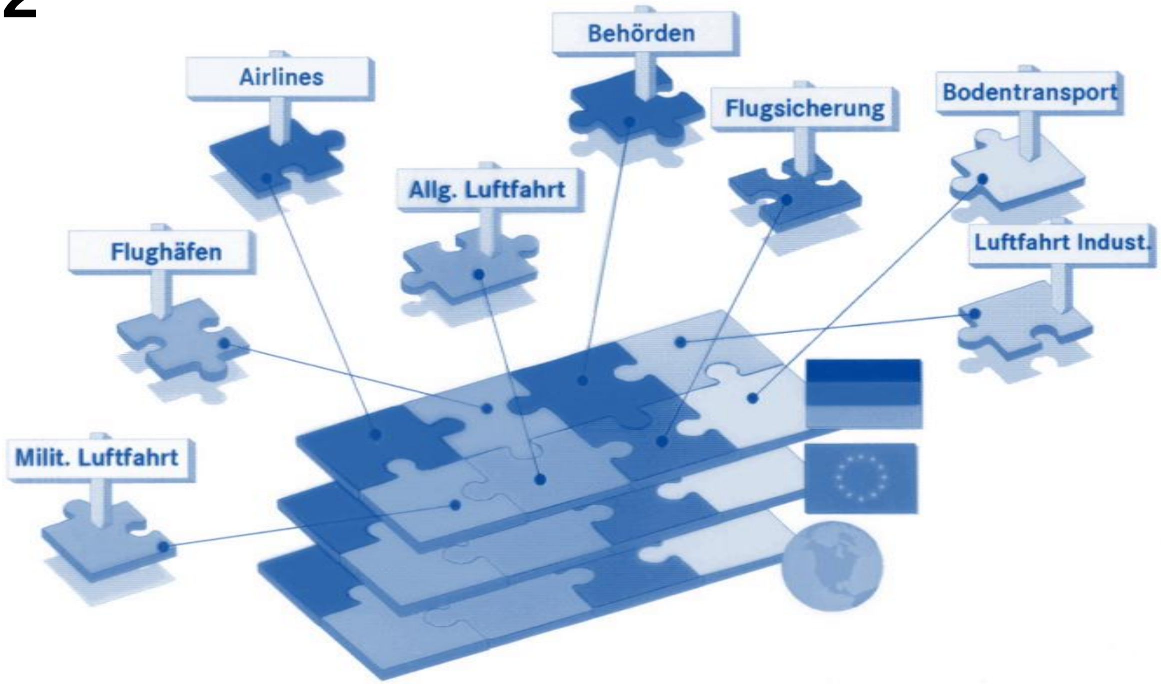
Air Transport System:

Lecturer: Prof. Dr.-Ing. Dieter Schmitt

Samara, April 2012



Curriculum vitae

Prof. h.c. Dr.-Ing. Dr.h.c. Dieter Schmitt

Telefon:	+49 (0)89 289-15981
Fax:	+49 (0)89 289-15982
Zimmer:	1605
E-Mail:	schmitt@llt.mw.tum.de
Anschrift:	Lehrstuhl für Luftfahrttechnik TU München 85747 Garching

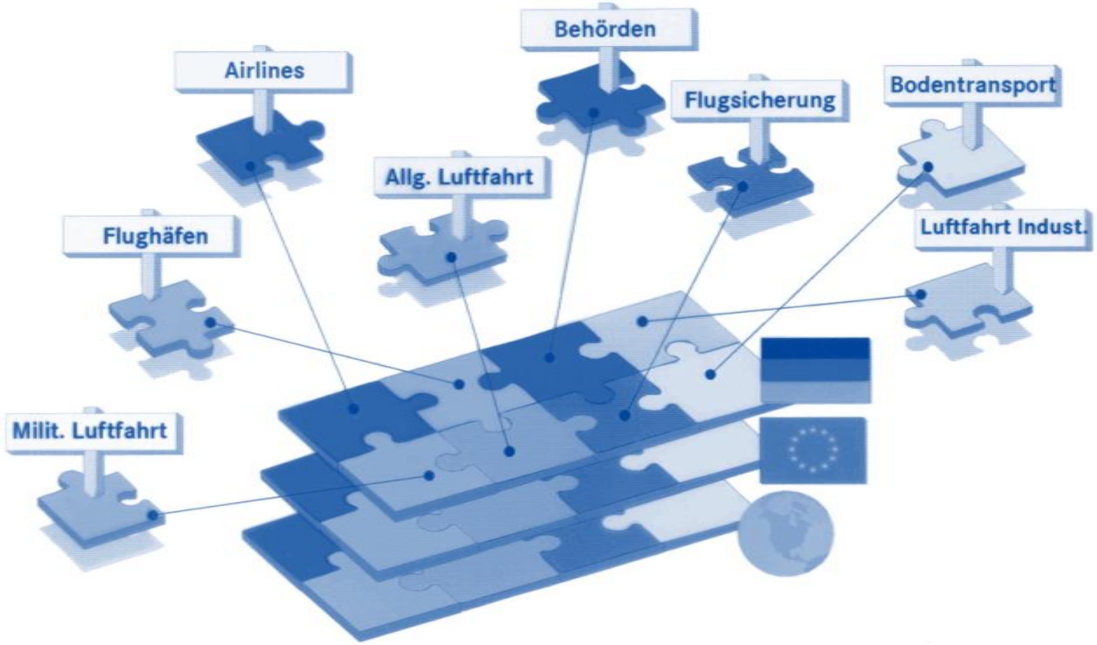
1961-1968	Studying Mechanical Engineering at TU Darmstadt
1968-1976	Scientific Assistent at TU Darmstadt (Prof. X. Hafer) finalizing with a PhD (Dr.-Ing.) in Flight mechanics
1976-1980	Starting as Engineer (flightmechanics) at MBB/Hamburg
1980-1985	Manager „Aerodynamics“ at Airbus in Toulouse
1985-1990	General Manager „Research & Development“
1990-1994	Vice-President „Future Projects“ bei DASA in Hamburg
1994-1996	Head of „Future Projects“ at Airbus Toulouse
1996-2002	Prof. ordin. at „Lehrstuhl für Luftfahrttechnik“ , TU Munich
2002-2007	Vice-President „Research and Technology“ at Airbus Toulouse
2008-2009	Technical Director „Bauhaus Luftfahrt e.V.“ in Munich
Since 2007	working as independant consultant for aeronautics

„Air Transport System“ – Content

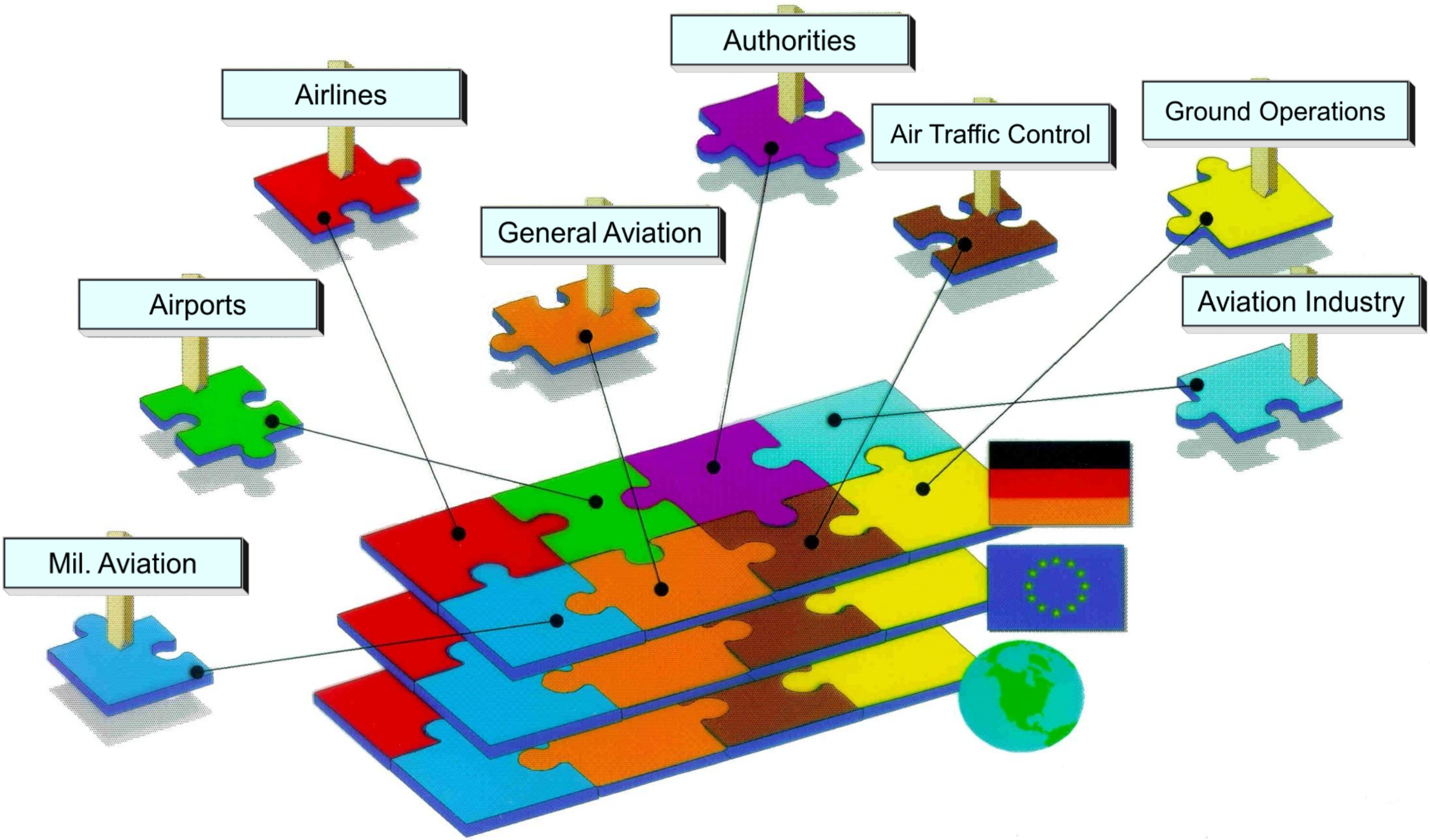
1. Air Transport as Part of a Global Transport System
2. Historical Development of Air Transport System (ATS)
3. Market Aspects
4. Legal Aspects of ATS
5. Aircraft Characteristics
6. Aircraft Industry
7. Aircraft Operation – Airlines
8. Airport
9. Navigation - Air Traffic Control System (ATC)
10. Air Transport and Environment

Chapter 1

The Air Transport as Part of a Global Transport System



Participants in the Air Transport System



Participants of the Civil Air Transport Systems

National Agency

-FAA -NTSB -Min Transp	EASA

Air Trafic Control

International Agencies

ICAO
IATA
FAA / EASA
IAC

Organisations

- Consumers
- Environm. Ag.
- Tourism Ag.
- Hotels

Aircraft industry

- Manufacturer
- Engine Manuf.
- Suppliers

Aircraft

Airlines

- Line
- Low Cost
- Charter

Agencies

- Travel agents
- Freight forward
- Integrators

Passenger

Freight

Maintenance-centres

Airports

Reservation - Systems (Amadeus .)

Infrastructure

- Meteo services
- Communication

Financing/ Services

-Banks
-Leasing Comp.
-Insurance

Historical Development of mobility

Review of a day trip (9h travel time)

Means of travel Speed [km/h]		Distance [km] 1 100 1000 10000 0	Infrastructure	Destination from Samara
	Walk Ca. 5 km/h	40 km (1h Pause)	Path	Samara Airport
	Stage-Coach ~ 12 km/h	96 km (1h Pause)	Paved path	Syzran
	Bicycle ~ 20 km/h	160 km (1h Pause)	Paved way	Simbirsk
	Ship ~ 40 km/h	360 km	Water	Kazan Saratov
	Railway ~ 70 km/h	630 km	Railway	Niznij Nowgorod
	Automobile ~ 100 km/h	900 km	motorway	Moskva / Moscow
	TGV-ICE ~ 200 km/h	1800 km	TGV	St. Petersburg
	Aircraft ~ 850 km/h	7500 km	Airport	Tokyo

Air Transport - Definition

„<u>Air Transport</u>" contains all ways and means,

- which will move
- persones, freight or mail(post)
- via air
- from an origin to a new destination

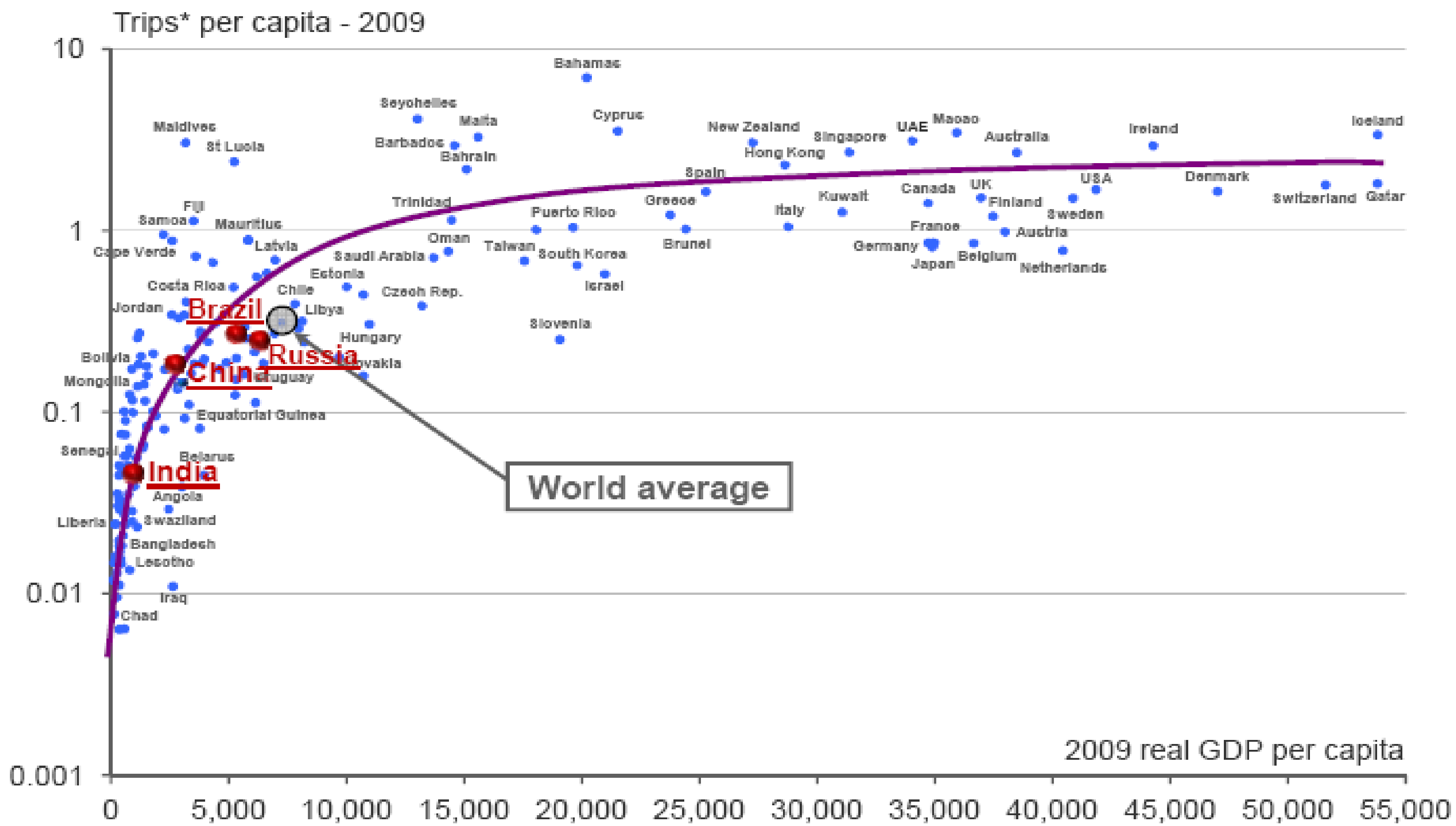
- and all directly related services.

Quelle: Rösger, Hünermann „Luftverkehrspolitik"

- Transport is traditionally a main focus for active governmental support and interest and especially the air transport, as it is mainly crossing borders!
- Transport has a priority compared to other sectors of the economy:
  - Economical reasons:
    - Export oriented industries need international market access
    - Industry places need fast transport means.
  - National reasons:
    - Demonstration of national power → air sovereignty
    - National air transport fleet → Reserve for transport needs during international crisis (war ?)
    - Prestige → national „flag carrier“ (Air France, Singapore Airlines, Iberia, Air India, Alitalia, British Airways, Air China, …).
- Based on the internationality (border crossing) of civil air transport on one side and the air sovereignty of the state on the other side close connections and common interest exist between the state and air transport.
- In many countries, the state is a major/dominant shareholder in the national flag carrier

Mobility

Propensity to travel

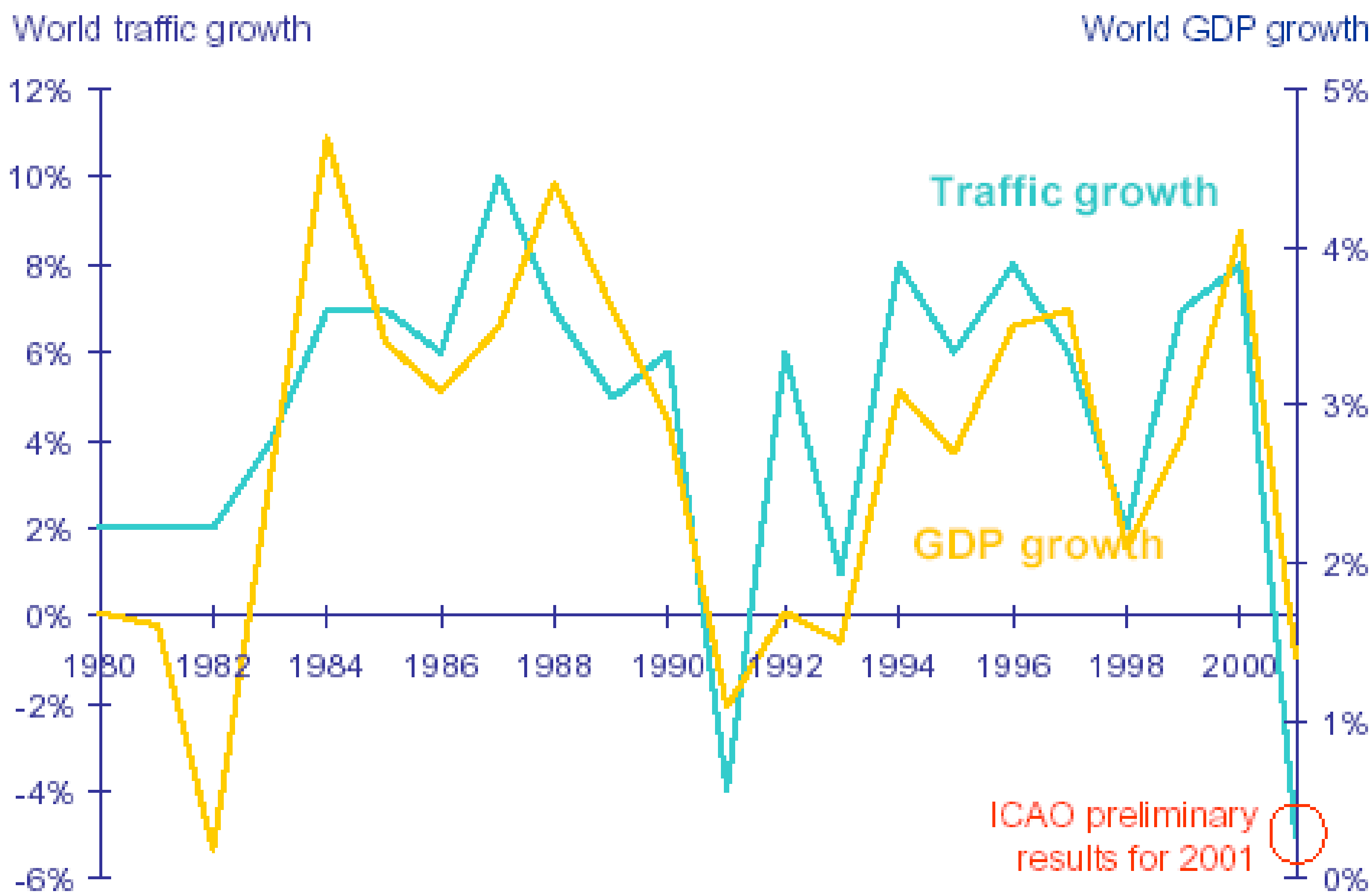


* Passengers originating from respective country

Note: GDP in US$2005

Source: IATA PaxIS, Global Insight, Airbus

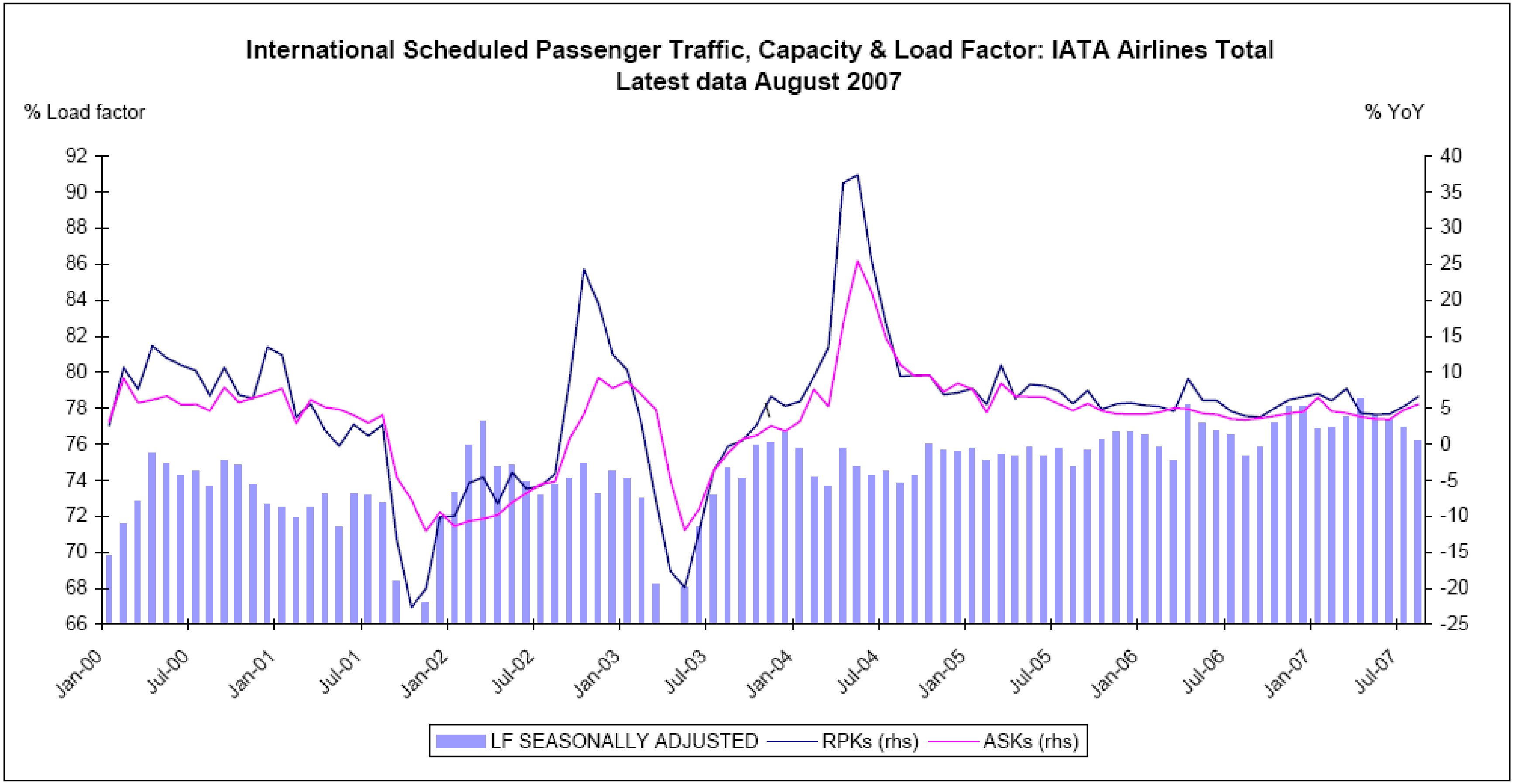
Revenue Passangermiles vs. GDP



The yearly growth of air traffic is strongly dependant on the growth of GDP (<u>G</u>ross <u>D</u>omestic <u>P</u>roduct)

Quelle: GMF 2002, Airbus Global Markt Forecast 2001-2020

Development of Load factor



Loadfactor = RPK / ASK

RPK: Revenue Passenger Kilometers
ASK: Available Seat Kilometers

Quelle: ICAO, AEA Yearbook 2001-2002

Passenger Requirements Today

Leisure

- ticket price of high importance
- 3 hours before check-in are accepted
- flight is part of holiday adventure
- a lot of baggage (bike,surfboard,.)
- comfort could be better, but ...

Business

- ticket price less important
- quick check-in (last minute)
- minimise non-working time
- A lot of hand luggage
- needs communication on-board
- comfort and service are important

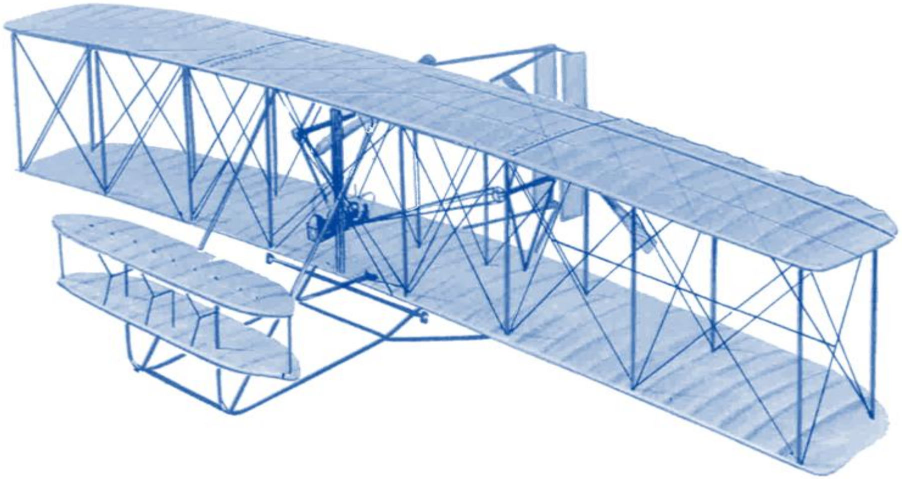
Characteristics of the product „air travel“

- The product „air travel“ ist an abstract, non-hardware like service.
- The passenger can neither see nor touch the product before buying
- The passenger is booking the flight expecting a proper service/performance
- In case of eventual malfunction/incommodity the passenger has no right to change or withdraw from the product/contract
- The salesman (airline) has no guarantee on the product if the customer/passenger will refuse to pay the ticket; he insists therefore on upfront payment!
- Production and consumption of the service „air travel“ are happening at the same time. A production for reserve or a storage of the product „air travel“ is impossible!
- An empty, not sold seat is a lost product unit and cannot be recovered lateron.
- The salesman needs for a cost balanced business a fairly high averaged load factor.
- Basic service of the product „air travel“ is the transport of a person from origin a to destination B. This service can be expanded by other services before, during or after the flight
- Services will become besides the flight plan (departure time, route, frequency) major competitive parameters.

Quelle: Pompl „Luftverkehr“

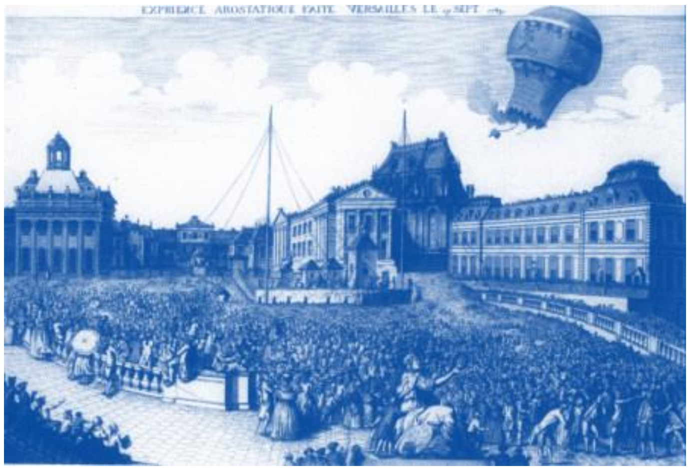
Summary

- The aircraft is without alternative on long haul routes (and over water) and is a complementary and competitive mode for rail and road on short haul routes (Modal Split).
- With respect to primary energy- and land- consumption the air transport is competitive with all other existing environmental friendly transport systems !
- Air traffic is a fundamental part of the global transport system.
- The growth in air transport is closely linked with the economic development (GDP). Therefore all states are interested in a positive interaction.
- The air traffic increases annually by 3-6% and is about doubling the world economic growth. This fact has been confirmed over the last 20 years. The air transport growth is a strong indicator for global economic growth!
- Linked to events like 11.09 2001 and economic crisis of 2008 air transport has suffered dramatically, confirming the strong role as an economic indicator!
- The product „air travel“ is a non-tangible service, which is created and consumed at the same time. No storage of service performance possible!
- A high load factor is a specificity for performing aircraft operators!

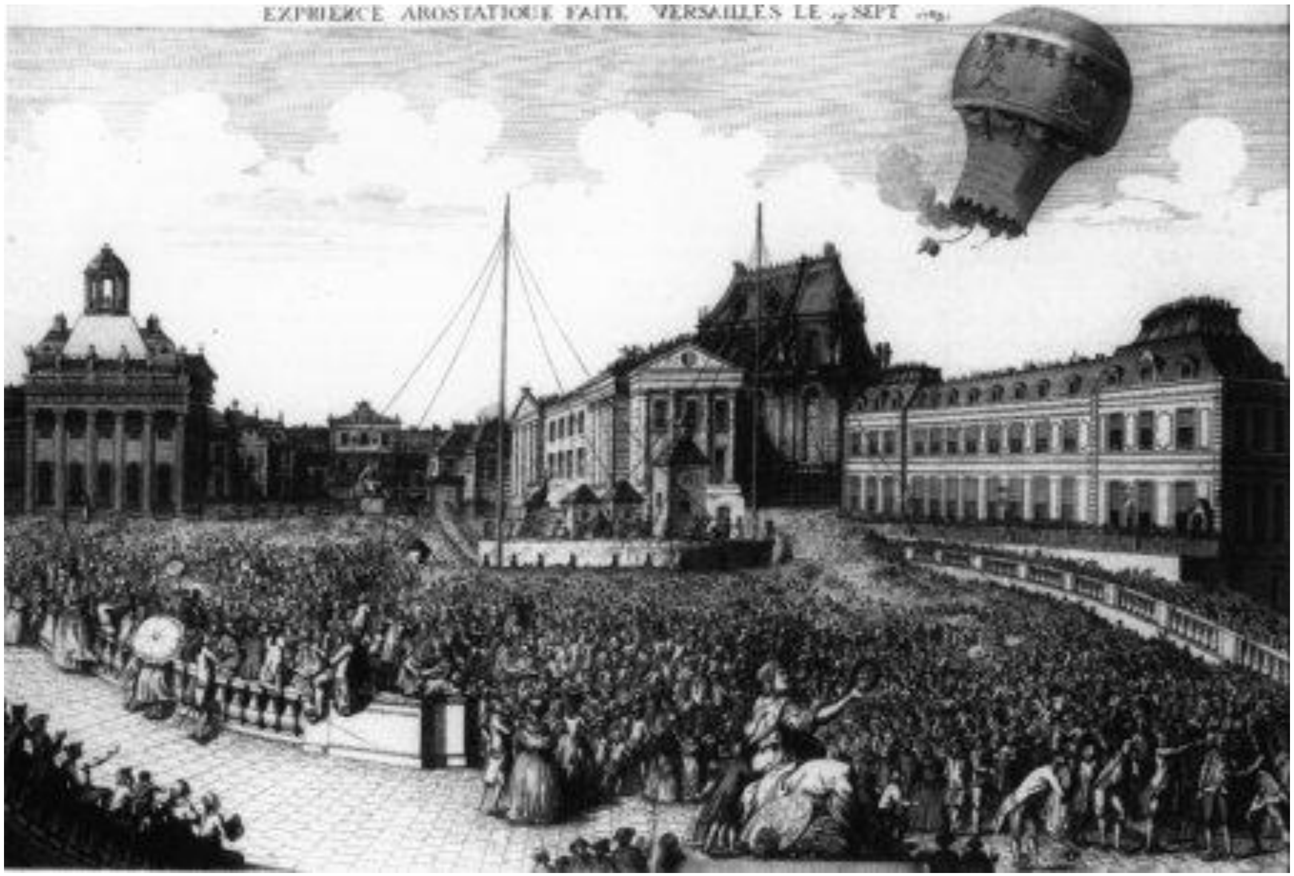


Chapter 2

Historical Development of Air Transport



Montgolfiere with three animals (Duck, Sheep and Coq) on board
19th September 1783 in Versailles in presence of the French King.



Historical events preparing air transport

1000 - 500 AD	Chinese Kites are known
	Legend from Daedalus and Icarus
1500	Leonardo da Vinci is sketching first air vehicles
1783	Montgolfier brothers are starting a hot air balloon
1813	George Cayley is defining the „principles of flight“
1889	Otto Lilienthal is publishing his book on „Fliegekunst“
1896	Lilienthal dies during his ~280th gliding flight
1903	Wright Brothers are making the first controlled flight
1912	Bleriot successfully crosses the English Channel
1919	Junkers is developing the F13, the first realistic aircraft
1927	Lindbergh is crossing the North Atlantic
1930-35	Development of long range aircraft (B307,DC4,Fw200)
1950	Development of first civil jet aircraft (British Comet)
1960	B707 and DC8 are enabling regular transatlantic flights
1974	Concorde – 1st civil supersonic aircraft – starts services

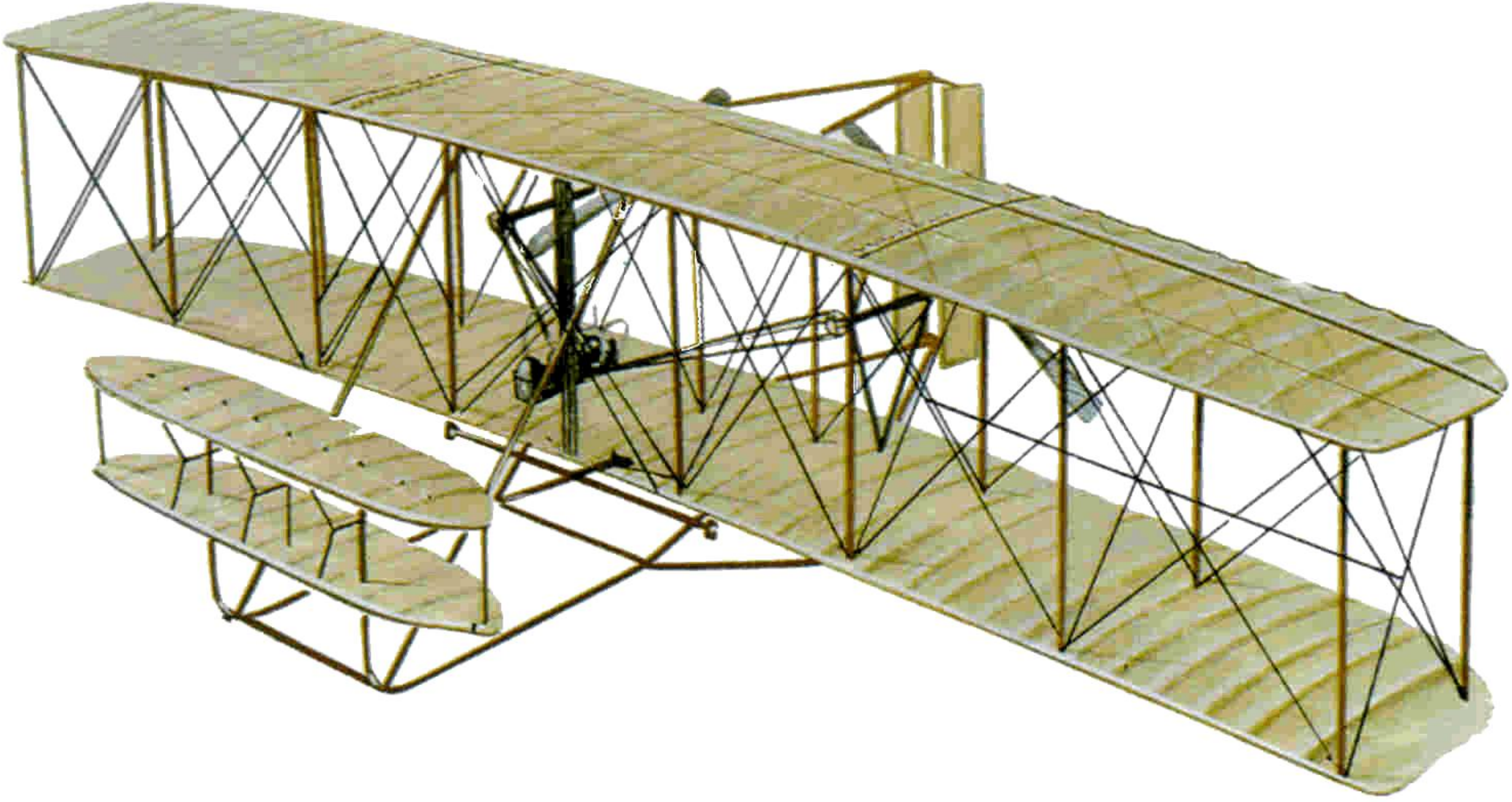
Cayley defined the initial principals for „Flying machines heavier than Air“:

- Necessity of Aerodynamic Lift
- Realisation of an independant propulsive system
- Necessity for sufficient stability and controlability
- Light Weight Structure
- Separation of air forces in Lift and Drag
- Independant Optimization of Subsystems

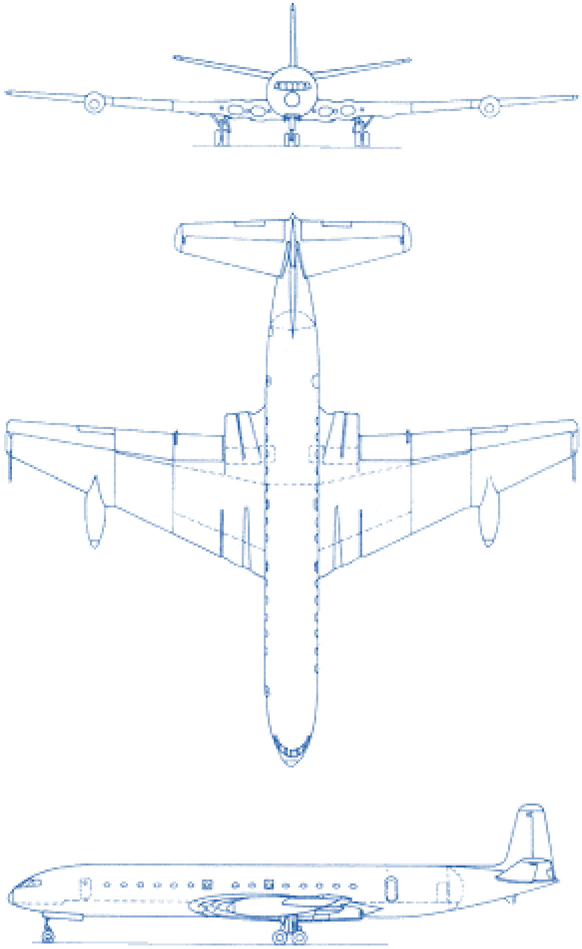
Historical Development – Otto Lilienthal (1848-1896)

1889 First Engineering Book on „Der Vogelflug als Grundlage der Fliegekunst“

(„Bird-flying as basis for art of flying“)



Historical development – Comet

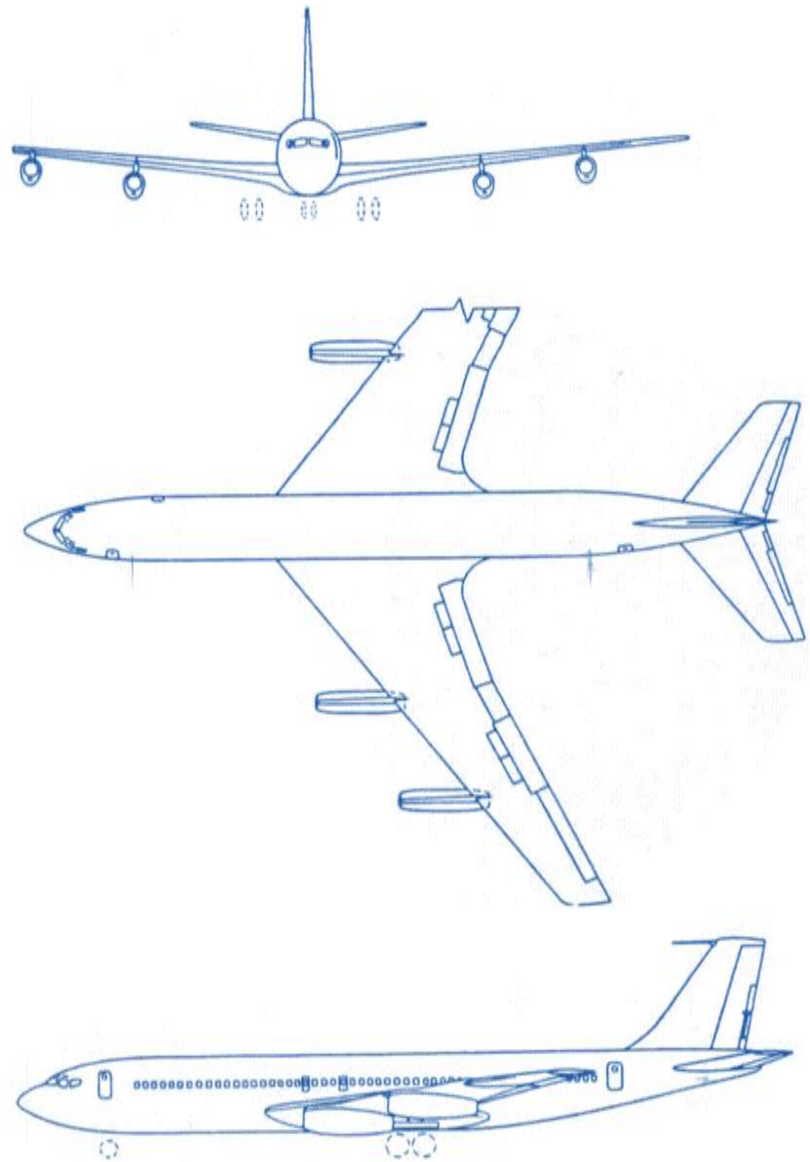


The first prototype of De Havilland D.H. 106 „Comet“ started for the first time 1949 with four jet engines! After intensive flight testing the second prototype has been flown another 500 hours in 1951. The first commercial flight with this type has been done in 1952 on the route London-Johannesburg and 1953 on the route London-Tokio.

On 2nd May 1953 a „Comet“ crashed, several other tragic accidents followed.

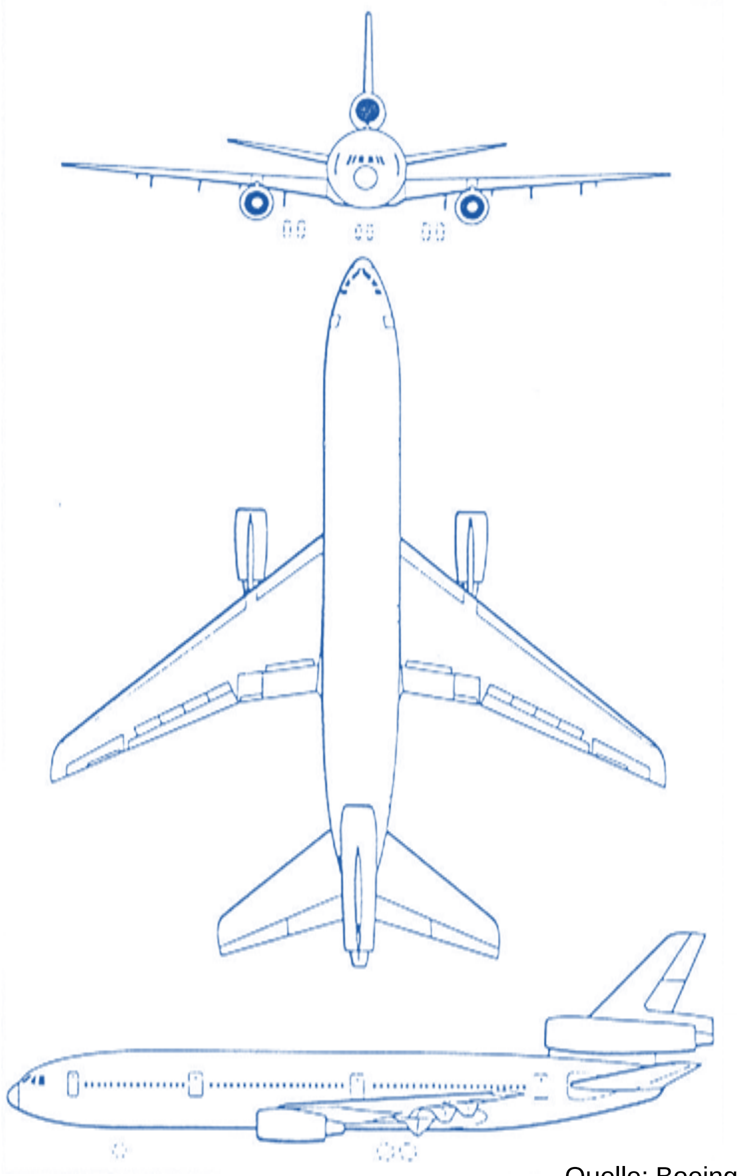
This caused the withdrawal of all „Comet“-aircraft from commercial operation!

Boeing 707



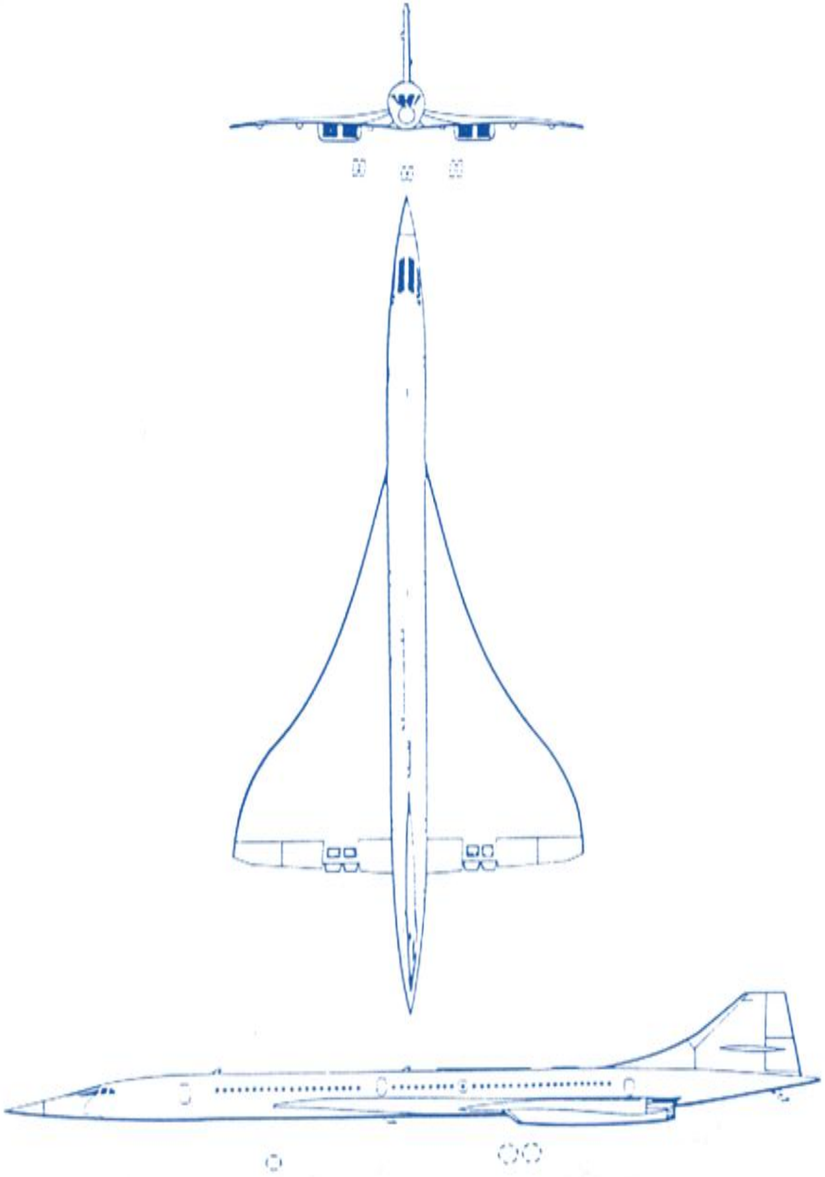
Quelle: Boeing

Widebody Aircraft – Douglas DC10-10

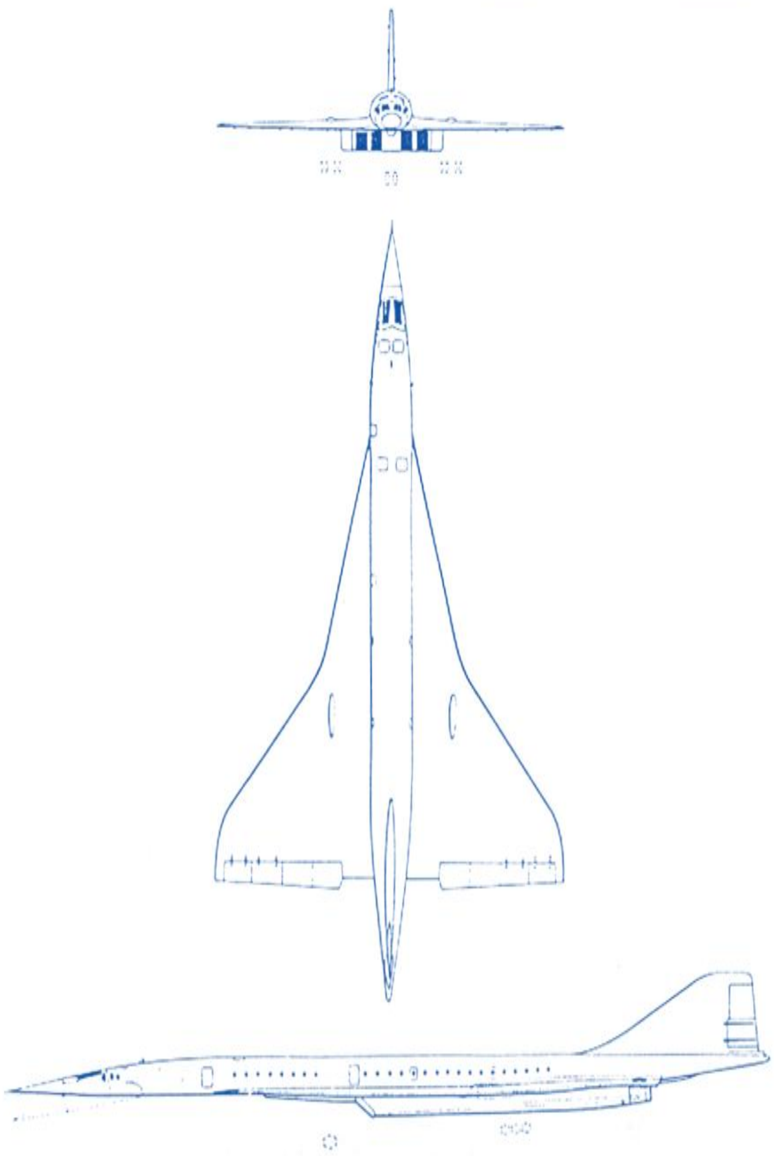


Quelle: Boeing

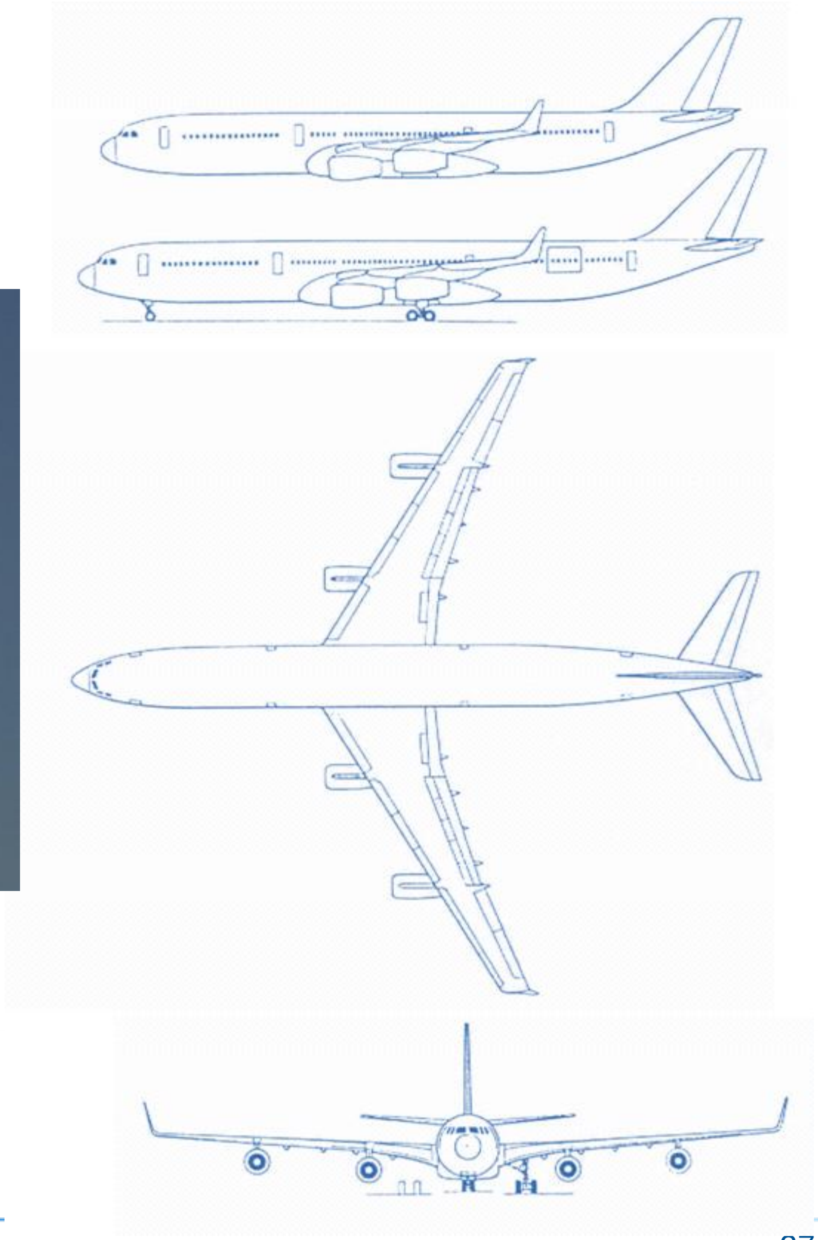
Supersonic Transport Aircraft - Concorde



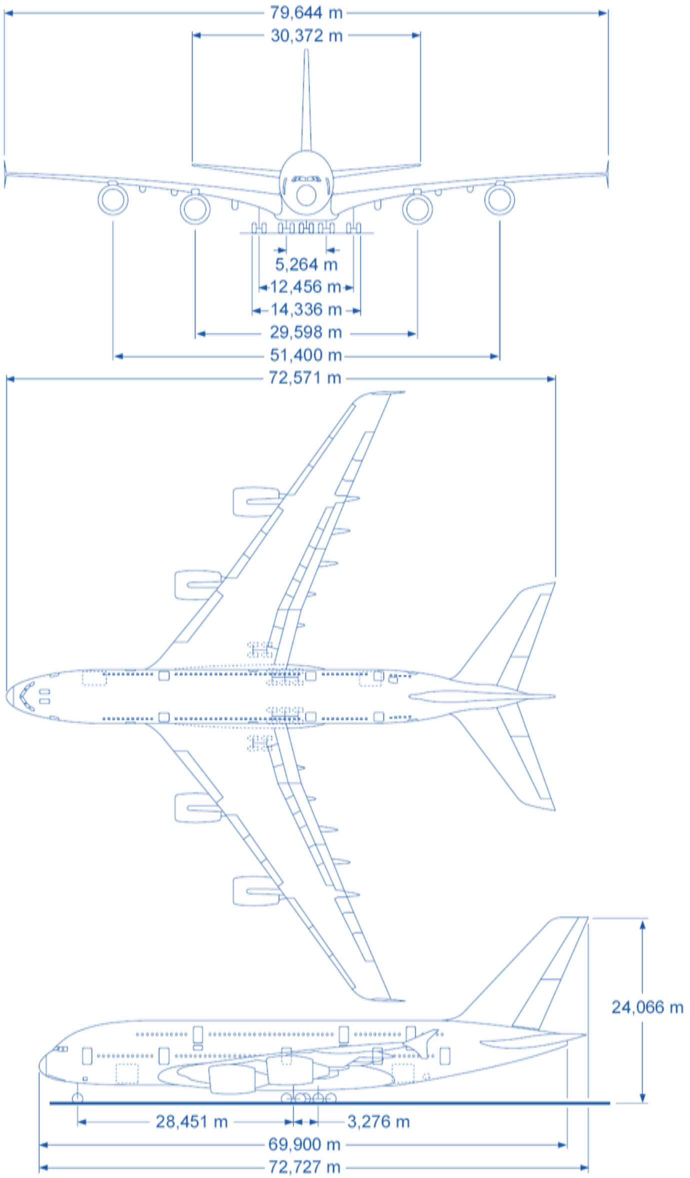
Supersonic Transport Aircraft – Tupolew Tu-144



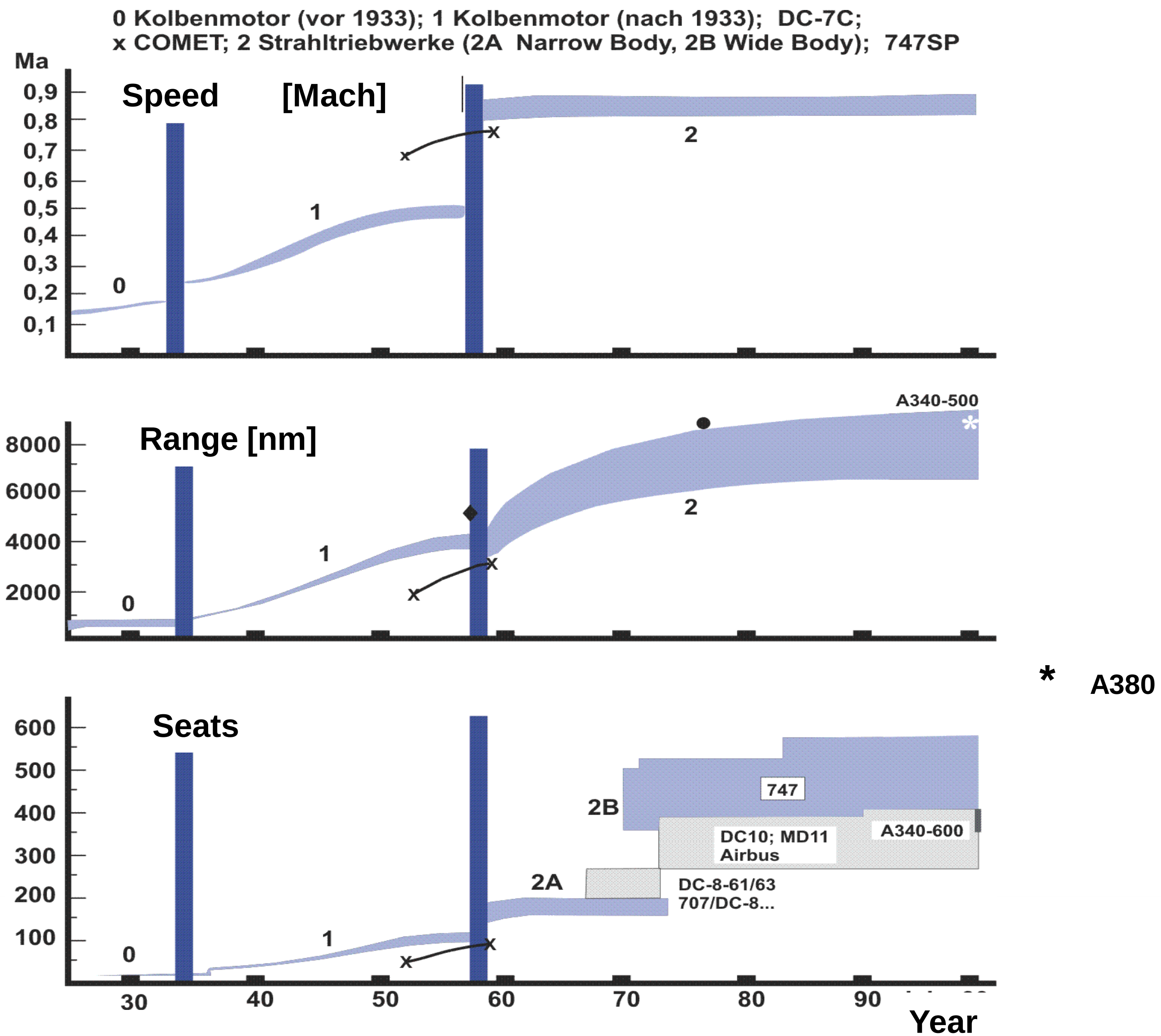
A340



A380

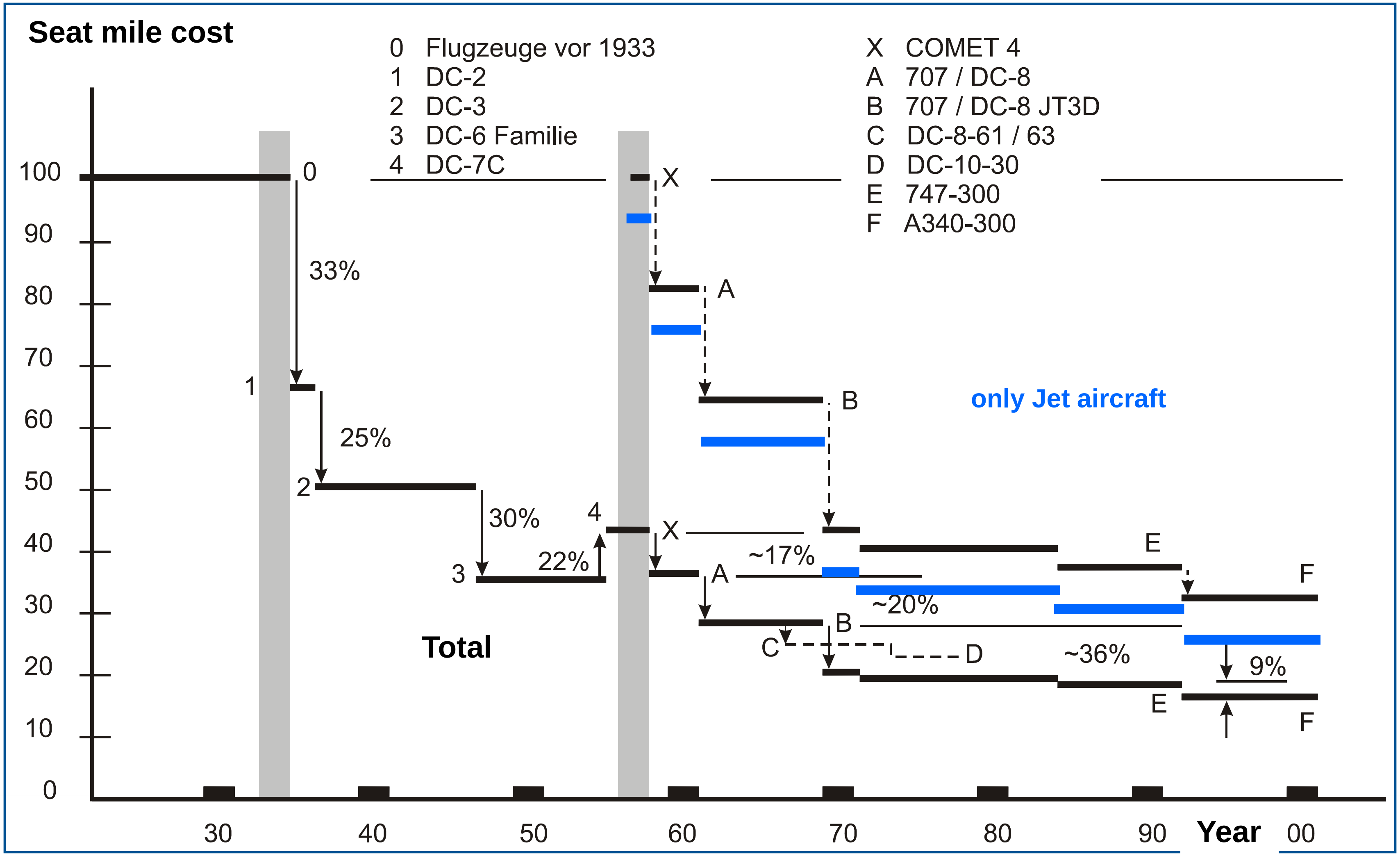

79,644 m
30,372 m
5,264 m
12,456 m
14,336 m
29,598 m
51,400 m
72,571 m
24,066 m
28,451 m
3,276 m
69,900 m
72,727 m

Passengers: 560 (3-Class- Configuration)
Range: 7500 nm
Takeoff Weight: 560 t
Cruise Speed: Mach 0,85 M_{Cr}
Geometry: l=73 m, b=79,8 m, h=24,1 m



0 Kolbenmotor (vor 1933); 1 Kolbenmotor (nach 1933); DC-7C;
x COMET; 2 Strahltriebwerke (2A Narrow Body, 2B Wide Body); 747SP
Ma
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
Speed [Mach]
0
1
2
Range [nm]
8000
6000
4000
2000
A340-500
Seats
600
500
400
300
200
100
2A
2B
747
DC10; MD11
Airbus
A340-600
DC-8-61/63
707/DC-8...
30
40
50
60
70
80
90
Year
* A380

Seat-mile Cost vs. time



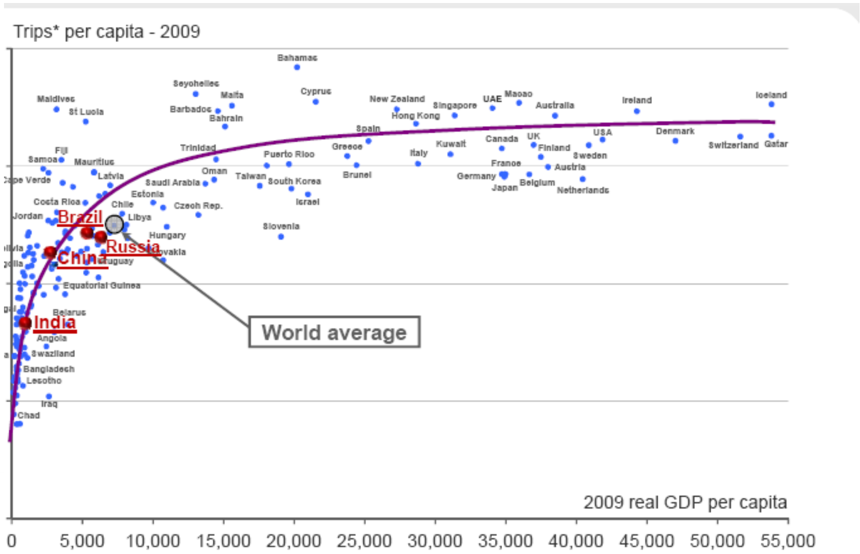
The Future: Boeings Dreamliner

Passengers:	223 (3-Class Configuration)
Range:	8,500 nm
Speed:	Mach 0,85

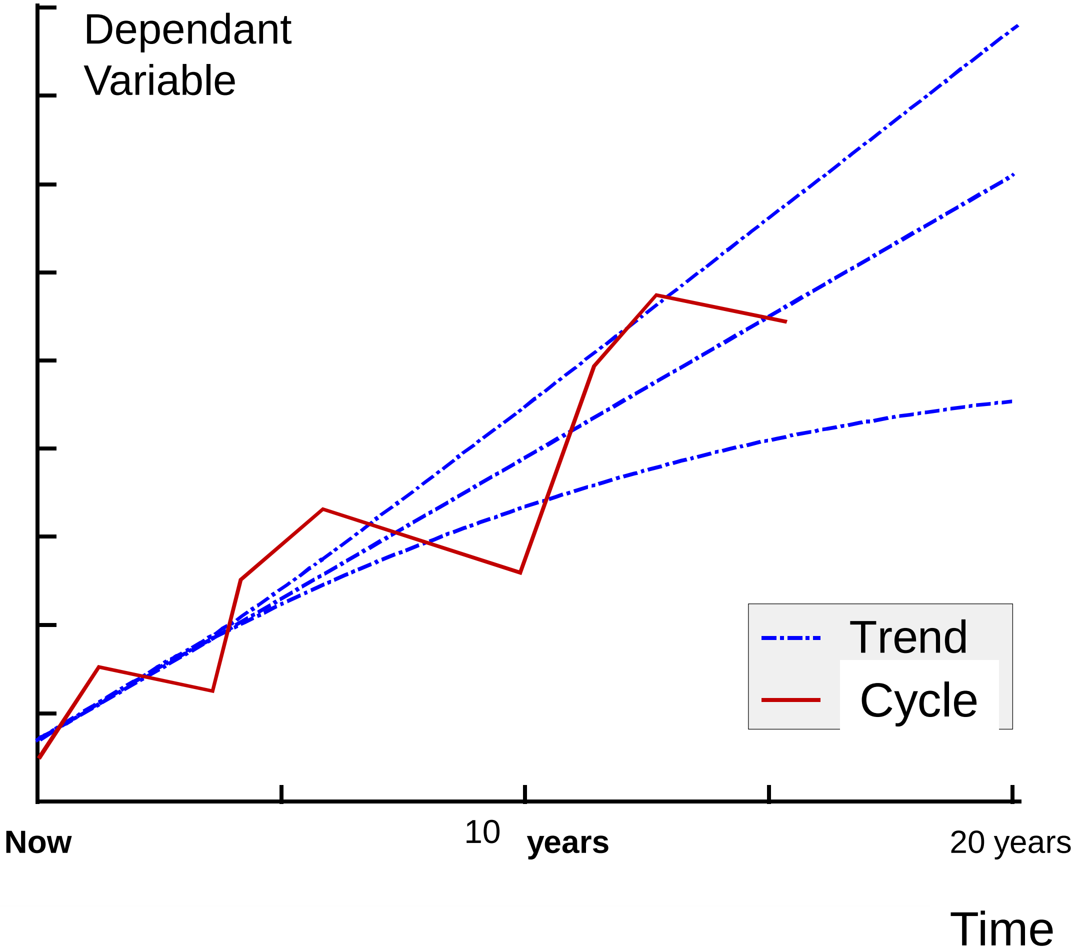
Source: Boeing Homepage/Airliners.net

Chapter 3

Market Aspects



Trends and Cycles



Long term trends:
- Investment-Analysis
- Evaluation of new products
- Business-models & Market
- Legislation
- Industrial Organization

Short term cycles:
- Production rates
- Financial planing
- Sales promotions
- „What if …"-Tests

Market forecast

- There exists no general methodology for market prediction.

