Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Vortrag für
DGLR / VDI / RAeS / HAW

Die Blended Wing Body (BWB) Flugzeugkonfiguration

28.09.2006

Prof. Dr.-Ing. Dieter Scholz, MSME

https://doi.org/10.5281/zenodo.6515774

Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

Lecture for
DGLR / VDI / RAeS / HAW

The Blended Wing Body (BWB) Aircraft Configuration

2006-09-26

Prof. Dr.-Ing. Dieter Scholz, MSME

Contents

Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

Acknowledgement

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Data for this presentation
was obtained from:

Internet
Literature
Diplomarbeiten / Master Thesis
Team Effort at HAW
Airbus
Personal Communication

Note:
This file contains only a selection of
presented information that was
considered suitable for public release.

Introduction

BWB Definition

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

http://en.wikipedia.org/wiki/Blended_Wing_Body

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.

Strategic Targets

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

http://www.acare4europe.org

Vision 2020 (January 2001)

ACARE (Advisory Council for Aeronautics Research in Europe)
October 2002 : The Strategic Research Agenda (SRA-1) — 5 Challenges

- Quality and Affordability
- Environment
- Safety
- Air Transport System Efficiency
- Security

October 2004 : The SRA-2 — 6 High level Target Concepts

- **Very Low Cost ATS**
- **Ultra Green ATS**
- **Highly Customer oriented ATS**
- **Highly time-efficient ATS**
- **Ultra Secure ATS**
- **22nd Century**

To meet Society's needs

To achieve global leadership for Europe

Strategic Targets

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Vision 2020 (January 2001)

Punctuality: 99% of all flights arriving and departing within 15 minutes of the published timetable, in all weather conditions.

Time spent in airports: no more than 15 minutes in the airport before departure and after arrival for short-haul flights, and 30 minutes for long haul.

Aircraft will achieve a five-fold reduction in the average accident rate of global operators.

A reduction in perceived noise to one half of current average levels.

A 50% cut in CO_2 emissions per pax-km (which means a 50% cut in fuel consumption) and an 80% cut in nitrogen oxide emissions.

An air traffic management system that can handle 16 million flights ... in European air space.

Potential Advantages

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

BWB target advantages compared to todays advanced aircraft

(from different internet sources)

reduction in weight :	10 to 15% less per pax
better L/D :	20 to 25% better
reduction in fuel consumption :	30% less than today
reduction in emissions :	NOX down 17%
reduction in noise :	only with engines on top
increase of airport capacity :	more than 750 pax per A/C
reduction in DOC :	down 12%

DOC: Direct Operating Costs

Square-Cube-Law

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

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

Square-Cube-Law

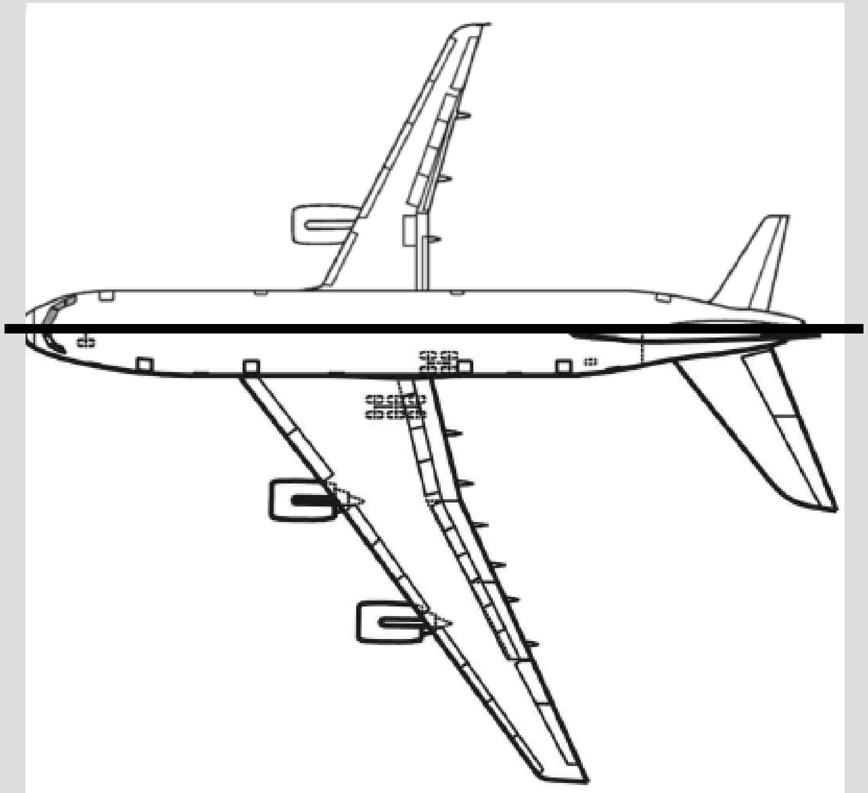
Hochschule für Angewandte Wissenschaften Hamburg

Hamburg University of Applied Sciences

The BWB configuration is favoured for ultra large aircraft.

Why does physics demand a BWB?

$$S_W \propto l^3$$



A321 scaled to the same size as the A380.

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

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

Aircraft even bigger => BWB

BWB Projects

BWB Projects

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

http://www.aircrash.org/burnelli/ch_rb1.htm

Burnelli RB-1: Lifting Body and Wings

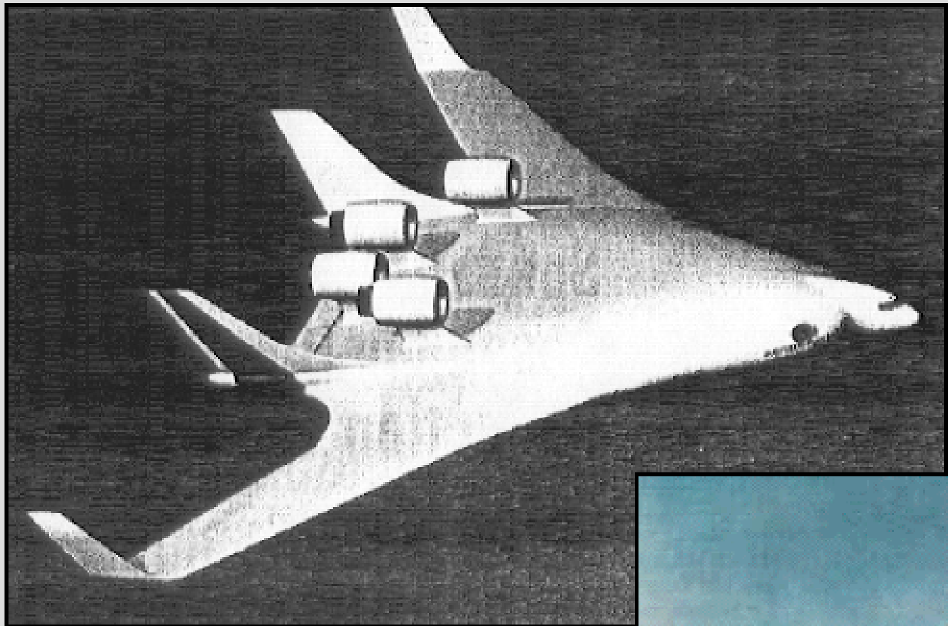
1921 - Long Island, NY
Burnelli RB-1 -- the first lifting-body reduced to practice.

In 1921 pioneering aviator and aircraft designer Vincent Justus Burnelli patented the concept of an airfoil shaped airframe to increase the lift and load capacity of aircraft.

Burnelli RB-1 interior (half)

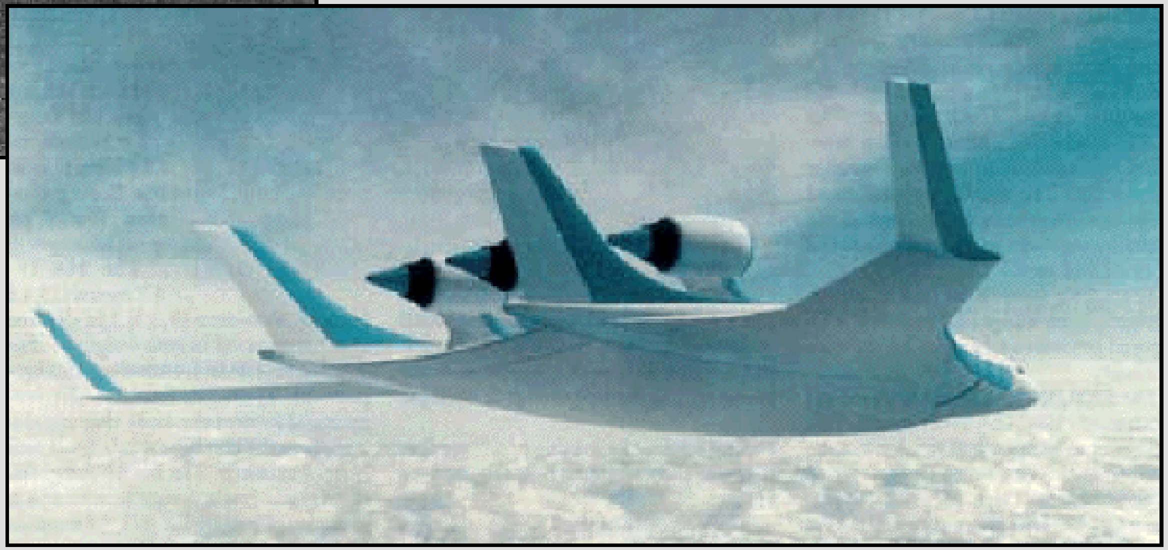
BWB Projects

Aerospatiale "Megajet"



Design study,1995:
1000 seats,
range 6450 NM,
span 96 m,
cruise at Mach 0.85.

Aviation Week, Aug. 7, 1995 pp.33
http://aero.stanford.edu/bwbfiles/AerospatialeBWB.html



S. Lee, Diplomarbeit,
Hamburg University of Applied Sciences

MDC, NASA, Stanford: BWB-17

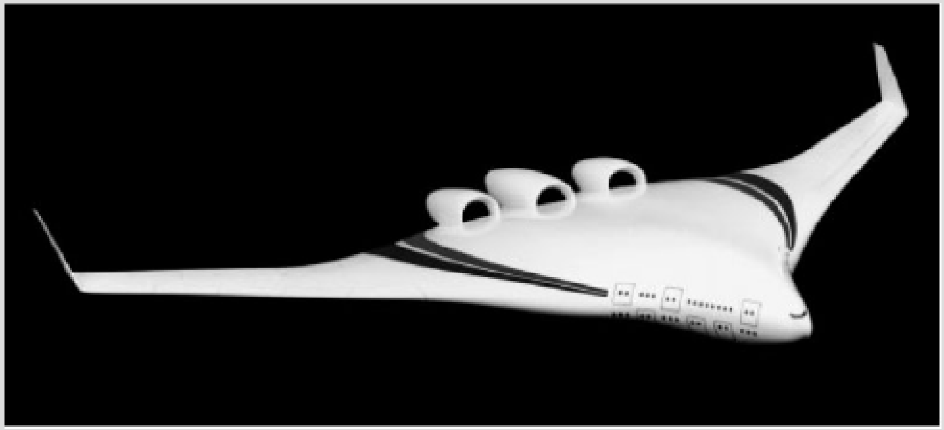
1997:
McDonnell Douglas (R. Liebeck),
NASA,
Stanford (Ilan Kroo), et. al.

17 ft span
radio controlled model aircraft

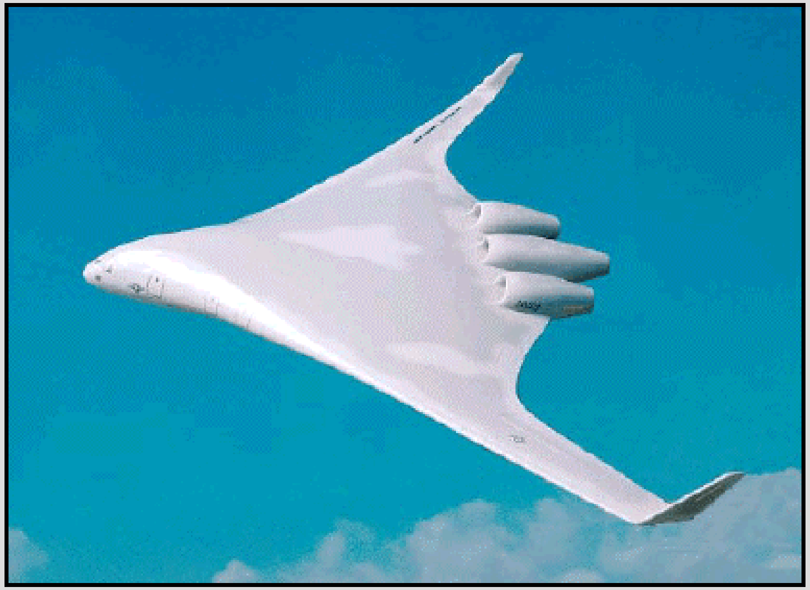
http://aero.stanford.edu/~frl/bwb/BWBProject.html
http://www.boeing.com/news/releases/mdc/97-158.html

NASA CR-2003-212670

Boeing BWB-450



Blended Wing Body systems studies based on BWB-450 as part of the programme Ultra Efficient Engine Technology (UEET): Boundary Layer Ingestion (BLI) inlets with Active Flow Control (AFC).



http://en.wikipedia.org/wiki/Boeing_X-48

Boeing X-48

Boeing; NASA; Old Dominion University, Norfolk, Va:

2001	construction started
2002	completion
2003	integration and ground tests
2004	wind tunnel tests
2004	flight test was planned with max. 165 mph at 10000 ft.
	no flight test results reported!

35 ft span wind tunnel and flight test model
(called BWB-LSV; low speed vehicle).

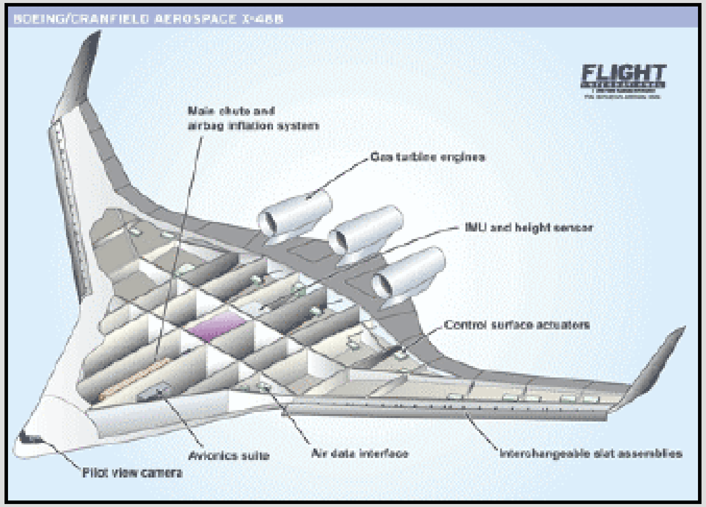
Original:
450 seats
span 250 ft = 76.2 m

BWB Projects

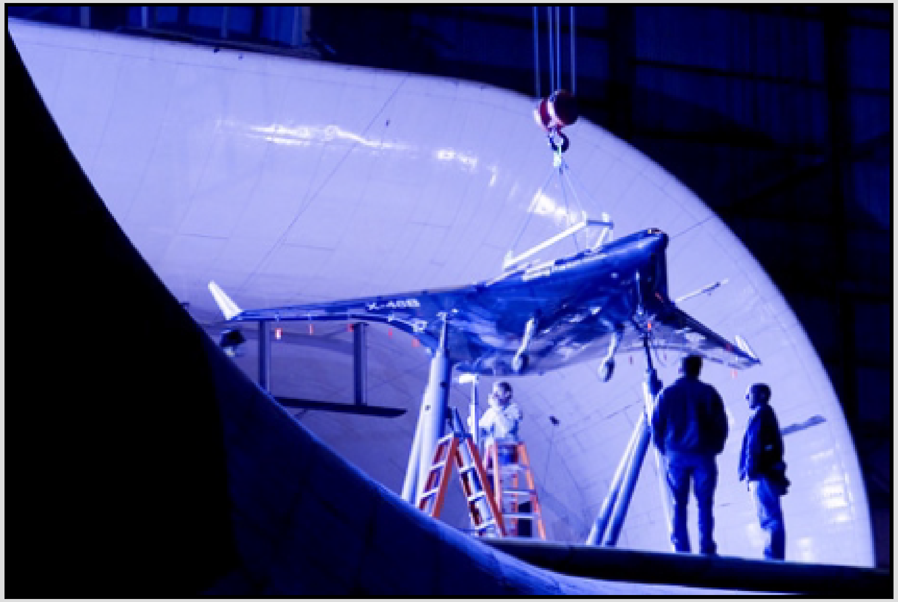
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Boeing X-48B

http://en.wikipedia.org/wiki/Boeing_X-48
Flight International, 30/05/06



__2006__: Boeing, NASA, U.S. Air Force. 21 ft span wind tunnel and flight test model. Two X-48B are built. Original: 450 seats, range 7000 NM, span 75.3 m, cruise: high subsonic.



BWB Projects

Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

Boeing X-48B - tanker

Air Force
Research Laboratory
(AFRL)

Boeing X-48B - tanker

X-48B prototypes were built for Boeing Phantom Works by Cranfield Aerospace Ltd.

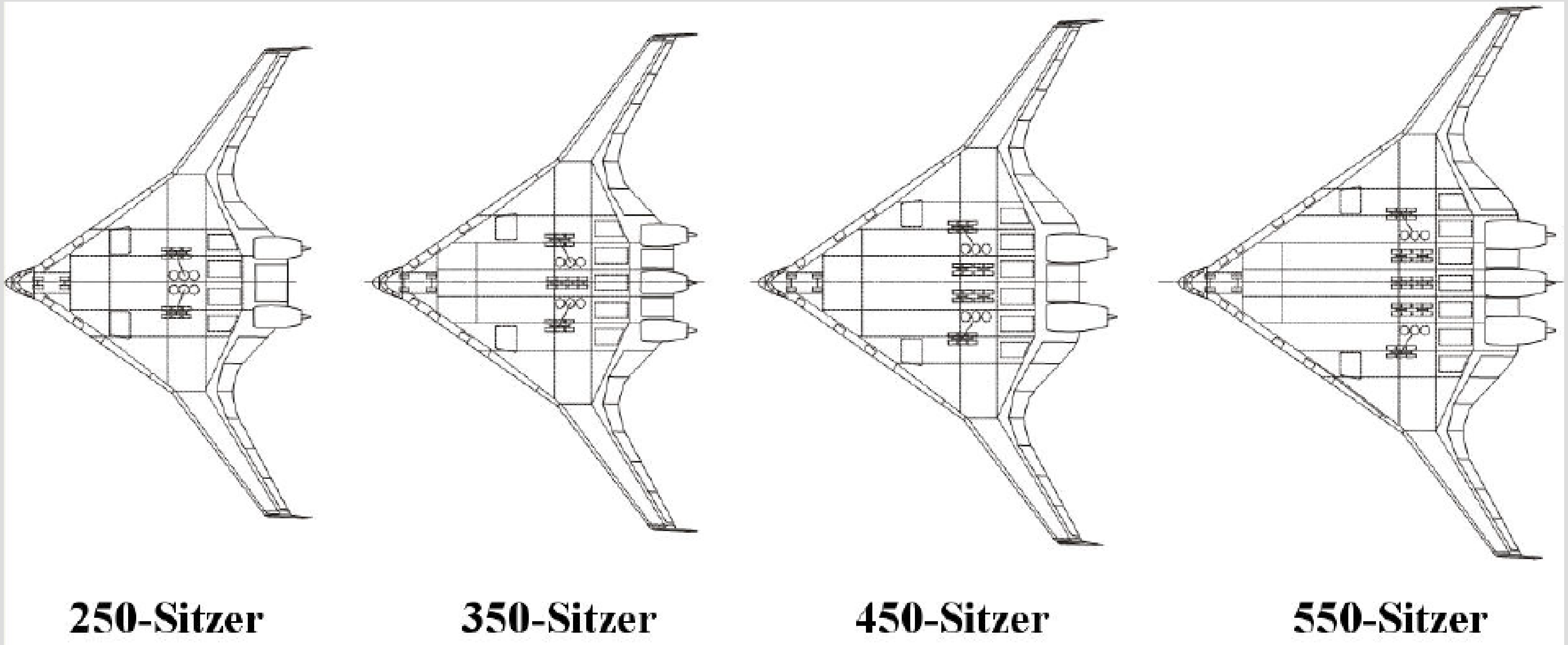
The X-48B prototypes have been dynamically scaled to represent a much larger aircraft.

BWB Projects

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

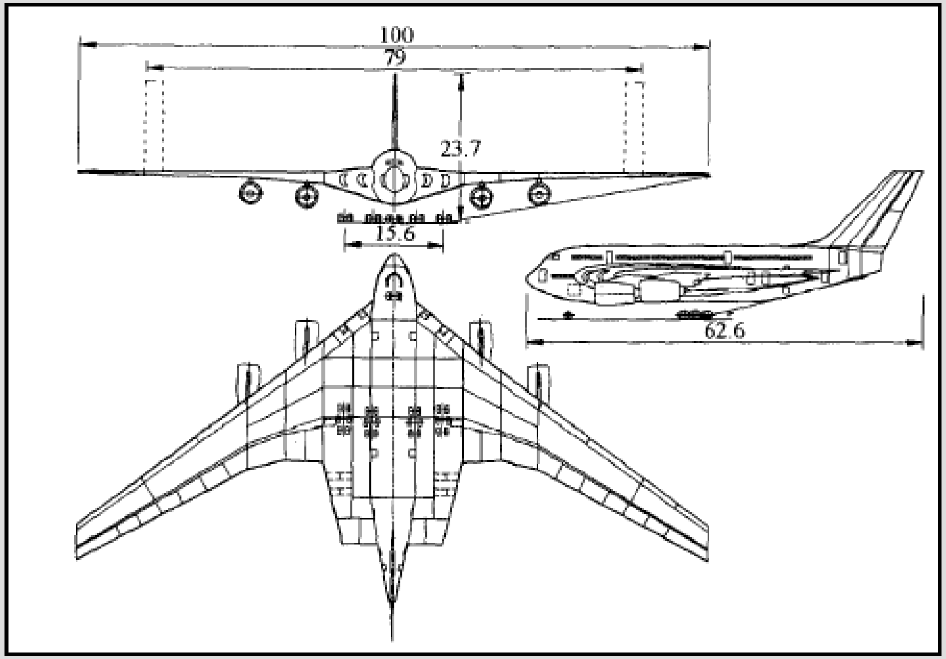
Boeing BWB-250 ... BWB-550

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!

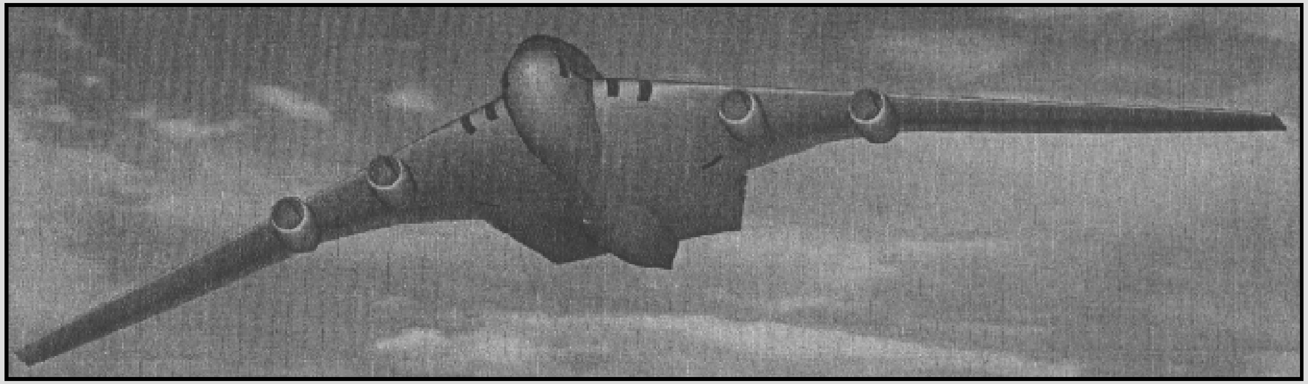
TsAGI (Russia) Integrated Wing Body (IWB)



Best configuration from comparison of four New Large Aircraft configurations based on VELA specification.

Research sponsored by AIRBUS INDUSTRIE

AIRCRAFT DESIGN, Vol 4 (2001)



BWB Projects

5th Framework Programme of the European Commision: VELA and MOB

1999 - 2002

17 partners: D, F, UK, E, I, NL, CZ, P

Very Efficient Large Aircraft (VELA)

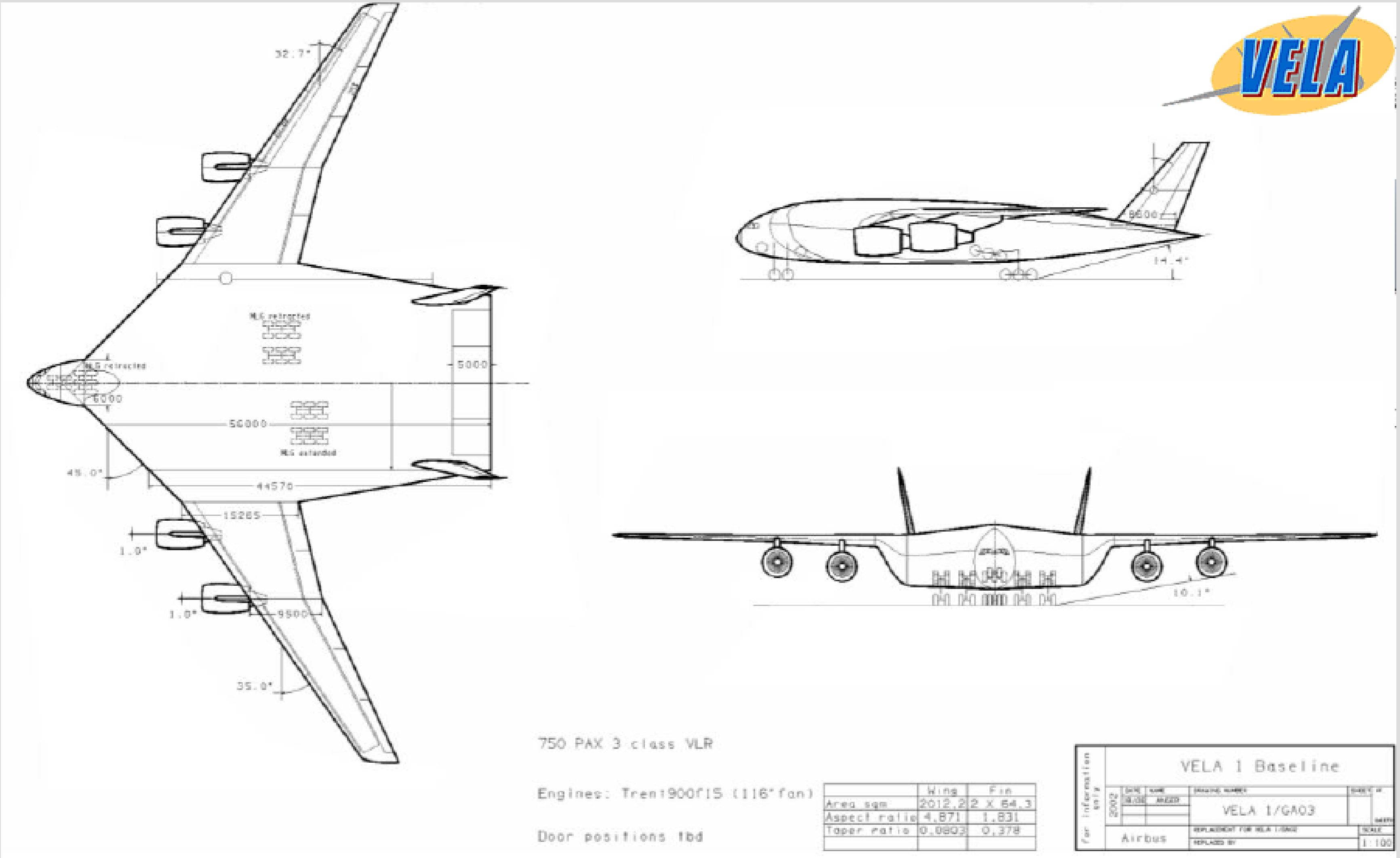
Three datum configurations for a flying wing (VELA 1, VELA 2 and VELA 3).
A first step in a long-term work plan was followed by further research work.
Passenger-carrying aircraft.

Multidisciplinary Optimisation of a BWB (MOB)
Freighter version.

