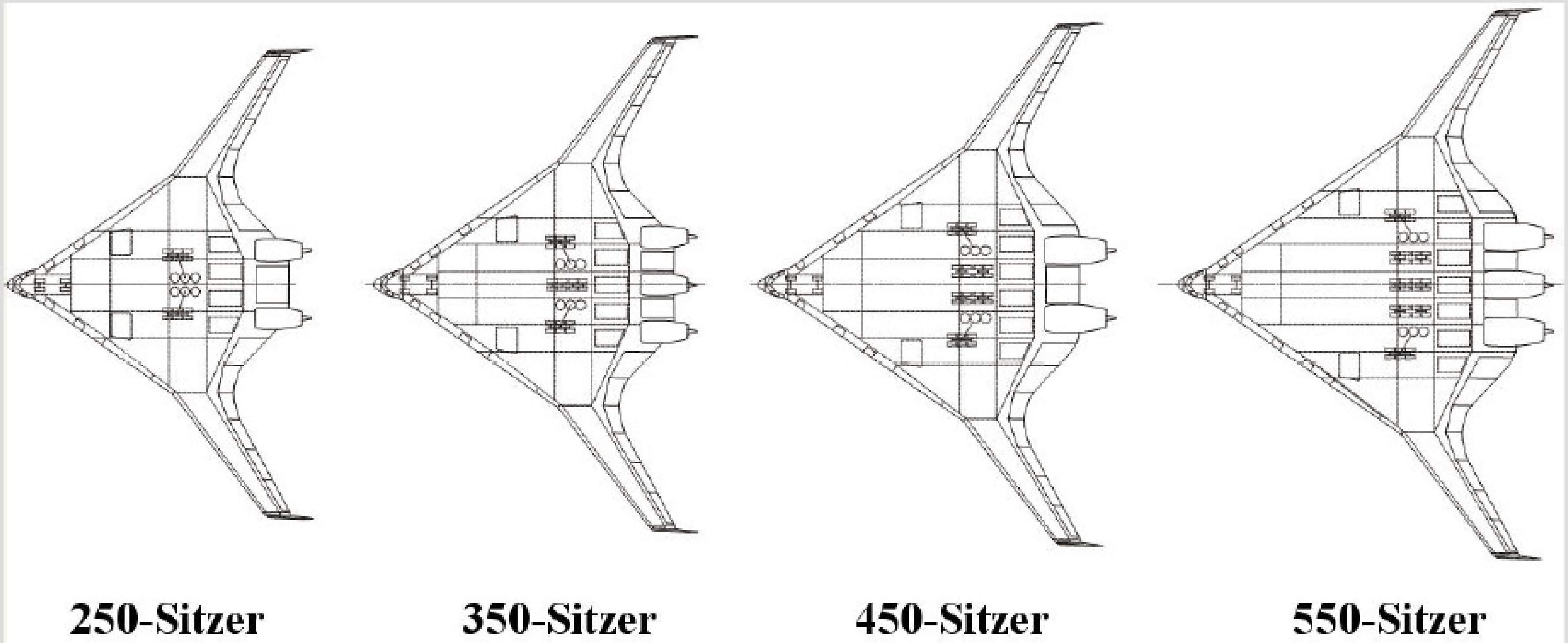
A380-800F: $$\frac{m_{MTO}}{S_W} = 698\ \mathrm{kg/m^2}$$

Aircraft even bigger => BWB

Blended Wing Body (BWB) --- Aircraft Family

Boeing BWB-250 ... BWB-550

F. Bansa, Diplomarbeit, Hamburg University of Applied Sciences



Boeing: study of BWB aircraft family
Today BWBs are not a topic anymore at Boeing for civil transport!

Blended Wing Body (BWB) --- Aerodynamics --- Max. Glide Ratio

Estimation of maximum glide ratio $E = L/D$ in normal cruise

A : aspect ratio
S_{wet} : wetted area
S_W : reference area of the wing
e : Oswald factor; passenger transports: e ≈ 0.85

$$E_{max} = k_E \sqrt{\frac{A}{S_{wet} / S_W}}$$

from statistics: $k_E = 15,8$

$$k_E = \frac{1}{2}\sqrt{\frac{\pi\, e}{\overline{c_f}}} = 14.9$$

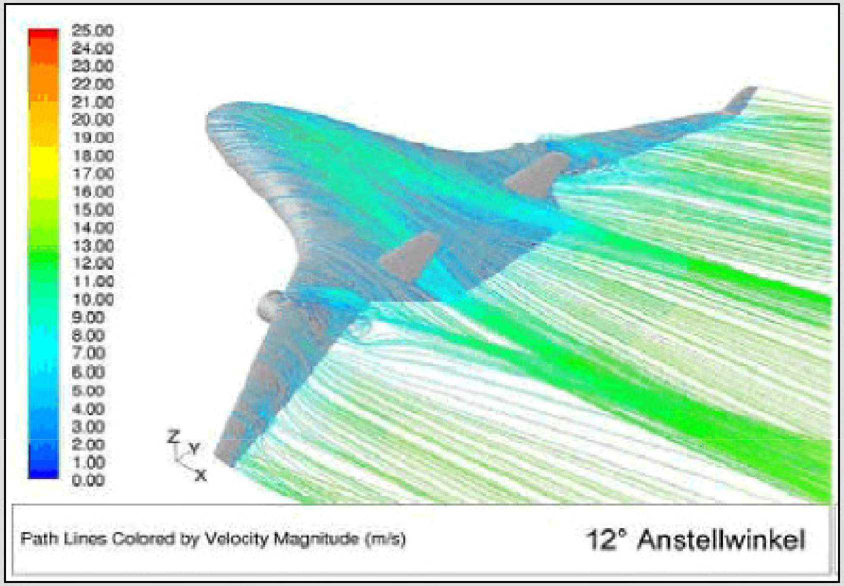
$$\overline{c_f} = 0.003$$

S_{wet} / S_W :	conv. aircraft	6.0 ... 6.2
	BWB	≈ 2.4
A :	conv. aircraft	7.0 ... 10.0
	VELA 2	5.2

$E_{max} = 23,2$

Blended Wing Body (BWB) --- Aerodynamics --- Stall Characteristics

AC20.30: CFD with FLUENT



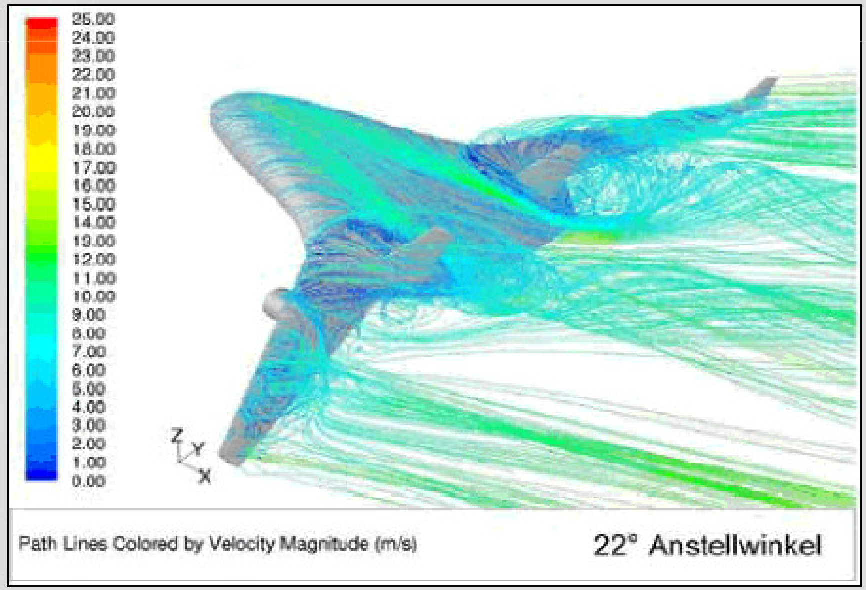
Stalls can easily be handled

Usable lift up to AOA of 12°

At 22° AOA:

- wings are stalled
- body continues to produce lift
- but control surfaces do not deliver control power

path lines



Blended Wing Body (BWB) --- No Certification with Transonic Airfoils

CERTIFICATION SPECIFICATIONS, CS-25.173 Static Longitudinal Stability:

(a) A pull must be required to obtain and maintain speeds below the specified trim speed, and a push must be required to obtain and maintain speeds above the specified trim speed.

hence for BWB:

A) Design to Requirements:

1.) Center of Gravity (CG) forward of Aerodynamic Center (AC).

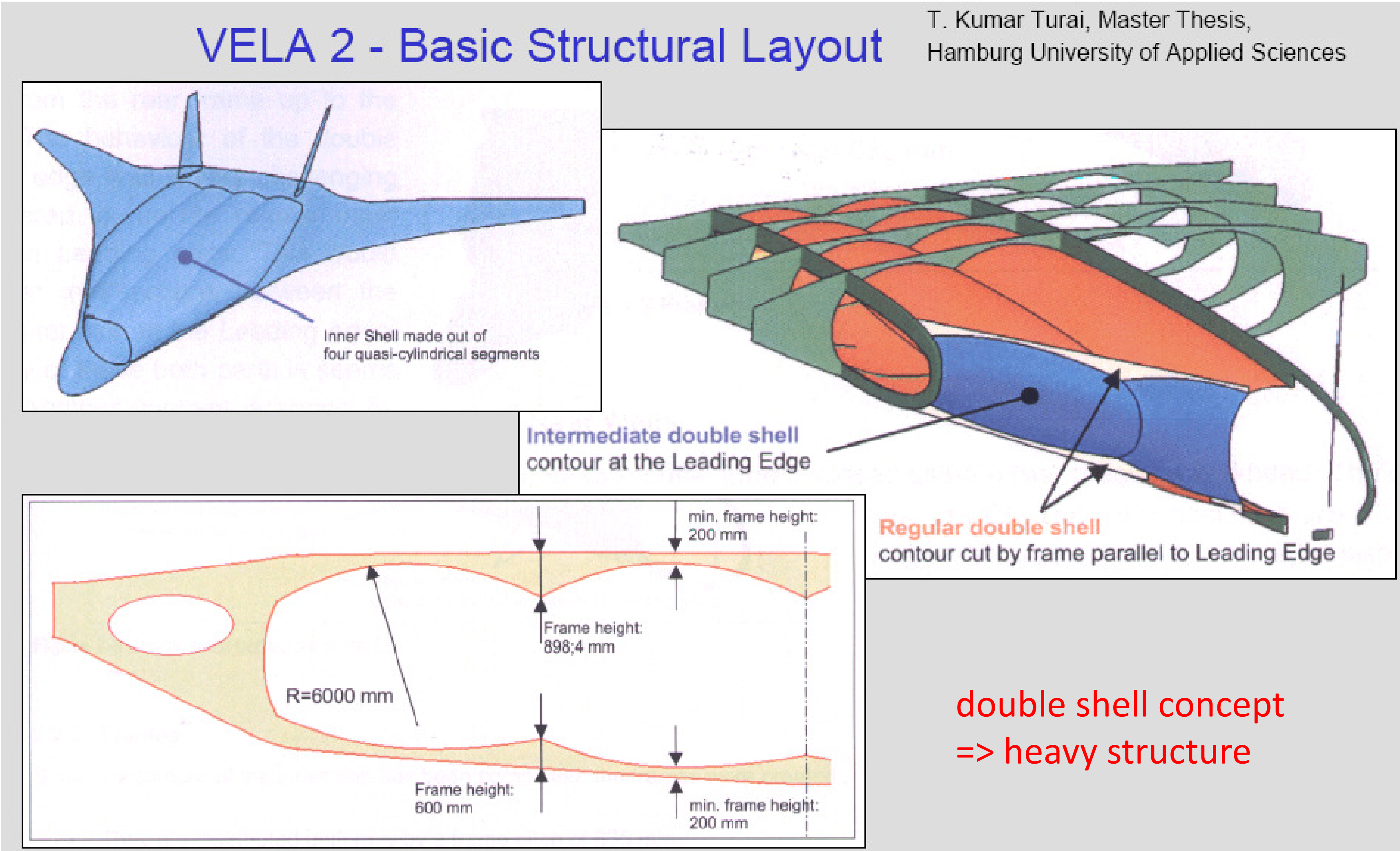
2.) Pitching Moment at C_L = 0 has to be positive.

or

B) Change Requirements (???):

Unstable aircraft stabilized by flight control system.