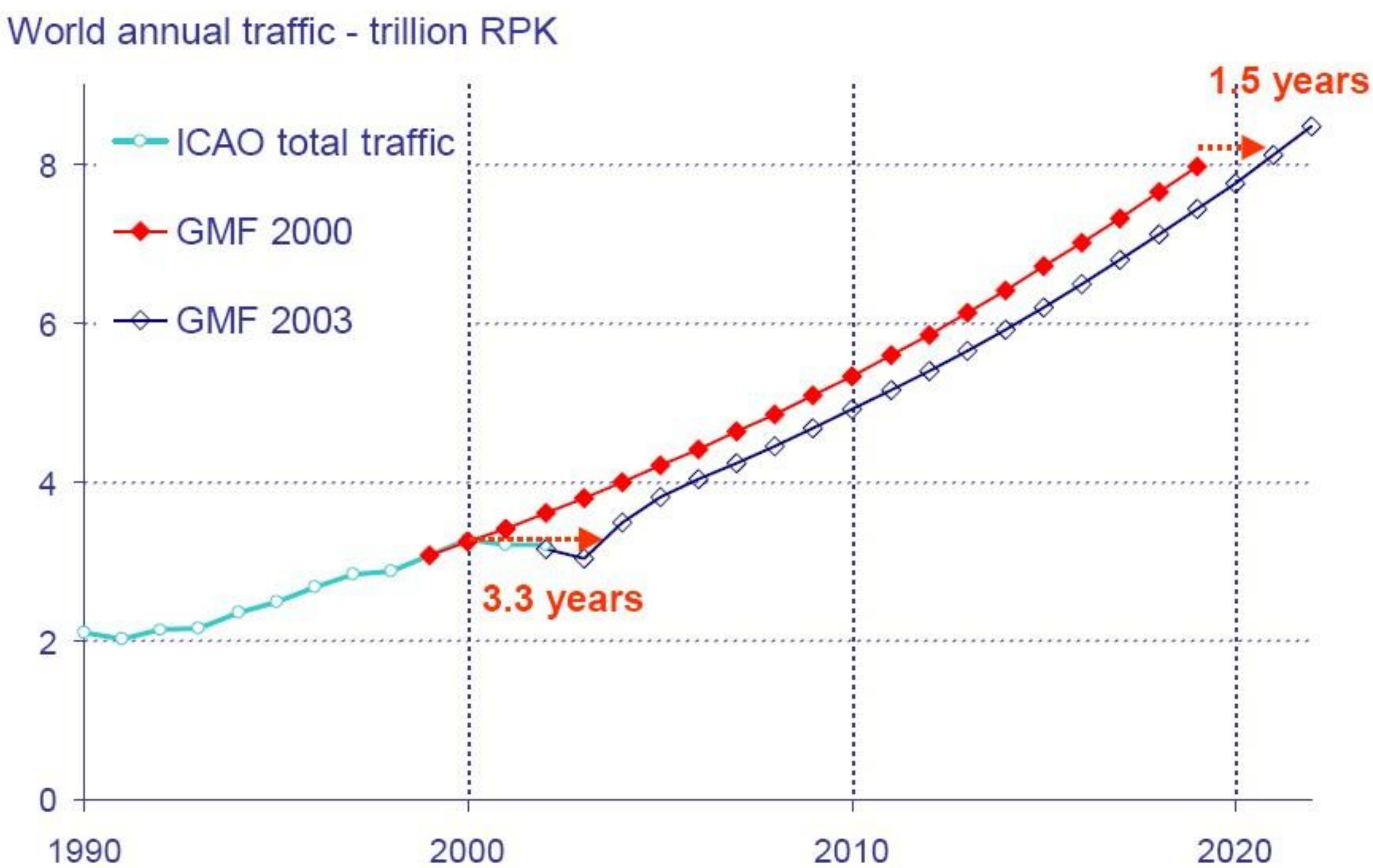
- Generally there is a combination of different methods which have to be used in order to capture the different needs:

  - „Top Down"-method > World traffic forecast
  - „Bottom Up"-method > regional/airline forecast

- In addition future scenarios have to be developed to investigate the influence of new parameters like:

  - Environmental parameters and - taxes
  - Capacity shortages at airports and in critical overloaded zones
  - Fuel price development (new resources ?, alternative fuels ?)
  - Alternative transport- und communication means

Comparison of different predictions show, that „major political“ events (11th September, SARS, Iraq war, etc.) will just slightly delay the longterm trend.



Quelle: Airbus Global Market Forecast 2003

Market Forecast – „*Top Down*“-Approach (1)

Based on the development of the past 10 – 20 years, an extrapolation of the longterm trend will be developed.

In a first step there will be taken as main parameters only:

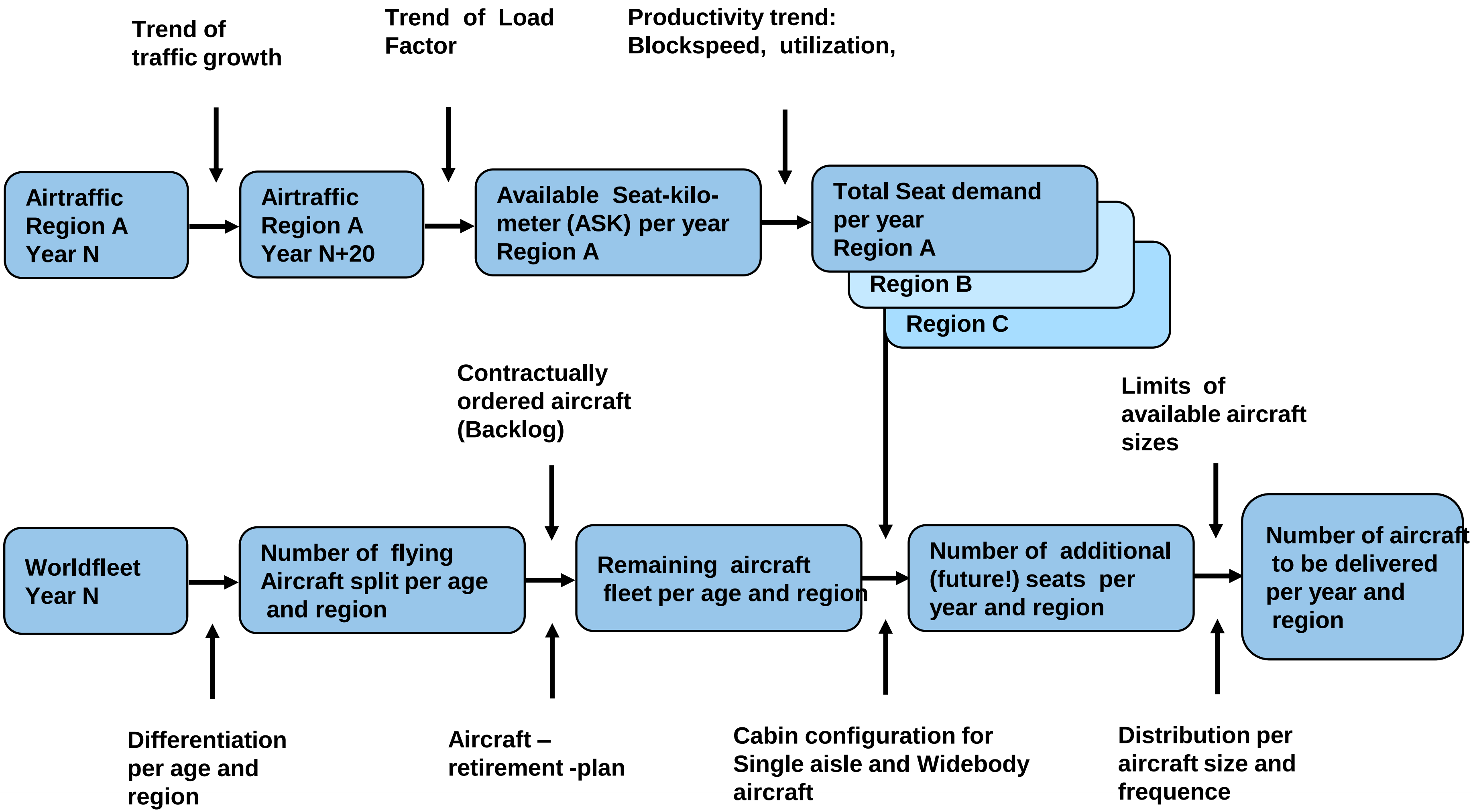
- **GDP Global Growth Domestic Product**
- **Yield of airlines (airline performance and profitability!)**

split in geographical regions (Northamerica, Europe, Asia-Pacific, Near-East, South America, …) and then the main traffic flows within and between these regions will be analyzed.

In addition some assumption for the economic performances and expectations have to be set.

The result will be a long term mean air traffic demand prediction (time horizon normally 20 years).

Market prediction – „*Top Down*“-Approach (2)



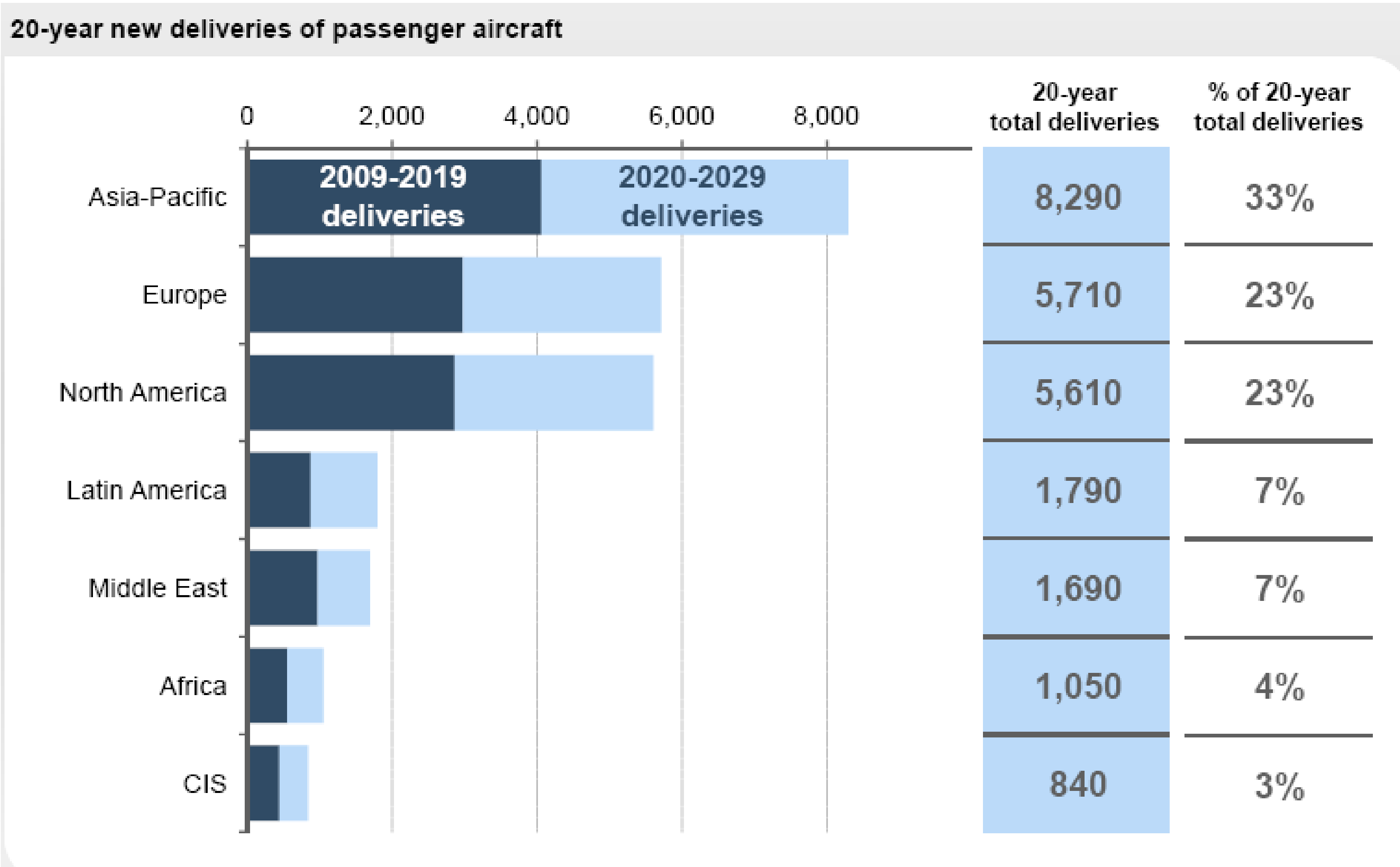
- **Assumptions for economical data:**

Economic growth:	**3,0% real**
Inflationrate:	**3,2%**
Interestrate:	**5,5%**
Ticket price trend:	**-0,7%**
Fuel price development:	**1,5% p.a. real**
RPK- development:	**4,8% p.a.**

- **Additional Assumptions:**

Growth of population:	**1,0% p.a.**
International trade development:	**stimulates long range traffic ?**
Political factors:	**slow liberalisation of market**
Competitive transport systems:	**telecommunication may reduce business trips and highspeed trains (ICE, TGV, ..) replace partly short range air routes**

20-Year Aircraft Deliveries per Region



Source: Airbus GMF

Growth in GMF

- Growth can be achieved mainly via 2 directions:

  - Increase in frequency
    - increase of daily flights between 2 destinations
    - Development of new routes (new destinations); enlarge the network

    Consequence: more aircraft of same size will be needed!

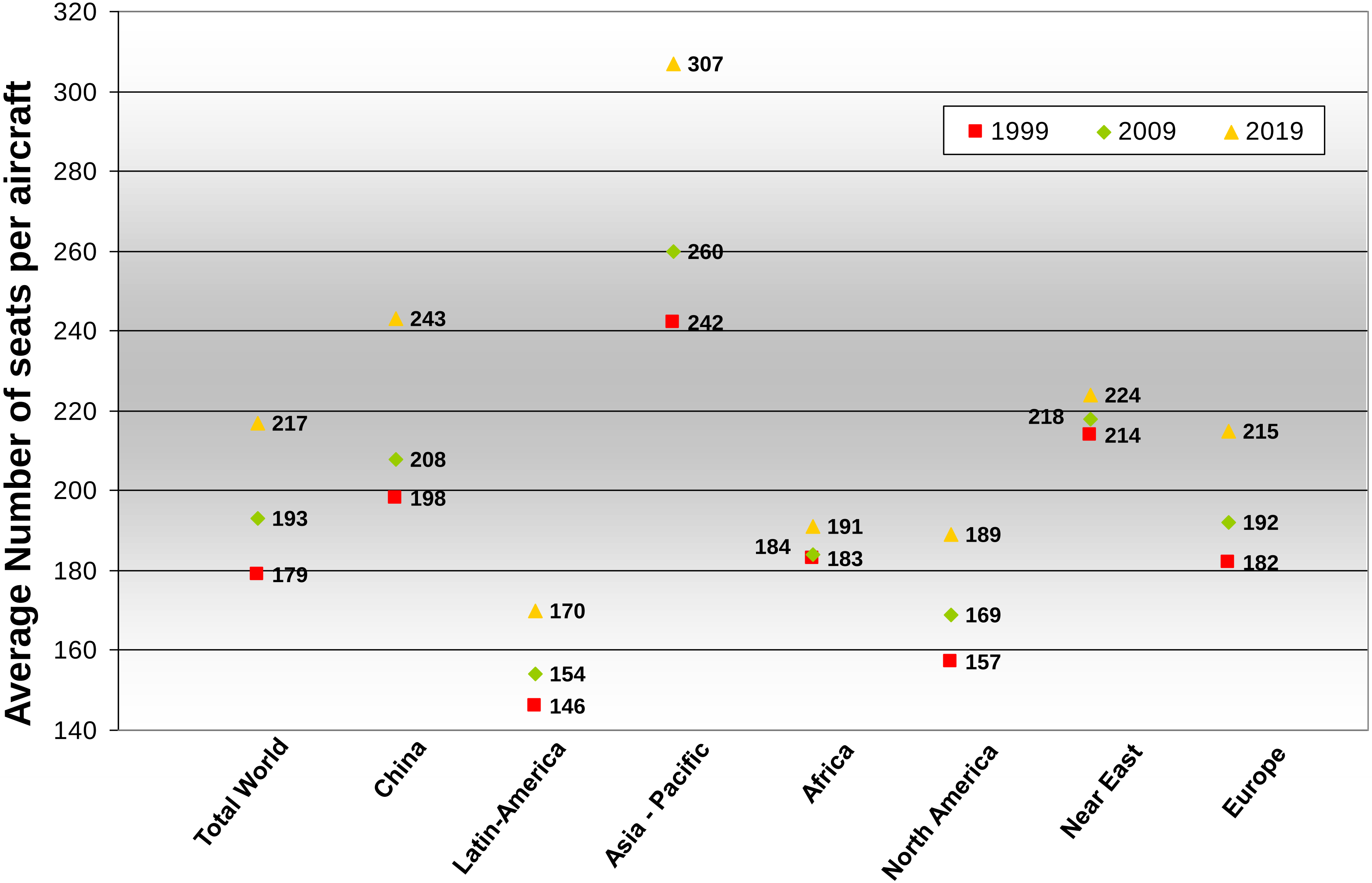
    (The passenger normally prefers this solution, to have more choices to select from!)

  - Increase in a/c size
    - The new aircraft needed will be bigger in size

    Consequence: airline keeps the same number of destinations but will use a bigger aircraft with more seats to manage the increase in demand

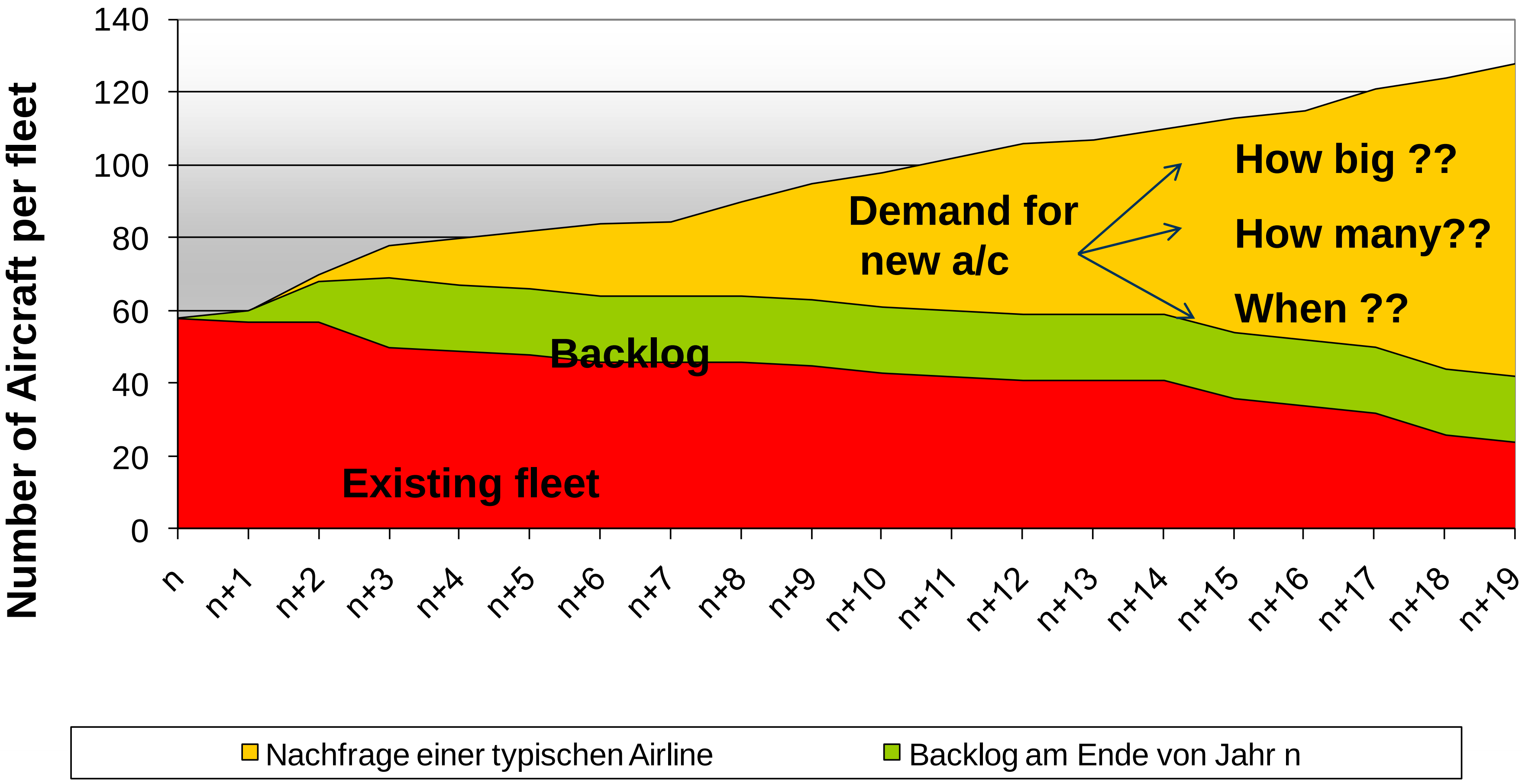
    (The capacity limit at certain crowdy airports may require this solution!)

Development of average number of aircraft seats

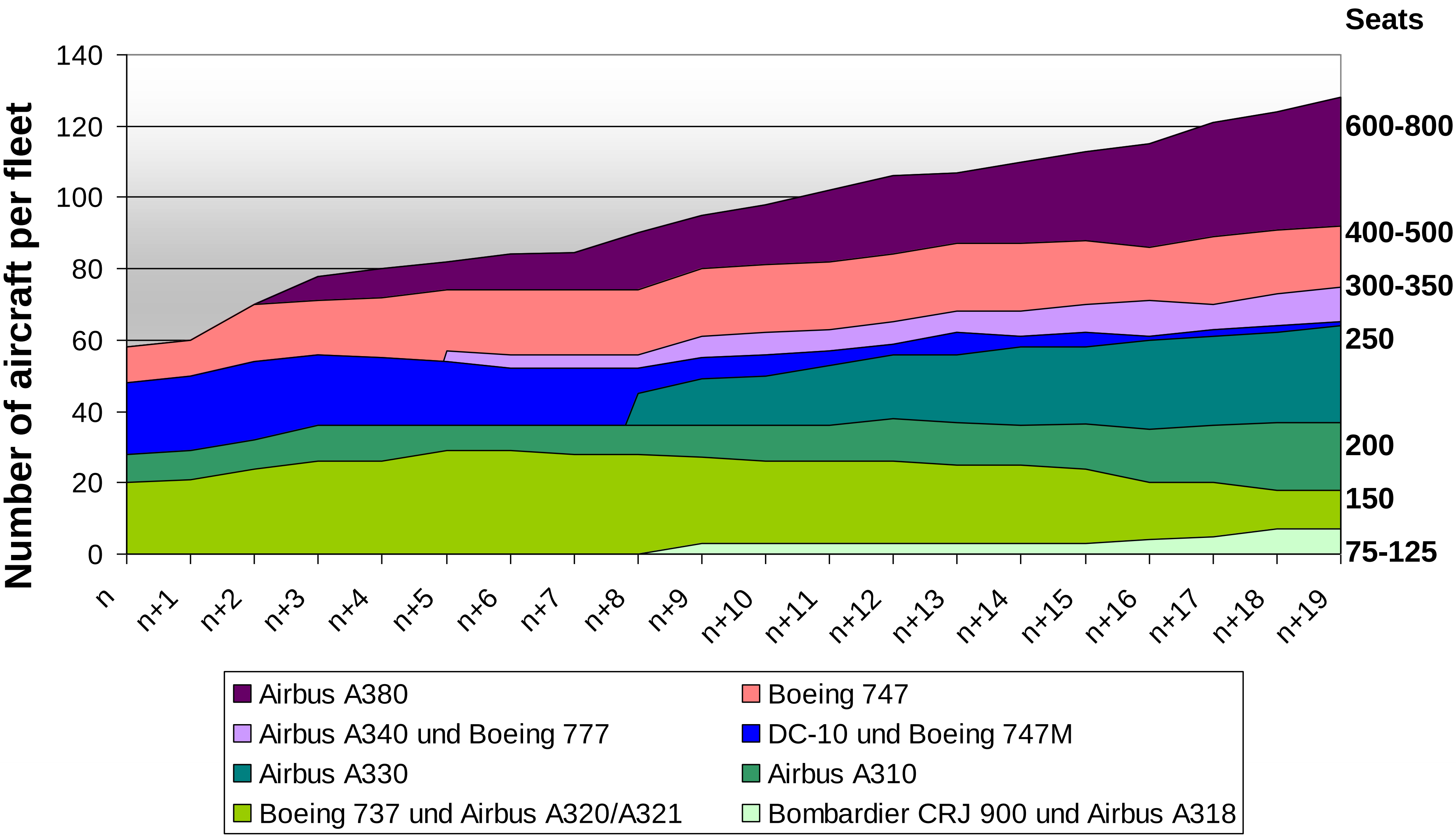


Quelle: Airbus Global Market Forecast 2000

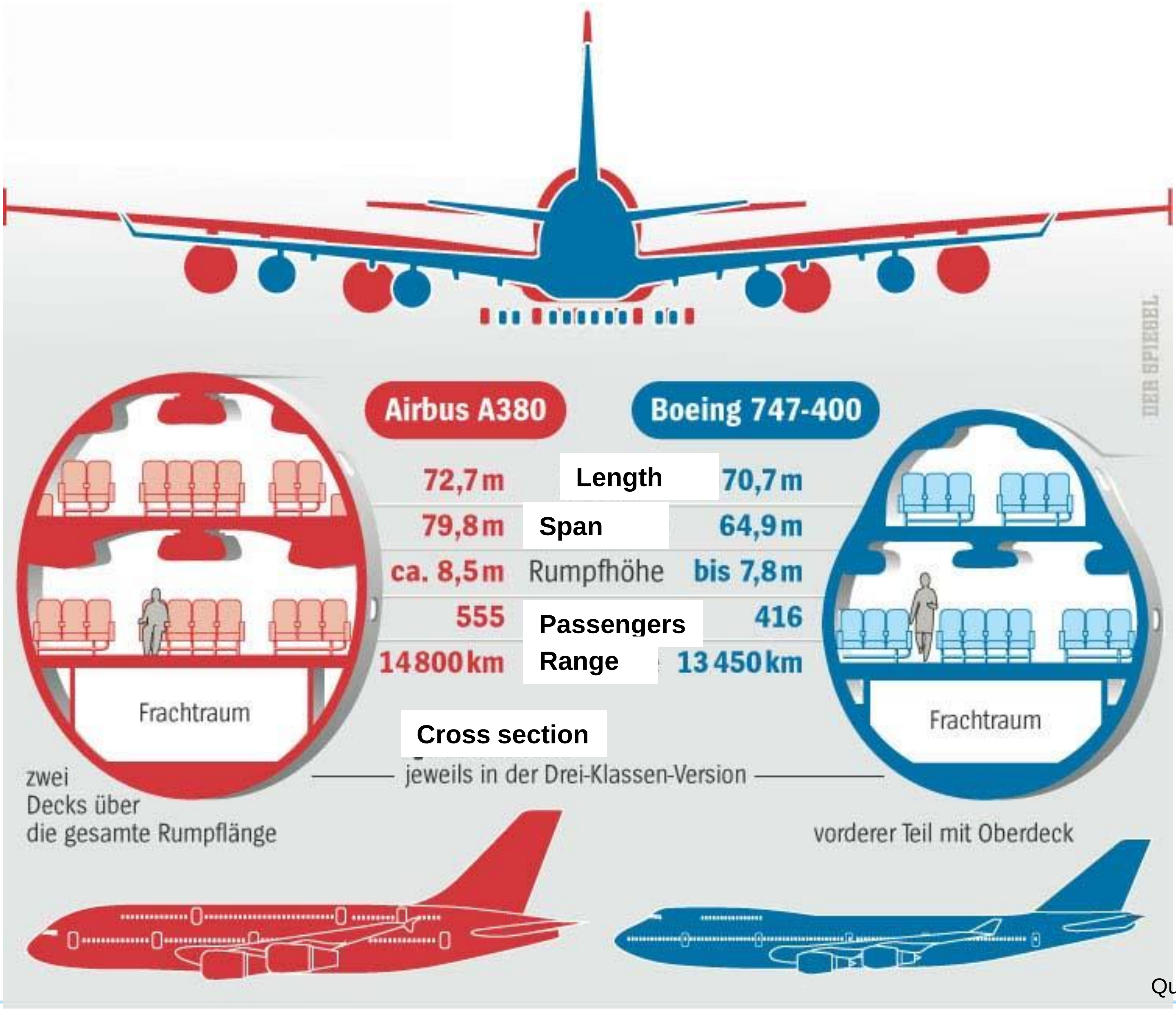
Development of a „typical airline“ (1)



Development of a „typical airline“ (2)

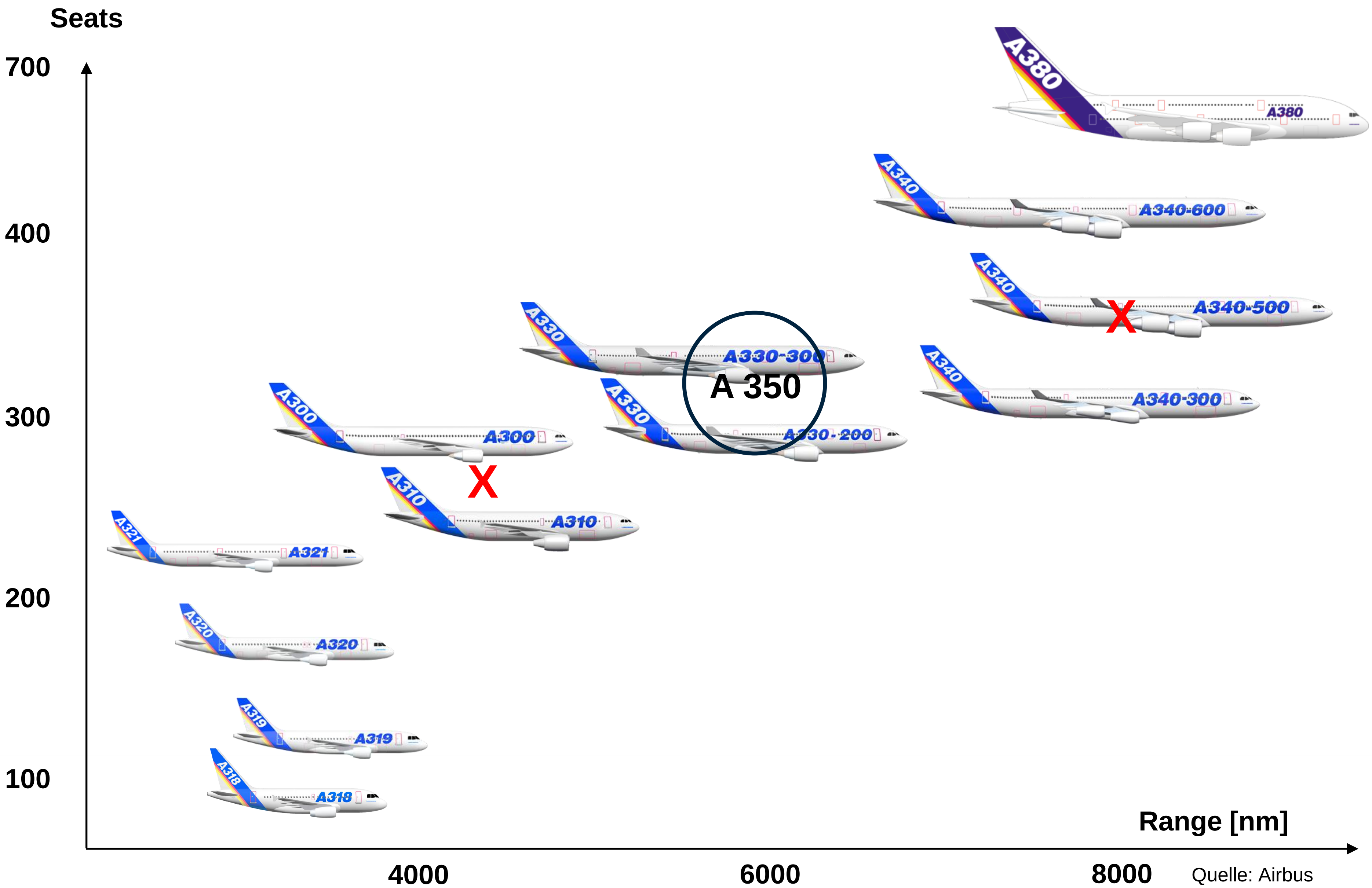


Competition Analysis



Quelle: Spiegel

Family Concept for Airbus



Quelle: Airbus

Family concept und Commonality

2 - Class-Configuration

2 - Class-Configuration	Model	
186	**A321**	+6,93 Meter +13 Frames
150	**A320**	Basis model
124	**A319**	-3,73 Meter -7 Frames
107	**A318**	-6,13 Meter -11,5 Frames

Source : Airbus

Commonality

Commonality is playing an important role in the decision making process of an airline .

Commonality relates to severa laircraft components>

- Cockpit – „Cross Crew Qualification“
- Airframe components
- Engines
- Several Subsystems

Commonality benefits are direct related to the size of the fleet

Commonality is no direct element in the DOC (Direct operating Cost) equation. Advantages for an airline can only be calculated individually!

Δcost = f (fleet type, Fleet size, etc.)

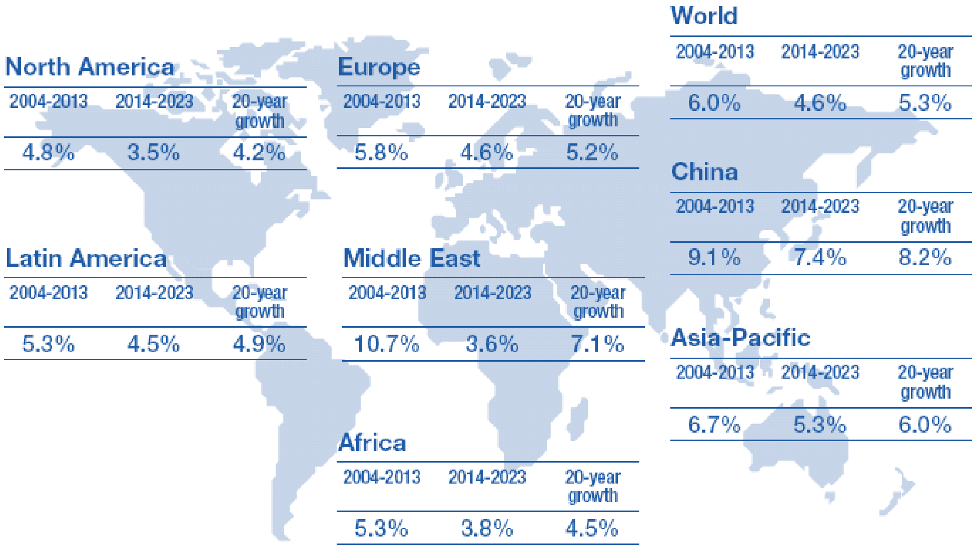
Quelle: Airbus

Questions

1. What means RPK or RPM??
2. When startet the Jet transport area? Before 30, 50 or 70 years?
3. Definition of „Loadfactor“
4. Market Forecast – 2 approaches ??
5. What are the elements of GMF by a „Top down approach“
6. Is GDP constant for all regions?
7. What means backlog??
8. What means commonality??

Airbus GMF

Global Market Forecast



World

2004-2013	2014-2023	20-year growth
6.0%	4.6%	5.3%

North America

2004-2013	2014-2023	20-year growth
4.8%	3.5%	4.2%

Europe

2004-2013	2014-2023	20-year growth
5.8%	4.6%	5.2%

China

2004-2013	2014-2023	20-year growth
9.1%	7.4%	8.2%

Latin America

2004-2013	2014-2023	20-year growth
5.3%	4.5%	4.9%

Middle East

2004-2013	2014-2023	20-year growth
10.7%	3.6%	7.1%

Asia-Pacific

2004-2013	2014-2023	20-year growth
6.7%	5.3%	6.0%

Africa

2004-2013	2014-2023	20-year growth
5.3%	3.8%	4.5%

Global Market Forecast

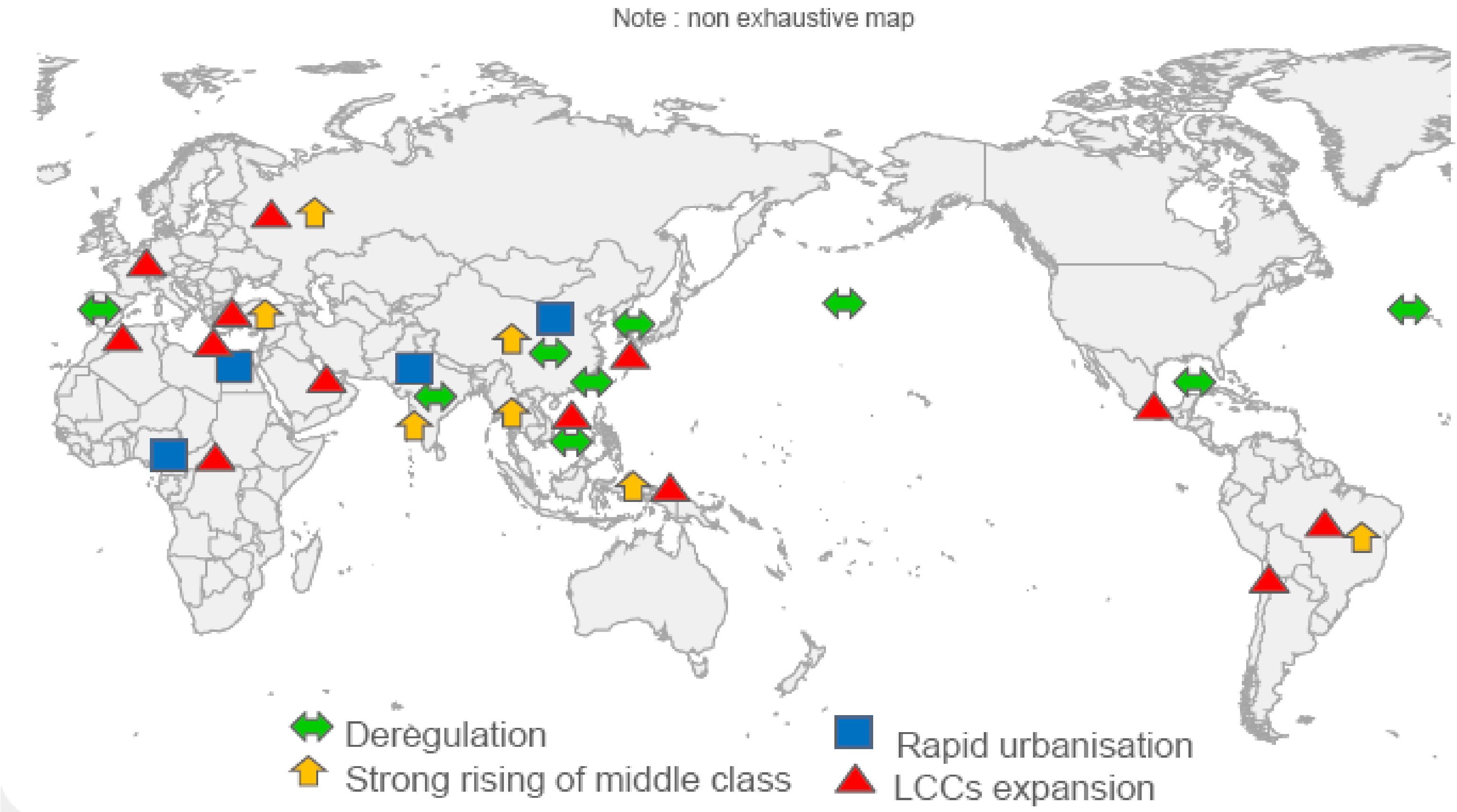
- 20 year aircraft demand forecast, **aircraft >19 seats**
- Traffic forecast modeling **155 distinct traffic flows**
- Detailed study of **network evolution**,
  including new routes, markets and deregulation hot spots
- Model the impact of **evolving airline models** e.g. Low Cost Carriers
- Fleet build-ups covering **938 passenger** and **217 freight carriers**
- In use for both Airbus **internal** and **external purposes**

Regularly updated to reflect market trends and evolution

Source: Airbus

Macro Factors leading to Growth

Recent traffic "hot spots"



Source: Airbus

Elements used in GMF

Economics

- Growth
- **Emerging markets**
- Trade
- Cycles

Demographics

- **Population growth**
- Age profiles
- Middle class
- **Urbanisation**

Networks

- **Global cities**
- Hubs
- **New routes**
- Deregulation

Passengers

- Ticket price
- Comfort
- **Origin and destination**
- Connectivity
- Environment

Airlines

- **Fuel**
- Range
- Fleet mix
- **Business models**
- Environment

Aircraft

- Seats, speed, utilisation
- **Frequency, load factor**
- Range, fleet mix
- Replacement
- Environment

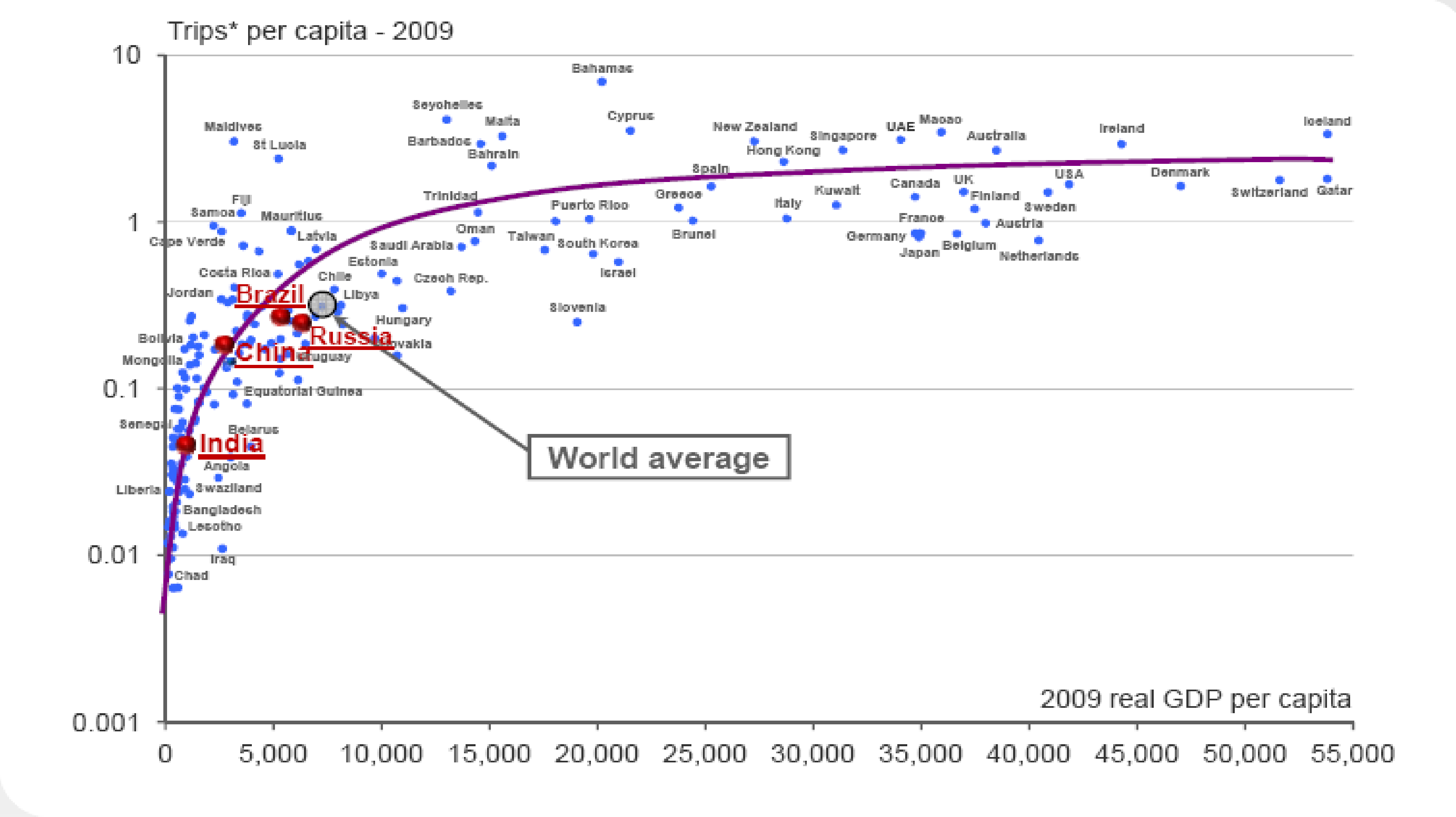
Source: Airbus

Main Drivers for Growth

- Replacement of aircraft in service in mature markets
- Dynamic growth in emerging markets
- Continued growth of LCCs, especially in Asia
- Greater and continued market liberalization
- Traffic growth on the existing route network where it is more efficient to add capacity than frequency

Source: Airbus GMF 2010

Propensity to travel



* Passengers originating from respective country

Note: GDP in US$2005

Source: IATA PaxIS, Global Insight, Airbus

Source: Airbus GMF 2010

Airbus Global Market Forecast

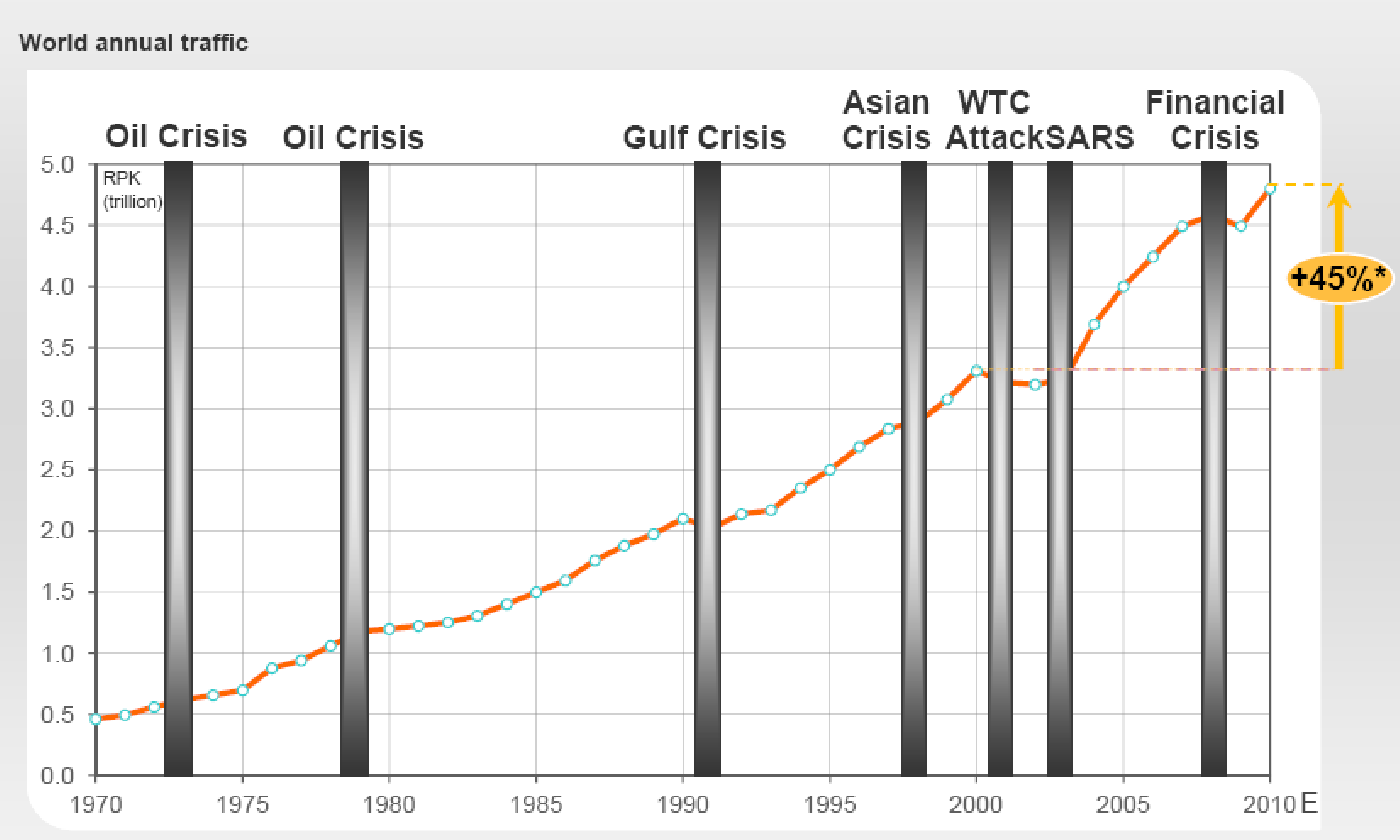
GMF 2010 key numbers and 20-year change

World fleet forecast	2009	2029	% change
RPK (trillion)	4.76	12.03	153%
Passenger aircraft	14,240	29,050	104%
New passenger aircraft deliveries	-	24,980	-
Dedicated freighters	1,550	3,350	+116%
New freighter aircraft deliveries	-	870	-
Total new aircraft deliveries		25,850	

Market value of $3.2 trillion

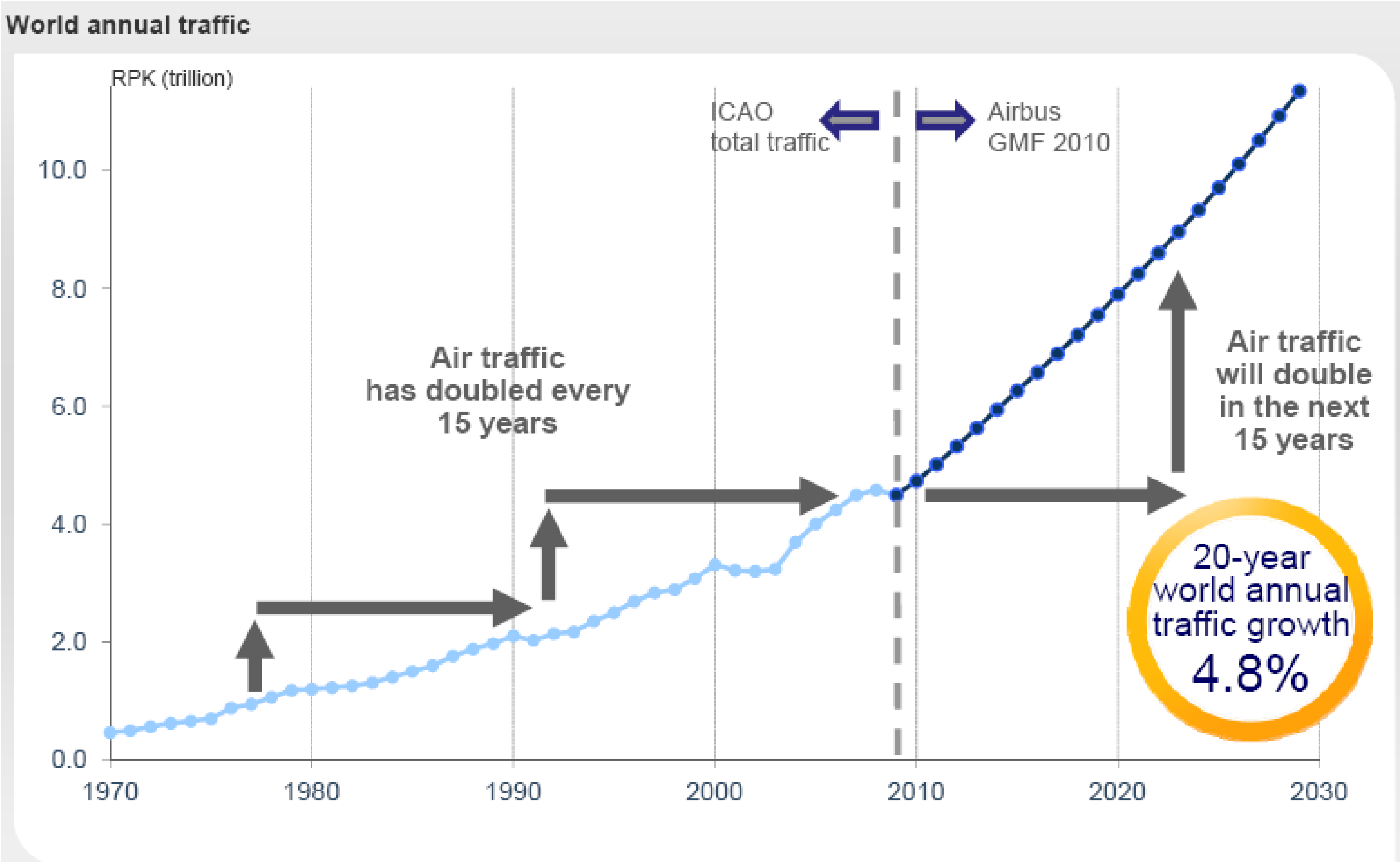
Source Airbus

Air Travel Continues to Grow



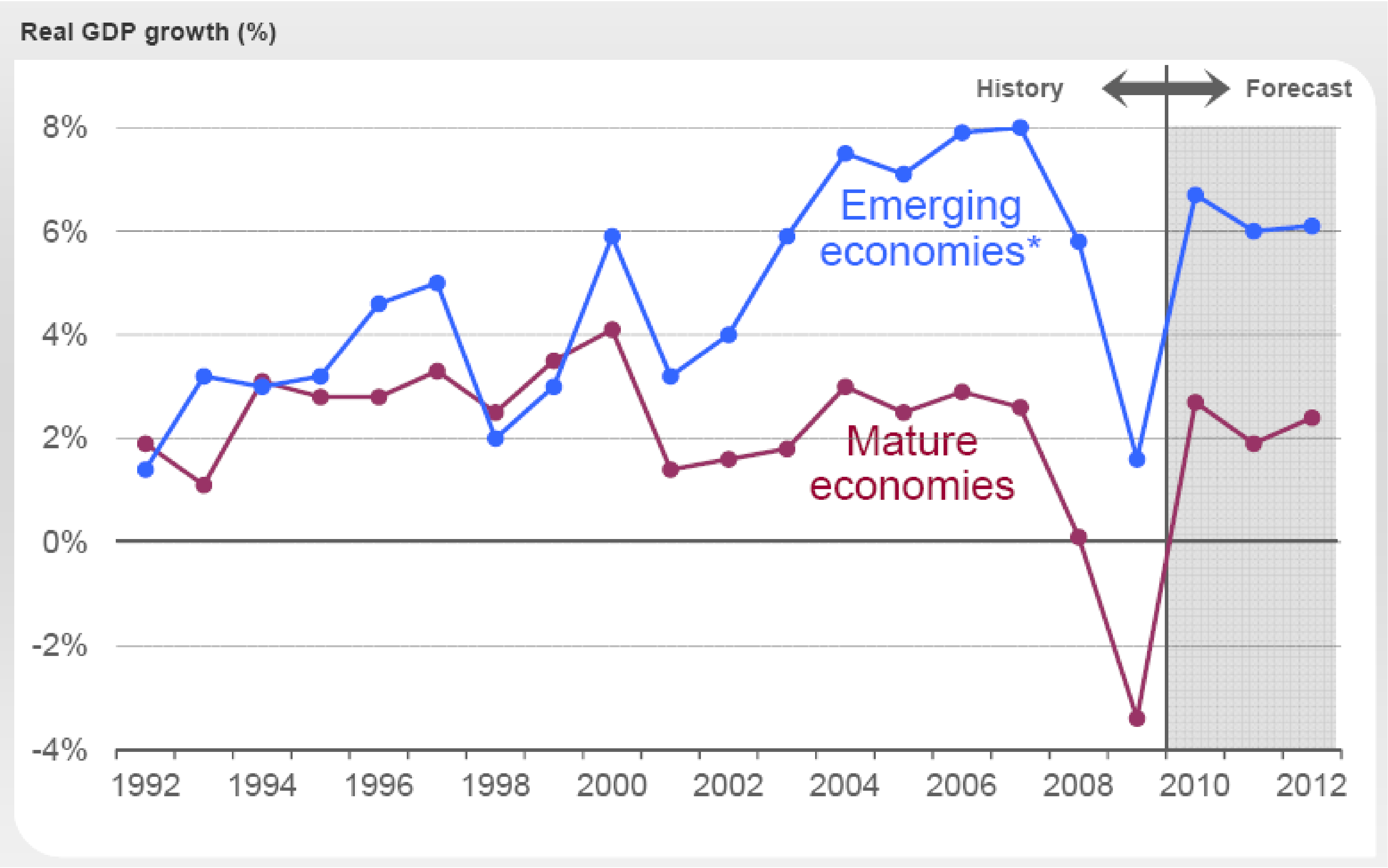
Source: Airbus

Long Term Traffic Growth



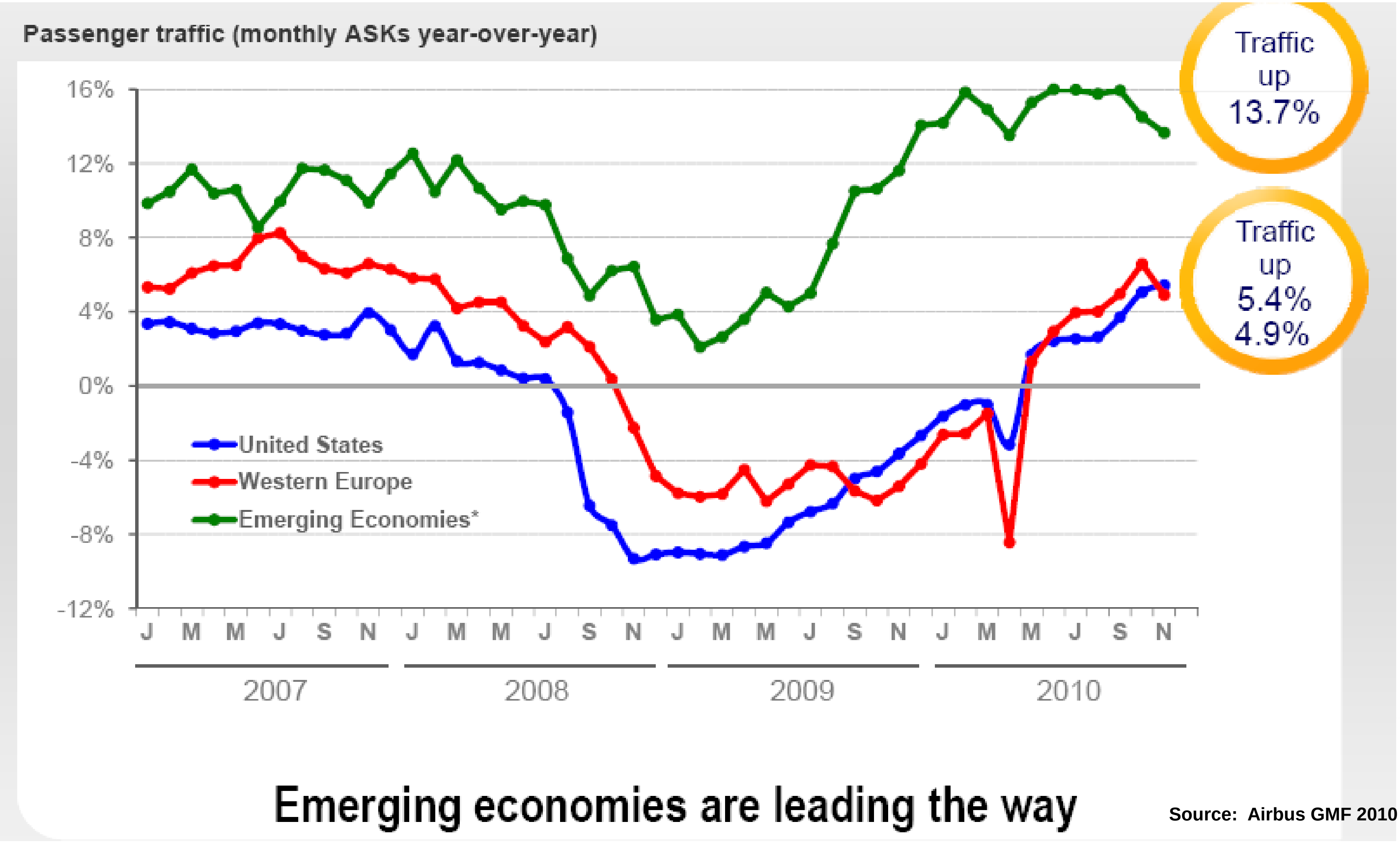
Source: Airbus

Air Transport develops in 2 speeds



Source: Airbus

All regions are currently growing



Source: Airbus GMF 2010

Air travel in emerging countries

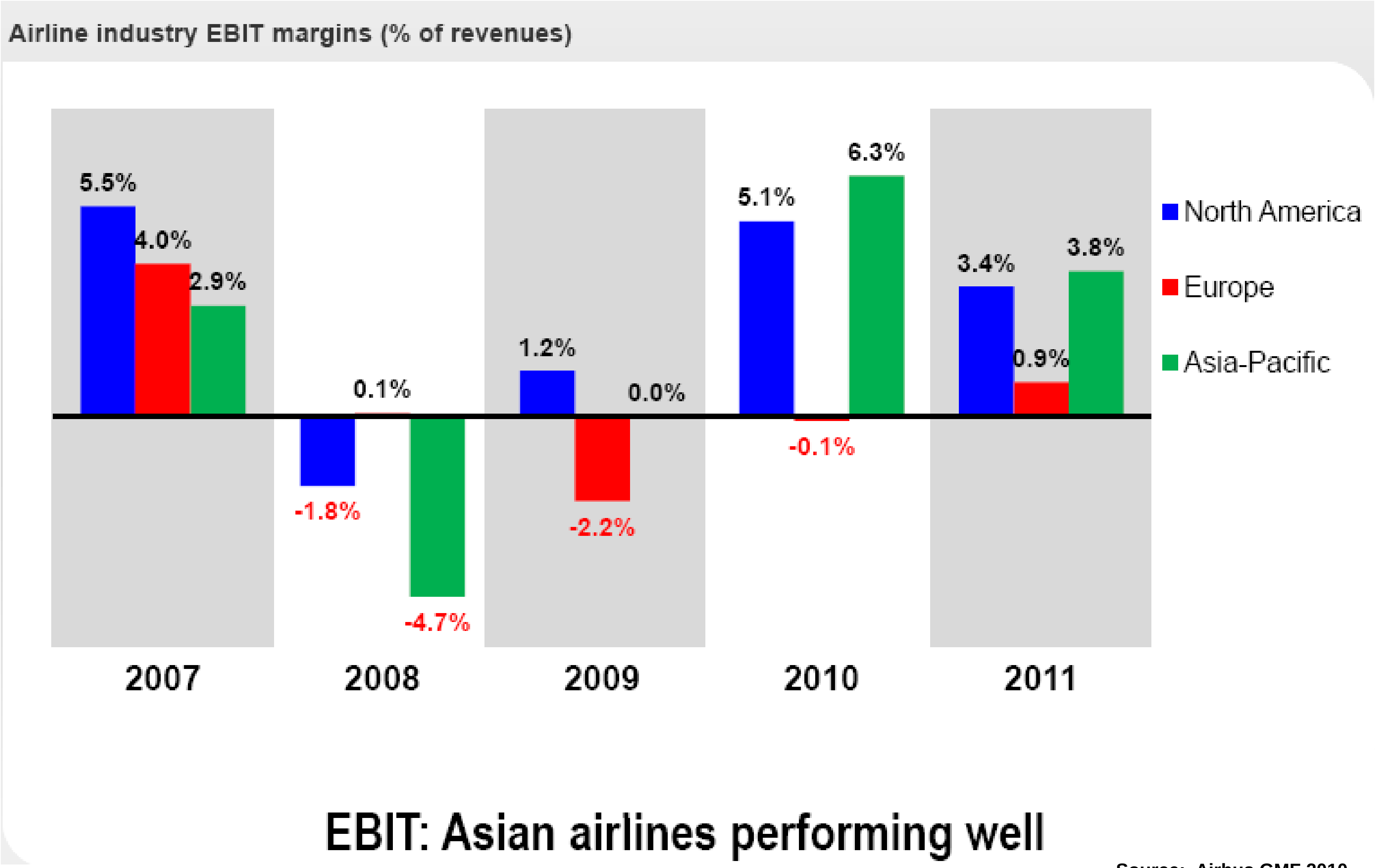
Passenger aircraft over 100 seats operated by airlines

		Jan 2000	Dec 2010	
China Mainland	Fleet in service	453	1386	×3
	Backlog	47	565	×12
India	Fleet in service	112	322	× 3
	Backlog	12	280	× 23