BWB Projects

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

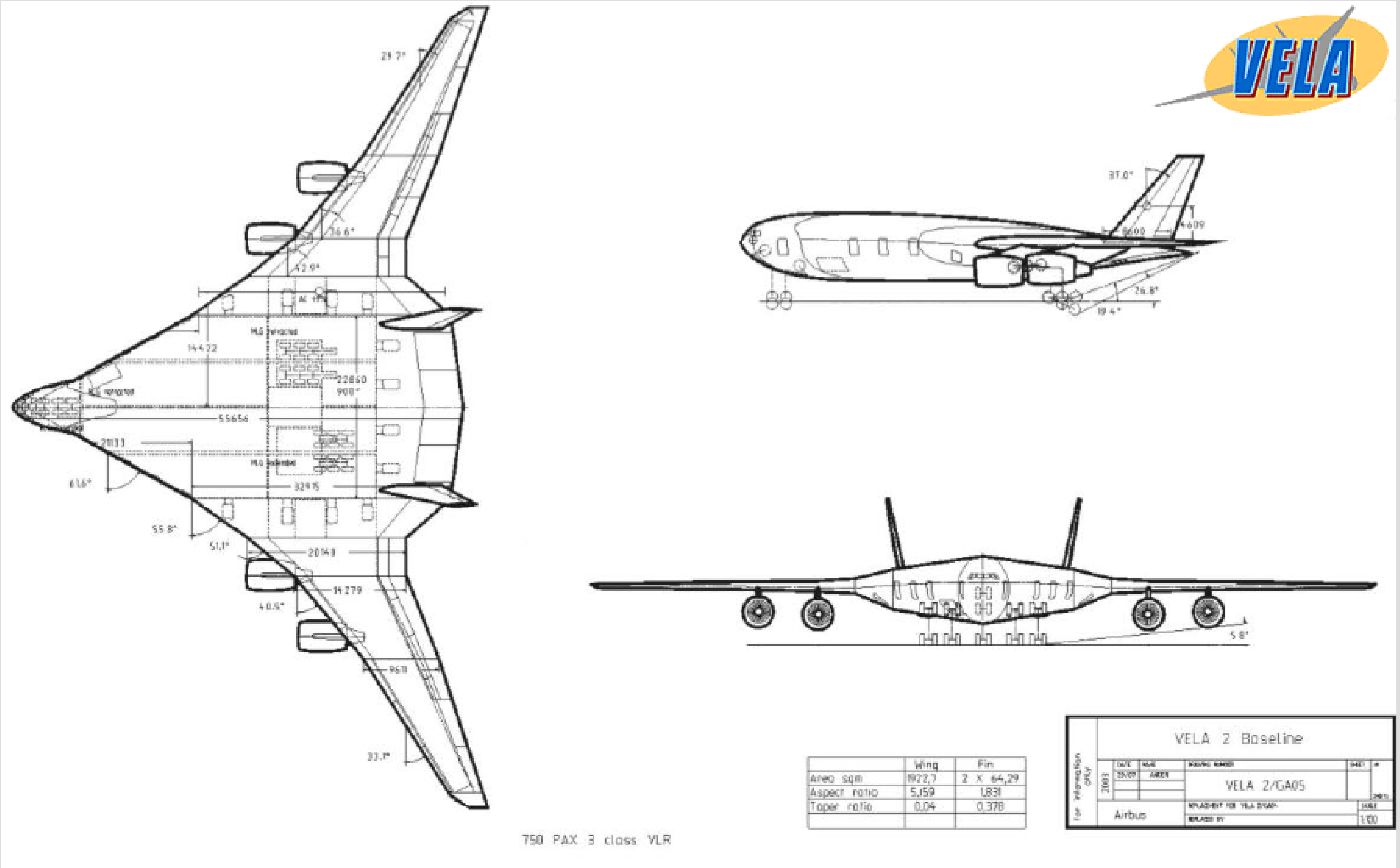
VELA 1



BWB Projects

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 2

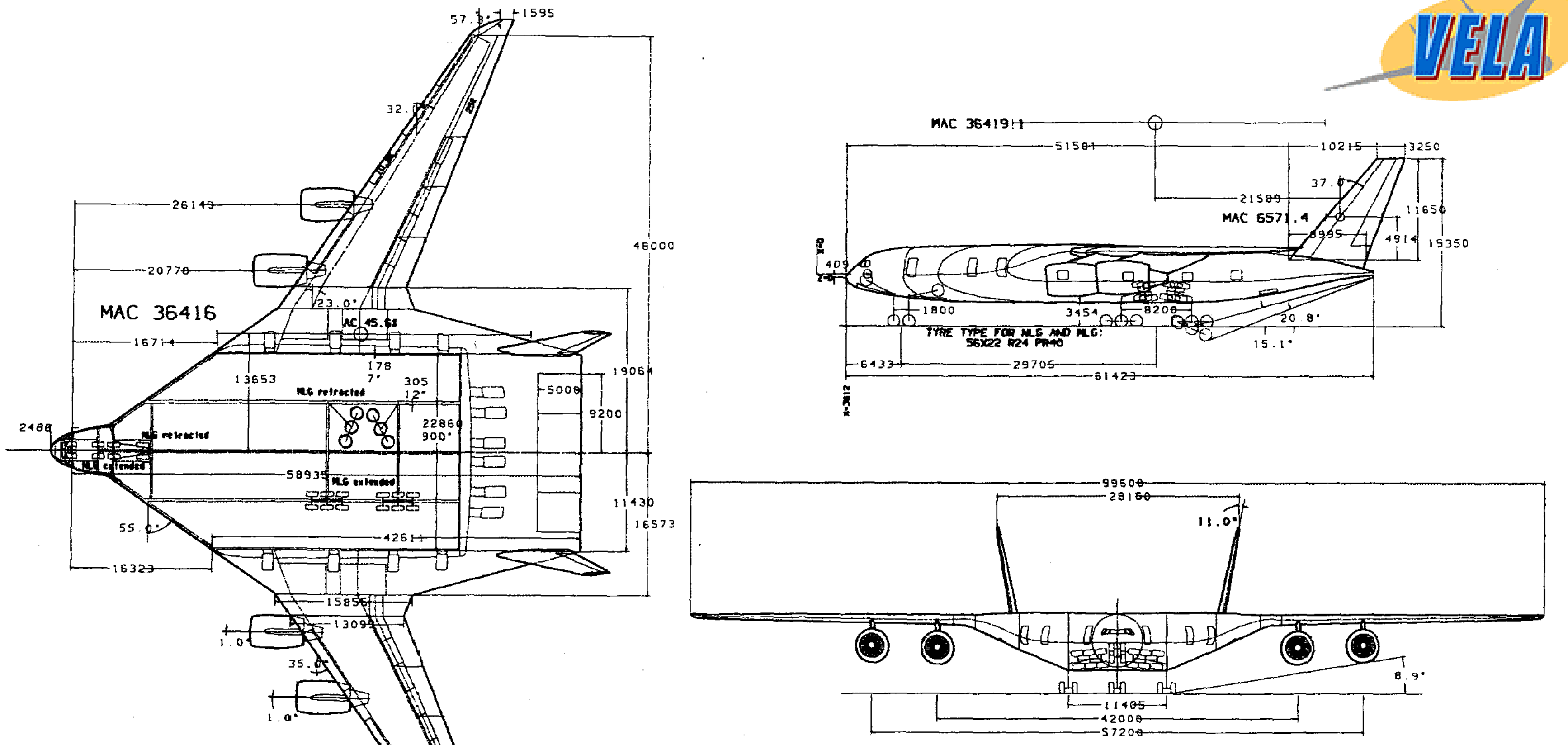


	Wing	Fin
Area sqm	1922,7	2 X 64,29
Aspect ratio	5,159	1,831
Taper ratio	0,04	0,378

BWB Projects

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 3



Engines: Trent900f15 (116"fan)

	Wing	Fin
Area sqm	2052	2 X 71.32
Aspect ratio	4.834	1.903
Taper ratio	0.242	0.361

for information only

Vela 3 - Baseline

2005 · Airbus · Vela 3 GA01 · 1:100

750 PAX 3 class VLR

BWB Projects

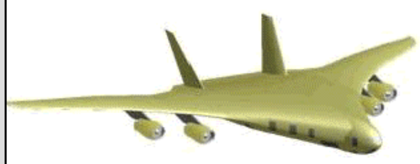
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

6th Framework Programme of the European Commision: NACRE with PDA

SIXTH FRAMEWORK PROGRAMME

2003 - 2006

WP3:	Payload Driven Aircraft (also: VELA 3 continued)
WP4:	Flying scale model for novel aircraft configuration



Payload Driven Aircraft (PDA)

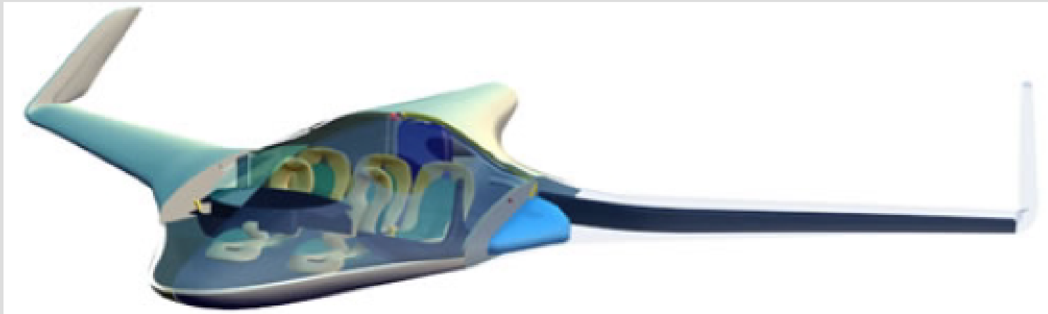
National: LuFo III, K2020

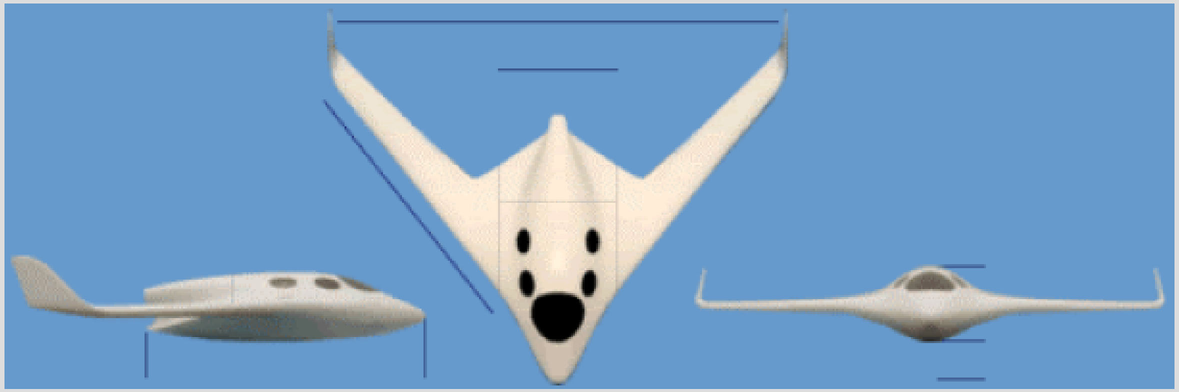
BWB (VELA 2) der Uni Stuttgart

http://www.wingco.com/atlantica_design.htm

Atlantica
Blended Wing & Body - Five Place Simplebuild™

Seats:	5
Span:	8.53 m
Range:	1800 NM
Max. Cruise Speed:	240 kt (TAS)
MTOW:	1134 kg
Power:	175 kW

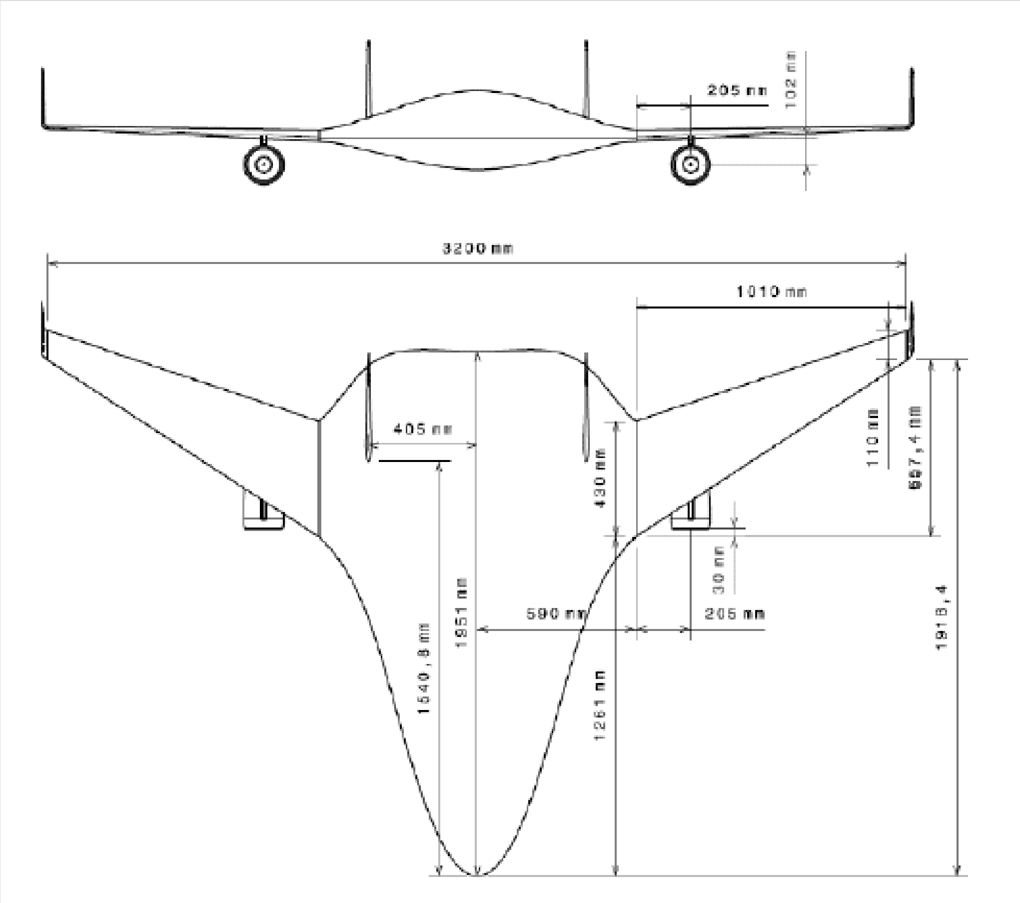




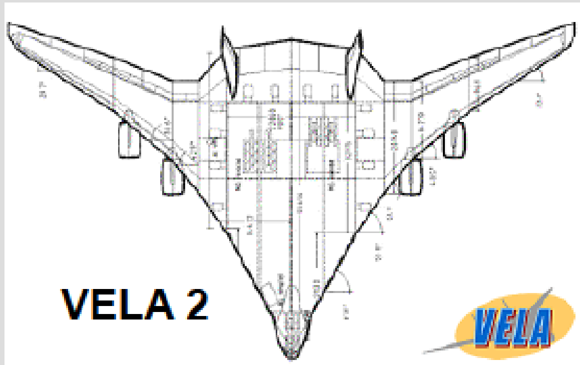
BWB Projects

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

HAW Student Project: AC 20.30



Wing profile: MH-45
(Martin Hepperle)
t/c = 9.85%,
low drag, improved max. lift,
low $c_{m,\ c/4}$,
proven even at Reynolds
numbers below 200000.
Body profile: MH-91.



AC 20.30: geometry is based on VELA 2; student project; sponsor: "Förderkreis"

Aeronautical Disciplines

Input Parameters for Preliminary Sizing

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

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

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

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

$$\overline{c_f} = 0.003$$

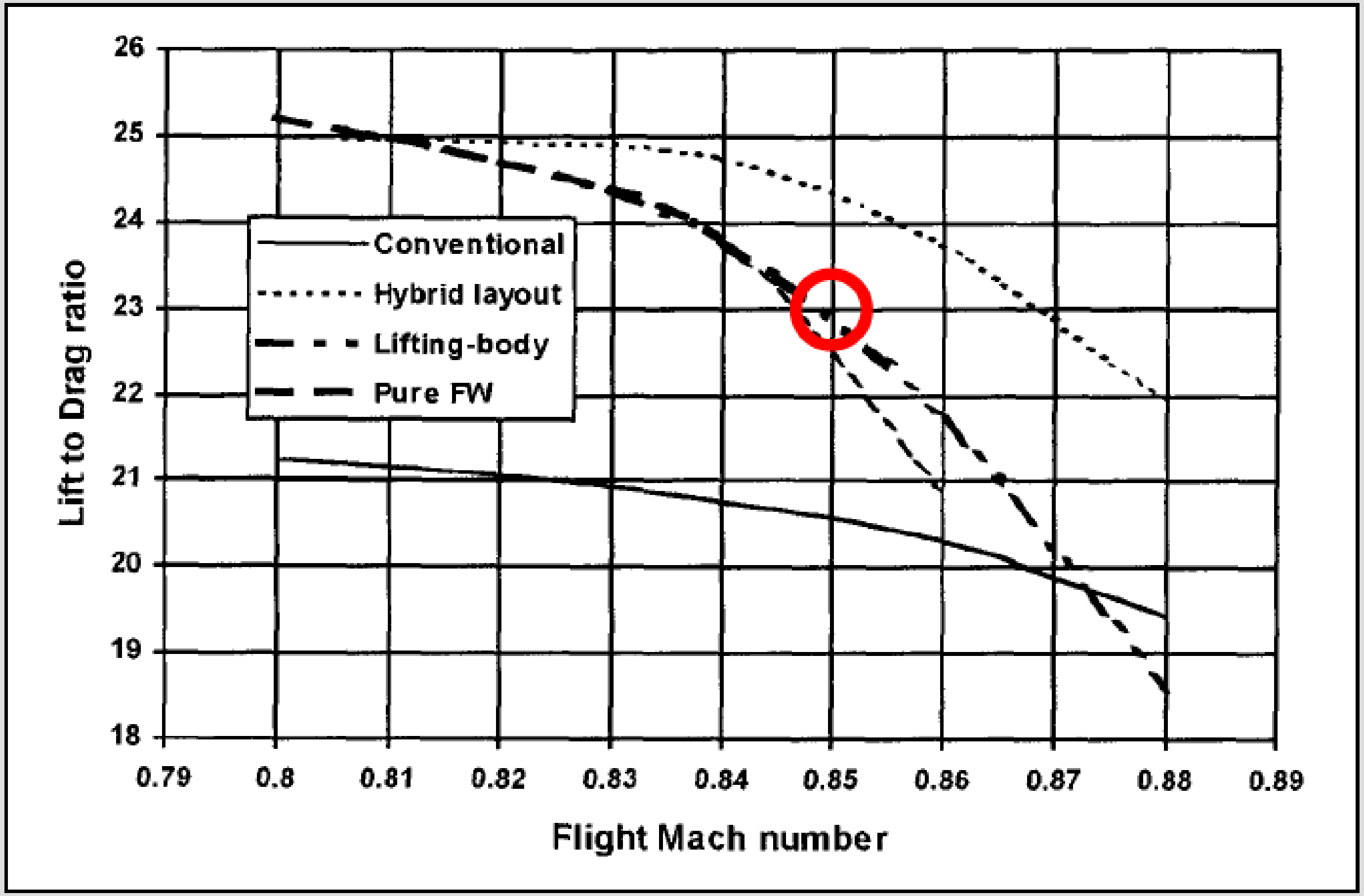
from statistics: $k_E = 15{,}8$

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

$E_{max} = 23{,}2$

Input Parameters for Preliminary Sizing

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



TsAGI for AIRBUS (AIRCRAFT DESIGN, Vol 4 (2001)

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Input Parameters for Preliminary Sizing

H. Zingel

Estimation of maximum lift coefficient take-off and landing

$$C_{L,max} = C_{L,0} + \frac{\partial C_L}{\partial \alpha}\alpha + \frac{\partial C_L}{\partial \eta_W}\eta_W + \frac{\partial C_L}{\partial \eta_B}\eta_B$$ **= 0.73**

Wind tunnel measurements of AC 20.30:

$C_{L,0}$ **= 0**

$\frac{\partial C_L}{\partial \alpha}$ **= 2,5**

α **= 12 °**

$\frac{\partial C_L}{\partial \eta_W}$ **= 0.22**

η_W **= 18 °**

$\frac{\partial C_L}{\partial \eta_B}$ **= 0.43**

η_B **= 18 °**

VELA Technical Data

VELA

Requirements:

3-class seating: 750 pax (22 / 136 / 592)

cargo capacity > 10 t

range: 7500 NM (200 NM to alternate, 30 min. holding, 5% trip fuel allowance)

high desity seating: 1040 pax

cruise Mach number: 0.85

M_{MO} : 0.89

take-off field length < 3350 m (MTOW, SL, ISA +15°C)

approach speed < 145 kt (here: approach speed = 165 kt)

ICA (300 ft/min, max. climb) > 35000 ft

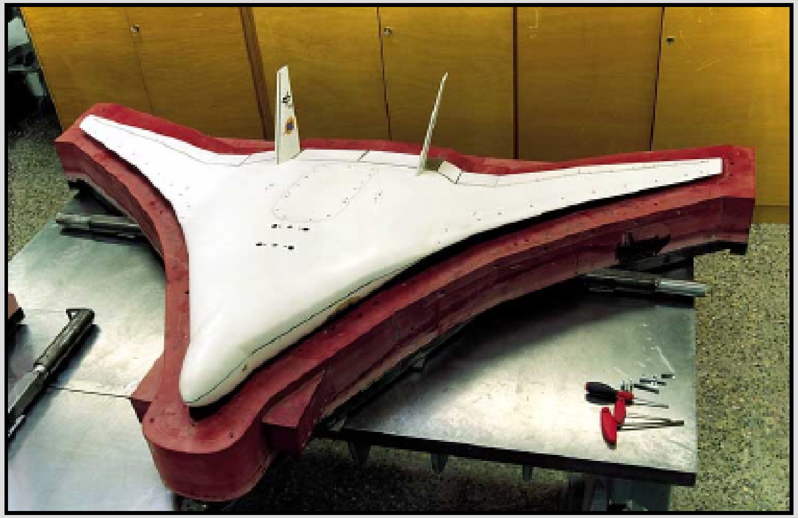
time to ICA (ISA) < 30 min.

max. operating altitude > 45000 ft (=> cabin Δp)

runway loading (ACN, Flex. B) < 70

span < 100 m

wheel spacing < 16 m



VELA 2 Sizing Study at HAW

Assumptions:

OEW / MTOW = 0,5	LOFTIN: 0,52 A380: 0,49 VELA 2: 0.55 → 0.48
SFC = 1.4 mg/(Ns)	latest technology assumed (GEnx)
approach speed = 165 kt	
mass of pax and luggage	for long distance flying: 97.5 kg per pax

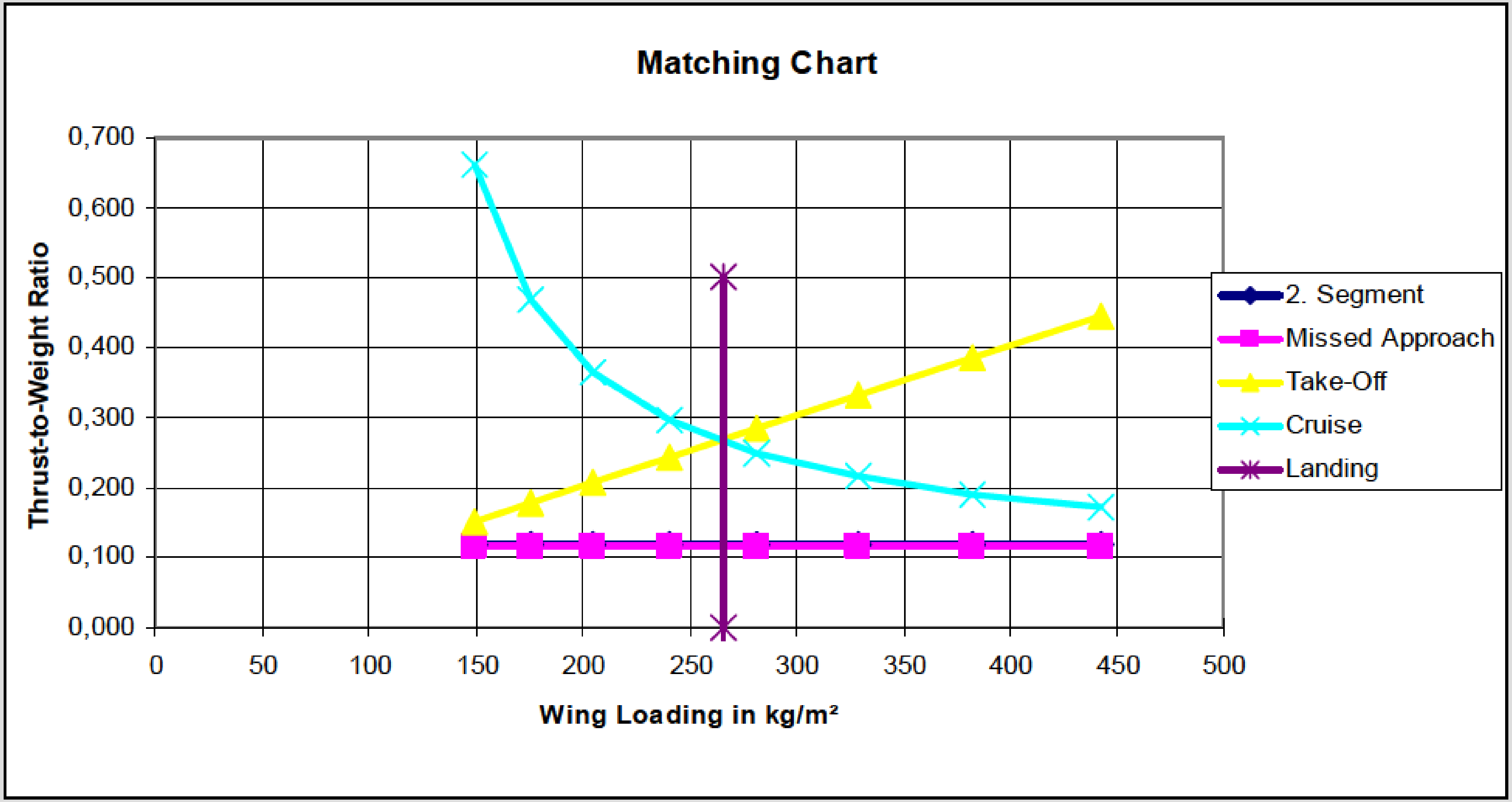
Given:

Wing Area:	1923 m²

Preliminary Sizing

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 2 Sizing Study at HAW



VELA 2 Sizing Study at HAW

Sizing Results:

L/D during 2. segment: 17.0 (higher than conv. due to small lift coefficient and small drag).
L/D during missed approach: 11.0 (normal, because landing gear drag dominates, FAR!)
V / V_{md} = 1.09 (normal: V / V_{md} = 1.0 ... 1.316) => E = 22.8
lift coefficient cruise: 0.25
trust to weight ratio: 0.28 (value is slightly high for 4-engined A/C, reason: TOFL and C_L)
wing loading: 260 kg/m² (very low for passenger transport, due to low lift coefficient)
Initial Cruise Altitude (ICA): 38400 ft (= 11.7 km)

payload:	83000 kg	
MTOW:	501000 kg	(VELA 2: 691200 kg)
Wing Area:	1923 m²	(VELA 2: 1923 m² - forced to fit)
MLW:	366000 kg	
OEW:	251000 kg	(VELA 2: 380600 kg)
Fuel:	167000 kg	(VELA 2: 278200 kg ?)
Thrust:	344 kN	(for each of the four engines)

VELA 3 Sizing Study at HAW

Assumptions:

OEW / MTOW = 0,5	LOFTIN: 0,52 (T/W) A380: 0,49 BWB structural benefits?
SFC = 1.6 mg/(Ns)	normal technology level assumed
approach speed = 165 kt	
Reserves:	200 NM to alternate, 30 min. holding, 5% trip fuel allowance

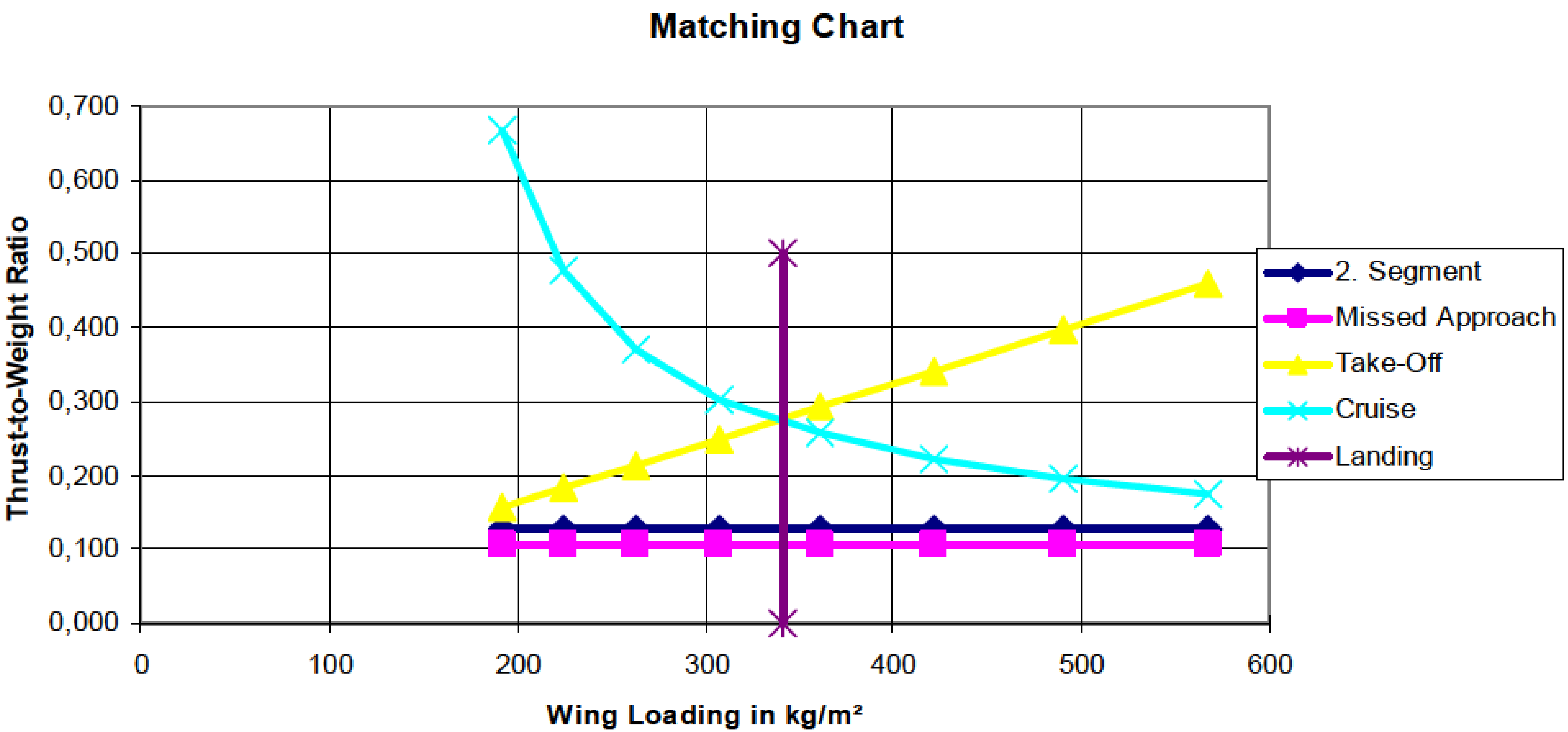
Given:

range:	7650 NM
MTOW:	700000 kg
Wing Area:	2052 m²
Wing Loading:	341 kg/m² (very low for pass. transp. due to low lift coeff.)
mass of pax and luggage:	95.0 kg per pax
payload:	71250 kg

Preliminary Sizing

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 3 Sizing Study at HAW



VELA 3 Sizing Study at HAW

Sizing Results:

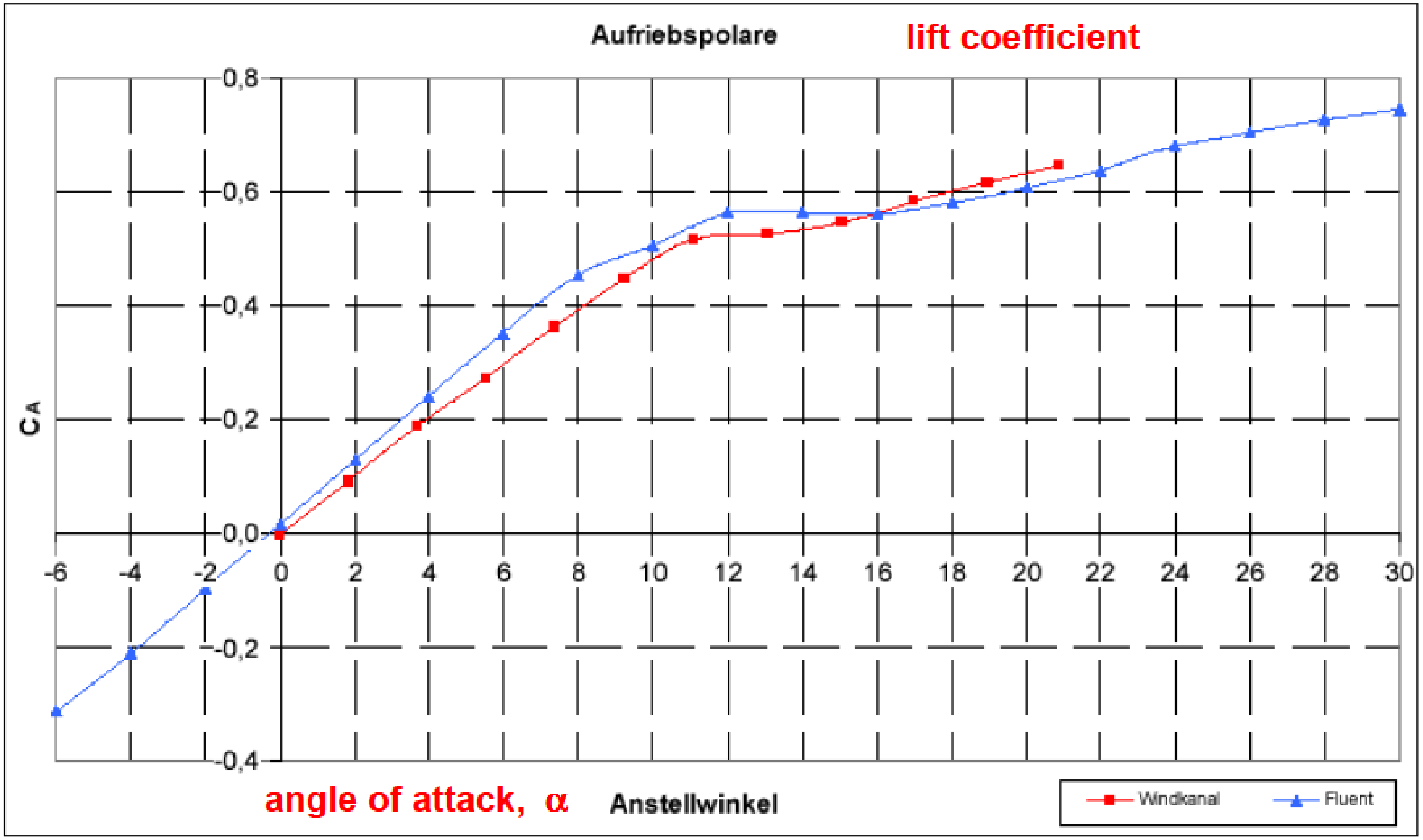
lift coefficient landing: 0.86 (higher than HAW wind tunnel results)
L/D during 2. segment: 15.2 (higher than conv. due to small lift coefficient and small drag)
L/D during missed approach: 11.0 (normal, because landing gear drag dominates, FAR!)
L/D_{max} : 20.9 (lower than BWB estimate)
V / V_{md} = 1.0 => $L/D = L/D_{\mathrm{max}}$ (normal: V / V_{md} = 1.0 ... 1.316)
lift coefficient cruise: 0.31
trust to weight ratio: 0.28 (value is slightly high for 4-engined A/C, reason: TOFL and C_L)
Initial Cruise Altitude (ICA): 37800 ft (= 11.7 km)
MLW: 469000 kg
OEW: 350000 kg
Fuel: 279000 kg (VELA 3: 282800 kg)
Thrust: 481 kN (for each of the four engines)

Aerodynamics

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AC20.30: CFD with FLUENT

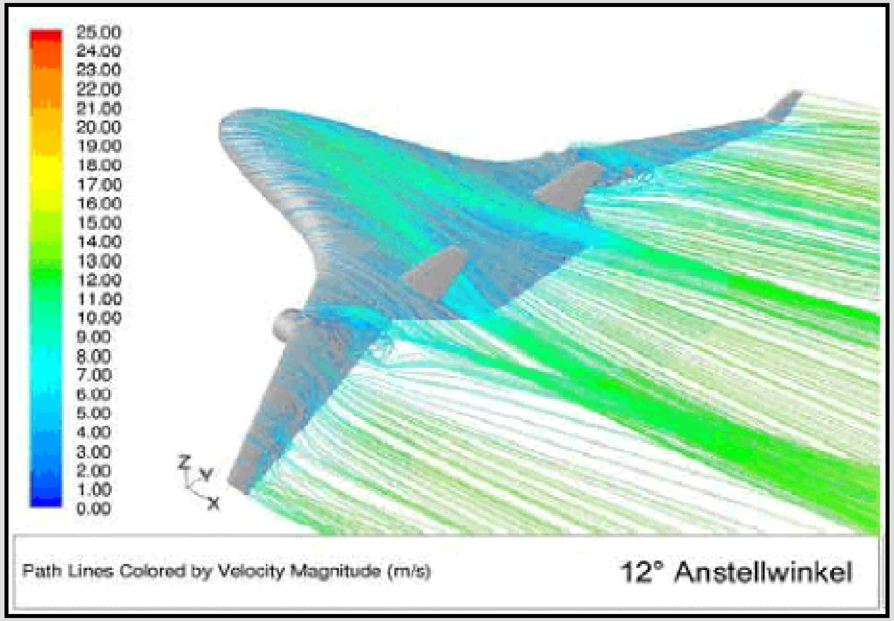
H. Brunswig, Diplomarbeit,
Hamburg University of Applied Sciences



Aerodynamics

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

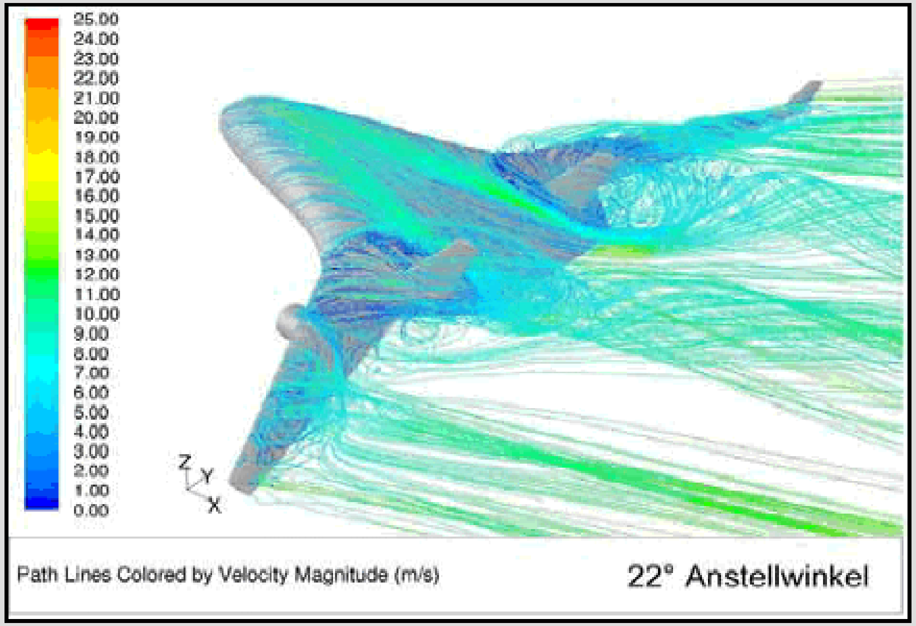
AC20.30: CFD with FLUENT



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

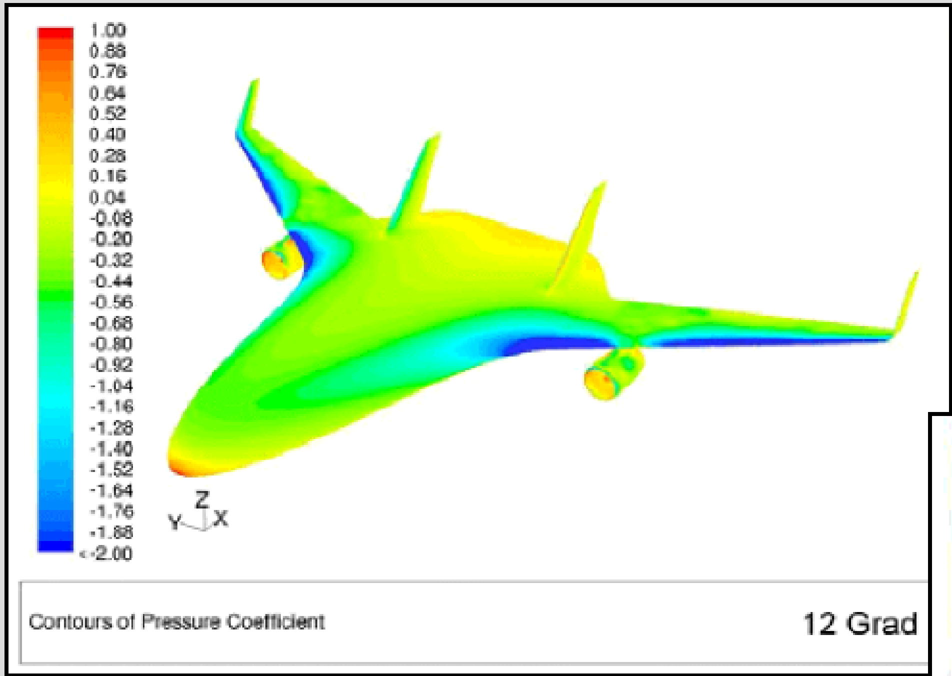
path lines



Aerodynamics

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AC20.30: CFD with FLUENT

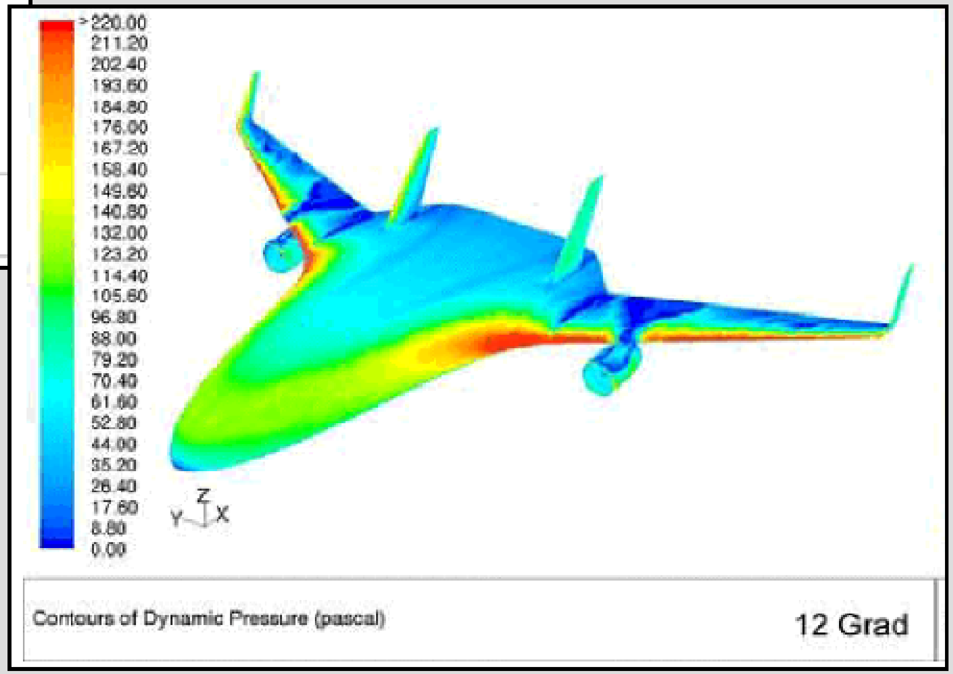


$$q = \frac{1}{2}\rho V^2$$

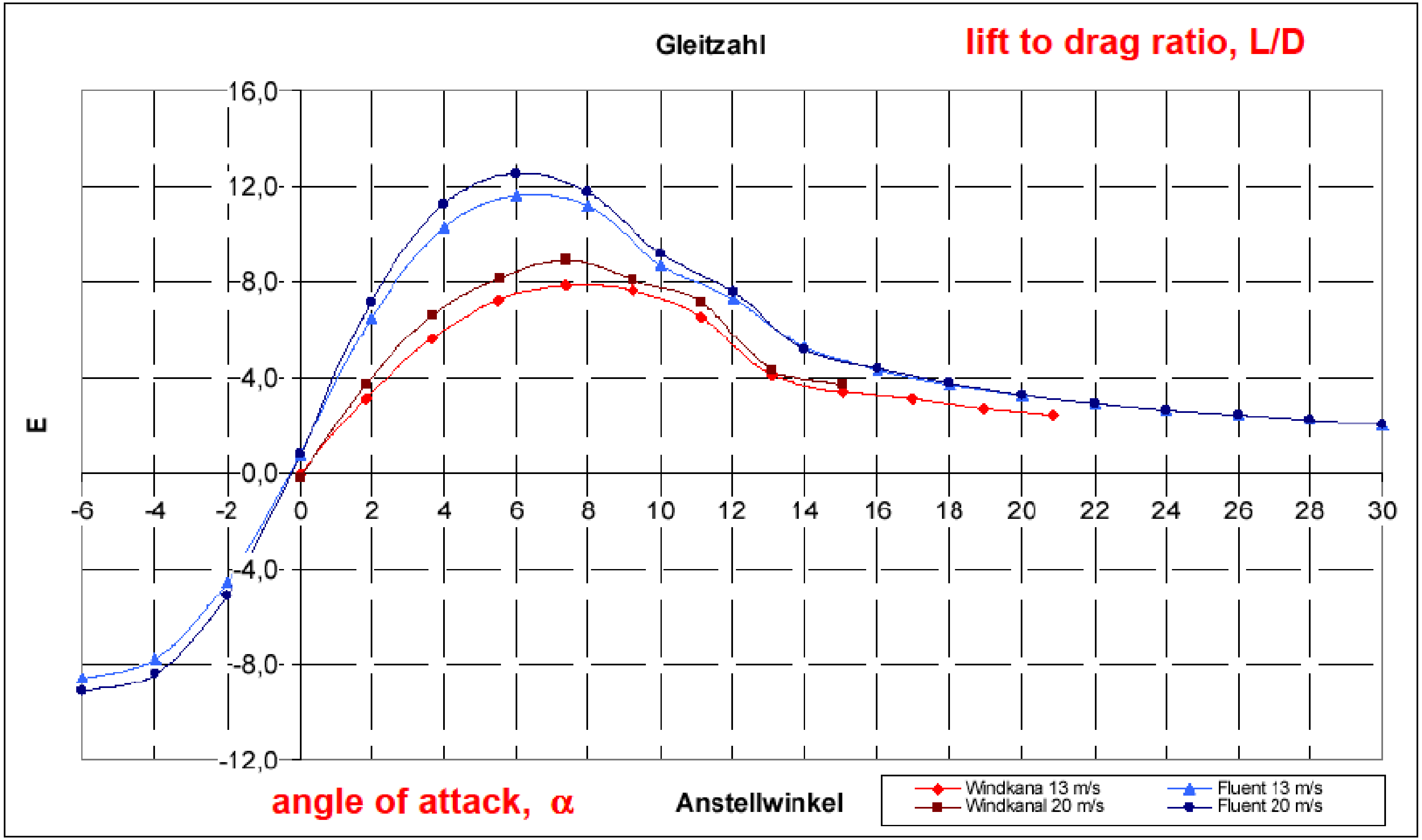
dynamic pressure

pressure coefficient

$$c_p = \frac{p - p_\infty}{q} = 1 - \left(\frac{V}{V_\infty}\right)^2$$



AC20.30: CFD with FLUENT

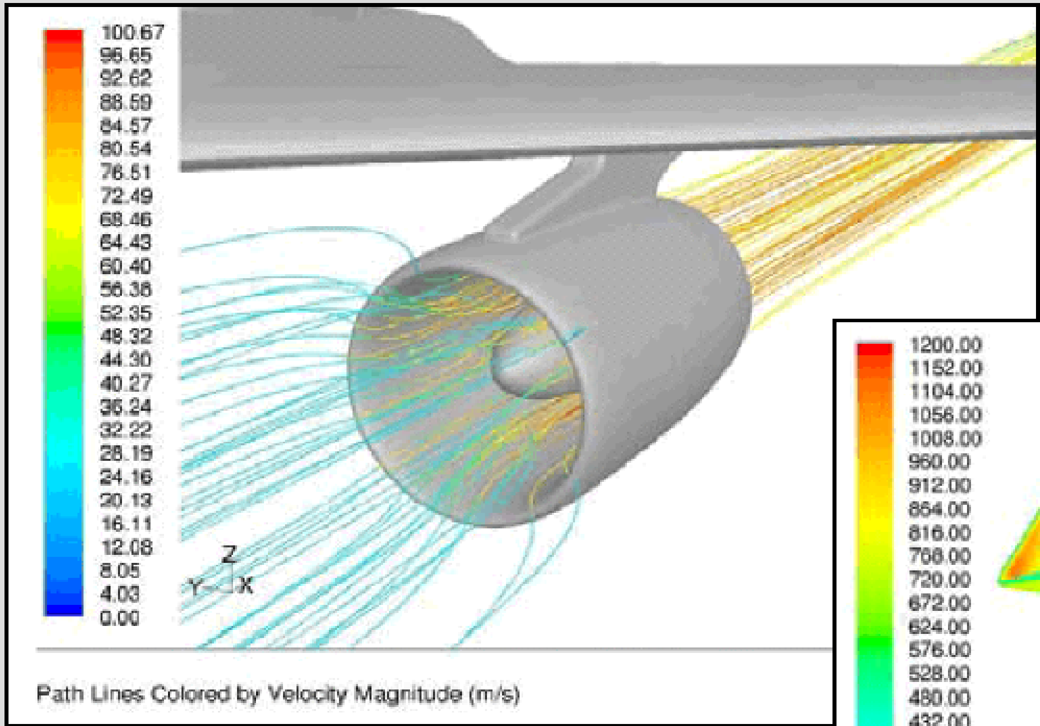


Aerodynamics

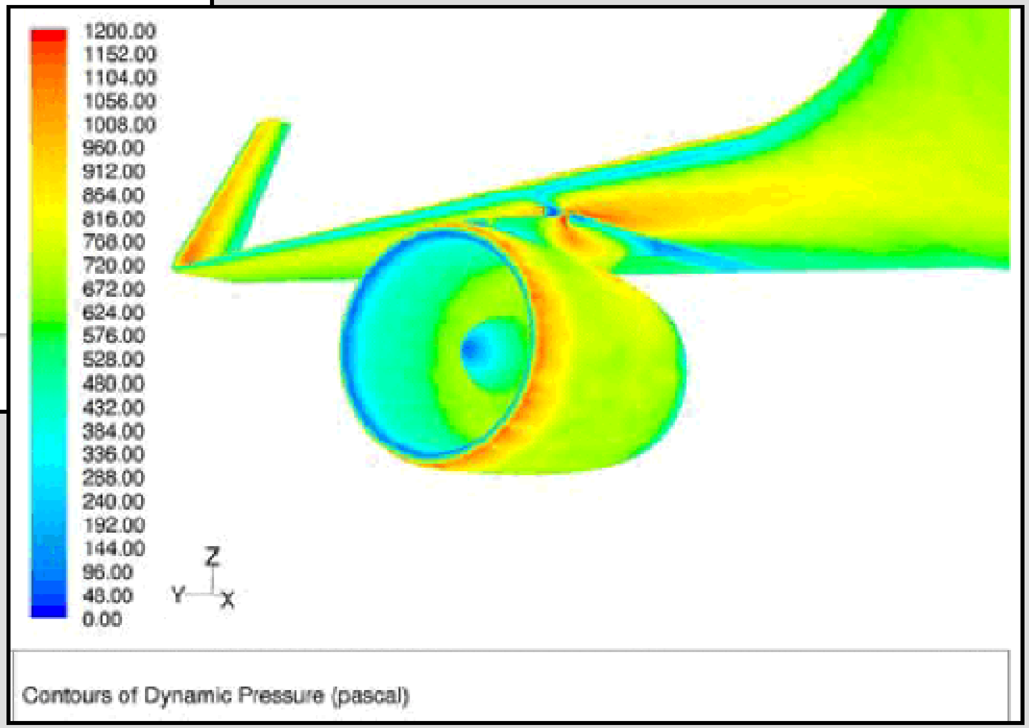
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AC20.30: CFD with FLUENT

Engine Integration

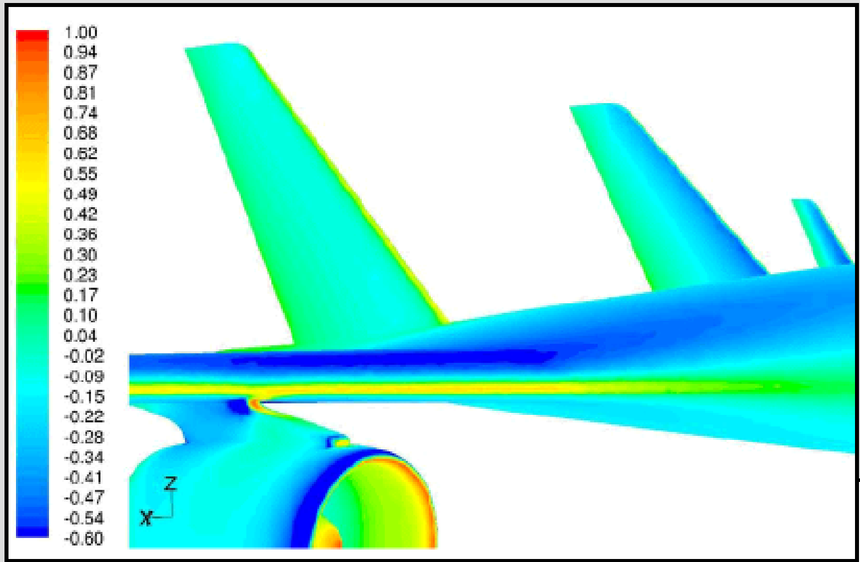


Path Lines Colored by Velocity Magnitude (m/s)



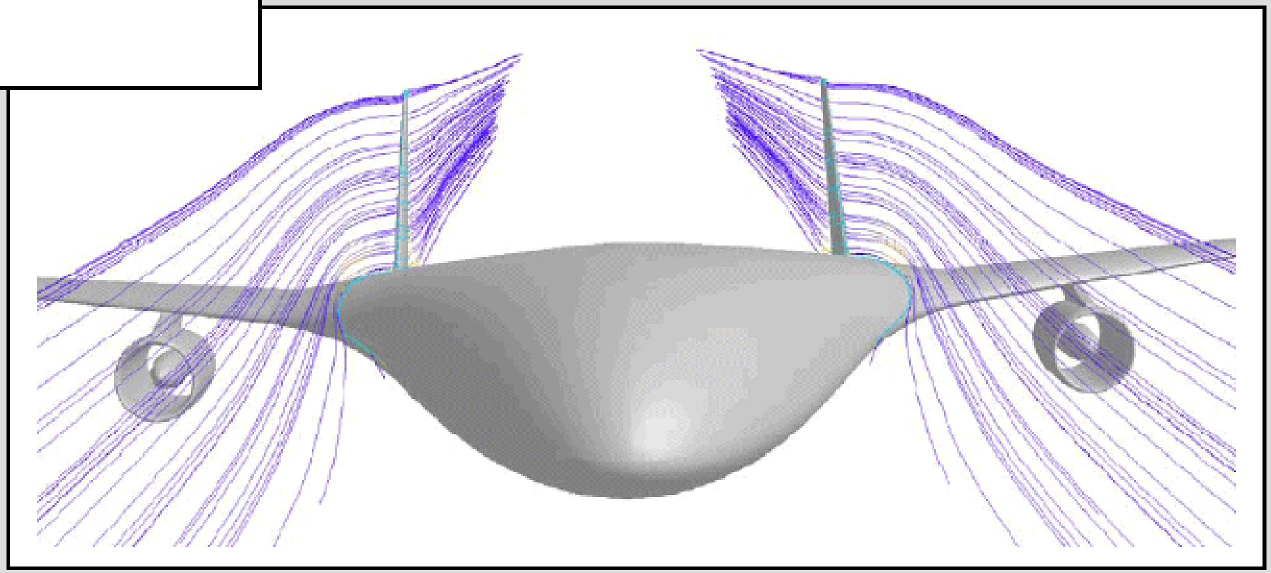
Contours of Dynamic Pressure (pascal)

AC20.30: CFD with FLUENT



Fin Integration:

The fins experience a cross flow at an angle of 3° ... 5°. An optimized fin setting could reduce drag.

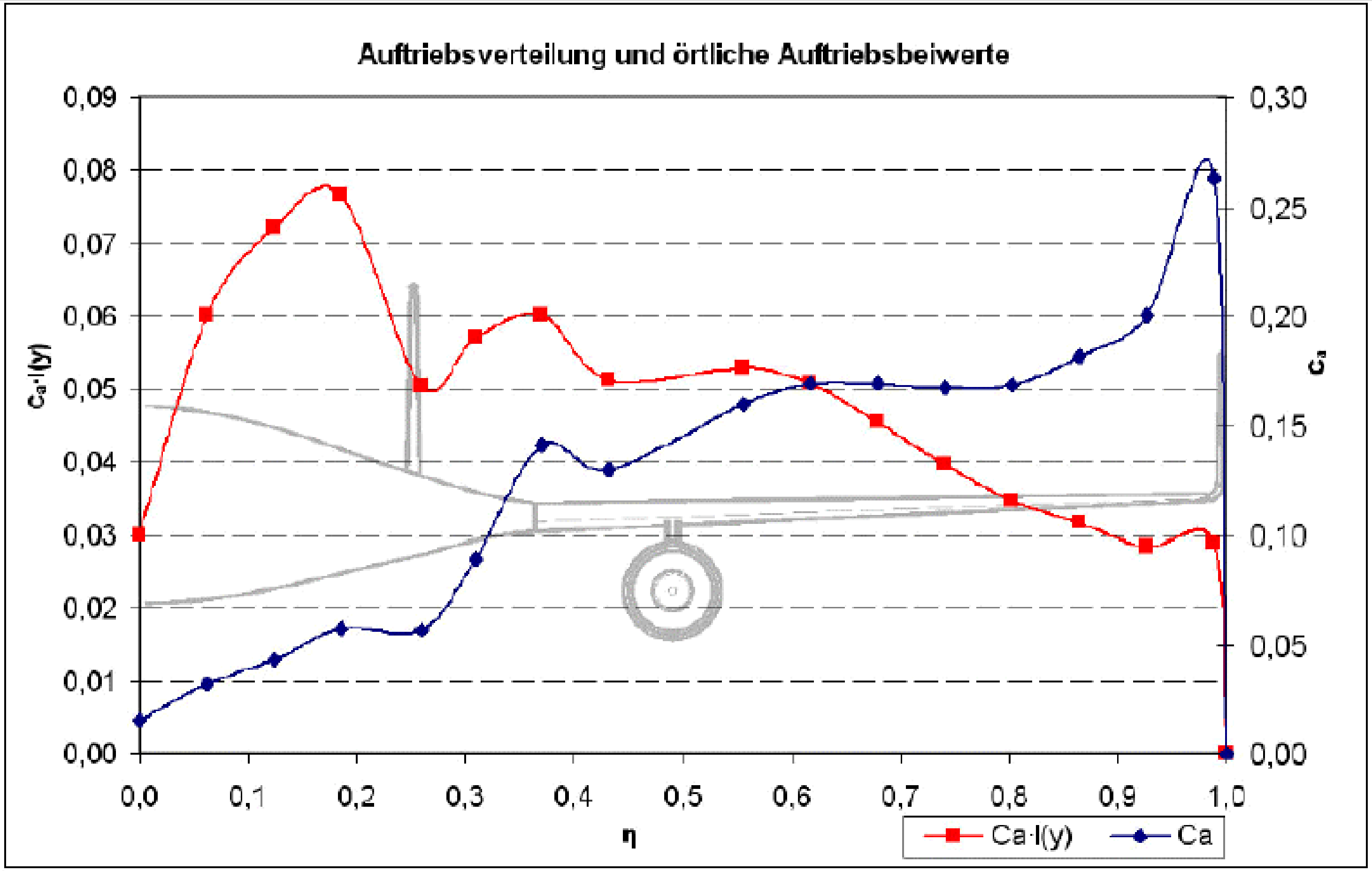


Aerodynamics

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

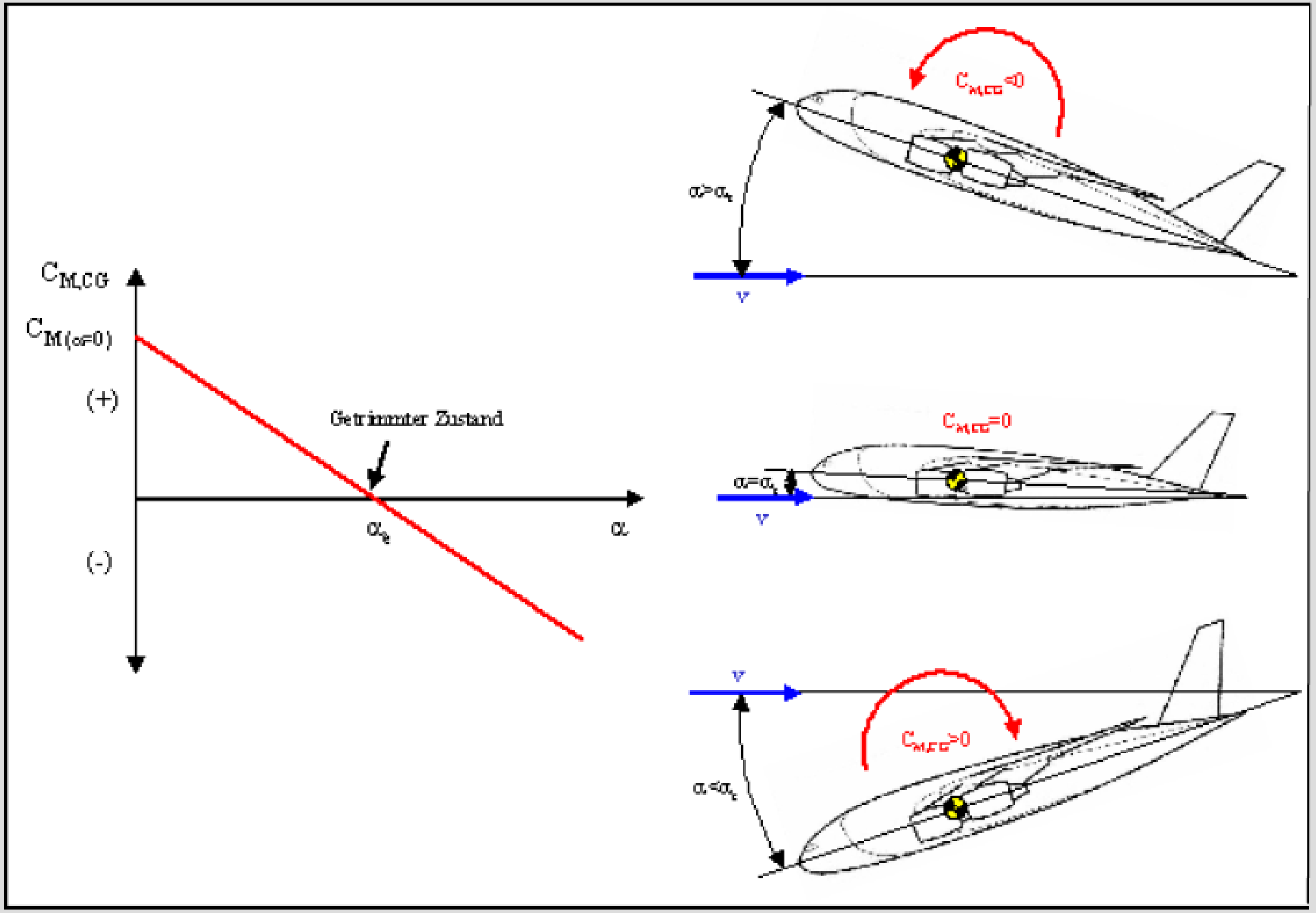
AC20.30: CFD with FLUENT

cruise, α = 1.2 °



lift distribution / distribution of local lift coefficient

Static Longitudinal Stability Fundamentals



Certification Requirements

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:

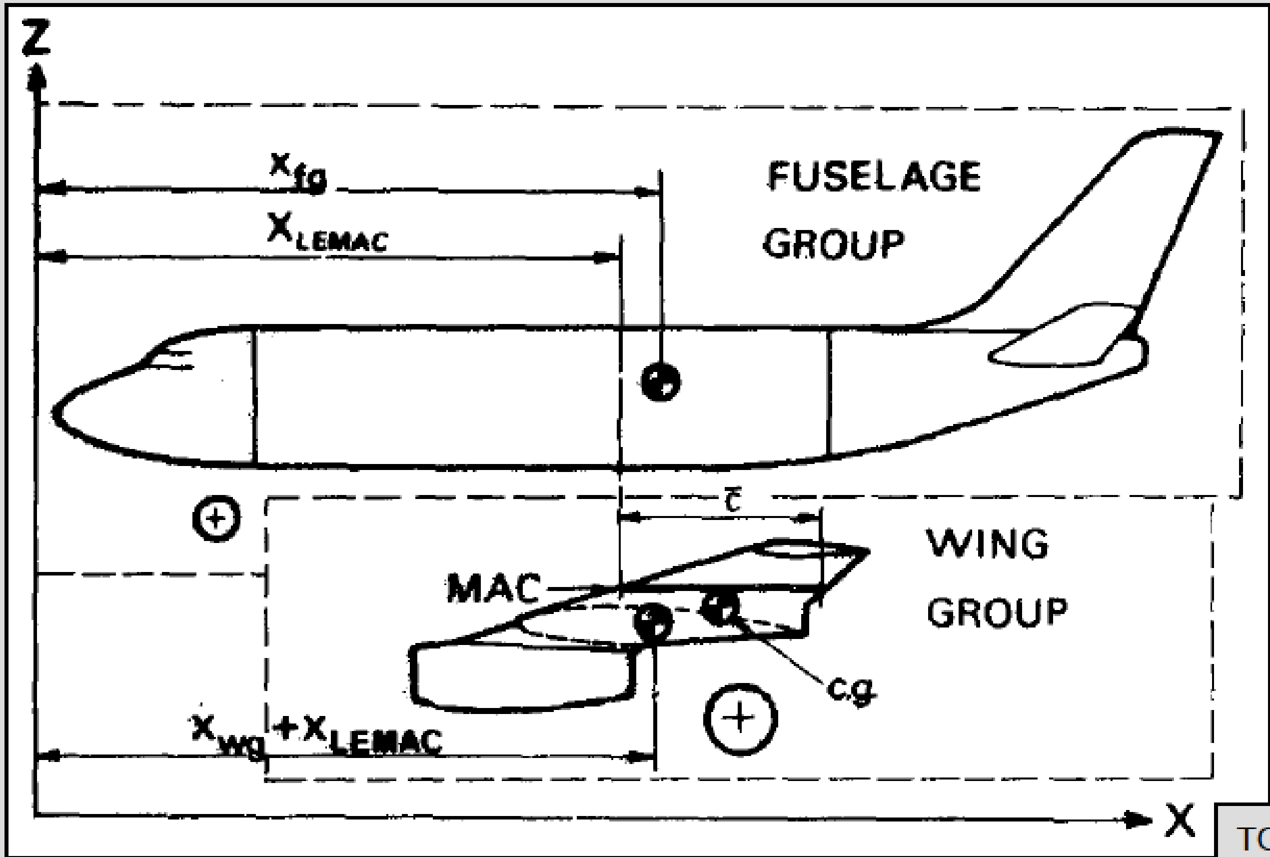
A) Design to Requirements:

- **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.



Positioning of the CG on the Mean Aerodynamic Chord (MAC) for required *static margin* is achieved in conventional design by shifting the wing with respect to the fuselage. This approach is not possible in BWB design!

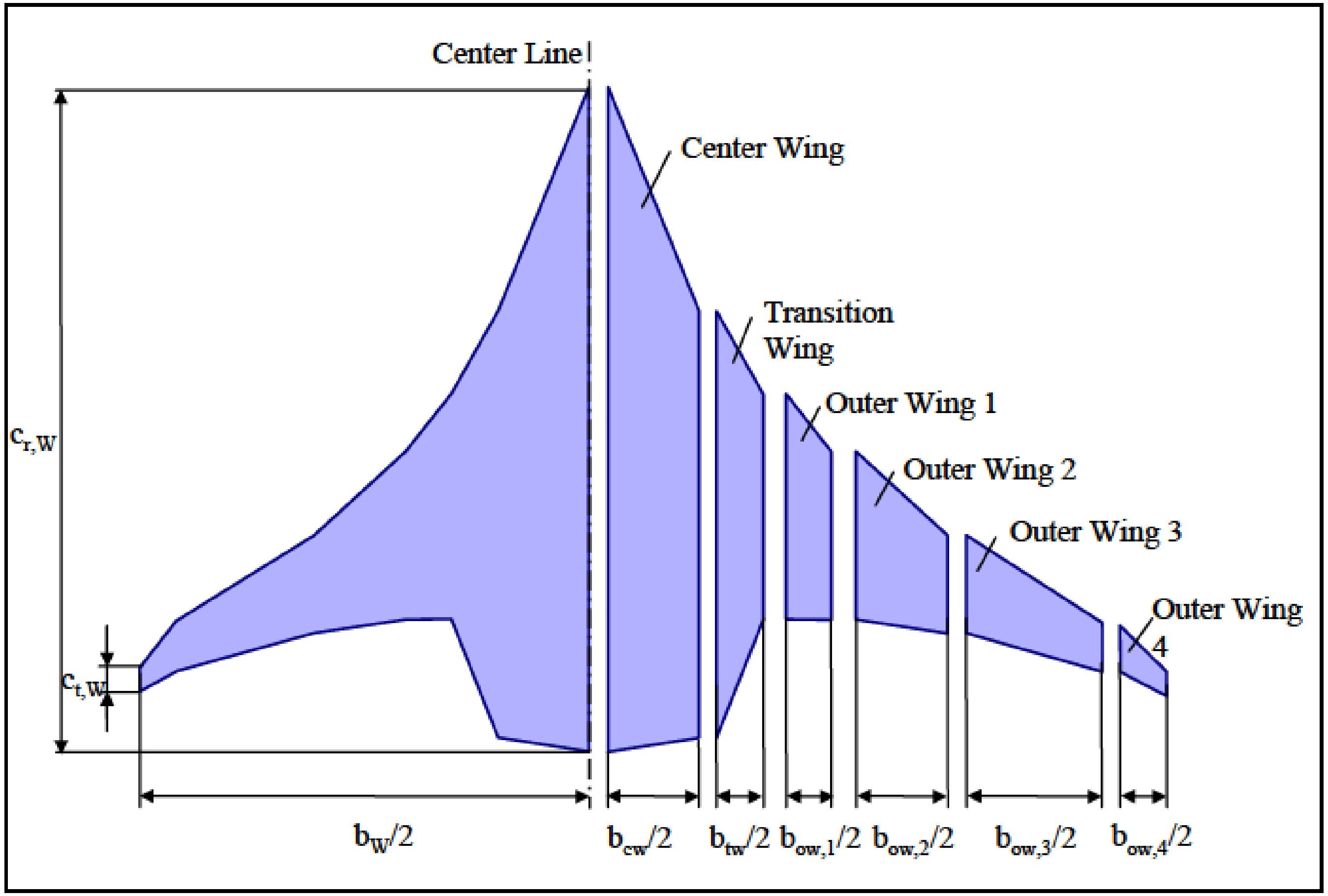
$$x_{LEMAC} = x_{fg} - x_{cg} + \frac{m_{wg}}{m_{fg}} \left(x_{wg} - x_{cg} \right)$$

TORENBEEK, E.: "Synthesis of Subsonic Airplane Design". Delft : Delft University Press, 1988

Flight Mechanics

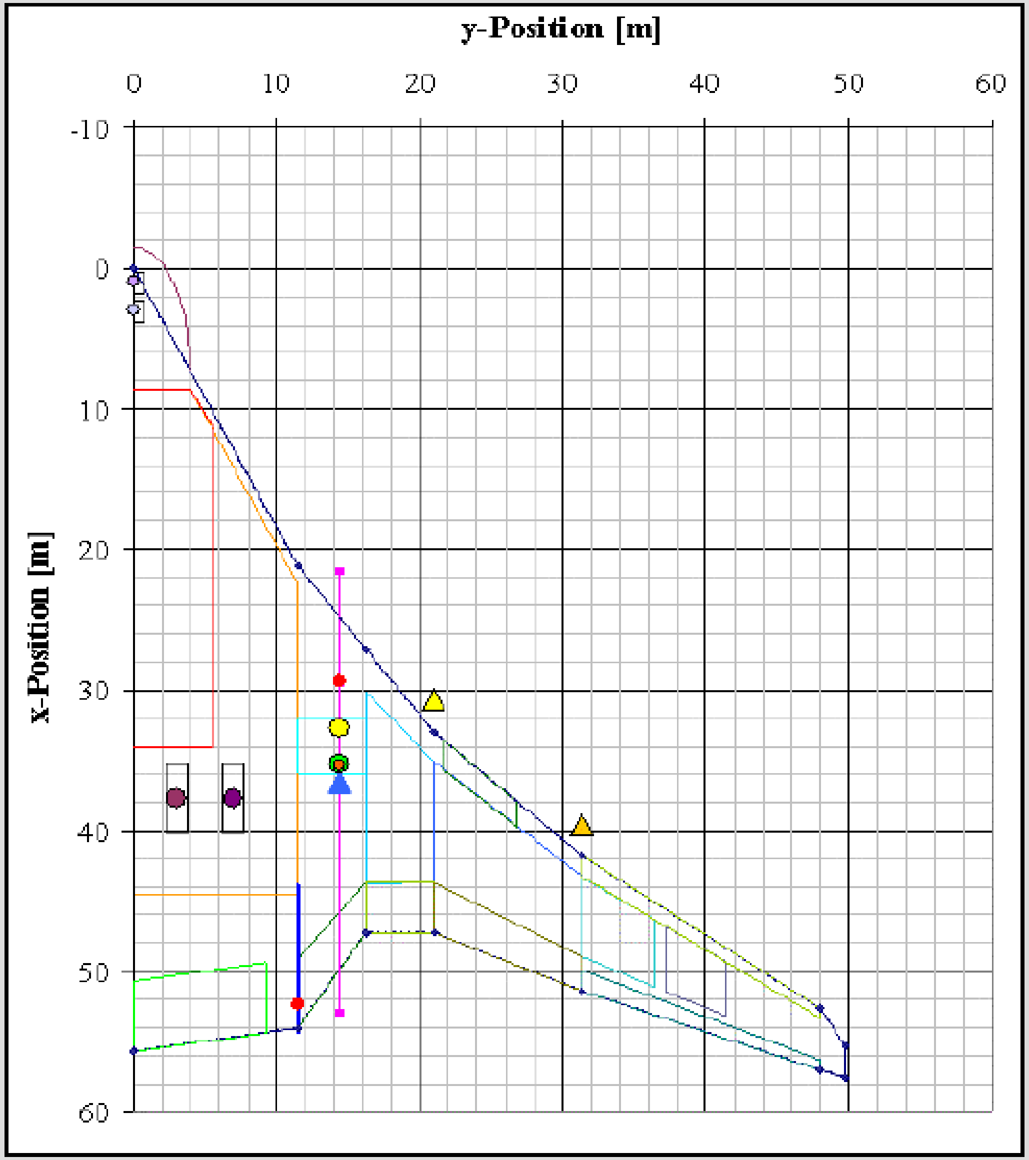
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Static Longitudinal Stability for BWB Configurations



F. Bansa, Diplomarbeit, Hamburg University of Applied Sciences

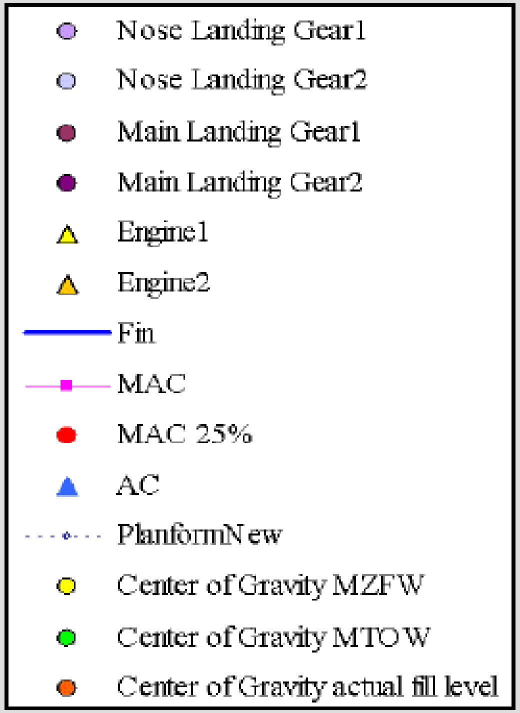
A BWB can be designed for static longitudinal stability with an interactive EXCEL-based program. The program assumes the BWB to consist of a maximum of 6 different wing trapezoids.



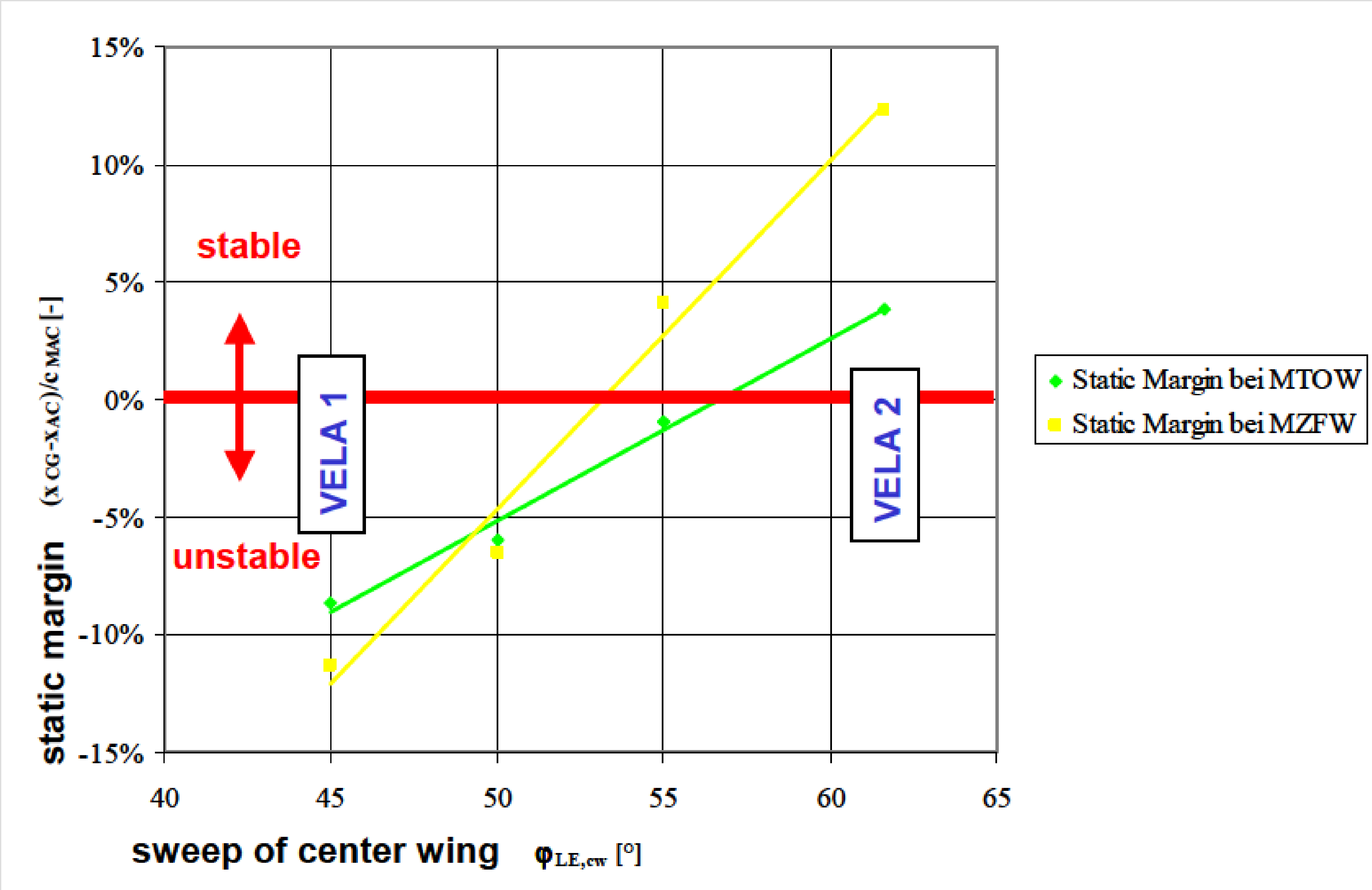
Interactive parameter variation to find a suitable static margin for BWB configurations by calculation of:

1.) center of gravity, CG

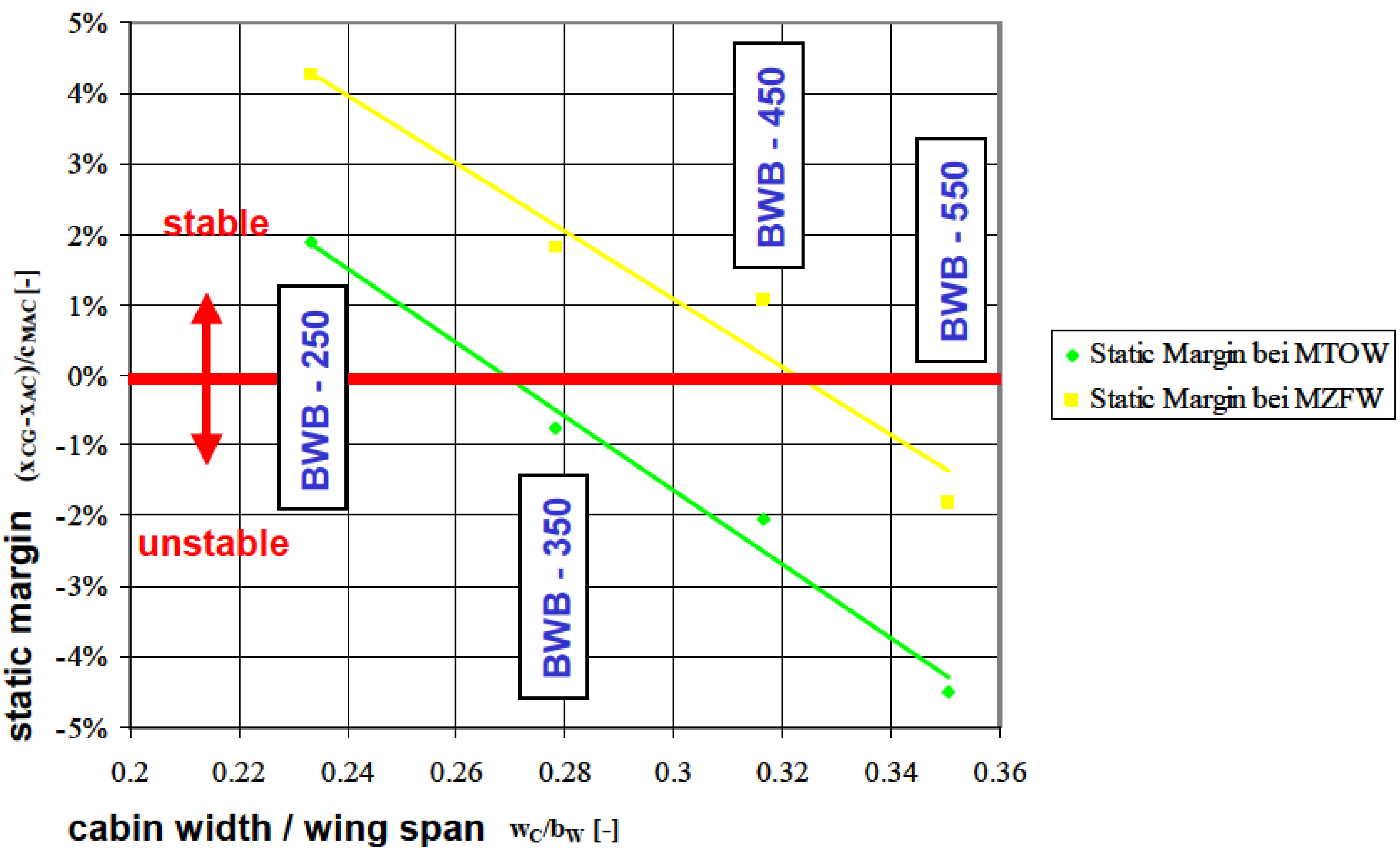
2.) aerodynamic center, AC.



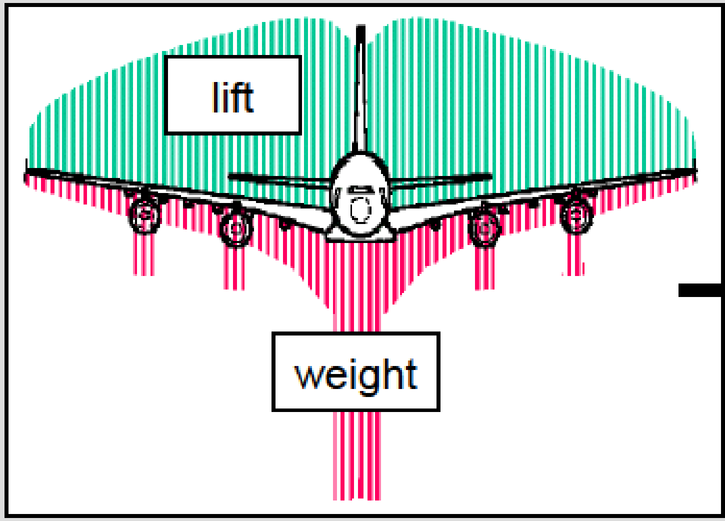
Static Longitudinal Stability for VELA Configurations

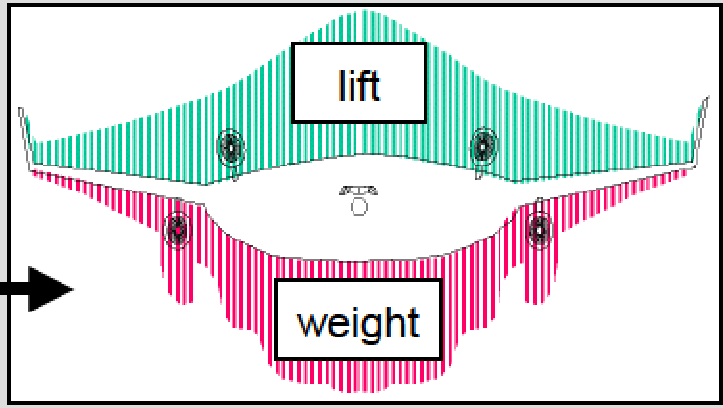


Static Longitudinal Stability for Boeing BWB Configurations

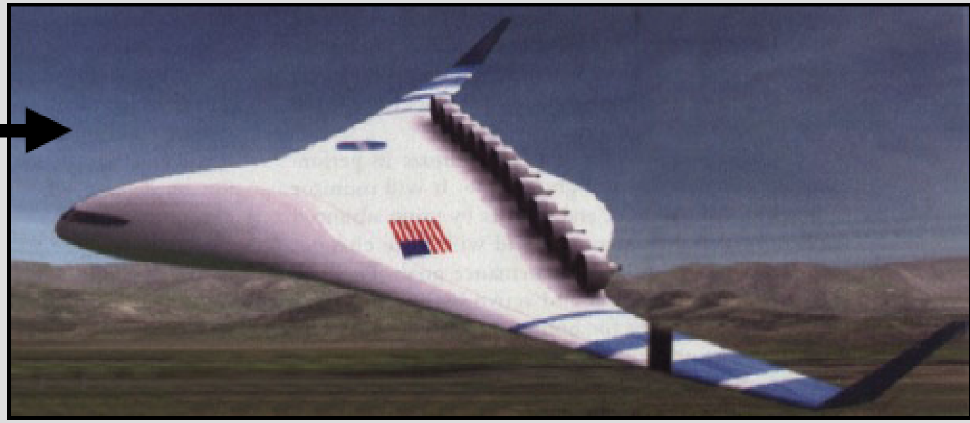


Weight Saving Potential of BWB Configurations

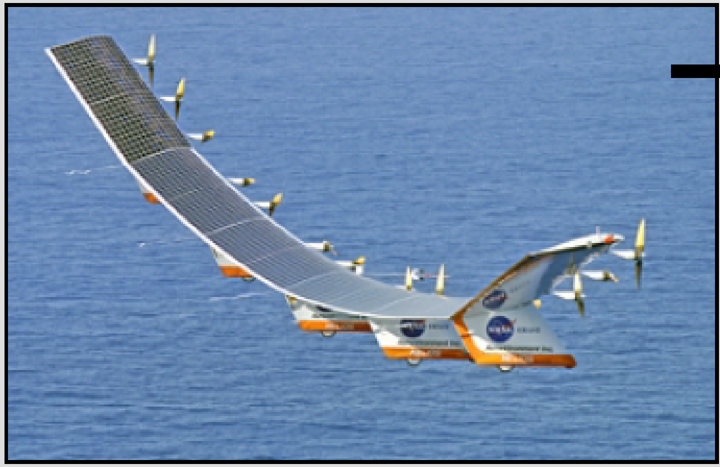




Less bending moments in a flying wing or BWB



BWB study with distributed propulsion (Virginia Polytechnic)

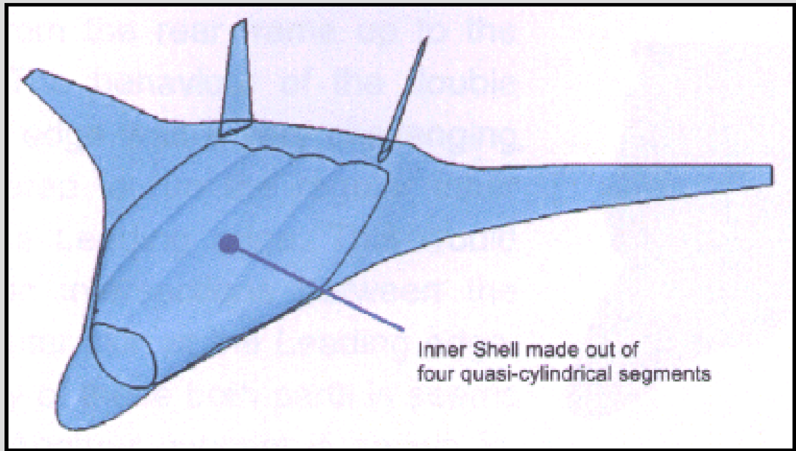


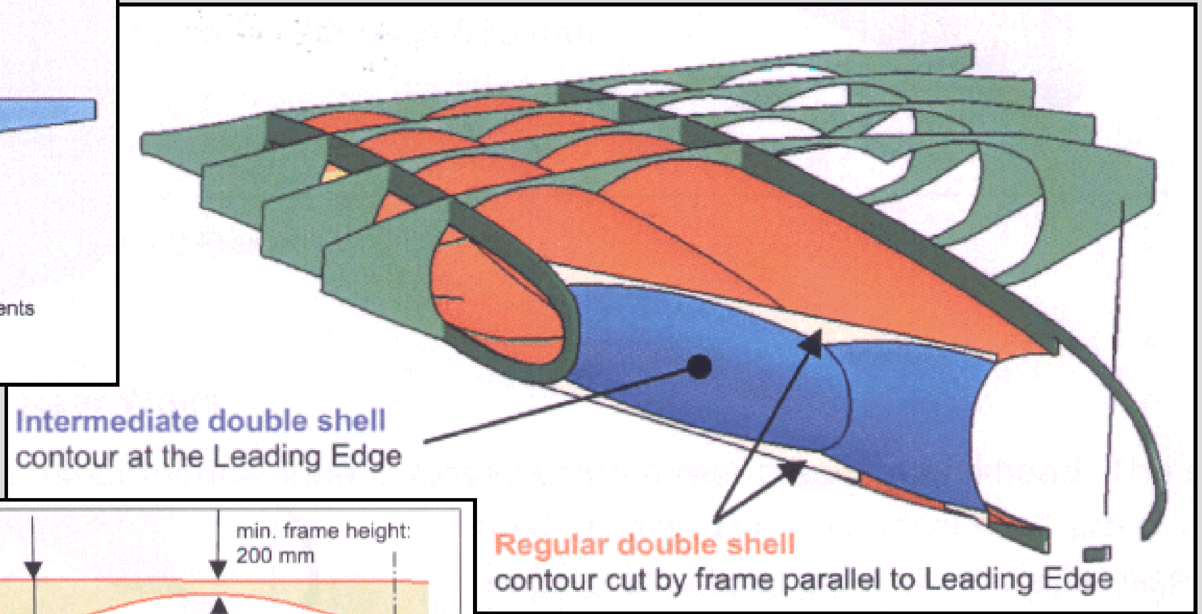
Helios - example of an extreme span loader with distributed propulsion (NASA / AeroVironment, Inc.)