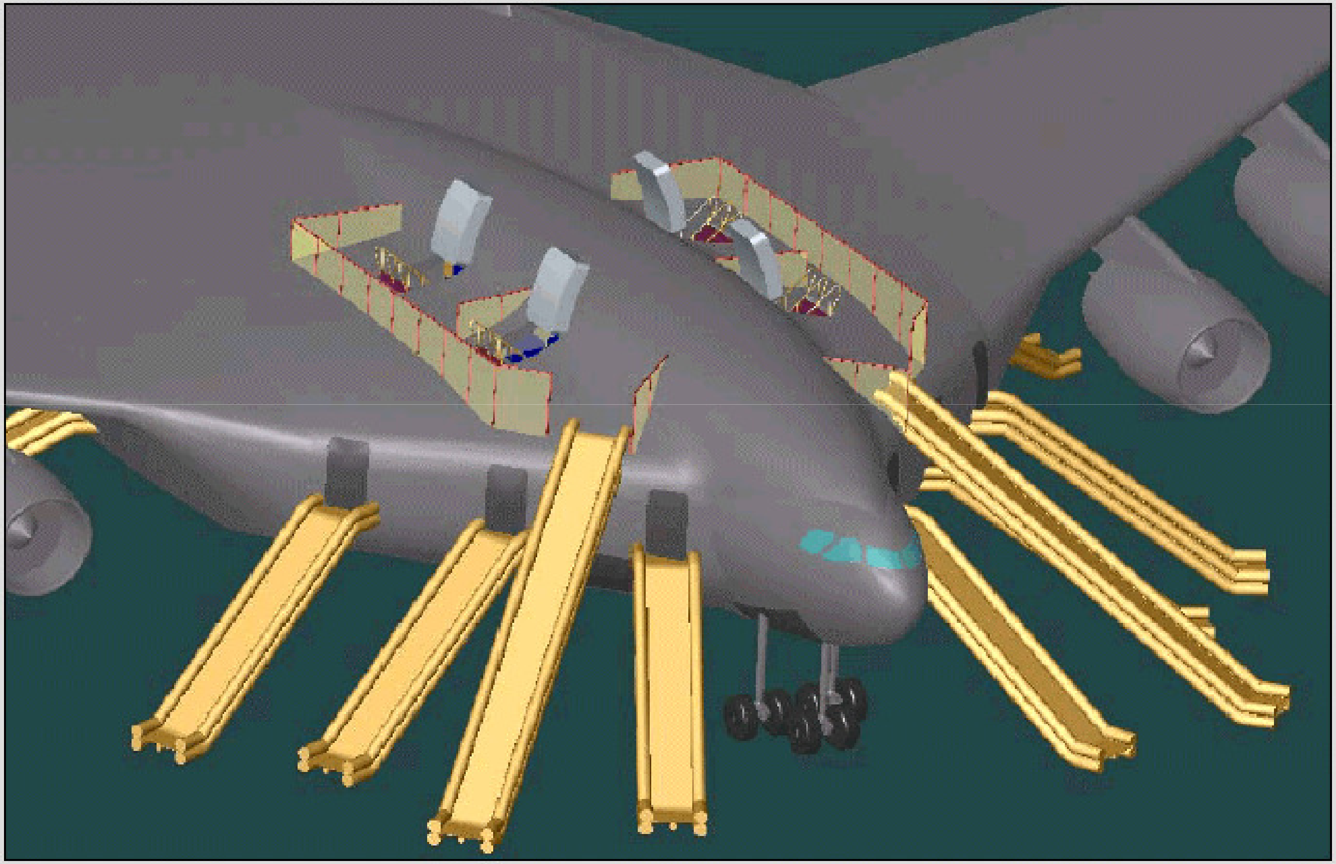
Blended Wing Body (BWB) --- Double Shell Concept



double shell concept
=> heavy structure

Blended Wing Body (BWB) --- Evacuation after Ditching Not Solved

VELA 1 - Emergency Evacuation - Slides - Ditching



Slides on forward doors.

This modification of VELA 1 allows also evacuation after ditching (into the water) through over wing doors.

VELA 1, 2, 3 standard configuration can not be certified, because doors will be submerged.

Blended Wing Body (BWB) --- Limitations at Airports for Span not Met

ICAO aerodrome reference codes [ICAO, 1999]

Aerodrome code number	Reference field length (m)	Aerodrome code letter	Wingspan (m)	Outer main gearwheel span (m)
1	<800	A	<15	<4.5
2	800–<1200	B	15–<24	4.5–<6
3	1200–<1800	C	24–<36	6–<9
4	≥1800	D	36–<52	9–<14
		E	52–<65	9–<14
		F	65–<80	14-<16

VELA 3: 11,4 m

FAA airport reference codes [FAA, 1989]

Aircraft approach category	Aircraft approach speed (kn)	Aeroplane design group	Aircraft wingspan (m)
A	<91	I	<15
B	91–<121	II	15–<24
C	121–<141	III	24–<36
D	141–<166	IV	36–<52
E	≥166	V	52–<65
		VI	65–<80

VELA 3: 99,6 m

Blended Wing Body (BWB) --- Summary

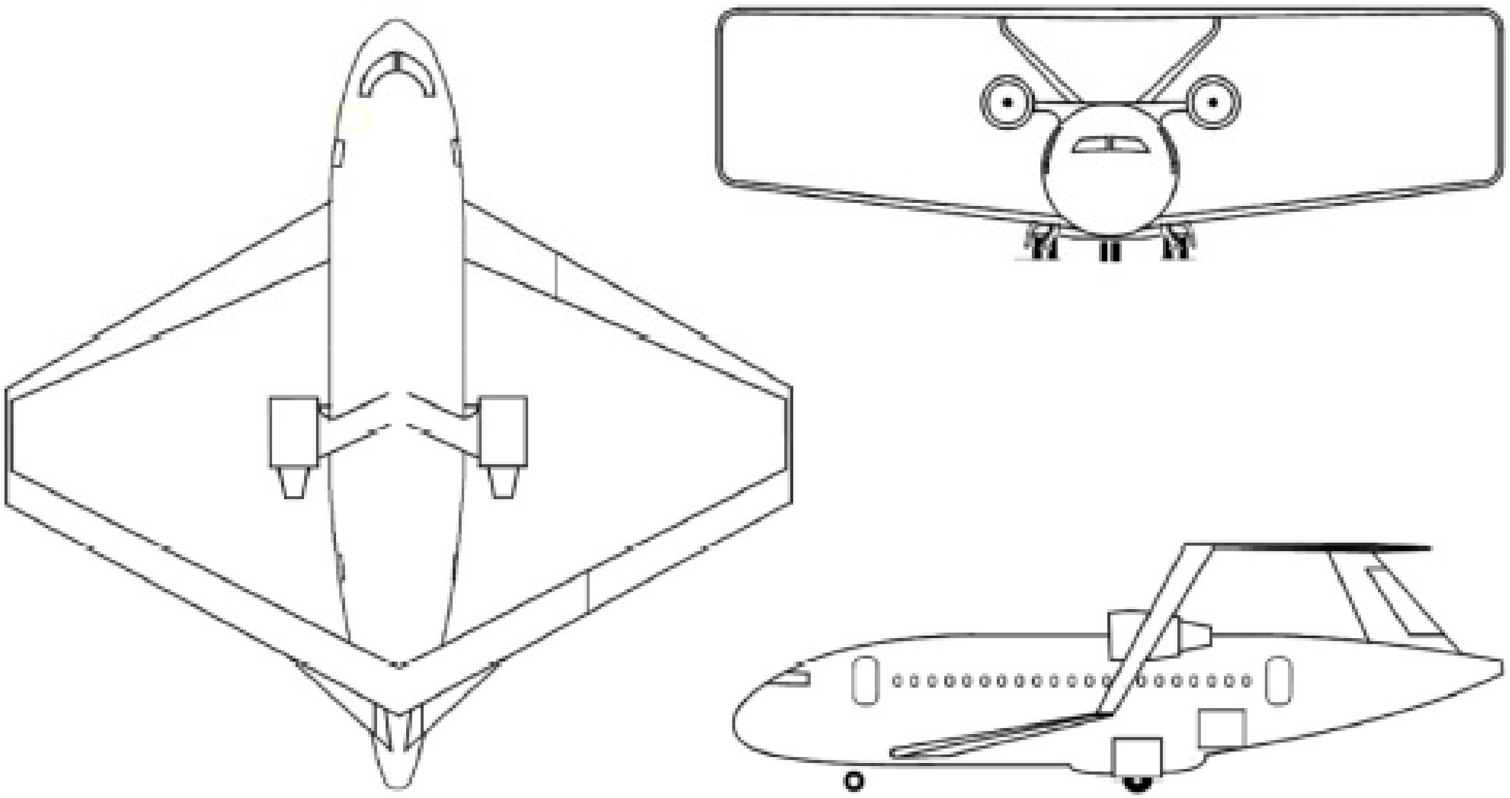
- The BWB is an option only for very large aircraft (more than 1000 passengers)
- Buiding an aircraft family is possible (stretching the fuselage <u>width</u>), but difficult
- Aerodynamics: Glide ratio of 23 is good, but only 30% better
- Good stall characteristics due to body lift at high angle of attack (AOA)
- BWB can not be certified for transonic airfoils, artifical stability required, negotiations with certification authorities necessary
- Structure needs (heavy) double shell (or very heavy single shell)
- Evacuation after ditching not solved
- Wing span of large BWB will exceed current ICAO/FAA limits

Blended Wing Body (BWB) --- Video

http://goo.gl/f4xhJl

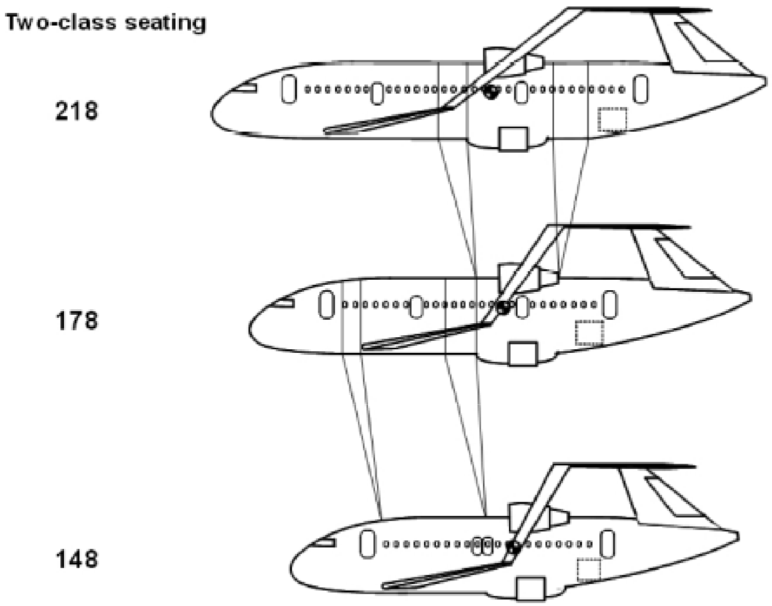
Box Wing Aircraft (BWA)

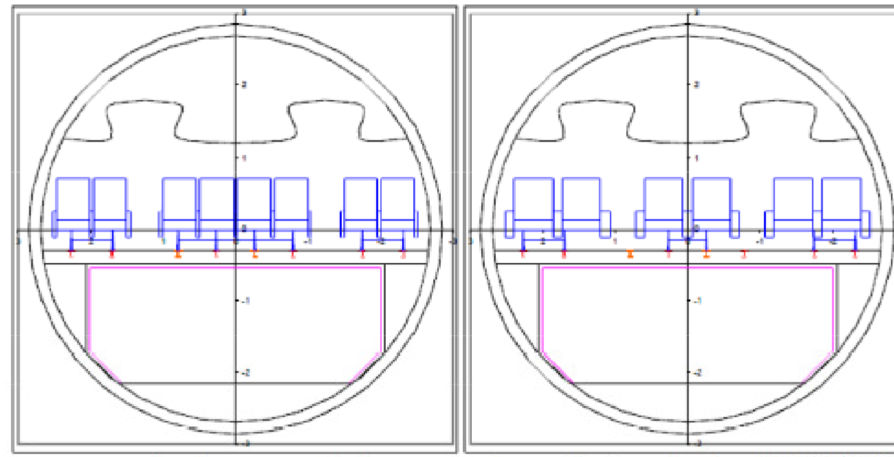
Box Wing Aircraft (BWA) --- 3-View-Drawing --- Wide Body