Source: Airbus GMF 2010

A380 growing network

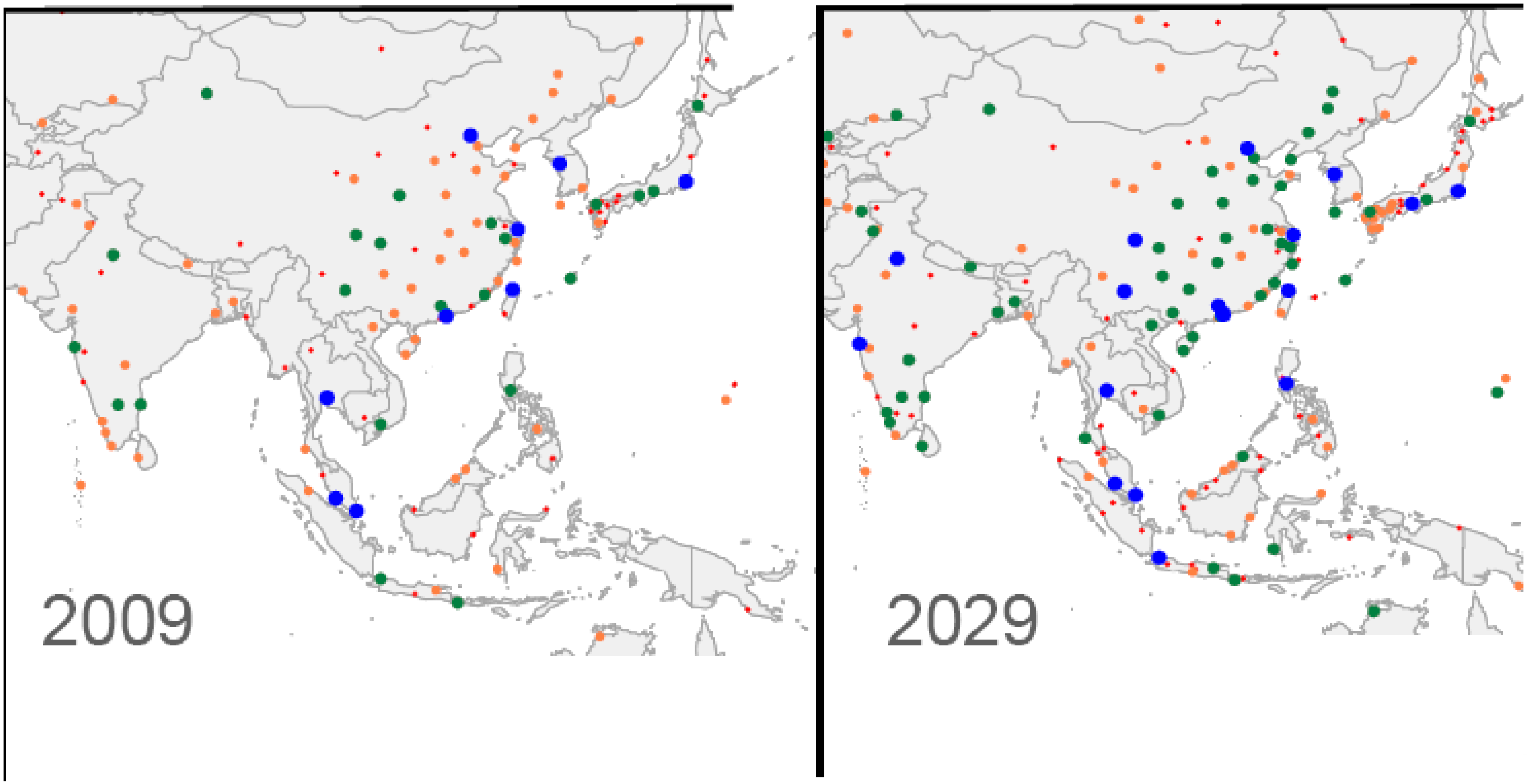
Source: Airbus GMF 2010



Source: Airbus GMF 2010

Strong Increase of Mega-cities in Asia

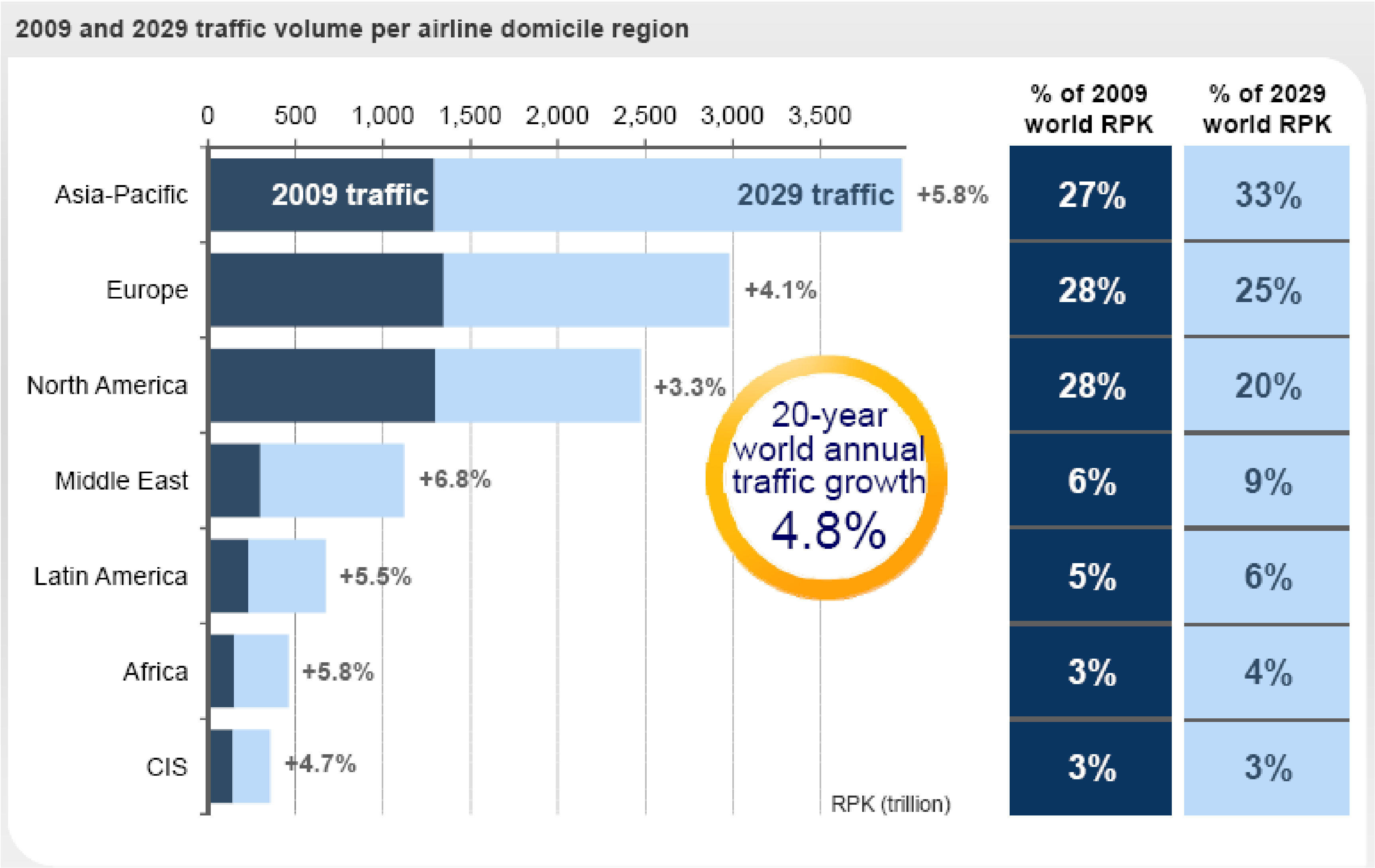
Level of RPK from/to each city in 2009 and 2029 for Asia



Source: Airbus GMF 2010

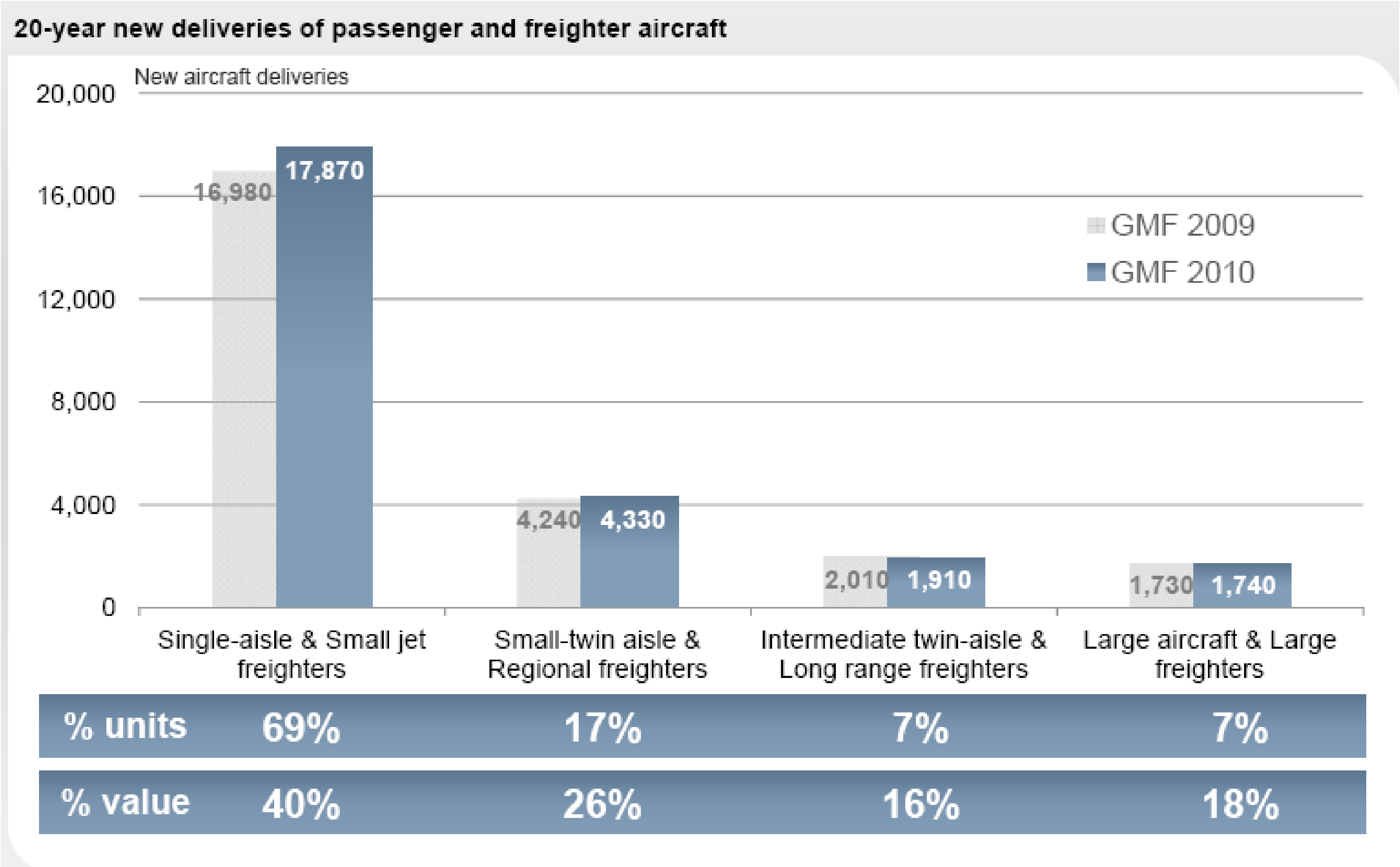
100-250 millions 250-1000 millions 1-5 billions >5 billions

Asia-Pacific Airlines will lead by 2029



Source: Airbus GMF 2010

New Aircraft Demand for next 20 years



Passenger aircraft (>100 seats) and freighter aircraft (>10 tons)

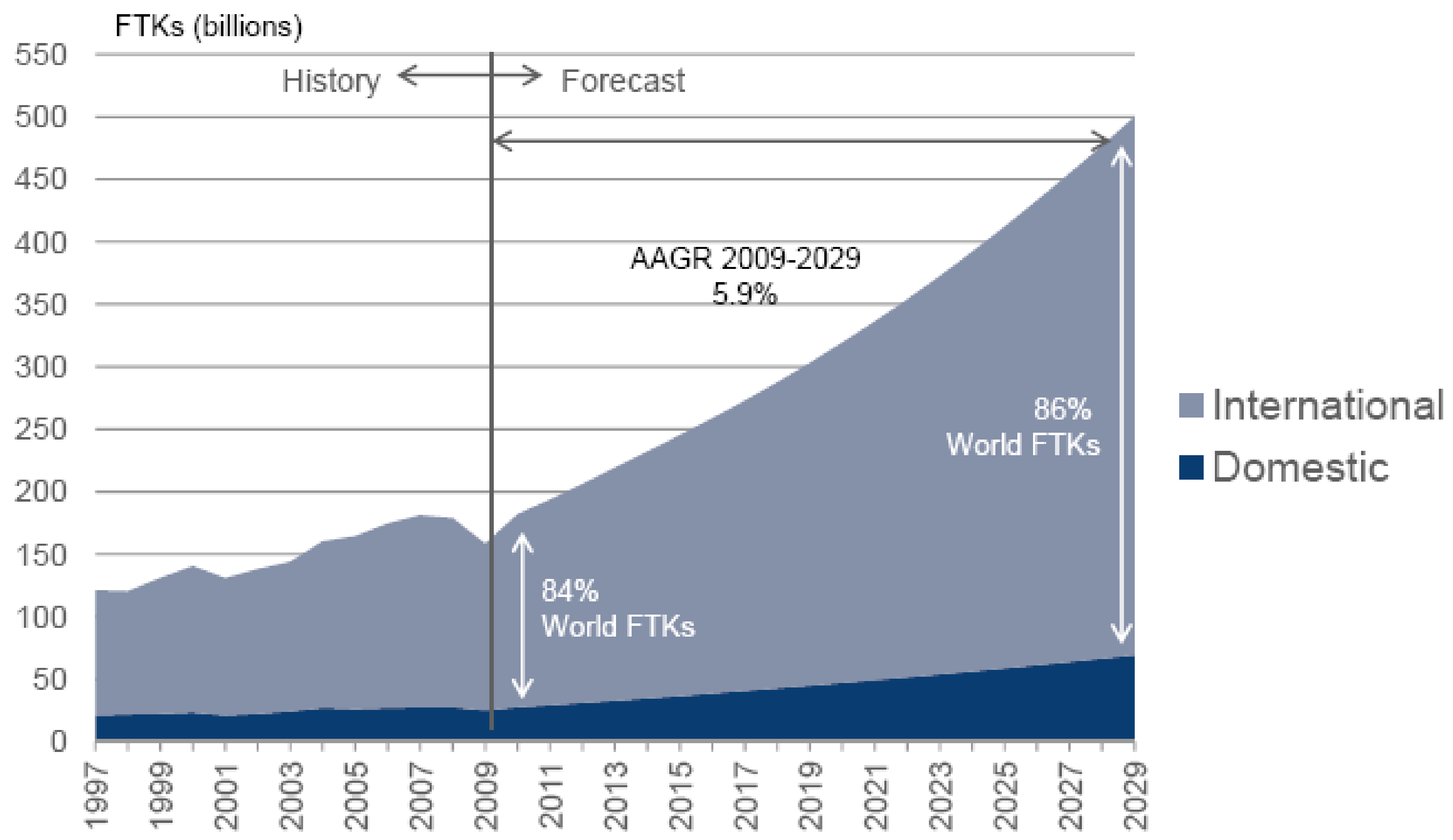
Source: Airbus GMF 2010

Airbus GMF freight forecast methodology

- **Specific methodology** for air cargo forecast
- **Regularly updated** to reflect market trends and evolution
- 20 year freighter aircraft demand forecast, payload **>10 tons**
- Traffic forecast modeling **144 distinct traffic flows**
- Fleet build-ups covering **217 freight carriers**

Freight Traffic Growth for next 20 Years

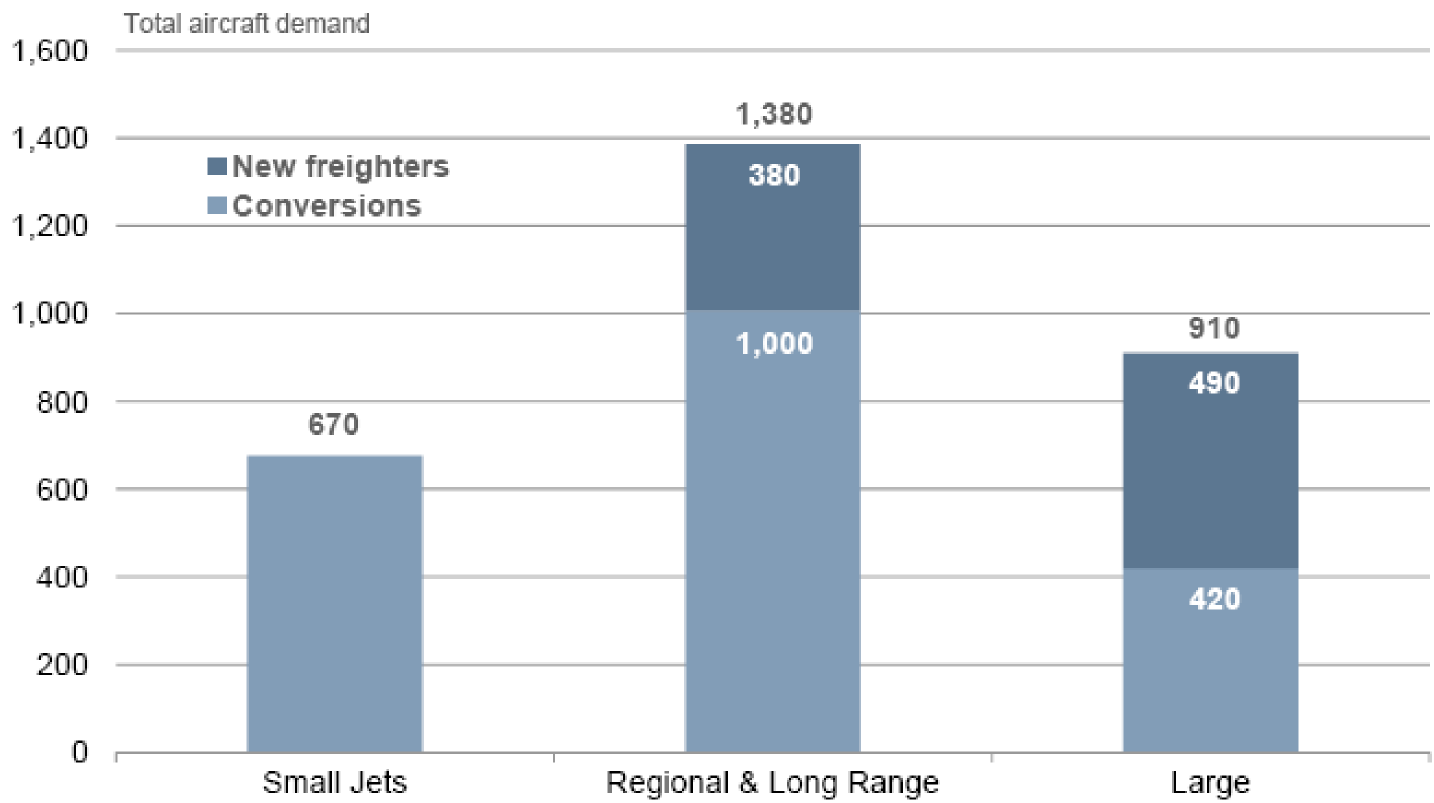
Freight traffic forecast



Source: Airbus GMF

20-Year Freighter Aircraft Demand

20-year freighter aircraft demand

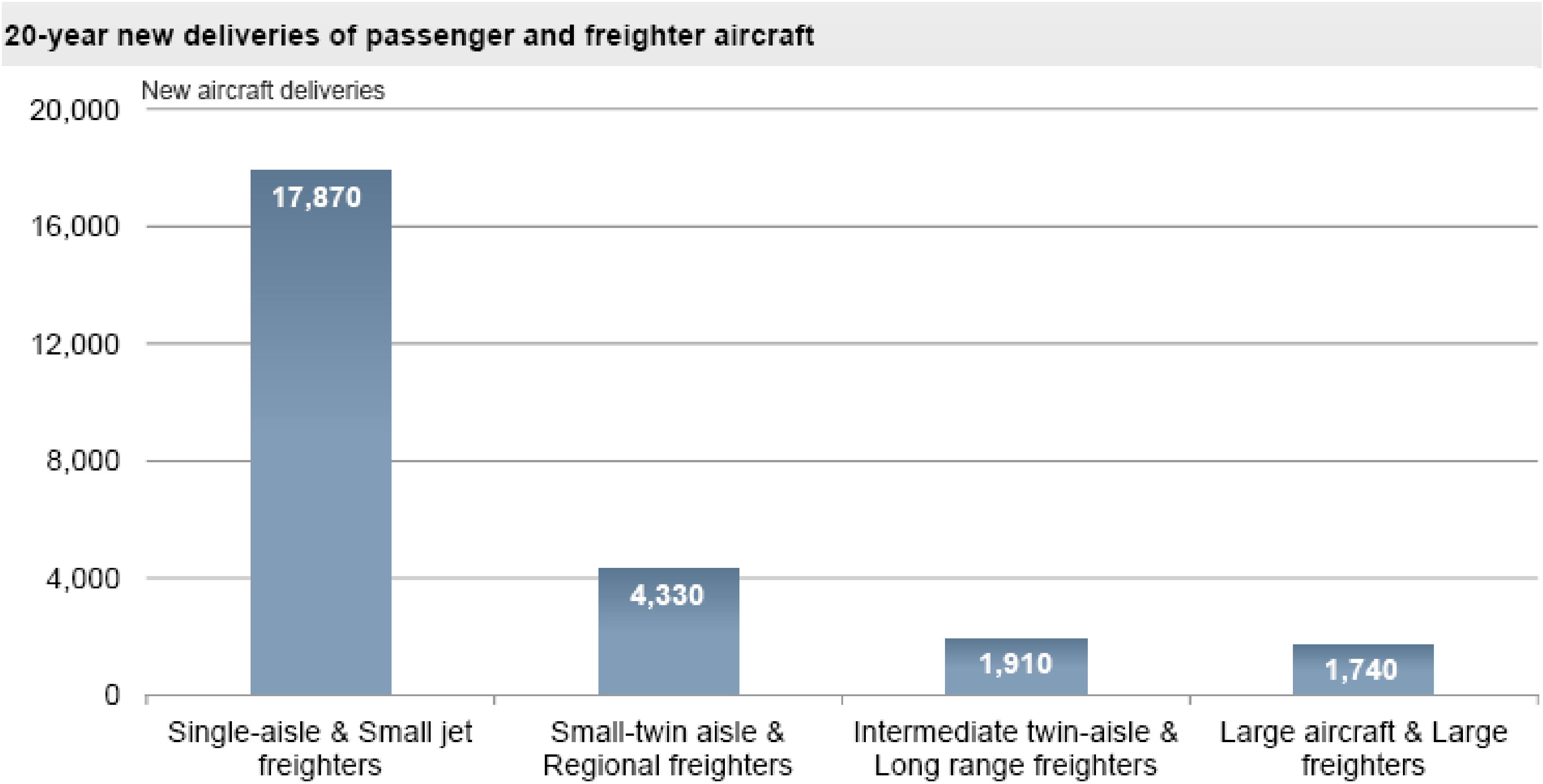


Source: Airbus

Airbus GMF 2010

Small jet freighters: 727, 737, A320P2F, BAe 146, DC-9, Tu-204 ;
Regional & long range freighters: 707, 757, 767-200, A300, A310, A321P2F, DC-8, DC10 -10, A330, 767-300, 747 Combi, DC10-30 ;
Large freighters: 747F, 777, A350, MD-11, A380

Total Aircraft Demand for next 20 Years

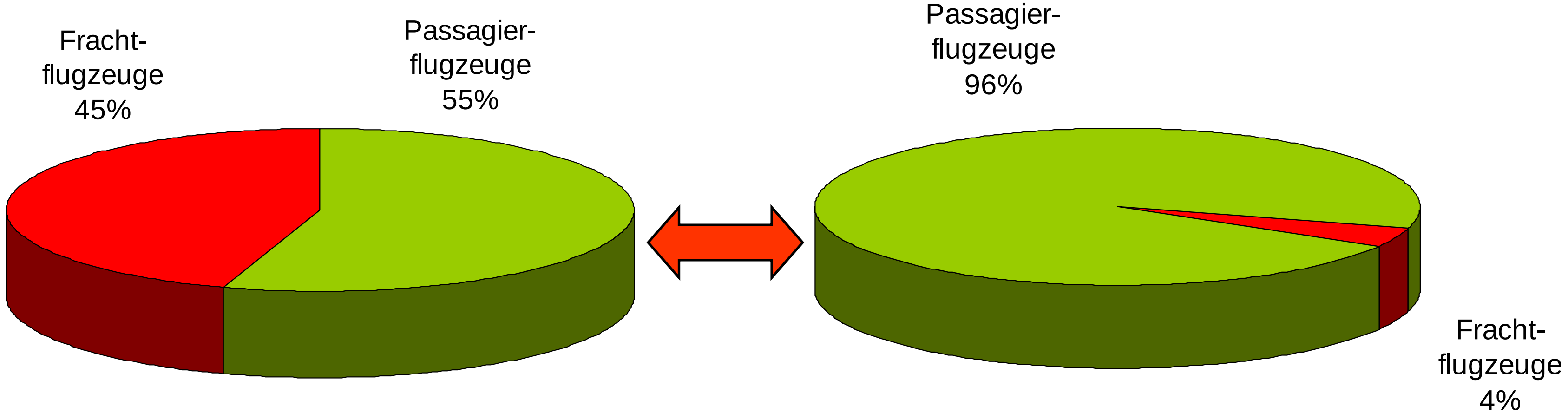


	Single-aisle & Small jet freighters	Small-twin aisle & Regional freighters	Intermediate twin-aisle & Long range freighters	Large aircraft & Large freighters
% units	69%	17%	7%	7%
% value	40%	26%	16%	18%

Passenger aircraft (≥ 100 seats) and freighter aircraft (> 10 tons)

Source: Airbus

Characteristics of Air Freight Market (2)



Freight transport

Flight movements

Source: Airbus GMF 2000

Characteristics of Air Freight Market (1)

- The growth of the world Aircargo market is 1-2% higher than the passenger market.
- The biggest growthmarkets for air freight in the future will be on routes between Europe/US and the Asian-pacific region.
- There exist 3 different sort of air freight operators:
- Es werden drei Arten von Luftfrachtbetreibern unterschieden:
  - „Integrators“ offer a „door to door“-Service (FedEx, UPS, DLH, …)
  - „All Cargo Airlines“ transport only freight (Cargolux, …)
  - „Combination Carriers“ transport passengers and freight (Lufthansa, Air France, …)
- 55% of air freight is transported in passenger aircraft.
- The average age of freighter aircraft is ~22 years. A disposal happens after roughly 35 years.
- Freighter aircraft are mainly used and converted passenger aircraft (i.e. B727, DC8, A300, … - these models will however mainly dissappear in the next years due to age and inconsistency with new noise regulations.)
- New freighter aircraft on the market are mainly B747, MD11, A310 and in the near future also A330, B767, B777 and B737/A320
- Not all freighter aicraft are complying with the recent noise regulations
- The normal delivery time for airfreight is about 4-6 days.

Quelle: Airbus Global Market Forecast 2000, JP Airliners Fleet 2005

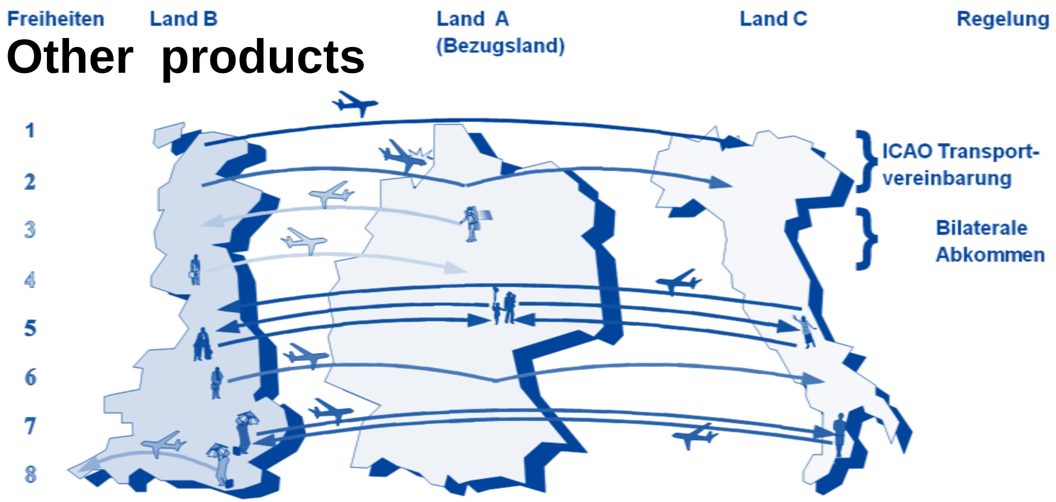
Summary

- Market Forecast is a critical subject, especially when a 20 years forecast perspective is needed like in air transport. 2 different methods are used today:
  - „Top Down“ - Approach
  - „Bottom Up“ – Approach
- Market forecast need a detailled data base in order to integrate and estimate all relevant effects of the various parameters
- In addition scenario technics and methods as well as competition analysis will help to complete the future vision.
- Each method has its advantages and weaknesses. Therefore in practical terms a combination of different methods is helpful and in use.
- GMF are mainly prepared by aircraft manufacturers! An important role is therefore the positioning of the own fleet relative to the aircraft family of the competitors. Here is a tendancy to introduce more range, more comfort, more seat width in a new version compared to the competitors product.
- Based on the results from the market forecast and the own positioning of the product family the manufacturer have to define their product strategy.

Chapter 4

Legal Basis for Air Transport

Other products



Air transport regulations
Safety
Certification Requirements
Security aspects

Participants of the Civil Air Transport Systems

National Agency

-FAA -NTSB -Min Transp	EASA

Air Trafic Control

International Agencies

ICAO
IATA
FAA / EASA
IAC

Organisations

- Consumers
- Environm. Ag.
- Tourism Ag.
- Hotels

Aircraft industry

- Manufacturer
- Engine Manuf.
- Suppliers

Aircraft

Airlines

- Line
- Low Cost
- Charter

Agencies

- Travel agents
- Freight forward
- Integrators

Passenger

Freight

Maintenance-centres

Airports

Reservation - Systems (Amadeus .)

Financing/ Services

-Banks
-Leasing Comp.
-Insurance

Infrastructure

- Meteo services
- Communication

International Air Transport Agreements (1)

- Air Transport is border crossing and therefore international!
- To ensure a safe and economic transport system international arrangements have to be developed and agreed.
- The oldest Agreement for Air Transport is the „Warsaw Agreement“, signed on 12th October 1929; The agreement coordinates rules for the operation in the international air transport
- The constitution of ICAO is the Convention on International Civil Aviation, drawn up by a conference in Chicago in November and December 1944
- ICAO consists today of 190 member states

- Conditions of Carriage: IATA has been established 1919 to elaborate common rules for the international air transport system.
- 1927 the proposal has been presented to the member states and 1933 inaugurated with the Warsaw Agreement.
- IATA has been recreated in 1945 as organization for commercial air transport with headquarters in Montreal, following Canadian law.

Freedoms of the Air (1)

The **freedoms of the air** are a set of commercial aviation rights granting a country's airline(s) the privilege to enter and land in another country's airspace. Formulated as a result of disagreements over the extent of aviation liberalisation in the Convention on International Civil Aviation of 1944, (known as the Chicago Convention) the United States had called for a standardized set of separate air rights which may be negotiated between states but most of the other countries involved were concerned that the size of the U.S. airlines would dominate all world air travel if there were not strict rules.

The convention was successful in drawing up a multilateral agreement in which the first two freedoms, known as the International Air Services Transit Agreement, or "Two Freedoms Agreement" were open to all signatories. As of the summer of 2007, the treaty is accepted by 129 countries.[1]

While it was agreed that the third to fifth freedoms shall be negotiated between states, the International Air Transport Agreement (or the "Five Freedoms Agreement") was also opened for signatures, encompassing the first five freedoms.

Source: Wikipedia

Freedom of the Air (2)

First Freedom of the Air - the right or privilege, in respect of scheduled international air services, granted by one State to another State or States to fly across its territory without landing (also known as a ***First Freedom Right***).

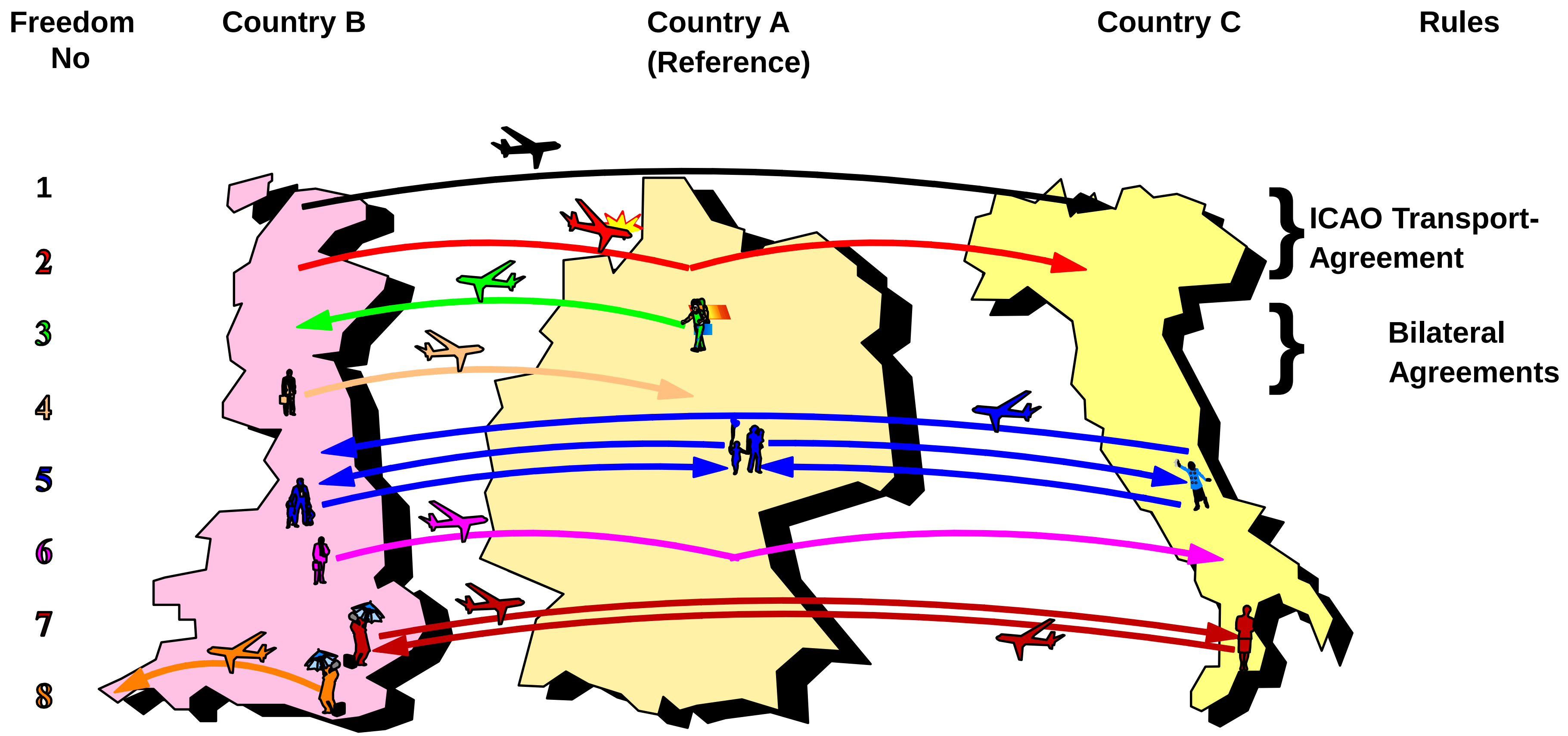
Second Freedom of the Air - the right or privilege, in respect of scheduled international air services, granted by one State to another State or States to land in its territory for non-traffic purposes (also known as a ***Second Freedom Right***).

Third Freedom of The Air - the right or privilege, in respect of scheduled international air services, granted by one State to another State to put down, in the territory of the first State, traffic coming from the home State of the carrier (also known as a ***Third Freedom Right***).

Fourth Freedom of The Air - the right or privilege, in respect of scheduled international air services, granted by one State to another State to take on, in the territory of the first State, traffic destined for the home State of the carrier (also known as a ***Fourth Freedom Right***).

Fifth Freedom of The Air - the right or privilege, in respect of scheduled international air services, granted by one State to another State to put down and to take on, in the territory of the first State, traffic coming from or destined to a third State (also known as a ***Fifth Freedom Right***).

Freedom of the Air (3)



STRATEGIC OBJECTIVES OF ICAO

The International Civil Aviation Organization, a UN Specialized Agency, is the global forum for civil aviation. ICAO works to achieve its vision of safe, secure and sustainable development of civil aviation through cooperation amongst its member States.To implement this vision, the Organization has established the following Strategic Objectives for the period 2005-2010:

- **Safety - Enhance global civil aviation safety**
- **Security - Enhance global civil aviation security**
- **Environmental Protection - Minimize the adverse effect of global civil aviation on the environment**
- **Efficiency - Enhance the efficiency of aviation operations**
- **Continuity - Maintain the continuity of aviation operations**
- **Rule of Law - Strengthen law governing international civil aviation**

Quelle: Zantke „ABC des Luftverkehrs“

Bodies and Agencies in Air Transport System

	Singapore	*Germany*	*Europe*	*International*
General Transport Guidelines	Ministry of Transport	Bundesministerium für Verkehr, Bau- / Wohnungswesen (**BMVBW)** *Berlin*	European Union **(CEC)** DG TREN Transport *Brüssel*	International Civil Aviation Organization (**ICAO)** *Montreal*
Certification, Airworthiness and Personal	Ministery for Transport	Luftfahrt-Bundesamt (**LBA)** *Braunschweig*	Joint Airworthiness Authorities (**JAA)** *Hoofddorp (NL)* → ***EASA***	Federal Aviation Administration (**FAA)** *USA*
Air Trafic Control	Ministry of Transport	Deutsche Flugsicherung (**DFS)** *Offenbach*	Eurocontrol *Maastricht*	*Future Air Navigation Systems* ***(FANS)***
Operator/Airline	Singapore Airlines	Deutsche Lufthansa *Köln/Frankfurt*	Association of European Airlines (**AEA)** *Brüssel*	International Air Transport Association (**IATA)** *Montreal*
Airport	Changi Airport	Arbeitsgemeinschaft deutscher Verkehrsflughäfen (**ADV)** *Stuttgart*	Airports Council International – Europe (**ACI-Europe)** *Brüssel*	Airports Council International (**ACI)** *Genf*
Manufacturer	(Singapore Airlines??)	Airbus Germany MTU, Liebherr	EADS	Boeing, Airbus, etc.

Role of FAA and EASA

Actual Tasks

- Preparation and implementation of possible rule making procedures as well as technical advice for the European Commission and its member states
- Realisation of inspections, trainings- and standardization- programs for a common definition of European safety requirements in the member states
- Type Certification of all technical air transport products (air vehicles, aero-engines, aero-subsystems, etc.)
- Certification and control of all aircraft development and - maintenance companies
- Data collection, analysis and research to further improve all aspects of air safety

Technical Requirements for Certification

JAR–1	Definitions and Abbreviations	***FAR–1***	Definitions and Abbreviations
JAR–21	Certification Procedures for Aircraft, and Related Products & Parts	***FAR–21***	Certification Procedures for Products and Parts
JAR–22	Sailplanes and Powered Sailplanes		
JAR–23	Normal, Utility, Aerobatic and Commuter Category Aeroplanes	***FAR–23***	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
JAR–25	Large Aeroplanes	***FAR–25***	Airworthiness Standards: Transport Category Airplanes
JAR–26	Retroactive air worthiness requirements		
JAR–36	Noise Standards	***FAR–36***	Noise Standards: Aircraft Type and Airworthiness Certification
JAR–147	Aviation Maintenance for technical schools	***FAR–147***	Aviation Maintenance Technician Schools
JAR–27	Small Rotorcraft	***FAR–27***	Airworthiness Standards: Normal Category Rotorcraft
JAR–29	Large Rotorcraft	***FAR–29***	Airworthiness Standards: Transport Category Rotorcraft
JAR–E	Engines	***FAR–33***	Airworthiness Standards: Aircraft Engines
JAR–P	Propellers	***FAR–35***	Airworthiness Standards: Propellers
JAR–APU	Auxiliary Power Units		
JAR–TSO	Joint Technical Standard Orders		
JAR–AWO	All Weather Operations		
JAR–VLA	Very Light Aeroplane	***FAR–103***	Ultralight Vehicles
JAR–145	Approved Maintenance Organisations	***FAR–145***	Repair Stations
JAR–OPS Part 1	Commercial Air Transportation (Aeroplanes)	***FAR–121***	Certification and Operations: Domestic, Flag, and Supplemental Air Carriers and commercial Operators of Large Aircraft
JAR–FCL	Licensing of flight personal	***FAR–61***	Certification: Pilots and Flight Instructors
JAR–OPS Part 3	Commercial Air Transportation (Helicopters)	***FAR–127***	Certification and Operations of Scheduled Air Carriers with Helicopters

JAR-25 Large Aeroplanes

Section 1 – Requirements:

- Subpart A – General
- Subpart B – Flight
- Subpart C – Structure
- Subpart D – Design and Construction
- Subpart E – Powerplant
- Subpart F – Equipment
- Subpart G – Operating Limitations and Information
- Subpart J – Gas Turbine Auxiliary Power Unit Installation

Section 2 – Acceptable Means of Compliance & Interpretations (ACJ)

Section 3 – Advisory Material (AMJ)

Chapter 4.2

Safety

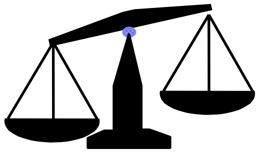
Definition of Safety

- Crash of an An-124 directly after Takeoff.
- 3 from 4 engines failed shortly after takeoff.
- Causes?? Maintenance? Badly managed operation??

- Absolut safety does not exist.
- Each technical or biological system can fail!
- Each technical and biological system is a compromise between contradicting requirements with respect to safety and efficiency.

Quelle: DFG Sicherheit im Luftverkehr

For all technical systems the engineer has to find a reasonable compromise between **economic efficiency** and **reliability**! This is defined as airworthiness



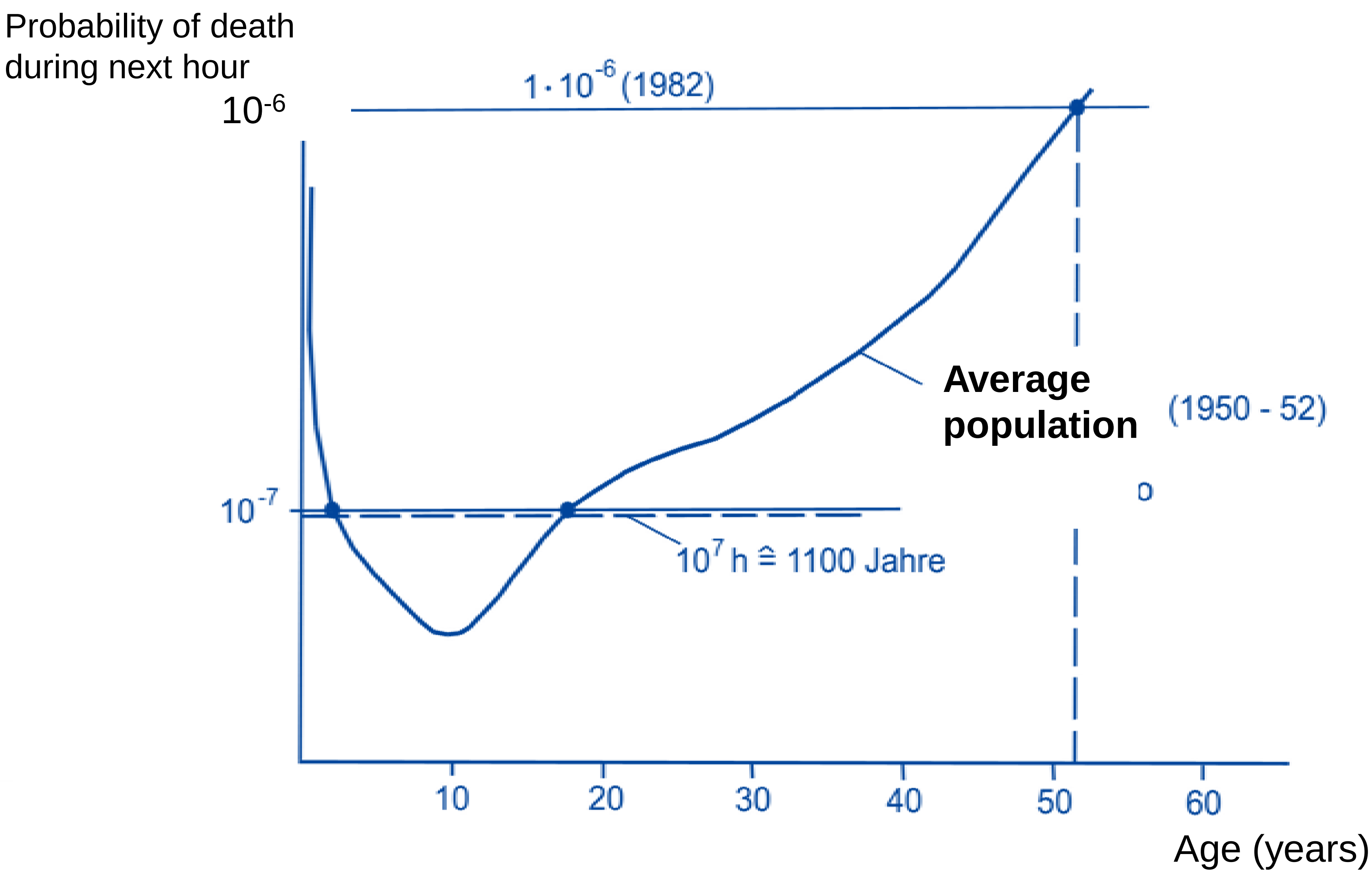
Definition of Airworthiness:

„ The acceptable safety standard of an aircraft,
- designed and produced in accordance with the equivalent requirements,
- operated in the defined environment and within the quantified limits
- maintained in accordance with the certified procedures“.

Relation between Probability and Impact

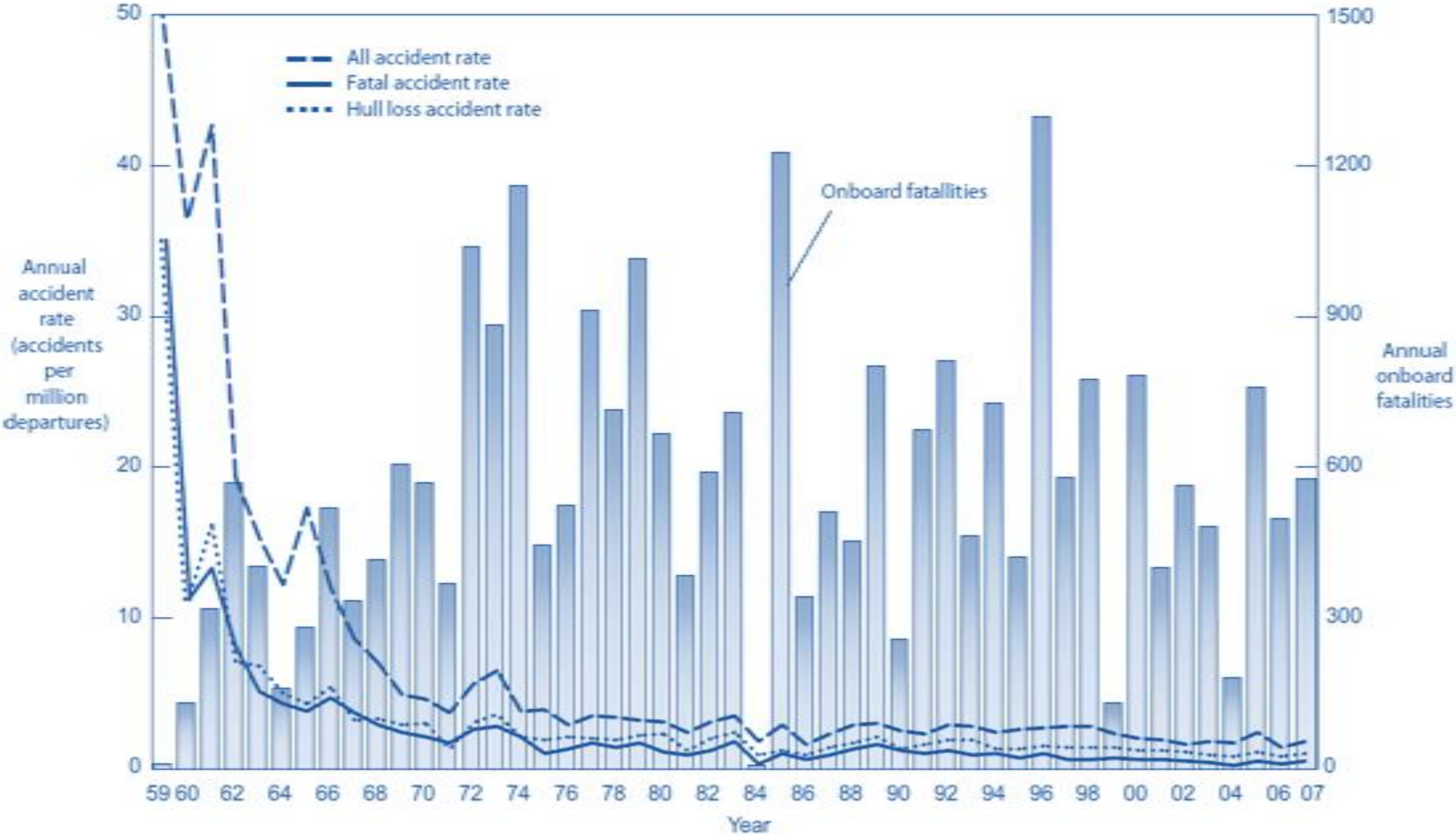
	Probability of an incident per flight									
	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
Probability	Often		Possible		Less probable		Unlikely		Very unlikely	
Effect/Impact	Minor				Larger		Risky		Catastrophic	
Description	Will happen probably often during the life time of an aircraft		Will most probably not or rarely happen during normal operation, but over the whole lifetime of an aircraft it may happen several times		Will most probably not happen in operation but can happen once or twice over the whole life of some aircraft		Unlikely for the whole life of an aircraft; but has to be considered as possible		So unlikely that it is not considered as design case	

Risk of sudden death in human life



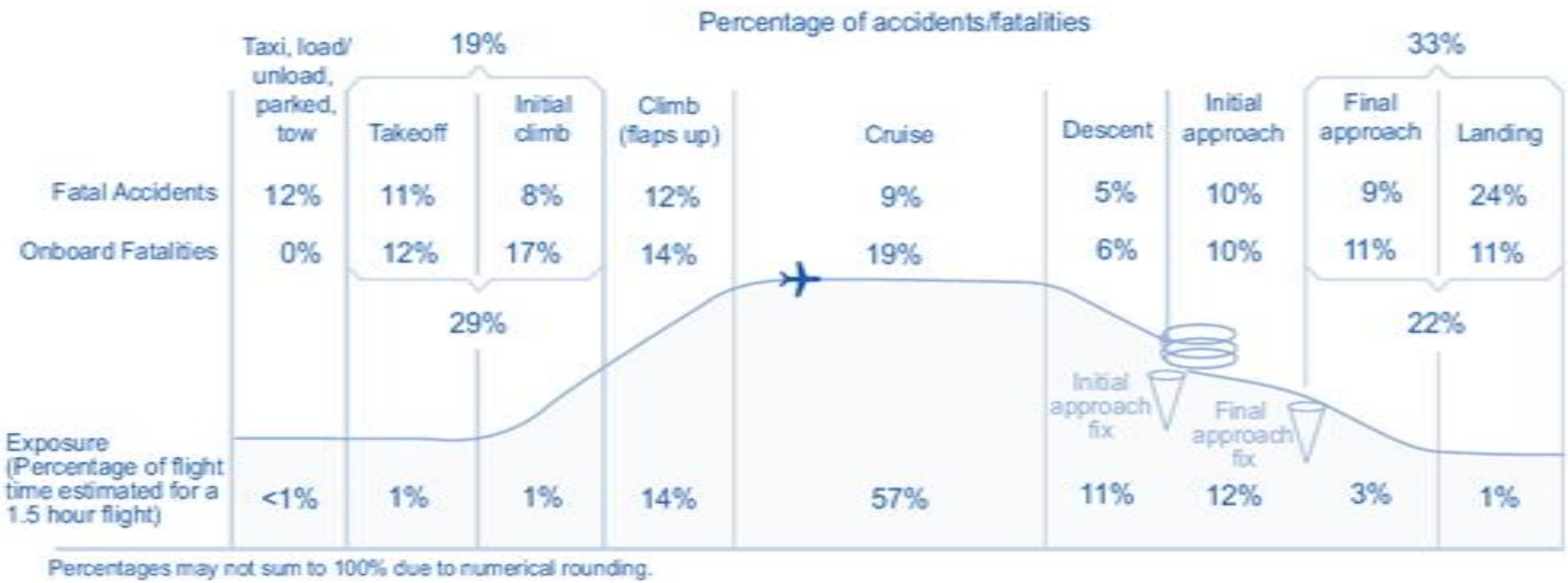
Quelle: DFG Sicherheit im Luftverkehr

Accidents and fatalities in air transport (1959-2007)



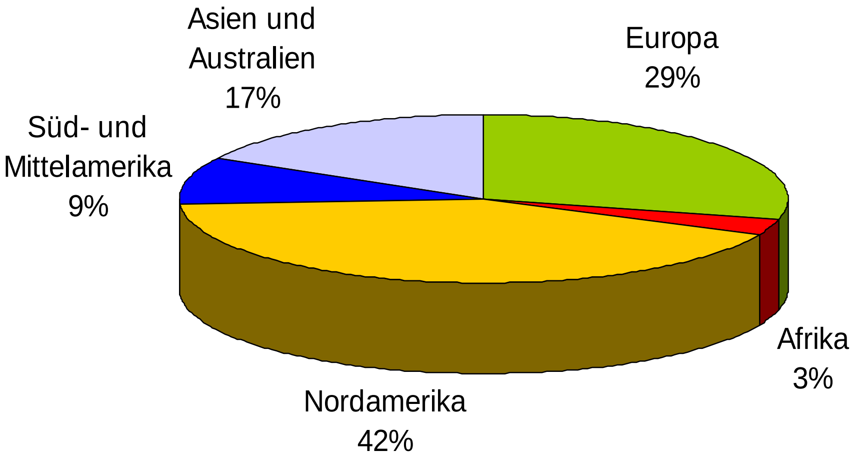
Quelle: Boeing Commercial Jet Airplane Accidents 2008

Accidents related to flight phase worldwide (1997-2007)

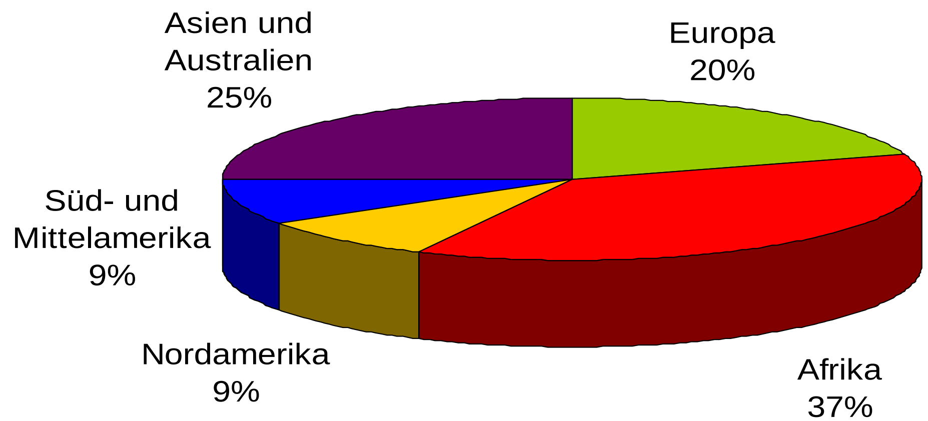


Quelle: Boeing Commercial Jet Airplane Accidents 2008

Accidents related to Regions (2005)



Takeoffs worldwide



Accidents worldwide

Source: Aviation Safety Network

Chapter 4.3

Security

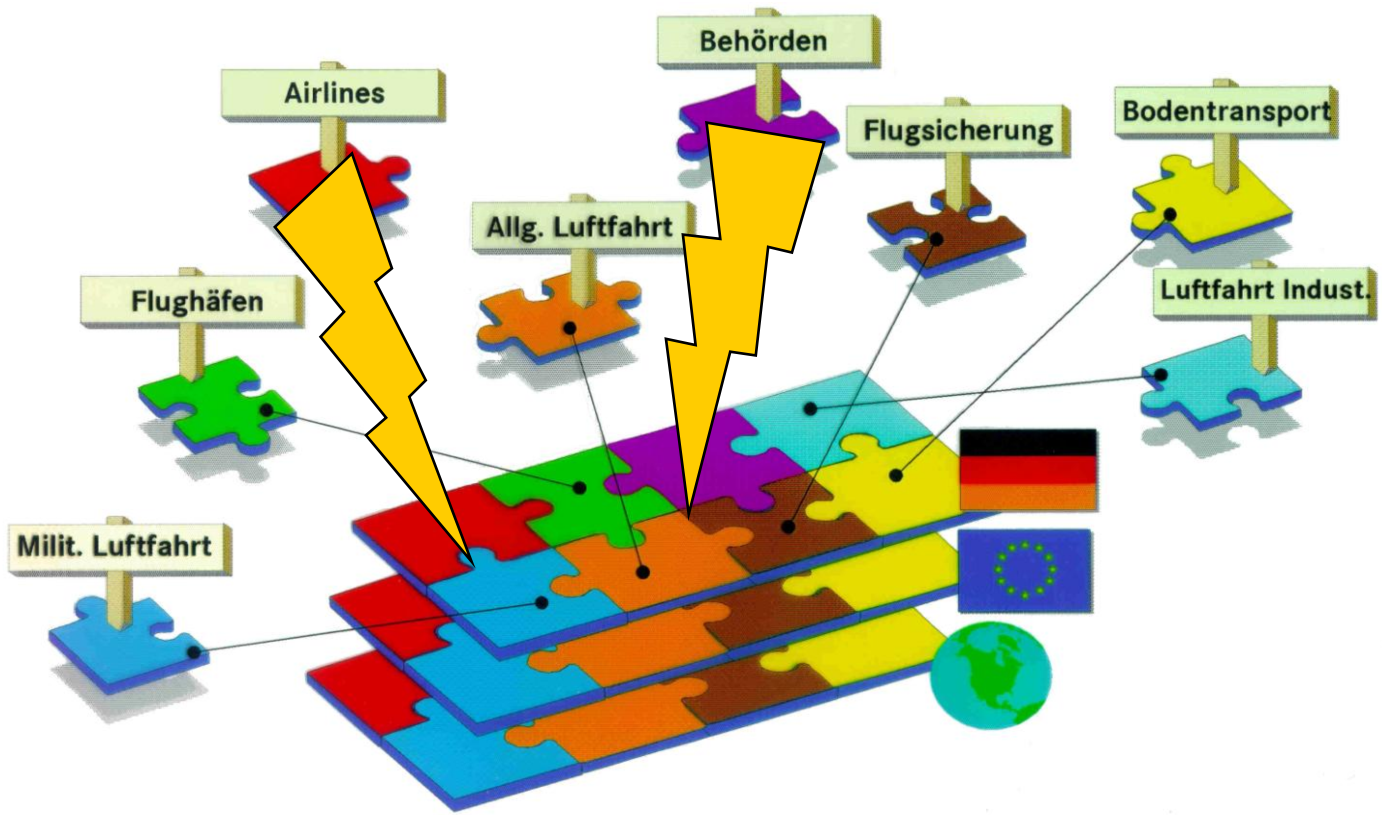
Security: Attack on World Trade Center

A new aspect has entered the air transport system: Misuse of an aircraft as a weapon!
Security is a new challenge for the air transport system
Aircraft hijackers are using the aircraft in a suicidal obsession to attack big objects as flying bombs!
Before hijacking was popular to achieve some personal or political concessions like pressing on liberation of political persons or to get asylum.

Counter measures:

- Increasing passenger control
- Use of Body scanners
- Closing cockpit doors
- Introducing „Air-Marshalls“
- Stronger control of personal in safety-critical areas
- **A lot of actionism!**

Fragility of the Air Transport System



State Agencies: Closing of air space – Aircraft have to stay on ground

Insurances: Immediate cancellation of all airline contracts related to war and terrorism

Airlines: Immediate reduction of passengernumbers leading to financial losses + increased cost for insurance

Summary of Chapter 4

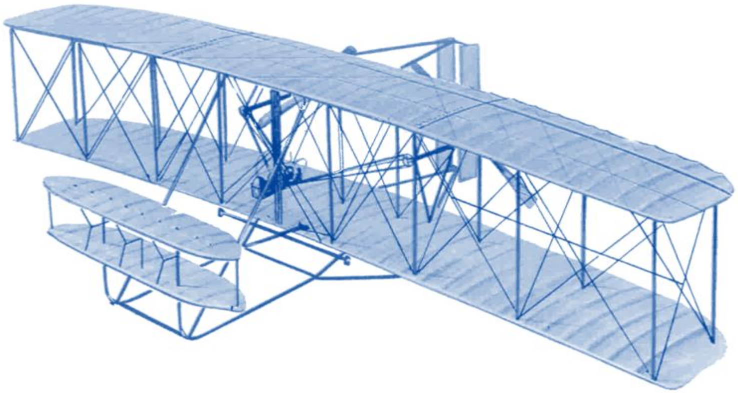
- In general the aircraft is one of the most reliable and safe transport modes
- This fact is a major factor in the passenger choice for air transport
- The air transport has defined airworthiness as the acceptable compromise between safety and economical performance.
- The acceptable probability for failures has been quantified in accordance with the human life cycle.
- Airworthiness is constantly increasing with the evolution of the technical standard
- Takeoff and Landing are the most critical mission phases with respect to accident probability.
- Accidents are mainly caused by humans. Obviously, the statistics blame the pilots as major causes for accidents. But more detailed analysis identify the difficult communication link between pilot and controller as a major cause (CFIT).
- Security is a new important element in air transport to avoid aircraft to be used as weapon for terrorist attacks

Summary

- The air transport system is border crossing and therefore international. This required very early international agreements and standards.
- Die creation of international agencies – ICAO, IATA, FAA, .. – forced to agree on common standards and regulations.
- The definition of „freedoms of the air“ are the baseline for bilateral agreements about traffic rights between related states.
- In accordance with these international Agreements also national agencies are existing in nearly all countries, who have to implement and control the international regulations and ensure proper safety standards.
- In Europe, a common agency EASA has been recently created as the European Airworthiness agency. EASA masters the European Airworthiness regulations JAR.
- JAR and FAR are representing the international certification standards and are trying to harmonize their standards as far as possible.

Chapter 5

Aircraft Characteristics



5. 1 Transportation task and
5. 2 Basics of Flight Physics
5. 3 Structure, Mass estimation and Balance
5. 4 Flight - performance and - mission

Participants of the Civil Air Transport Systems

National Agency
- -FAA
- -NTSB
- -Min Transp

EASA

Air Trafic Control

International Agencies
- ICAO
- IATA
- FAA / EASA
- IAC

Organisations
- Consumers
- Environm. Ag.
- Tourism Ag.
- Hotels

Aircraft industry
- Manufacturer
- Engine Manuf.
- Suppliers

Aircraft

Airlines
- Line
- Low Cost
- Charter

Agencies
- Travel agents
- Freight forward
- Integrators

Passenger

Freight

Maintenance-centres

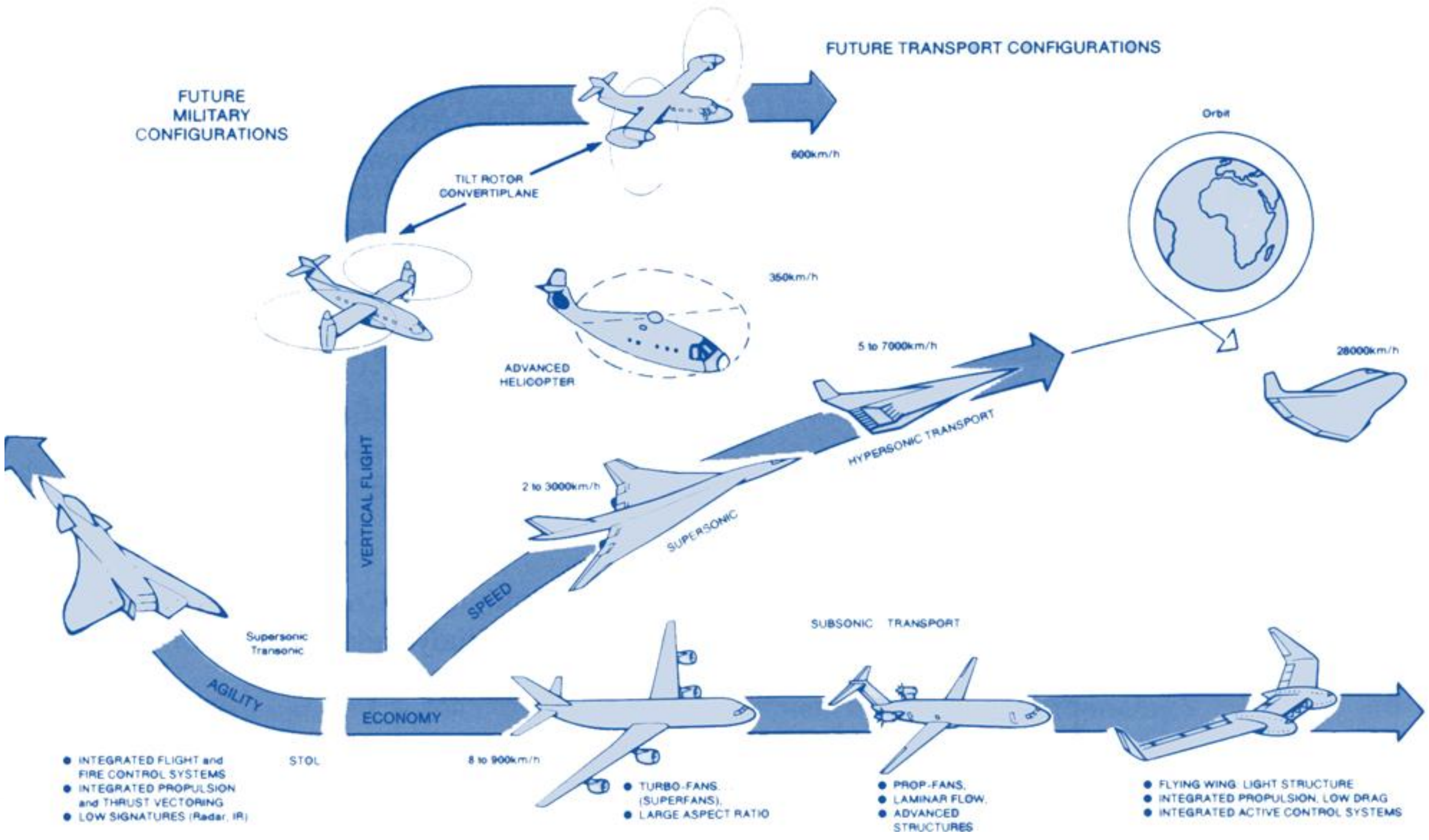
Airports

Reservation - Systems (Amadeus .)