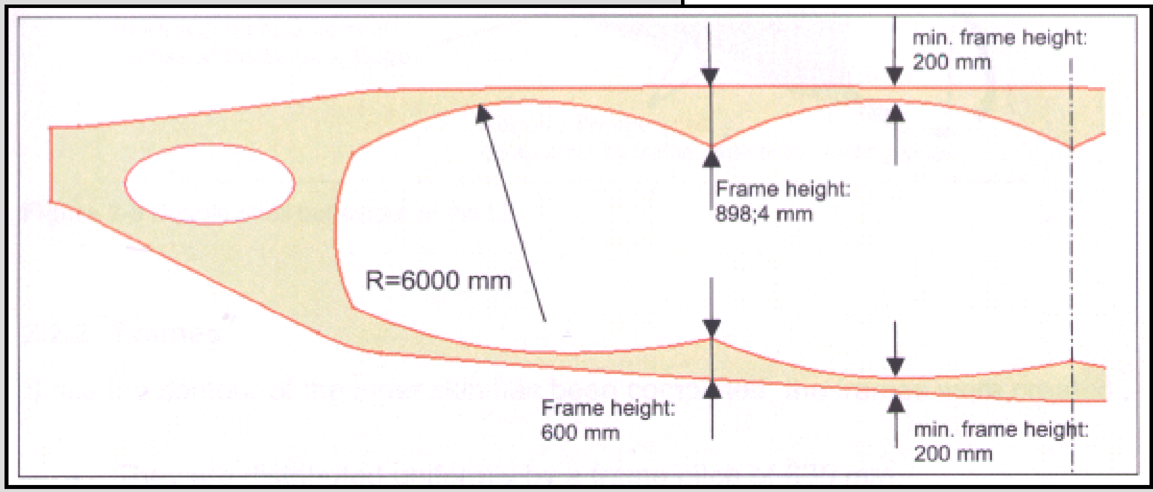
Structures

VELA 2 - Basic Structural Layout

T. Kumar Turai, Master Thesis,
Hamburg University of Applied Sciences



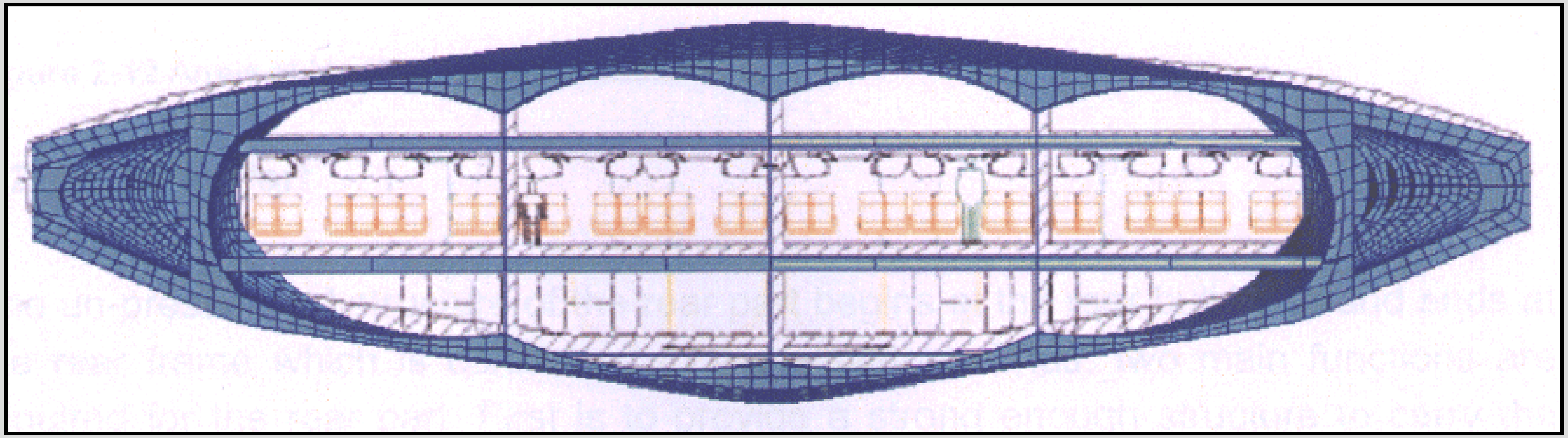


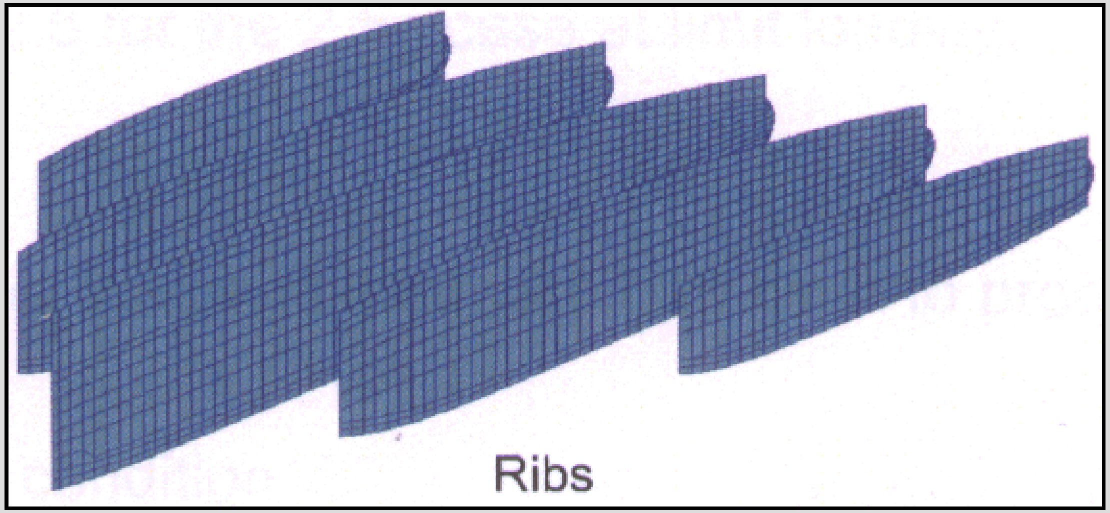


Structures

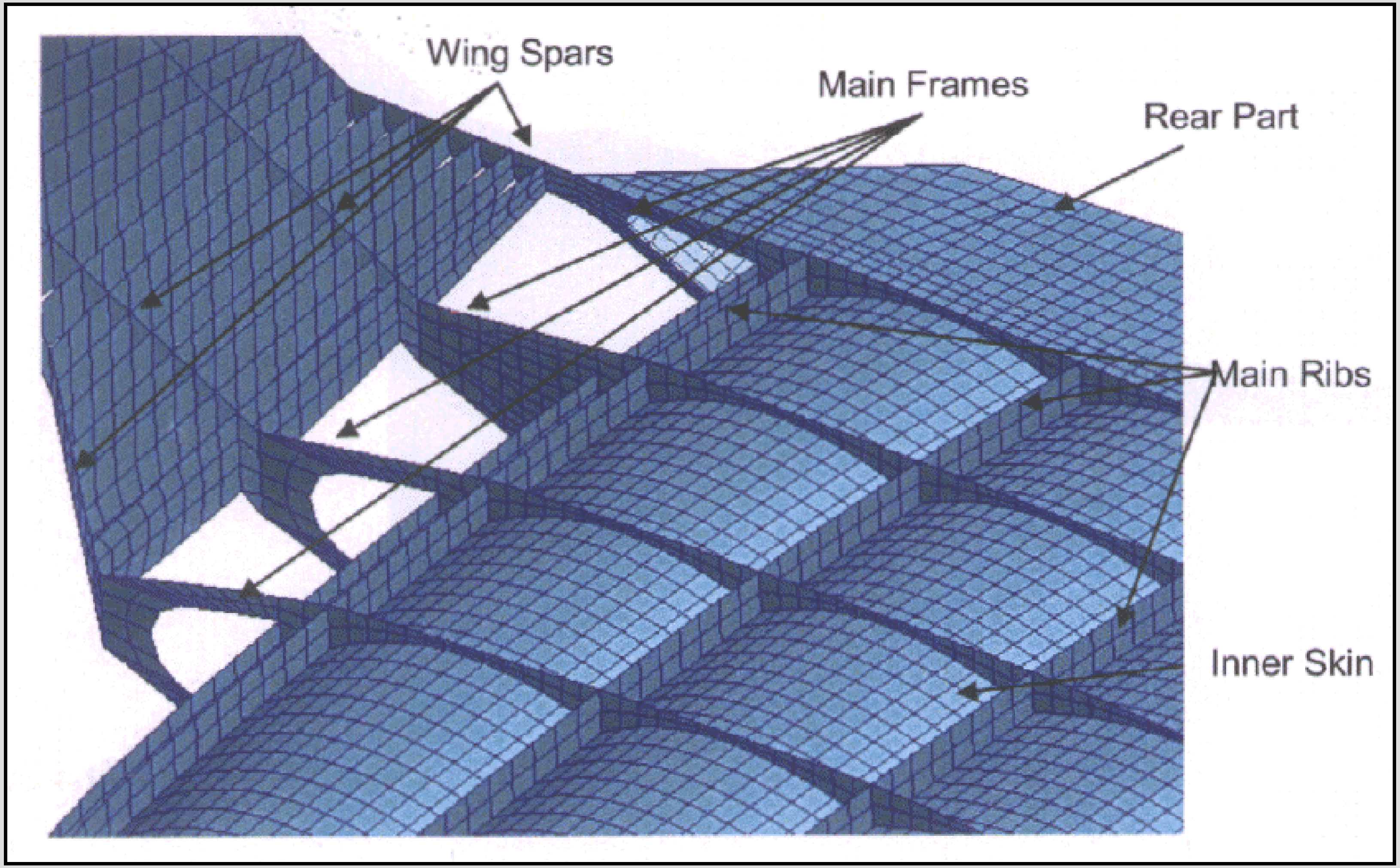
Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 2 - Cabin

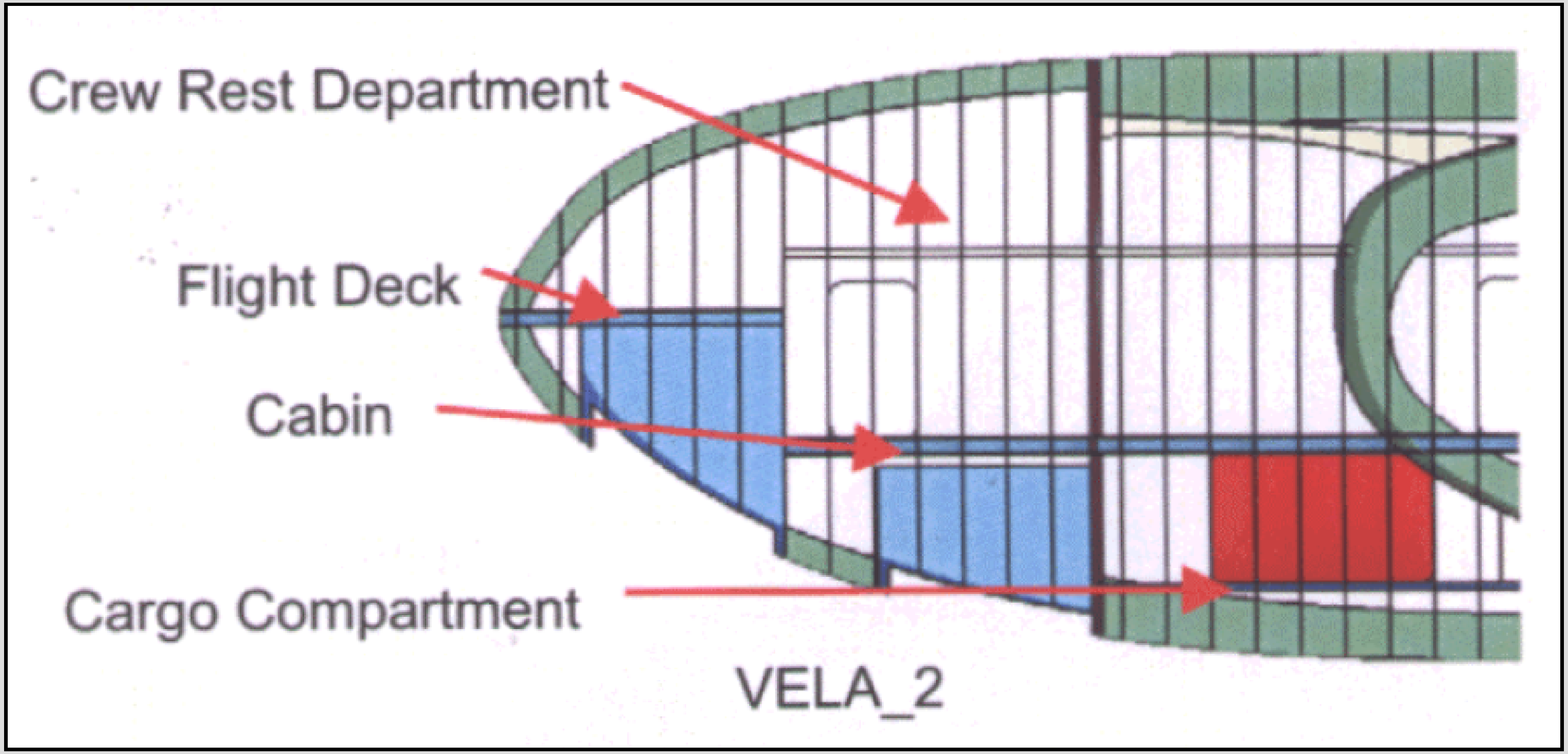




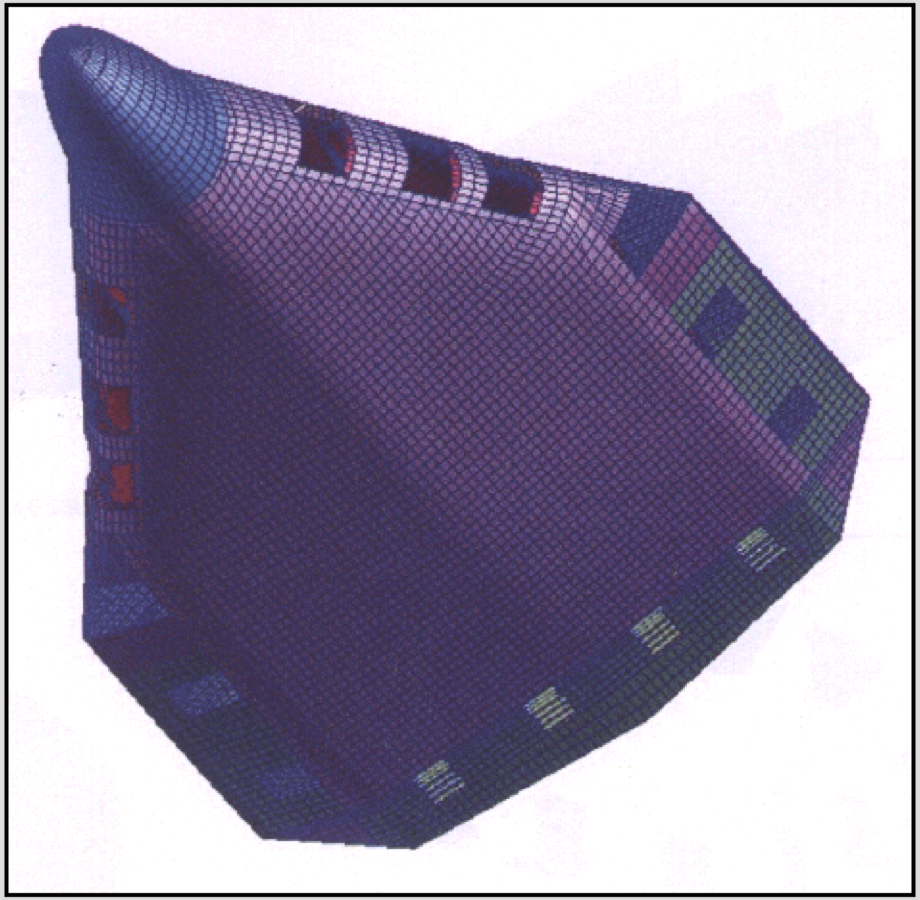
VELA 2 - Wing Integration



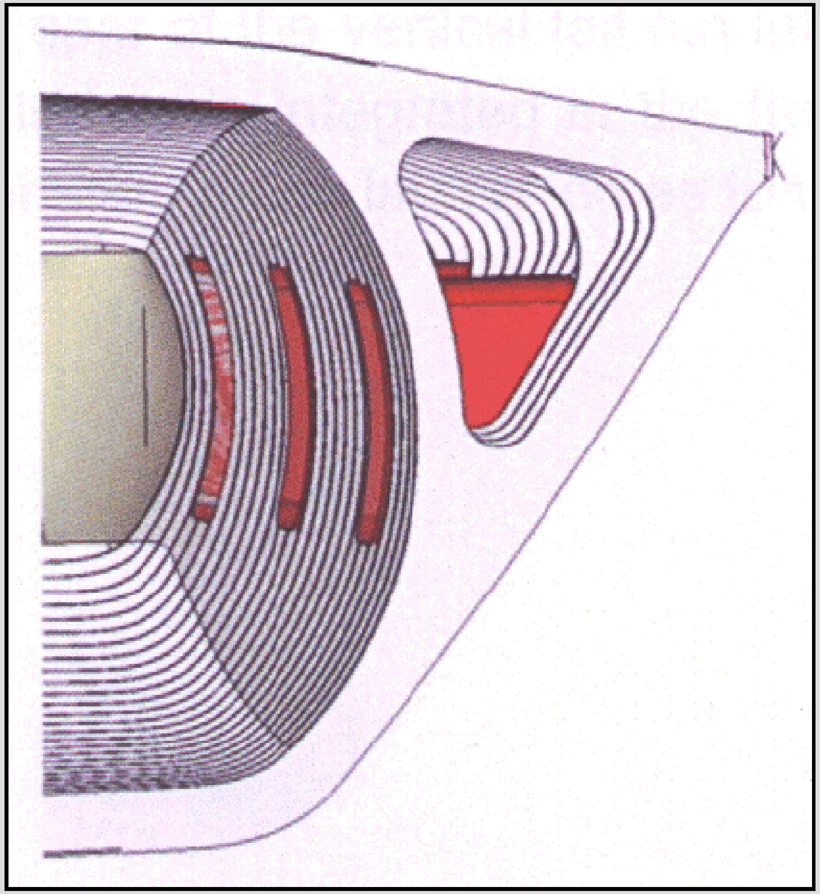
VELA 2 - Floor Integration



VELA 2 - Doors

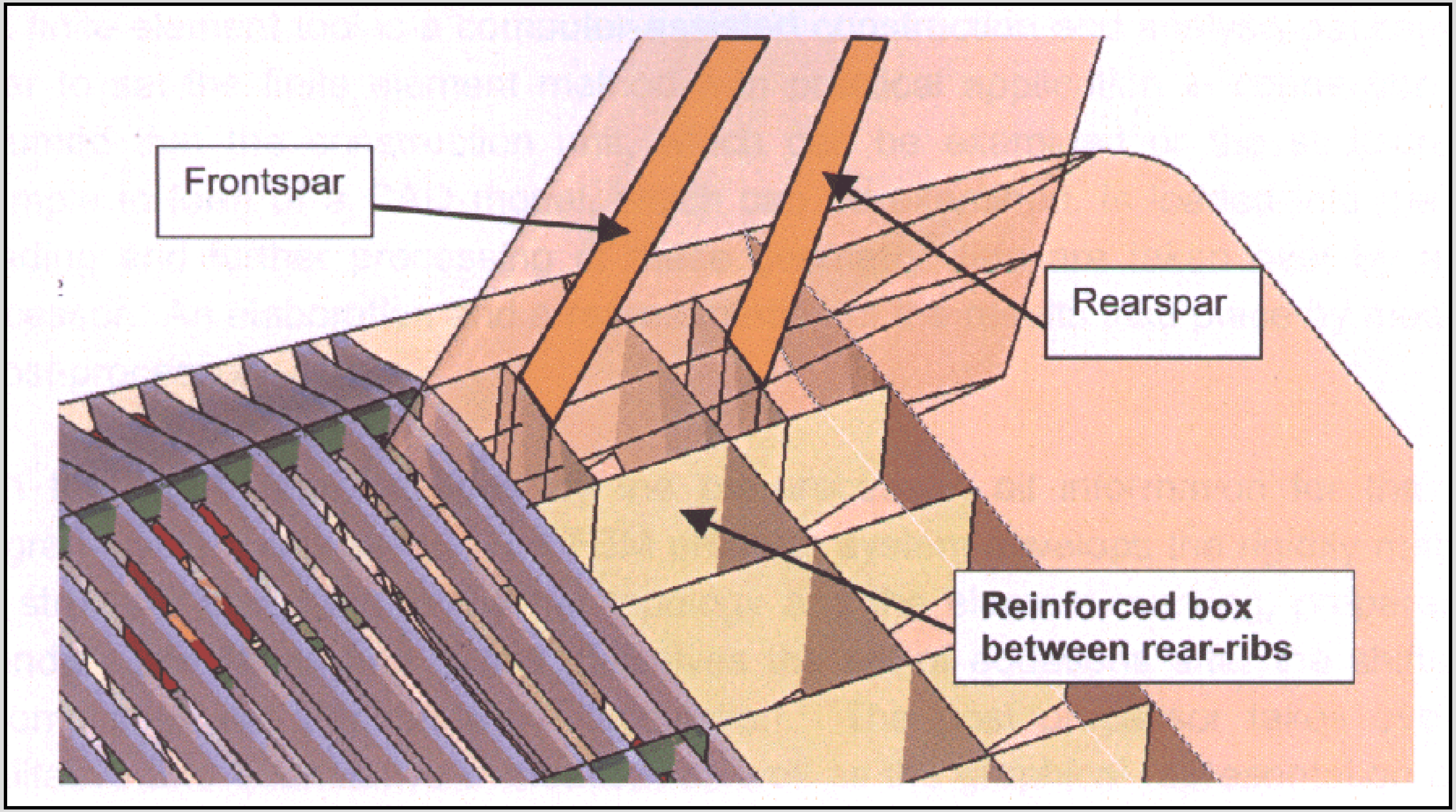


Door cut-outs

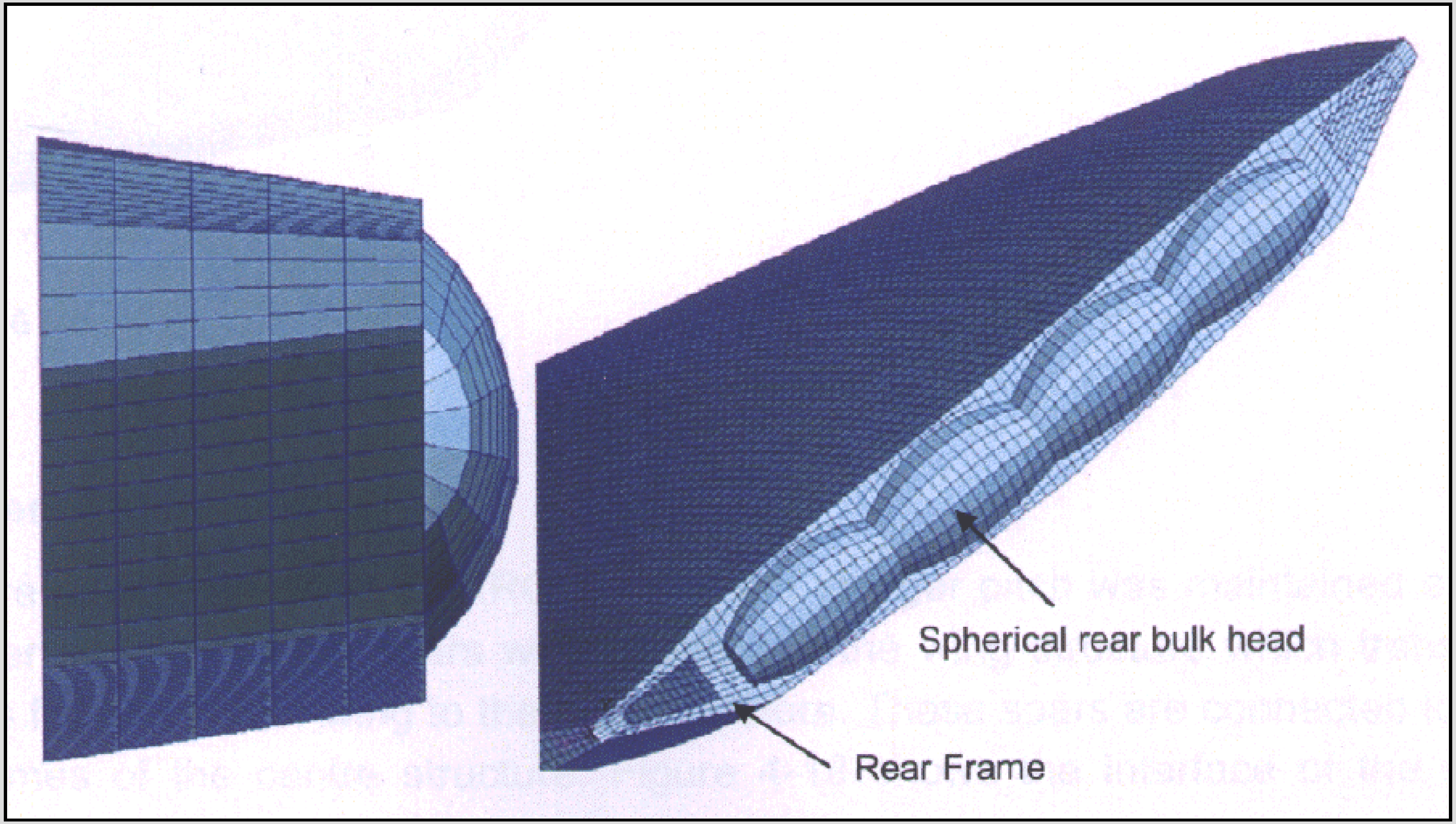


Side door integration

VELA 2 - Fin Integration



VELA 2 - Rear Pressure Bulkhead



Mass Prediction

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 2

Weight Chapter	F. Bansa	T. Kumar Turai	T. Kumar Turai (FEM)
10 Structure	234669 kg	253529 kg	210070 kg
20 Power Units	37731 kg	36603 kg	->
30/40 Systems	19795 kg	23302 kg	->
50 Furnishings	35313 kg	27588 kg	->
60 Operator Items	35313 kg	39578 kg	->
OWE	362820 kg	380600 kg	337141 kg
OWE/MTOW	**0.525**	**0.551**	**0.488**
Loftin	0.521		
Marckwardt	0.462		
A380-800	**0.501**		
A340-600	**0.475**		

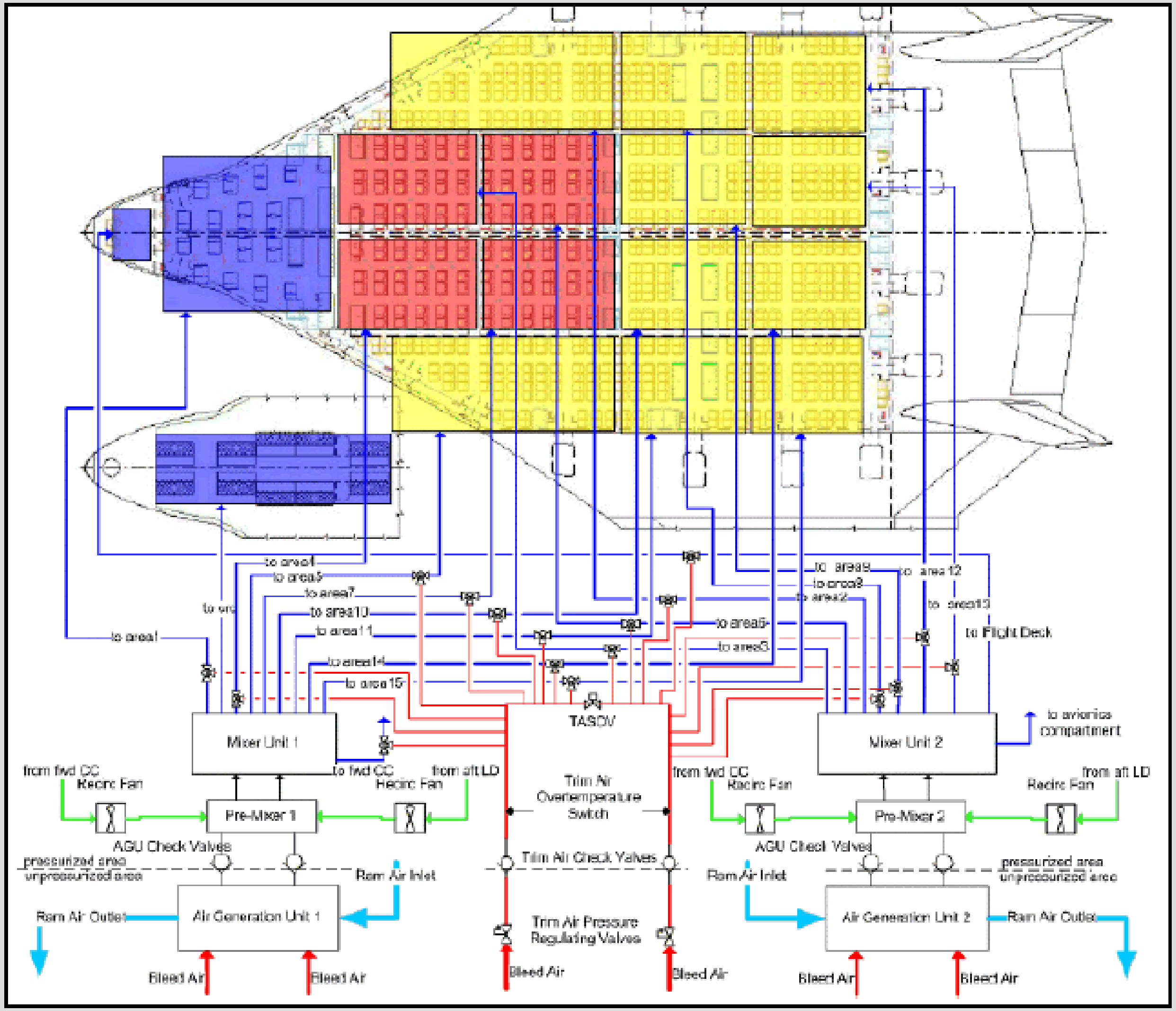
Taken for Preliminary Sizing: **0.500**

Result: The BWB design does not significantly improve the OWE/MTOW ratio!
Latest News: One-shell layout can lead to OWE/MTWO = **0.44 ... 0.46** !