Box Wing Aircraft (BWA) --- Family Concept

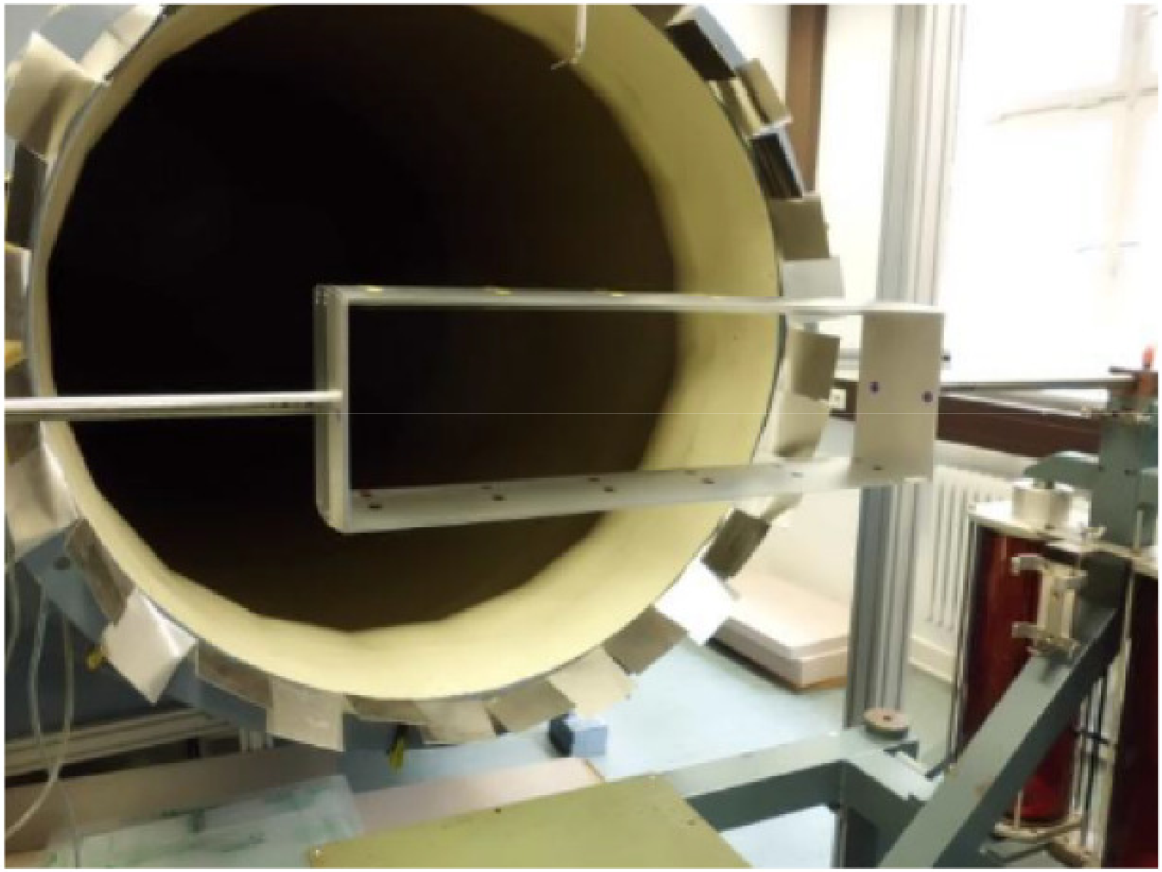
Twin Aisle Family Highlights





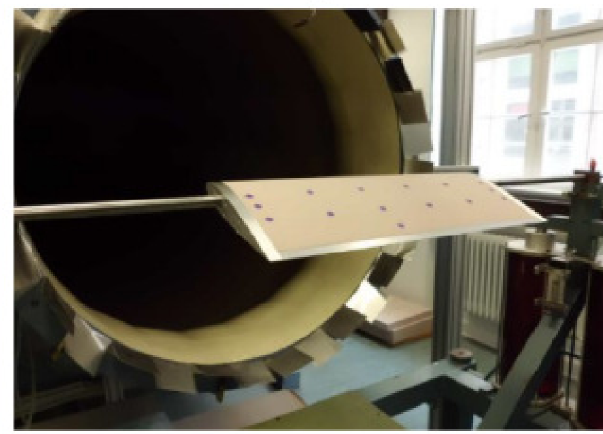
Fusélage cross section for economy class and business class (modelled with PreSTo Cabin)

Box Wing Aircraft (BWA) --- Induced Drag Measurements



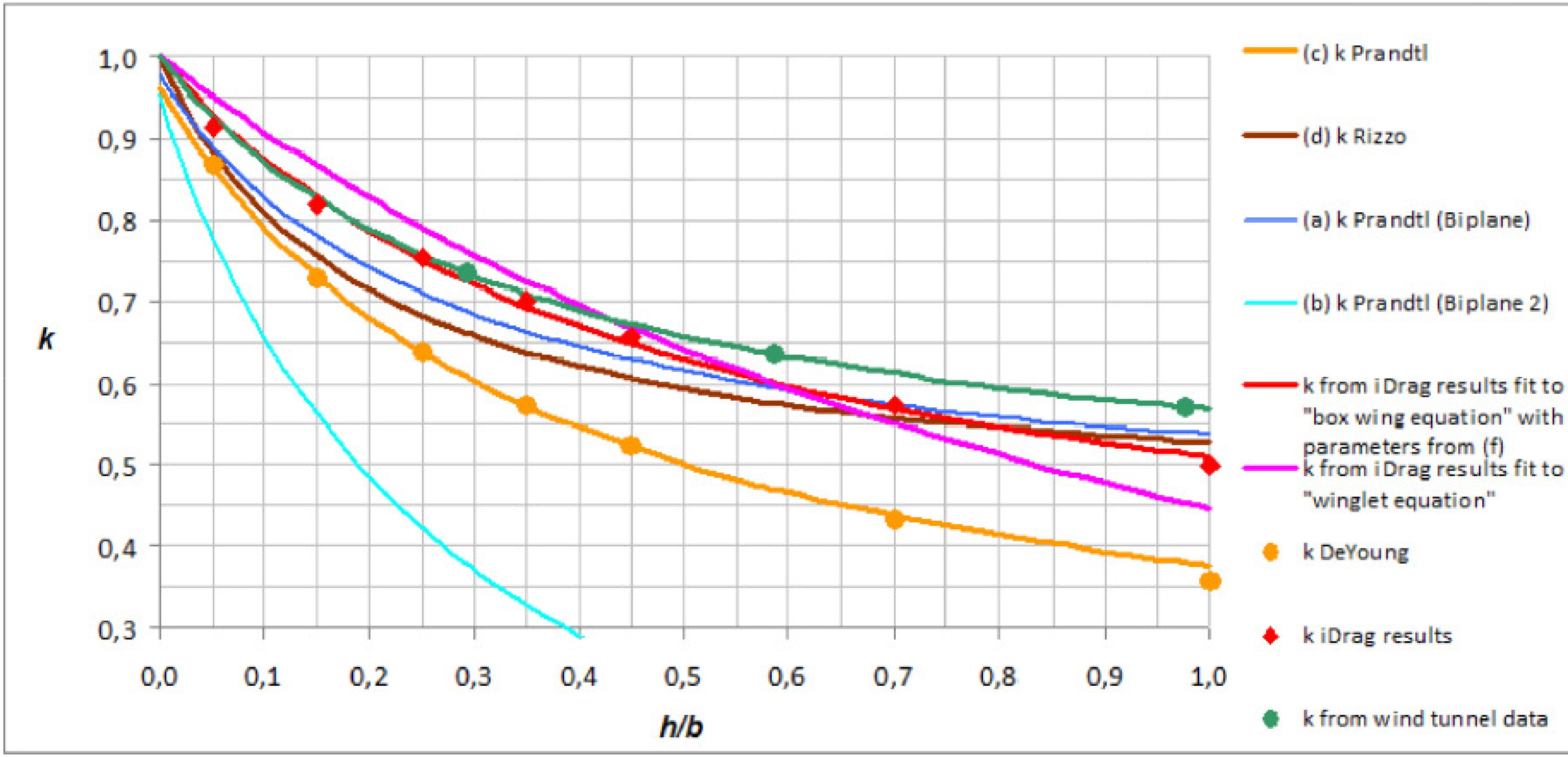
Measurements of induced drag of different box wings in the wind tunnel of HAW Hamburg

The reference wing



Box Wing Aircraft (BWA) --- Reduced Induced Drag --- Theory

$$\frac{D_{i,box}}{D_{i,ref}} = \frac{e_{ref}}{e_{box}} = k$$



Box Wing Aircraft (BWA) --- Reduced Induced Drag --- Practical

For E_{max}: $C_{D0} = C_{Di}$??? for Box Wing Aircraft ???

Considering a ratio $h/b = 1$, it yields to $C_{Di,BW}/C_{Di,ref} \approx 0.5$:

- Box Wing flies at reference Aircraft Altitude

$$\frac{E_{max,BW}}{E_{max,ref}} = \frac{4}{3} = 1.33$$

- Reference Aircraft flies at Box Wing Altitude

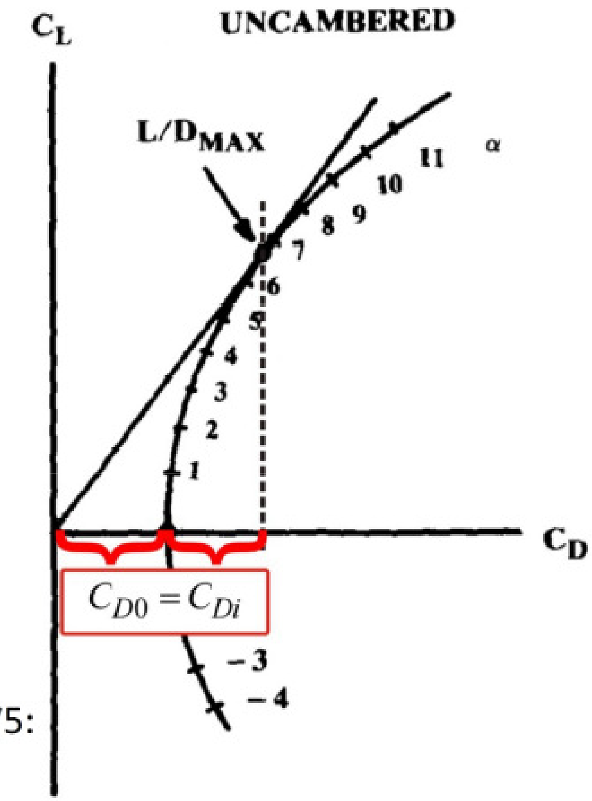
$$\frac{E_{max,BW}}{E_{max,ref}} = \frac{3}{2} = 1.5$$

- „Fair“ comparison:

$$\frac{E_{max,BW}}{E_{max,ref}} = \sqrt{2} = 1.41$$

Considering a realistic ratio $h/b = 0.25$, it yields to $C_{Di,BW}/C_{Di,ref} \approx 0.75$:

$$\frac{E_{max,BW}}{E_{max,ref}} = 1.15$$



Glide ratio of a Box Wing Aircraft is 15 % higher than that of the reference aircraft

Box Wing Aircraft (BWA) --- Reduced Induced Drag --- Increase Wing Mass

Ideally $\frac{E_{max,BW}}{E_{max,ref}} = 1.5$

Fair comparison $\frac{E_{max,BW}}{E_{max,ref}} = 1.41$

Limited h/b ratio $\frac{E_{max,BW}}{E_{max,ref}} = 1.15$

$\frac{m_{W,BW}}{m_{W,ref}} = 2.2$ Thin wings

$\frac{m_{OE,ref}}{m_{OE,handbook}} = 1.16$ Calibration

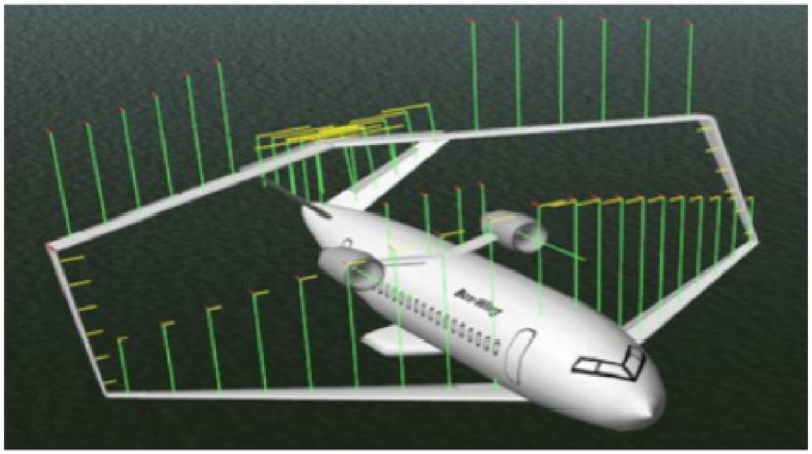
$\frac{m_{OE,BW}}{m_{OE,ref}} = 1.4$ Snowballeffects

Disadvantages outweigh advantages $\frac{m_{F,BW}}{m_{F,ref}} = 1.1$

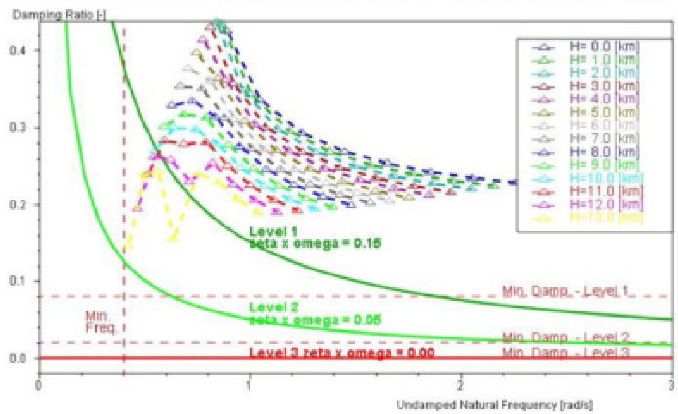
$$\frac{DOC_{BW}}{DOC_{ref}} = 1.19$$

DOC 19 % **higher**
than reference aircraft
=> **BWA not recommenced**

Box Wing Aircraft (BWA) --- Flying Qualities --- Flight Simulation



Simulator X-Plane with Aircraft Generator PlaneMaker



Dutch Roll Mode:

Damping
versus
Frequency

h = 0 km ... 13 km,
V = 100 m/s ... 240 m/s

Simulator Flight Gear / Flight Dynamics Model / JSBSim

CAJA CALLEJA, R.; SCHOLZ, D.: Box Wing Flight Dynamics in the Stage of Conceptual Aircraft Design. Berlin, DLRK 2012

CAJA CALLEJA, R.: Flight Dynamics Analysis of a Medium Range Box Wing Aircraft. Master Thesis, 2012

Box Wing Aircraft (BWA) --- Summary

O The BWA can be built as an aircraft family

O BWA (no tail) allows only little CG-shift.