Financing/ Services
- -Banks
- -Leasing Comp.
- -Insurance

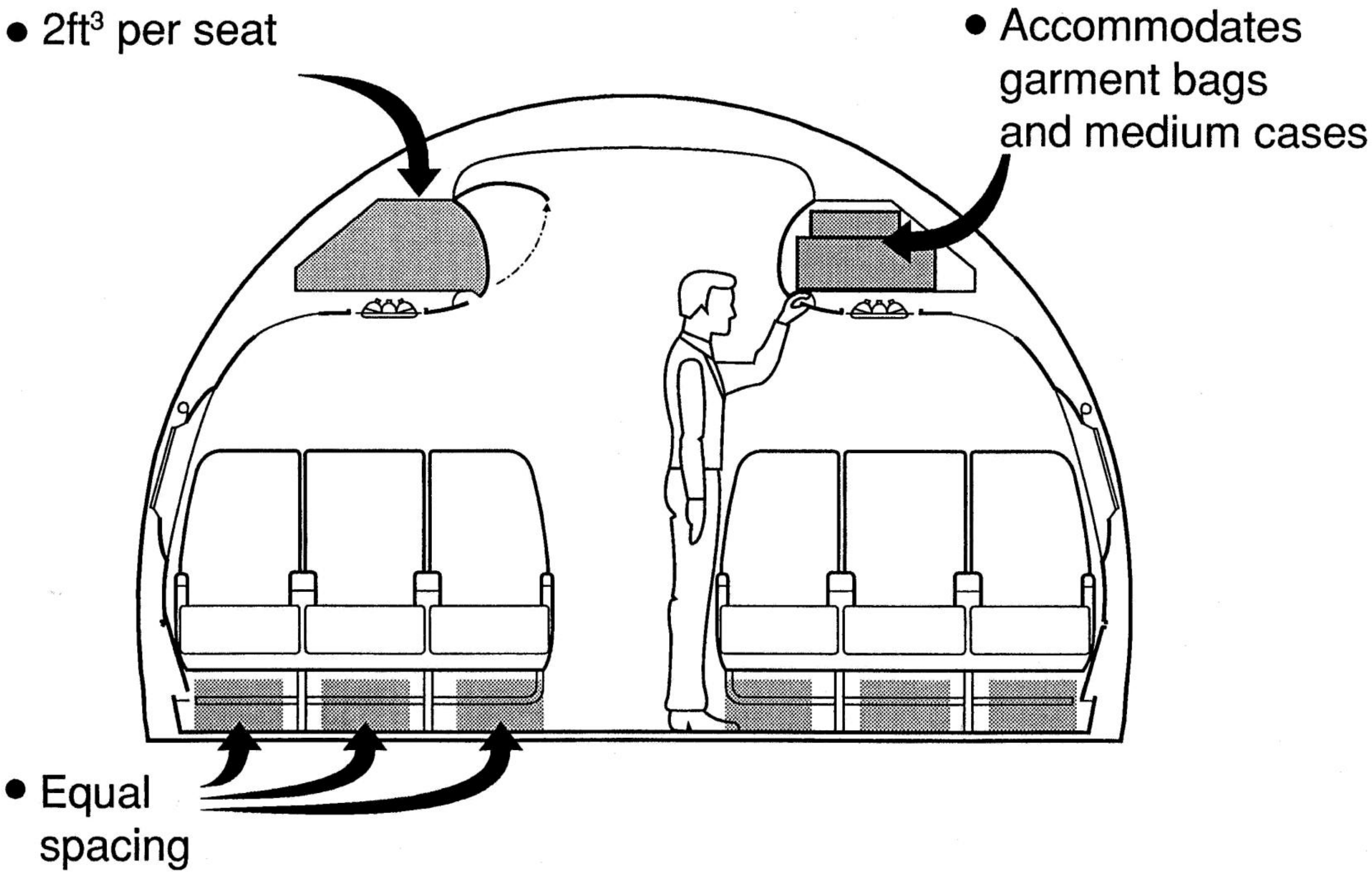
Infrastructure
- Meteo services
- Communication

Classification of Flight Vehicles



Quelle: Euromart Study Report 1988

Cabin Space

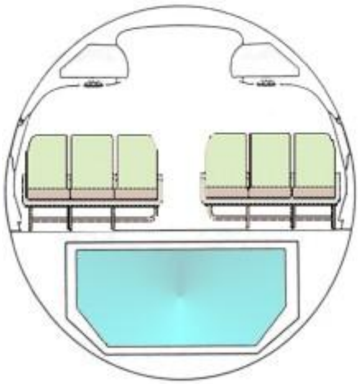


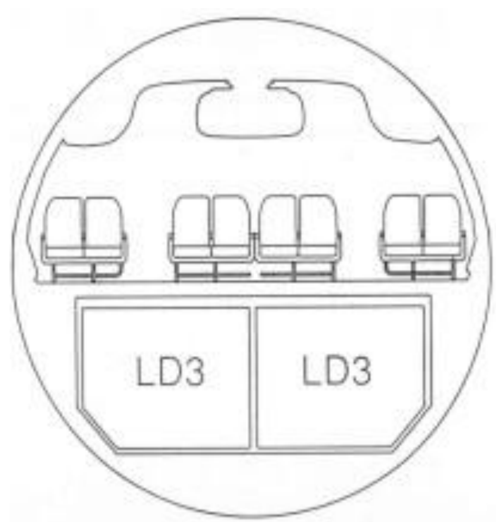
• $2ft^3$ per seat
• Accommodates garment bags and medium cases
• Equal spacing

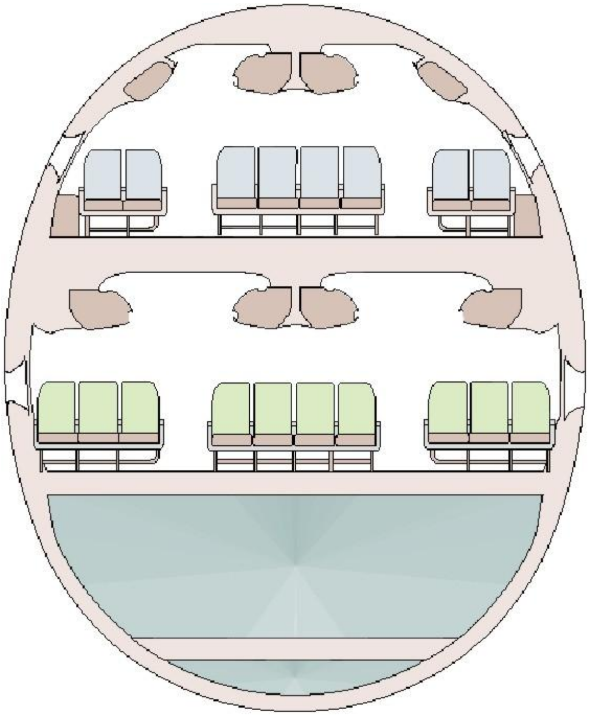
Cross Section

Systems have to be integrated and installed

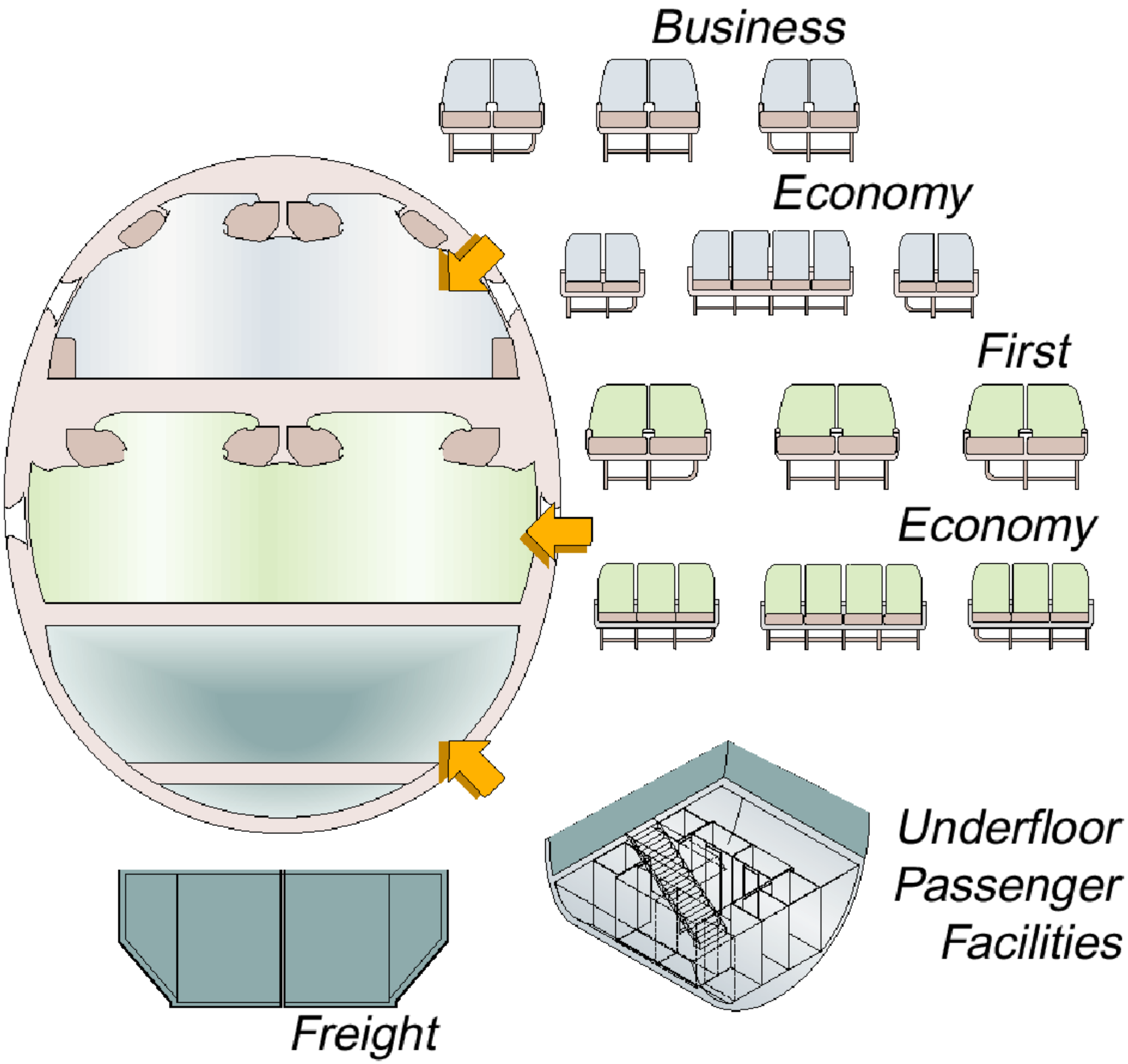
Commuter | Narrow- / Standardbody | Widebody | Macrobody





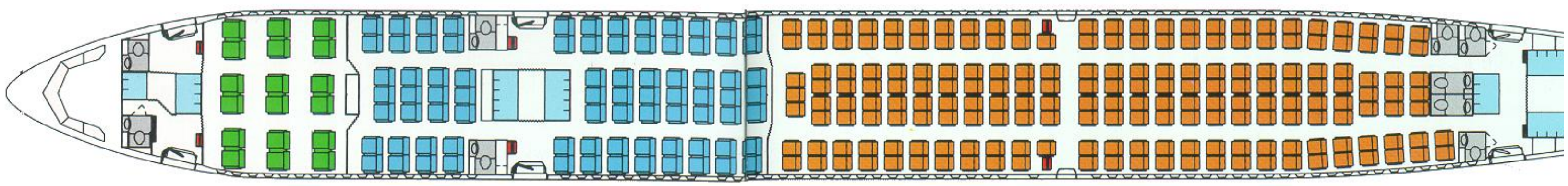


Single Aisle | Single Aisle | Twin Aisle | Double Deck

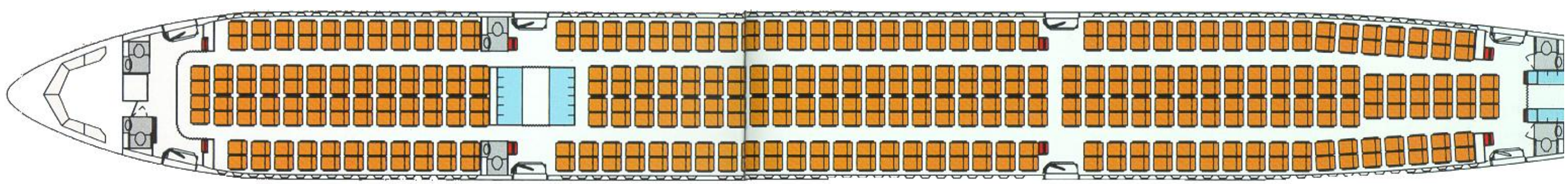


Business
Economy
First
Economy
Underfloor
Passenger
Facilities
Freight

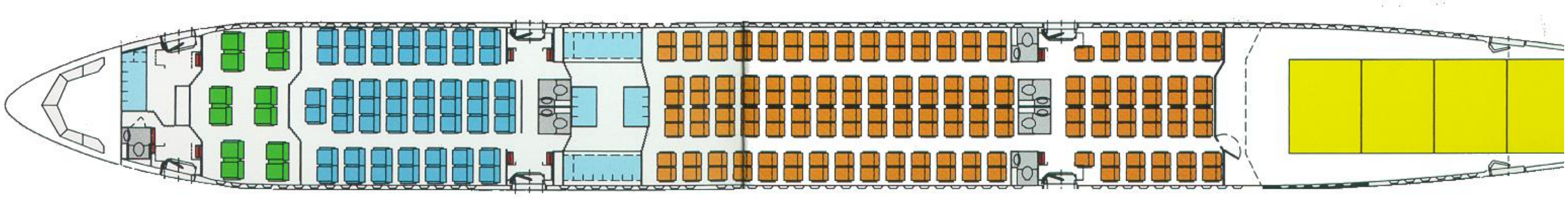
Cabin Layout Twin Aisle



A340-300 295 seats 3-class Typical scheduled long range



A340-300 398 seats Single class Long range charter



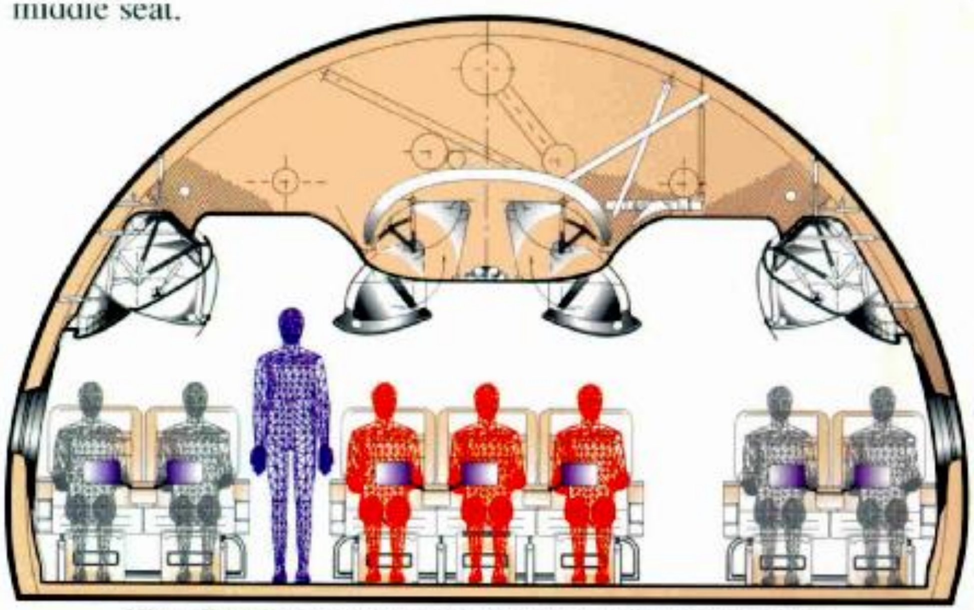
A340-300 Combi 221 seats + 4 pallets Long range mixed passengers and freight

Cabin Design - Definition of Standards

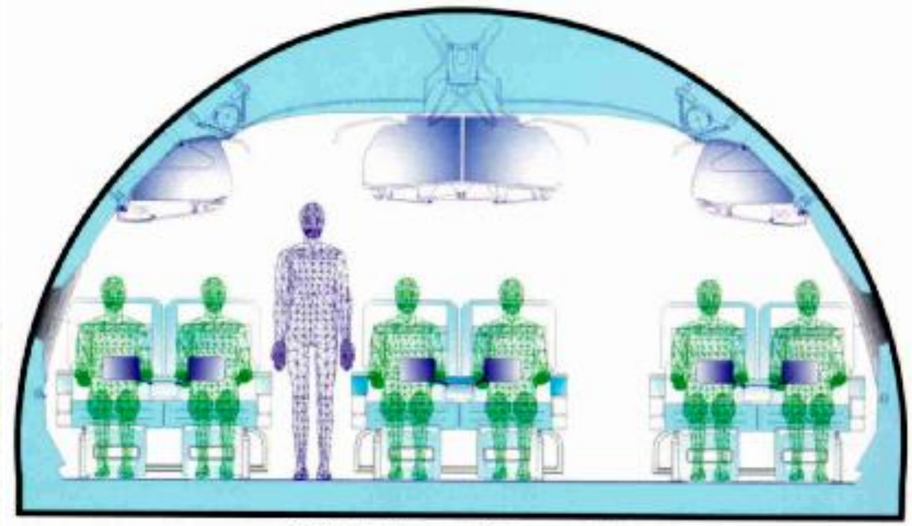
		SR short range SR ≤ 3000 nm	MR medium range 3000 nm < MR < 5500 nm		LR long range LR ≥ 5500 nm		
		YC	FC	YC	FC	BC	YC
seats	seats in %	100	8 - 10	90 - 92	5 - 7	18 - 20	73 - 77
	seat pitch [inch]	32	40	32	60	38	32
	seat decline [inch]	5	7.5	5	15	7	5
	seat width (two-man bench)	40	48	40	53	50	40
cabin attendants per pax		1 / 45	1 / 8	1 / 35	1 / 8	1 / 20	1 / 35
lavatory per pax		1 / 60	1 / 14	1 / 45	1 / 14	1 / 25	1 / 45
trays per pax		1.7	9	2.3	9	7	2.7
coat stowage [inch/Pax]		no	1.5	no	1.5	1.5	no

Cross Section - Comparison

middle seat.



777 : "Prisoner" seat disturbs 3 people, more hard-to-sell seats.



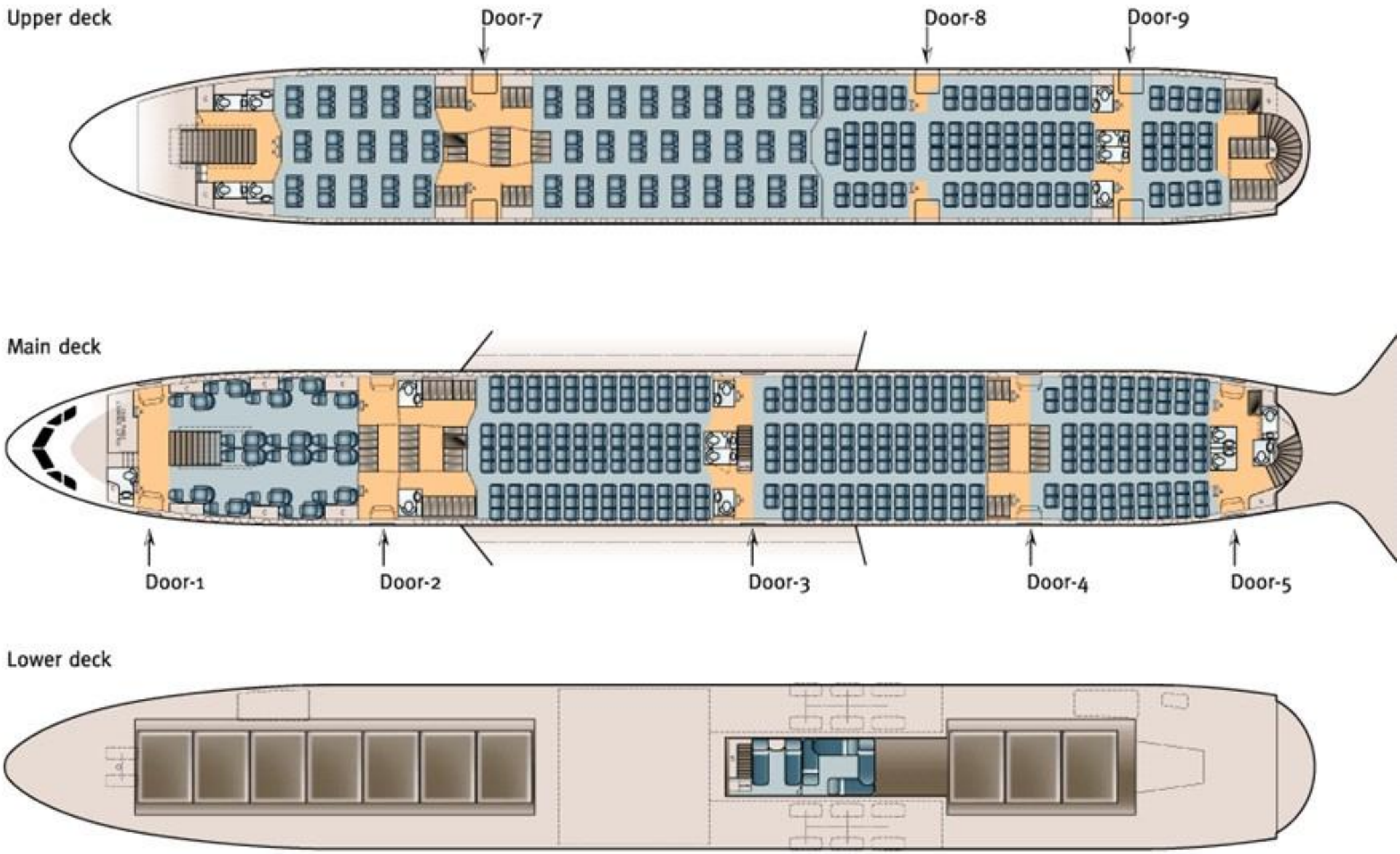
A330 : 6-abreast Mega-comfort.

Cabin Layout – „Prisoner Seat“

95% of business travelers prefer an aisle or a window seat!

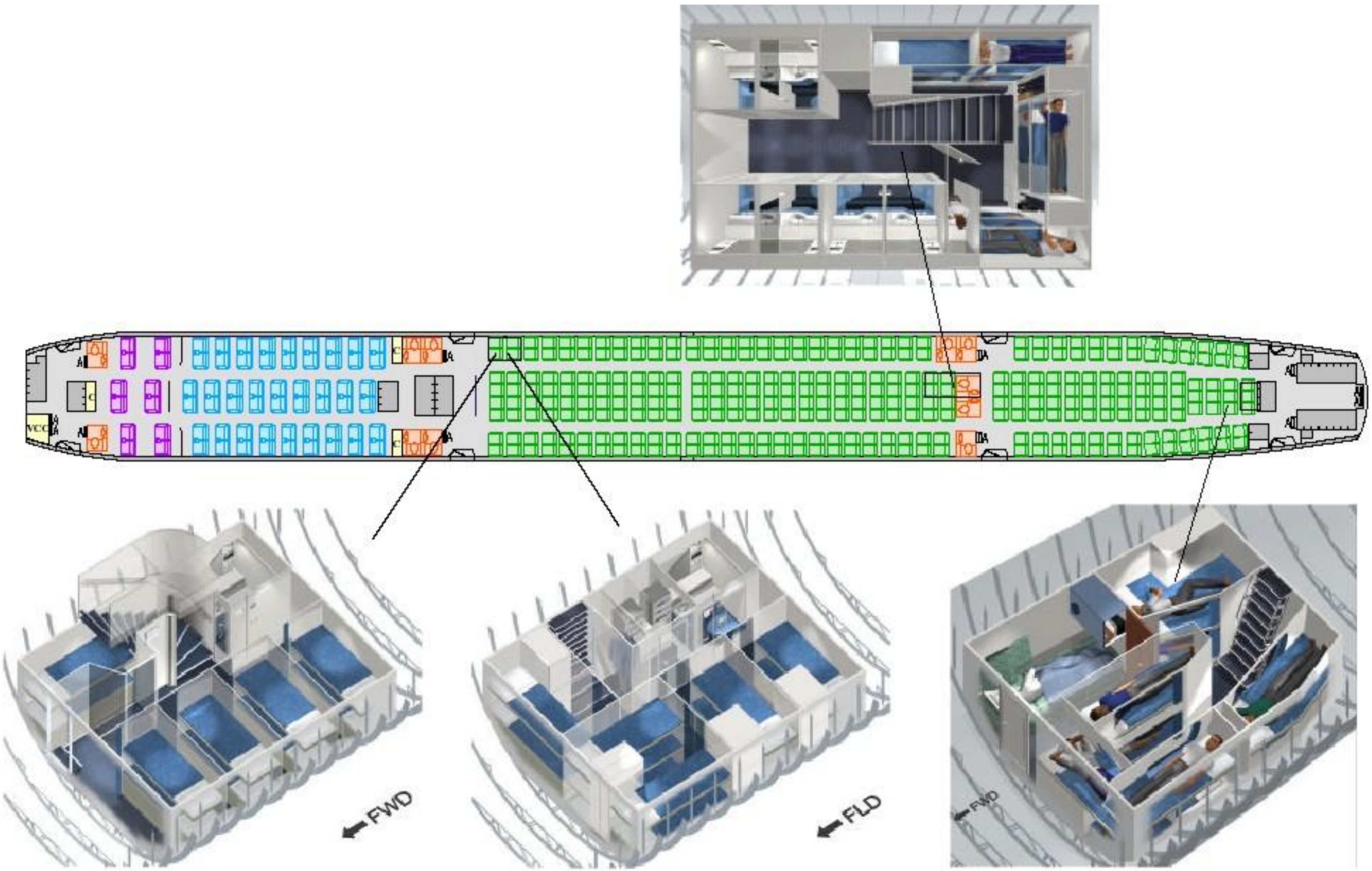
Quelle: Flight International

Cabin Design A380



Source: Airbus

Lower Deck Facilities

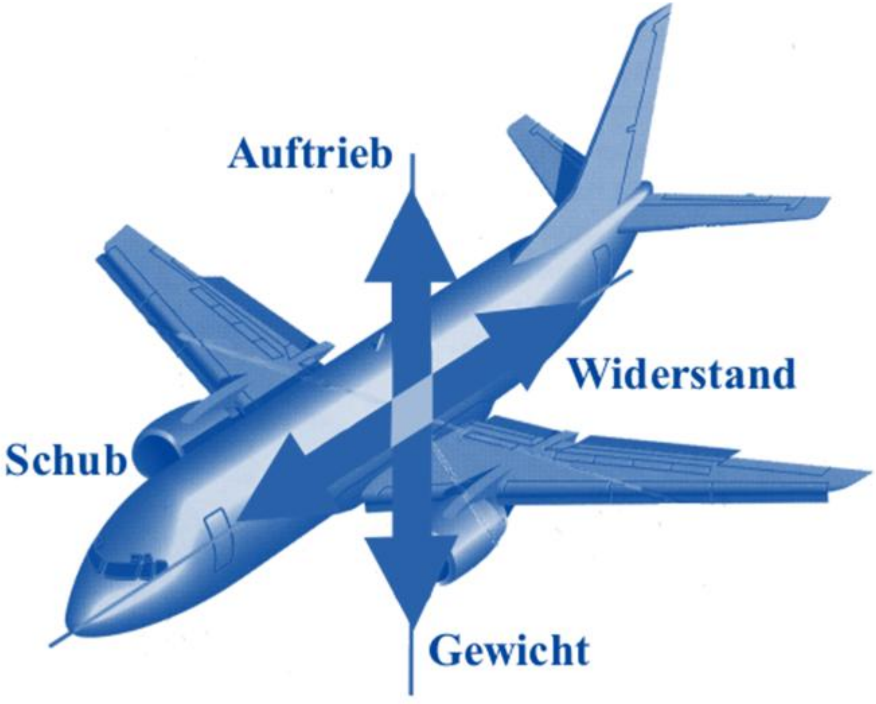


Questions

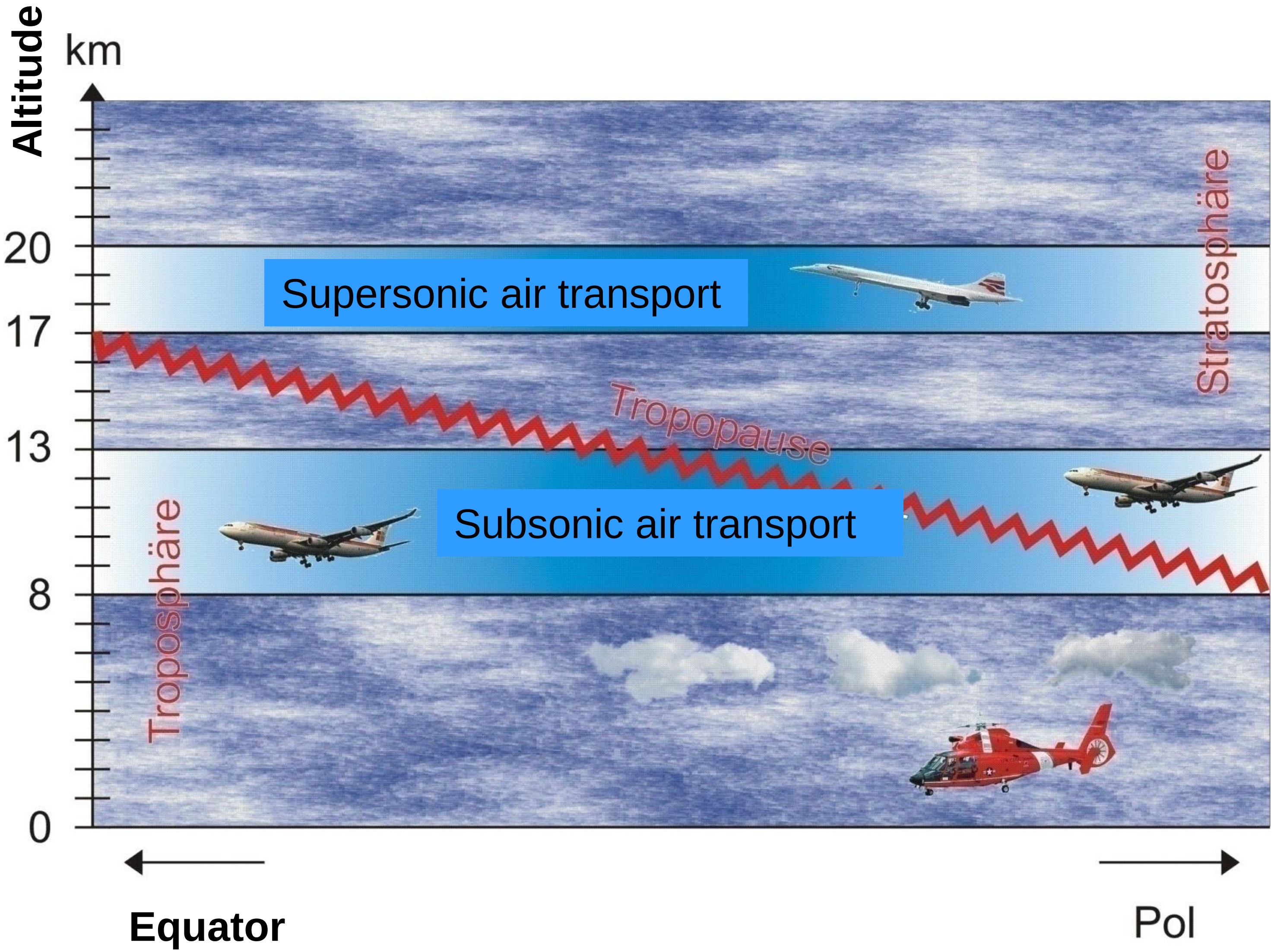
1. **What are Main drivers for Growth??**
2. **Which regions are growing faster?**
3. **Freedom of the air?? What does it mean?**
4. **Who is defining certification rules?**
5. **Difference between safety and security?**
6. **What means „abreast"??**
7. **Major elements of cabin layout??**

Chapter 5.2

Basics of Flightphysics



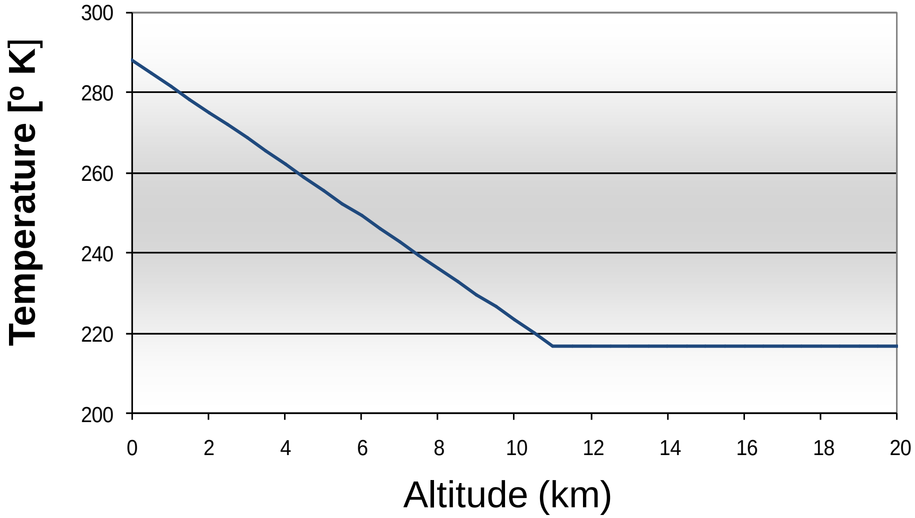
Structure of atmosphere



Stratosphere:
- Constant Temperature
- Limited vertical Exchange
- Long duration

Troposphere:
- High vertical Exchange
- Diminishing duration

ICAO-Standardatmosphere

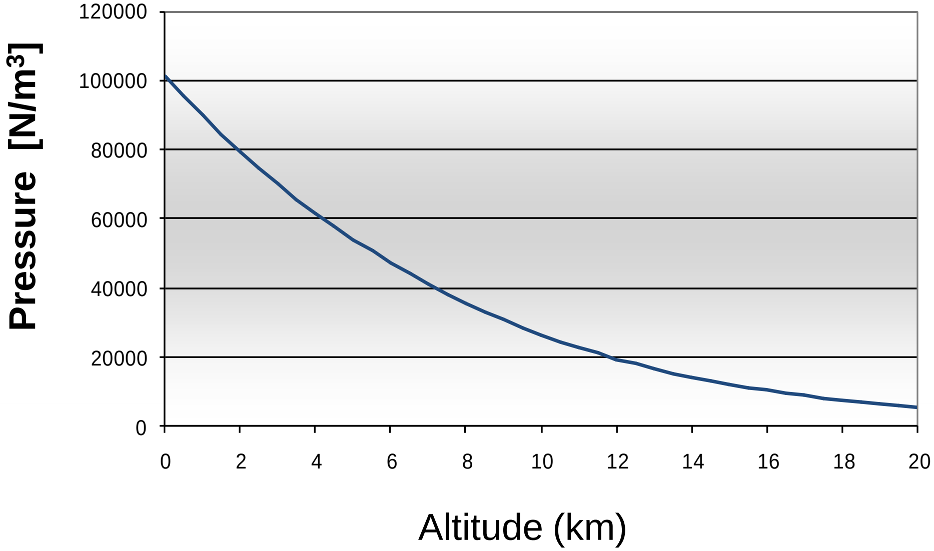


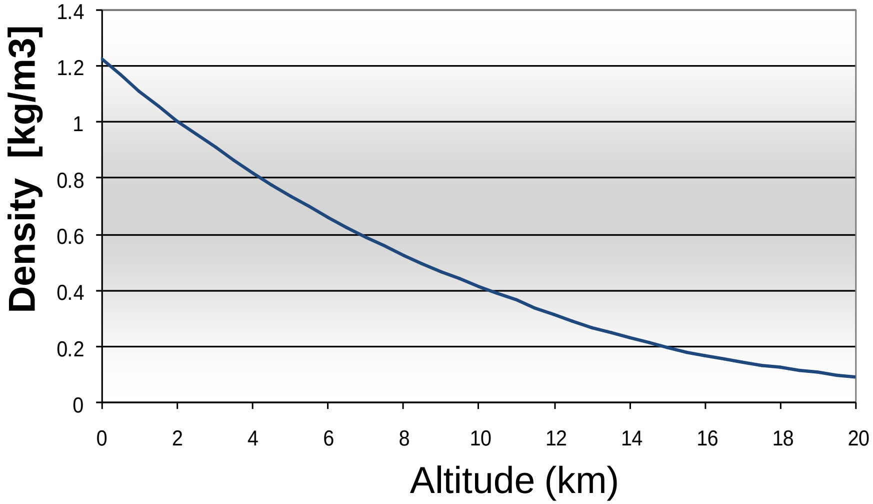
$H < 11000\,m:$

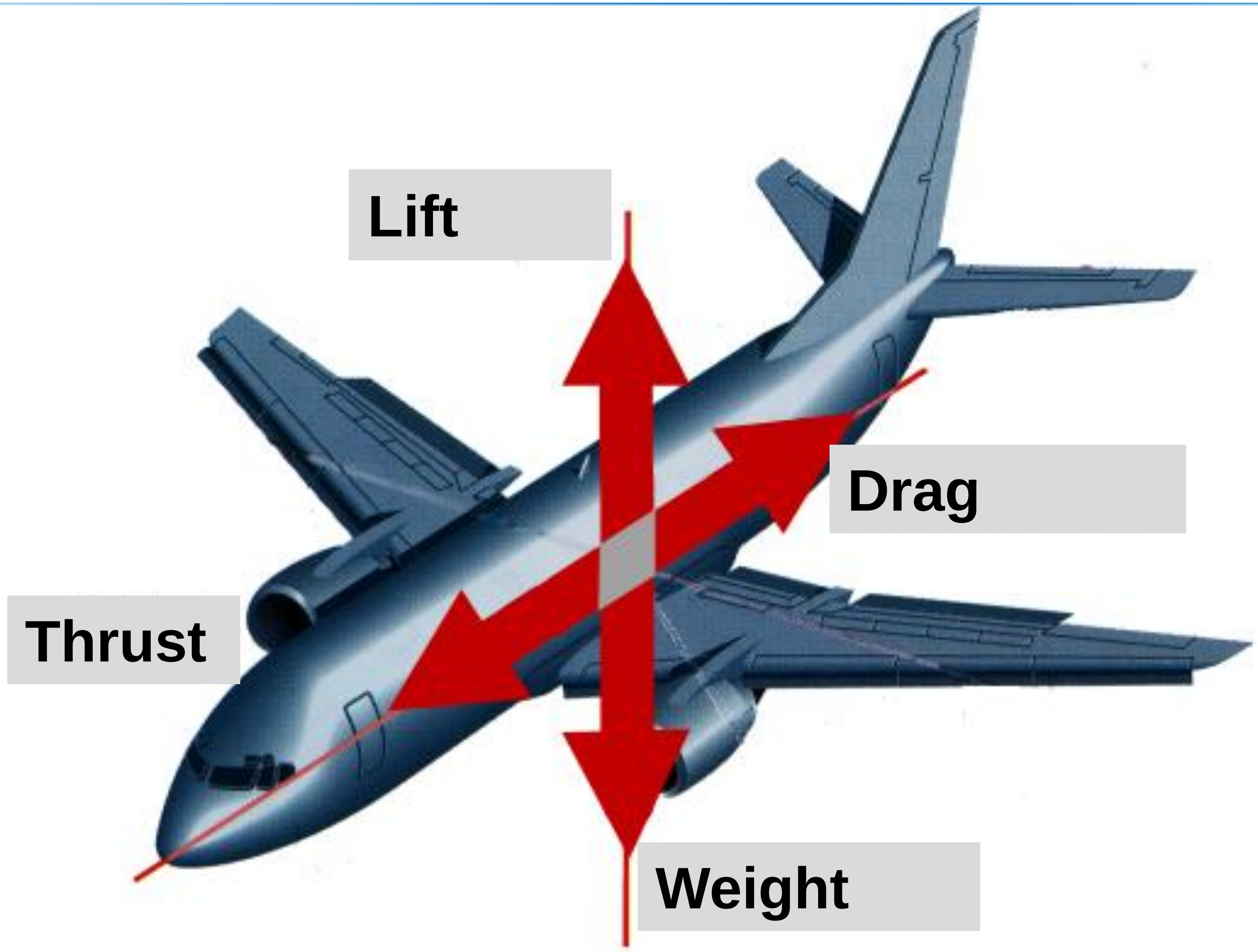
$$T(H) = 288.15K - 6.5K \cdot \frac{H}{1000\,m}$$

$11000\,m <= H < 20000\,m:$

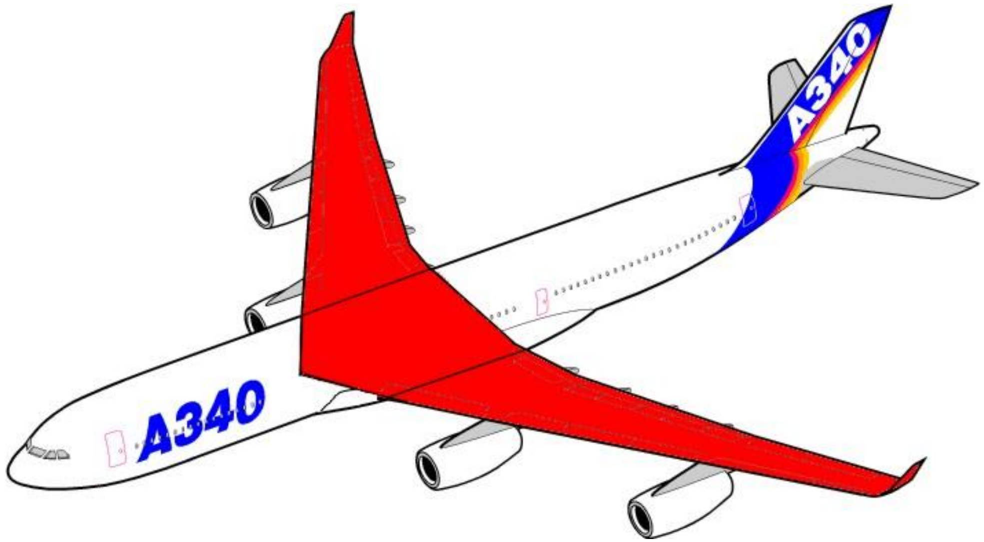
$$T = 216.65K$$






Lift
Drag
Thrust
Weight

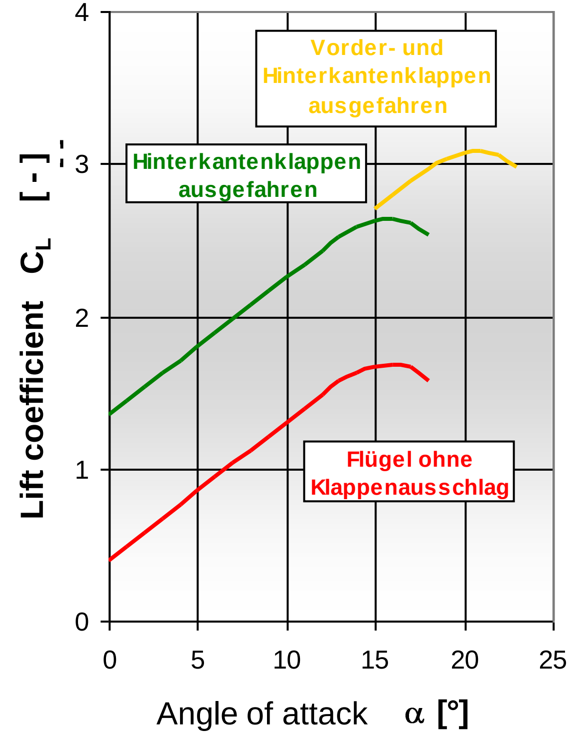
Lift – Wing characteristics



Angle of attack α [°] [rad]

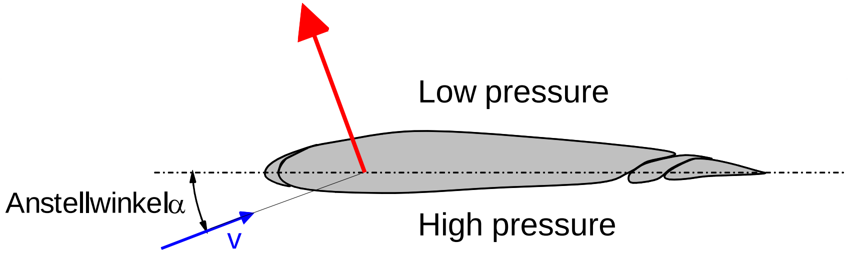
Surface S [m²] [ft²]

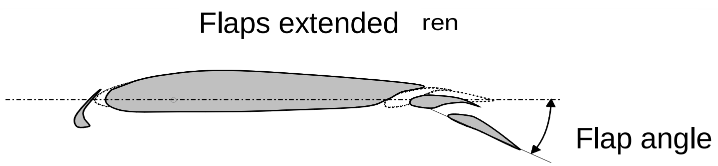
Define the lift forces at a given speed



$$L = C_L \frac{\rho}{2} v^2 S$$

Resulting Force = Lift **L**





Lift – Definiton

$$L = C_L \frac{\rho}{2} v^2 S$$

The Lift L is dependant on

1. The Flight condition

- Flight Speed V
- Air density $\rho = f(H)$
- Angle of attack α

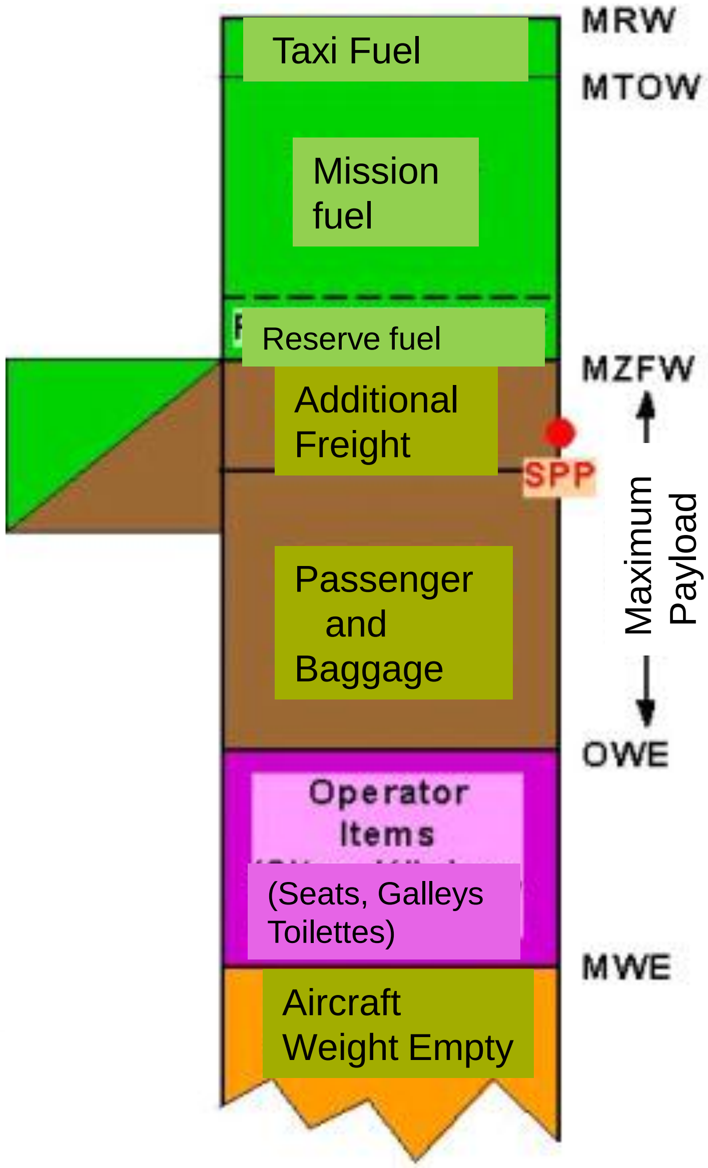
→ Dynamic pressure $q = 0.5\, \rho\, v^2$

2. The aircraft configuration

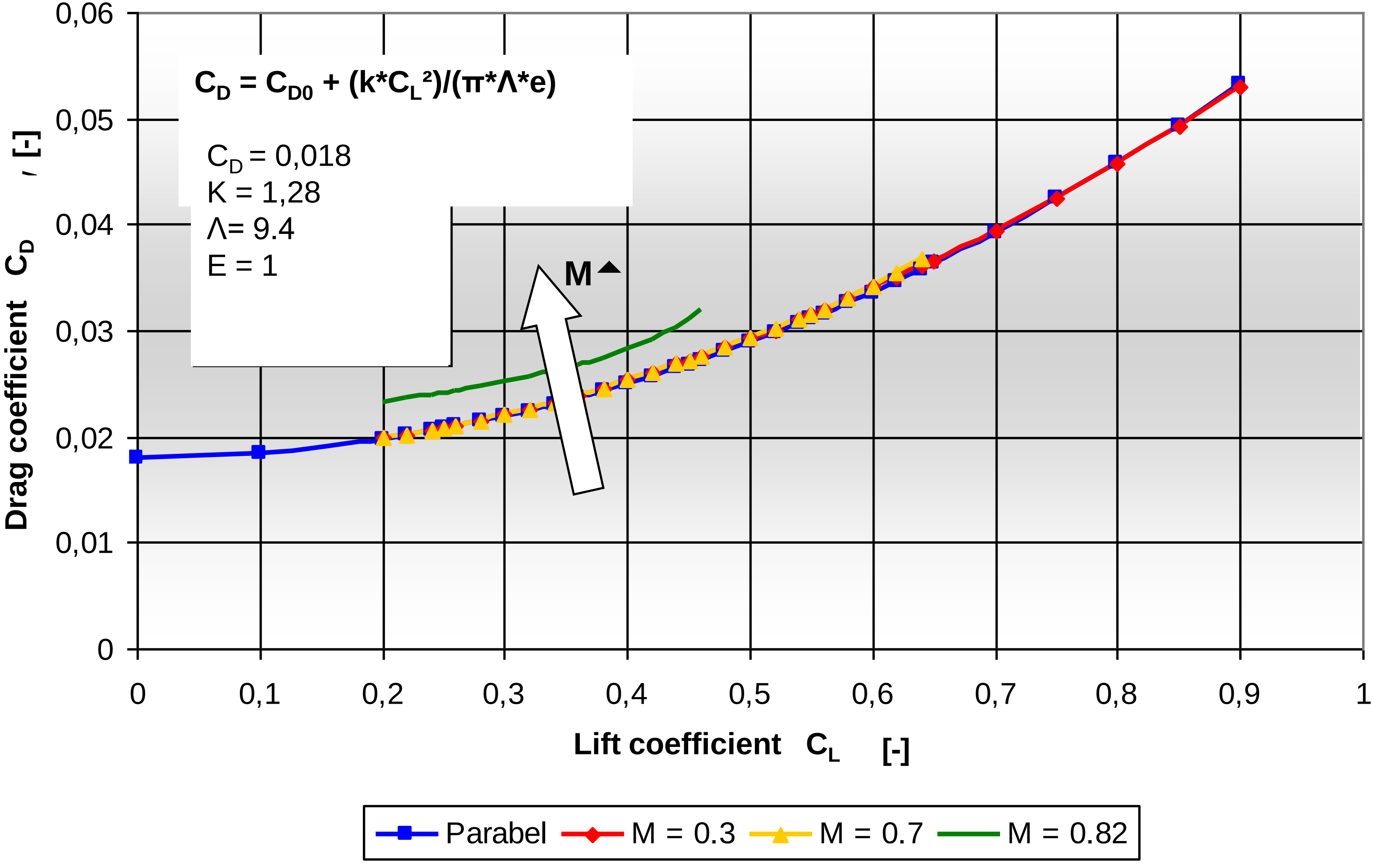
- Size of the lifting surface (Wing) S
- Geometry of lift generating Surface (shape i.e. (camber, twist, flaps, slats, etc.)

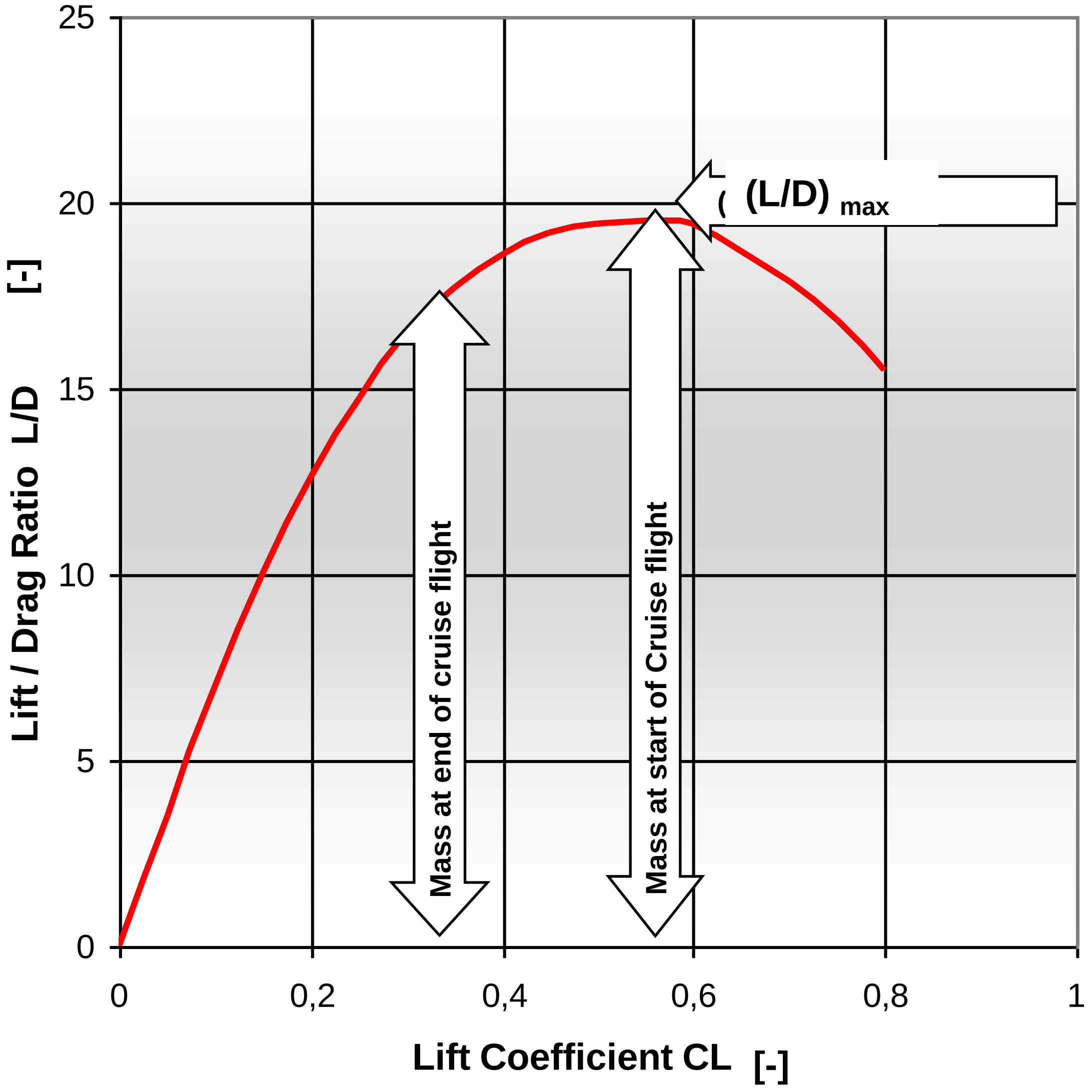
Definition of aircraft masses

SPP: Standard Passenger Payload
MRM: Maximum Ramp Mass
MTOM: Maximum Take Off Mass
MZFM: Maximum Zero Fuel Mass
OME: Operating Mass Empty
MME: Manufacturer Mass Empty



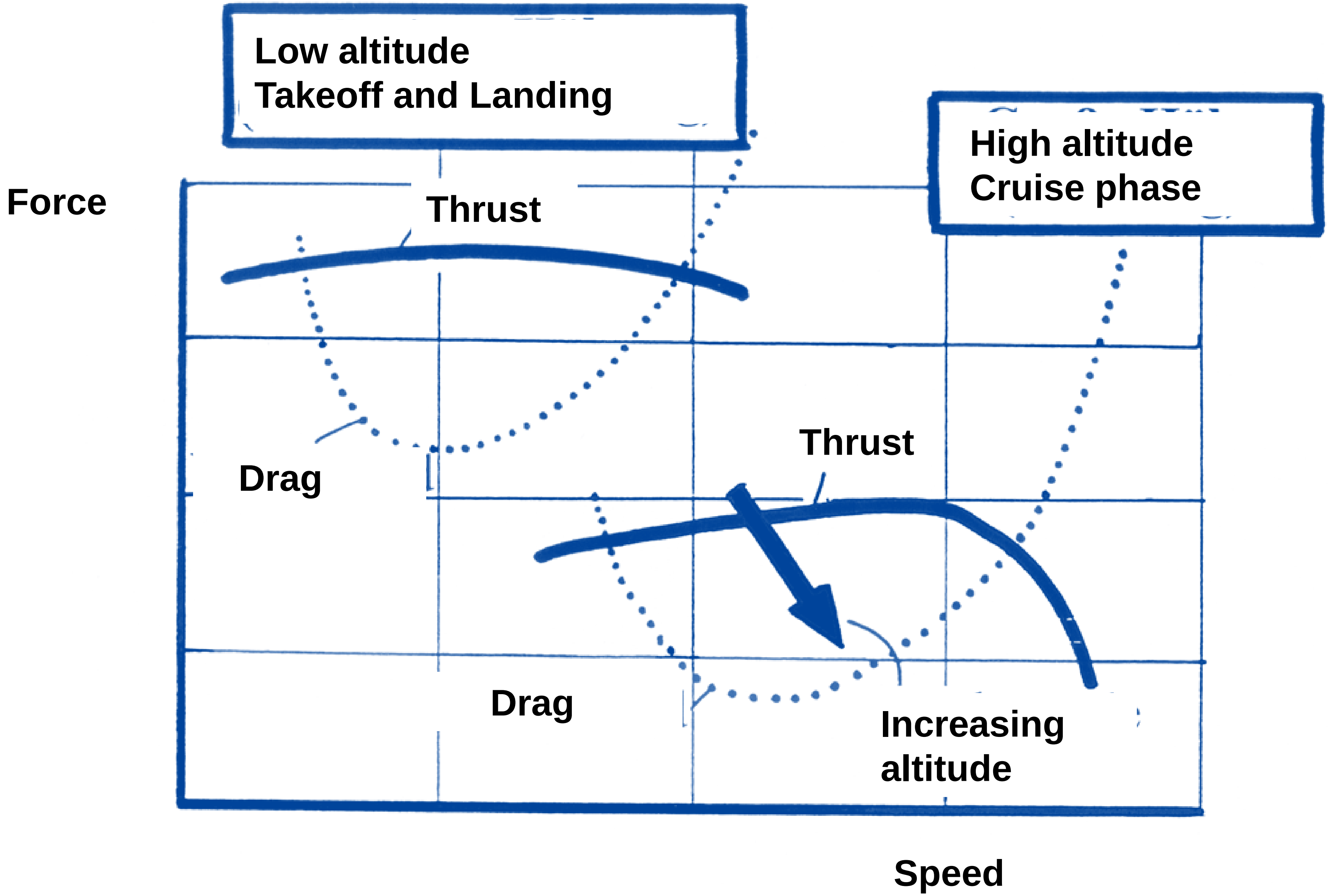
Drag Polar of a Typical Transport Aircraft





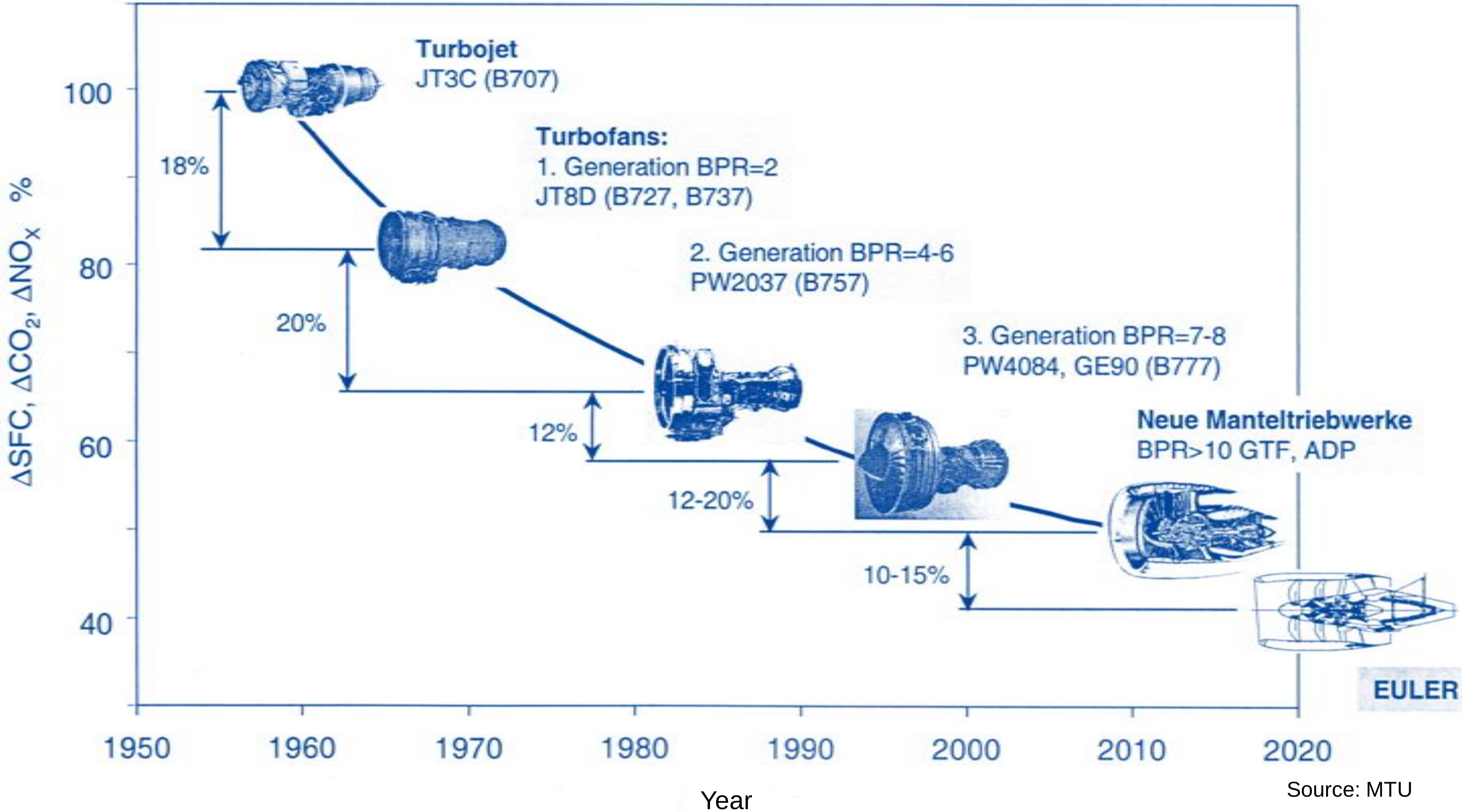
Valid for Ma=constant

Thrust and Drag



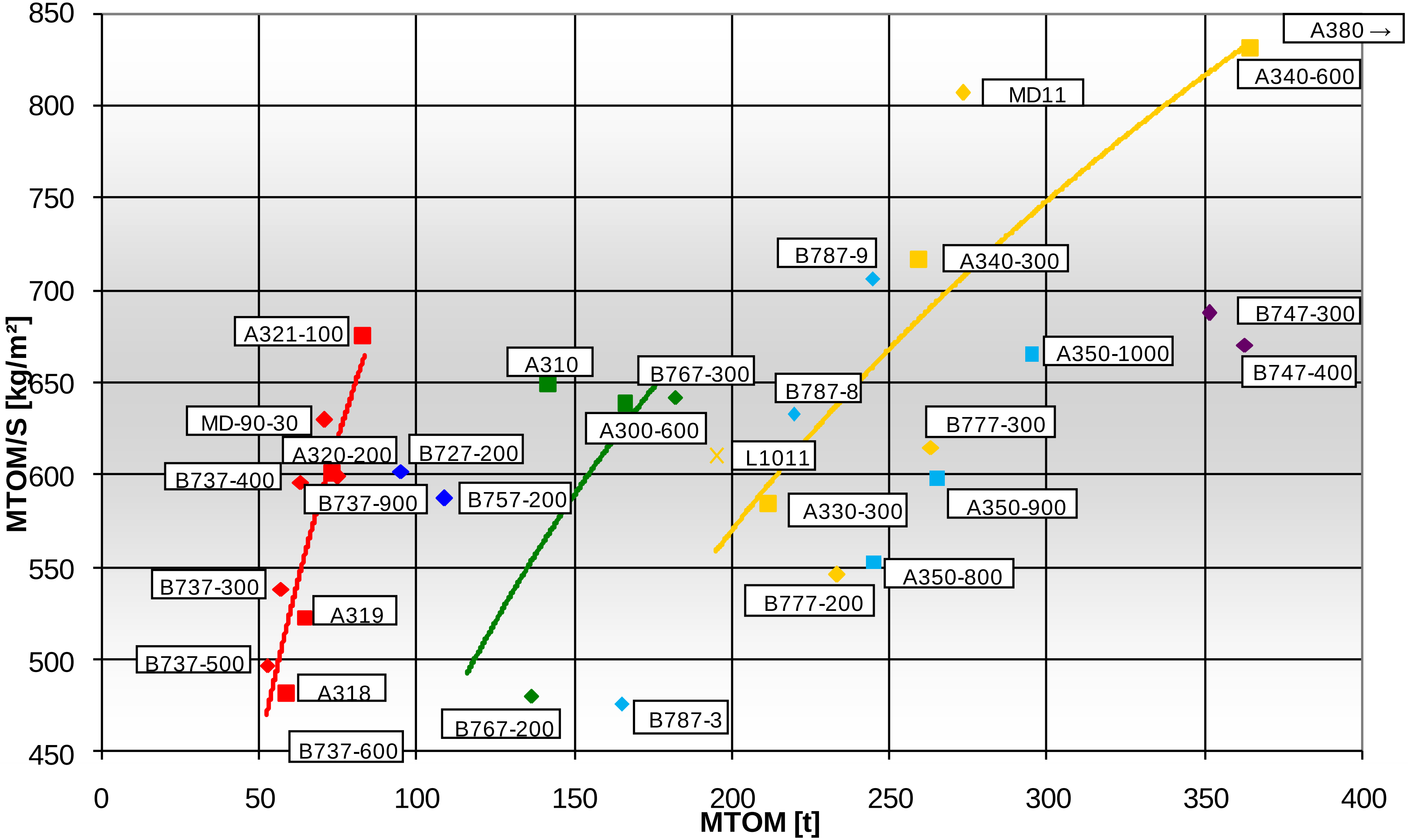
Engine generations:

Influence Bypass ratio (BPR) vs. fuel burn (SFC), CO_2 und NO_x Emission



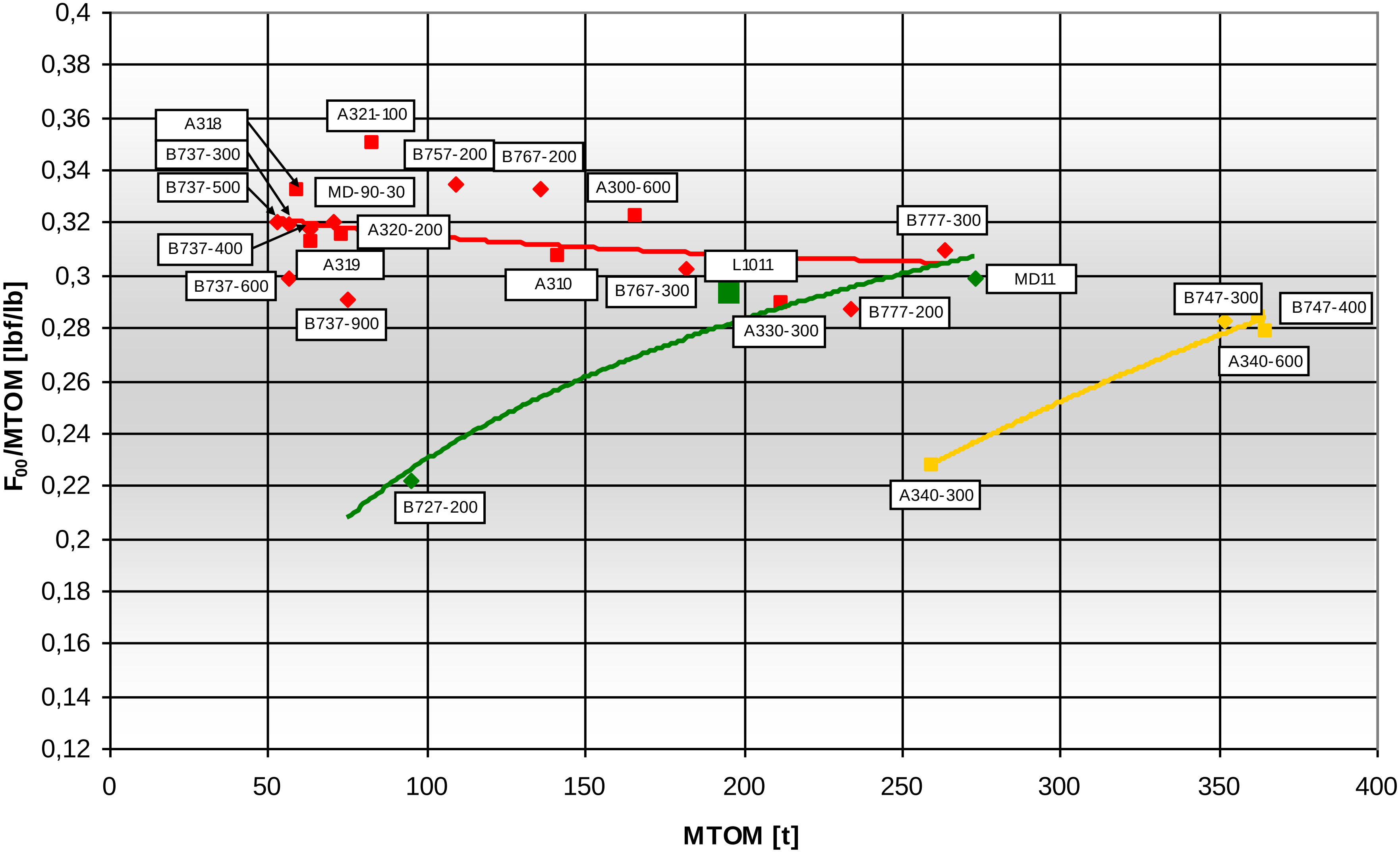
Source: MTU

Wing loading

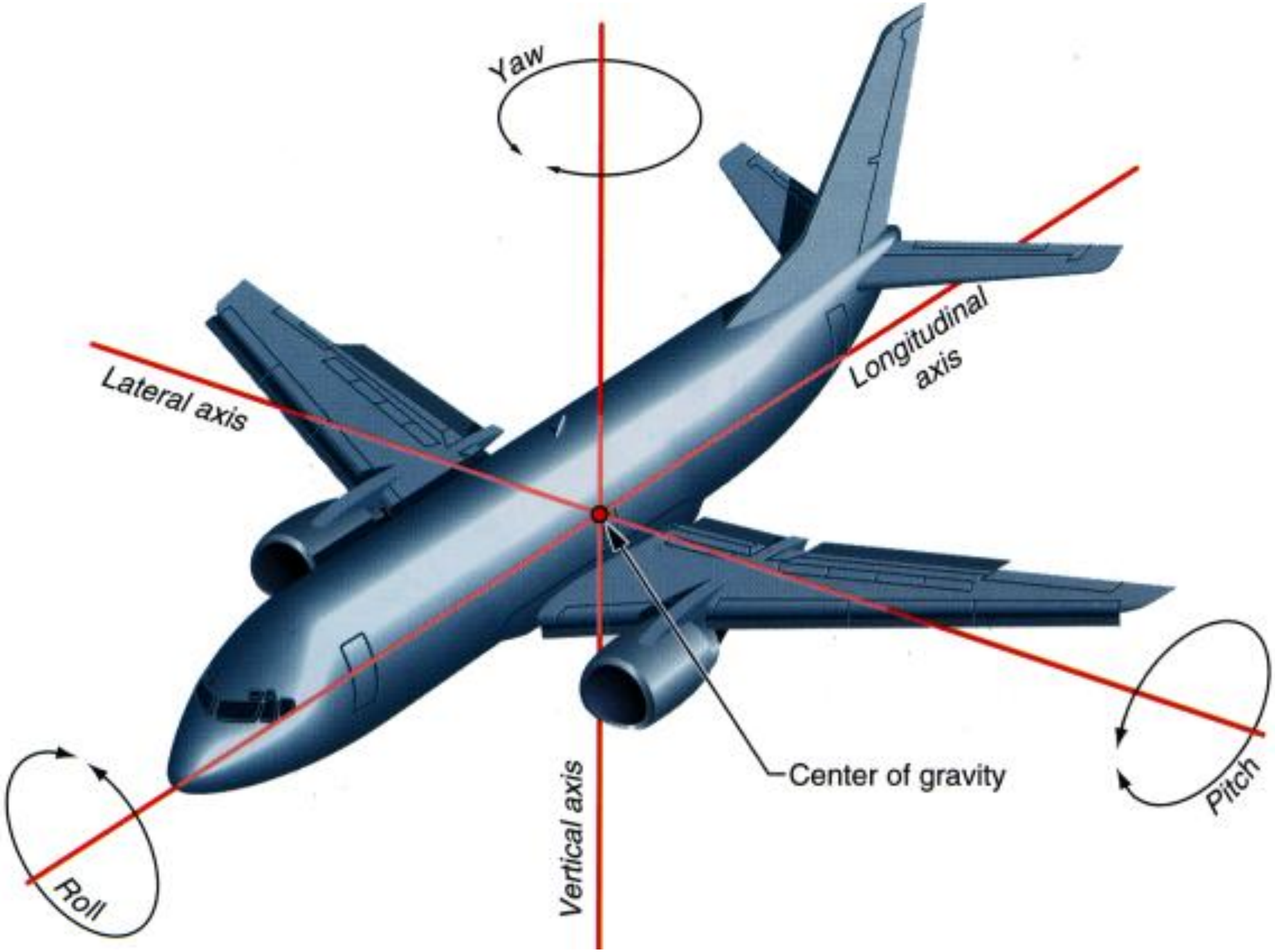


Quelle: Airbus; Boeing

Thrust to Weight Ratio

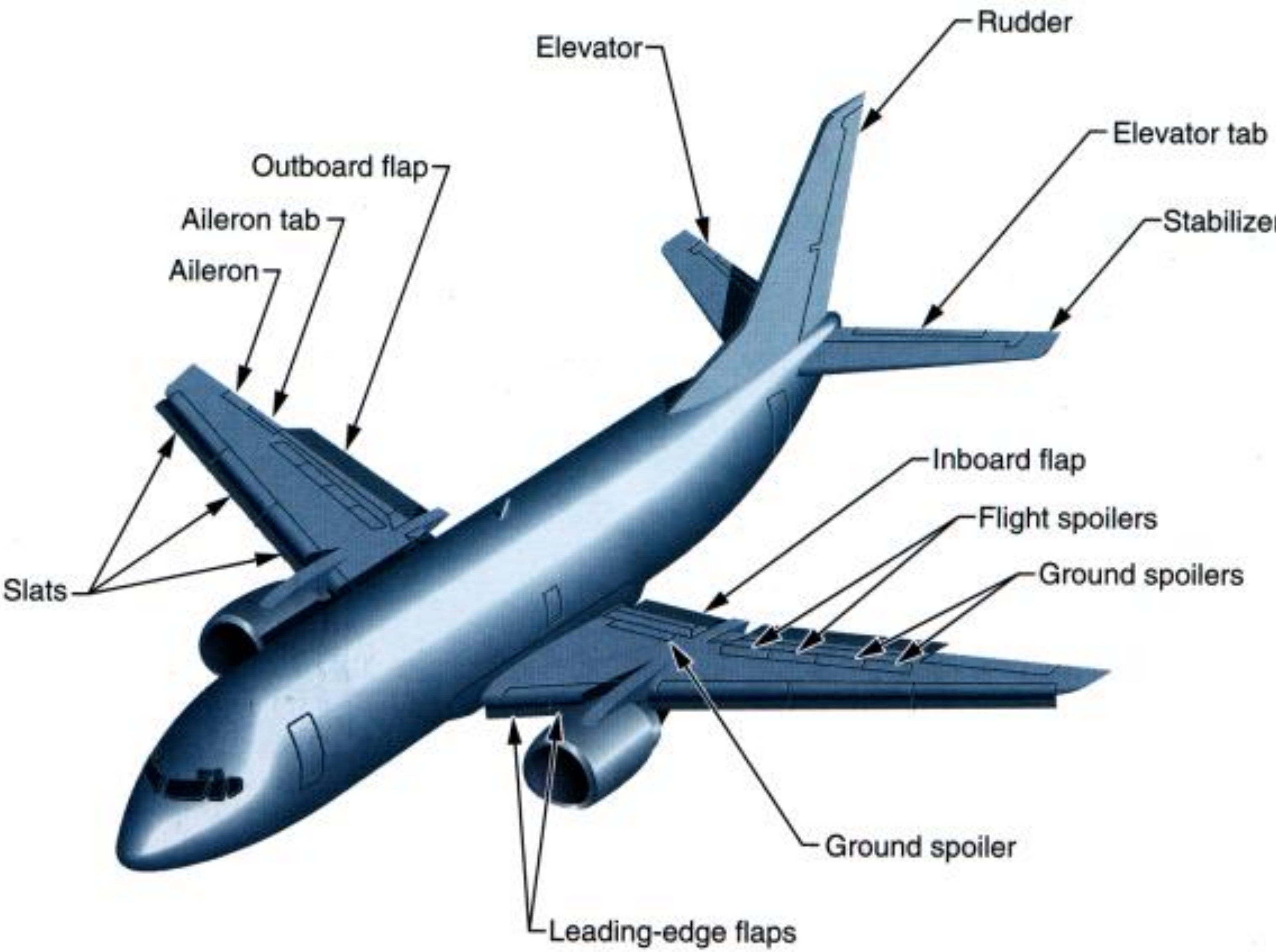


6 Degrees of freedom

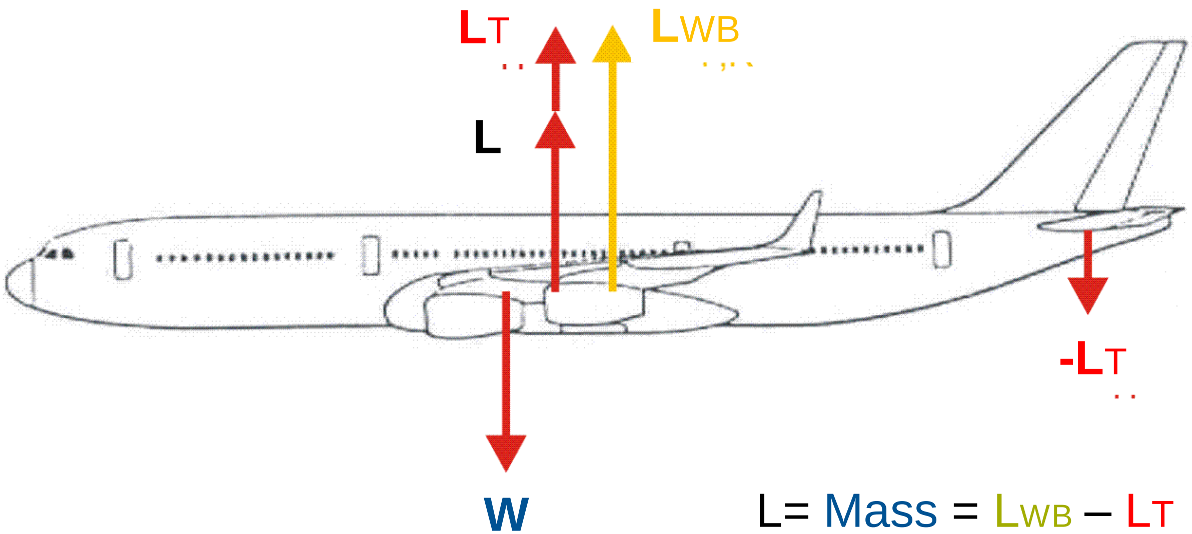


Quelle: Airliner 1995

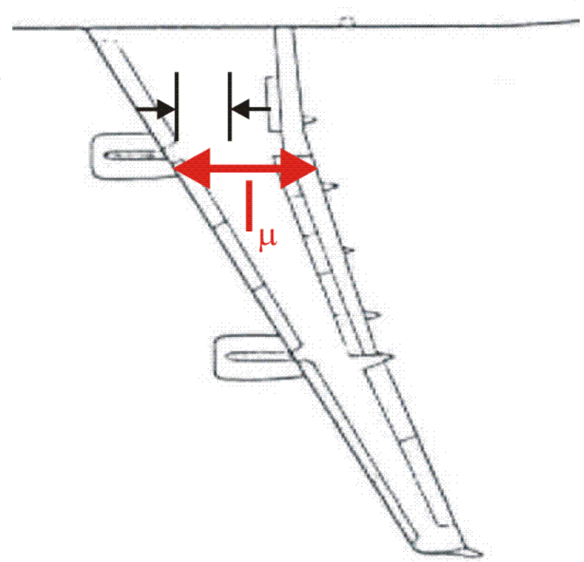
Control surfaces



Quelle: Airliner 1995



L= Mass = LWB – LT



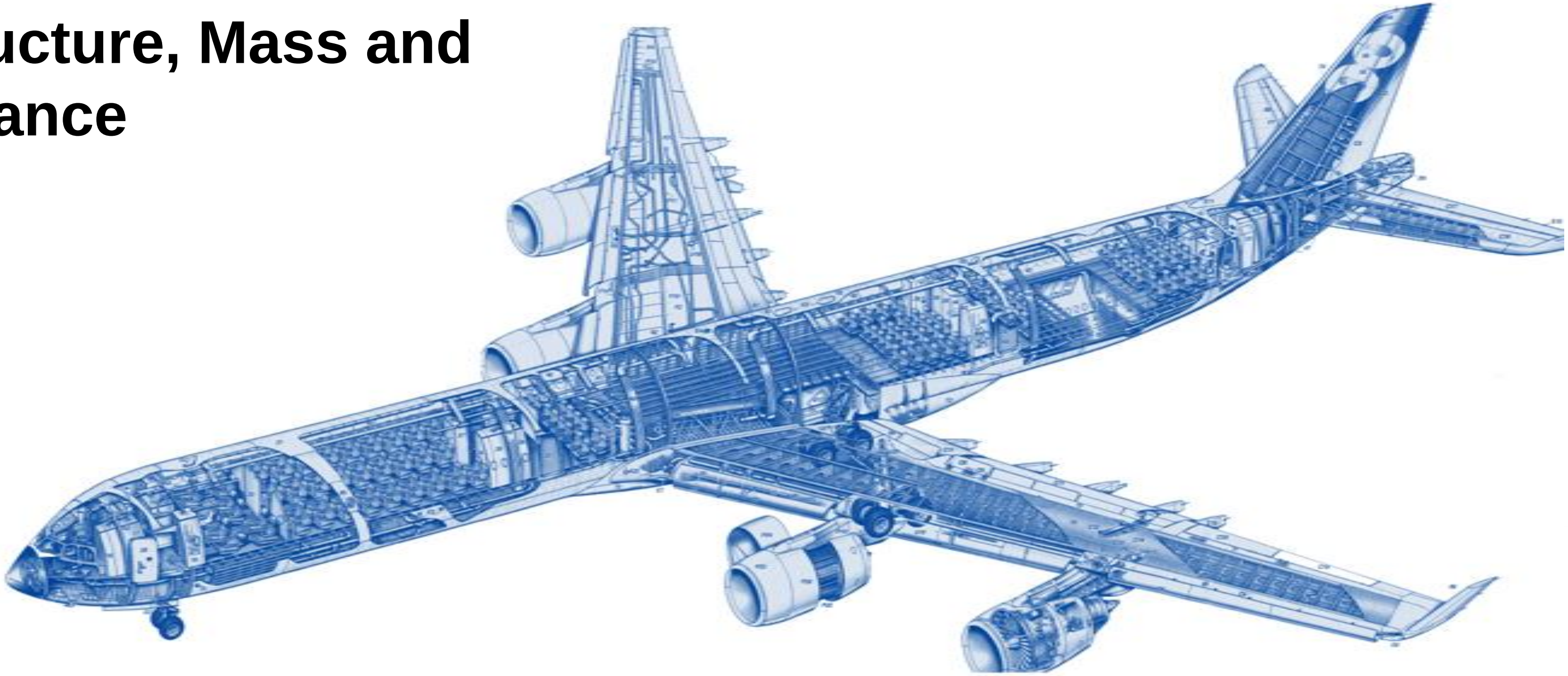
Center of Gravity range

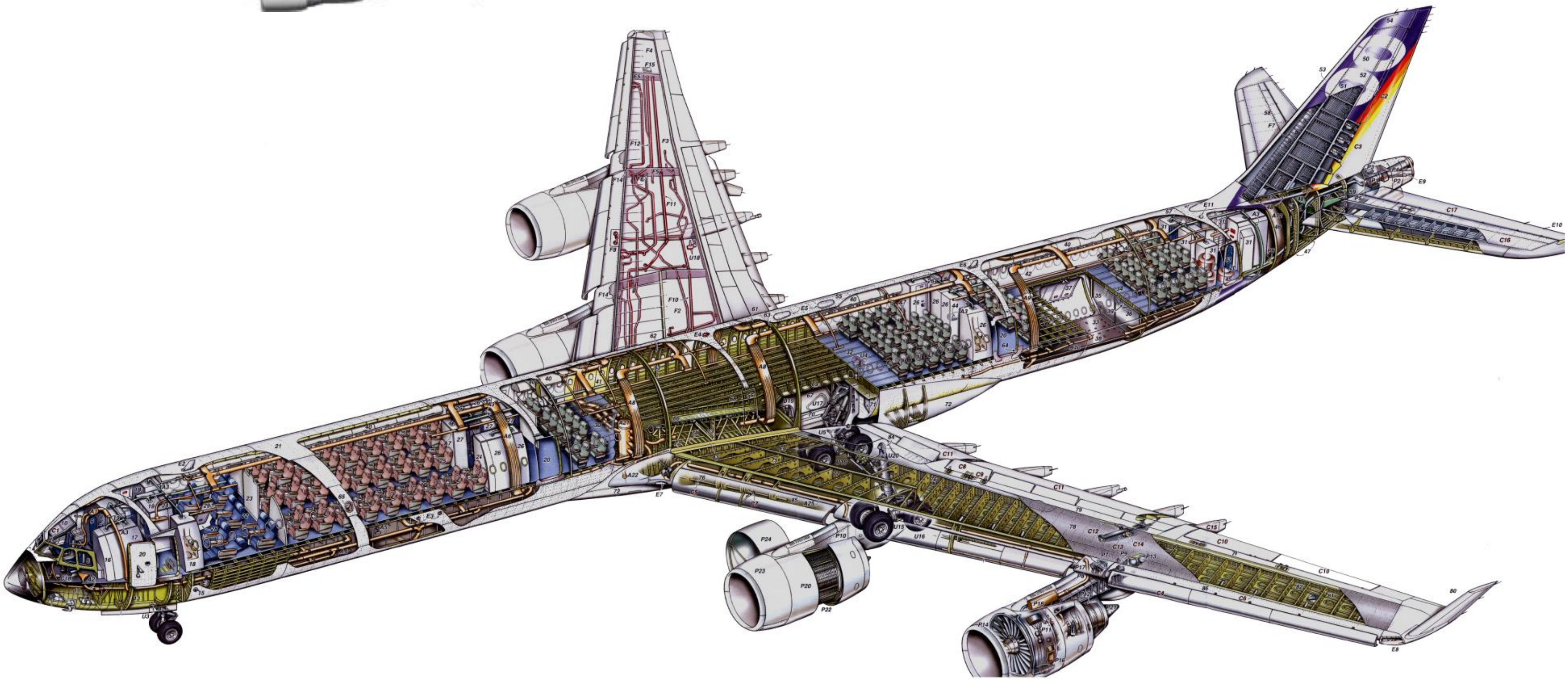
$$0{,}18\ l_{\mu} <= x_{SP} <= 0{,}4\ l_{\mu}$$

L = Total Lift = Mass
L_{WB} = Lift (wing and body)
L_T = Lift (tailplane)

Chapter 5.3

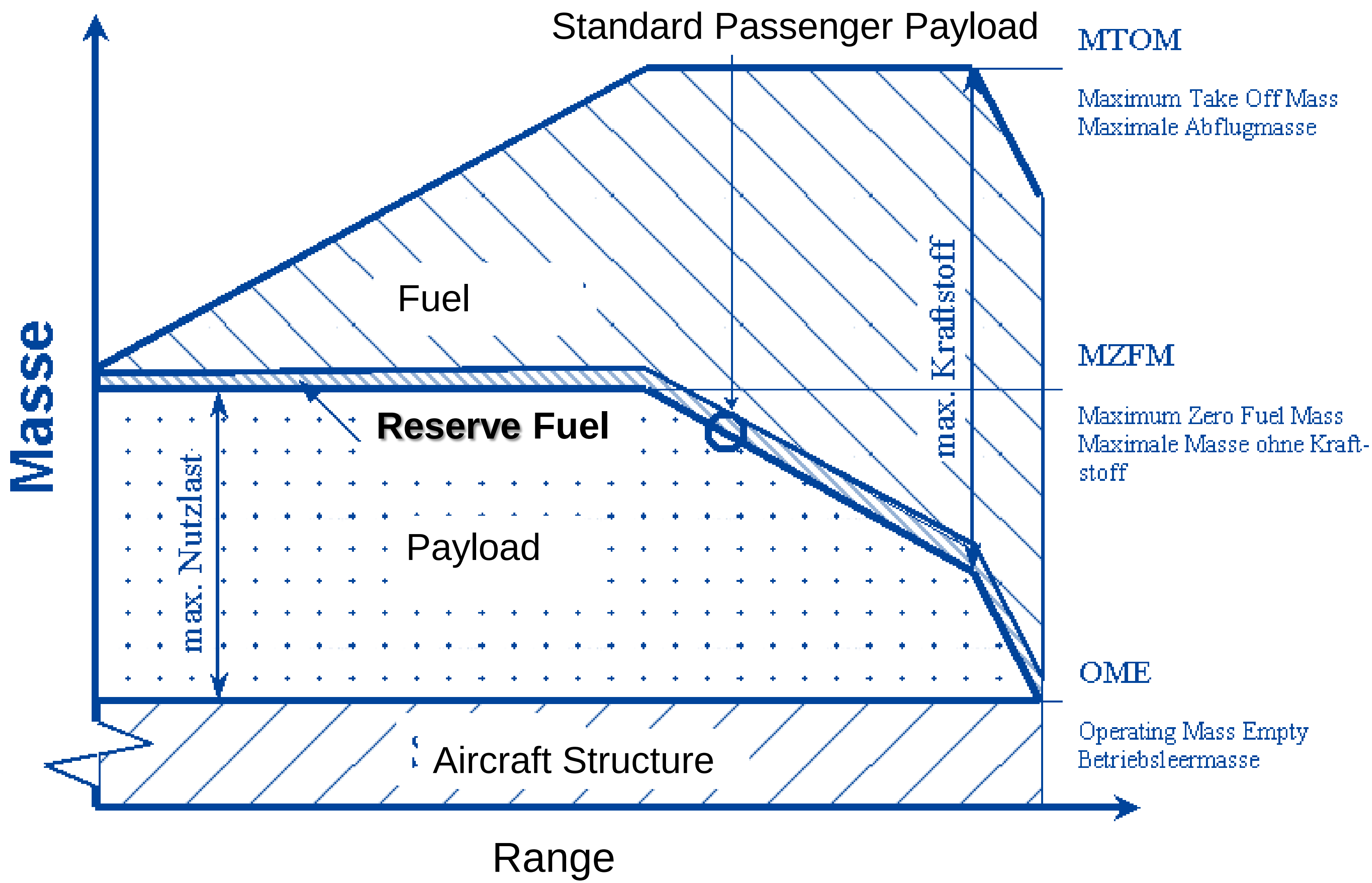
Structure, Mass and Balance



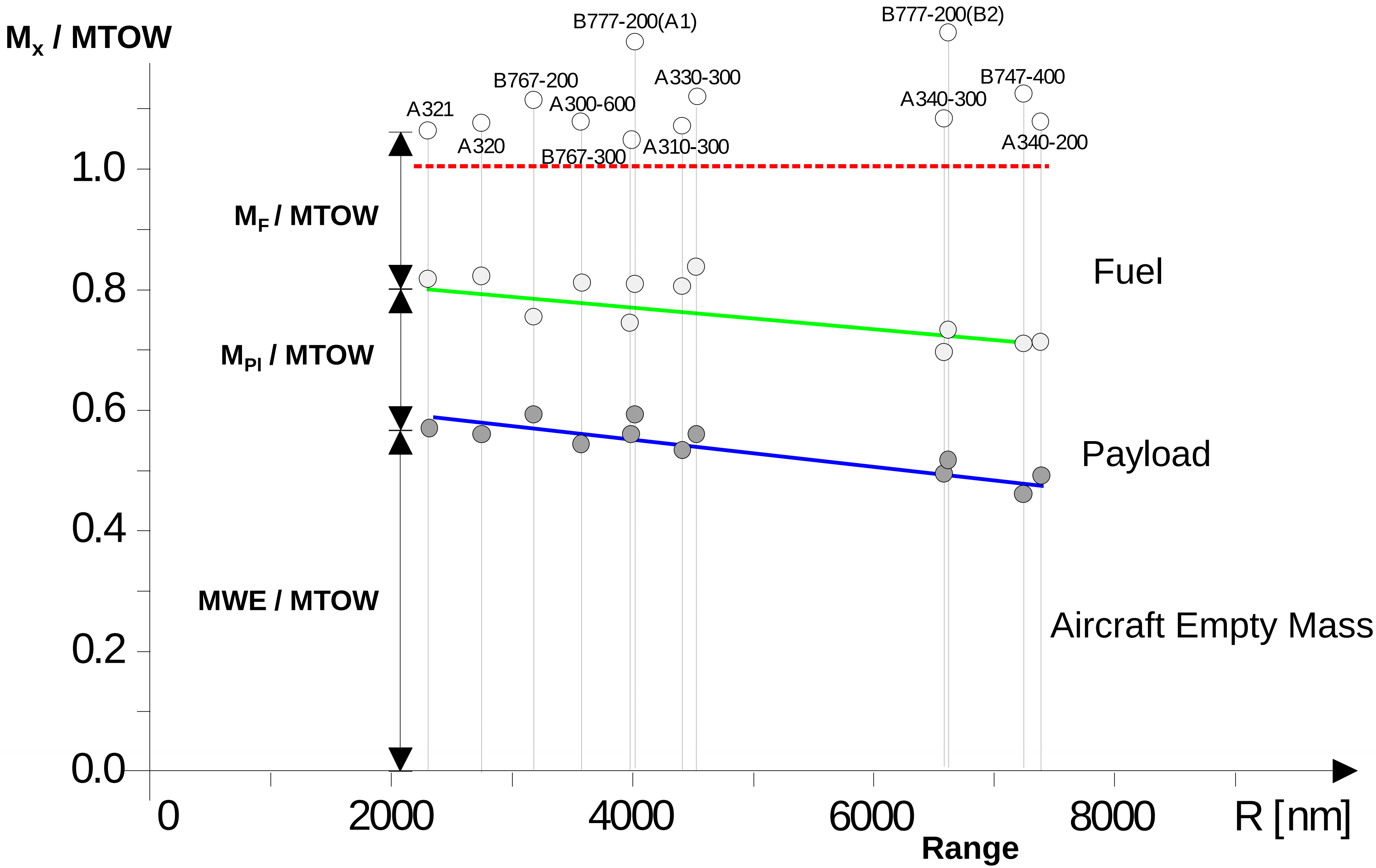


Quelle: Flight International

Payload – Range - Diagram

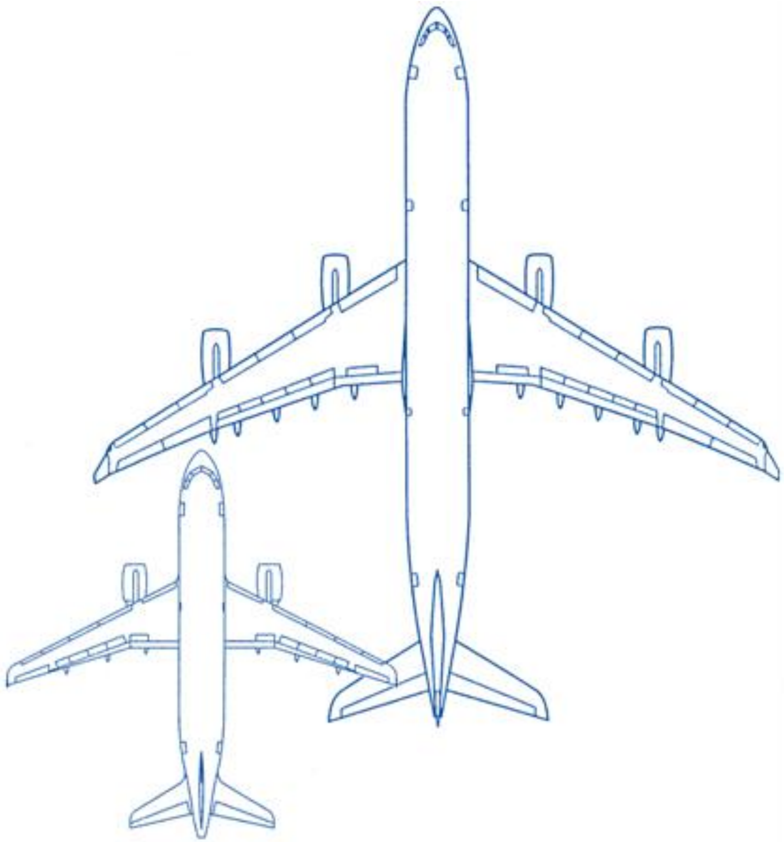


Comparison of mass proportions vs. range



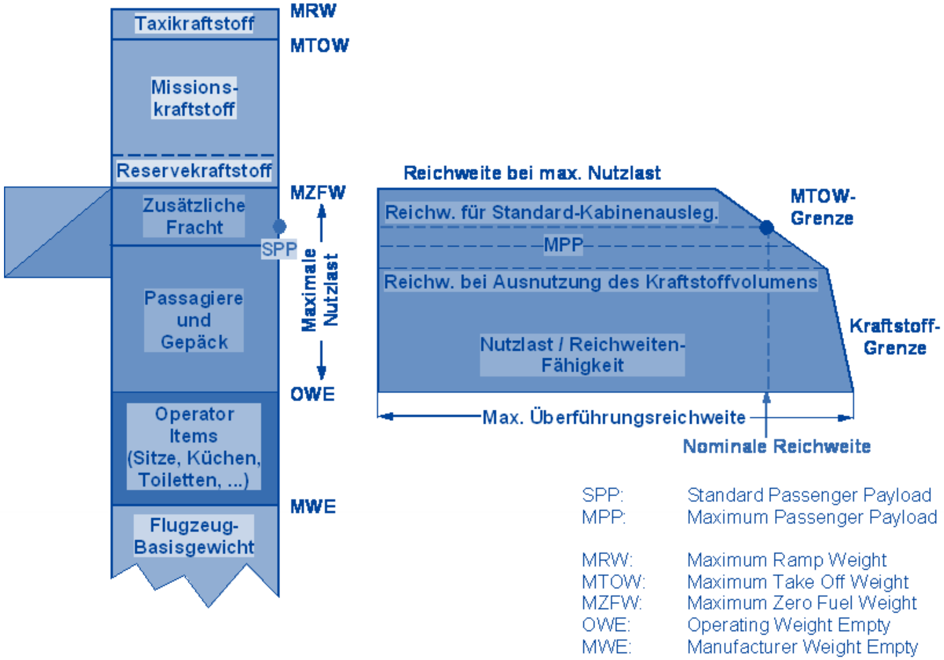
Typical Configurations

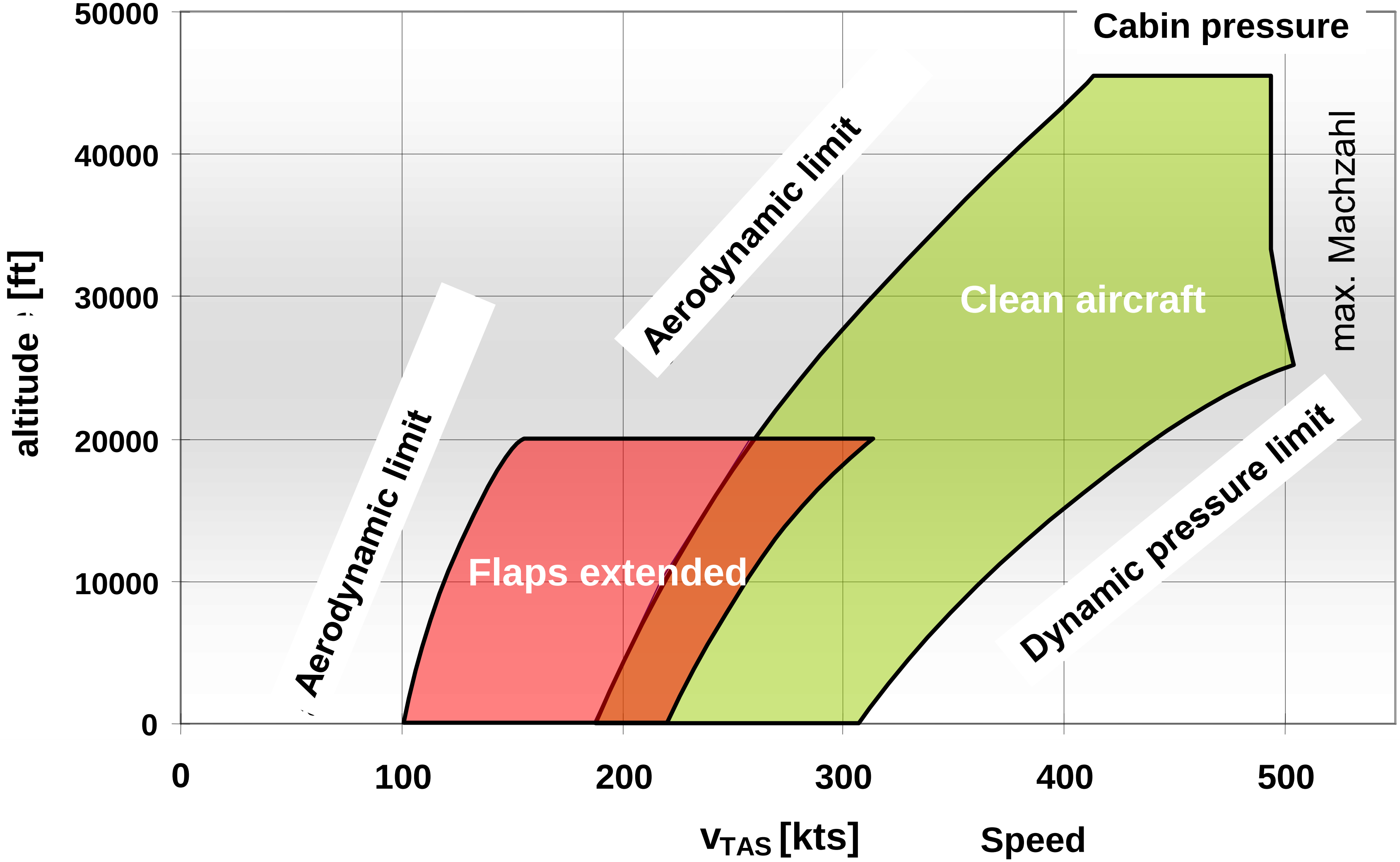
Short- and Medium range		*Long range*
64 000 (141 100) 68 000 (149 900) 70 000 (154 300)	Max. Takeoffmass MTOM kg (lb)	257 000 (566 600)
40 100 (88 500)	Operating mass Empty OME kg (lb)	126 900 (279 700)
23 860 (6 300)	Max. fuel volume l (USg)	140 000 (36 980)
122.40 (1318)	Wingreference area m^2 (ft^2)	363.10 (3909)
9.40	Aspect ratio	9.26
0.25	Taper ratio	0.29
2 × 22 500 2 × 24 000	Thrust (lb)	4 × 31 200 4 × 32 500 4 × 34 000
124 (typ. 2-Class) 145 maxim.	Seats	335 (typ. 2-Class) 295 (typ. 3-Class)
1900 ÷ 2650	Range [nm]	6700 ÷ 7300
Airbus A319		*Airbus A340-300*



Chapter 5.4

Flight - performanc and -mission



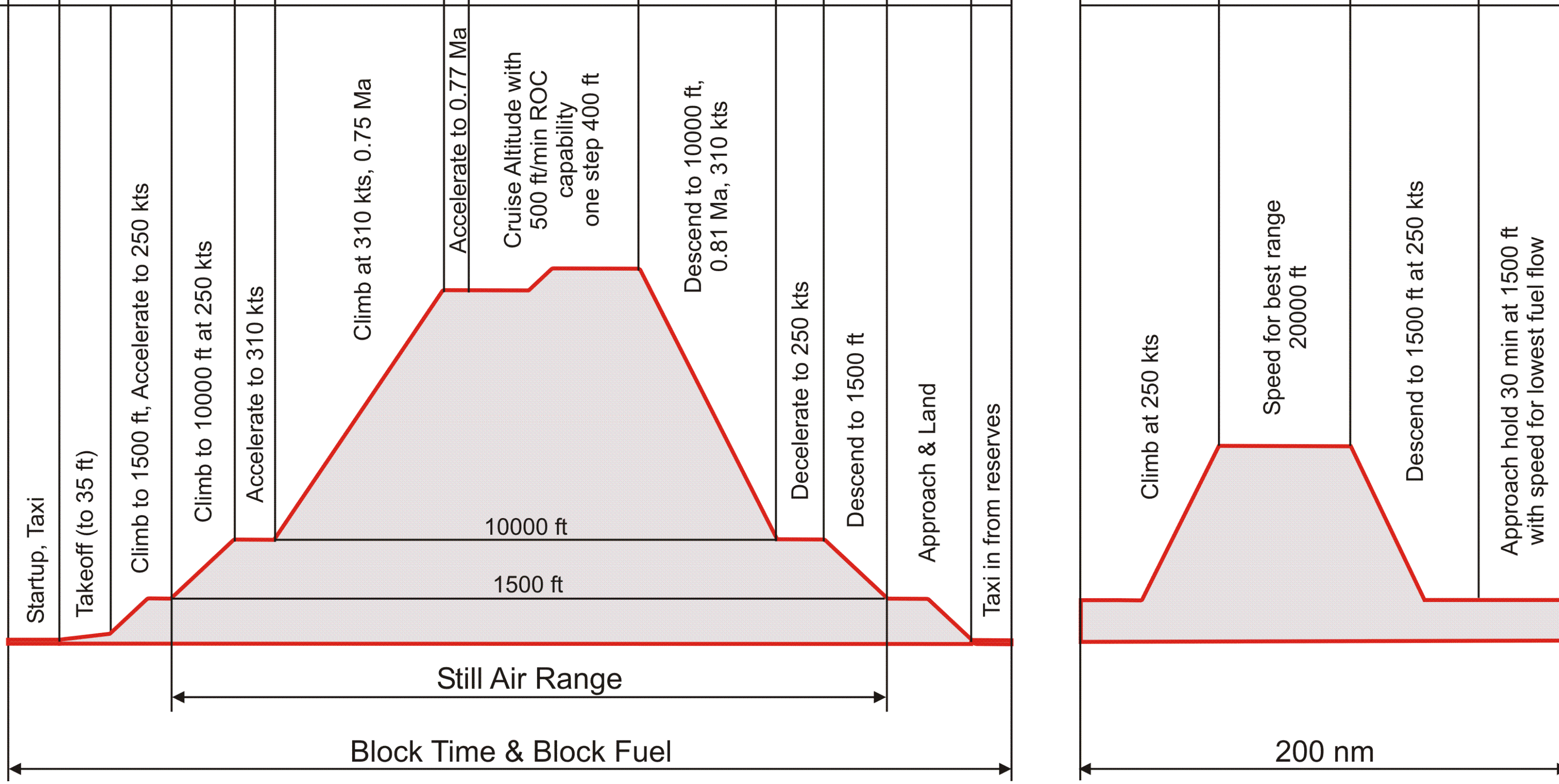


50000
40000
30000
20000
10000
0
altitude [ft]
0
100
200
300
400
500
v_{TAS} [kts]
Speed
Cabin pressure
Aerodynamic limit
Aerodynamic limit
Clean aircraft
Flaps extended
Dynamic pressure limit
max. Machzahl

Missionprofile Transport Aircraft

Distance [km]	--	--	30	8	270	8	2820	130	10	50	10	--
Fuel Cons. [kg]	10	280	220	50	970	20	5280	60	10	50	200	50
Time [min]	10	2	4	1	20	1	208	10	1	5	8	5

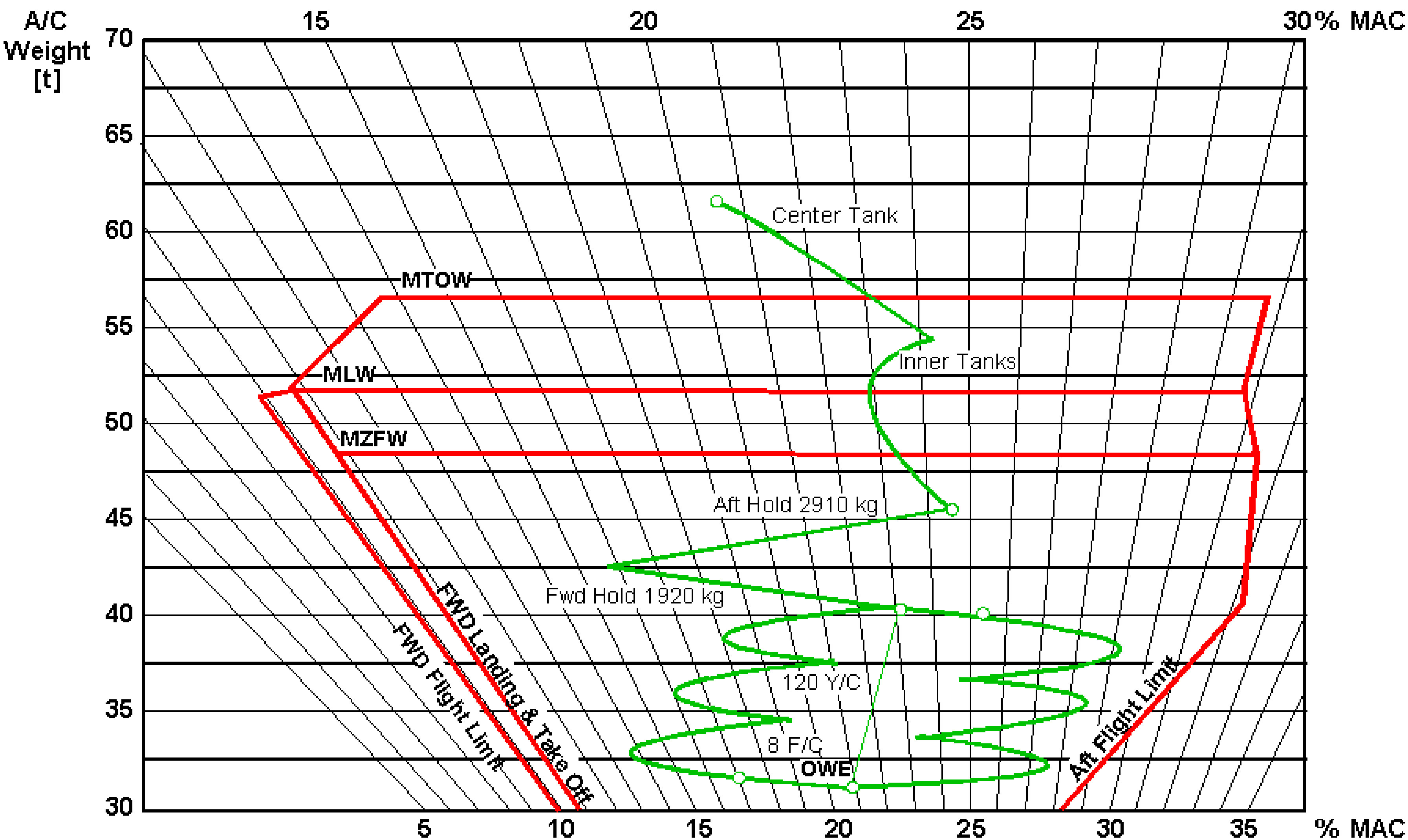
Reserves			
950		700	
10	15	12	30



Aircraft example: 100 Seater with a still air range of ~ 1500 nm

Quelle: Airbus

Weight-and-Balance Sheet



Summary (1)

- The air transport starts officially with the first controlled flight of the Wright Flyer in 1903.
- The military use of these vehicles does not yet play a major role during World War 1, however became decisive during WW 2. The civile air transport starts during the 1930-ties!
- During time the very simple air vehicles became more efficient and more complex. With the further technical development – safety standards, reliability, all weather capability – the acceptance of air travel increased as international transport mean.
- With the introduction of jet-engines, new flight regions (higher altitudes, higher speed) could be realised and the acceptance increased further.
- Air transport started its „Highflyer" – carreer!
- Today a lot of different flight vehicles are in operation, who all have been developed to serve a specific requirement/need. Besides military high performance aircraft, helicopters, specific mission aircraft (agricultural, fire fighting etc.) the major amount of aircraft is dedicated to economic passenger and cargo transport.

Summary (2)

- The inner geometry of the passenger cabin – seats, galleys, toilettes etc. – is configured by the aircraft operator. For comparison reasons for different aircraft types, a very detailled definition of cabin standards is required.
- The atmosphere of the earth is a very complex and timely varying system. The main parameters (temperature, density,..) vary with geographical location, season and meteorological conditions. For technical and operational needs, an „International Standard Atmosphere“ (ISA) has been defined.
- During horizontal and stationary cruise flight the aerodynamic lift has to be equal to the actual mass.
- The aerodynamic lift is mainly generated by the wing of the aircraft. The ratio of aircraft mass and wing surface is named as wing loading – a characteristic parameter for the aircraft.
- The aircraft drag has several characteristic elements (friction and induced). The drag has to be balanced during cruise flight by an equivalent Thrust.
- The ratio of thrust and aircraft mass (T/MTOM) is a characteristic parameter for each aircraft.

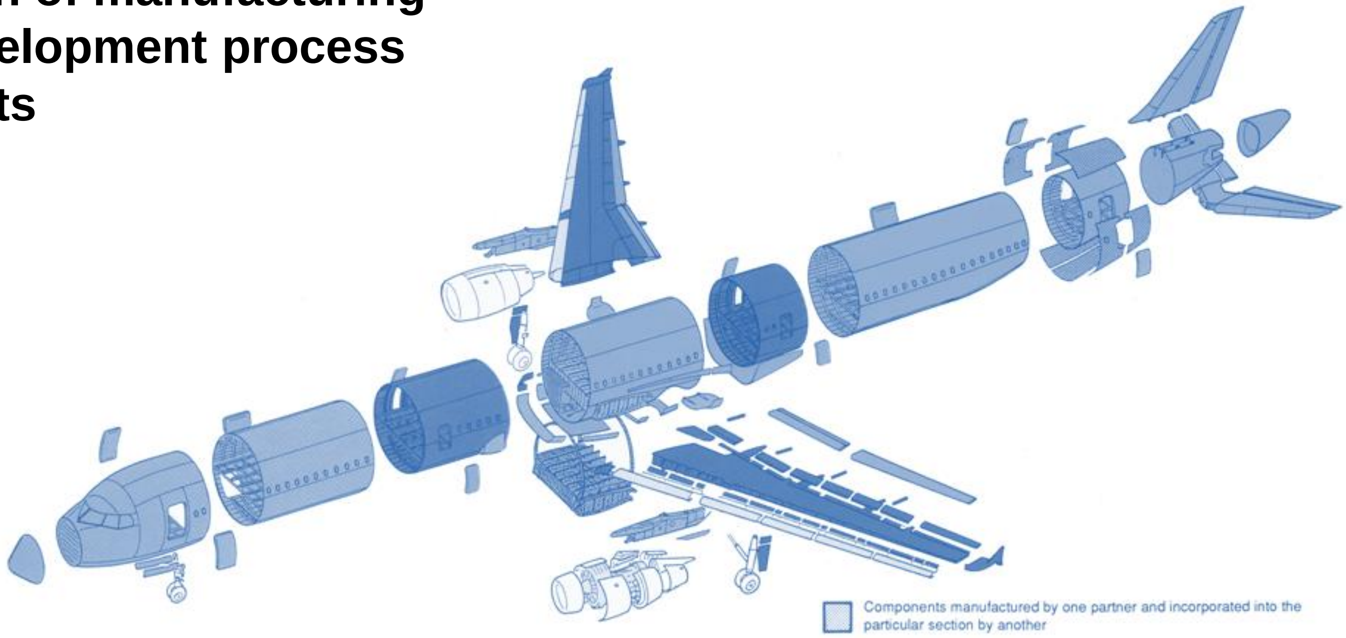
Summary (3)

- The aircraft mass can be divided into 4 parts (MME, OME, MZFM, MTOM)
- The aircraft can takeoff with a variable TOM, depending on payload and range.
- The payload range diagram of an aircraft shows its mission flexibilty and is a major performance characteristic.
- The aircraft can be controlled during all mission phases by a deflection of different control surfaces.
- The aircraft can be trimmed for all stationary flight conditions. The right trim depends on the aircraft payload an ist c.g. position
- For each aircraft the acceptable limits for the operation have to be defined in a so called „flight enveloppe“ – an altitude vs. speed diagram.
- The aircraft mission for a typical flight consists of several phases – takeoff, climb, cruise, descend, approach, landing. The Flight Manual contains fo eahc phase the characteristic time, distance and fuel consumption sfc. The optimum fuel for a defined mission has to be increased by the reserve fuel, the meteorological uncertainties (wind, ice, etc.) and some contingencies.

Chapter 6

The Aircraft Manufacturer

5.1 Organisation of manufacturing
5.2 Aircraft Development process
5.3 Cost aspects



Participants of the Civil Air Transport Systems

National Agency

-FAA -NTSB -Min Transp	EASA

Air Trafic Control

International Agencies

ICAO
IATA
FAA / EASA
IAC

Organisations

- Consumers
- Environm. Ag.
- Tourism Ag.
- Hotels

Aircraft industry

- Manufacturer
- Engine Manuf.
- Suppliers

Aircraft

Airlines

- Line
- Low Cost
- Charter

Agencies

- Travel agents
- Freight forward
- Integrators

Passenger

Freight

Maintenance-centres

Airports

Reservation - Systems (Amadeus .)

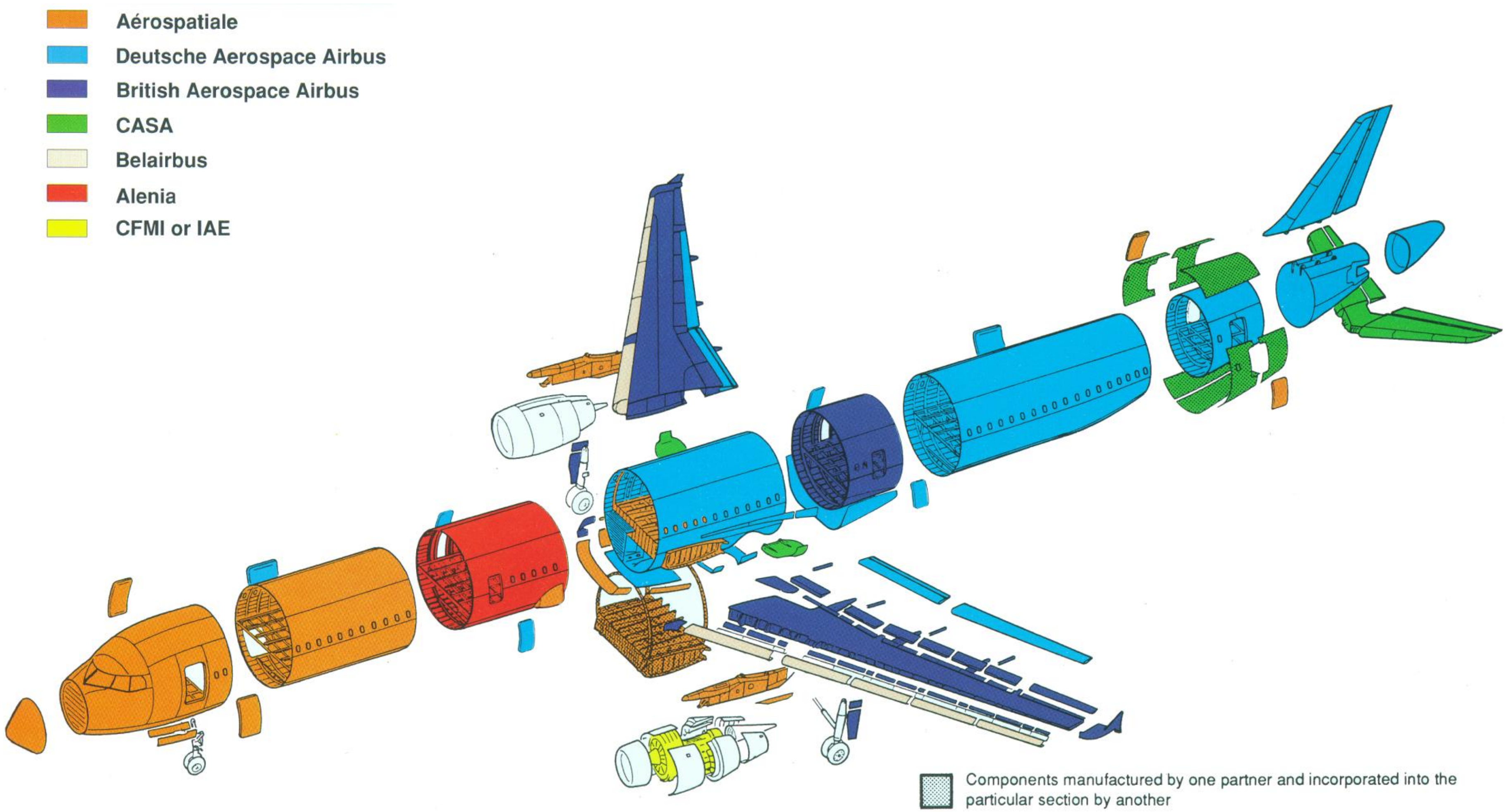
Financing/ Services

-Banks
-Leasing Comp.
-Insurance

Infrastructure

- Meteo services
- Communication

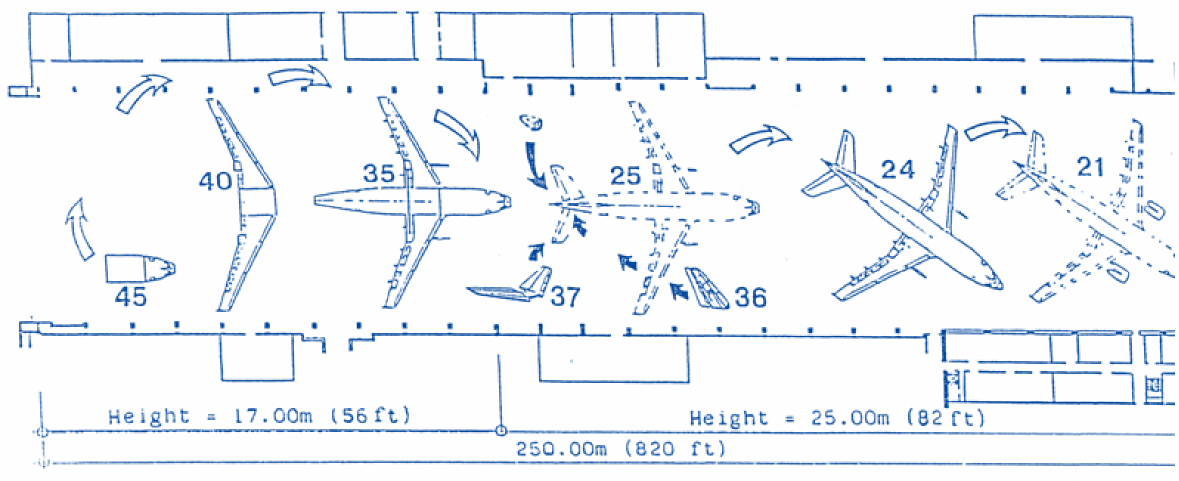
Production Sharing – Airbus A321



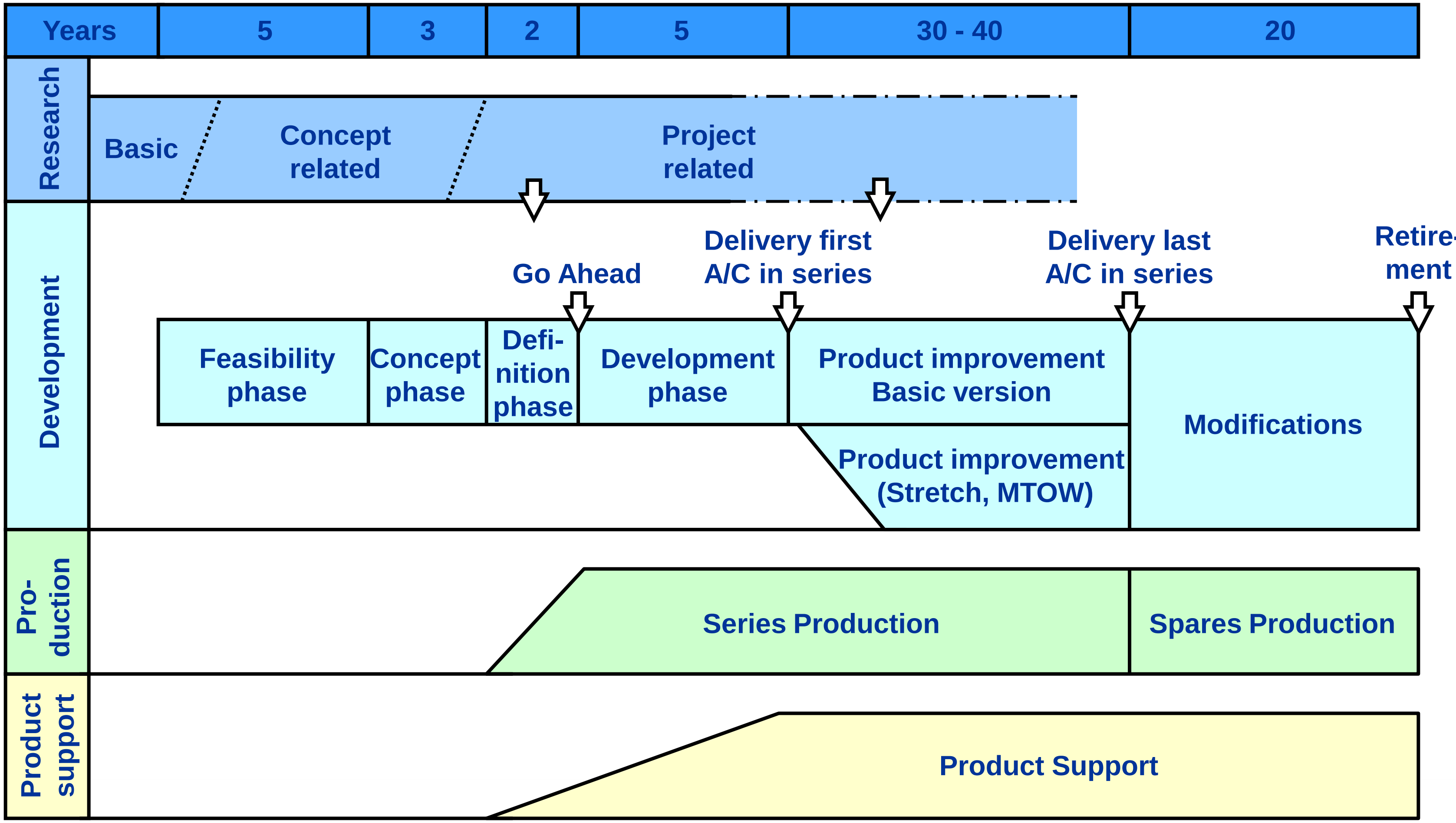
Source: Airbus

Chapter 6.2

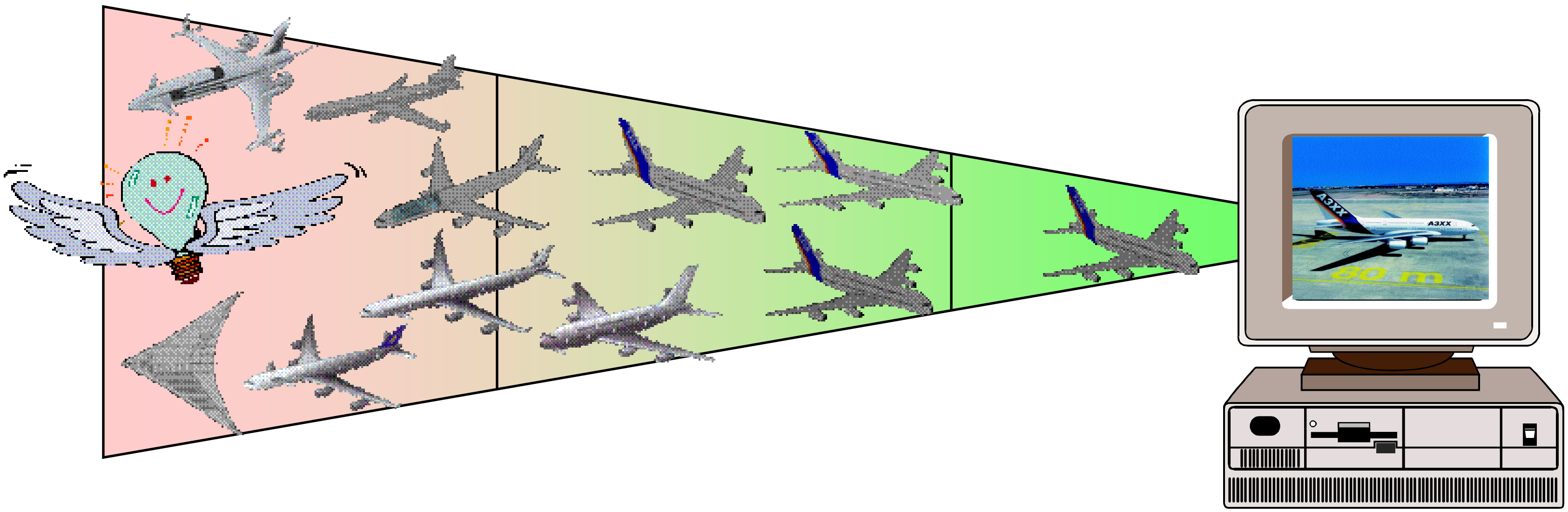
Aircraft Development Process



Typical life cycle of a civil program



From first idea to definition

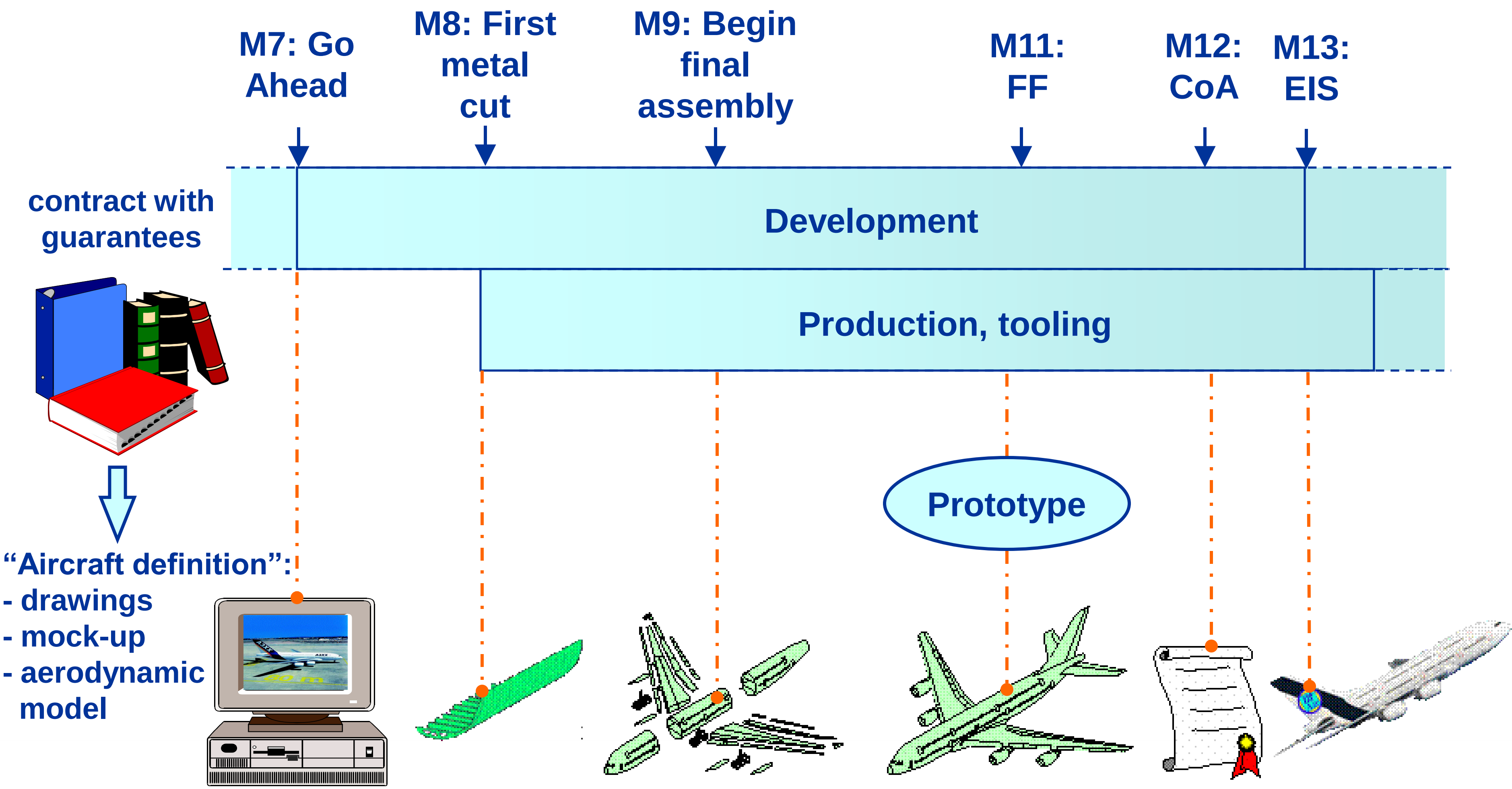


definition of a "marketable" aircraft which is attractive to customer for contract signature
"VR -model"
hardware model

⇒ **need for a strong and competent project manager!**

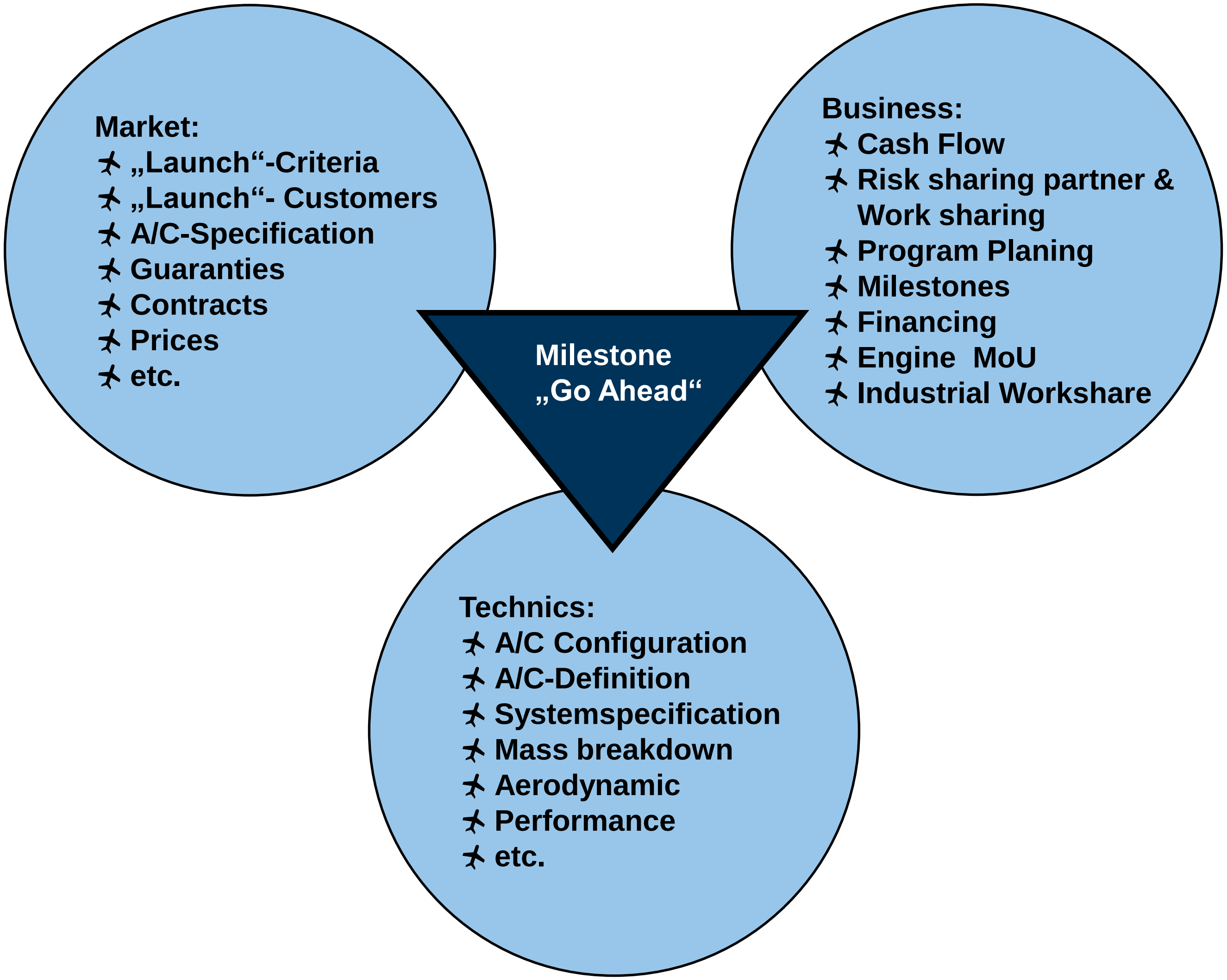
M0	M1	M3	M5	*2 years*	M7
	Feasibility phase	Concept phase	Definition phase		

From Go Ahead to EIS



EIS: Entry into Service

„Magic Triangle before Program Start



Process "*product definition*"

This process is completely different to all other product processes of the aircraft!