System Integration

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 2 - ATA 21 - Temperature Control & Ventilation



M. Mahnken, Diplomarbeit, Hamburg University of Applied Sciences

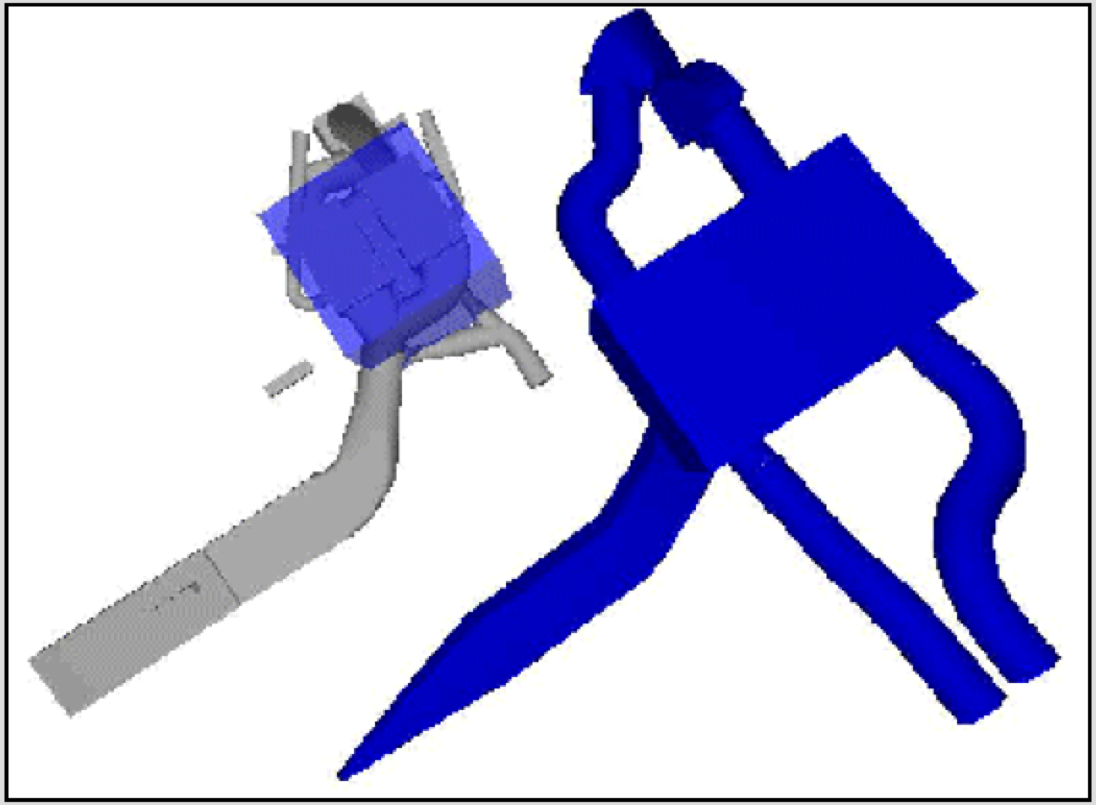
Steps in system integration:

1.) System diagram

2.) Sizing

3.) Routing & ducting

VELA 2 - ATA 21 - Pack Sizing

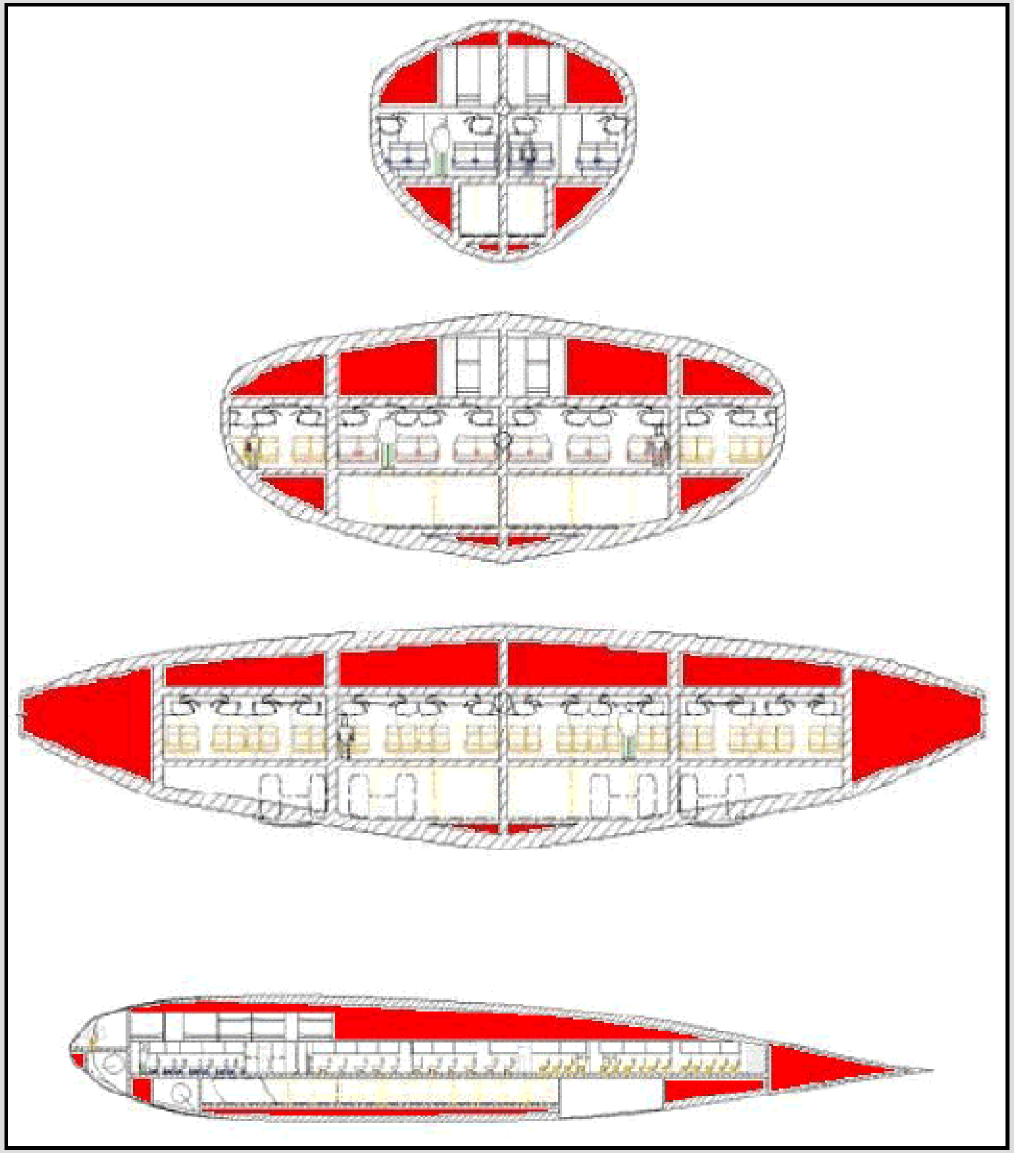


Air Generation Unit (pack): A380 and VELA 2

Steps in system integration:

1.) System diagram
2.) Sizing
3.) Routing & ducting

System Integration



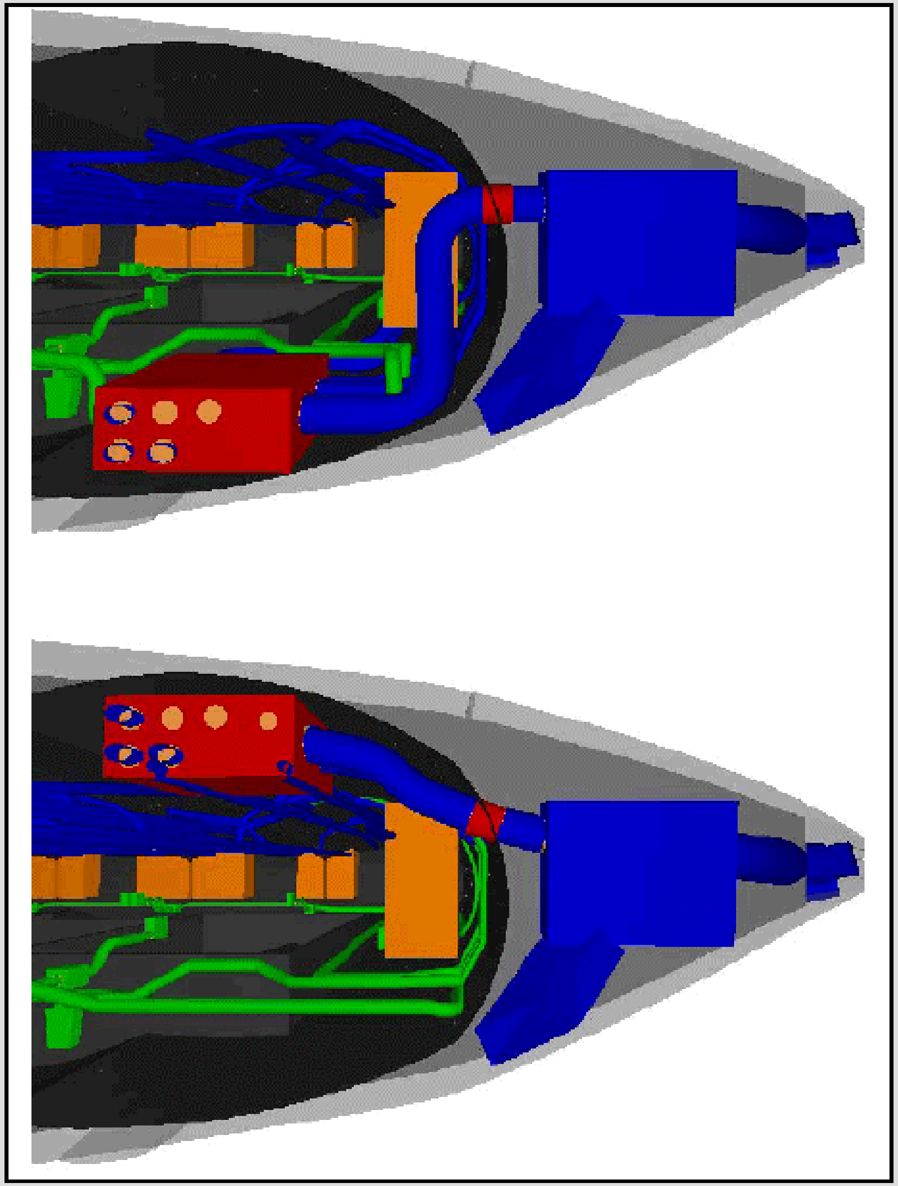
VELA 2 - System Installation Areas

Steps in system integration:

1.) System diagram

2.) Sizing

3.) Routing & ducting



VELA 2 - ATA 21 - Positioning of the Mixing Unit

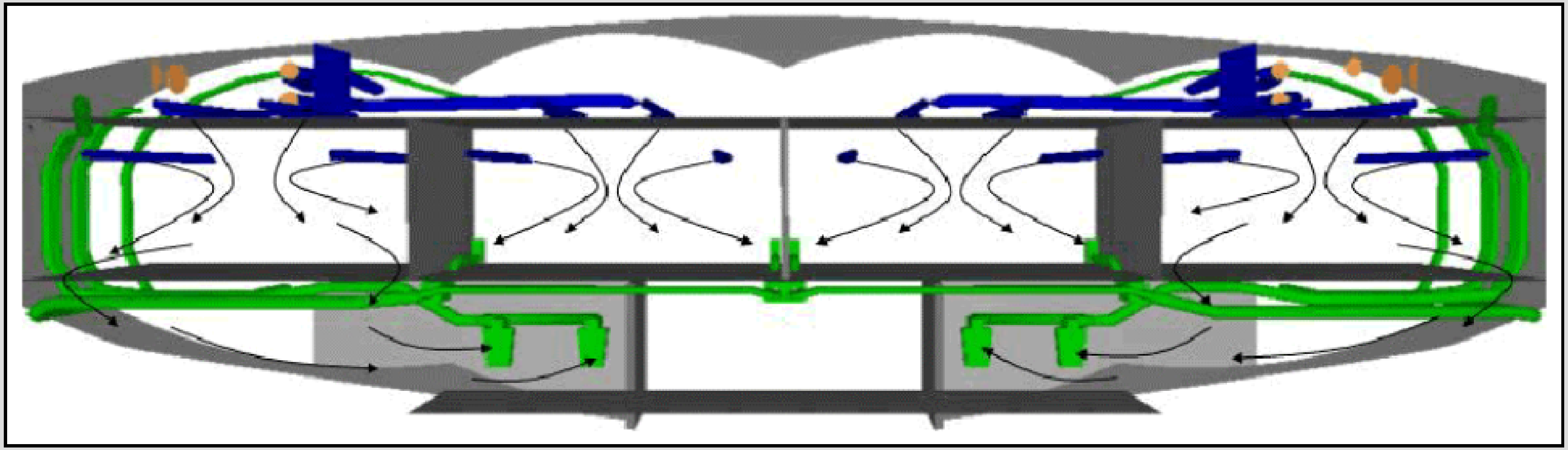
Steps in system integration:
1.) System diagram
2.) Sizing
3.) Routing & ducting

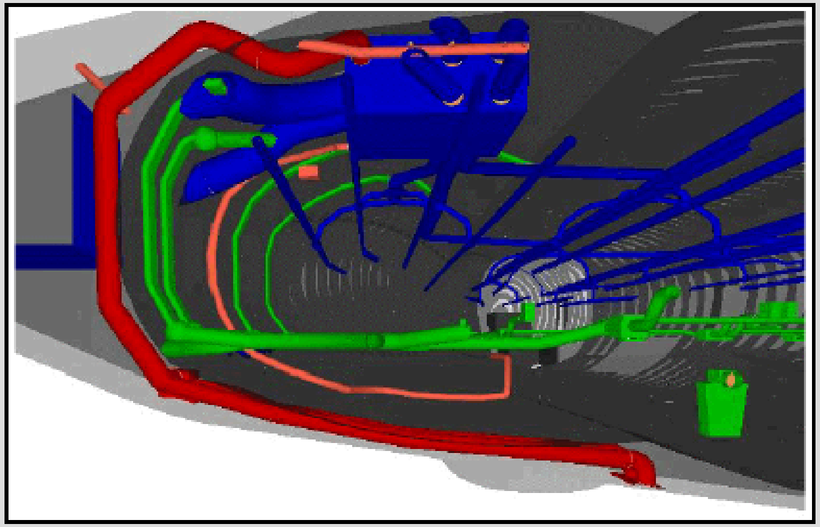
Air Generation Unit is positioned in the transition wing.

Alternative position (above cabin) of the Mixing Unit eliminates riser ducts.

Ducts for recirculation air.

VELA 2 - ATA 21 - Ducting



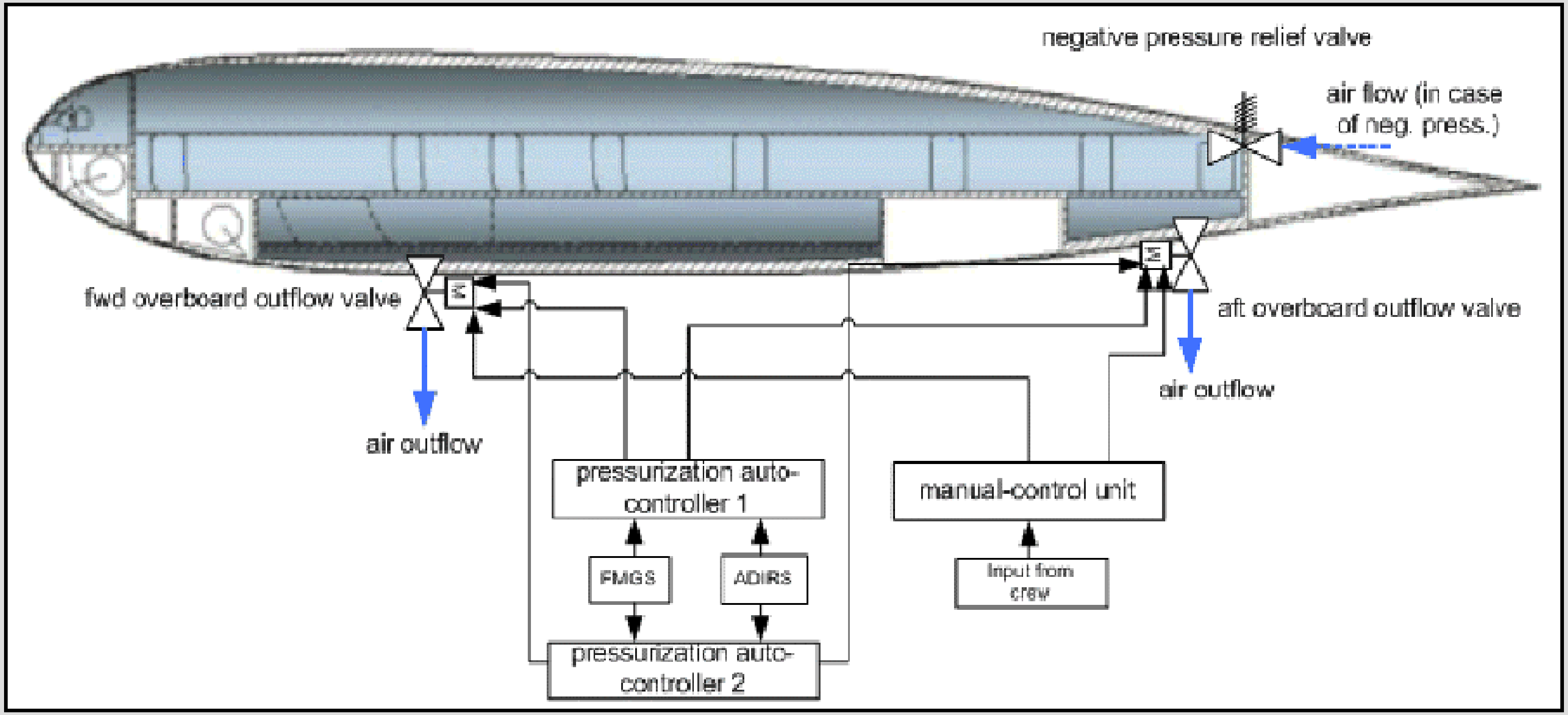


Air circulation. Recirculation requires ducts.

Low pressure air connector and duct to mixing unit.

Duct for emergency air.

VELA 2 - ATA 21 - Pressure Control



Steps in system integration:

1.) System diagram

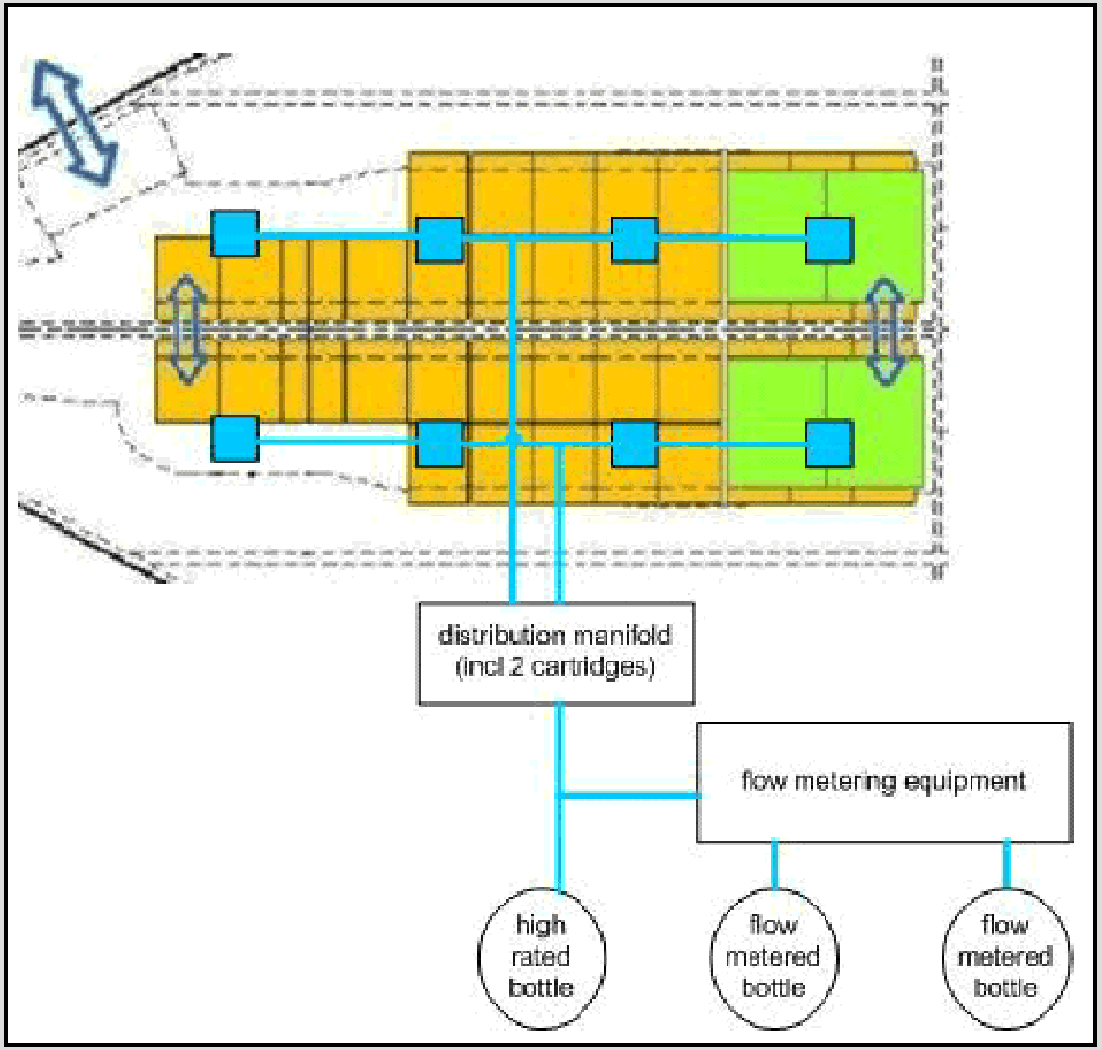
2.) Sizing

3.) Routing & ducting

System Integration

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 2 - ATA 26 - Cargo Fire Suppression System



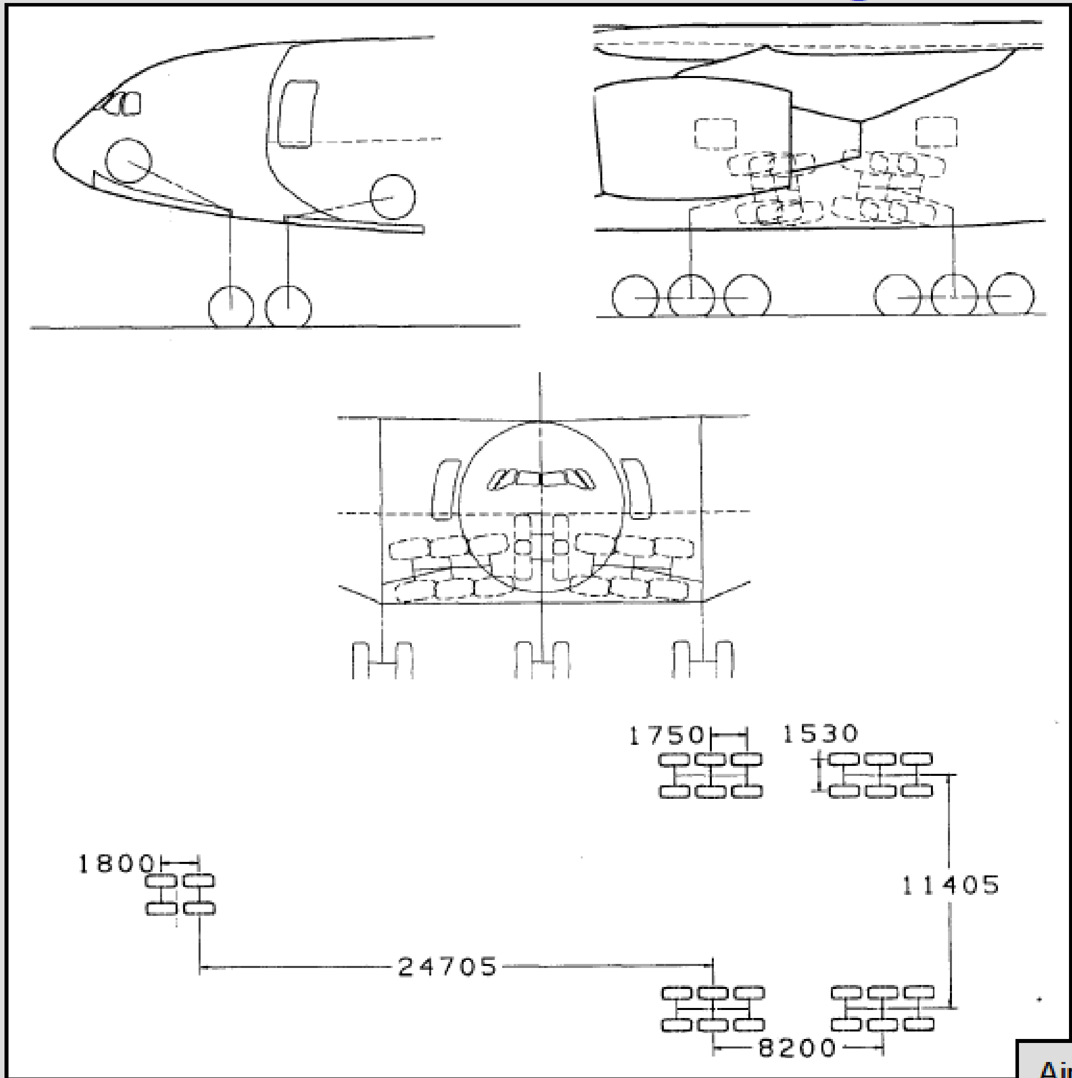
Steps in system integration:

1.) System diagram

2.) Sizing

3.) Routing & ducting

VELA 3 - Landing Gear Integration



Twin tandem (Bogie) nose landing gear.
Two retraction mechanisms.

Two twin tri-tandem (6-wheel) main landing gears on each side.
Special retraction mechanism.

MLG wheel spacing only 11.4 m due to rib location (requirement: wheel spacing < 16 m)

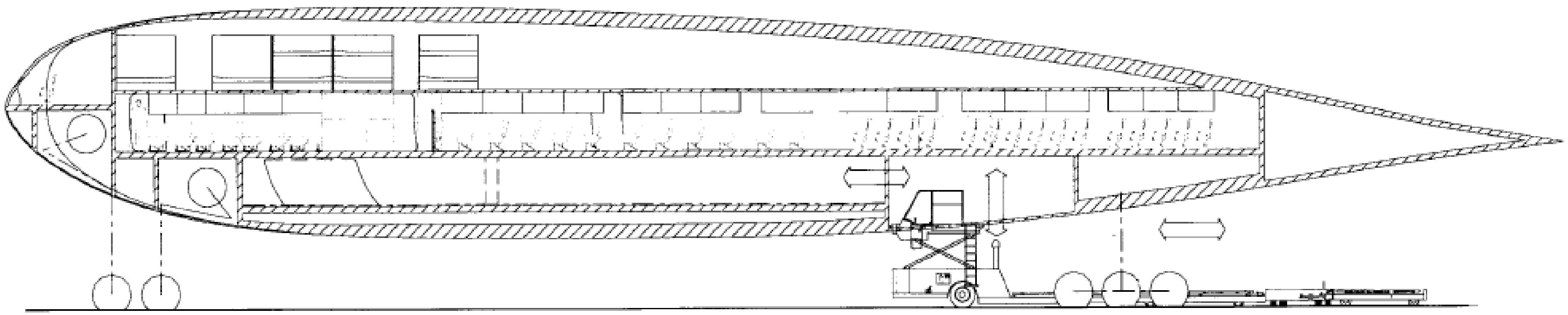
Rule of Thumb: 30 t / MLG wheel => max. MTOW: 720 t

Airbus, FPO, Hamburg

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Air Transport System

VELA 3 - Cargo Loading



Airbus, FPO, Hamburg

A cargo loading vehicle drives in between the MLGs.
Cargo loading from below with lifting system.

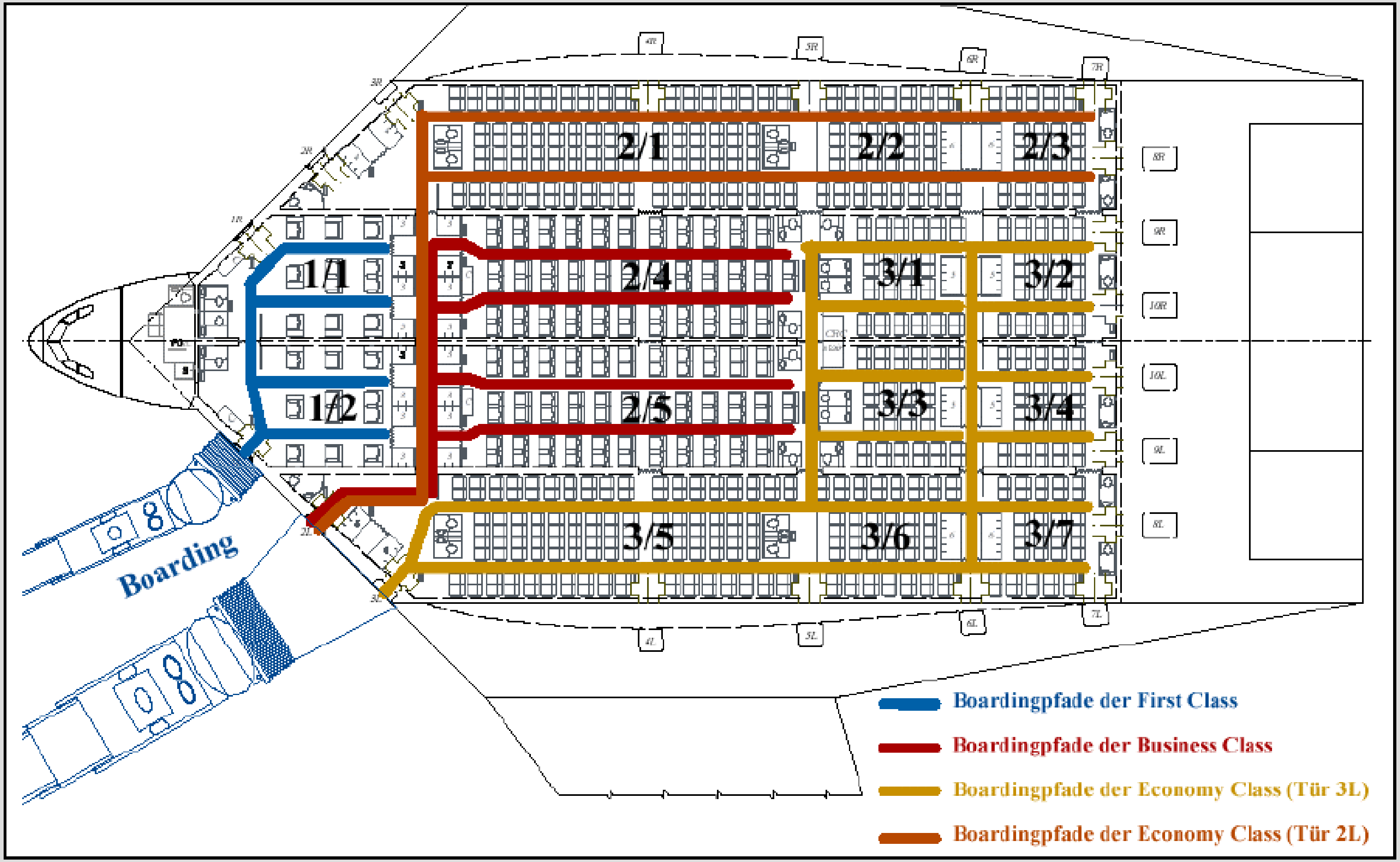
Note also:
1.) NLG / MLG and wheel well positions.
2.) Far aft position of MLG => problem to rotate the aircraft on take-off.