O Limited CG-shift reached with short twin-aisle fuselage and engine at mid fuselage position

O Aerodynamics: Glide ratio of 20 is only 15% better

O BWA needs to fly higher than reference aircraft – this leads to heavier engines

O BWA has very heavy thin wings

O Natural longitudinal static stability (=> aircraft can be certified)

O Good flying qualities

O Fuel does not fit into the wings (=> extra fuel tank below cargo floor)

O Substantial disadvantage in Direct Operating Costs (DOC)

Box Wing Aircraft (BWA) --- Video

https://youtu.be/en65adjJpqk

Smart Turboprop

Smart Turboprop --- Idea

- Standard Prop Configuration

  - Turboprop engines are more fuel efficient than turbofan engines
  - Low flying → higher speed of sound → same speed at lower Mach number
  - Additional future technologies:
    - Natural laminar flow
    - Strut braced wing

Smart Turboprop --- Design for Low Direct Operating Costs (DOC)

- **Choosing the optimum aircraft configuration:**

Smart Turboprop optimized for low DOC compared to A320

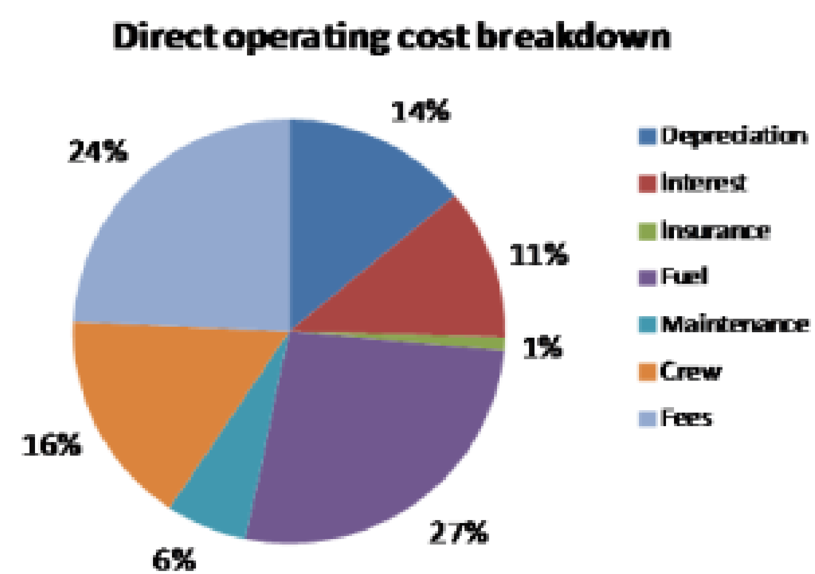
Turboprop w/o NLF/SBW	T-tail		Conventional tail	
	2 engines	4 engines	2 engines	4 engines
High wing	**-13,6%**	**-11,4%**	**-13,3%**	**-11,1%**
Low wing	**-12,4%**	**-11,5%**	**-12,9%**	**-11,1%**

Best configuration

- **Wisdom from this Optimization Study:**
  - **2 engines better than 4 engines**
  - **For 2 engines: High wing better than low wing (0,4 ... 1,2 % PT)**
  - **For 4 engines: Low wing as good as high wing**
  - **NLF improves results by about 2,8 % PT**
  - **Struts improve results by about 0,5 % PT**
  - **NLF and Struts improve results by about 3 % PT**

Smart Turboprop ---Low Fuel Burn, Low Direct Operationg Costs (DOC)

Parameter	Value	Deviation from A320*
DOC mission requirements		
R_{DOC}	755 NM	0 %
$m_{PL,DOC}$	19256 kg	0 %
EIS	2030	-----
c_{fuel}	1.44 USD/kg	0 %
Results		
$m_{F,trip}$	3700 kg	- 36 %
$U_{a,f}$	3600 h	+ 5 %
DOC (AEA)	83 %	- 17 %



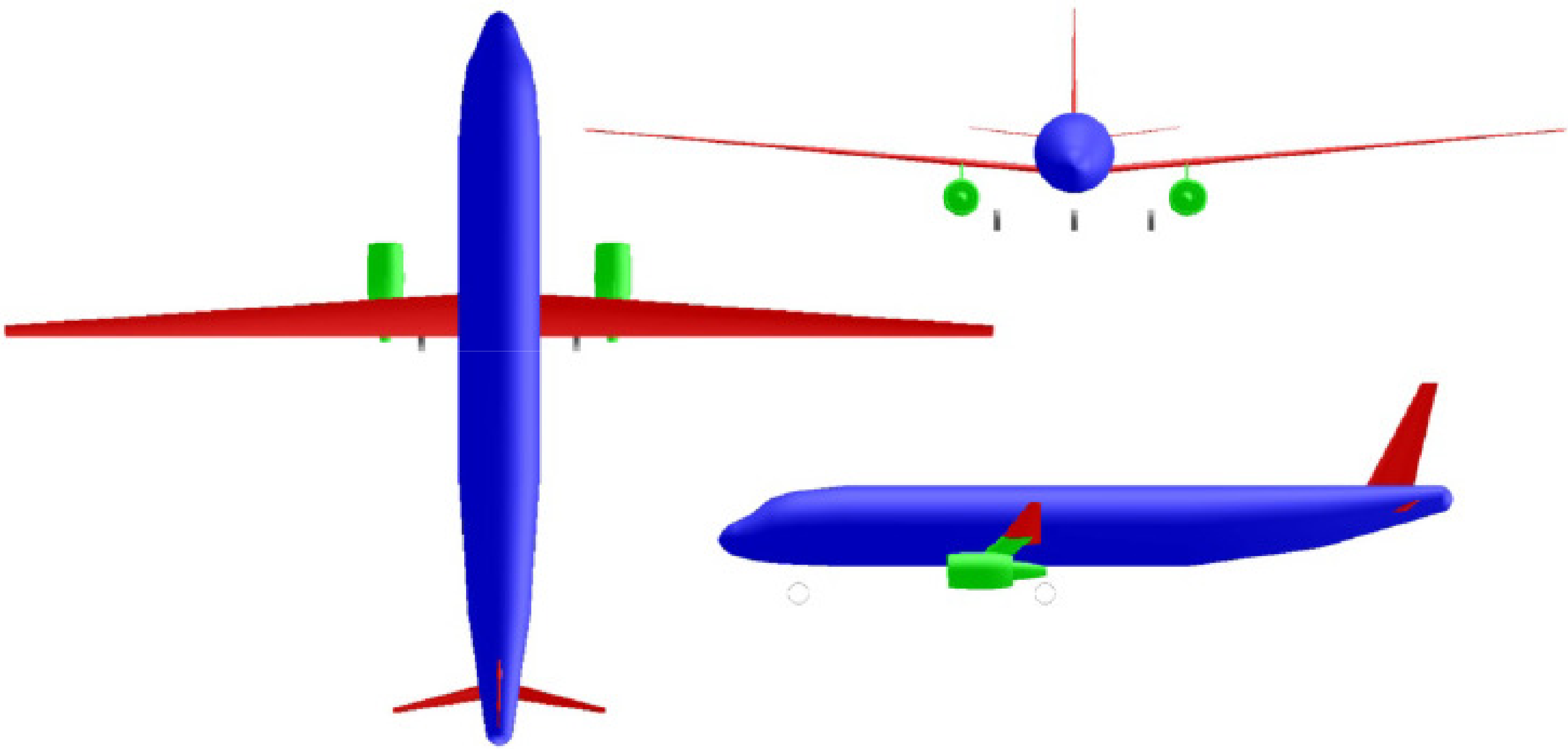
Smart Turboprop --- Summary

- o Cruise Mach number is low – it is optimized for minimum Direct Operating Costs (DOC)
- o Efficient large propeller (used here on a bigger passenger aircraft than before)
- o Integration of further technologies: strut, natural laminar flow (NLF)
- o Beneficial snow ball effects lead to higher aspect ratio
- o 36% less fuel burn and 17% lower Direct Operating Costs (DOC) !!!

Smart Turboprop --- Video

https://youtu.be/Q4O1uJmwEzo

“The Rebel”

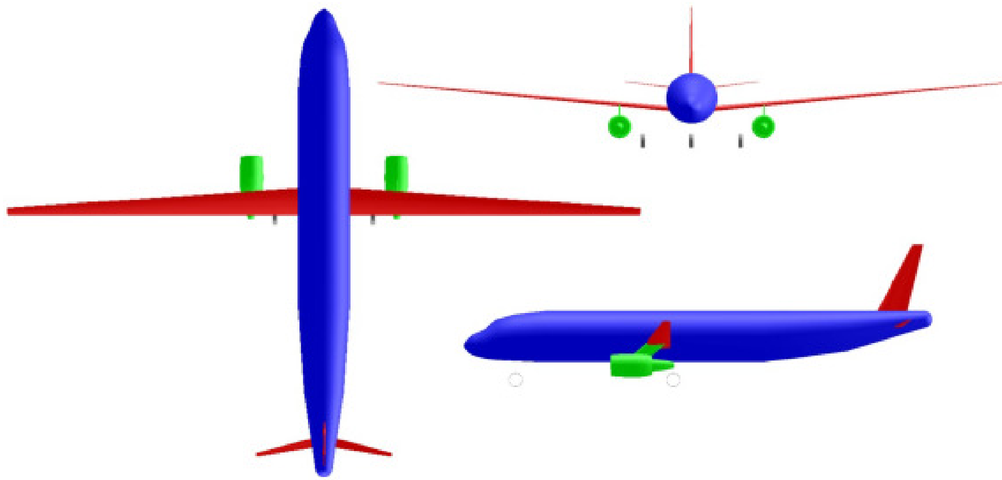


"The Rebel" --- Requirements (ICAO)

Code element 1		Code element
Aeroplane reference field length (2)	Code letter (3)	Wing span (4)
Less than 800 m	A	Up to but not including 15 m
800 m up to but not including 1 200 m	B	15 m up to but not including 24 m
1 200 m up to but not including 1 800 m	C	24 m up to but not including 36 m
1 800 m and over	D	36 m up to but not including 52 m
	E	52 m up to but not including 65 m
	F	65 m up to but not including 80 m

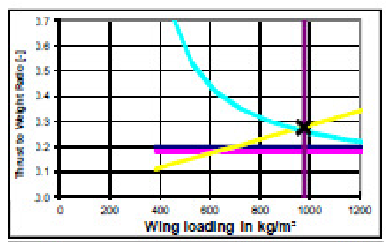
"The Rebel"

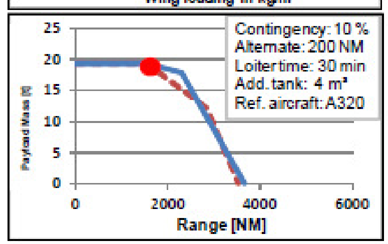
Standard Jet Configuration: A320 "optimized"



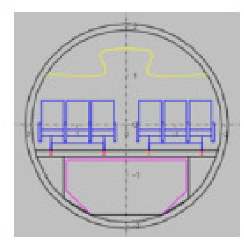
Early conceptual design

Parameter	Value	Deviation from A320*
Requirements		
m_{MPL}	19256 kg	0 %
R_{MPL}	1510 NM	0 %
M_{CR}	0.55	- 28 %
max(s_{TOFL} , s_{LFL})	2700 m	+ 53 %
n_{PAX} (1-cl HD)	180	0 %
m_{PAX}	93 kg	0 %
SP	28 in	- 3 %