Why?

The target is not clearly fixed! – engineering wise

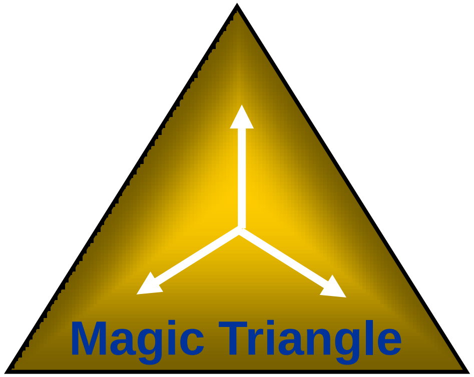
- **define an aircraft configuration which is „marketable"**
- **there is no clear „market specification"**
- **the payload -range capability is about fixed**
- **the technology level should be high but cost efficient for the user**
- **the competition will not wait for your final „product definition"**
- **your „product proposal" has to show a „significant" market benefit relative to existing products**
- **the schedule to achieve „Go Ahead" is defined, but will depend on market situation**
- **the management normally is reluctant to spend the necessary money in advance.**

Time – Cost – Quality

Time to Market

- keep market share
- increase market share
- early breakeven
- confidence of market forecast
- availability of resources

at the right time in the market



Quality to Market

- performance
- reliability
- profitability
- delivery time
- service

meet the customer's requirements

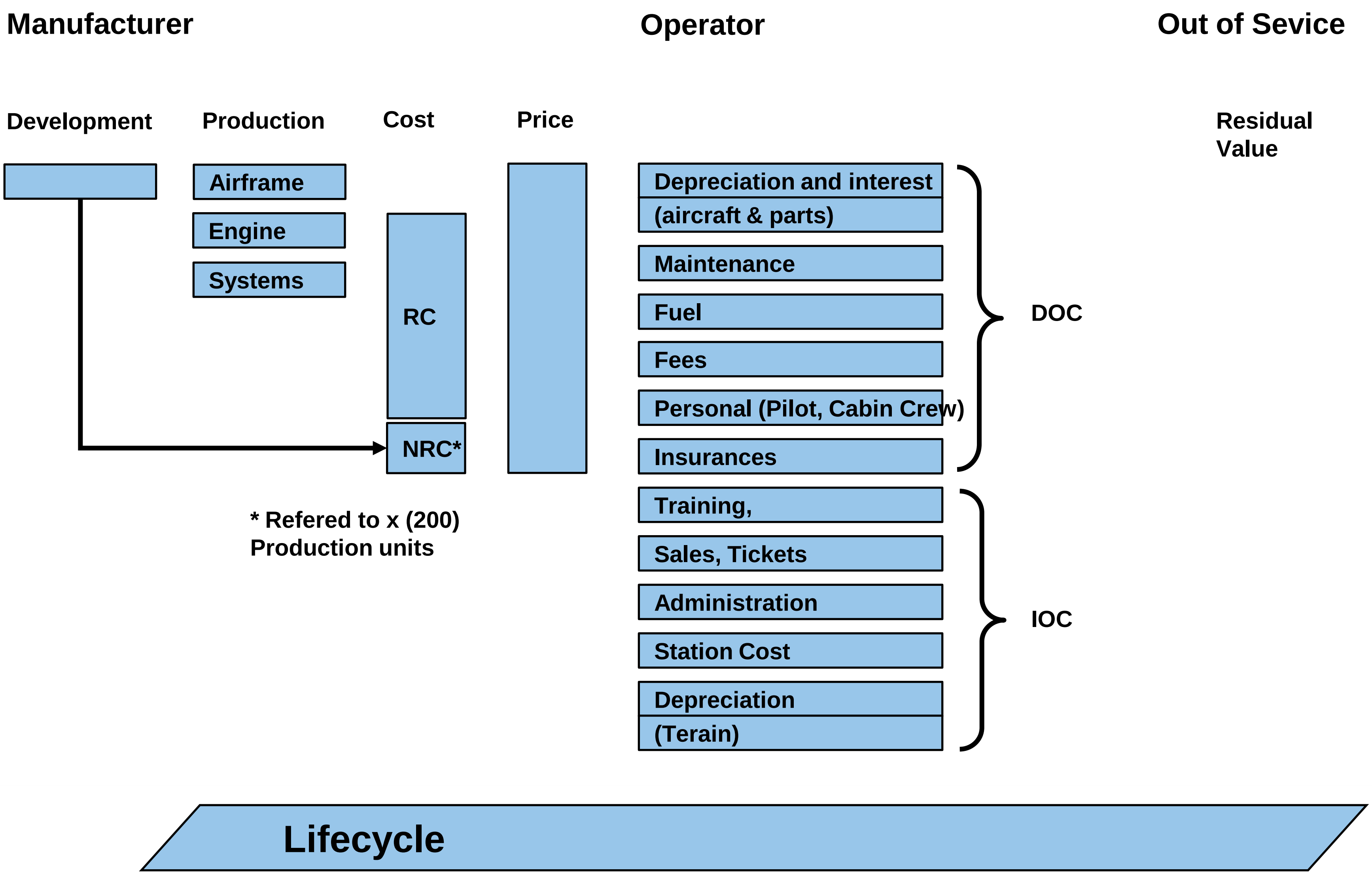
Cost to Market

- market price
- DOC
- value
- competition

build a profitable product

An optimum of all three areas cannot be achieved!

Life Cycle Cost



Summary

- The typical life cycle of a successful transport aircraft program will last today for more than 70 years.
- Each aircraft program starts as a „paper"- or „virtual"- aircraft on the computer in preliminary studies. If these results are convincing, more detailled concept- and definition phase will follow.
- The critical decision point for an aircraft company is the program start called „Go Ahead". This decision will only be taken if sufficient airline orders „launch orders" are signed. The technical aircraft definition has to be very mature in order to give performance guarantees to the launch customers which are in the order of 3%. At this point, the aircraft is only „virtually" defined.
- After the program launch „Go Ahead" the development phase begins with the elements Detail construction, Production, First Flight, Structural and Flight testing up to the Type Certification.

Chapter 7

The Operator / Airlines

7.1 Network and Operation
7.2 Globalization Strategy
7.3 Operating Cost
7.4 ETOPS Operation
7.5 Maintenance Aspects

Participants of the Civil Air Transport Systems

National Agency

-FAA -NTSB -Min Transp	EASA

Air Trafic Control

International Agencies

ICAO
IATA
FAA / EASA
IAC

Organisations

- Consumers
- Environm. Ag.
- Tourism Ag.
- Hotels

Aircraft industry

- Manufacturer
- Engine Manuf.
- Suppliers

Aircraft

Airlines

- Line
- Low Cost
- Charter

Agencies

- Travel agents
- Freight forward
- Integrators

Passenger

Freight

Maintenance-centres

Airports

Reservation - Systems (Amadeus .)

Financing/ Services

-Banks
-Leasing Comp.
-Insurance

Infrastructure

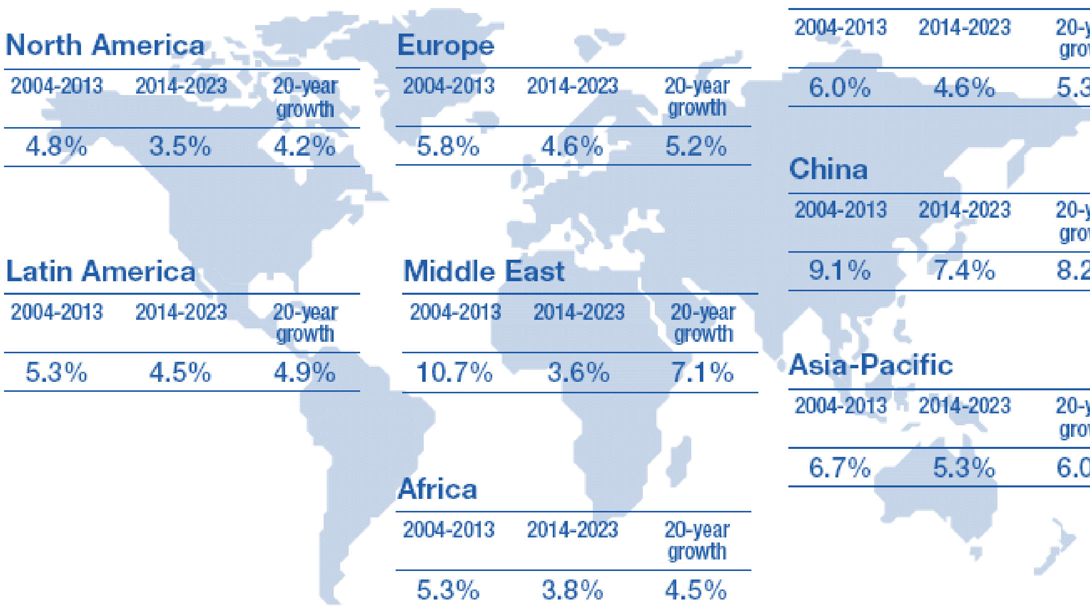
- Meteo services
- Communication

Besides the transport of persons between two airports/cities, the product „air travel“ consists of some additional elements like:

- **Safety**
- **Flight plan**: airline network, route structure, route frequencies (per day or week), departure- /arrival-time, flight time
- **Flexibility**: Reservation, Seat availability, flight change without cost
- **Regularity:** even in critical weather conditions (aircraft with good all weather equipment)
- **Punctuality**: less than 15 minutes delay at departure
- **Services**:
  - Before flight: Shuttle service to airport, Pickup from hotel, Lounges at airport, Check-In the evening before, special Check-in counters, etc.
  - During flight: Seat comfort, On-Board service (from lunchbox up to 5-course-menue), Drinks, entertainment (audio, video, internet,), Flight crew (multilingual, friendly, chic, etc.), „Give-Aways“
  - After flight: Transfer to City Center (Paris, New York, etc.), Lounges,

Chapter 7.1

Network and Operation



World

2004-2013	2014-2023	20-year growth
6.0%	4.6%	5.3%

North America

2004-2013	2014-2023	20-year growth
4.8%	3.5%	4.2%

Europe

2004-2013	2014-2023	20-year growth
5.8%	4.6%	5.2%

China

2004-2013	2014-2023	20-year growth
9.1%	7.4%	8.2%

Latin America

2004-2013	2014-2023	20-year growth
5.3%	4.5%	4.9%

Middle East

2004-2013	2014-2023	20-year growth
10.7%	3.6%	7.1%

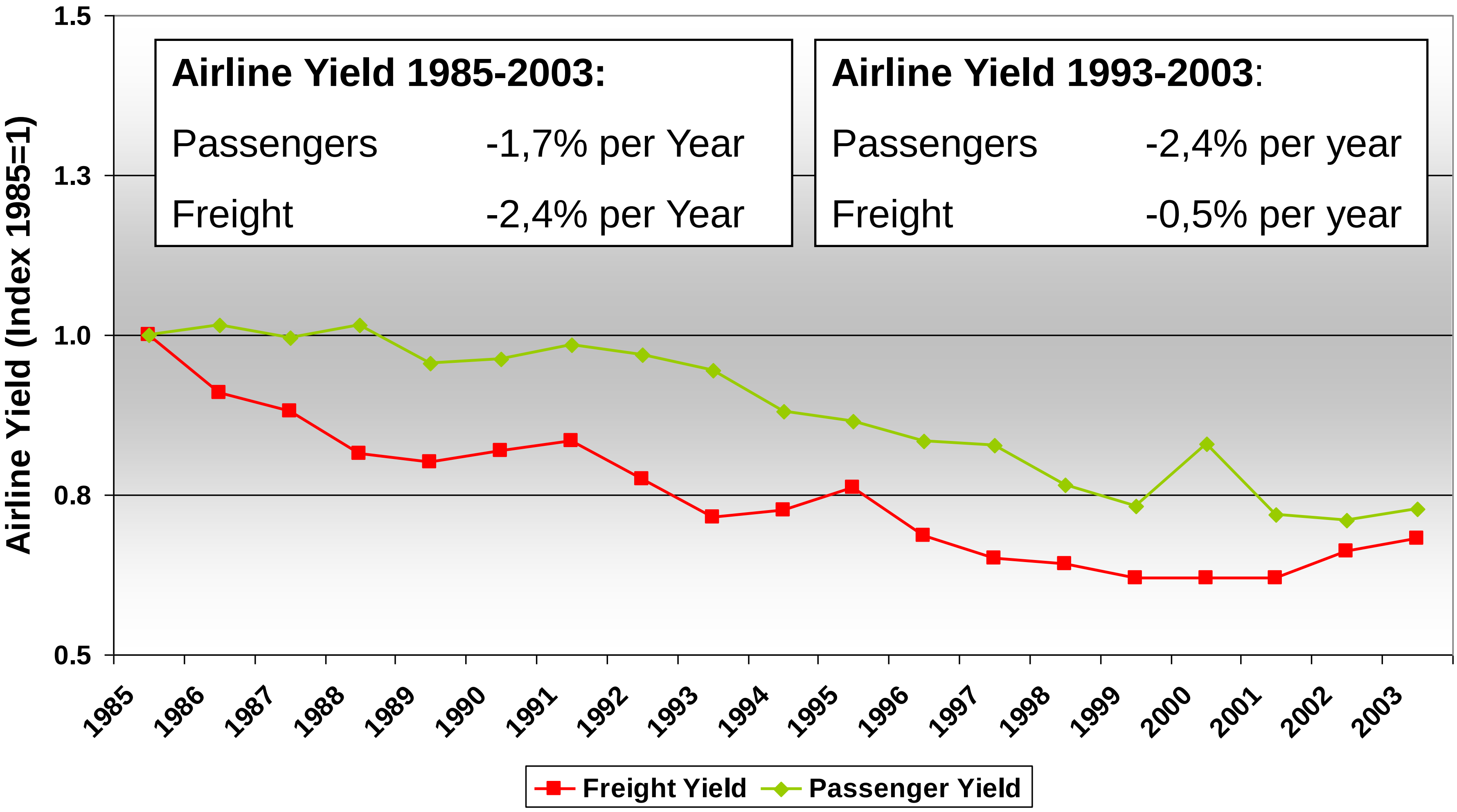
Asia-Pacific

2004-2013	2014-2023	20-year growth
6.7%	5.3%	6.0%

Africa

2004-2013	2014-2023	20-year growth
5.3%	3.8%	4.5%

Airline Yield Development



Source: Boeing

Hub & Spoke versus Point to Point

Source: Beder

Main Hubs in the World and in Europe (2005)

World
Passengers (2005)

Rank	Airport Name	Number of Passengers per year
1.	Atlanta/Hartsfield	85,9
2.	Chicago/O'Hare	76,8
3.	London-Heathrow	67,9
4.	Tokio/Haneda	63,3
5.	Los Angeles	61,5
6.	Dallas/Fort Worth	59,1
7.	Paris Charles De Gaulle	53,8
8.	Frankfurt Rhein-Main-Flughafen	52,2
9.	Las Vegas/Mc Carran	44,3
10.	Amsterdam-Schiphol	44,2

Europe
Passengers (2005)

Rank	Airport Name	Number of Passengers per year
1.	London-Heathrow	67,9
2.	Paris Roissy-Charles De Gaulle	53,8
3.	Frankfurt Rhein-Main-Flughafen	52,2
4.	Amsterdam-Schiphol	44,2
5.	Madrid-Barajas	41,9
6.	London-Gatwick	32,8
7.	Rom-Fiumicino	28,6
8.	München	28,6
9.	Barcelona	27,1
10.	Paris-Orly	24,9

Quelle: ACI (Stand: 2005)

Chapter 7.2

Globalization Strategy

Advantages of a Global Strategy

- Global network with multi-national Hubs (market presence)
- Global marketing system and market access (marketing presence)
- Network synergies and cost reduction due to size
- Global Airline politics (worldwide brand image)
- Global customer services (generating new market potential)
- Usage of geographical personal cost benefits
- Risk reduction by multi national business agreements (limitation to market segments, regional currency relations, regional business opportunities, ..)

Source: Beder

- In Global Cooperations like STAR ALLIANCE the airline members agree to accept the tickets of their partners, the so called „Code-Sharing“. This helps the passenger when booking a flight to have access to the whole alliance network of all partner airlines (2010: about 1160 destinations in 181 countries).
- The partners agree to provide a common standard fpor passengers and harmonize flight plans.
- Frequent Flyers and business travellers can get additional mileage bonus from all partner airlines and have access to common business lounges at nearly all airports..
- Besides the attractivity for the customer the airlines can better manage their capacity by common and flexible use of aircrafts and also adjustment of slot availability at the airports.

STAR ALLIANCE

AIR CANADA
AIR NEW ZEALAND
ANA
Asiana Airlines
Austrian
bmi
LOT POLISH AIRLINES
Lufthansa
Scandinavian Airlines
SINGAPORE AIRLINES
Spanair
Thai
UNITED
US AIRWAYS
VARIG

Quelle: Star Alliance

Airline-Partners of Lufthansa outside of Star Alliance

Cooperation partner in Europe:
- Adria Airways
- Air Dolomiti
- Air Baltic
- Air One
- Croatia Airlines
- CSA Czech Airlines
- LOT Polish Airlines
- Luxair
- Maersk Air
- Spanair

Cooperation partner outside Europe:
- South African Airways
- Air China

Team Lufthansa:
- Augsburg Airways
- Cimber Air
- Cirrus Airlines
- Contact Air

Cooperation partner of Lufthansa Cargo:
- DHL International
- Japan Airlines Cargo
- Cathay Pacific
- South African Cargo
- Singapore Airlines Cargo
- SAS Cargo
- Air China

Cooperation partner for Technics:
- Shannon Aerospace Ltd.
- Ameco Beijing
- Lufthansa Technik Budapest

Cooperation partner of „sister“ Condor:
- Eurowings
- America West Airlines
- Sun Express
- American Eagle
- Deutsche BA (Strecke: München-Korfu)

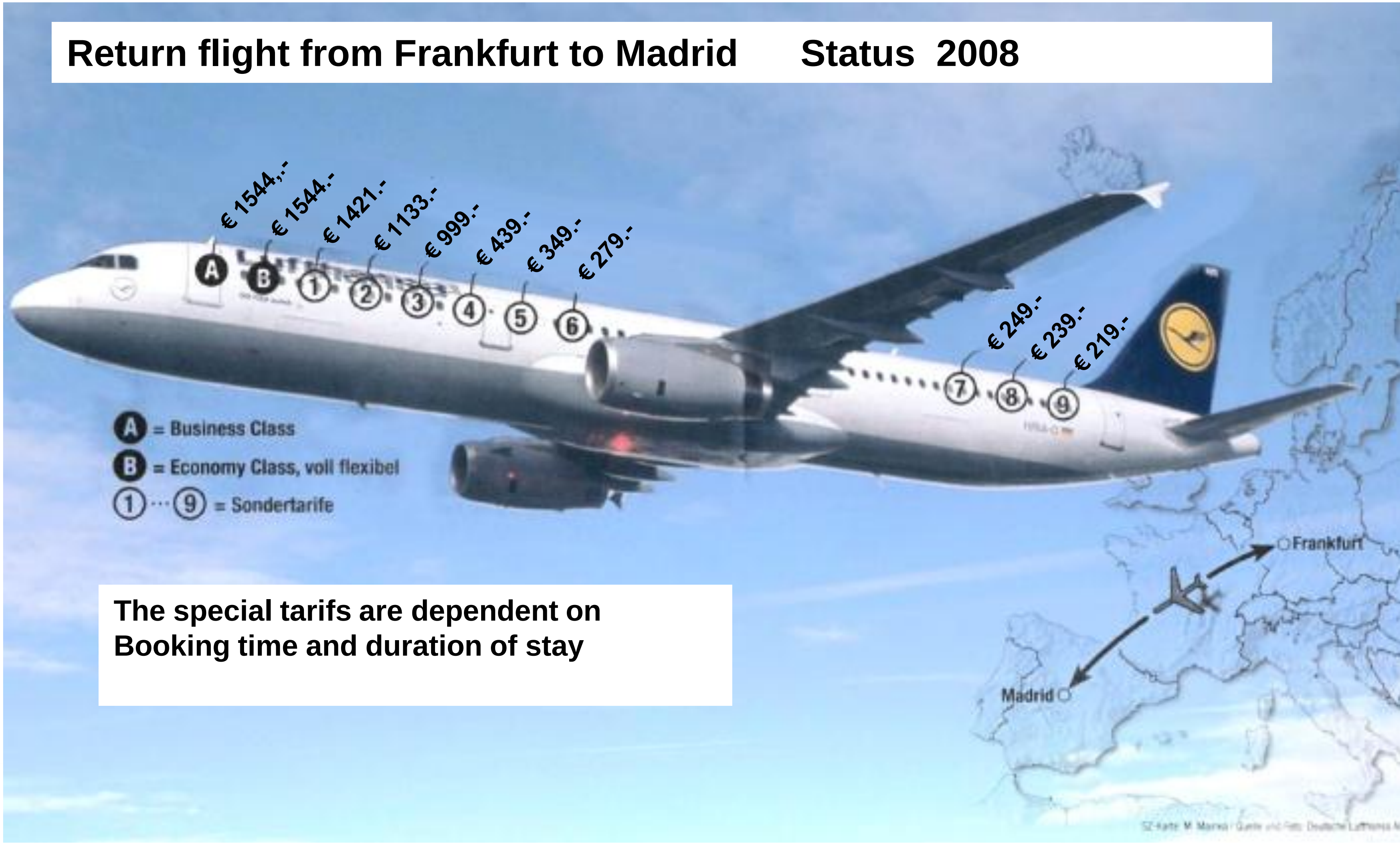
Quelle: Lufthansa

Global Airline-Alliances

	SKYTEAM	STAR ALLIANCE	oneworld
Partners	27 (2010)	27 (2010)	12
Connected Countries:	169 (2010)	181	136
Connected Airports :	1160 (2010)	1160	573
Dayly destinations (flights):	13.000 (2010)	21,000	
Revenue - Passenger - Kilometers RPK:	1.175,5 (bn RPK, 2010)	1.175,5 (bn RPK,)	485,7 (bn RPK, 2002)
IATA-Market share:	~15 %	~30 % (2004)	18 % (2002)
transported Passengers:	384 Mio. (2010)	603,8 Mio. (2010)	86,4 (Mio., only int. trafic, 2002)
Tonne-kilometer:	32,3 (Mio., nur int. Verkehr, 2002)	89 (Mio., nur int. Verkehr, 2005)	43,7 (Mio., only int. traffic, 2002)
Employees in 1.000:	316.445 (2010)	402.208 (2010)	243,8 (2002)

Source: OneWorld, Skyteam, Star Alliance

Return flight from Frankfurt to Madrid   Status 2008

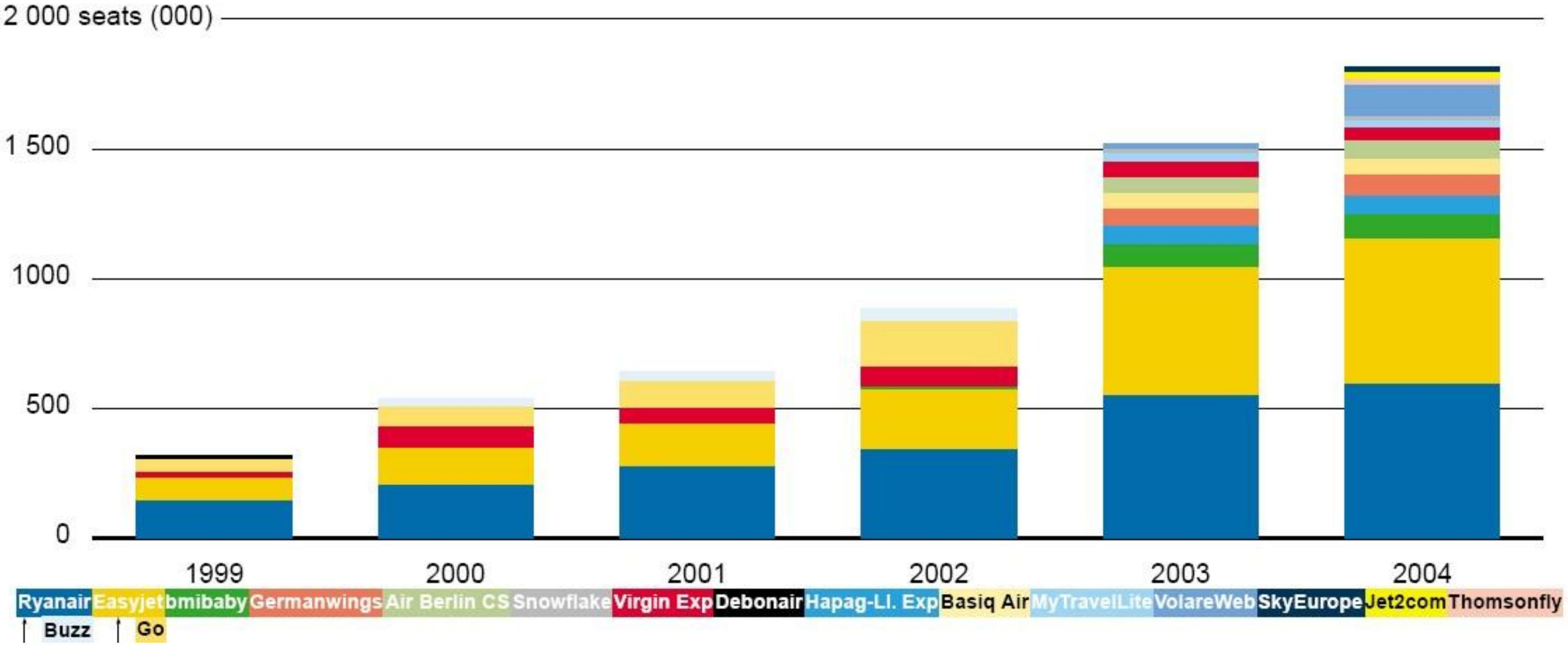


The special tarifs are dependent on Booking time and duration of stay

Source: Lufthansa, Traveloverland

Since more than 10 years so called „No-Frills Airlines“ (Low Cost Airlines) have been created, which offer ticket prices from 5 € onwards (exclusive tax and fees) for a simple one-way route. Despite some crisis and a difficult competition situation (too many airlines on the market!) the Low Cost Carriers have increased their market share dramatically..

Number of Seats per Week



Source: AEA Yearbook 2004

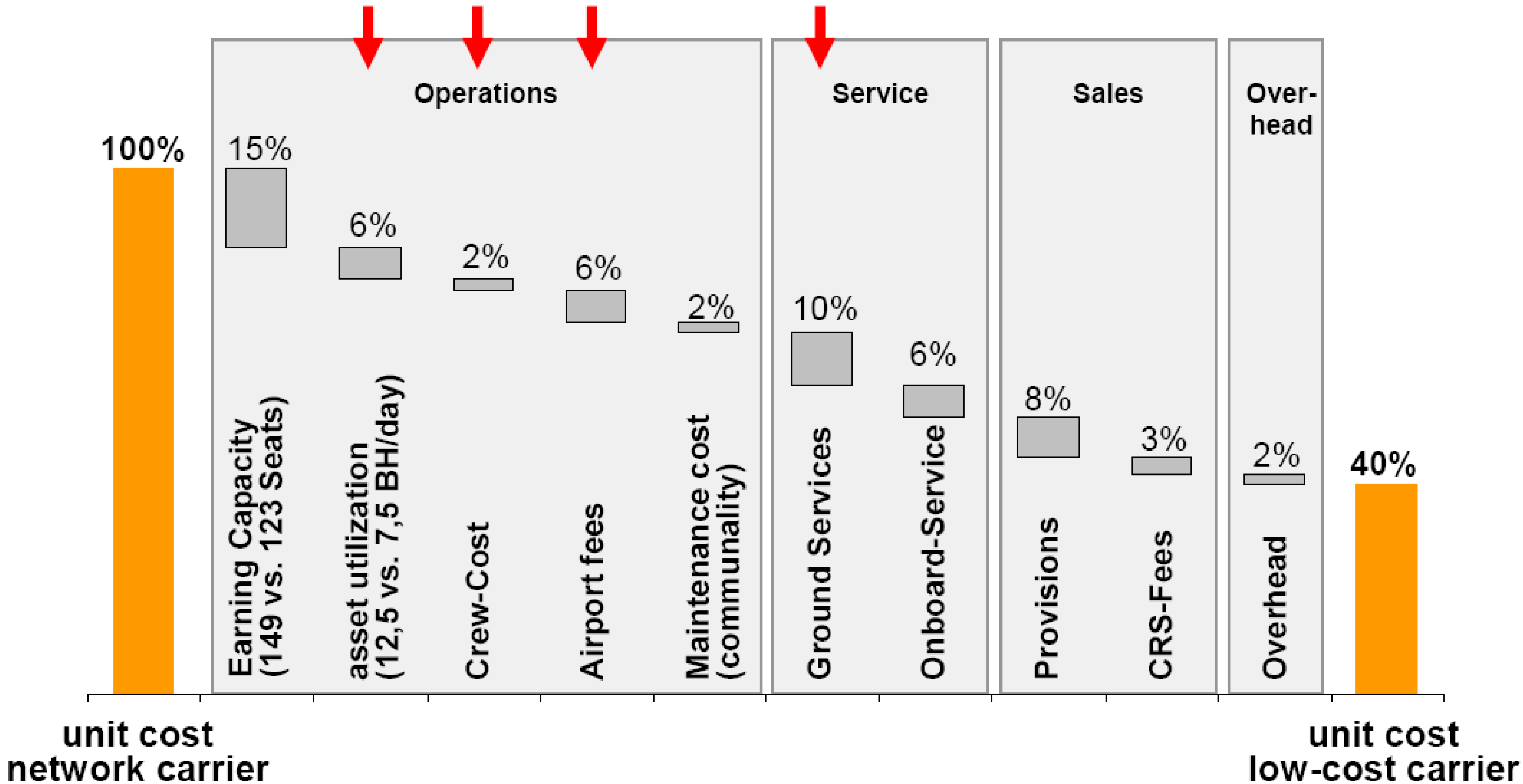
Cost Advantage for Low Cost Airlines

The cost reduction of a Low Cost Carrier can be achieved by the following elements:

- Takeoff and landing from small and regional airports with reduced fees and faster turn around capability:
  - Fees per Passenger in Frankfurt/Hahn: € 2,18
  - Fees per passenger in Frankfurt am Main: € 8,26
- Food service only by direct cash
- Booking only via Internet (Ryanair: 92%) or telefon (often specific costly telephon numbers).
- Reduced Personal service:
  - Personal cost per passenger by Ryanair: € 6,60
  - Personal cost per passenger by Lufthansa: € 44.-
- Few expenses for marketing and sales.
- Use of a standardised fleet (only 1 aircraft type, B737 or A320) → Reduction in maintenance and training cost.
- Very cheap tickets are only available in a small quantity and when booking is very early. For the rest of the seats the prices will increase accordingly. At Ryanair the average price for a ticket is around 50 € (plus fees, one way) and is therefore very costefficient compared to a network airline (BA,AF,LH,.)

Cost Advantage for Low Cost Airlines

Actually, some cost advantages even result from not being a hub-and-spoke carrier



Source: easyJet

Elektronic Tickets

- Booking of Ticket via telephon or Internet.
- Paying of ticket via Credit Card.
- By presenting either passport or credit card at the automatic Check-in station at the airport, the Boarding Card will be issued.

→ No agent or agency needed for Boarding Pass delivery.

Nearly all Low Cost carriers are only using electronic ticketing.

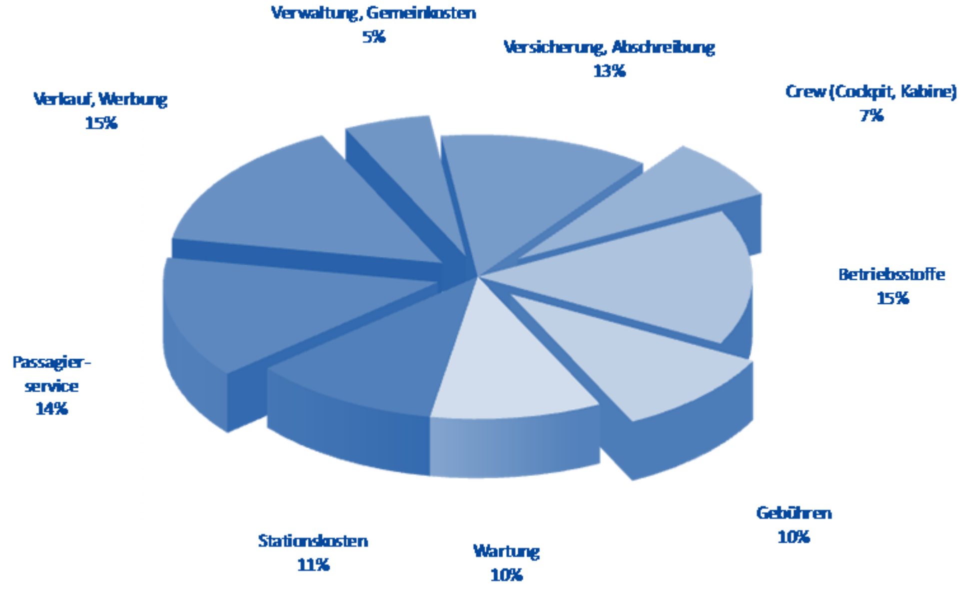
But also network carriers are offering electronic ticketing with some related cost reductions

Example Lufthansa – etix®:

- Booking with Miles & More- or Credit Card Number for personal identification.
- Payment via Credit Card or by bill (for serious guest!.)
- „Quick Check-In“- stations with integrated baggage acceptance for up to 2 pieces.
- Interactive View of cabin layout and open seat choice.
- Boarding Card and Bill with actual travel dates and price details delivered at automatic counter.
- Check-In also possible via Internet or Mobile phone (24h in advance).

Chapter 7.3

Operating Cost



Definition of Operating Cost (DOC) (1)

Normally an airline is analysing for each route the specific cost breakdown with aircraft type, crew, fuel etc included. These models are very precise however very difficult and time consuming and only valuable for the particular airline.
Therefore and for comparison reasons there are several organizations who have proposed general methods for the calculation of Direct Operating Cost:

- AEA (AEA 89)
- IATA
- ATA (ATA 67)

These models are using assumptions for cabin standards, route network, fleet size, flight profile and financial parameters like depreciation, insurance, interest rates, etc. The methods are quite different with respect to some parameters (insurance included?)
The aircraft manufacturers have also developed their own DOC methods using common airline standards to support their strategy..
The DOC are normally expressed in the unit \$(€)/Seat, \$(€)/nm oder \$(€)/h. It is clear, that the DOC method will only include cost relevant items. Differences in quality, comfort and operation (fleet size, commonality, etc.) are not considered

Definition of Operating Cost (DOC) (2)

The following elements are not included in the Direct Operating Cost (DOC):

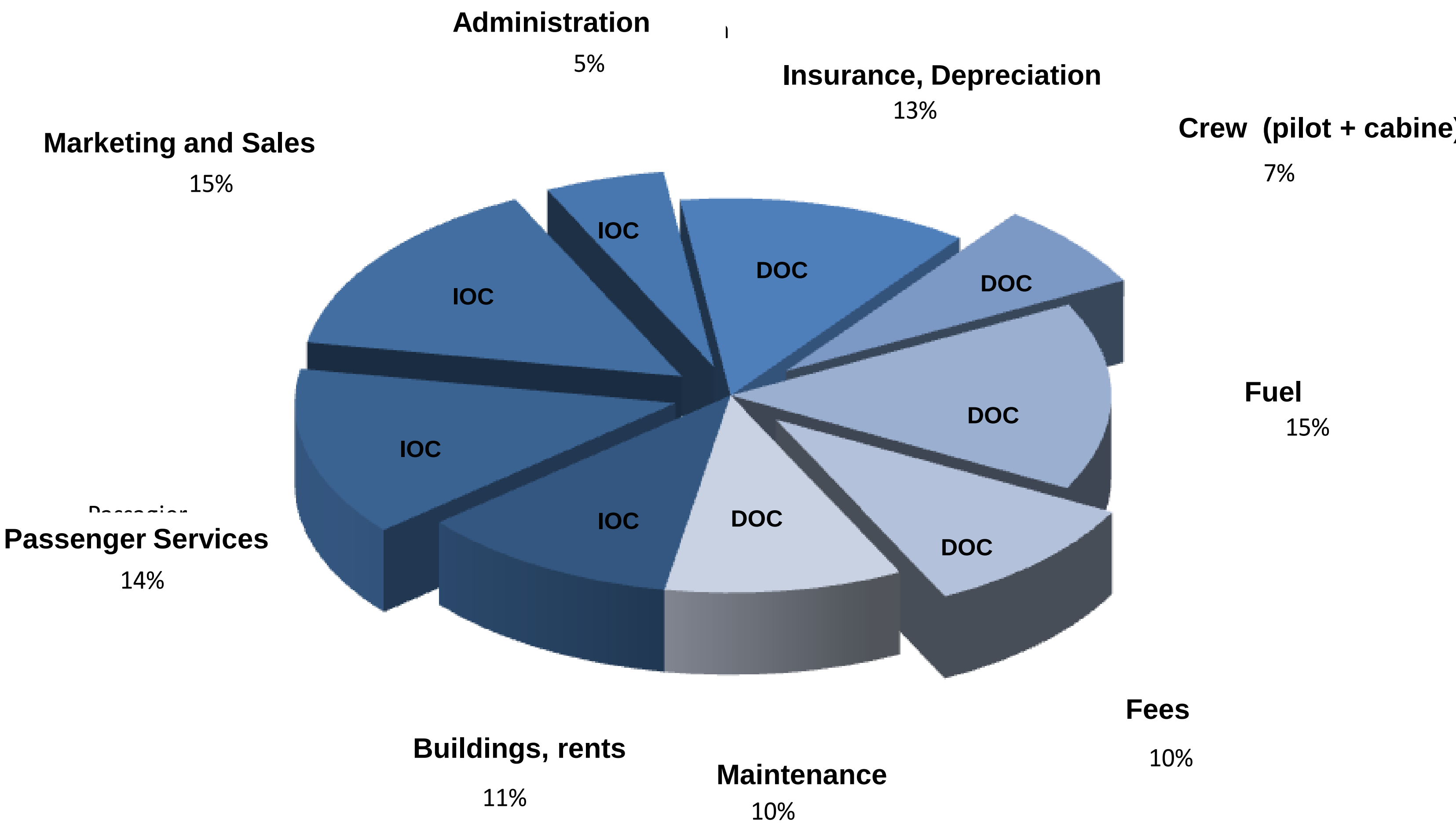
- Comfort (Climate, Baggage capacity, Seats, aisle width, …)
- Operational flexibility
- Range potencial
- Commonality (Cockpit, Cabine, Maintenance, …)
- Family Concept (Development potential)
- Turn-Around-Time / Airport compatibility
- Speed (Cruise, Takeoff, Landing,..)
- Cost of training (Cockpit, Kabine, Wartung, …)
- Product Support
- Freight capacity
- Takeoff- and Climb -performance

Cost Breakdown

- **Total Operating Cost**
  - **Indirect Operating Cost IOC**
    - **Ground and Infrastructure on gound**
      - Depreciation
      - Maintenance
    - **Freight/Cargo**
      - Cargo Handling
      - Sales, ticketing
      - Marketing
    - **Passage**
      - Catering
      - Passenger Check-In
      - Baggage handling
      - Booking, Sales
      - Marketing
    - **General Cost and Administration**
      - Buildings, Infrastructure
      - Training, Education
      - Leasing and rents
  - **Direct Operating Cost DOC**
    - **Aircraft Fixcost**
      - Depriciation
      - Interest
      - Insurance
    - **Flying Aircraft**
      - Crew (Cockpit, Cabin)
      - Landing fees
      - Navigation fees
      - Ground Handling
      - Maintenance airframe, engine)
      - Fuel

Source: Airbus

Distribution of Operating Cost (Status: 2005)



IOC and DOC are normally split by ~ 50% ; for Low Cost carriers less IOC

Quelle: IATA

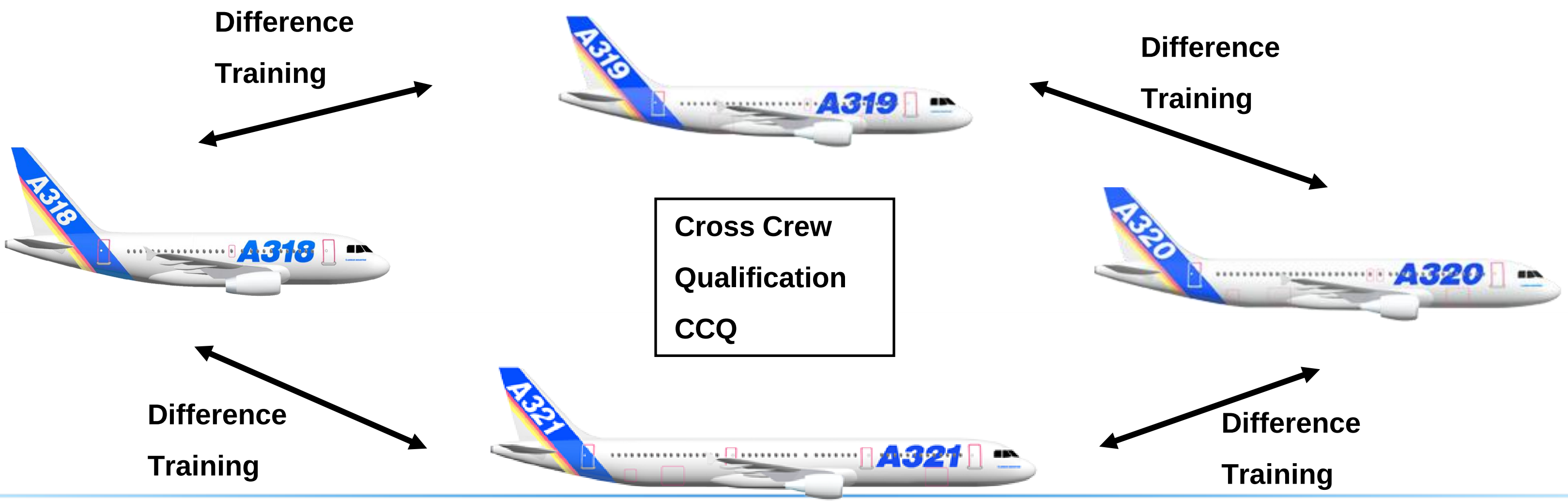
Cross Crew Qualification (CCQ)

Due to a common cockpit layout, the crews (pilots) can have a common „Type-Rating“ . In combination with a „Difference Training“ the pilots can achieve a „Cross Crew Qualification“, which allows the qualification of all aircrafts of a common family. This improves the productivity, which is defined as ratio of flight duty time to overall working time.

CCQ reduces the ratio of non productive pilot time (Standby-time, time for training).

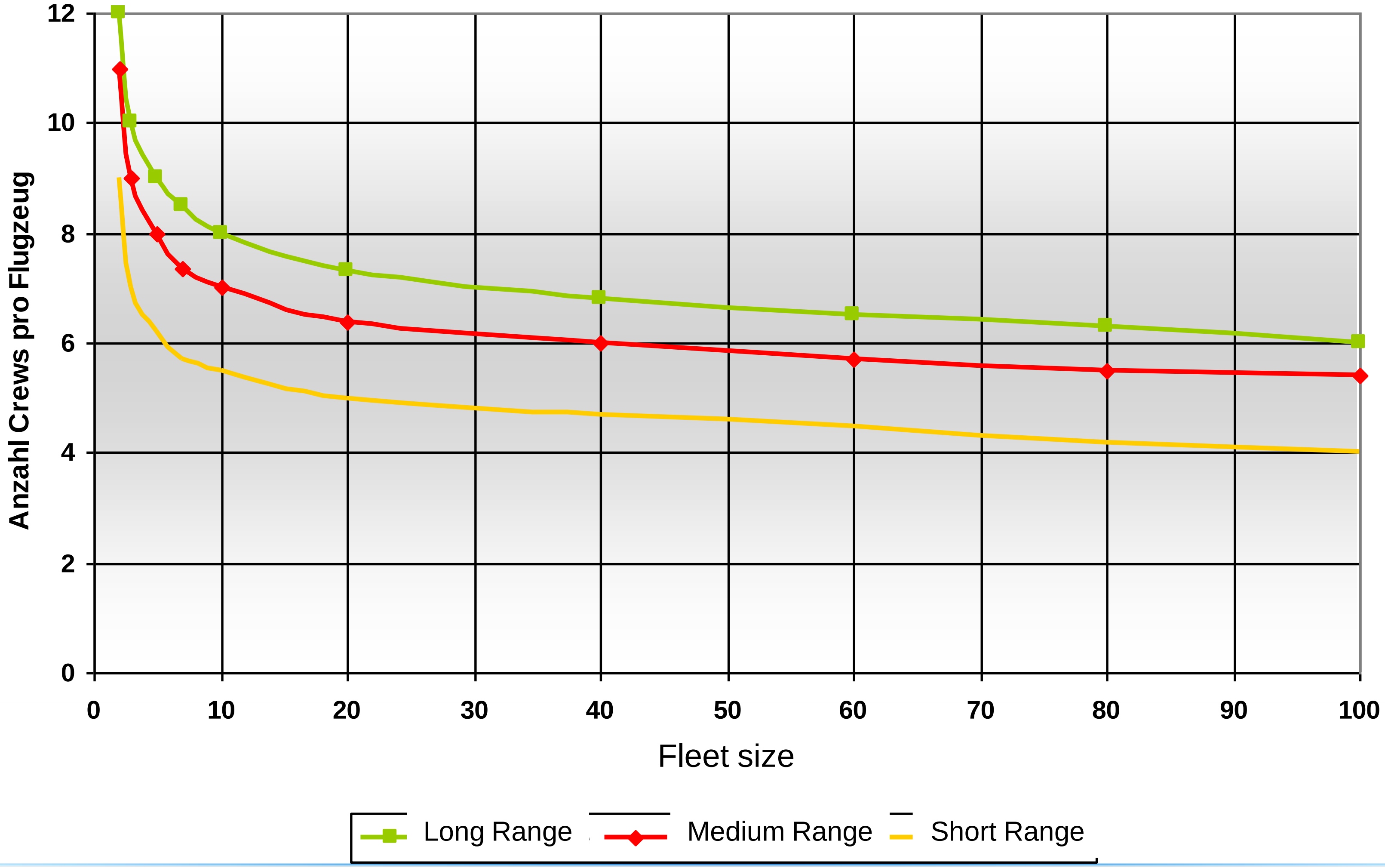
CCQ can lead to the following direct cost improvements:

- Less Cockpit Crews
- Reduced time for training
- Less investment for simulators and related cost



Influence of Fleet Size on Productivity

The saving potential due to commonality depends strongly on the type and size of the airline fleet. The number of required crews per aircraft is shown as an example for this influence.

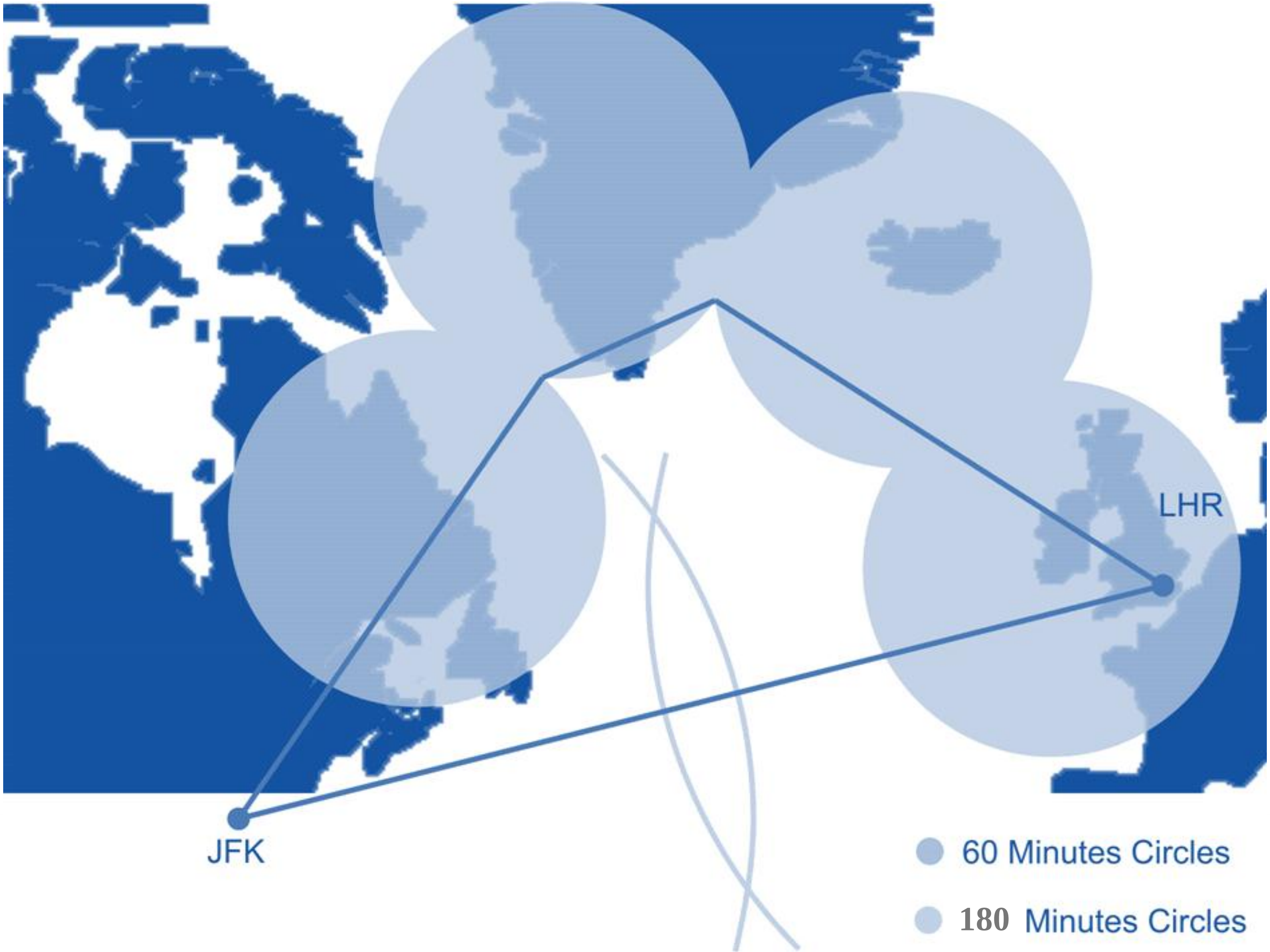


Chapter 7.4

ETOPS Operation

- For a long time according to flight regulations twin-engined commercial aircrafts were allowed to be only 60 minutes by air away from the next alternative airport (Calculation based on: calm, cruising speed, OEI – One Engine In-operating). This led to different flight routes (also above the North Atlantic), to diversions and to deviation from the ideal course along the great circle. The regulation was invoked in the 50s (FAR 121.161).
- With the improvement of jet-engine technology and the new capabilities of twin-engined aircrafts (A300, A310, B757 or B767) to fly longer routes the regulation started to soften. On some routes under certain boundary conditions 90 minutes were permitted.
- Both European and American authorities were accelerating the reconsideration of the ETOPS-rule in the 80s. Nowadays twin-engined aircrafts are allowed to operate even 180 minutes by air away from the next airport, under certain boundary conditions (there are intermediate stages at 90, 120 and 138 minutes).
- ETOPS is the collection of rules that allow airlines to operate beyond the 60-minute rule. The engine must be certified „ETOPS-Type“ and also the airline has to possess a „ETOPS Operating Permit”.

ETOPS – Route planner (2)



Source: Airbus

Aim of the ETOPS-Rule:
The general operating safety of a twin-engined aircraft is comparable to modern 3- and 4-engined aircrafts.

- **The possibility of a second engine breakdown by advanced engines is highly unlikely, although certain system redundancy has to be ensured. It is not sufficient to introduce additional redundance. It must be safeguarded that critical errors (local fire, mechanical damages) are covered.**
  → Specific system design is required.
- **Weather induced aspects: After an engine breakdown the airplane will descend to a lower flight level FL 100-250, where worse weather conditions (ice, clouds) are possible.**
- **Pilot induced aspects: Under stress the crew can inadvertently shut down the wrong engine or execute other grave mistakes. Flying further with only one functional engine can result in additional stress.**
- **Maintenance induced error: On twin-engine aircrafts identically faulty maintenance procedures for the engine or basic systems can have more dangerous impact as on quad-engined plane.**

→ ETOPS-rules affect all aspects!

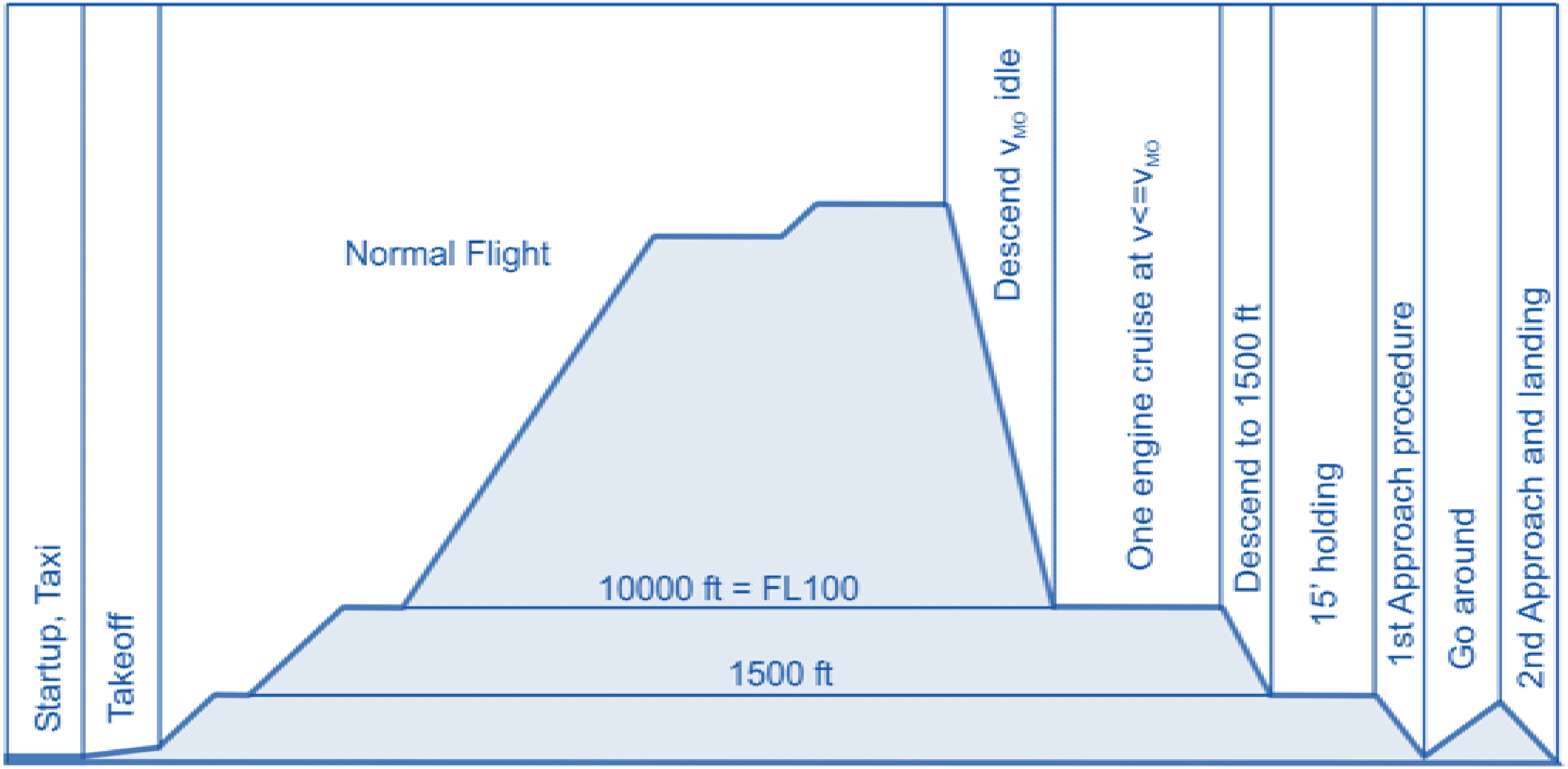
Three basic aspects of ETOPS-Approval:

- **The aircraft has to receive an „ETOPS Approval“.**
  → Design determined by the system.
- **The engine has to achieve the ETOPS rating, that means the Inflight-Shutdown-Rate (IFSD) has to exceed a specified minimum standard (generally all the equipped aircrafts as well as the remaining fleet).**
- **The airline has to attest the ability of „ETOPS-Operation”. Accordingly maintenance services, pilot training programs and route planning have to comply with „new specific standards” in order to acquire „ETOPS Operational Approval”. Airlines have to verify these incrementally by local authorities.**

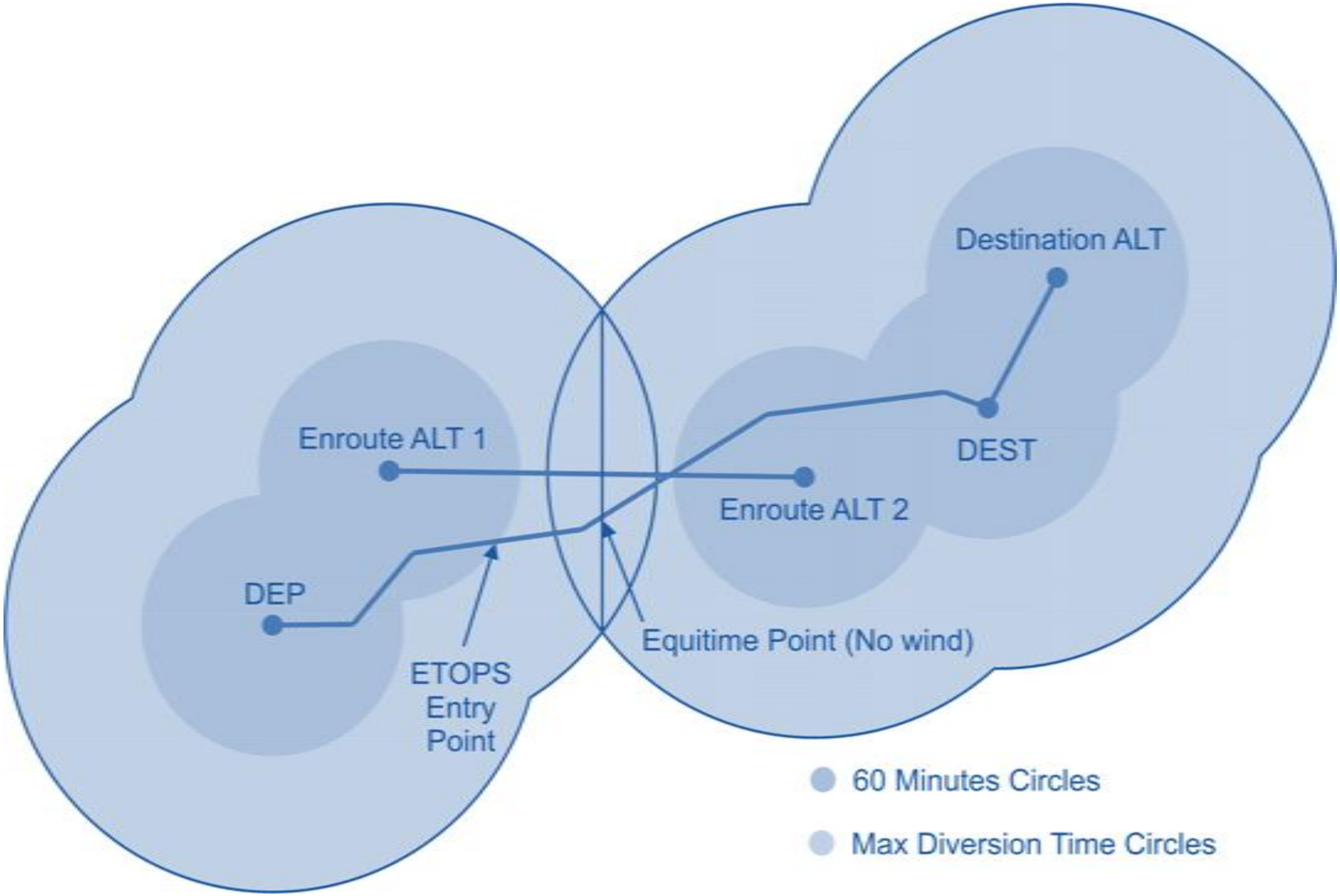
Three basic aspects of ETOPS-Approval:

- **Route planning: During route planning appropiate diversion airports must be selected. The weather conditional minimum operating time is more stringent as determined in standard atmosphere, in order to make a safe landing with faulty engines more possible.**
- **Airplane status before take-off: The so called Master Minimum Equipment List (MMEL) states the level of system redundancy when ETOPS-Operation can be started. Critical components (engine driven generators, tank valves and pumps, de-icing system, etc.) are specified in the MMEL. Canada requires in addition an ACARS-Link for 2 men cockpit operation.**
- **Fuel planning: ETOPS flights require a particular fuel reserve planning. The determined reserves have to take into account**
  - **cruising flight in low altitude**
  - **stronger winds**
  - **operating de-icing systems**
  - **increased drag due to engine failure**

ETOPS – Critical mission profile



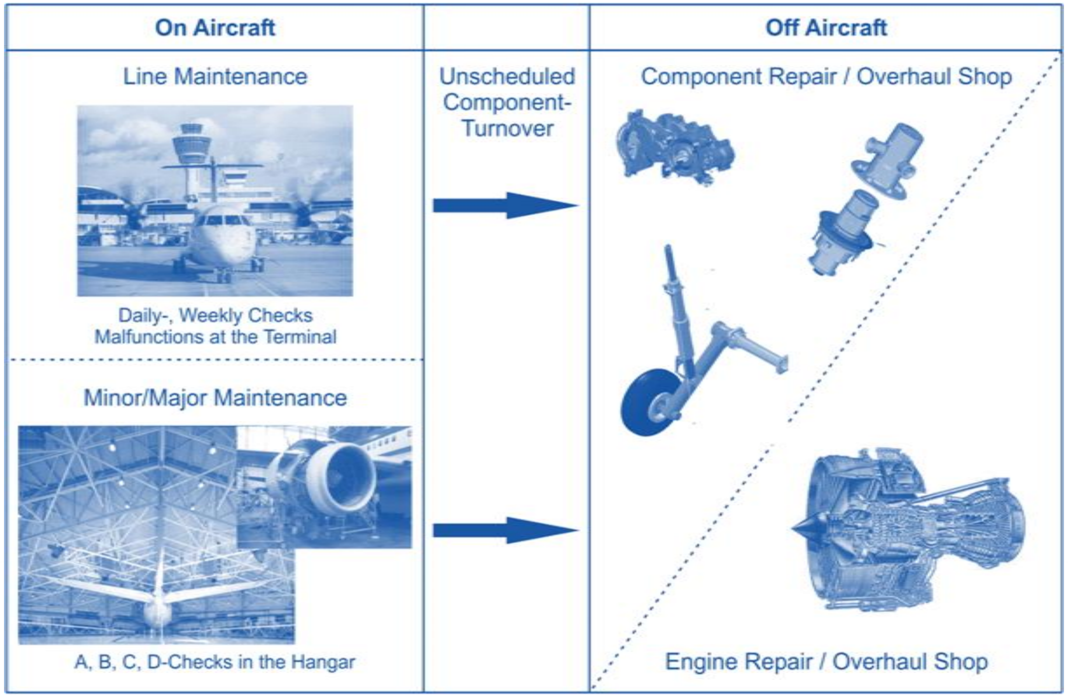
Source: Airbus



Source: Airbus

Chapter 7.5

Technical Part Maintenance



Functions of aircraft inspections

- **Aircraft Maintenance**: All regular visible and functional inspections, maintenance tasks, repair tasks, change of parts as well as failure related change and repair tasks.
- **Aircraft Overhaul**: In the framework of a substantial Dock-time all major inspection work will be done (C-Check, D-Check, …).
- **Equipment- and parts- overhaul**: equipment and parts like pumps, engines, undercarriage, electrical and environmental systems, etc. have to be inspected and tested in regular time intervalls and will be removed and replaced for this purposes. This has the advantage that the aircraft can stay in ist flight plan.
- **Introduction of New Equipment and Modifications:** Via so called „Service Bulletins“ the aircraft manufacturer is announcing necessary safety related modifications, as well as recommendations to the airlines. These modifications and inspections will also be done if possible during normal servive/overhaul opportunities.