Ground Handling

Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 1 - Boarding

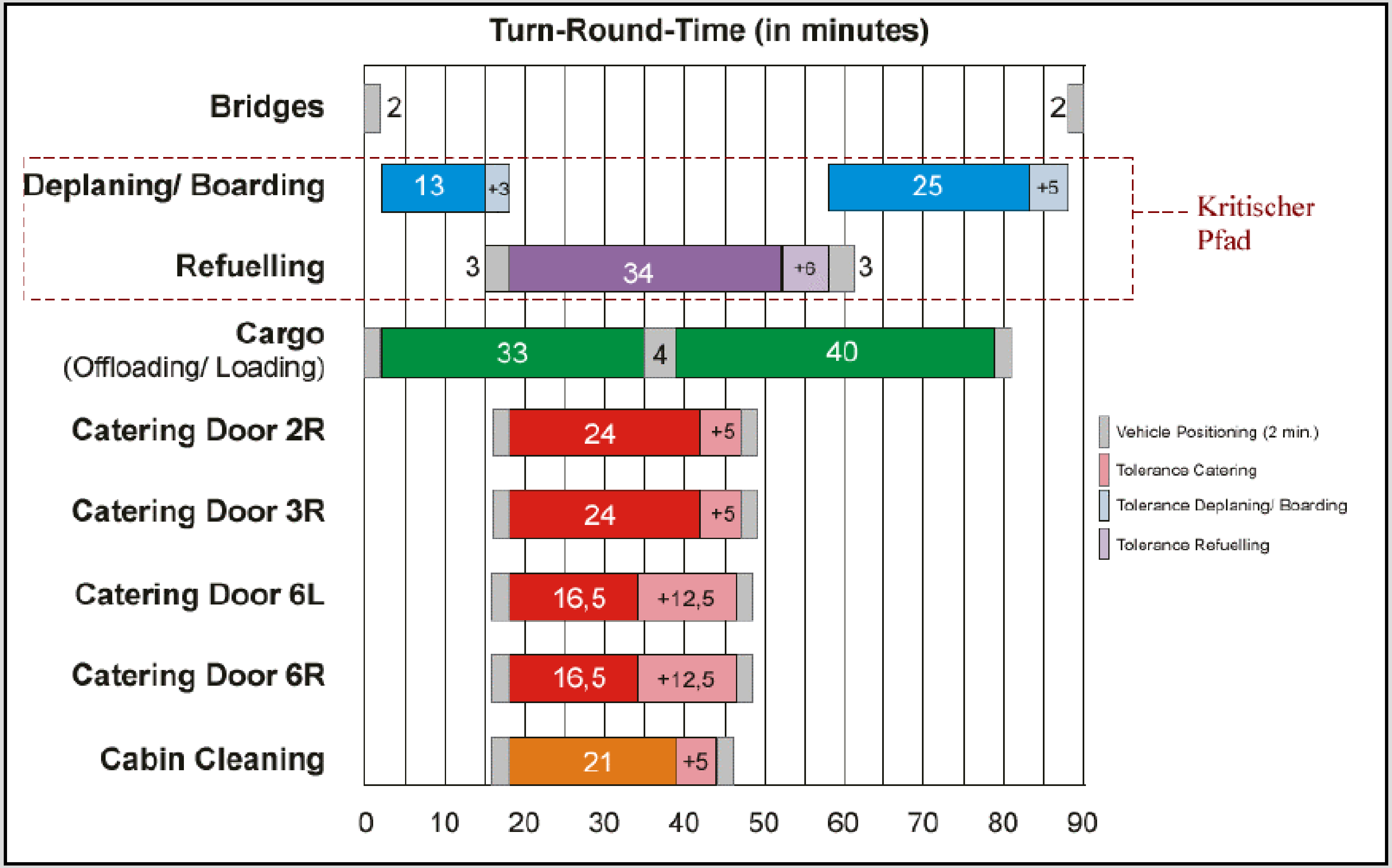
S. Lee, Diplomarbeit,
Hamburg University of Applied Sciences



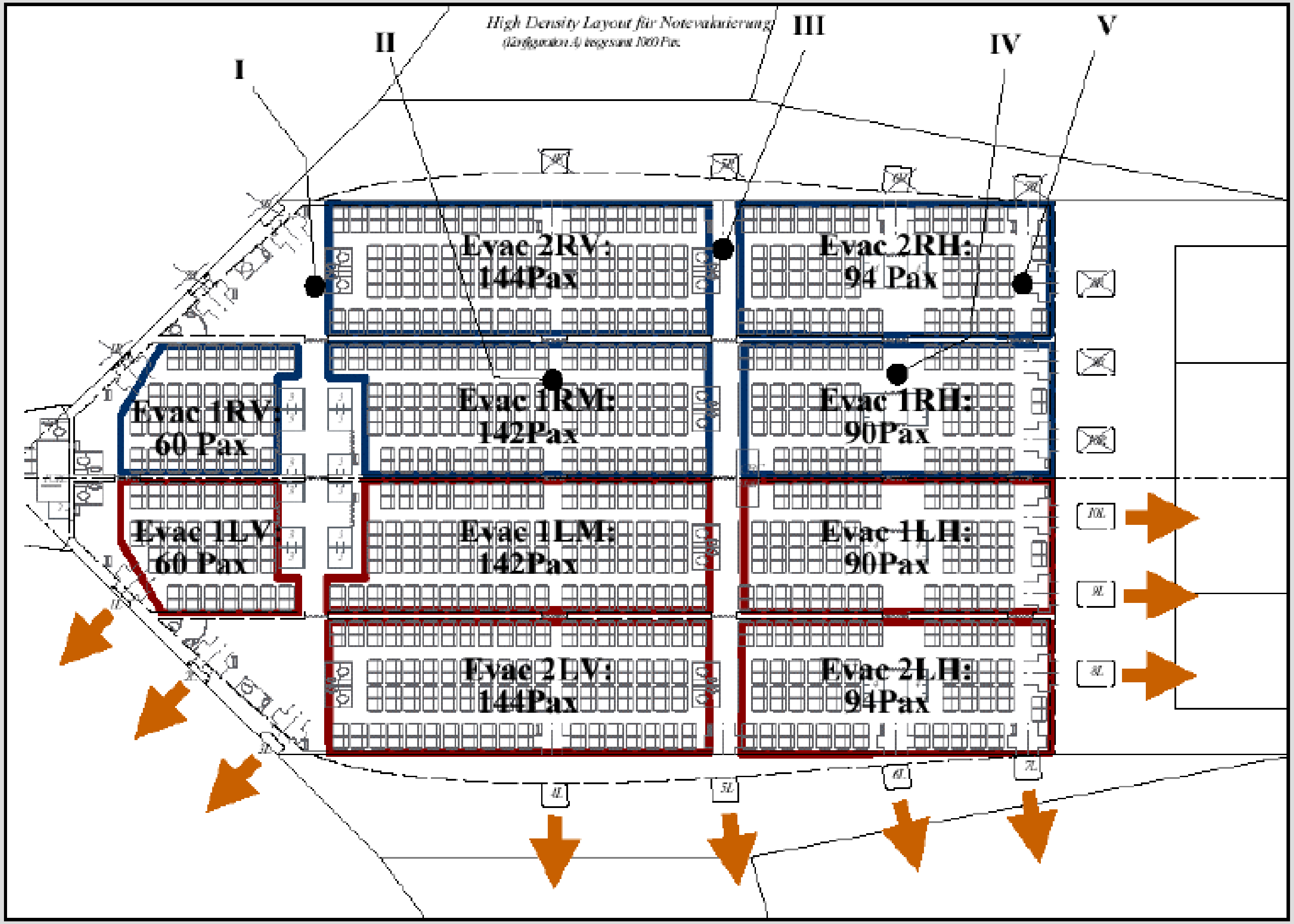
Ground Handling

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

VELA 1 - Turn Around Time



VELA 1 - Emergency Evacuation

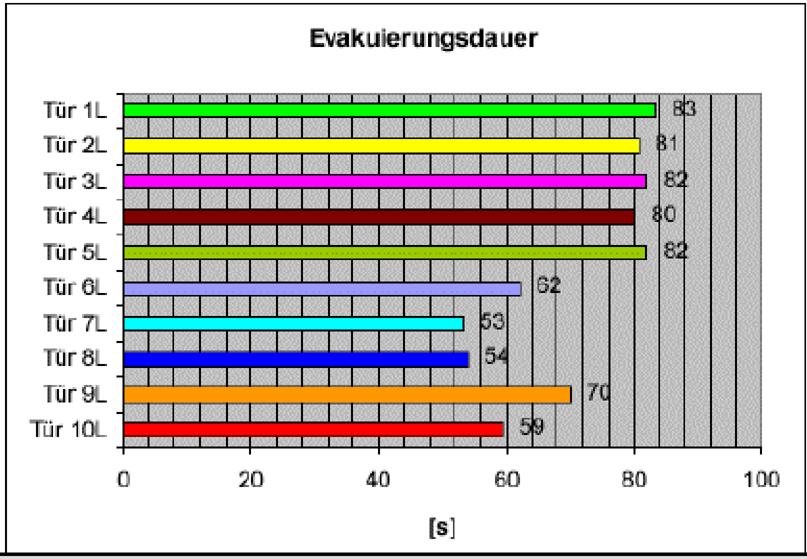


Emergency

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Evakuierungsdauer und –aufteilung an den Türen 1L bis 10L

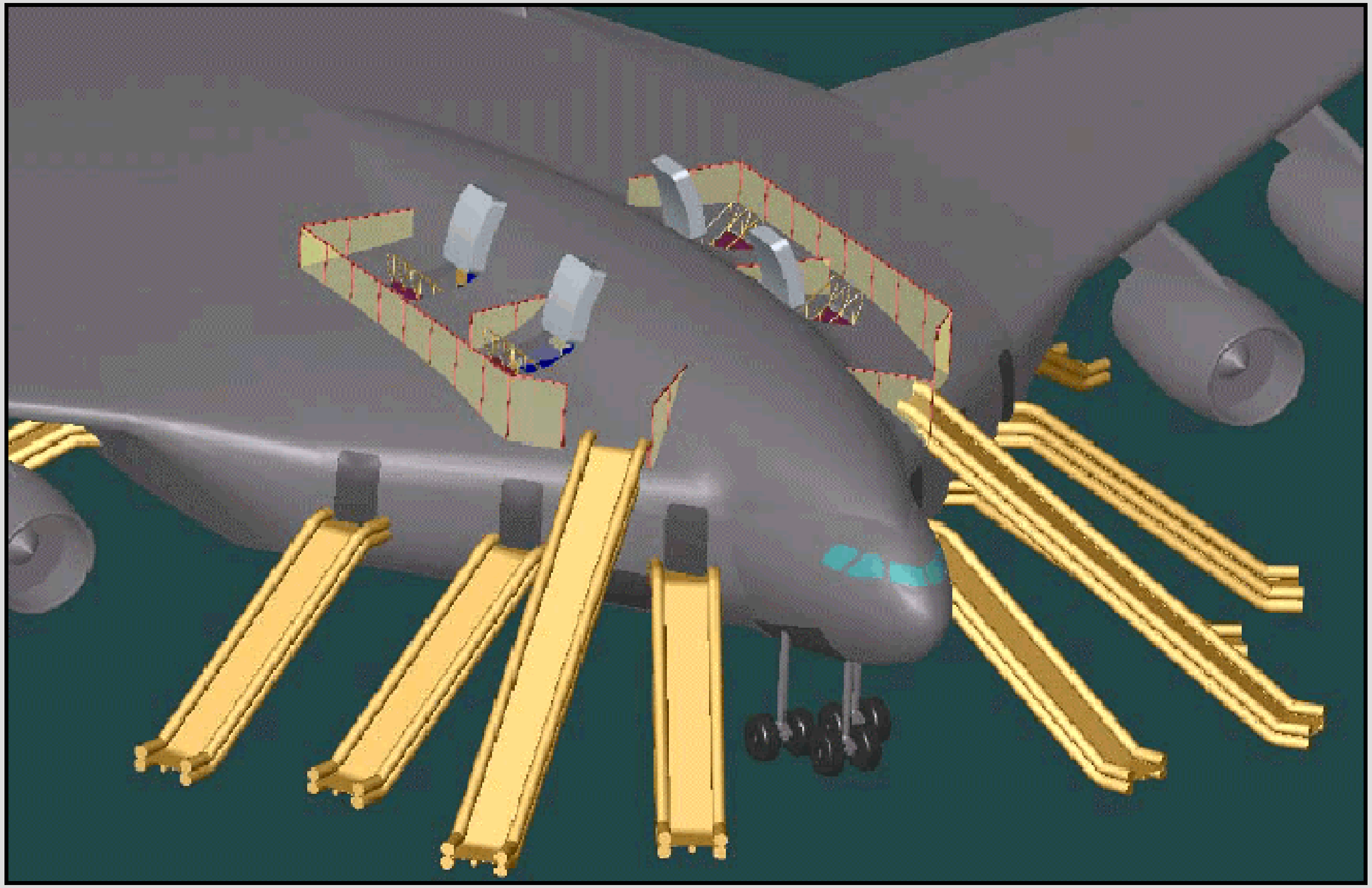
Türen	Evakuierungs- Zone (Evac)										Pax an Tür	Zeit [s]
	1 LV	1LM	1LH	2LV	2LH	1RV	1RM	1RH	2RV	2RH		
Tür 1L	60					60	5				125	**83**
Tür 2L		34		35			32		20		121	**81**
Tür 3L		30		35			28		30		123	**82**
Tür 4L		26		37			32		25		120	**80**
Tür 5L		26		37			25		35		123	**82**
Tür 6L					32			27	34		93	**62**
Tür 7L					31			27		22	80	**53**
Tür 8L					31			18		32	81	**54**
Tür 9L		13	44				10	18		20	105	**70**
Tür 10L		13	46				10			20	89	**59**
Summe [Pax]	**60**	**142**	**90**	**144**	**94**	**60**	**142**	**90**	**144**	**94**	**1060**	



VELA 1 - Emergency Evacuation

Evacuation of possible in less than 90s if passengers are routed through their assigned door.

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.

Wake Turbulence

Hochschule für Angewandte Wissenschaften Hamburg

Hamburg University of Applied Sciences

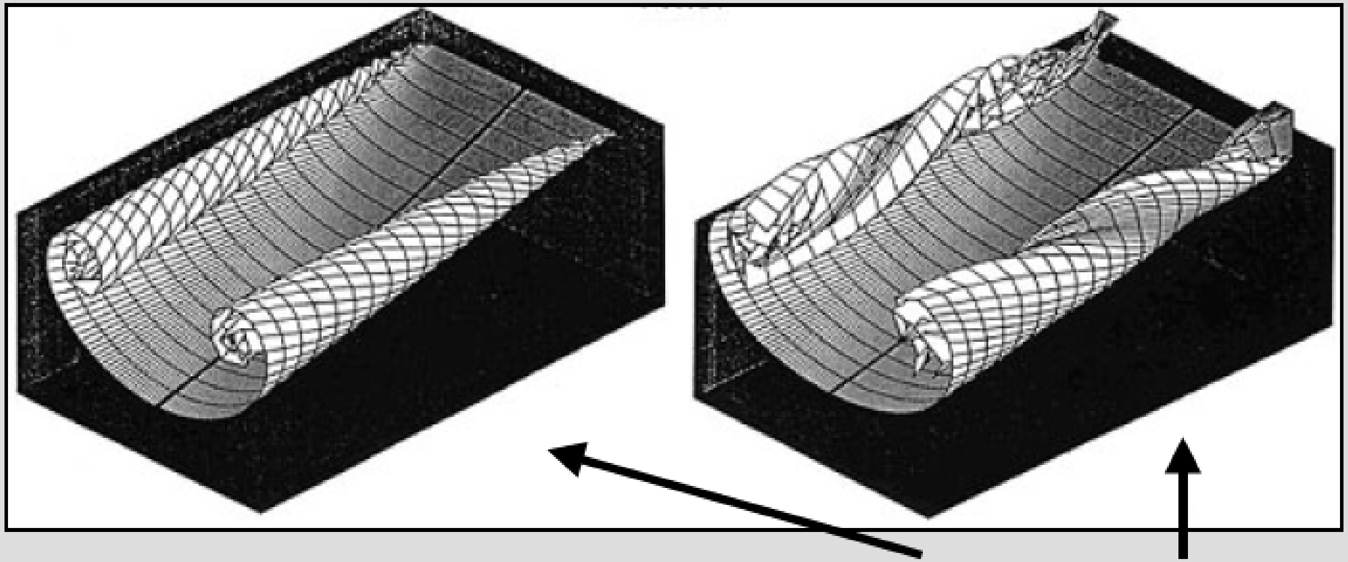
Wake Turbulence - Fundamentals

Wing tip vortices cause induced drag, D_i .

Wake turbulence cause a danger to following aircraft.

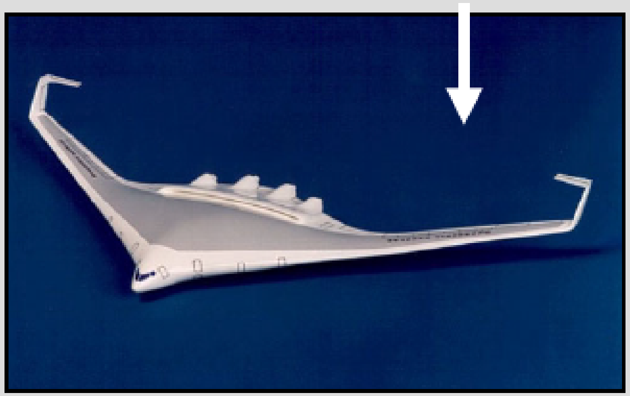
The initial strength of the wake turbulence
is based on basic aircraft parameters:

$$P_{wake} = D_i V = \frac{2g^2}{\pi A e} \frac{m(m/S)}{\rho V}$$



Decay of wake turbulence from a conventional wing and a C-wing.

C-Wing-BWB:



Wake Turbulence

Wake Turbulence - Comparison

$$\frac{P_{wake,BWB}}{P_{wake,A380}} \approx \frac{A_{A380}}{A_{BWB}} \cdot \frac{m_{MTO,BWB}}{m_{MTO,A380}} \cdot \frac{(m/S)_{BWB}}{(m/S)_{A380}} = \frac{7.53}{4.83} \cdot \frac{700}{560} \cdot \frac{341}{663} = 1.00$$

with BWB-Data from VELA 3. Result: no major problems expected.

Wake Turbulence - Separation

IFR Minimum Separation Rules on Approach (nm)

	Trailing aircraft type[a]		
Leading aircraft type[a]	Small	Large	Heavy
Small	3.0	3.0	3.0
Large	4.0	3.0	3.0
Heavy	6.0	5.0	4.0

Source: FAA [1978]

[a] Small: aircraft weighting no more than 12,500 lb. (5,625 kg)
Large: aircraft weighting more than 12,500 lb. (5,625 kg) and less than 300,000 lb. (135,000 kg)
Heavy: aircraft weighting in excess of 300,000 lb. (135,000 kg)

A380 interim value:
10 NM

Federal Aviation Administration: Parameters of future ATC Systems Relating to Airport Capacity and Delay. Washington, DC, USA, 1978. - Rep. FAA-EM-78-8A

ICAO and FAA Requirements on Aircraft Parameters for Airport Compatability

Airport Category	Airplane Overall Length (m)
1	0-9
2	9-12
3	12-18
4	18-24
5	24-28
6	28-39
7	39-49
8	49-61
9	61-76

VELA 3: 65 m

International Civil Aviation Organization: Airport Services Manual, Part 1: Rescue and Fire Fighting. Montreal, QC, Canada, 1983

Requirements from Aerodrome

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]

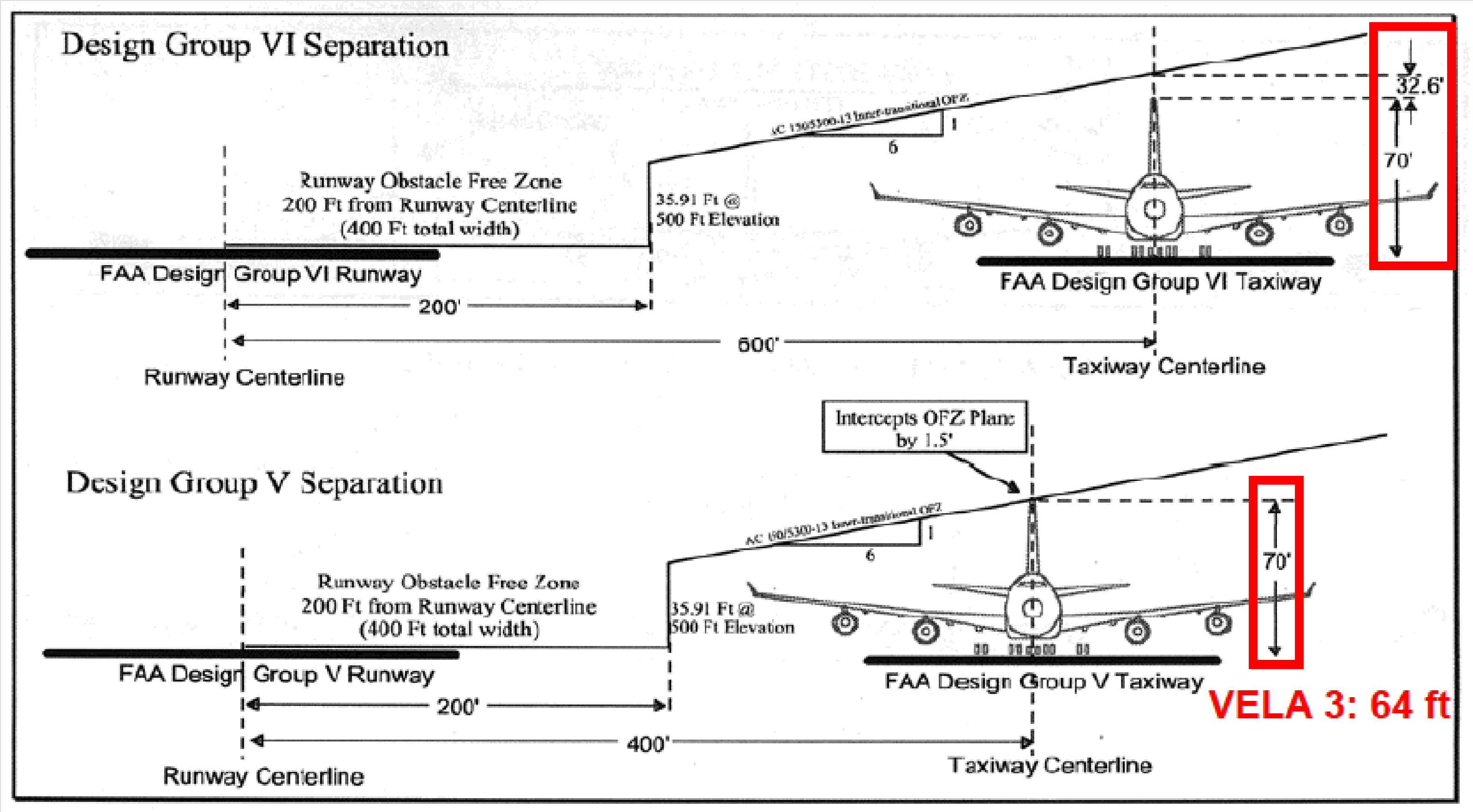
Aircraft approach category	Aircraft approach speed (kn)	Aeroplane design group	Aircraft wingspan (m)
A	<91	I	<15
B	91–<121	II	15–<24
C	121–<141	III	24–<36
D	141–<166	IV	36–<52
E	≥166	V	52–<65
		VI	65–<80

VELA 3: 99,6 m

International Civil Aviation Organization: Annex 14 – Aerodromes. Montreal, QC, Canada, 1999
Federal Aviation Administration: Airport Design. Washington, DC, USA, 1989. - Advisory Circular No. 150/5300-13

Requirements from Aerodrome

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

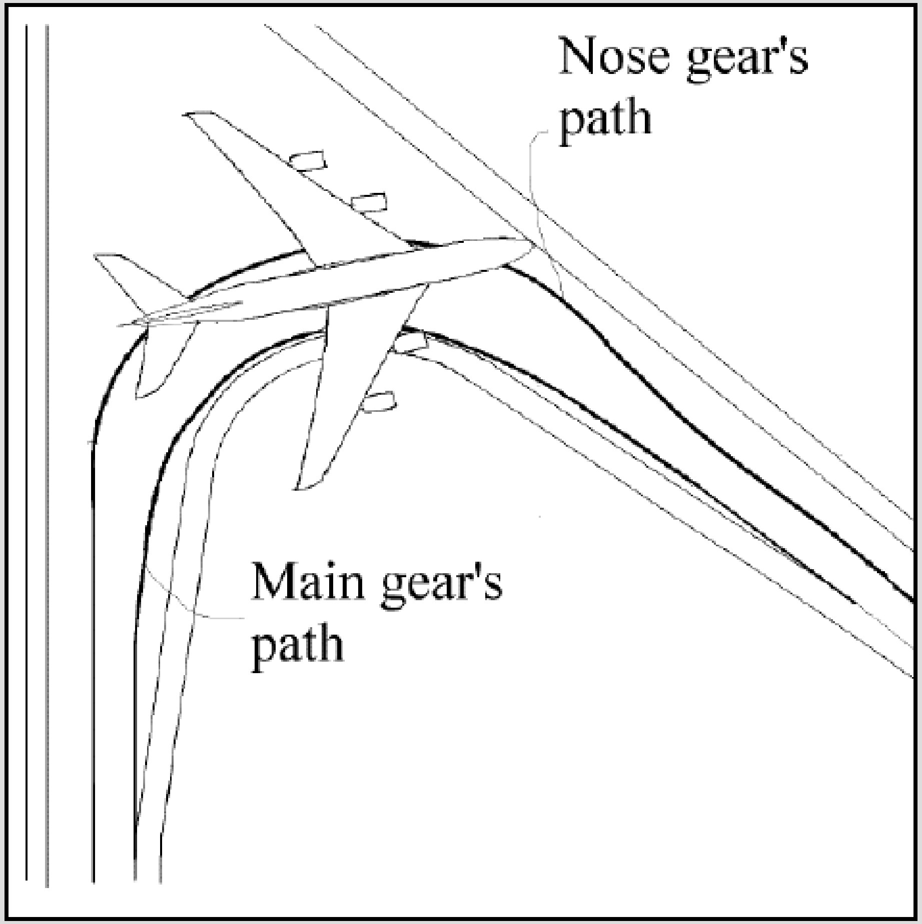


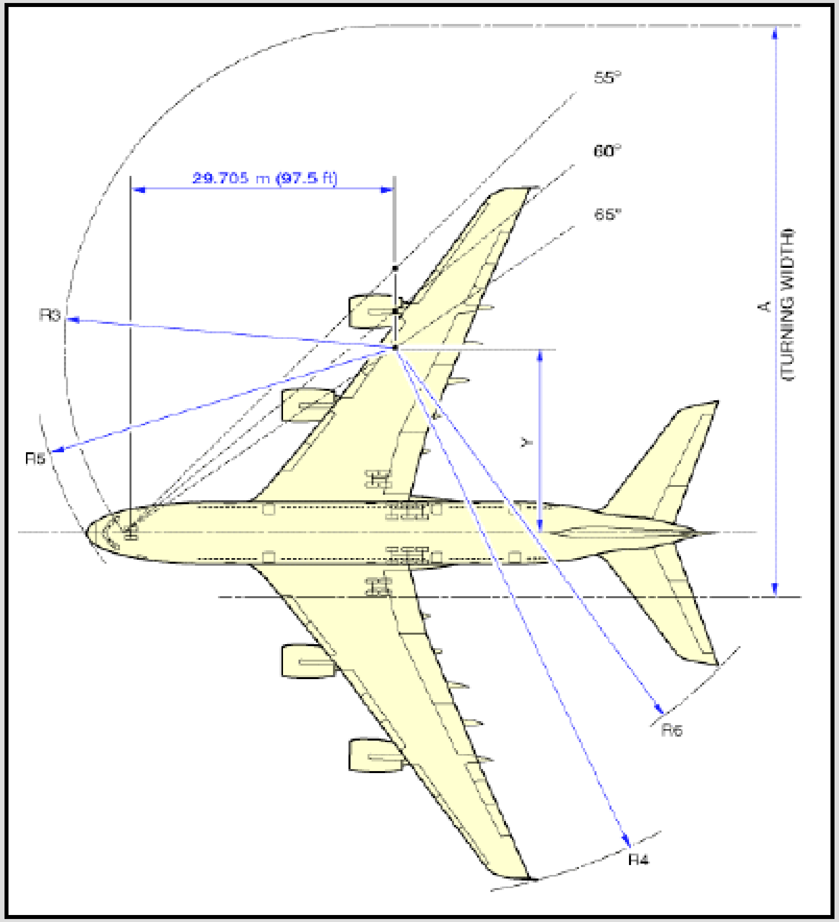
Clearance between runway and parallel taxiway (FAA 1998) =>
Maximum aircraft height (80 ft).

Federal Aviation Administration, Office of Aviation Research: Impact of New Large Aircraft on Airport Design.
Washington, DC, USA, 1998. - OT/FAA/AR-97/26

Requirements from Aerodrome

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences





Turning radius and taxiway fillets for aircraft turning.

Wheel span: A380: 12.5 m

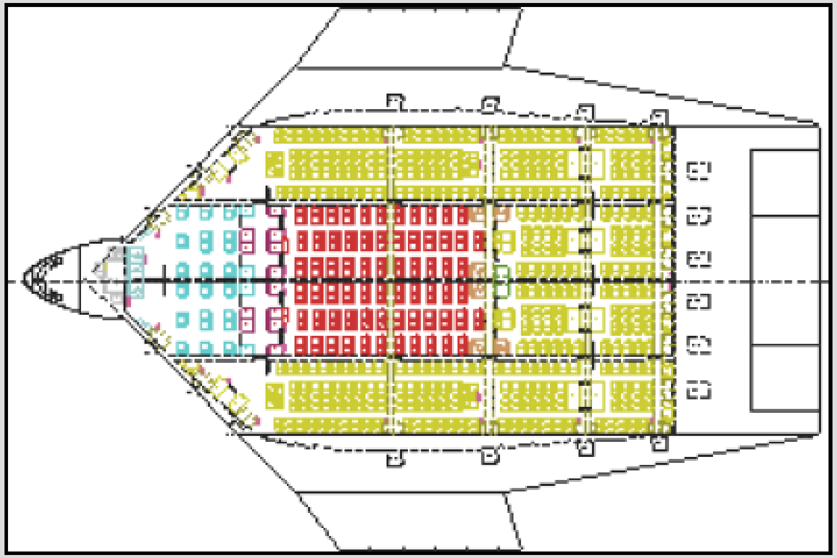
VELA: 11.4 m => similar turn characteristic.