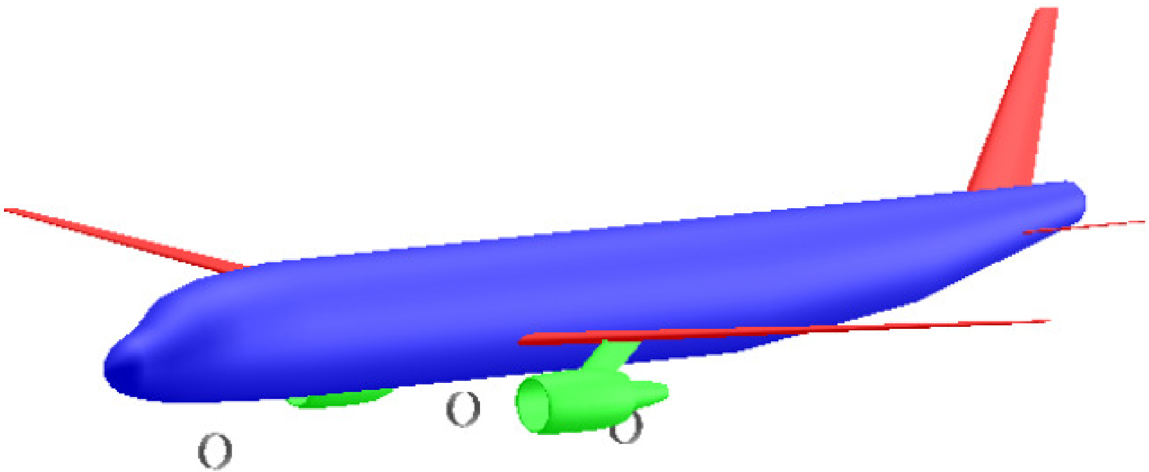
Parameter	Value	Deviation from A320*
Main aircraft parameters		
m_{MTO}	66000 kg	- 10 %
m_{OE}	39200 kg	- 5 %
m_F	7500 kg	- 42 %
S_W	68 m²	- 45 %
$b_{W,geo}$	48.5 m	+ 42 %
$A_{W,eff}$	34.8	+ 266 %
E_{max}	26.1	+ 48 %
T_{TO}	89100 N	- 20 %
BPR	15.5	+ 158 %
SFC	1.03E-5 kg/N/s	- 37 %
h_{ICA}	30000 ft	- 23 %
s_{TOFL}	2490 m	+ 41 %
s_{LFL}	2110 m	+ 45 %
t_{TA}	32 min	0 %



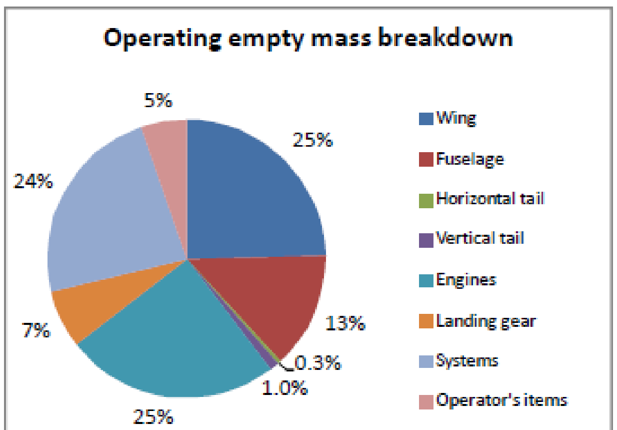
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

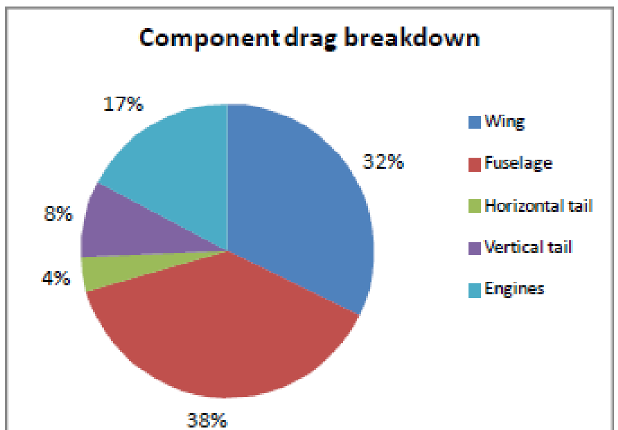
"The Rebel"

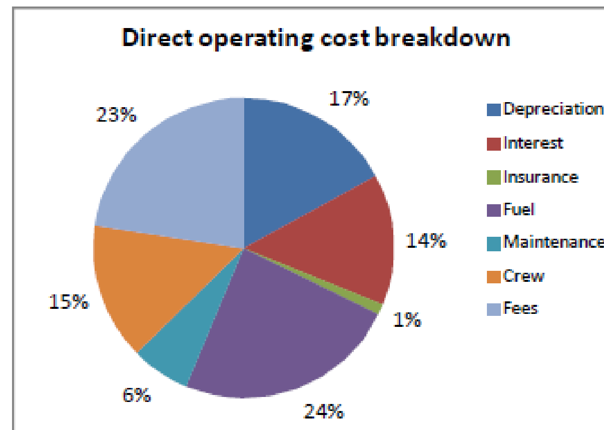
Standard Jet Configuration: A320 "optimized"



Parameter	Value	Deviation from A320*
DOC mission requirements		
R_{DOC}	750 NM	0 %
$m_{PL,DOC}$	19256 kg	0 %
EIS	2030	-----
c_{fuel}	1.44 USD/kg	0 %
Results		
$m_{F,trip}$	3700	- 36 %
$U_{a,f}$	3070	+ 6 %
DOC (AEA)	93 %	- 7 %





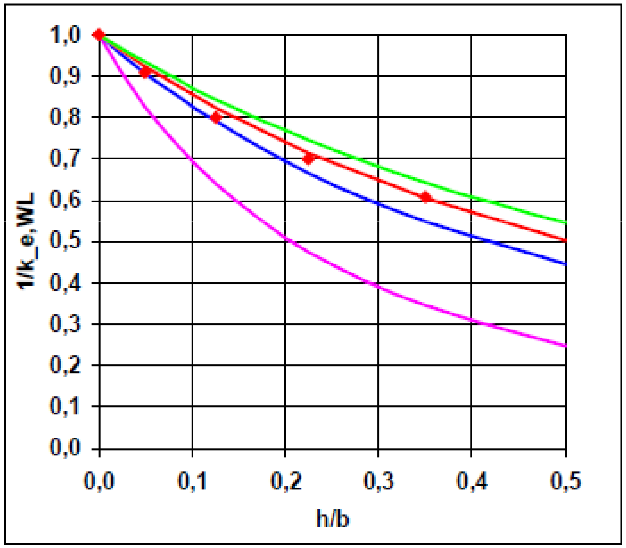


With Knowledge from “The Rebel”:

Proposal: Horizontal Wing Tip Extension on A320 as Option

Results from an *additional study* in Airport2030:
“Airport Compatibility of Medium Range Aircraft with Large Wing Span”

- **Wingtip devices: Very limited efficiency compared to the same length of material used to horizontally extend the wing** [3]



$$k_{e,WL} = \left(1 + \frac{2}{k_{WL}} \frac{h}{b}\right)^2 = \frac{A_{eff}}{A} = \left(\frac{b_{eff}}{b}\right)^2$$

- **Consider this option: Extend the wing span and just deal with consequences at airports**

- **Airbus should also offer a horizontal wing tip extension as option**

With Knowledge from "The Rebel":

Proposal: Horizontal Wing Tip Extension on A320 as Option

- Optional horizontal wing tip extension limits risk and costs compared to a new wing
- A slow introduction of aircraft with larger wing span (Class C => Class D) will force airports to accept this
- Landing fees are based on MTOW and are hence unchanged
- Study [4] showed: Many airports still have some capacity for a limited number of former Class C aircraft now with larger span
- Airports will start to rearrange gate layout initially with additional markings

"The Rebel" --- Conclusion

- Aircraft could be **more efficient** if some **requirements were relaxed**, limiting some paramters today:
  - **aspect ratio, *A***
  - **span, *b***
  - cruise Mach number, M_{CR}
  - take-off field length, s_{TOFL}
  - landing field length, s_{LFL}
- Existing aircraft could benefit much from **(horizontal) wing tip extensions** (ignoring conventional span limitations)

Content

Aviation History – Further / Faster / Higher → Economic

Aviation Law – Unlimited Freedom?

Aviation Growth – Uncontrolled & Booming?

Aviation Off-Course? – Eco-Efficiency / Sustainability

Introduction to Aircraft Design

Blended Wing Body (BWB)

Box Wing Aircraft (BWA)

Smart Turboprop

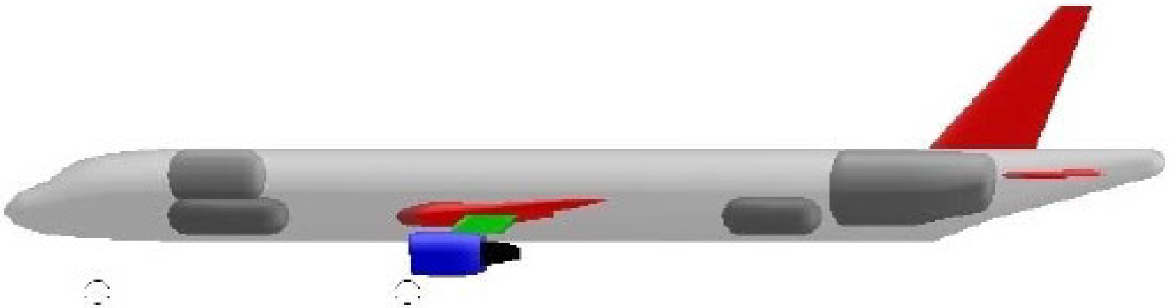
"The Rebel"

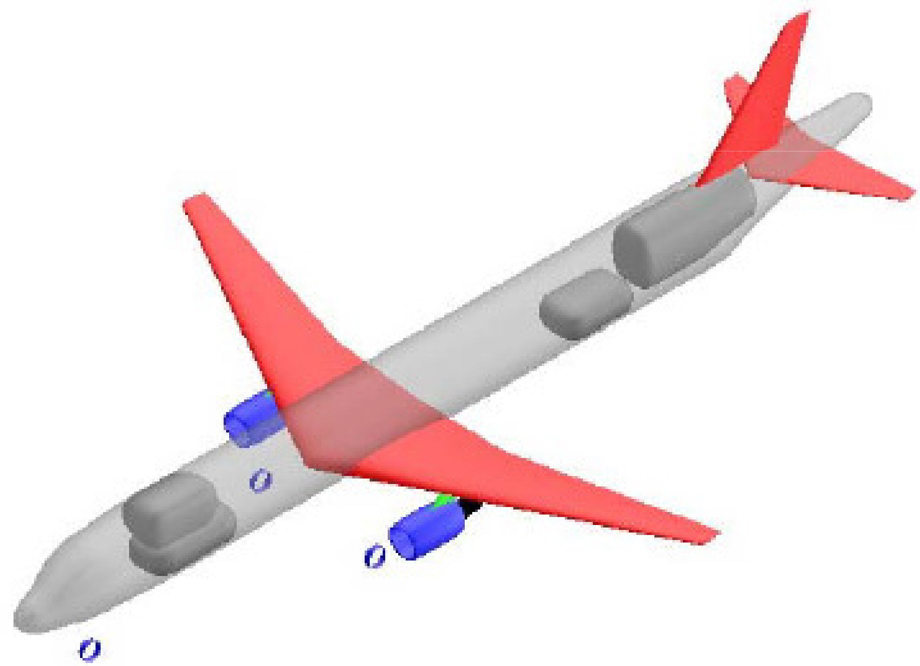
Hydrogen Powered Aircraft

Outlook: Synthetic Fuel --- Drop-in Fuel

Overall Conclusions

Hydrogen Powered Aircraft





The Availability of Energy is Important!

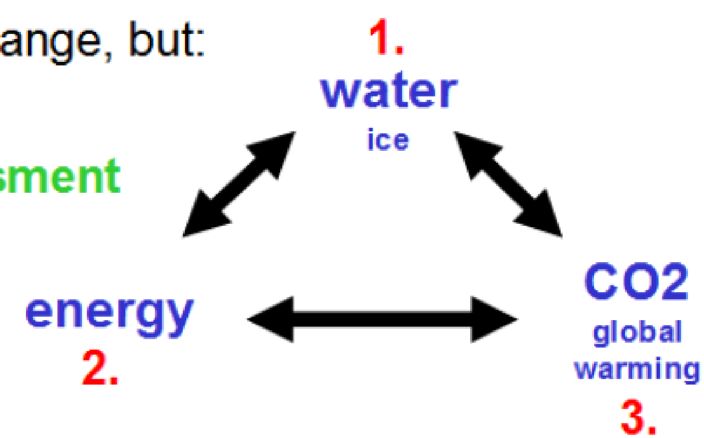
- Depletion of fossile fuels => **aviation energy carrier** instead of **aviation fuel**
- The **search** for the aviation energy carrier of the future **is ongoing**:

# biofuel, synthetic fuel, drop-in fuel	*advantage*: aircraft stay the same
# batteries	*advantage*: direct use of electricity
# **hydrogen**	*advantage*: **best known technology**

- Current focus: CO_2, Global Warming, Climate Change, but:
- **There are more issues than CO2**
- **Needed: Balanced look with Life Cycle Assessment**
- **Ensure:**

  Future availability of energy in aviation !