Quelle: Beder; Lufthansa

Inspection program

Example: Maintenance of an Airbus A310

Event	***Intervalle***	***Work/Task***	***Down Time***	***Man-hours***
Trip-Check	Before each flight	✈ Walk around aircraft (visual inspection) ✈ Cabin- and Cockpit-Check ✈ Check of all liquids (oil, water, etc.) ✈ Cleaning of cabin	35 min	0,5
Service-Check	Weekly	✈ Renewal of all liquids (oil, etc.) ✈ Intensive cabin cleaning	4 h	20
A-Check	After each 250 flight hours	✈ Service-Check ✈ Additional cabin- and systemchecks	6 h	40
C-Check	All 13 months	✈ A-Check ✈ Detailed strukcural inspection and system tests ✈ Partly removal of fairings / interior panels	30 h	700
R-Check	All 15 month	✈ Cabin Overhaul	Parallel to other Checks	10
IL-Check (Intermediate Layover)	All 4 years	✈ In-depth overhaul of cabin and structure ✈ Polishing and refreshment of external paint	2 Weeks	12000
D-Check	All 8 years	✈ Overhaul of airframe (alle Systeme) ✈ Change of big parts ✈ New external paint ✈ Intensive cabin overhaul ✈ Includes all other inspections	4 weeks	30000

Source: Lufthansa

Maintenance Features

On Aircraft

Line Maintenance

Daily-, Weekly Checks
Malfunctions at the Terminal

Minor/Major Maintenance

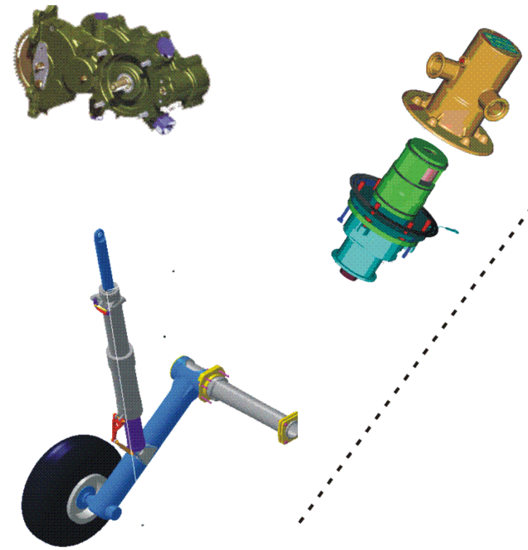
A, B, C, D-Checks in the Hangar

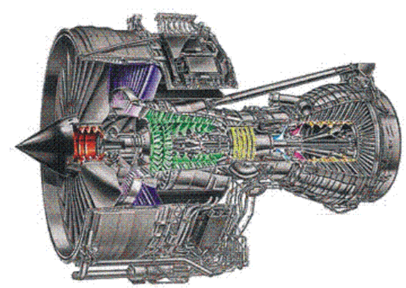
Unscheduled Component-Turnover

→

Off Aircraft

Component Repair / Overhaul Shop





Engine Repair / Overhaul Shop

Summary (1)

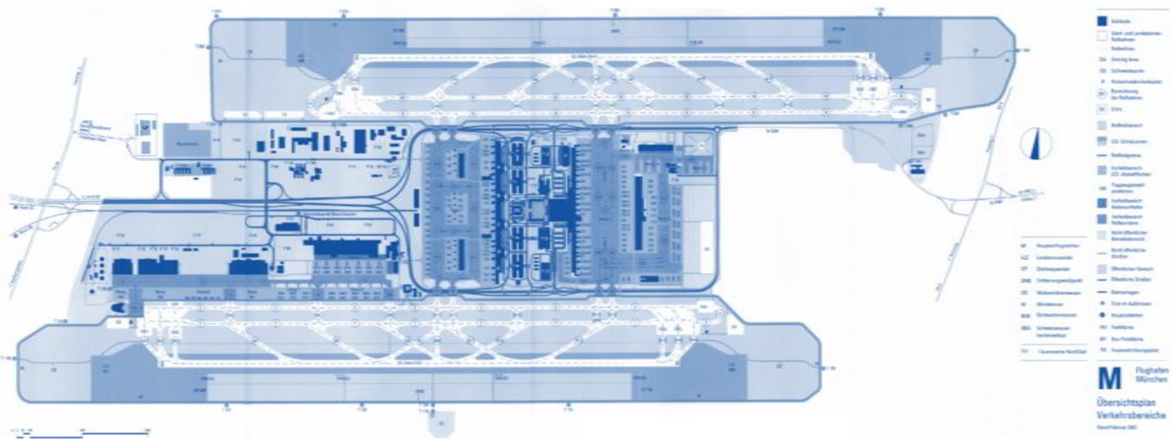
- The product „Air travel“ is characterised by several parameters.
- The civil air transport is liberalised in the USA and in the EU.
- In terms of route network, most/all network airlines are using a „hub & spoke“ system
- Low Cost carriers are using mainly direct point to point connections
- National airlines are often integrated in „Global alliances“ to enlarge their route network.
- Besides the traditional IATA-Normaltarif system a lot of new pricing instruments are visible. Prices are not always related to the flown distance, more depending on competition and market opportunities.
- Several „Low Cost Carriers“ have appeared on the market and are helping to increase competition and reduce travel prices.

Summary (2)

- The main part of flight tickets is no longer sold by travel agencies, but via telephon and internet (electronic tickets).
- The Operating Cost of an airline can be separated in Direct Operating Cost (DOC) and Indirect Operating Cost (IOC), which are about similar
- The yield situation of an airline is striongly dependant on load factor and ticket price.
- In addition to the operational (flying) part the airlines need also technical competences and tasks to be performed for maintenance, aircraft inspections etc. This can be done by the airline themselves or can be outsourced to specific maintenance providers.
- ETOPS operation requires specific measures for the aircraft, the airlines and the specific flight preparation .

Chapter 8

The Airport



Participants of the Civil Air Transport Systems

National Agency

-FAA -NTSB -Min Transp	EASA

Air Trafic Control

International Agencies

ICAO
IATA
FAA / EASA
IAC

Organisations

- Consumers
- Environm. Ag.
- Tourism Ag.
- Hotels

Aircraft industry

- Manufacturer
- Engine Manuf.
- Suppliers

Aircraft

Airlines

- Line
- Low Cost
- Charter

Agencies

- Travel agents
- Freight forward
- Integrators

Passenger

Freight

Maintenance-centres

Airports

Reservation - Systems (Amadeus .)

Financing/ Services

-Banks
-Leasing Comp.
-Insurance

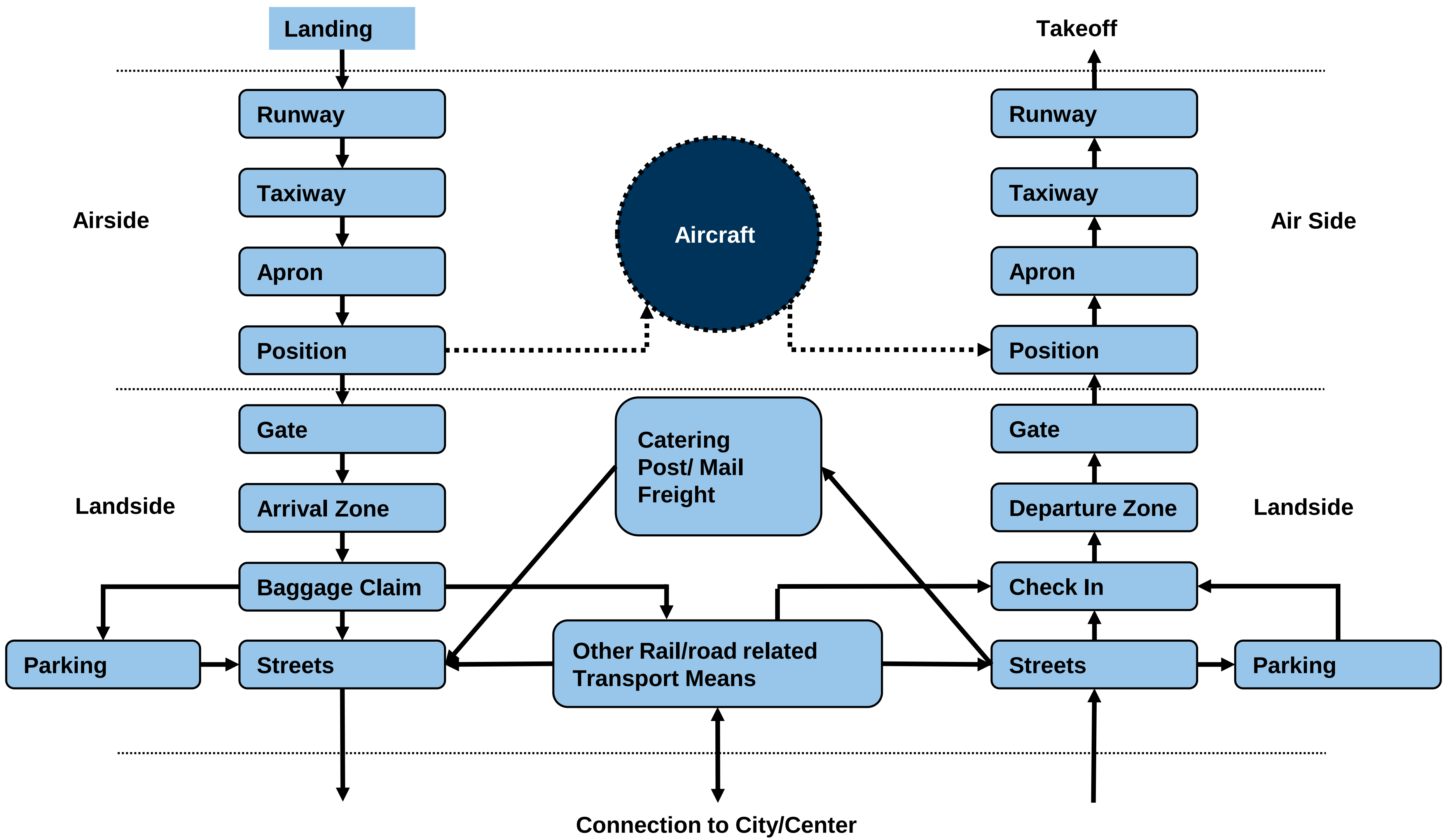
Infrastructure

- Meteo services
- Communication

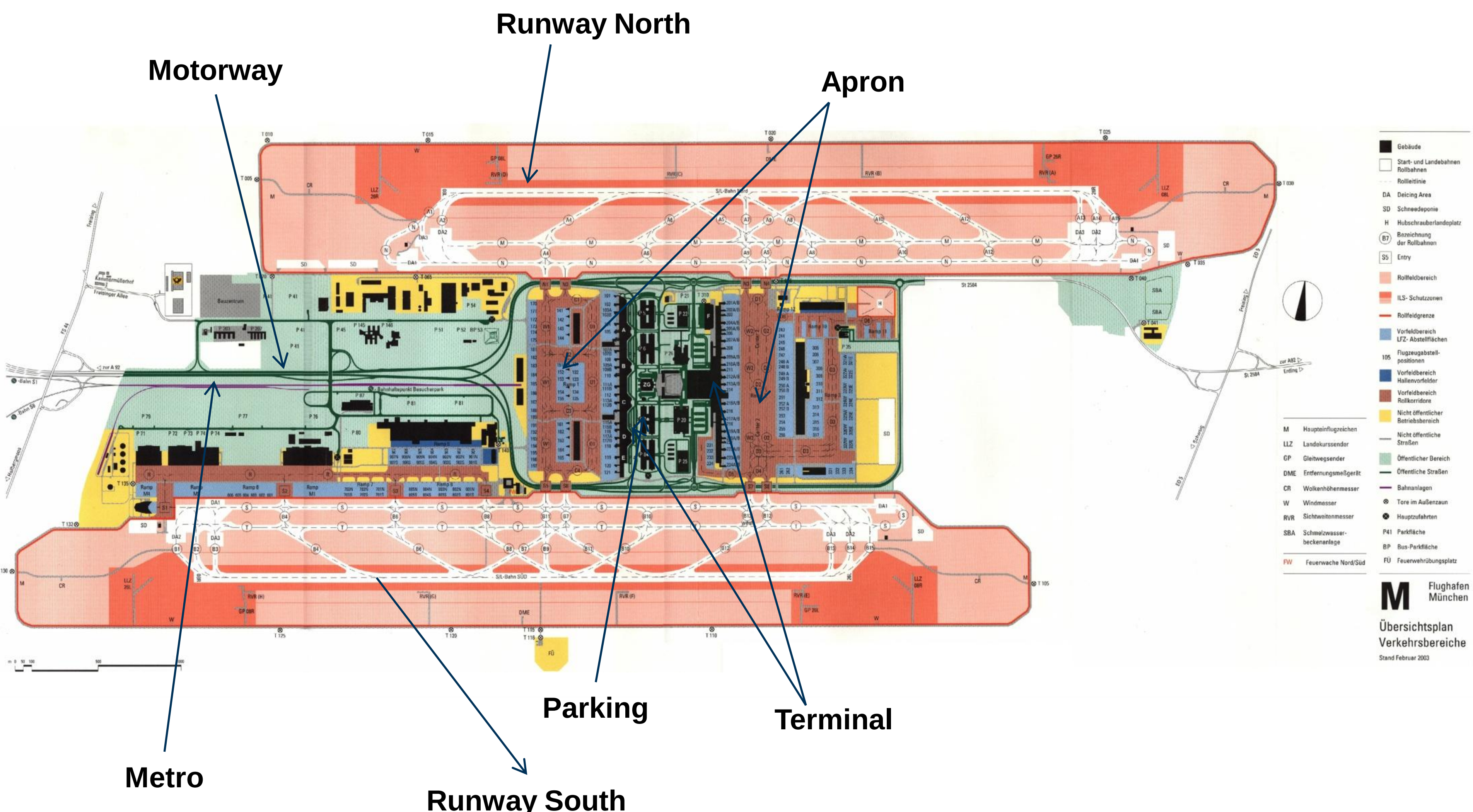
Chapter 8.1

The Airport System

The Airport System



Source: Ashford „Aircraft Operations“



Source: Flughafen München

Major Airport Elements

- Takeoff-/Landing-Runway
- Taxiways
- Tower for Air Trafic Control
- Navigation means
- Illumination
- Kerosin Reservoirs
- Passenger terminals and Apron
- Cargo terminals and apron
- Terminal and Apron for General Aviation
- Catering-Service
- Maintenance hangars
- Shortterm-, Longterm-parking
- Motorway connection
- Railway-, Metro- connection
- Airport maintenance and winter service
- Electrical system
- Waste system
- Safety fences and doors
- Hotels
- Meeting rooms
- Medical Care system
- Fire brigade

Facts and Figures about Munich Airport (2005)

Owners:	
State of Bavaria	51%
Germany	26%
City of Munich	23%

Statistical Data (2009):	
Passengers	32,7 Mio
Aircraft Movements	396.800
Air Cargo	229.000 t

Takeoff and Landing Runways:

Two parallel 4000m long and 60m wide runways with a distance of 2300m; Staggering 1500m

Infrastructure at Apron/Terminal:

19 + 24 Boarding Bridges at Terminal 1 + 2

14 + 47 Aircraft positions on the apron West + East

Jobs at the airport:

More than 26000 (July 2009)

Quelle: Flughafen München

Requirements for an Airport:

- Function related and safe operation
- 24-hours operation
- Public Acceptance and Economical operation
- Good accessability by road and rail
- Minimizing of environmental charges (noise, pollution)
- Optimum use and distribution of space/area

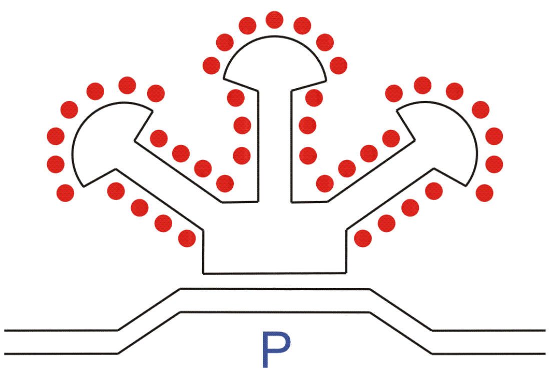
Factors for airport design:

- Number and direction of runways
- Number and distribution of taxiways
- Size and form of Apron
- Country geometry of landscape
- Navigation hinderances
- Use of Land within and outside airport
- Meteorology (fog, snow,)
- Size of planned airport system (space for future expansion?)

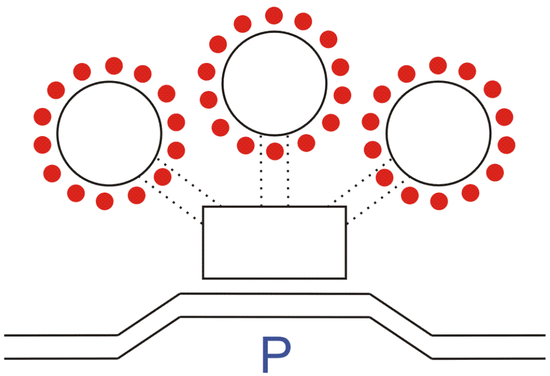
Parallel runways , which can operated only dependently!
(**Airport Frankfurt Rhein-Main**).

Parallel Runways to be operated independently
(**Airport Munich).**

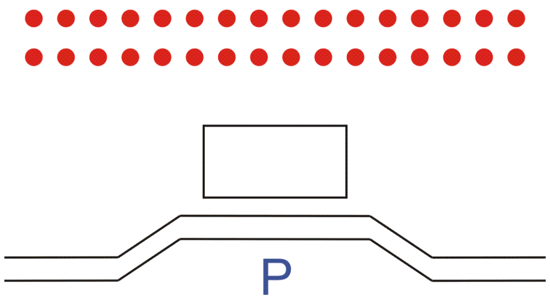
Arrangement of Terminal Gates



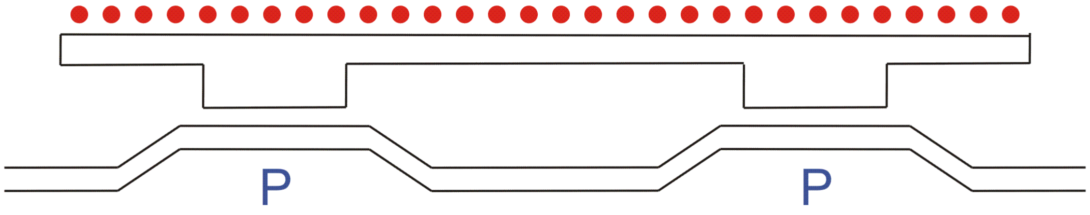
Pier/Finger-Konzept



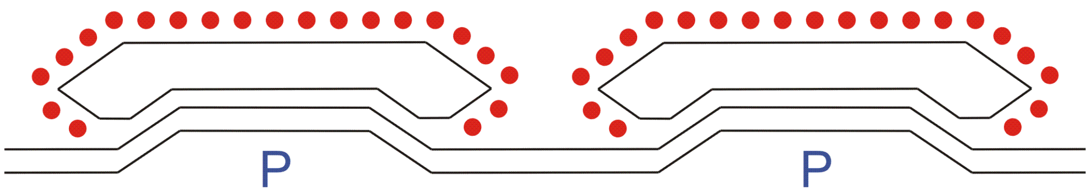
Satelliten-Konzept



Transport-Konzept

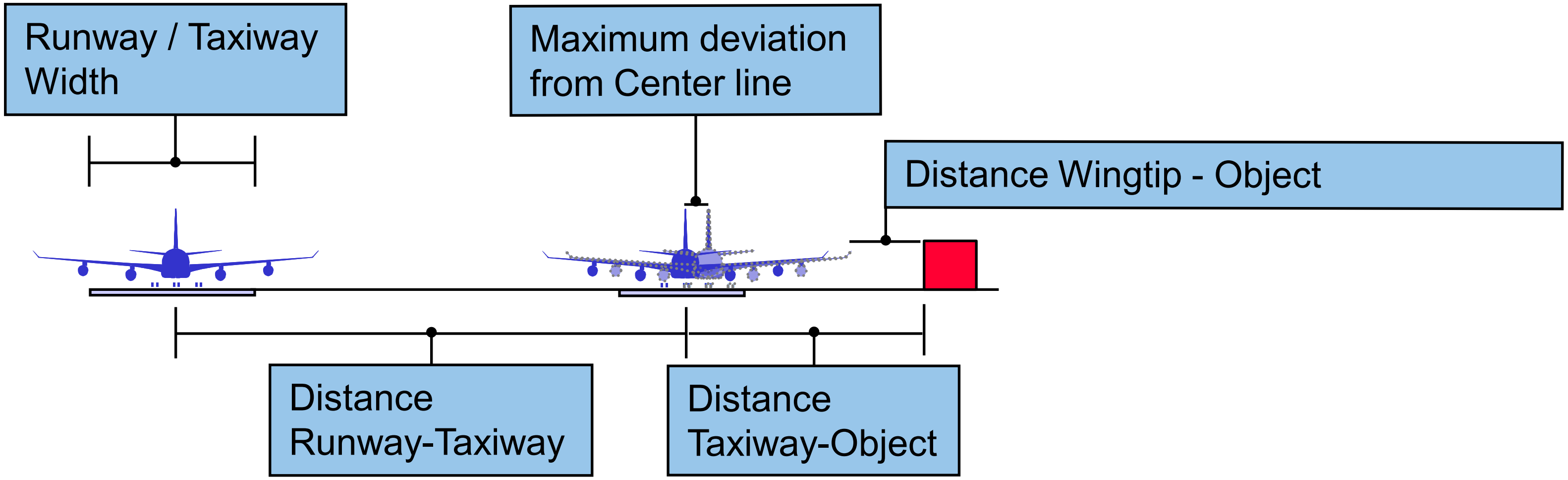


Linear-Konzept

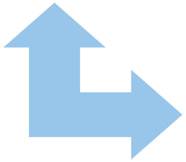


Modul-Konzept

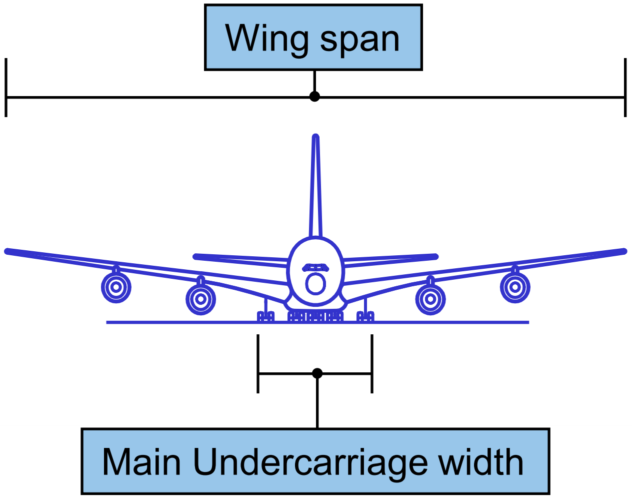
Aircraft Reference Codes



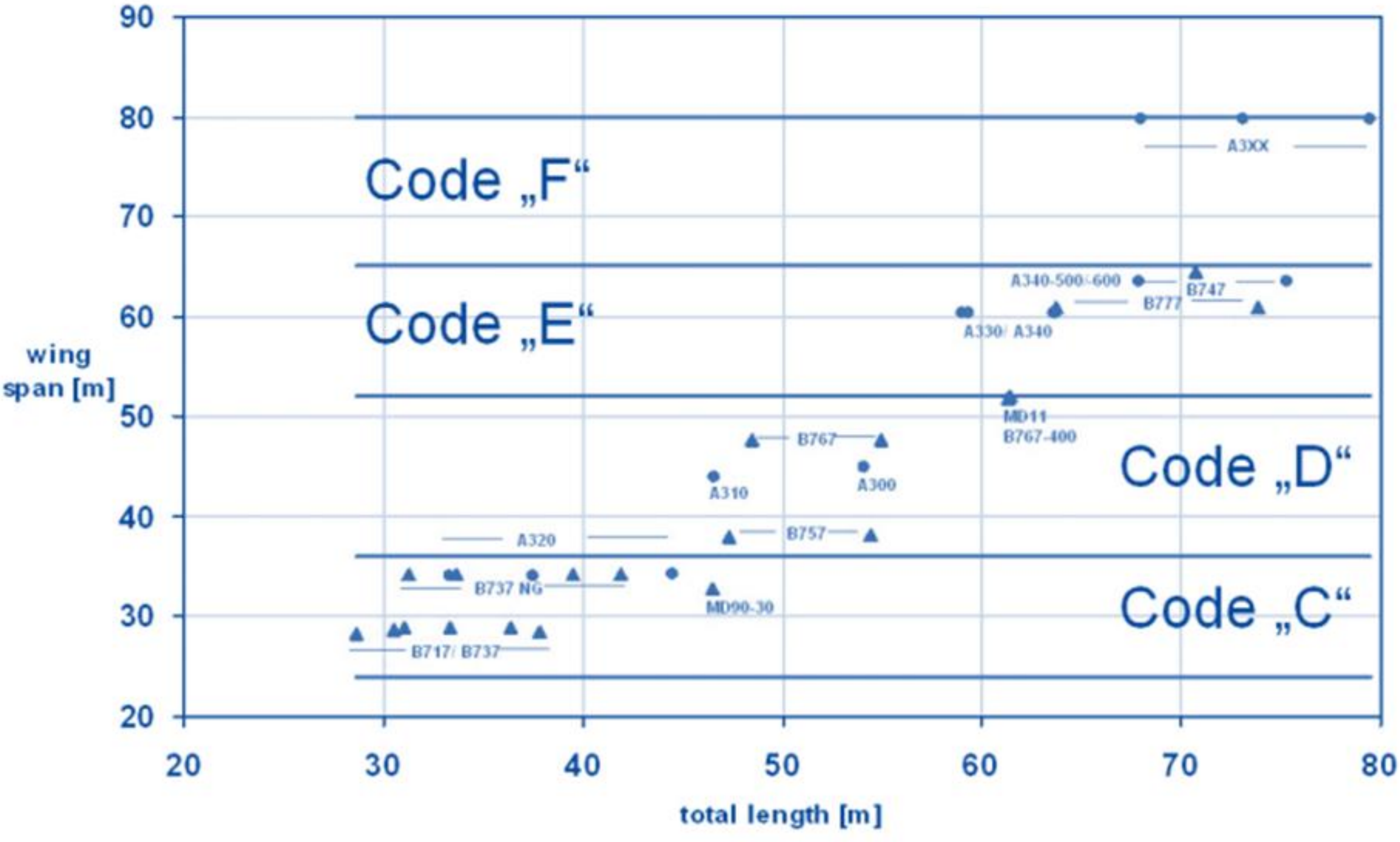
6 Airport Codes
(Definition of geometrical Minimum requirements)



Aircraft - parameters

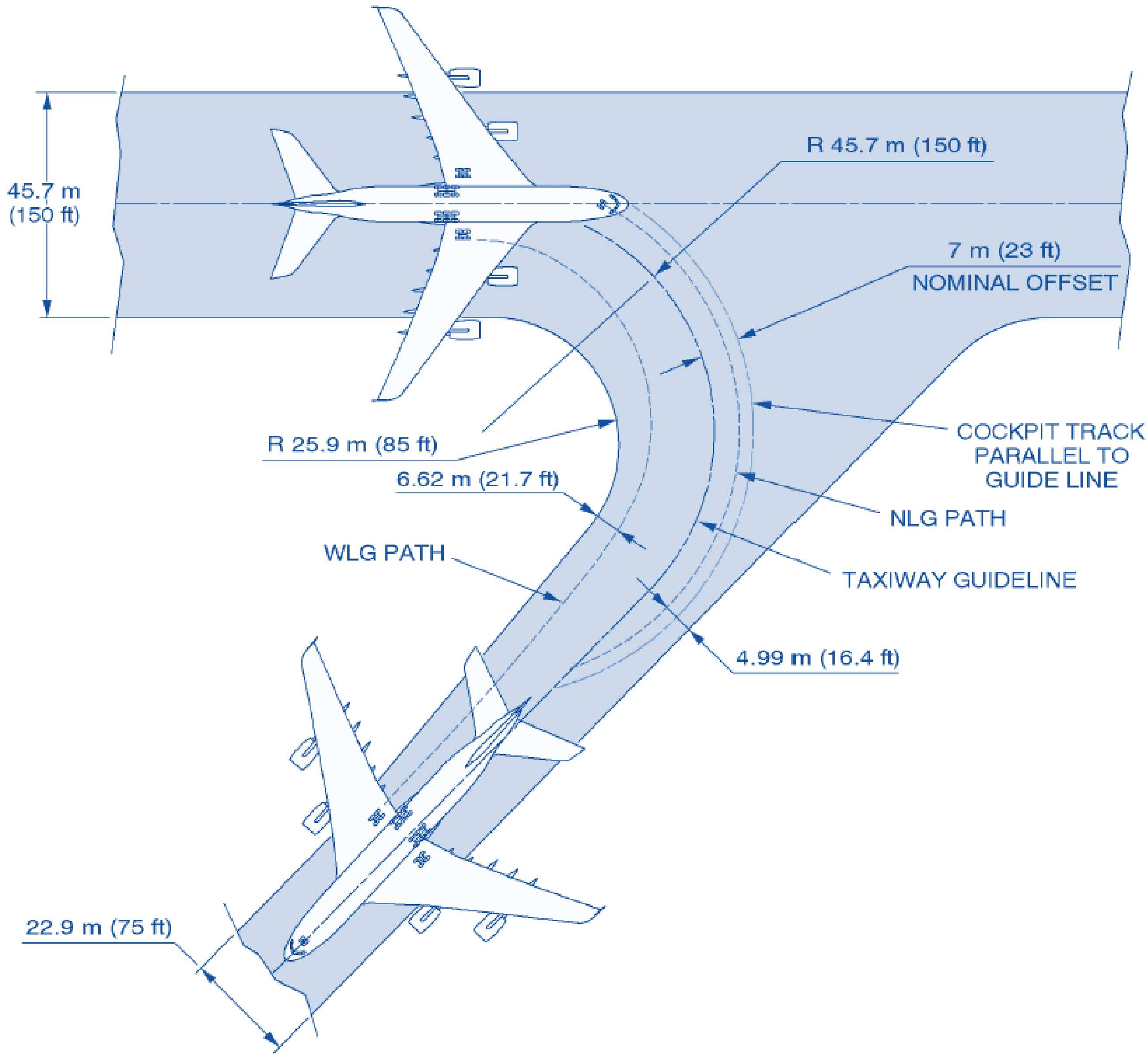


Wing Span and Total Length



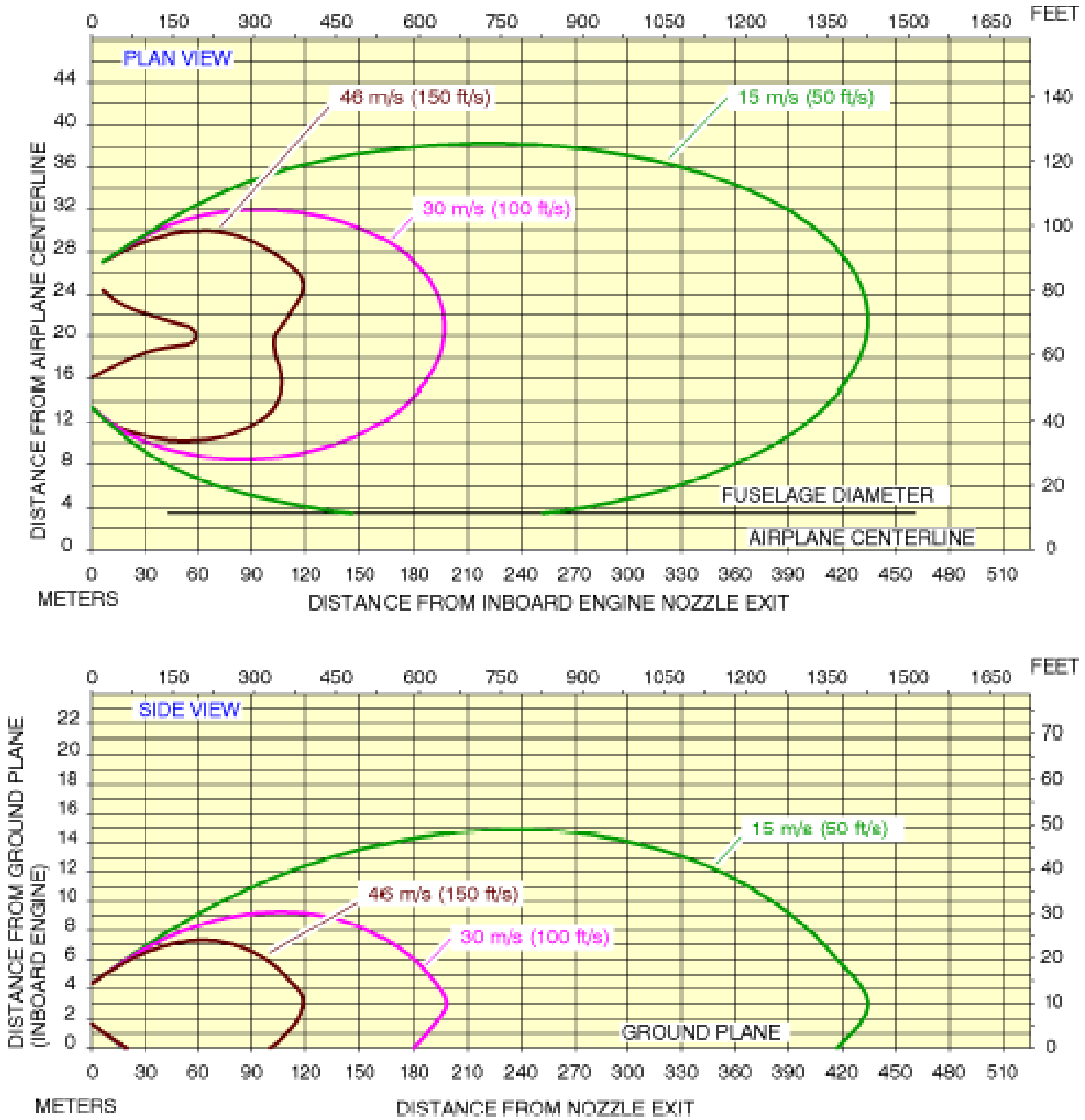
Quelle: EADS

Turning Radius – Airbus A380



Quelle: Airbus

Engine Exhaust Speeds (A380)

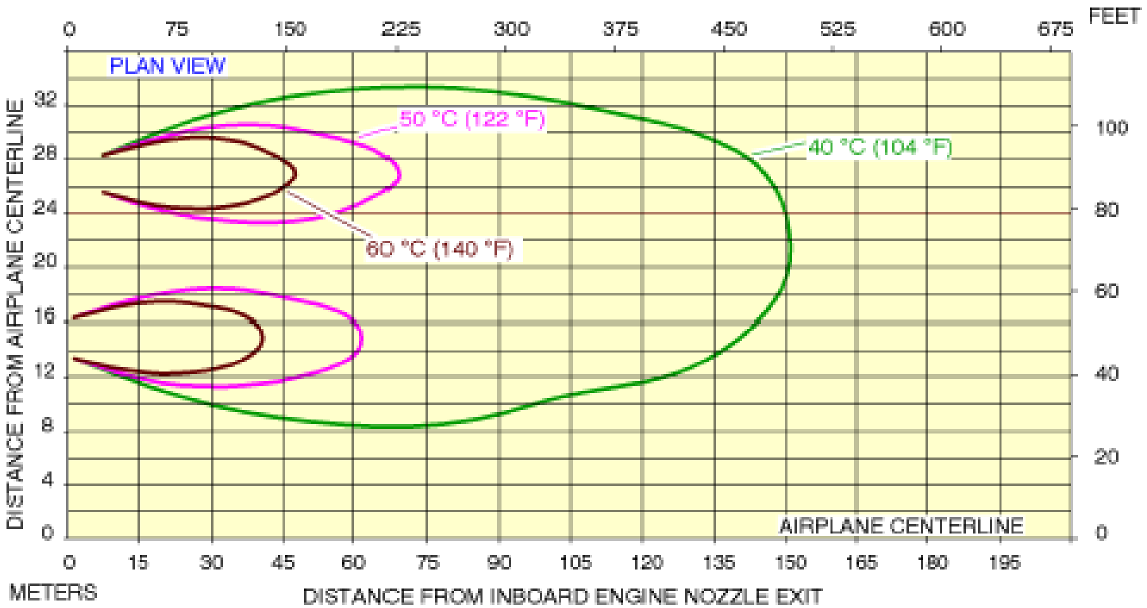


Condition:

- Sea level
- ISA +15°C
- No Wind

Trent 970 (Max. Take-Off Power)

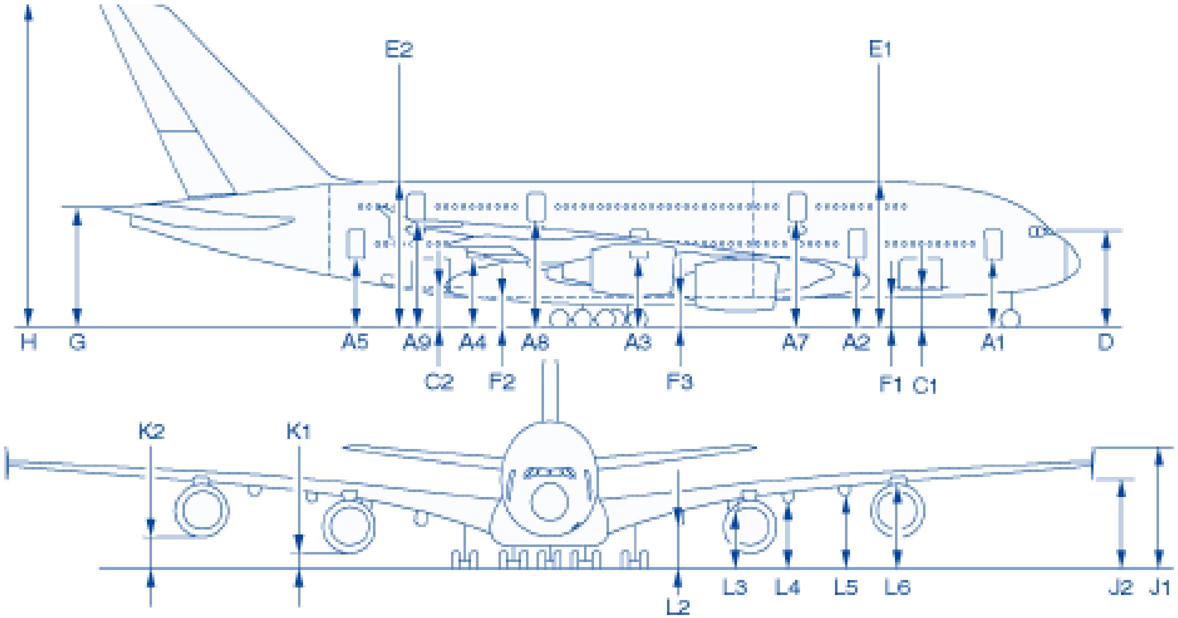
Source: Airbus



Condition:
- Sea level
- ISA +15°C
- No Wind

Trent 970 (Max. Take-Off Power)

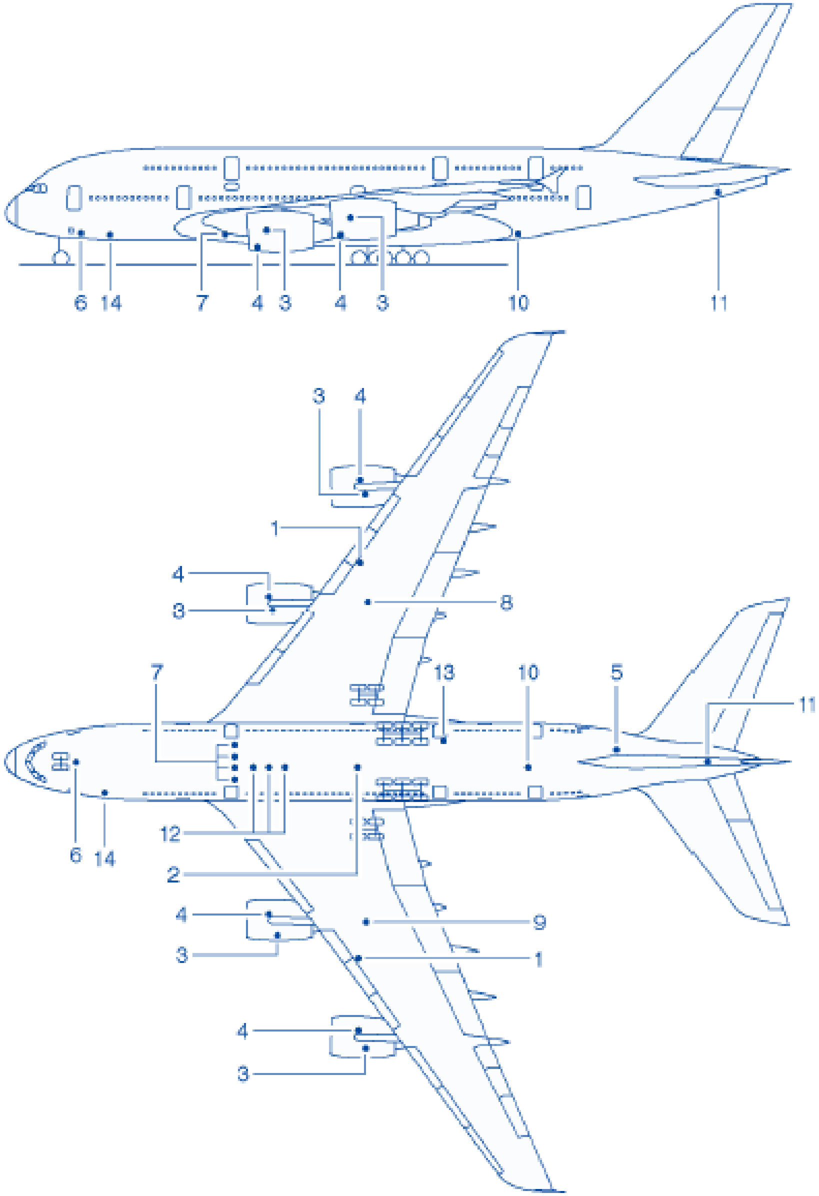
Source: Airbus



A/C CONFIGURATION	MRW FWD CG		MRW AFT CG		320t AFT CG		OWE MID CG		A/C JACKED FDL = 7.2 m (23.6 ft)	
	m	ft	m	ft	m	ft	m	ft	m	ft
A1	5.11	16.8	5.18	17.0	5.44	17.9	TO BE ISSUED LATER	TO BE ISSUED LATER	7.15	23.5
A2	5.11	16.8	5.16	16.9	5.38	17.6			7.15	23.5
A3	5.12	16.8	5.12	16.8	5.27	17.3			7.15	23.5
A4	5.13	16.8	5.10	16.7	5.19	17.0			7.15	23.5
A5	5.13	16.8	5.08	16.7	5.14	16.9			7.15	23.5
A7	7.87	25.8	7.90	25.9	8.10	26.6			9.90	32.5
A8	7.88	25.8	7.86	25.8	7.98	26.2			9.90	32.5
A9	7.88	25.9	7.84	25.7	7.92	26.0			9.90	32.5
C1	3.08	10.1	3.14	10.3	3.38	11.1			5.12	16.8
C2	3.10	10.2	3.06	10.0	3.15	10.3			5.12	16.8
D	7.17	23.5	7.26	23.8	7.53	24.7			9.22	30.2
E1	10.79	35.4	10.84	35.6	11.07	36.3			12.82	42.1
E2	10.80	35.4	10.76	35.3	10.84	35.5			12.82	42.1
F1	2.38	7.8	2.43	8.0	2.66	8.7			4.41	14.5
F2	2.24	7.4	2.21	7.3	2.31	7.6			4.27	14.0
F3	1.65	5.4	1.66	5.4	1.81	5.9			3.68	12.1
G	9.13	30.0	9.03	29.6	9.00	29.5			11.14	36.6
H	24.10	79.1	24.00	78.7	23.97	78.7			26.11	85.7

Source: Airbus

Ground connection points – Airbus A380



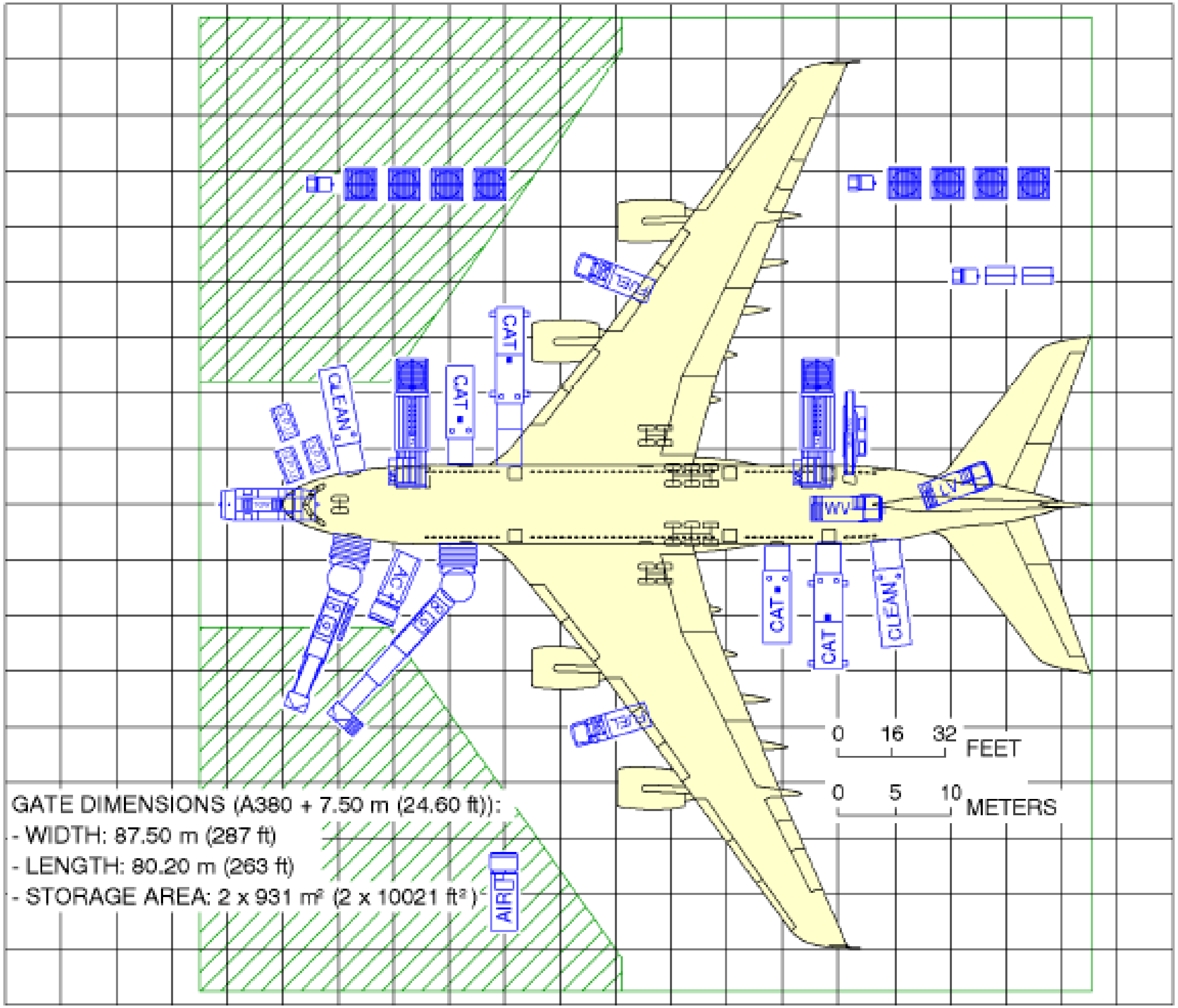
1 - PRESSURE REFUEL CONNECTORS
2 - HYDRAULIC RESERVOIR SERVICING PANEL
(RESERVOIR FILLING AND RESERVOIR PRESSURISATION)
3 - ENGINE OIL FILLING
4 - VF GENERATOR OIL FILLING
5 - TOILET AND WASTE SERVICE PANEL
6 - GROUND ELECTRICAL POWER
7 - LOW PRESSURE PRECONDITIONED AIR
8 - YELLOW HYDRAULIC GROUND CONNECTOR
9 - GREEN HYDRAULIC GROUND CONNECTOR
10 - POTABLE WATER SERVICE PANEL
11 - APU OIL FILLING
12 - HIGH PRESSURE AIR ENGINE START
13 - REFUEL/DEFUEL CONTROL PANEL
14 - OXYGEN SYSTEM

Quelle: Airbus

Chapter 8.2

Turn-Around

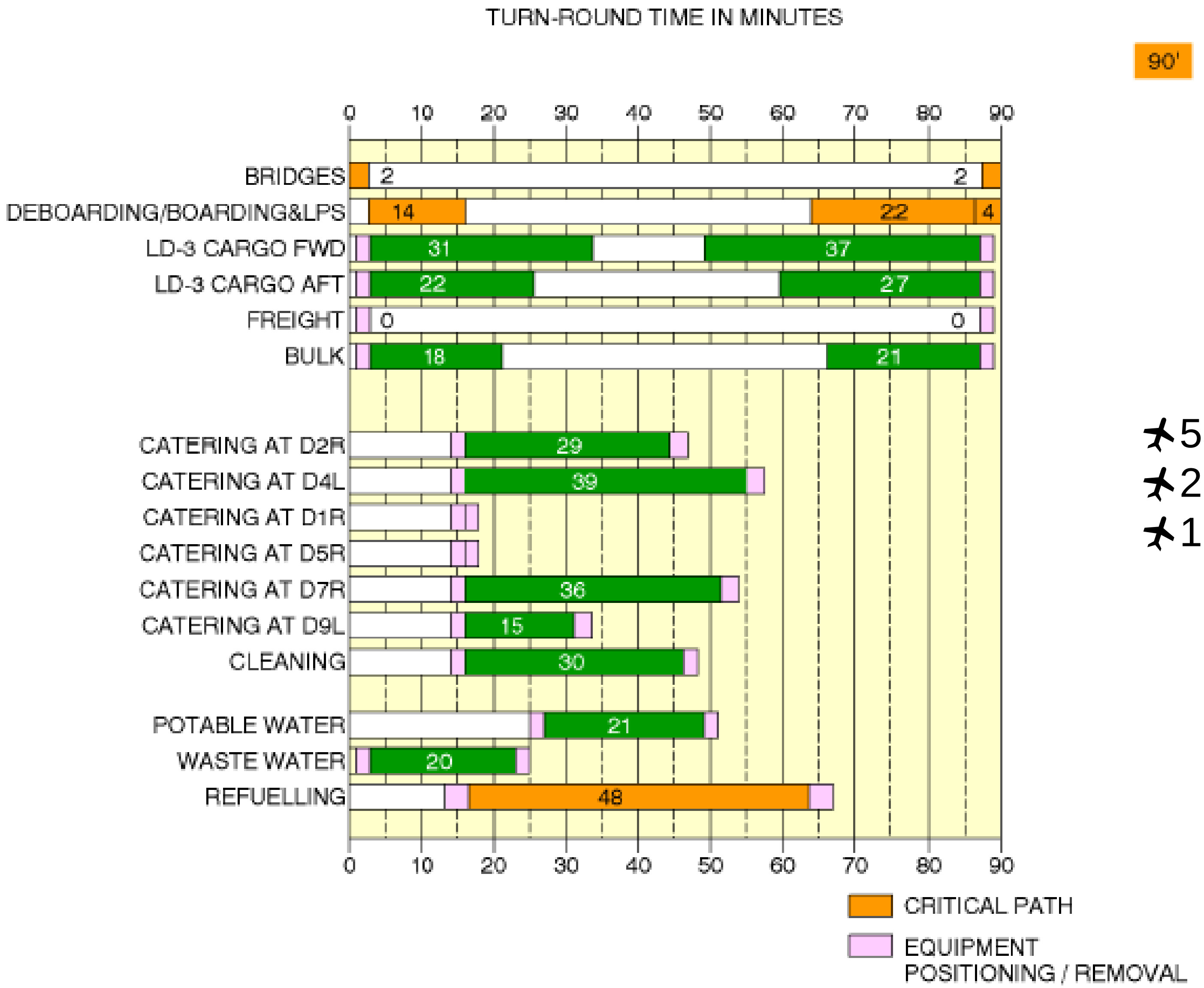
Arrangement of Ground Vehicles – Airbus A380



AC: AIR COND UNIT
AIR: AIR START UNIT
CAT: CATERING VEHICLE
CLEAN: CLEANING VEHICLE
CONVEYOR: CONVEYOR BELT
FUEL: FUEL HYDRANT DISPENSER
GPU: GROUND POWER UNIT
LV: LAVATORY VEHICLE
PL: PALLET/CONTAINER LOADER
TOW: TOWING TRACTOR
WV: POTABLE WATER VEHICLE

Source: Airbus

Turn-Around – Airbus A380



- 555 Passengers
- 2 Doors Main Deck
- 1 Door Upper Deck

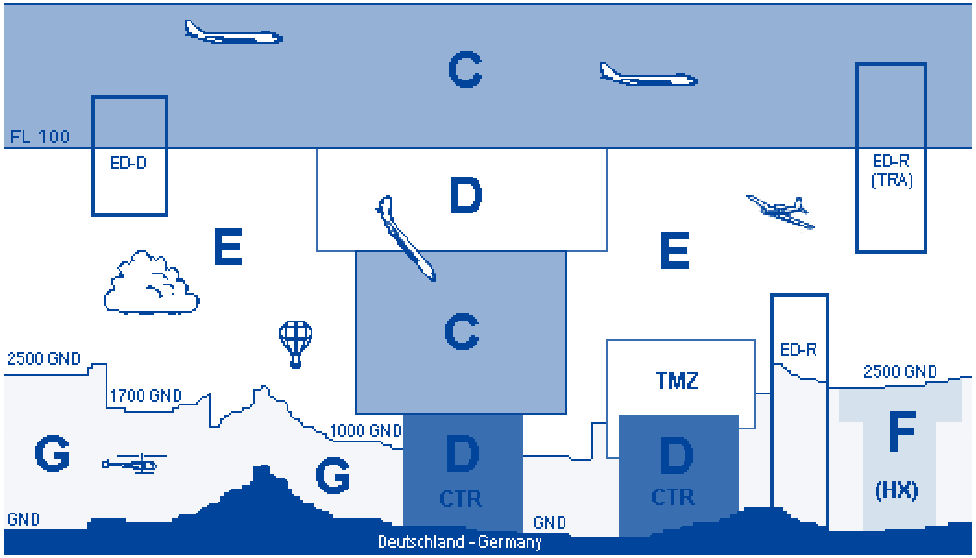
Quelle: Airbus

Summary

- The airport is a complex system with a variety of installations and services, far beyond just the ground surfaces
- Similar to the design requirement for an aircraft definition, the airport planning has to follow a requirement catalogue, taking into account the geographical situation.
- Inspite of major initiatives for capacity increase, the majority of European airports has reached their extension limits (only internal capacity stretch!)
- During takeoff and landing a wake vortex system develops behind the wing tips which may influence the following aircraft. Specific wake vortex seperation rules have been developed to ensure a safe operation.
- Special attention is concentrated for the Turn-around procedure, which should be done in minimum time. Turn around depends not only on aircraft size but also on the external aircraft geometry and its accessability of doors and connection points.

Chapter 9

Air Traffic Management



Participants of the Civil Air Transport Systems

National Agency

-FAA -NTSB -Min Transp	EASA

Air Trafic Control

International Agencies

ICAO
IATA
FAA / EASA
IAC

Organisations

- Consumers
- Environm. Ag.
- Tourism Ag.
- Hotels

Aircraft industry

- Manufacturer
- Engine Manuf.
- Suppliers

Aircraft

Airlines

- Line
- Low Cost
- Charter

Agencies

- Travel agents
- Freight forward
- Integrators

Passenger

Freight

Maintenance-centres

Airports

Reservation - Systems (Amadeus .)

Financing/ Services

-Banks
-Leasing Comp.
-Insurance

Infrastructure

- Meteo services
- Communication

Structure of air space

- The air space structure is a complex, 3-dimensional framework. Horizontally the boundaries are those of the natiional boarder with may be sometimes differences with regards to the seaside.

- Flight level is defined as altitude (in feet) / 100
  i.e. altitude 33 000ft corresponds to FL 330

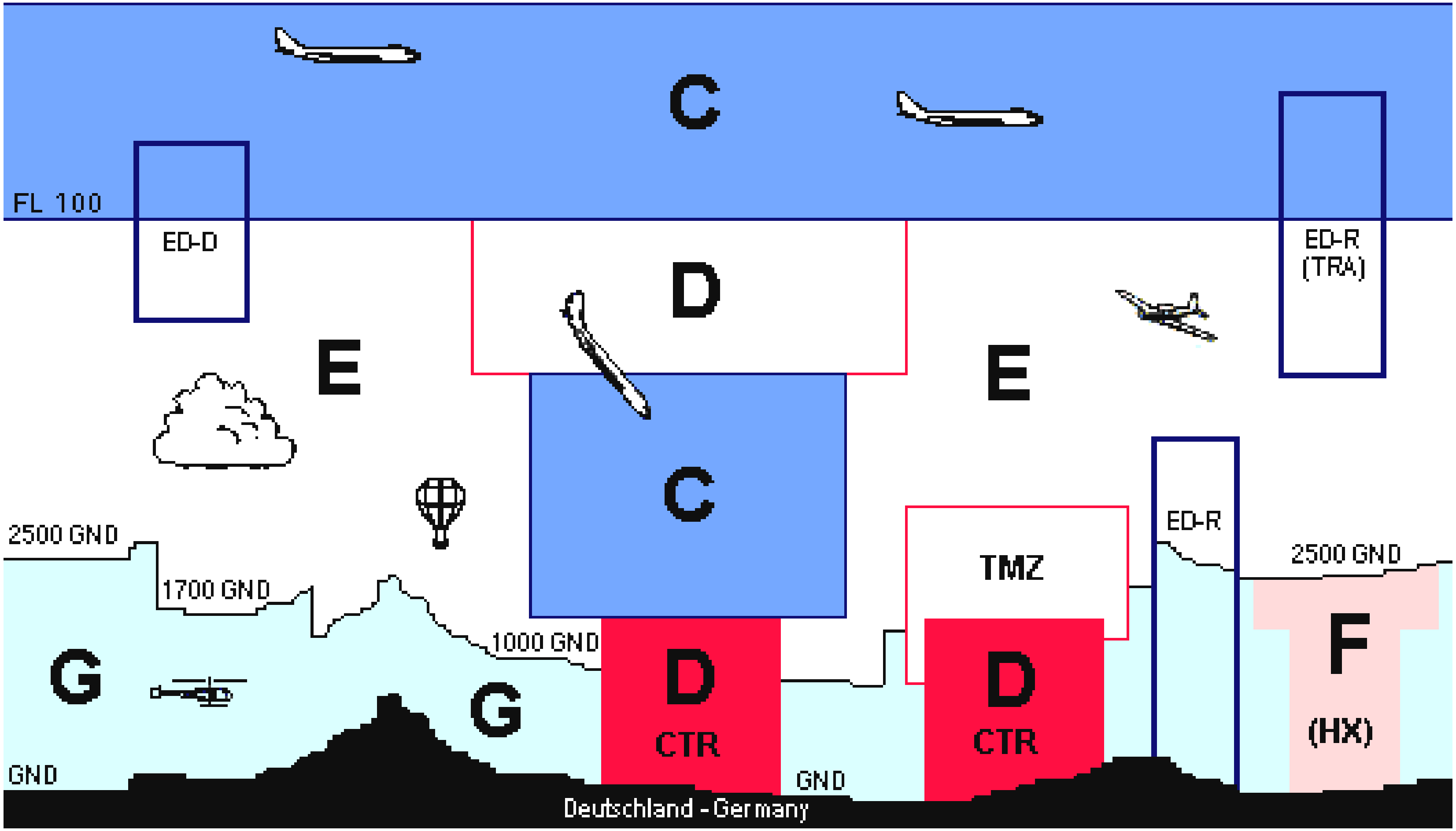
- Vertical definition of air space :
  - Lower air space: Ground surface GND – Flight level 245 (FL 245)
  - Upper air space: Flight level 245 – unlimited

- Within those vertical boundaries a controlled air space is defined:

  - Lower level: 2500 ft above Grund (close to the airport also areas with 1700ft resp. 1000 ft
  - Upper level: FL 460

Quelle: Mensen „Moderne Flugsicherung“

Air Space Structure in Germany



Quelle: www.luftrecht-online.de

Flight Level System (1)

- An essential requirement to avoid collisions in the air space is a sufficiently large vertical separation of aircraft.

- The safe vertical separation is based on a barometric altitude measurement. The following air pressures are specified:

▪ QFE	Existing air pressure at the airport.
▪ QNH	Air pressure in altitude SL (sea level), calculated via the standard atmosphere ISA, based on the actual existing and measured QFE
▪ QFF	Air pressure of actual atmosphere at Sea level (SL)
▪ 1013,25 hPa	Air pressure of Standard atmosphere ISA at Sea level (SL)

Quelle: Mensen „Moderne Flugsicherung“

Flight Level System (2)

Rules for barometric altitude measurement:

- **IFR-Flights (Instrument Flight Rules):**

  Use of QNH reference at Takeoff; - when reaching the Transition Altitude (i.e. 5000 ft above MSL) change to 1013,25 hPa- reference.
  Each aircraft, flying with these references, is given a certain pressure level. As all aircraft fly with the same references, and therefore having the same error with respect to the real altitude, the safe separation between the flying aircraft is guaranteed.
- Based on this altitude reference system and splitting the horizontal surface into 2 halfs (magnetic compass course 0°-179° and 180°-359°) leads to the hemisperical standard system:

- **Eastbound - Magnetic Track 000 to 179° - odd thousands (FL 250, 270, etc.)**
  Westbound - Magnetic Track 180 to 359° - even thousands (FL 260, 280, etc.)

At FL 290 and above, 4,000 ft intervals are used to separate same-direction aircraft (instead of 2,000 ft intervals below FL 290), and only odd flight levels are assigned,

Eastbound - Magnetic Track 000 to 179° - odd flight levels (FL 290, 330, 370, etc.)
Westbound - Magnetic Track 180 to 359° - odd flight levels (FL 310, 350, 390, etc.)

Source: Mensen „Moderne Flugsicherung“

Radar Separation

Since ATC Centers control a large airspace area, they will typically use long range radar that has the capability, at higher altitudes, to see aircraft within 200 nautical miles (370 km) of the radar antenna.

Aircraft are separated by the ATC using the following separation criteria:

- Using analogue radar screens:
  - 3 nm separation - when the distance between aircraft and radar antenna is less than 30 nm
  - 5 nm - when distance is more than 30 nm.

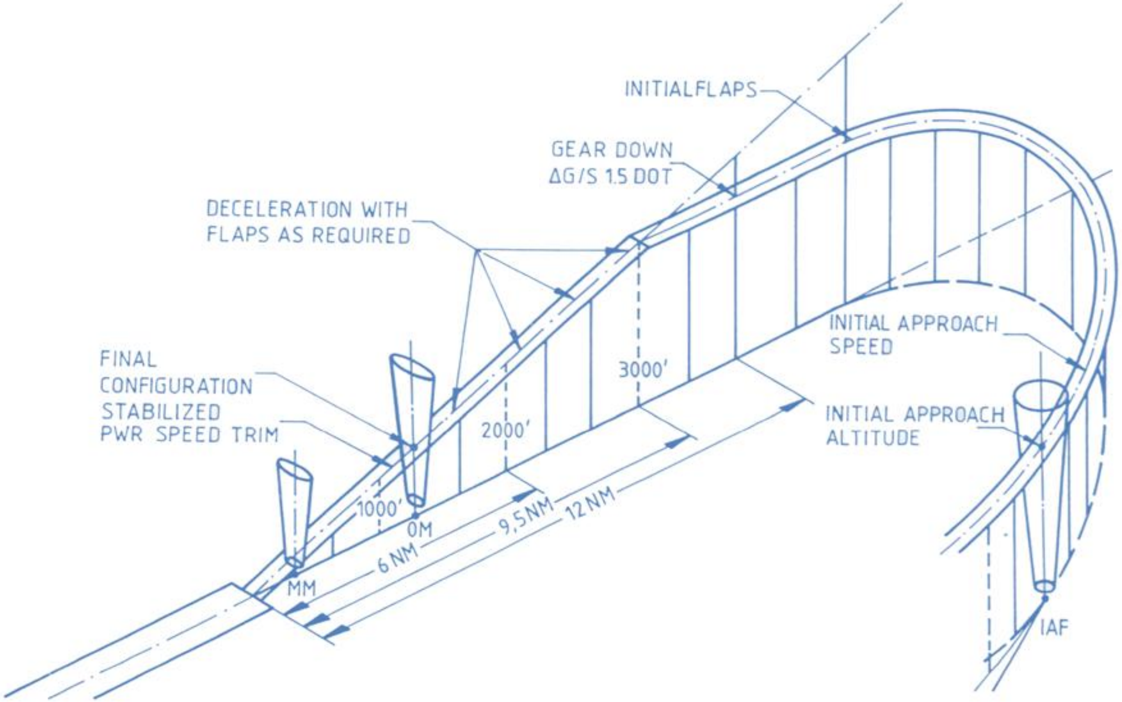
- Using synthetic (digital) radar screen technology:
  - 4 nm separation, when distance is up to 30 nm
  - 6 nm separation, when distance is 30 to 60 nm
  - 8 nm separation, when distance is 60 to 120 nm
  - 10 nm separation, when distance is more than 120 nm

- For the final approach a separation of minimal 3 nm is required.