Interior Design

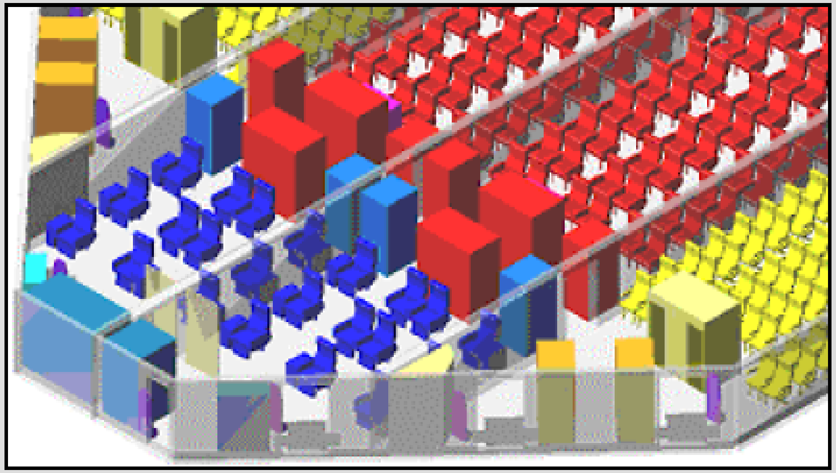
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

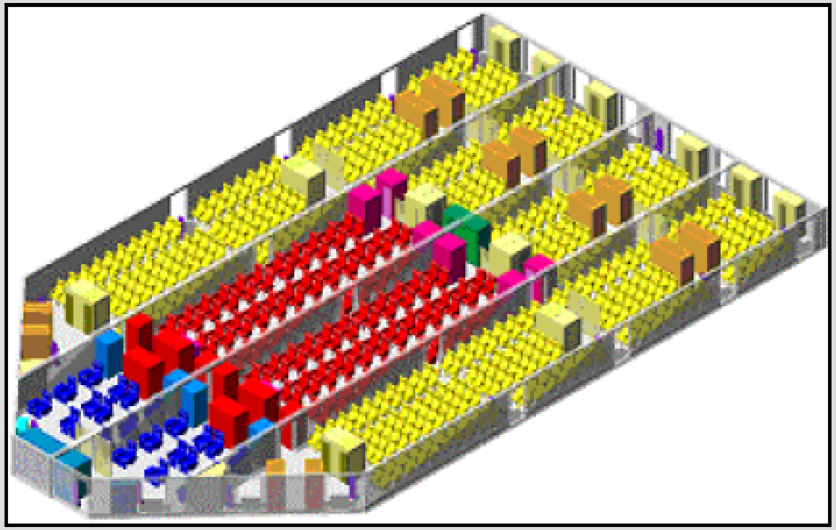
VELA 1 - Cabin Layout

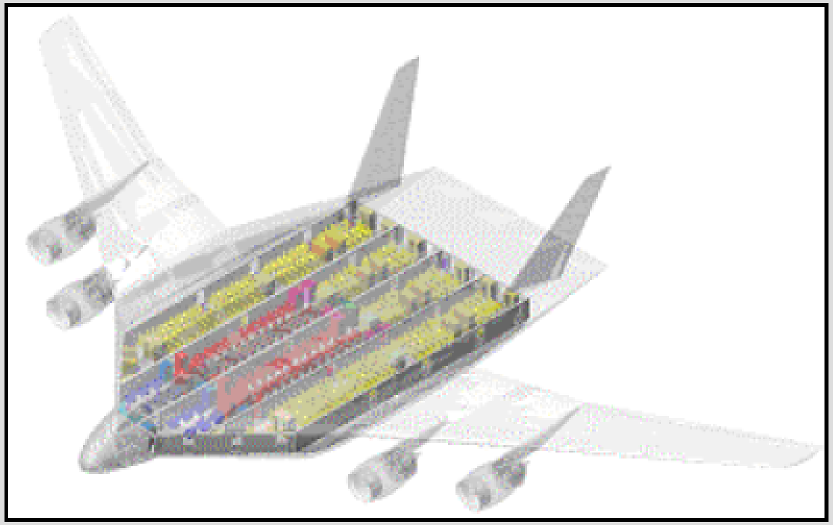
Diplomarbeit: S. Lee



Vertical acceleration for pax on outer seats.

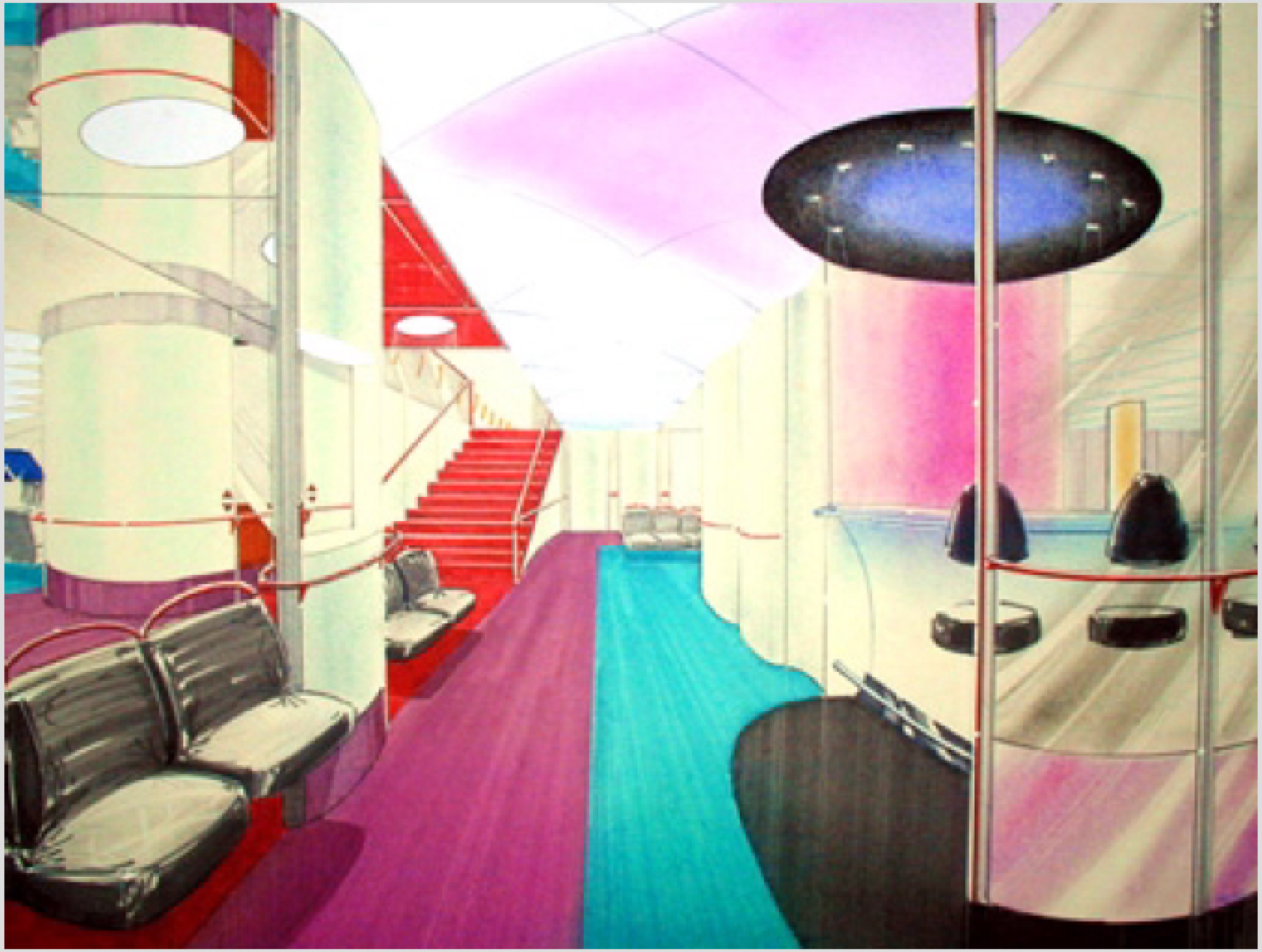






Double Deck BWB

W. Granzeier



Interior Design

Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

Underfloor Usage - Artificial Windows

W. Granzeier

BWB Center Wing Shapes from Inside

W. Granzeier

Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

AC20.30

http://www.haw-hamburg.de/f/personal/projekte/Blended-Wing-Body.html
http://www.ac2030.de

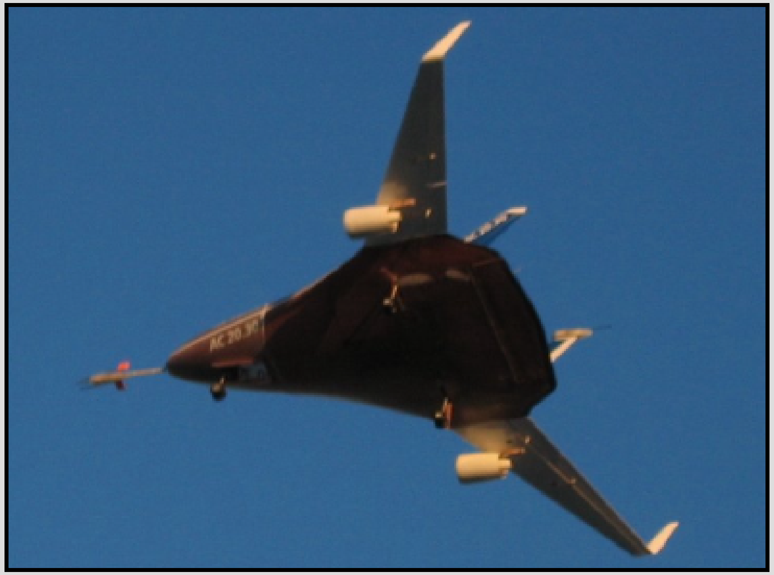
AC20.30

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Test Flights

AC20.30 Parameters

Scale	1:30
Span	3.24 m
Length	2.12 m
MTOW	12.5 kg
Engines	2 electric driven fans
Thrust	2 x 30 N
Power input	2 x 1400 W



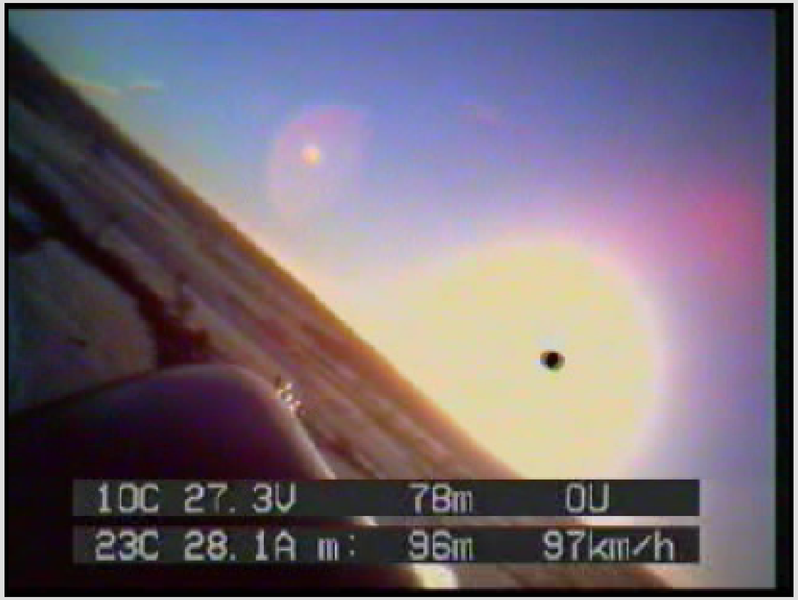
AC20.30

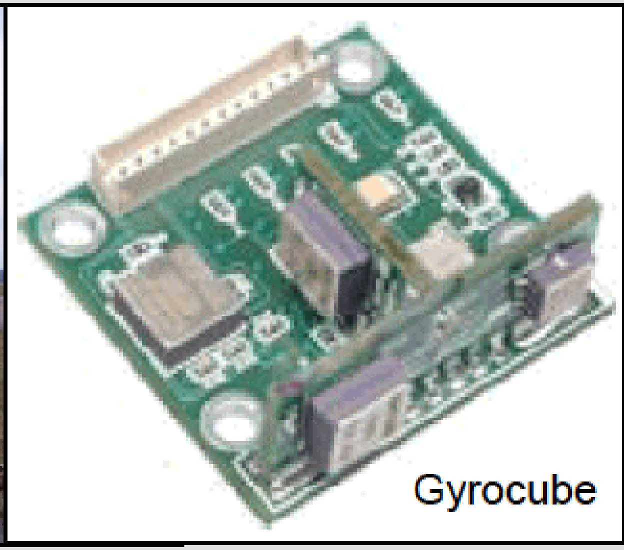
Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

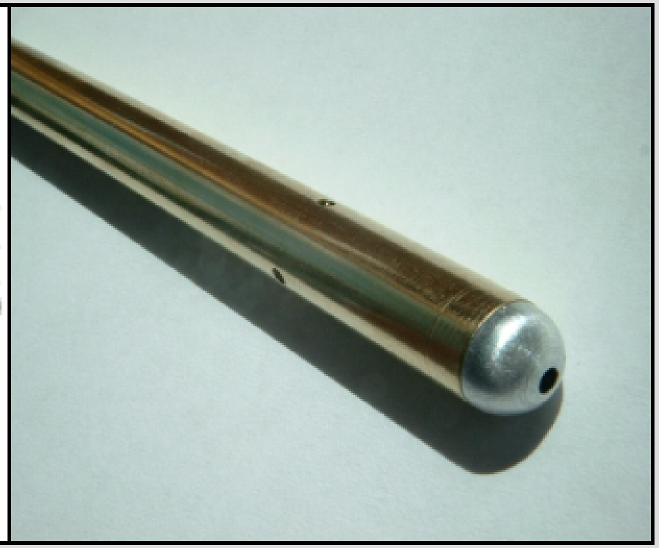
Test Flights

Recorded Parameters

barometric height, two temperatures
voltage, current
air speed, engine RPM
GPS-Coordinates (=> position and ground speed)
angle of attack, side slip angle
3 accelerations, 3 rotational speeds
position of 4 control surfaces
turn coordinator, ping, aerborne camera picture

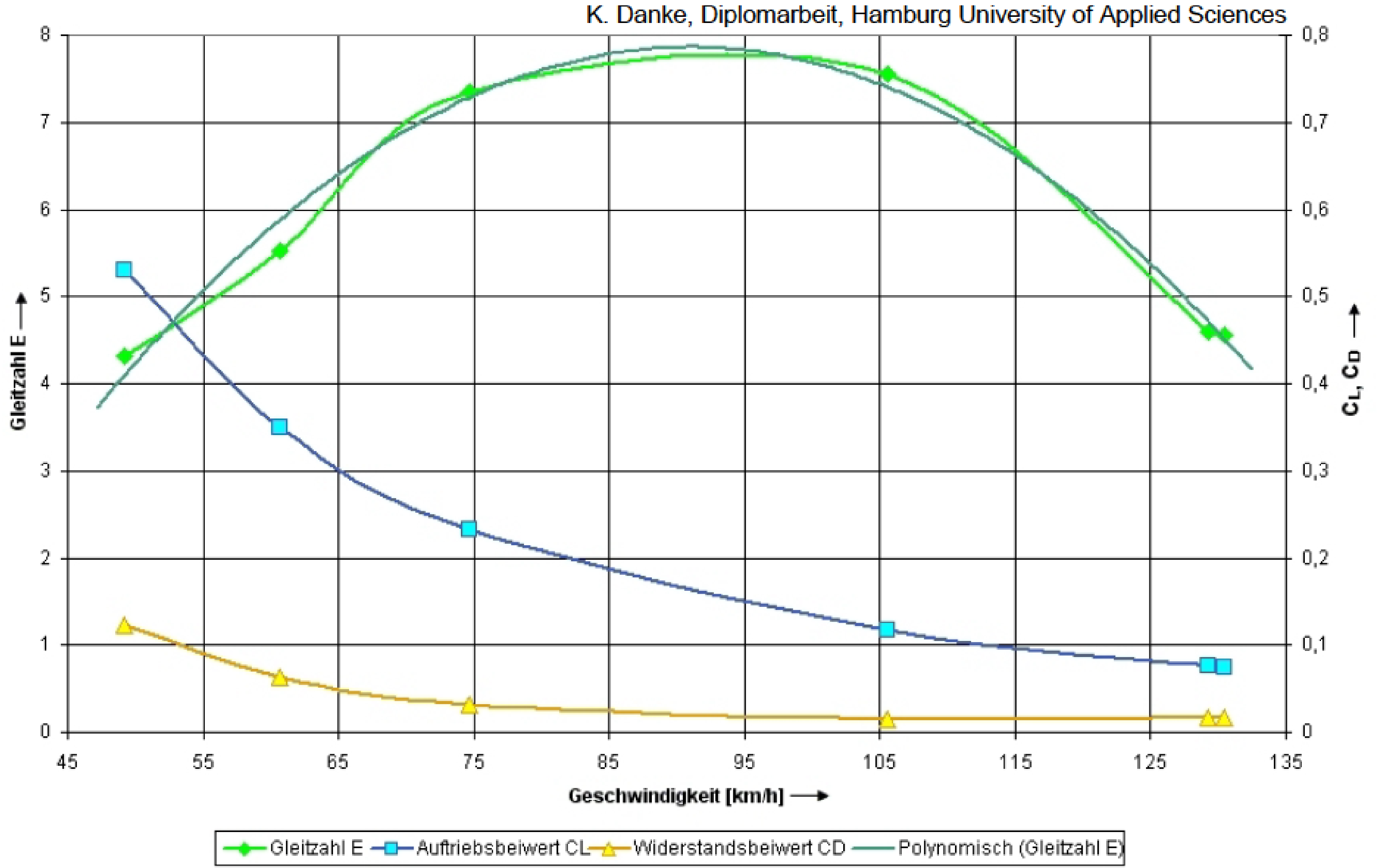






AC20.30

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences



Euler Angles form Test Flights with "Gyrocube"

$$U = V_T \cos\beta \cos\alpha$$
$$V = V_T \sin\beta$$
$$W = V_T \cos\beta \sin\alpha$$

$$a_x = \dot{U} + QW - RV + g\sin\Theta$$ ← solved for pitch angle, Θ

$$a_y = \dot{V} + RU - PW - g\cos\Theta\sin\Phi$$ ← solved for roll angle, Φ

$$a_z = \dot{W} + PV - QU - g\cos\Theta\cos\Phi$$ ← check results

Experience with Measurement Technique:

Simple and inexpensive method.

Drift problems are simply not present.

Good results only for manoeuvres with moderate dynamic.

AC20.30

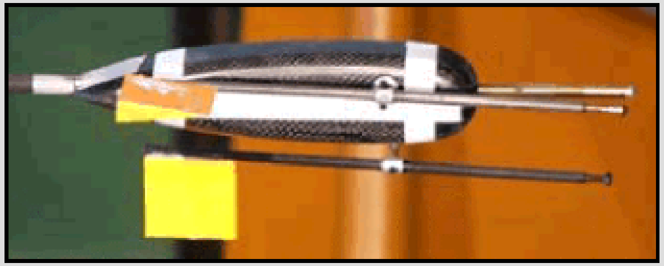
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

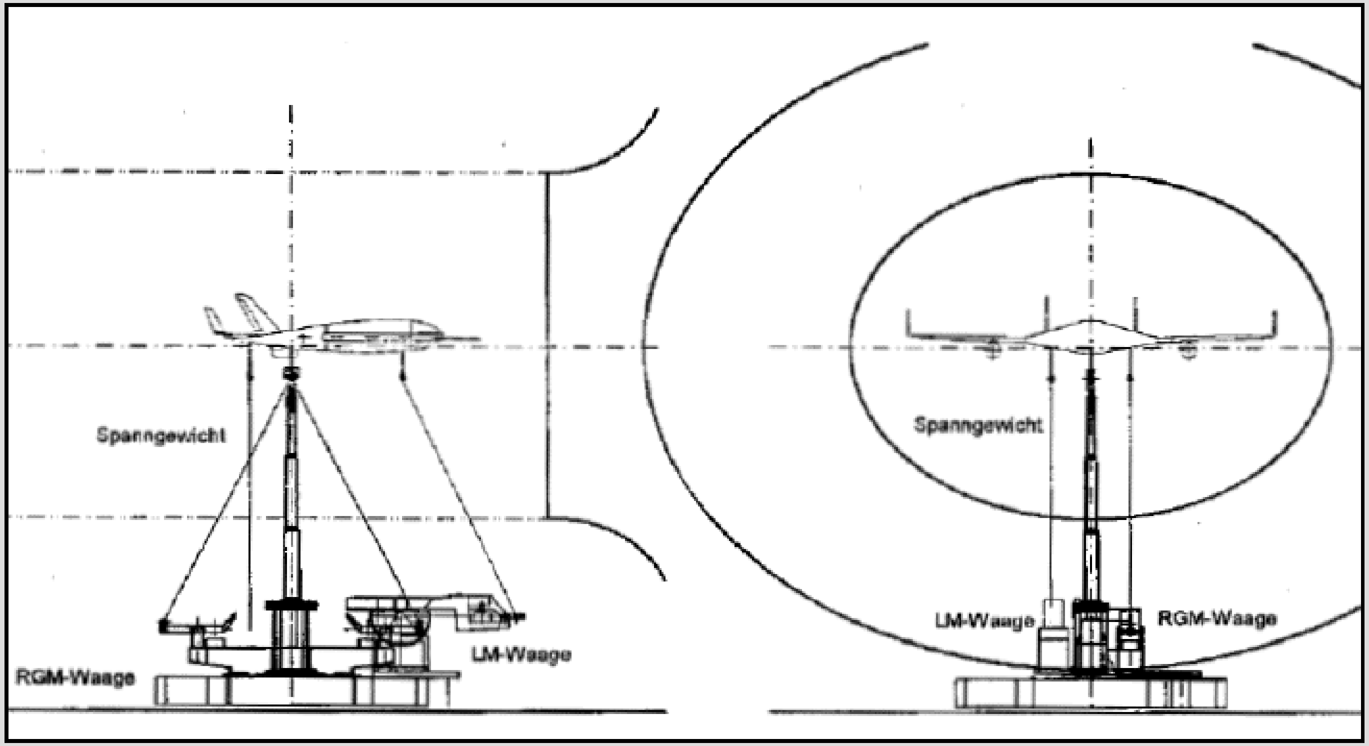
Wind Tunnel Tests

AC20.30

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

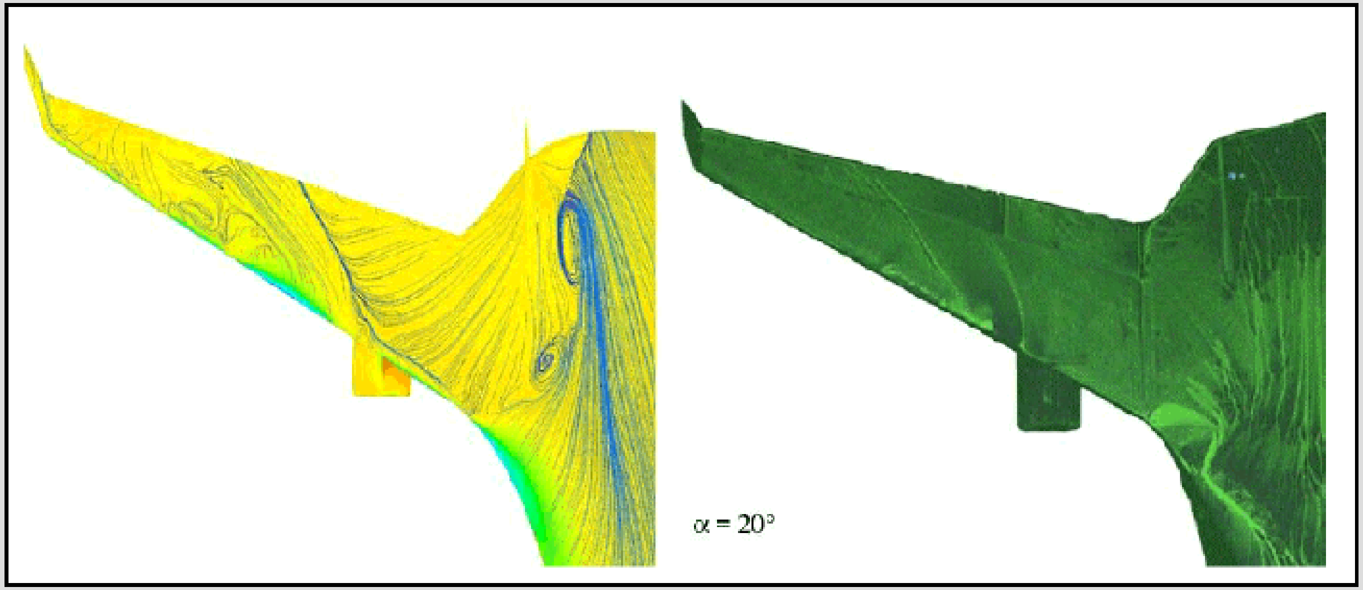
H. Zingel

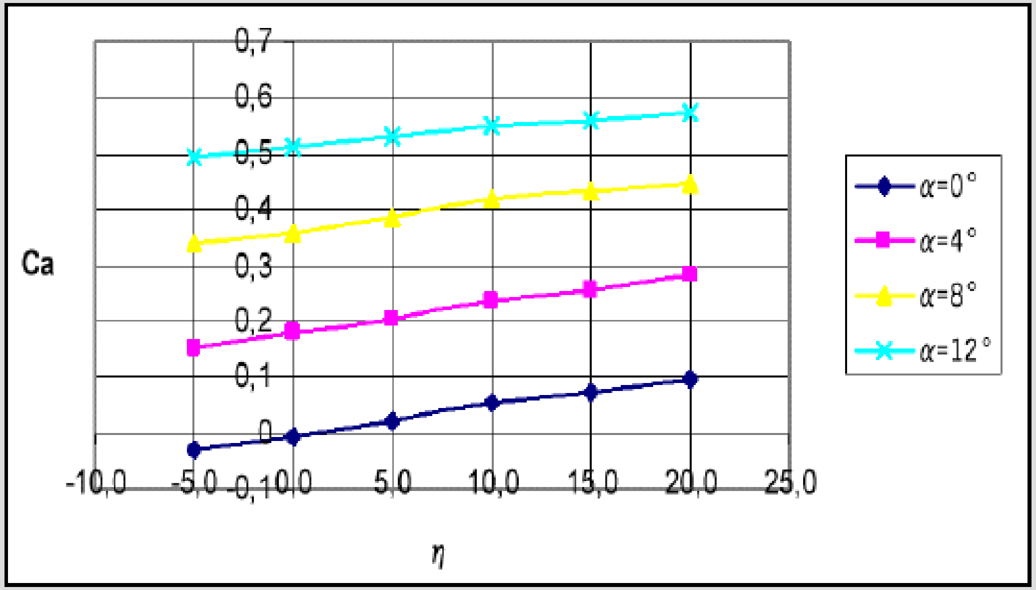




AC20.30

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences





CFD surface stream lines (left)
Fluorescend paint in wind tunnel (right).

Lift coefficient dependend on flap angle (wing) and angle of attack.

Hochschule für Angewandte Wissenschaften Hamburg

Hamburg University of Applied Sciences

Summary

W. Granzeier

Summary

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

BWB actual advantages compared to todays advanced aircraft

(summary of results from this investigation)

reduction in weight :	single shell required. In this case: 8% better
better L/D :	10 to 15% better (not apparent from AC20.30)
reduction in fuel consumption :	yes, due to L/D
reduction in emissions :	yes, lower CO_2 emmisions due to less fuel burn
reduction in noise :	only with engines on top
increase of airport capacity :	yes, more than 750 pax per A/C (probably no problems with wake turbulence)
reduction in DOC :	down ??% (mostly due to scale effect)

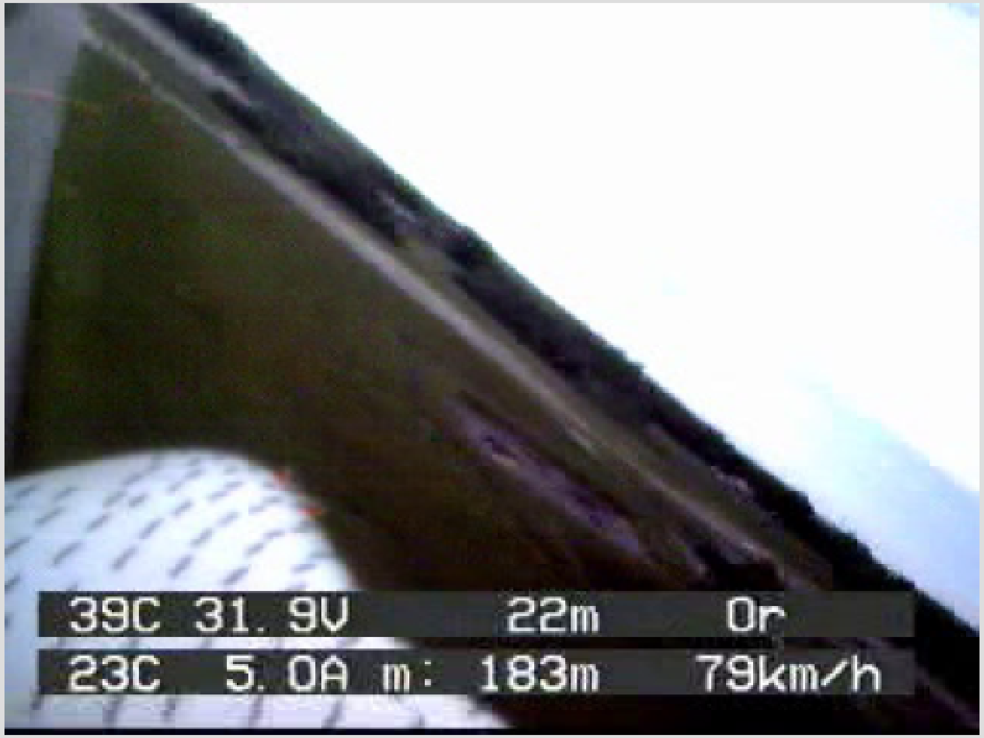
But:

open certification problems :	unstable configuration (?), ditching
open design problems :	rotation on take-off, landing gear integration, ...

AC20.30 Flight Test

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Flight Test Video:



The End

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

W. Granzeier