  (or tell your kids the party is over)

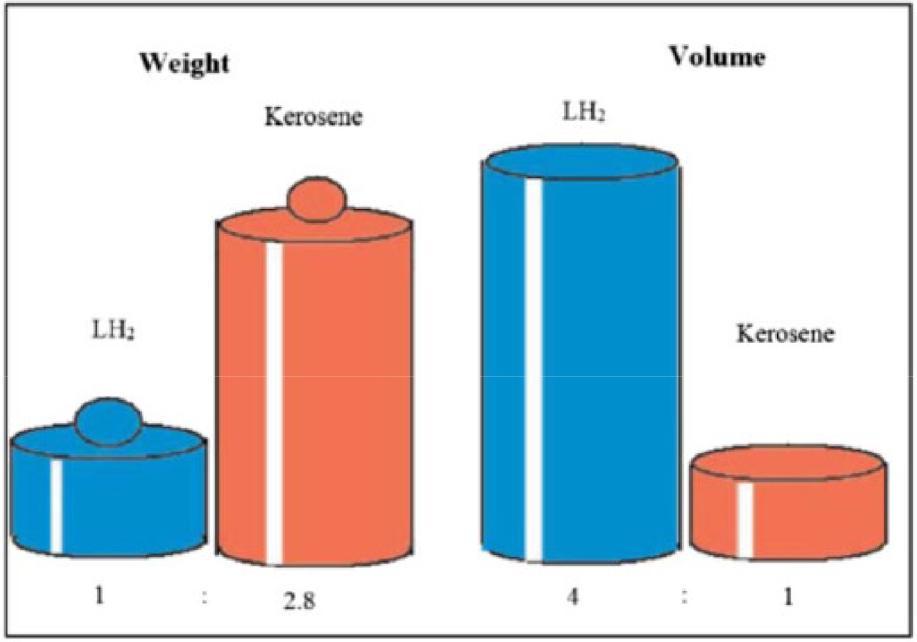


Note the Scale of the Energy Consumption in Aviation!

- **Global energy consumption in aviation** (2009):
  - \# 230 Mtoe (million ton oil equivalent) per year
  - \# with 0.8 t/m³ this is 9.1 m³/s (flow of a smaller tributary of the river Elbe)
  - \# with heating value, H = 41.9 MJ/kg this is 300000 MW or 300 nuclear power plants (simple energy comparison)
- Clearly, after peak oil (2050?) there will be **more than one energy carrier** in aviation => necessary. **Hydrogen** must be one of these energy carriers! Or we won't make it.

Characteristics of Hydrogen --- Important for Aircraft Design

- **Comparison at equal energy:**

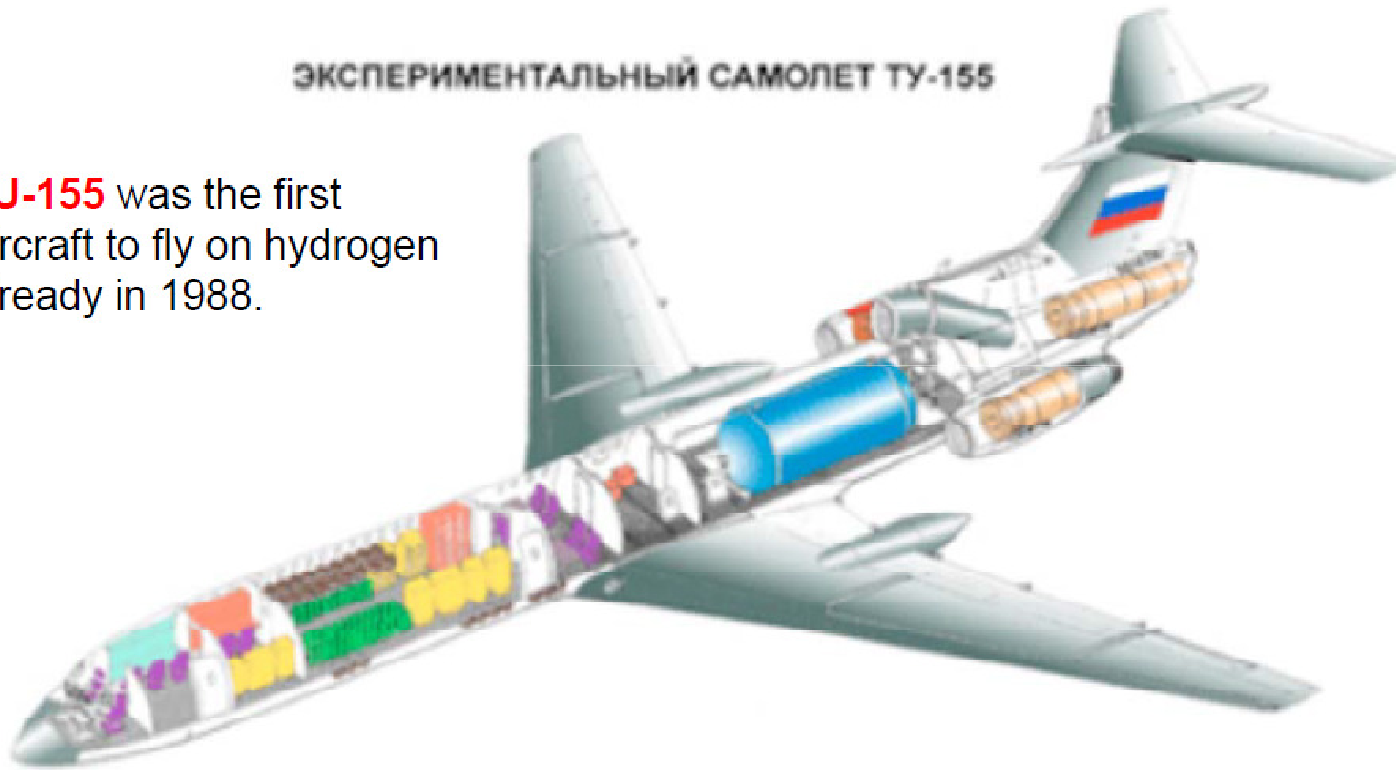


- **Boil-off**

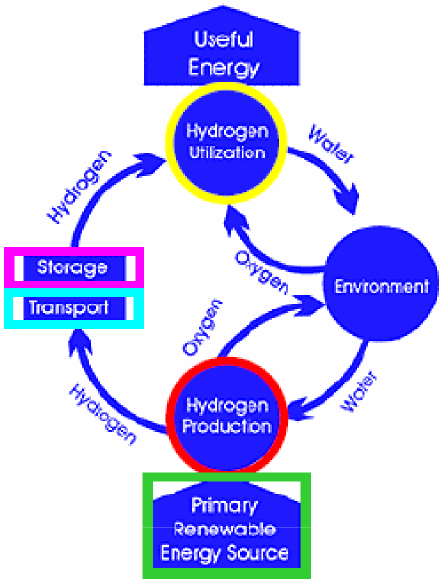
- **Hydrogen embrittlement** (Wasserstoffversprödung) **of materials**

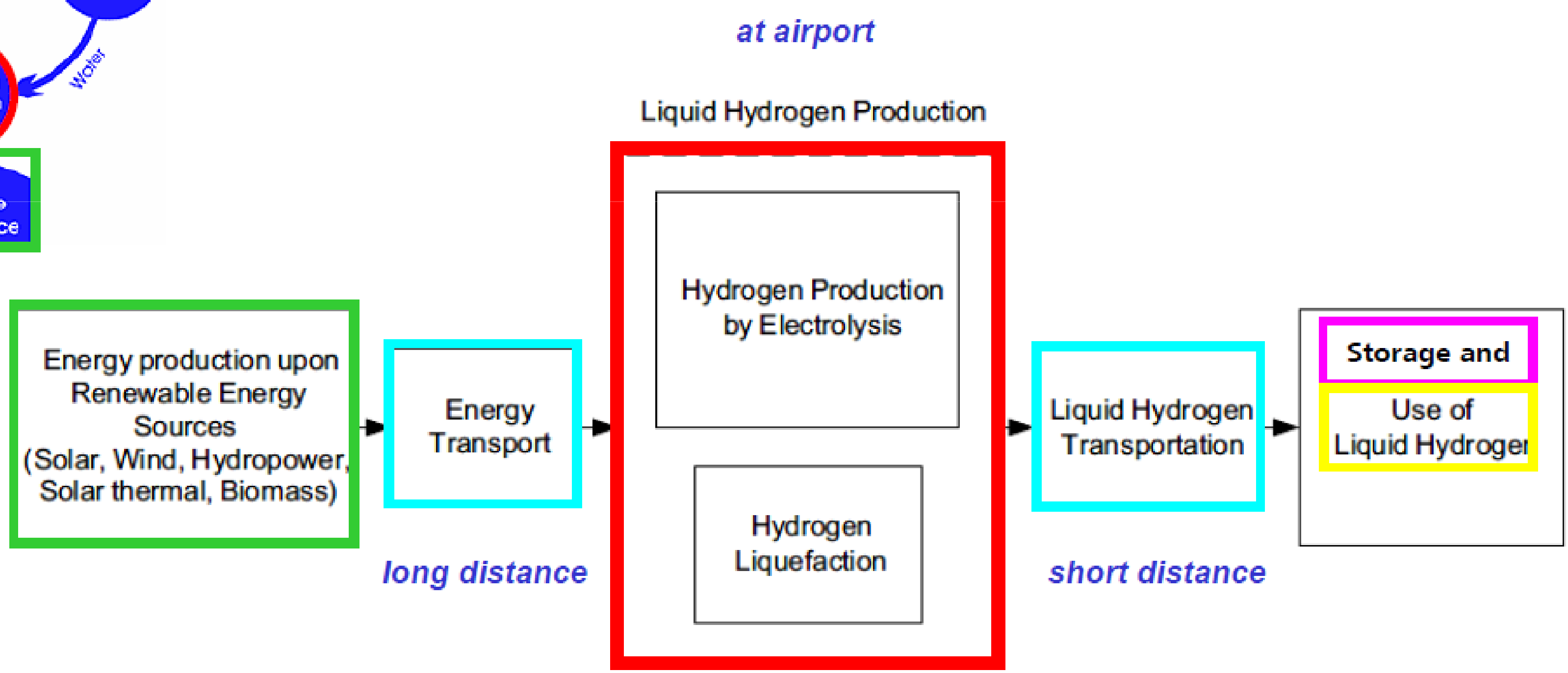
LH2-Technology Already Tested in Aviation

TU-155 was the first aircraft to fly on hydrogen already in 1988.



Hydrogen Life Cycle





Hydrogen's Show Stopper in Aviation

Hydrogen's show stopper in aviation is the necessary **big investments**

1.) in new aircraft

2.) in new airport infrastructure
  * liquid hydrogen production
  * new refueling equipment at airports

In contrast:
Drop-in fuel (biofuel, synthetic fuel) needs **no investment in the aviation system**

1.) same aircraft

2.) same airport infrastructure
  * no extra production fascility at airport
  * same refueling equipment

Hydrogen's Show Stopper in Aviation

Hydrogen's show stopper in aviation is the necessary **big investments**

1.) in new aircraft

2.) in new airport infrastructure
 * liquid hydrogen production
 * new refueling equipment at airports

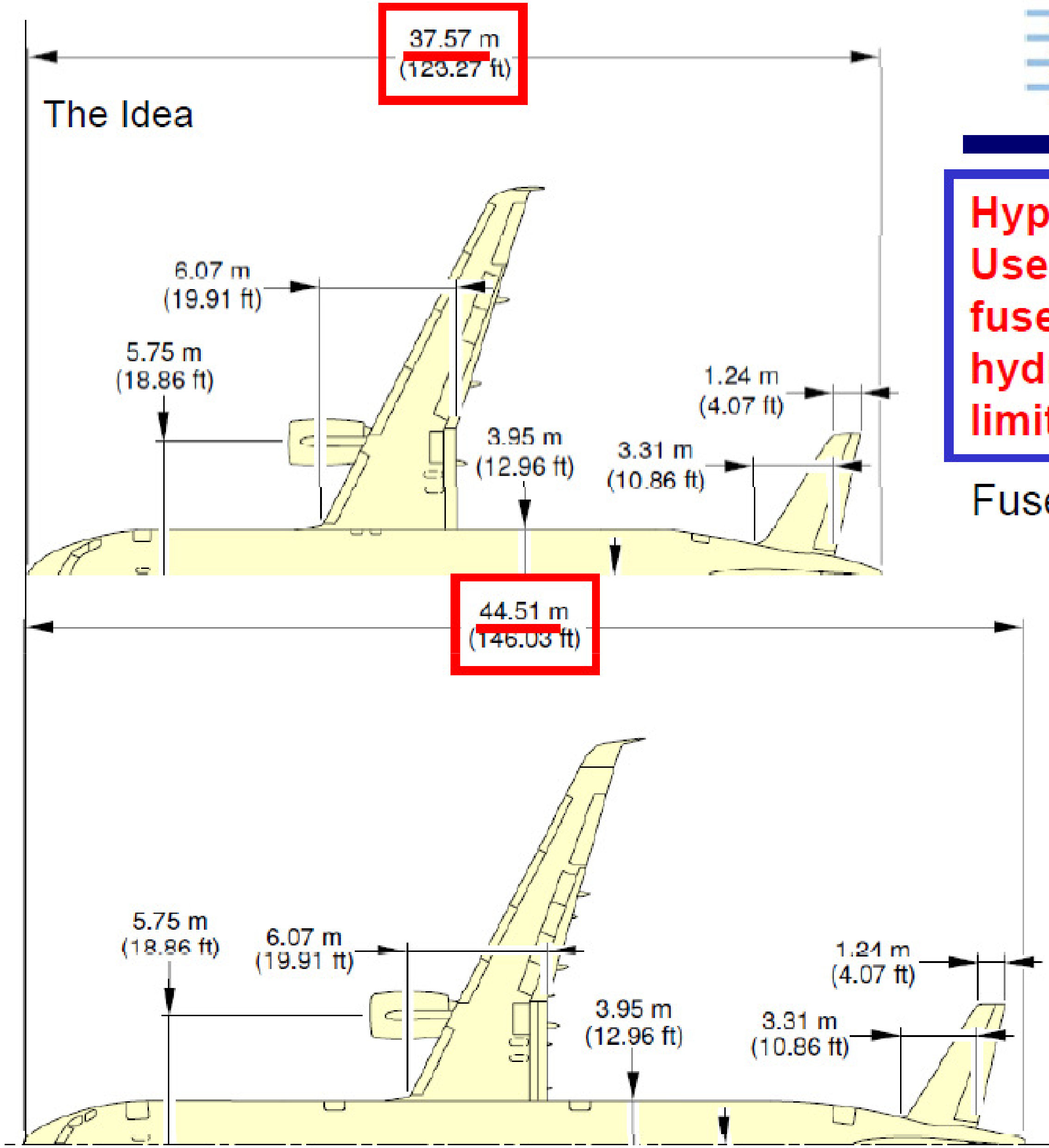
Can we reduce the investment by using modified existing aircraft for the new energy carrier hydrogen?

In contrast:
Drop-in fuel (biofuel, synthetic fuel) needs **no investment in the aviation system**

1.) same aircraft

2.) same airport infrastructure
 * no extra production fascility at airport
 * same refueling equipment

The Idea



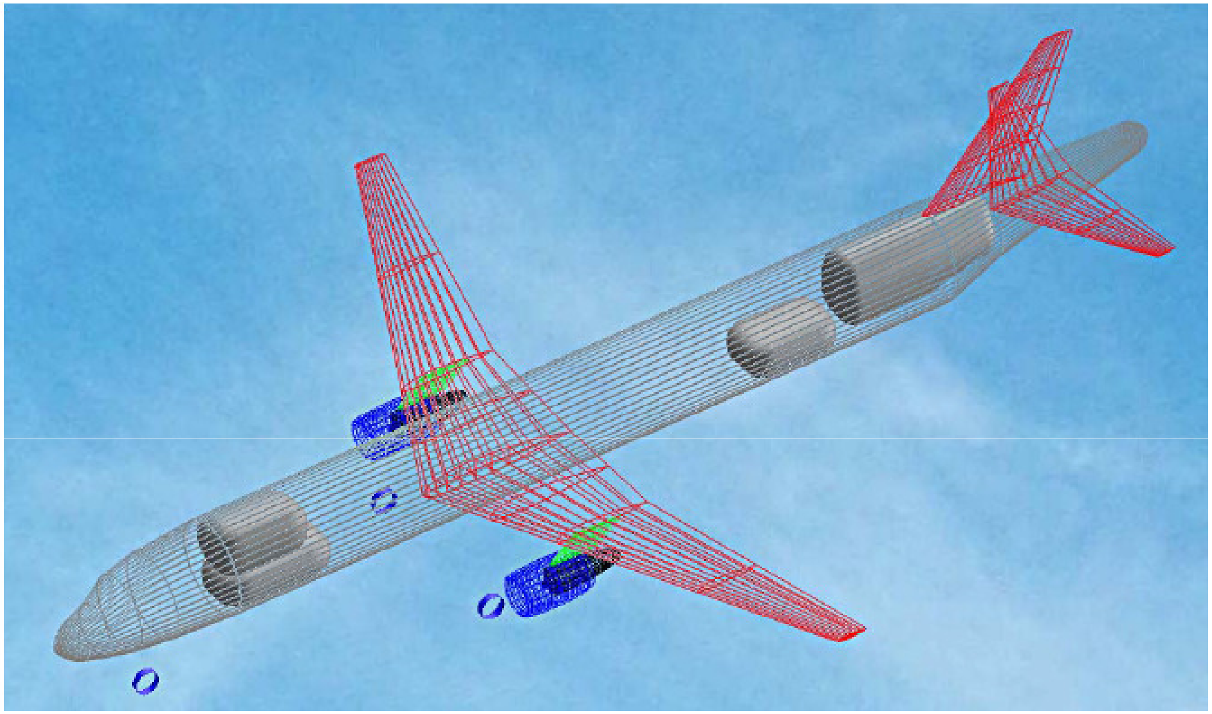
Hypothesis:
Use an existing (longer) fuselage to integrate the hydrogen tanks to limit investment!!!

Fuselage Length Compared:

A320

A321

Hydrogen Storage in the Fuselage (Front and Rear)

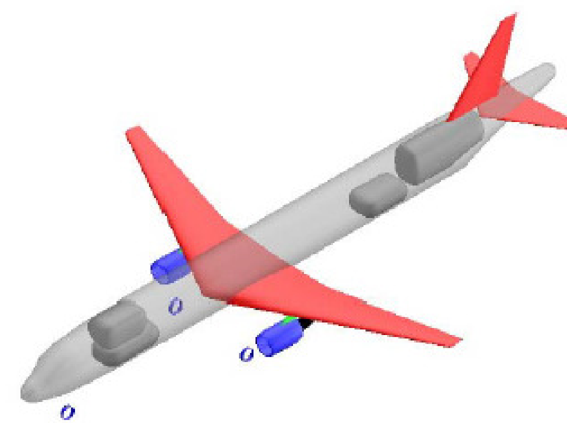


Distribution of the tank in the front and in the back to **balance CG**.

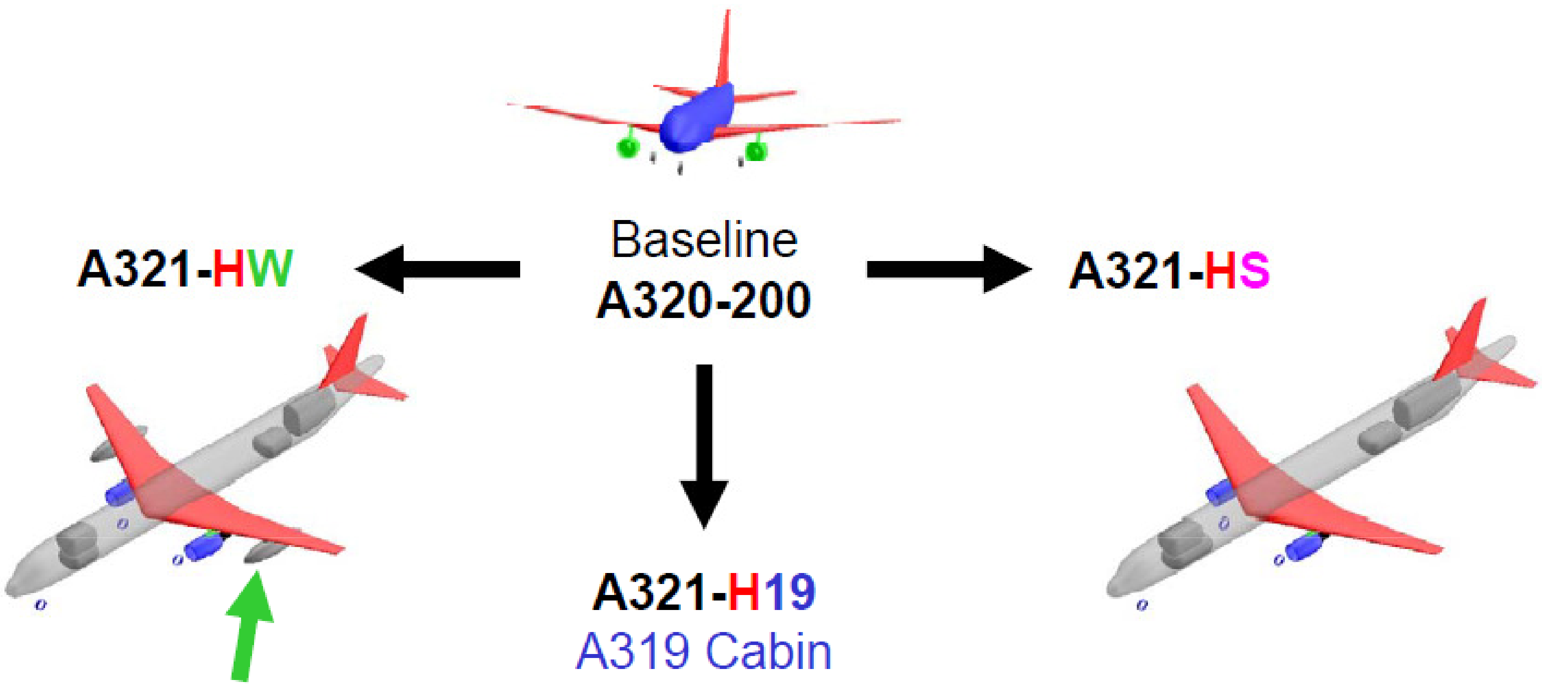
Two tanks forward and two tanks aft.
Assume no double **tank failure**
or aircraft robust against CG shift.

Use of some portion of the front and aft **cabin**.

Use of an even bigger protion of front and aft **cargo compartment**.

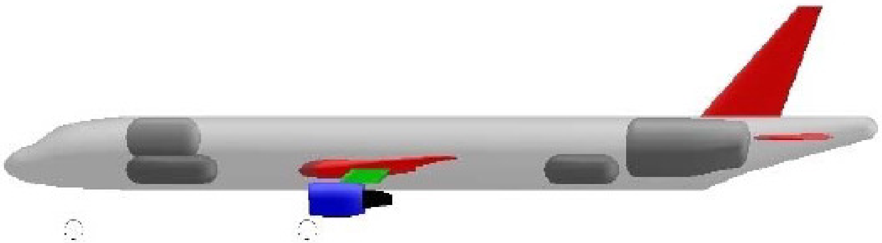


Hydrogen Powered Aircraft Variants



H:	LH2 Aircraft
W:	A321 with addtional hydrogen tanks under wing
S:	A321 with additional stretch (to give more volume for LH2 tanks)
19:	A321 filled only with 156 (instead of 180) one-class passengers (more room left for LH2 tanks). Same payload & range kept

Comparison of A321-H19 with A320-200



Parameter	A321-H19	Variation (A320)
m_{MTO} [kg]	70916	-1.9
m_{OE} [kg]	45208	+12.5
m_F [kg]	6443	-49.7
DOC (AEA) [€/NM/t]	1.78	+34.9
DOC (TUB) [€/NM/t]	1.61	+39.8
l_F [m]	46.2	+20.5
S_W [m^2]	126.5	+5.1
$b_{W,geo}$ [m]	34.7	+2.5
$A_{W,eff}$	9.5	0
φ_{25} [°]	25	0
λ	0.21	0
E_{max}	17.6	+0.3
T_{TO} [kN]	100.2	-8.4
BPR	6	0
SFC [kg/N/s]	5.82E-06	-64.8
h_{CR} [ft]	37676	-3.1
m_{MTO}/S_W [kg/m^2]	560.7	-6.6

energy up 41 %

A321: l_F = 44.5 m
Delta: 1.7 m

If DOC are based on A319:
DOC (AEA) +17%
DOC (TUB) +21%

Hydrogen Powered Aircraft --- Conclusion

News where at one time distributed via Newpapers –
- then via Newspapers and Radio,
- then via Newspapers and Radio and TV,
- then via Newspapers and Radio and TV and Interent,
- …

We will say: Aircraft flew at one time with Kerosene –
- then with Kerosene and Drop-In Fuel,
- then with Kerosene and Drop-In Fuel and Hydrogen,
- …

The question will NOT be one or the other energy carrier?, but
what mixture of energy carriers for the aviation system?

Outlook: Synthetic Fuel --- Drop-in Fuel

o The aviation industry wants **Drop-In Fuel** because it allows **continued use of all existing assets**

o **Biofuel** is „nonsense“ due to **low efficiency of the photosynthesis process**

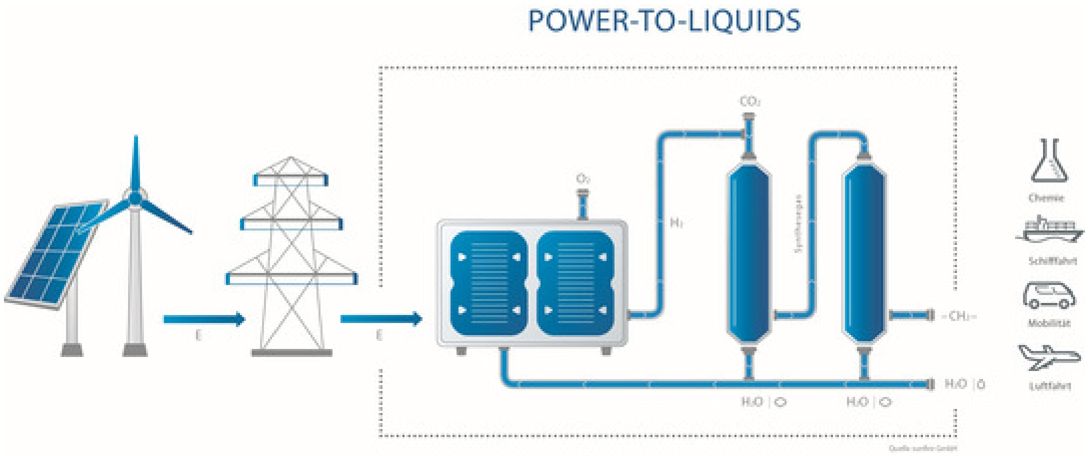

DOI: 10.1002/anie.201200218

The Nonsense of Biofuels

*Hartmut Michel**

o **Electric flight with batteries** will be **limited to** niche markets in aviation
for **very short range** up to 700 km

o **Power-to-Liquid (PtL) may be the answer for the future of aviation:**



Synthetic Fuel from Power to Liquid (PTL)

Step 1:
High-temperature steam electrolysis (efficiency above 90%)

Step 2:
Reverse water-gas shift reaction. It involves the use of the hydrogen (H_2) yielded by the steam electrolysis step to reduce carbon dioxide (CO_2) to carbon monoxide (CO)

Step 3 (FISCHER-TROPSCH synthesis):
The carbon monoxide (CO) and additional hydrogen (in the form of renewable synthesis gas) can be converted to petrol, diesel, kerosene and other base products for the chemicals industry (e.g. waxes).

The feeding of the heat released during synthesis back into the process ensures a high degree of system efficiency (70%) for the overall process.

Overall Conclusions

- Goals throughout aviation history were/are:
  1. Further / Faster / Higher
  2. Improved Economics
  3. Sustainability
- Aviation is growing quity steadily with 5 % per year.
- Self set goals by various aviation organizations to limit carbon emissions ...
  - are unlikely to be met (in 2020, in 2050, ...).
  - Carbon offset schemes will not be fully in place in 2020.
    Carbon offset schemes only make limited sense and are debatable.
- Unconventional aircraft configurations (here: BWA, BWB) do not show an overall benefit and will not be a solutions to aviation‘s future.
- Conventional configurations questioning established design rules and requirements show much potential!
- It is important to come early to a conclusion about which aviation fuels should be used together (not just one) to meet demand. Candidates are:
  - remaining fossile kerosene
  - hydrogen
  - drop in fuel from Power-to-Liquid

Contact:

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http://AERO.ProfScholz.de

Welcome of Participants to the Lecture (see also next pages)

- Before the „official“ start of the lecture some videos where played:
  1.) The Kid and the Kite (Aviation History and Enthusiasm)
  (Video: https://youtu.be/SzyE808ARDY)
  2.) Airbus A320 Family Presentation (Aircraft Systems)
  (Video: http://goo.gl/6ULg56)
  3.) Design, Build, Fly, BWB, HAW Hamburg
  (Video: https://youtu.be/-Qtw9QrDrQA)

- A recap of the announcements of the lecture showed which promises were made about the lecture‘s coverage => content of the lecture

- Further reading hints

Hamburg Metropolitan Region

http://www.hamburg-aviation.de

HAMBURG AVIATION

/ START / ÜBER UNS / AKTUELLES / AKTIVITÄTEN / MITGLIEDSCHAFT / INTERNATIONALES / FORSCHUNG / KARRIERE

‹ Alle Veranstaltungen

25 OCT

Vortrag: Inspire Me - Die Zukunft des Fliegens

HAW Hamburg

HAW Hamburg

Über den Wolken ist die Freiheit grenzenlos(?) – bis Flugzeuge aber überhaupt fliegen konnten, mussten viele Grenzen überwunden und knifflige Fragen geklärt werden. Prof. Dr. Dieter Scholz forscht an der HAW über die Zukunft der boomenden Luftfahrt und nimmt dich an diesem Abend mit auf eine spannende Reise durch die Entwicklung der Fliegerei. (Ergebnisse aus der Forschungsgruppe AERO)

19:00 Uhr

Veranstaltungsort

Mercedes me Store, Ballindamm 17, 20095 Hamburg

http://Airport2030.ProfScholz.de

Beschreibung

Von ersten waghalsigen Versuchen bis hin zu den effizienteren Flugzeugtypen der Gegenwart und Zukunft erfährst du viel über die technischen, energetischen, räumlichen und zeitlichen Herausforderungen. Im Leuchtturmprojekt "Effizienter Flughafen 2030" wurden ökonomischere Konzepte und Lösungen für den steigenden Flugverkehr entwickelt. Von diesen und anderen Ergebnissen soll berichtet werden. Wer gern gemeinsam mit uns abheben möchte, den laden wir herzlich ein, im Mercedes me Store Hamburg eine möglichst angenehme Sitzposition einzunehmen. Anmeldung unter: zukunftfliegen.mercedes-me-store-hamburg.de/user/registration

Weitere Informationen

http://hamburg-aviation.de/uploads/media/poster_2016_10_25_DieZukunftDesFliegens.pdf

http://hamburg.dglr.de

Download this presentation later from here!

Veranstaltungen 2. Halbjahr 2016 und Ausblick

Veranstaltungsprogramm 2-2016 (Stand: 18.10.2016)

In die **Liste der Veranstaltungen** (unten) werden noch wenige weitere Veranstaltungen aufgenommen werden. Bitte informieren Sie sich hier regelmäßig. Wir hoffen es sind bereits interessante Themen für Sie dabei!

Veranstaltungen 2. Halbjahr 2016

Datum	Thema	Referent	Org.	Einladung zum Vortrag	Texte zum Vortrag/ Bemerkungen	btlg.
Dienstag, 05.07.16, 18:00 Airbus Conference Centre, Finkenwerder	3rd GERHARD SEDLMAYR LECTURE: **Training for Resilience**	Capt. **David Owens**, Senior Director, Flight Crew Training Policy, Airbus	RAeS	PDF		RS
01.09.16, Ort: ZAL	**Corporate Jet Cabin Evolution**	**David Velupillai**, Marketing Director, Airbus Corporate Jets	RAeS	PDF	PDF 8.1 MB	RS
Mittwoch, 19.10.16, 16:00	**ETW – Bis an die Grenzen des Möglichen**	Dr.-Ing. **Guido Dietz**, geschäftsführender Direktor ETW	HAW	PDF		DS
Dienstag, 25.10.16, 19:00	**Inspire Me - Die Zukunft des Fliegens** (Ergebnisse aus der Forschungsgruppe AERO)	Prof. Dr.-Ing. **Dieter Scholz**, HAW Hamburg	HAW	PDF	**Veranstaltungshinweis** auf eine Veranstaltung vom Mercedes me Store Hamburg, Ballindamm 17. Mit der Bitte um Anmeldung.	DS

Praxis-Seminar Luftfahrt

Veranstaltungen im WS 2016/2017

Datum	Thema	Referent	Einladung	Bemerkungen
Mittwoch, 19.10.16, 16:00	**ETW – Bis an die Grenzen des Möglichen**	Dr.-Ing. **Guido Dietz**, geschäftsführender Direktor ETW	PDF	Aerodynamik
Dienstag, 25.10.16, 19:00	**Inspire Me - Die Zukunft des Fliegens** (Ergebnisse aus der Forschungsgruppe AERO)	Prof. Dr.-Ing. **Dieter Scholz**, HAW Hamburg	PDF	Flugzeugentwurf In Kooperation mit dem Mercedes me Store Hamburg, Ballindamm 17. Mit der Bitte um Anmeldung.

http://psl.ProfScholz.de

http://seminar.ProfScholz.de

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Praxis Seminar Luftfahrt

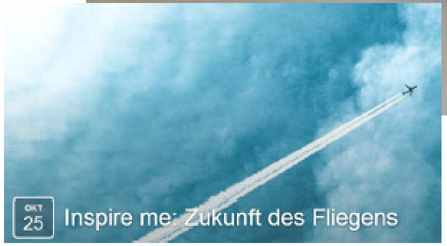
Inspire Me - Die Zukunft des Fliegens
(Ergebnisse aus der Forschungsgruppe AERO)

Prof. Dr.-Ing. Dieter Scholz, HAW Hamburg

Datum: Dienstag, 25. Oktober 2016, 19:00 Uhr
Ort: Mercedes me Store
Ballindamm 17, 20095 Hamburg

Über den Wolken ist die Freiheit grenzenlos(?) – bis Flugzeuge aber überhaupt fliegen konnten, mussten viele Grenzen überwunden und knifflige Fragen geklärt werden. Prof. Dr. Dieter Scholz forscht an der HAW über die Zukunft der boomenden Luftfahrt und nimmt dich an diesem Abend mit auf eine spannende Reise durch die Entwicklung der Fliegerei. Von ersten waghalsigen Versuchen bis hin zu den effizienteren Flugzeugtypen der Gegenwart und Zukunft erfährst du viel über die technischen, energetischen, räumlichen und zeitlichen Herausforderungen. Im Leuchtturmprojekt „Effizienter Flughafen 2030" wurden ökonomischere Konzepte und Lösungen für den steigenden Flugverkehr entwickelt (Bild). Von diesen und anderen Ergebnissen soll berichtet werden. Wer gern gemeinsam mit uns abheben möchte, den laden wir herzlich ein, im Mercedes me Store Hamburg eine möglichst angenehme Sitzposition einzunehmen. (Text: Mercedes me Store)

http://Airport2030.ProfScholz.de



http://www.facebook.com/events/344344675902323

Praxis Seminar Luftfahrt (PSL)	http://seminar.ProfScholz.de
Mercedes me Store	http://www.mercedes-benz.com/de/mercedes-me/store/mercedes-me-store-hamburg
... auf Facebook	http://www.facebook.com/Mercedes.me.Hamburg
Prof. Dr.-Ing. Dieter Scholz	Tel.: (040) 42875 8825 info@ProfScholz.de

Further information / recommended reading:

http://www.ProfScholz.de

http://AERO.ProfScholz.de

http://Airport2030.ProfScholz.de

http://indien.ProfScholz.de

Promising Configurations for Future Passenger Aircraft

3 pages

Dieter Scholz

http://goo.gl/RD6ggK

Abstract A promising aircraft configuration for typical short to medium range would be a turboprop aircraft with large propeller diameter. The concept can benefit further from a strut braced wing and natural laminar flow. Most important for an efficient aircraft design is a high aspect ratio. For a given span (limits at airports need to be observed) the effective aspect ratio can be increased with winglets or folding wings. Much better would be to offer wing tip extensions to standard aircraft, accepting the next larger ICAO wing span category for some aircraft in the fleet. Electric flight on batteries is not the answer due to severe range limitations. Regenerative energy could be converted to hydrogen with electrolysis and stored as liquid hydrogen (LH2) in a stretched fuselage with hydrogen tanks installed in front and aft of the cabin. Research is on the way to directly convert (regenerative electrical) energy to hydrocarbons. Such synthetic fuel could be used even in older aircraft offering a fast improvement for the environment.