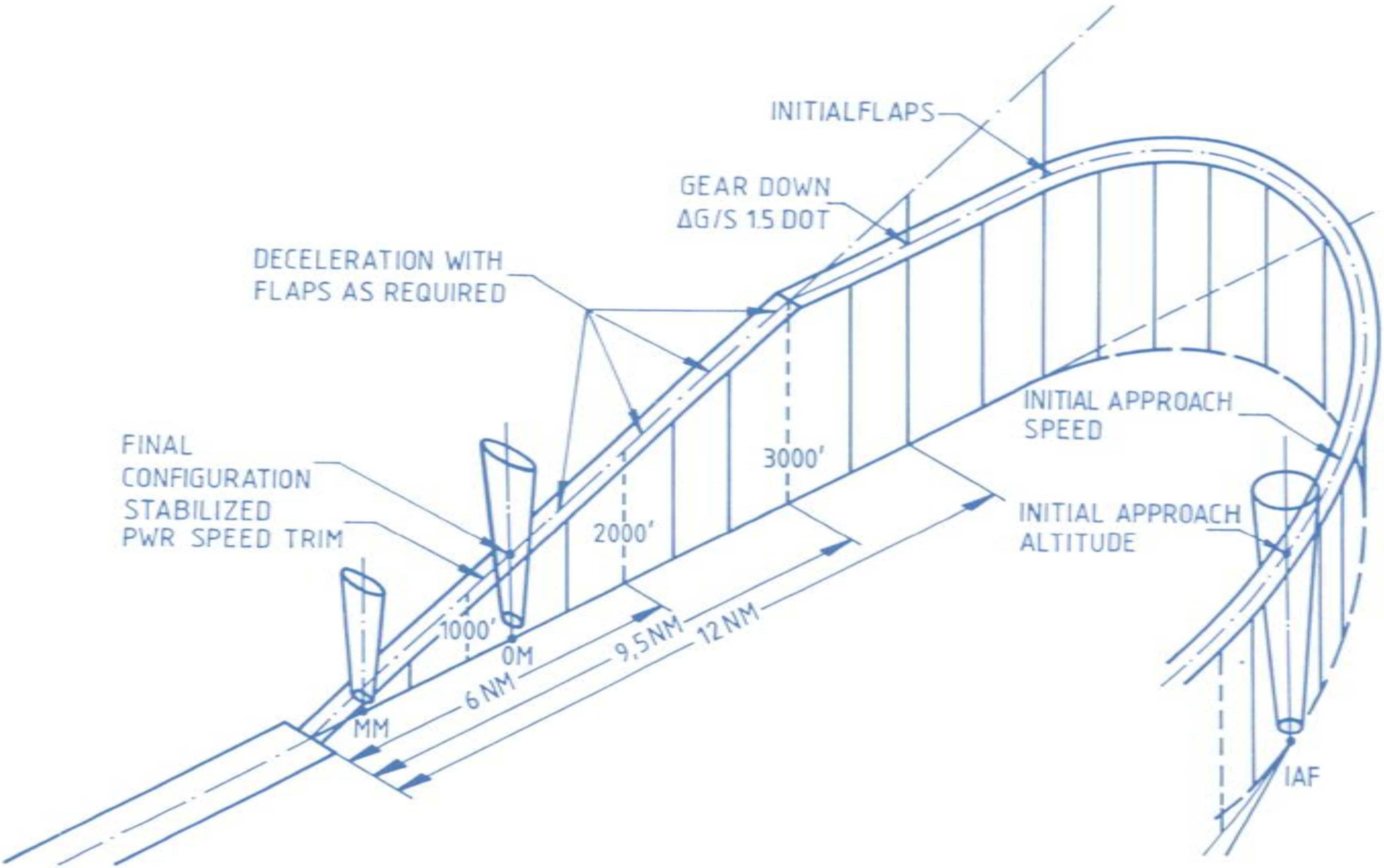
Quelle: Mensen „Moderne Flugsicherung“

Chapter 9.2

Takeoff and Landing

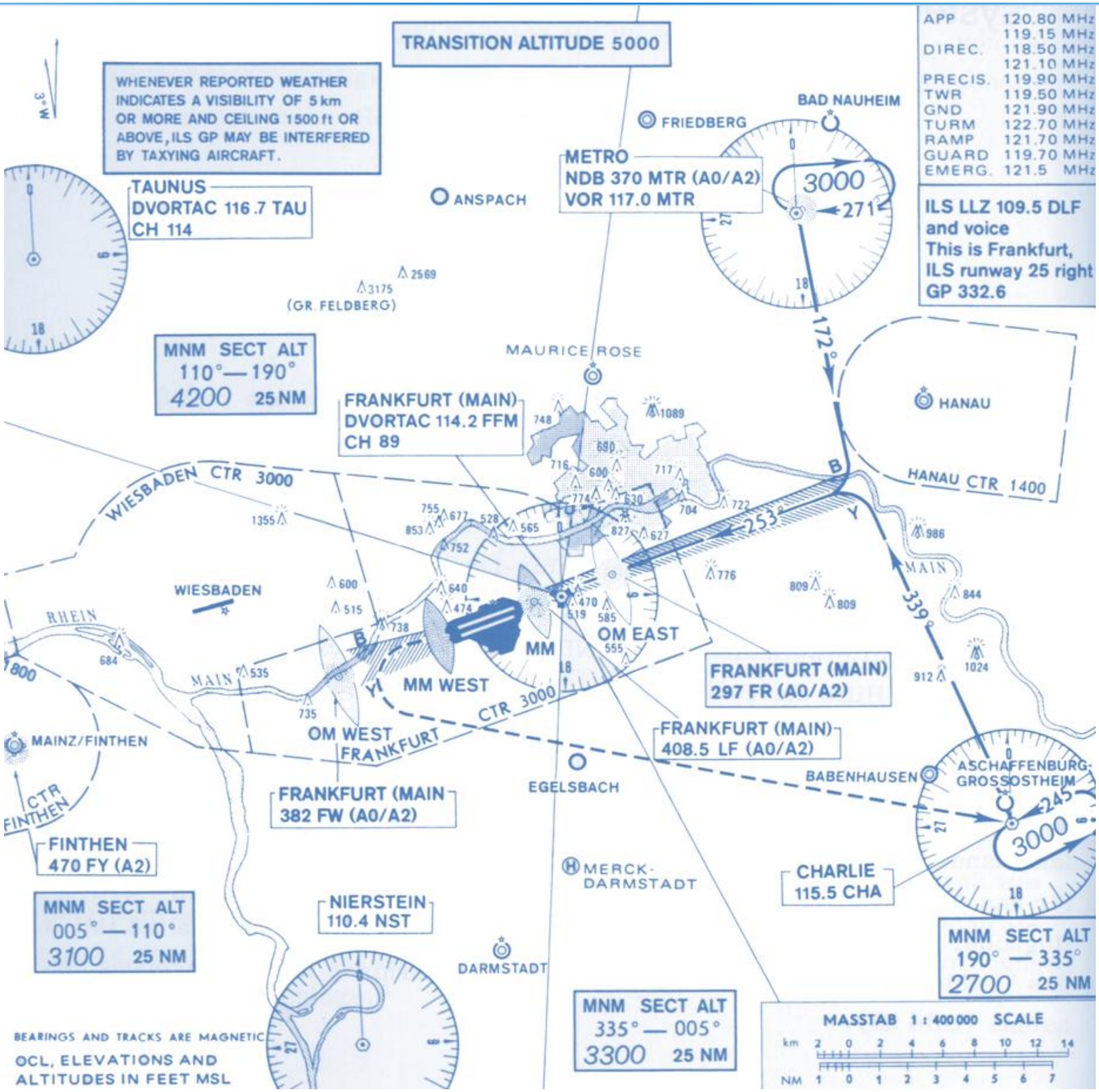


Standard Approach



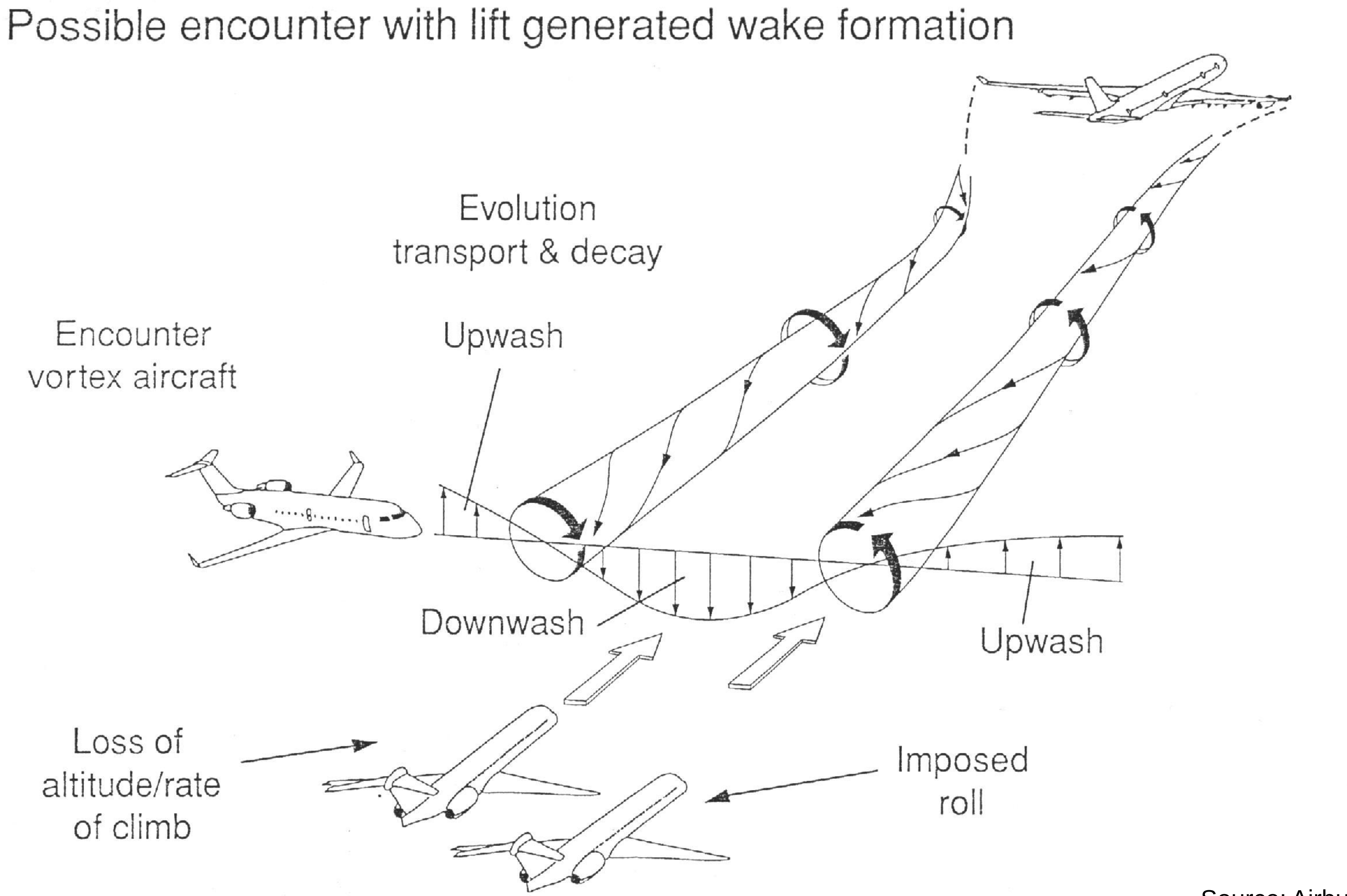
Quelle: Mensen "Moderne Flugsicherung"

Takeoff and Approach Routes



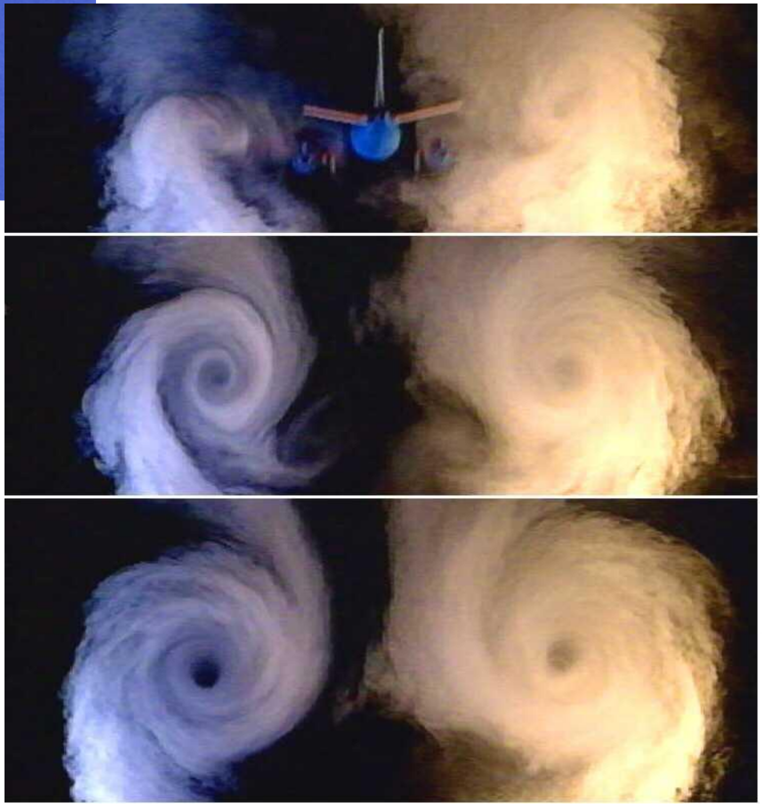
Source: Mensen “Flugsicherung“

Wake Vortex (1)

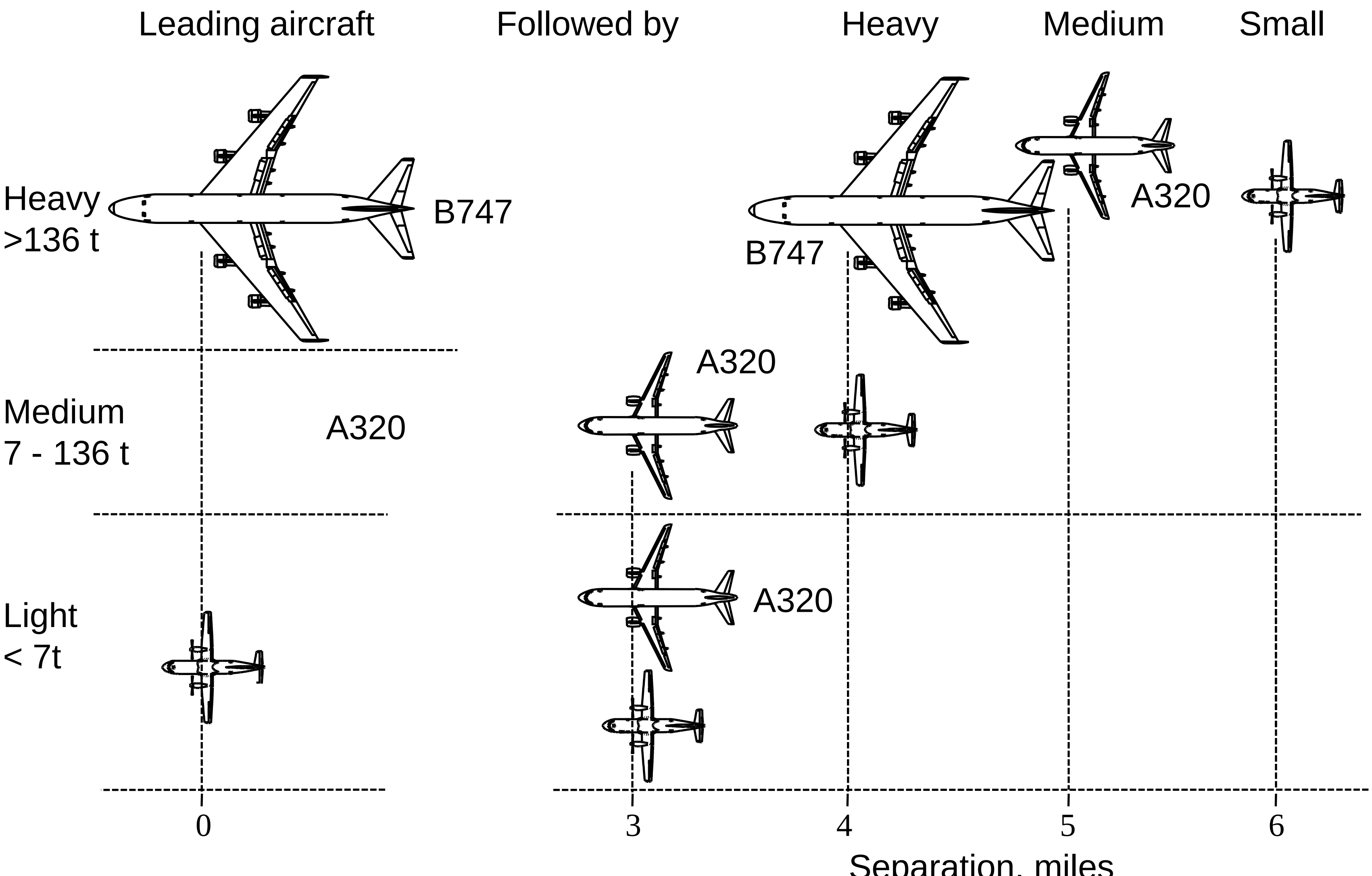


Source: Airbus

Wake Vortex (2)



Wake Vortex - Separation



Quelle: Airbus

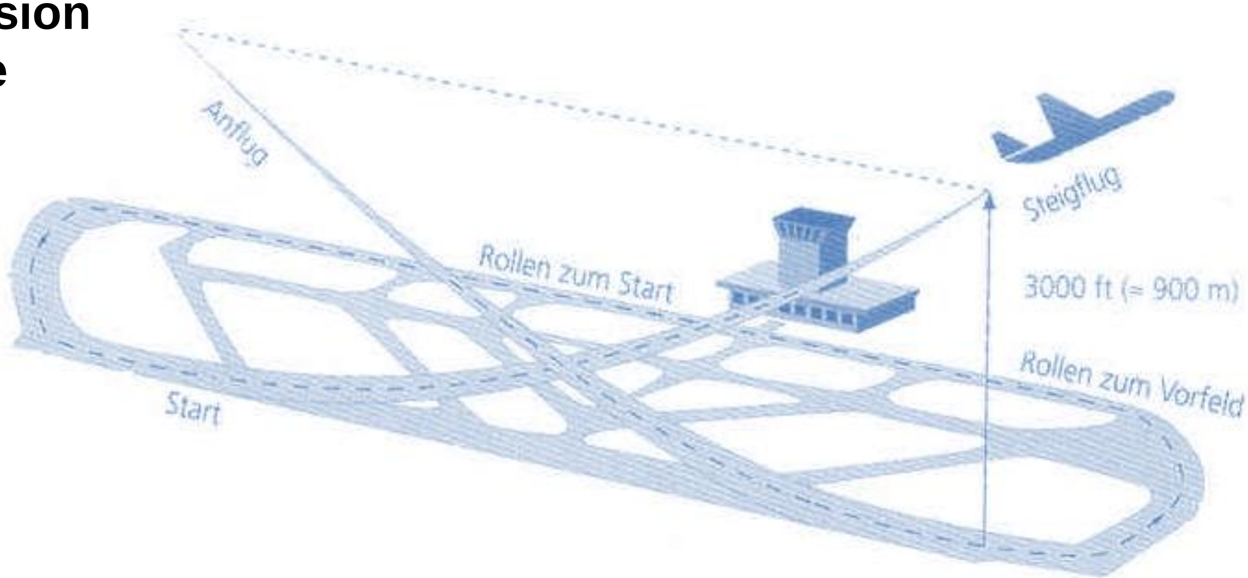
Summary

- A flight can be done under Visual Flight Rules (VFR) or Instrumental Flight Rules (IFR).
- The air space is structured horizontally and vertically. The vertical structure is very important, as the major domain is controlled by national ATC agencies.
- Aircraft are operating at „flight levels“; the flight levels are identified via a barometric altitude measurement. Accuracy of instruments is allowing a separation by 1000ft.
- Collision and wake vortex interaction of following aircraft can be avoided by sufficient horizontal separation (distance) on the same flight level.
- Takeoff and landing procedures are defined for each airport and are published
- For the flight in the controlled air space specific air navigation fees are defined.

Chapter 10

Aviation and Environment

10.1 Exhaust emission
10.2 Aviation noise



Participants of the Civil Air Transport Systems

National Agency

-FAA -NTSB -Min Transp	EASA

Air Trafic Control

International Agencies

ICAO
IATA
FAA / EASA
IAC

Organisations

- Consumers
- Environm. Ag.
- Tourism Ag.
- Hotels

Aircraft industry

- Manufacturer
- Engine Manuf.
- Suppliers

Aircraft

Airlines

- Line
- Low Cost
- Charter

Agencies

- Travel agents
- Freight forward
- Integrators

Passenger

Freight

Maintenance-centres

Airports

Reservation - Systems (Amadeus .)

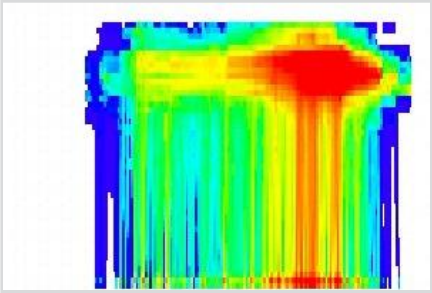
Financing/ Services

-Banks
-Leasing Comp.
-Insurance

Infrastructure

- Meteo services
- Communication

Society

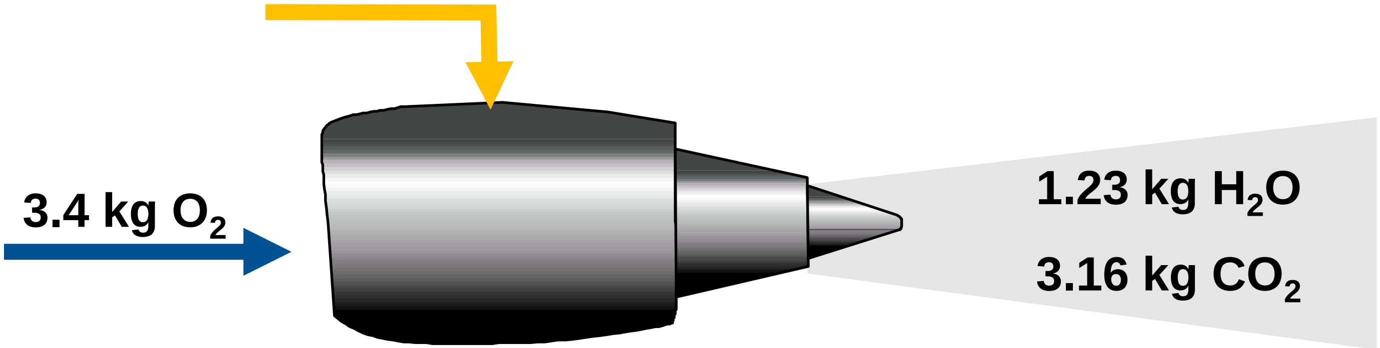
Aviation		
noise	**emissions**	
local	**local**	**global**
		
health of residents	**local air quality**	**climate change**
Environmental impact		
regulations, fees, external costs		

Chapter 10.1

Exhaust emissions in general

Emission products by kerosine combustion

Pro 1 kg kerosine during stochiometrical combustion ca. 4,4 kg exhaust gas develops:



<u>Contaminants in variable amounts pro kg kerosine:</u>

Nitric oxides NOx ~ 4 - 40g
Sulphur oxides SOx ~ 0.6 - 1g
Particles / Soot ~ 0.01 - 0.03g
Hydrocarbons UHC/HC
Traces of OH, methane, lube oil,
Water vapour (contrails)

forms / destroys ozone O_3

destroys methane CH_4

→ ozone and methane are greenhouse gases.

The emissionindex gives the amount of the respective contaminant pro kilogramm burnt fuel:

Emission index EI [g/kg fuel]

Pollutant`s effect on humans and nature near-ground

NO_X (NO and NO_2)
- Impairment of the lungfunction
- During summer support of ozone forming (ozone is poisonous for humans)
- Jointly responsible for acidication / overfertilization of soil and water

CO (carbon monoxide)
- Humantoxic effect: CO binds the red blood pigment hemoglobin 200-300 times better as oxygen -> death through suffocation

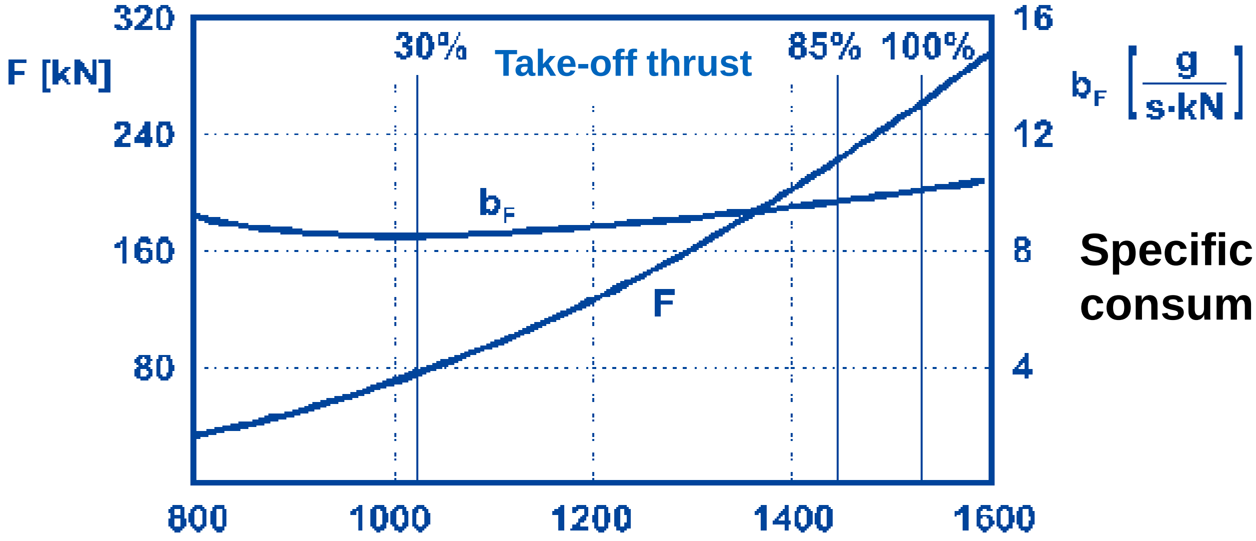
UHC (unburned hydrocarbon)
- Carcinogenic
- Producer of photochemical Smog

SO_2 (sulfur dioxide)
- Responsible for acid rain

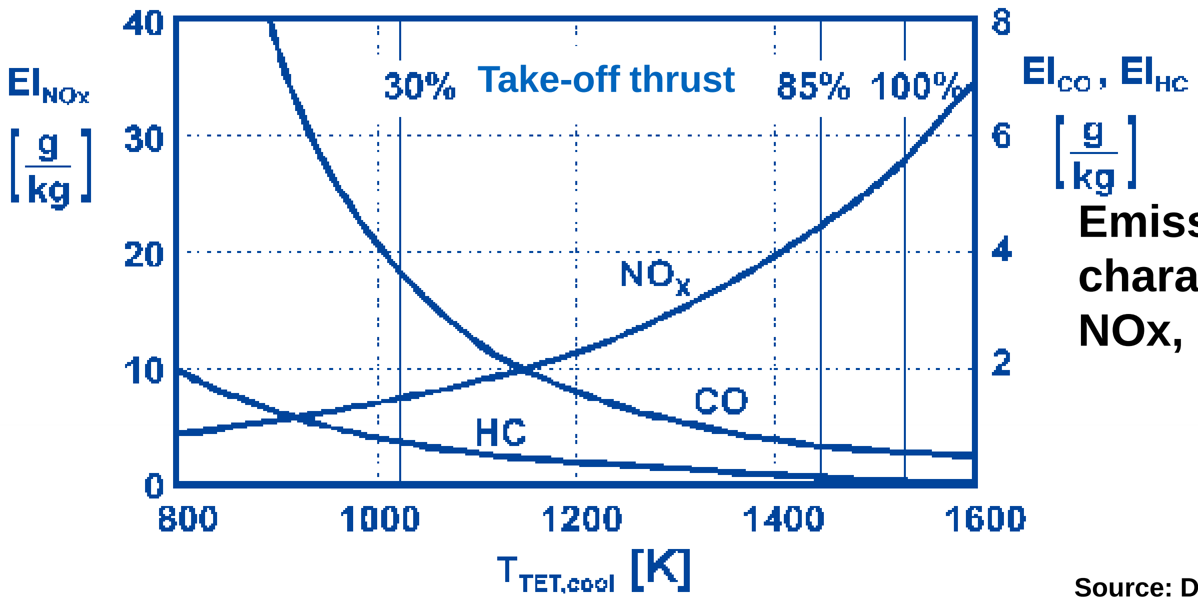
Soot
- Carrier of toxic substances
- Carcinogenic

Source: Österreichisches Umweltbandesamt
Lehrstuhl für Flugantriebe

Dependency of emission characteristics and load level



Specific fuel consumption

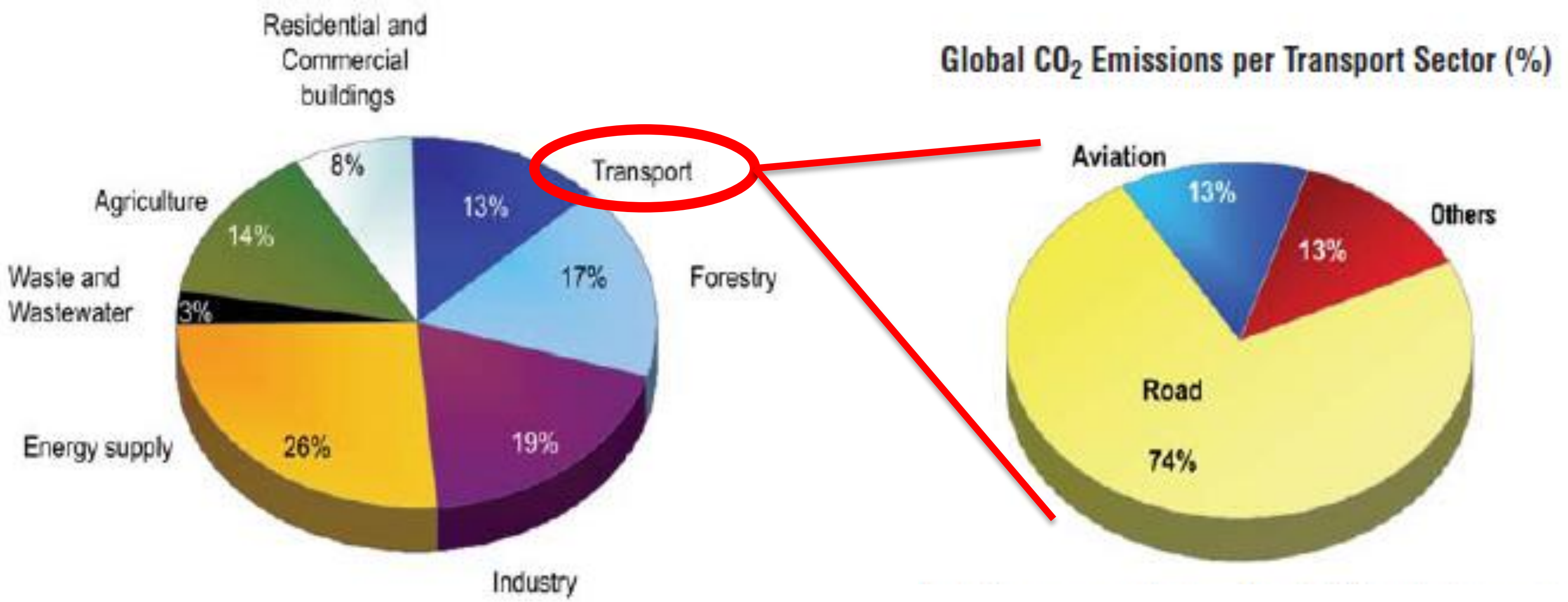


Emission characteristics for NOx, HC and CO

Source: DGLR-Jahrbuch 1994

Comparison to other pollution emitters

Share of aviation in the global CO2-emissions in 2004



In 2004 civil aviation had a share of 2% of the global CO2 emissions.

Source: IPCC

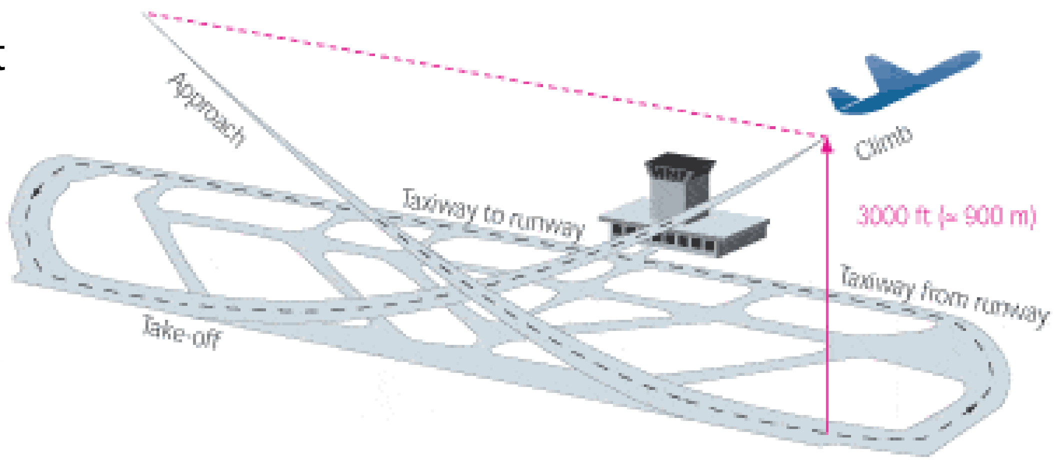
Chapter 10.2

Local impact of the pollutants

Emission calculation of aircrafts – LTO cycle

- The LTO cycle was defined in the 70s through studies and surveys.
- This reference cycle includes all aircraft emissions up to 915 m (3000ft) above the ground. All emissions under this height contribute to the LAQ.
- The measured values are converted to reference conditions of the environment (ISA standard atmosphere on sea level).
- The ICAO LTO-cycle is applicable for rough calculations and simple emission inventories. For detailed studies it is not sufficiently accurate.
- LTO-cycle calculation doesn‘t include:
  - the pilot`s behaviour (e.g. thrust derate),
  - flight profile,
  - aircraft mass or
  - atmospherical conditions.

ICAO LTO Cycle		
Operating Conditions	**At thrust**	**Time**
Taxi Out	7%	19‘
Take-off	100%	0,7‘
Climb	85%	2,2‘
Approach	30%	4,0‘
Taxi In	7%	7,0‘

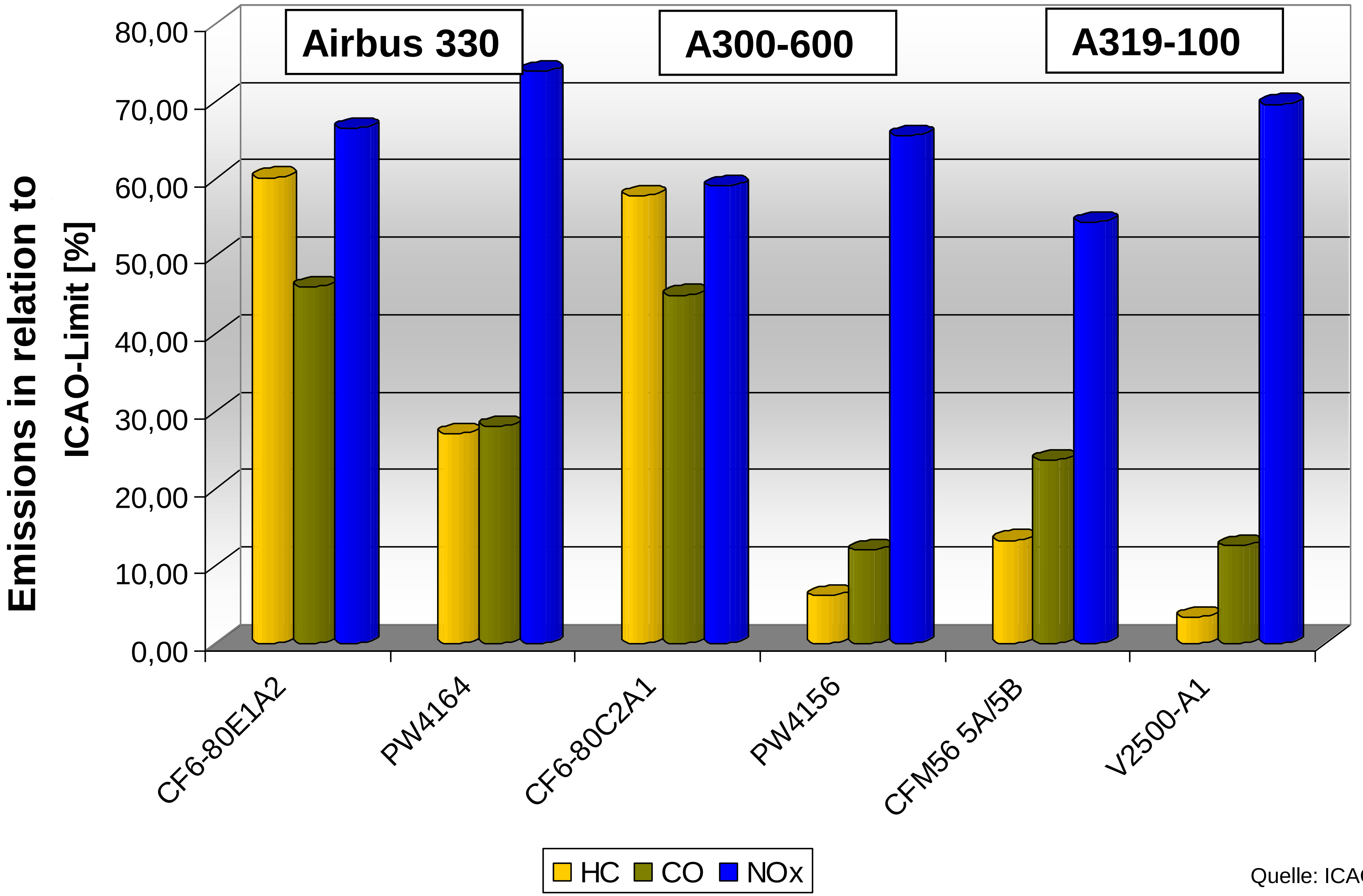


Source: ICAO

Detailed emission calculation aroand the vicinity of the airport

ICAO-LTO Limits

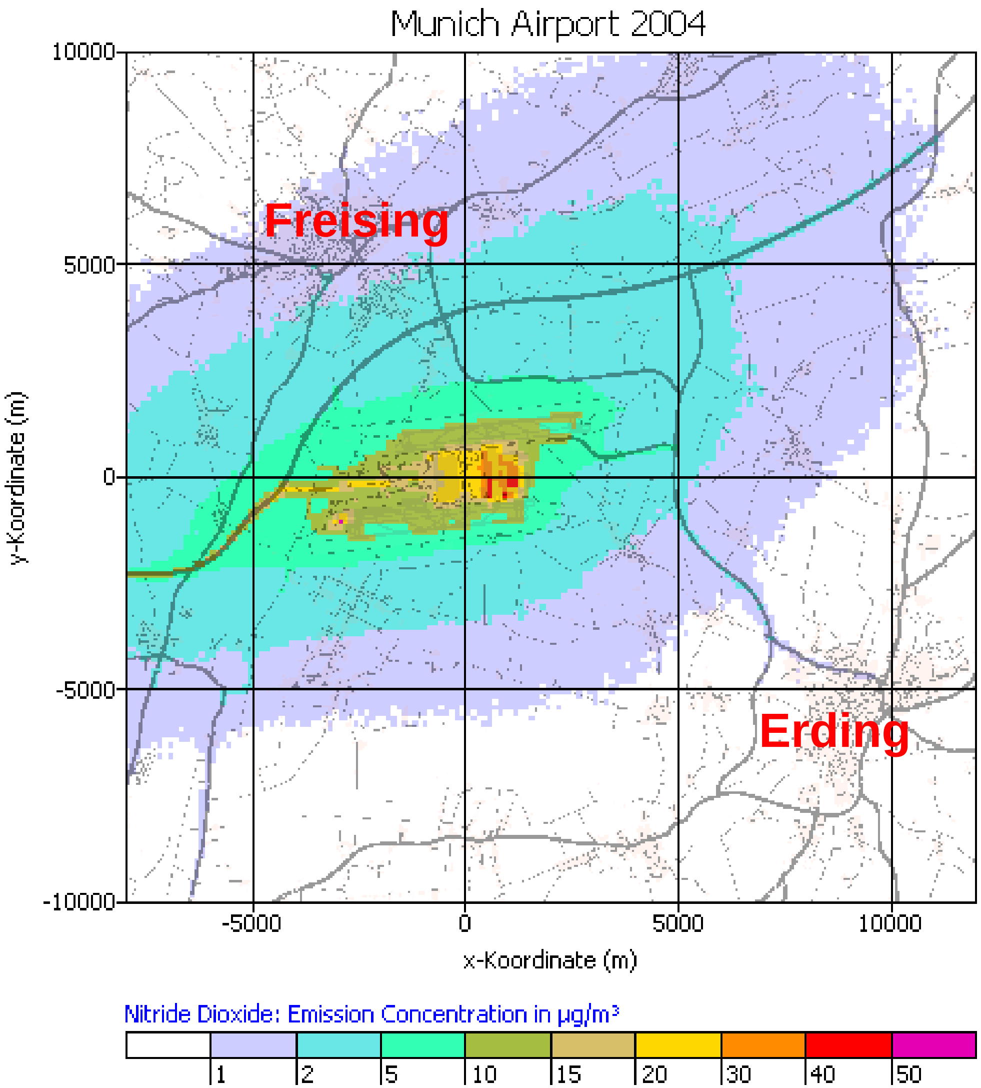
Comparison of engine emissions with LTO-limits:



Quelle: ICAO

The primary emission sources at the Munich Airport

NO_2- Total immission input of the Airport Munich in 2004

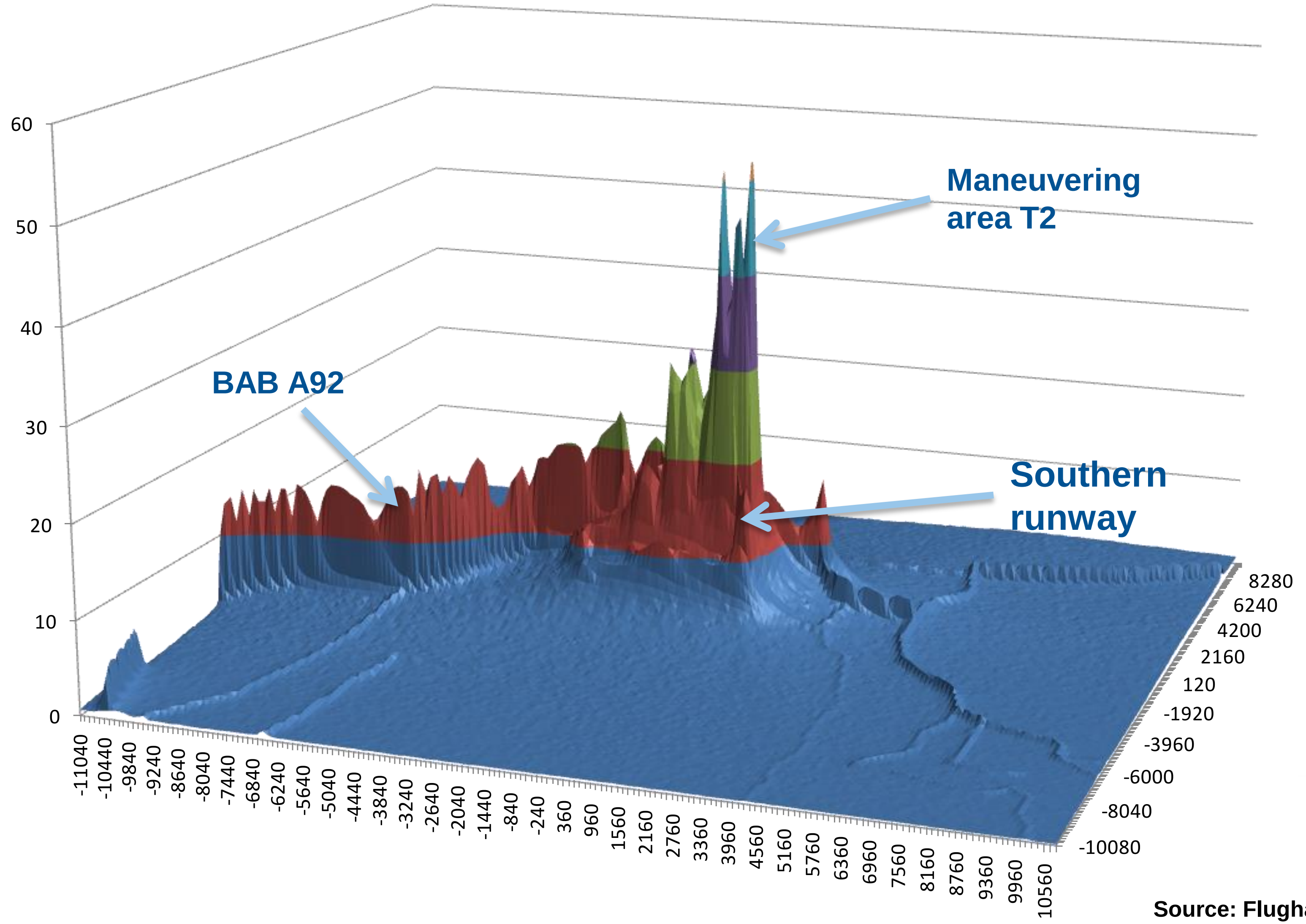


Starting from 2010 the valid, by law regulated annual mean value is 40µg/m³.

The airport adds beyond the airport territory between 5 and 8 µg/m³ NO2 to the annual mean. This equals to 12,5 – 20% of the allowed mean value.

Source: Flughafen Munich GmbH

NO_2- Immission share of the Airport Munich in 2004



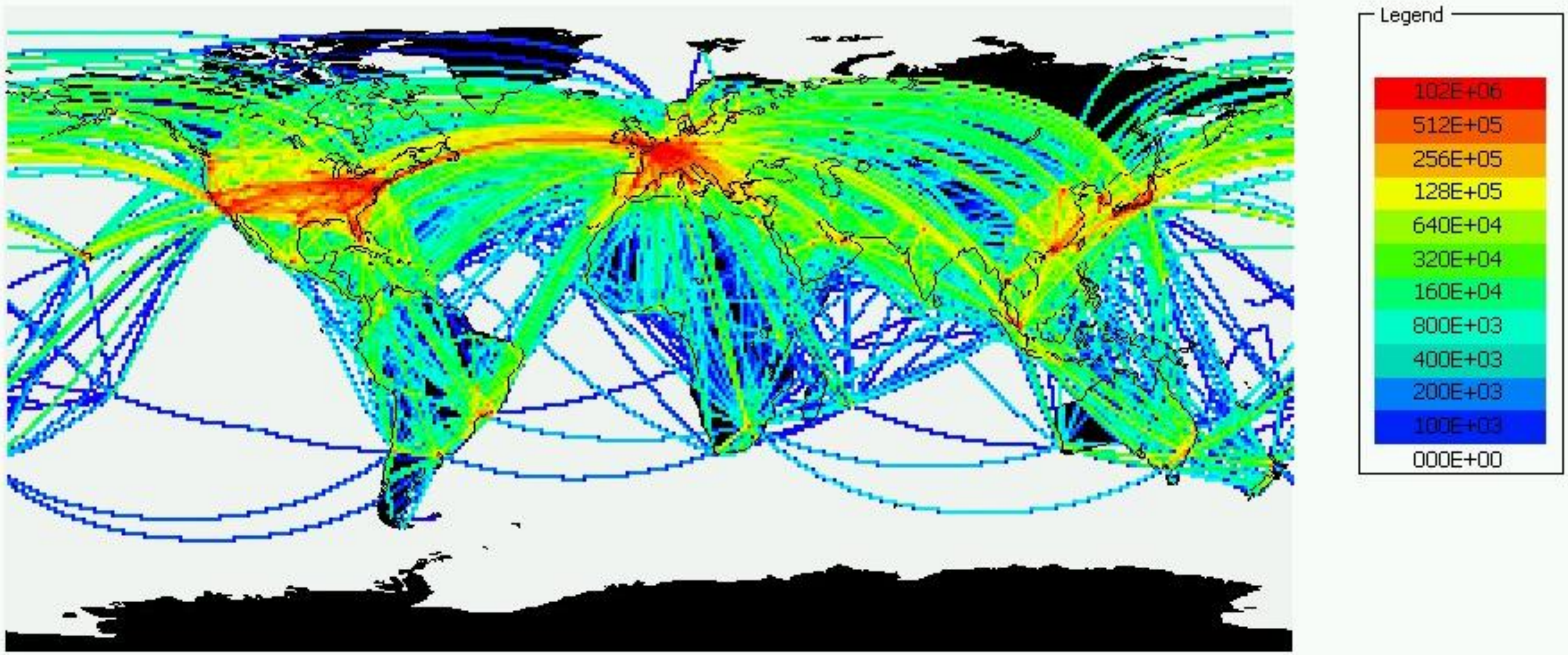
Source: Flughafen Munich GmbH

Chapter 10.3

Global impact
of the pollutants

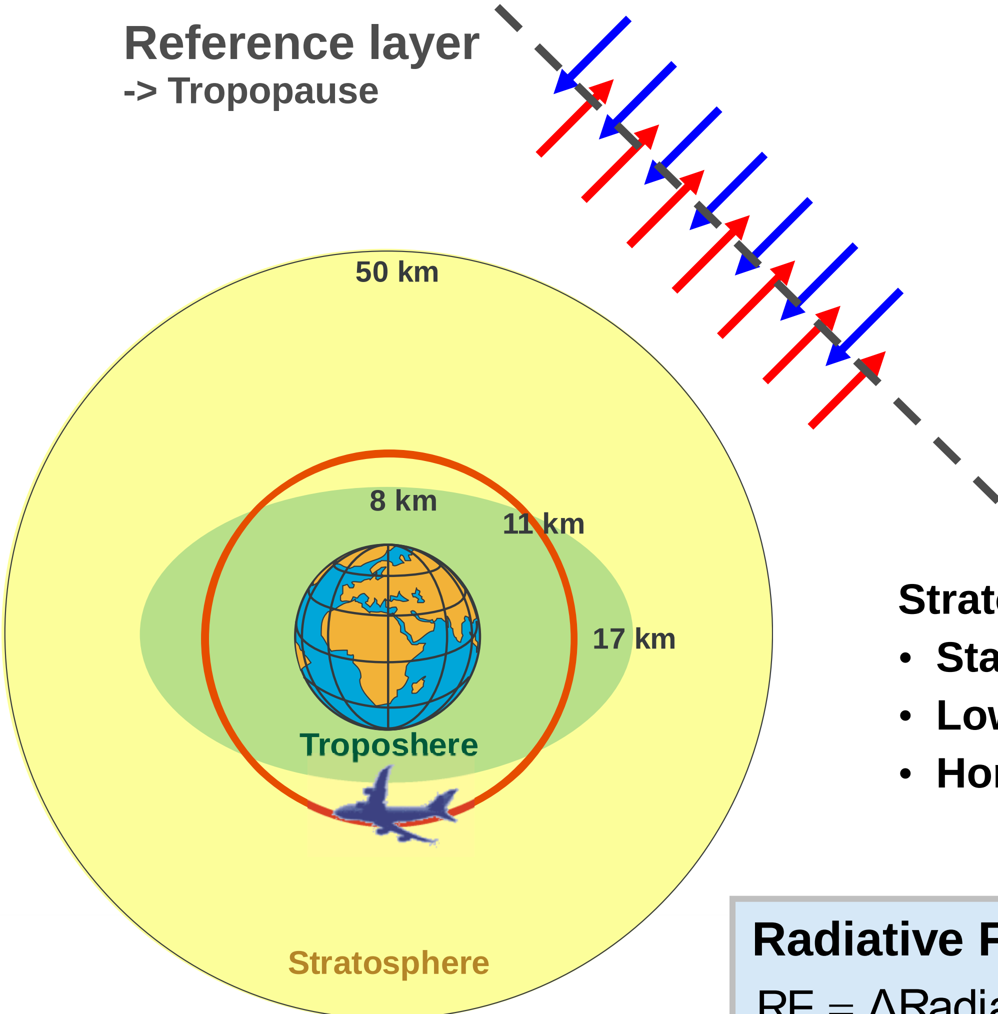
Fuel in *kg/atmospherical cube/year*, summed up over flight levels

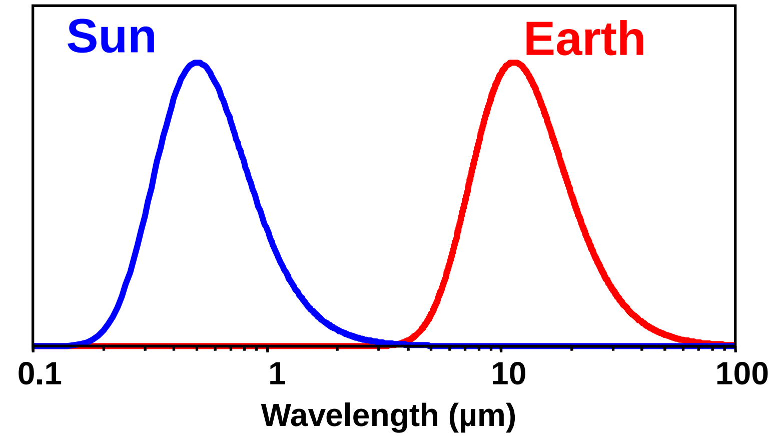
1° Latitude x 1° Longitude x 1000ft altitude



Source: LLS-Calculation, Verkehrsszenario 2002, Optimized flight routes (ATC not accounted)

Reference layer
-> Tropopause





Stratosphere
- Stable layering
- Low humidity
- Horizontal winds

Troposphere
- "Weather layer"
- High humidity
- Horizontal and vertical winds

Radiative Forcing (RF):

$$RF = \Delta Radiation = Radiation_{Sun} - Radiation_{Earth}$$

Climate metrics based upon radiative forcing

Radiative Forcing RF: W/m²/kg

Integration: $GWP_{Absolute} = \int_{Horizon} RF(t)\,dt$

Global Warming Potential: J/m²/kg (Metric of the Kyoto-Protocol)

Heat capacity of the earth considered

Global Temp. Change Pot.: K/kg

Estimation of emission amount

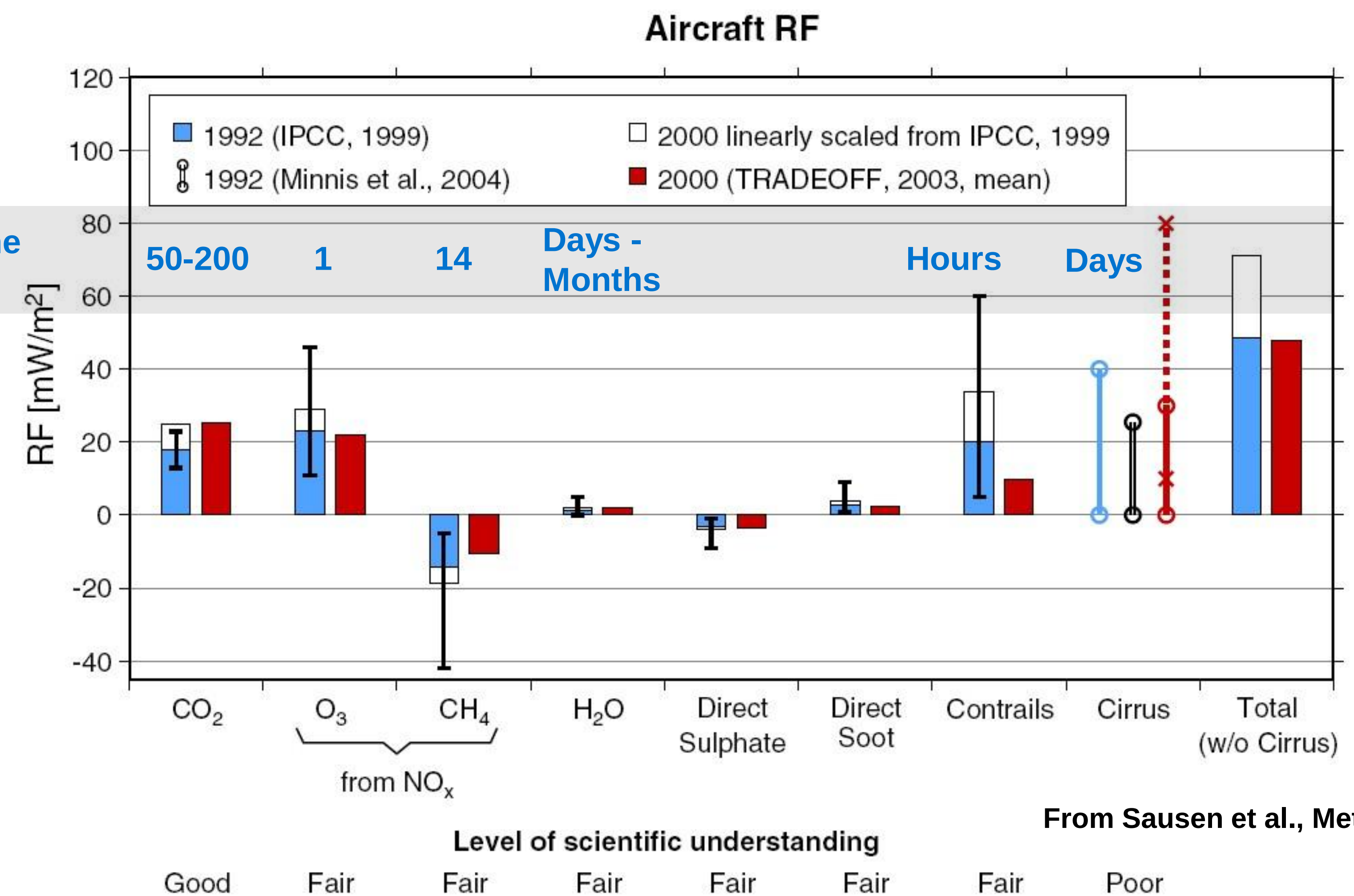
Global Temperature Change: K

Empirical model for durable gases (in aviation only CO_2):

$$\Delta Temp = \lambda \cdot RF$$

Disadvantage: Value of λ depends on the model and gas!

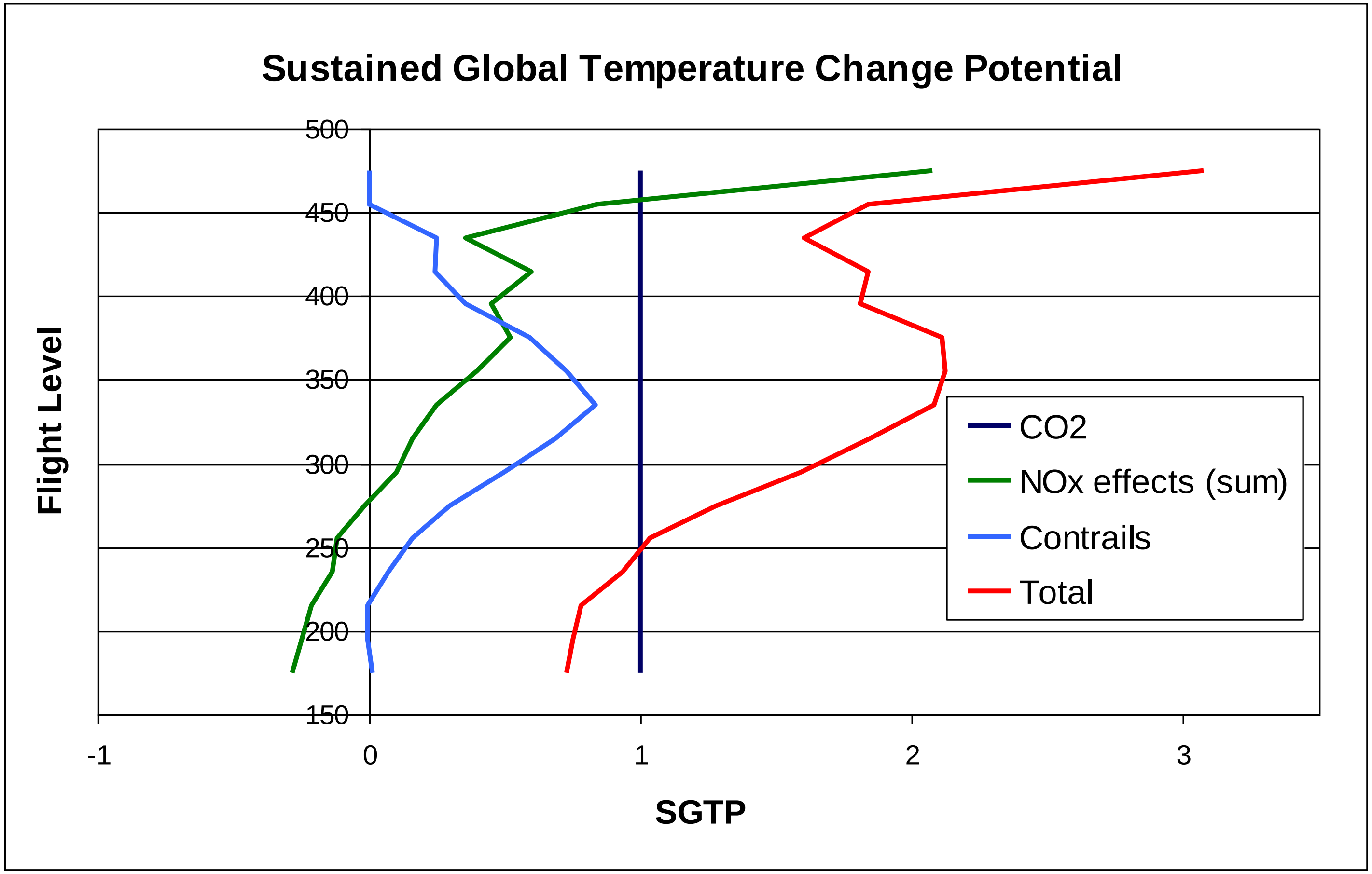
Sources:
Shine et al., 2005
Berntsen et al., 2005
Schumann et al., 2002



From Sausen et al., Met.Z. (2005)

Radiative forcing is NOT suitable as metrics for planning future flights! “backward looking metric”

The LEEA-Project studied the climate effects of airplanes as a function of flight levels. The results still contain considerable uncertainties, yet they supply a first evaluation metric in aircraft design. Currently there are several projects researching similar topics (e.g. DLR in Oberpfaffenhofen: „AirClim“).



SGTP:

Metric based on continuous emissions. Output: temperature change. Here normalized to CO2.

NOx effects:

ozone forming, methane destruction and feedback of the ozone destruction on the methane concentration

LEEA Projekt - Köhler et al., 2006, Rädel et al., 2006, Shine et al., 2005

Global effects of exhaust emission

H_2O
- Formation of contrails
- Greenhouse gas (contributes for 65% of the natural greenhouse effect)
- Climate relevant in form of clouds

CO_2
- Greenhouse gas

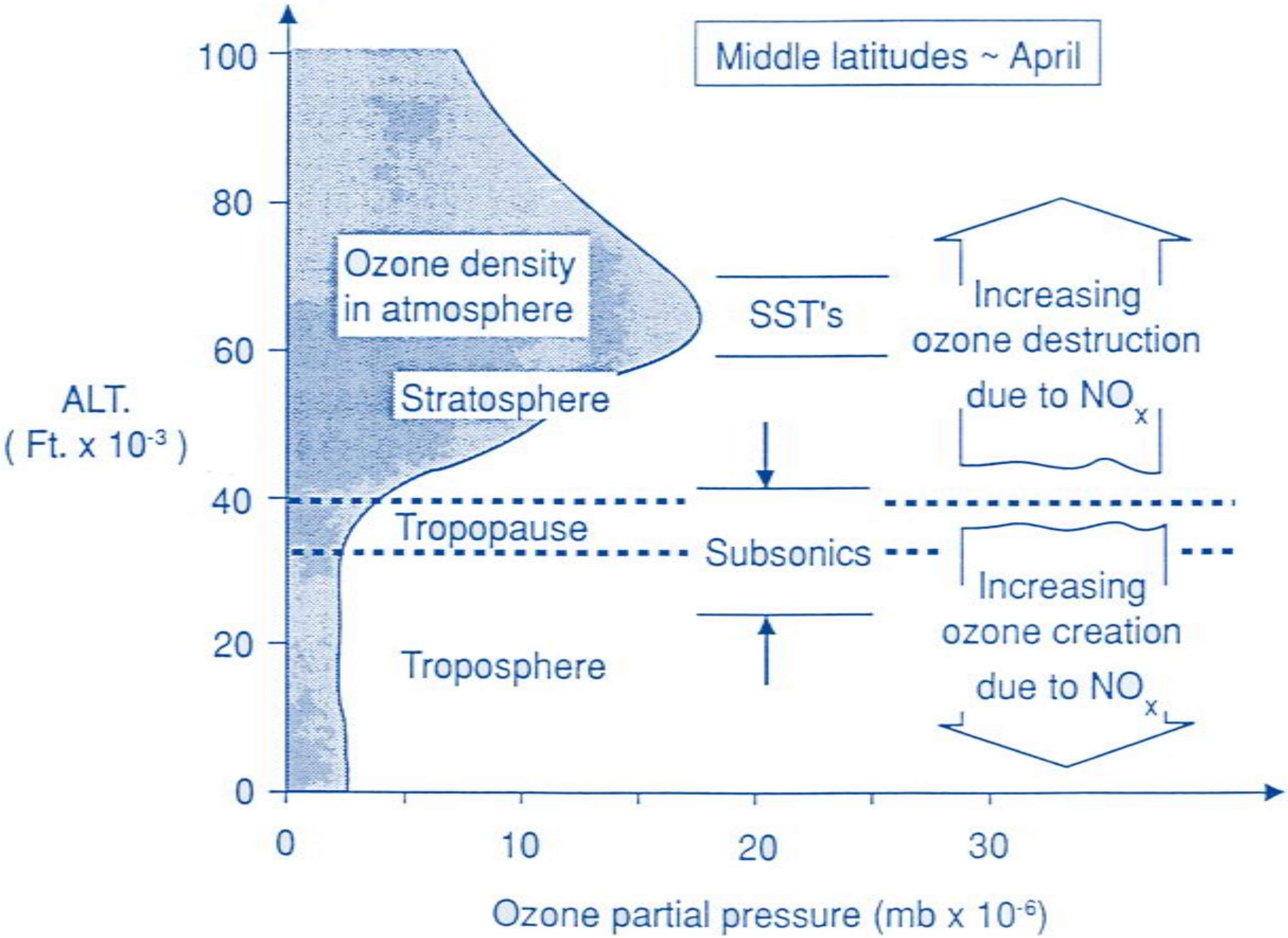
NO_X
- Destruction of ozone in the stratosphere (supersonic aircrafts)
- Forming of ozone in the troposphere (conventional aircrafts)

CO
- With CH_4 (methane) and Hydroxyl-radical relevant for the ozone forming

SO_2
- Influence on aerosol layer and NO_2-concentration
- Annual increase of 5% can presumably traced back to aviation

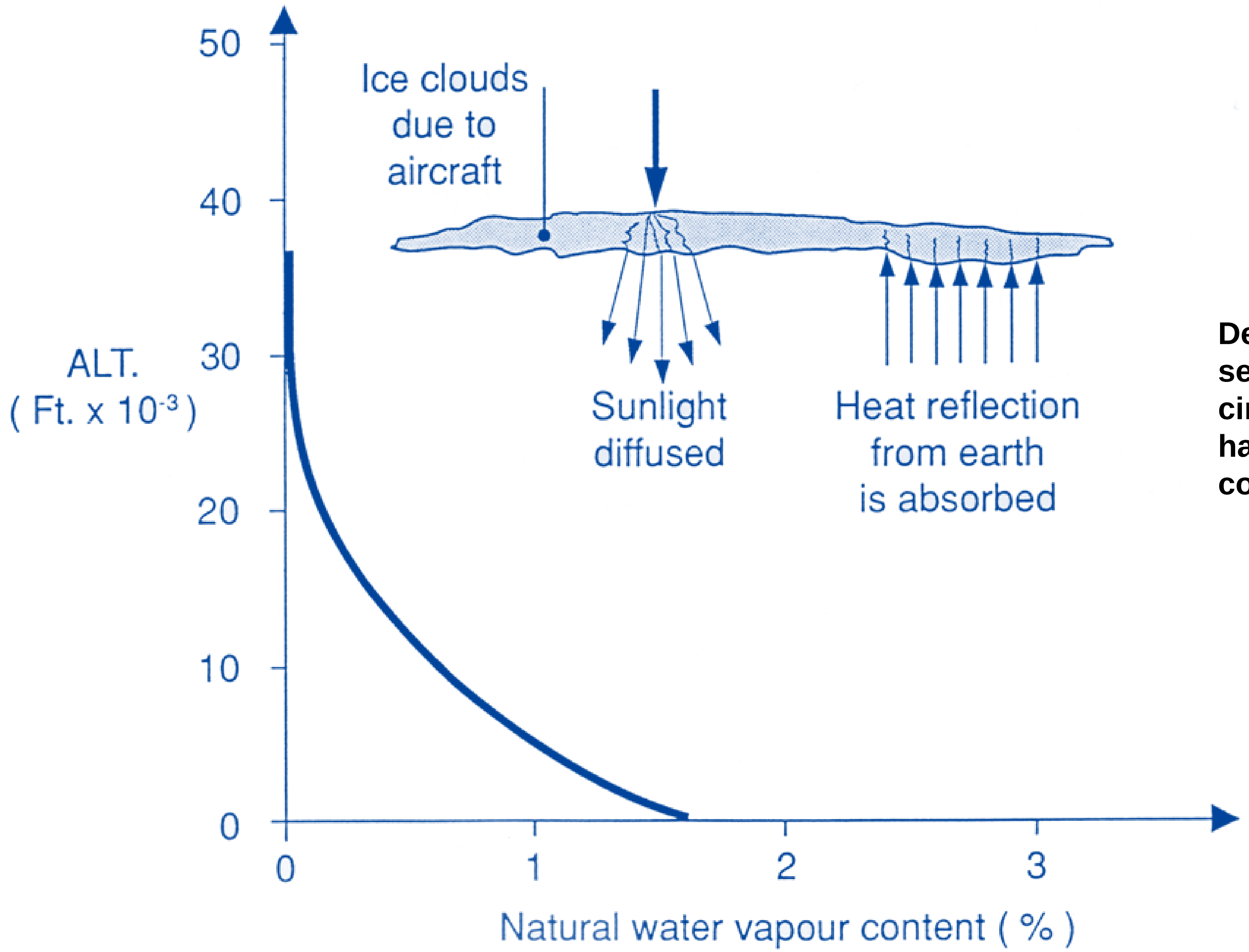
N_2O (laughing gas)
- Influence on ozone in the stratosphere
- Important for radiation balance of the stratosphere (through oxidation of methane)

Influence of NO_x in the Atmosphere



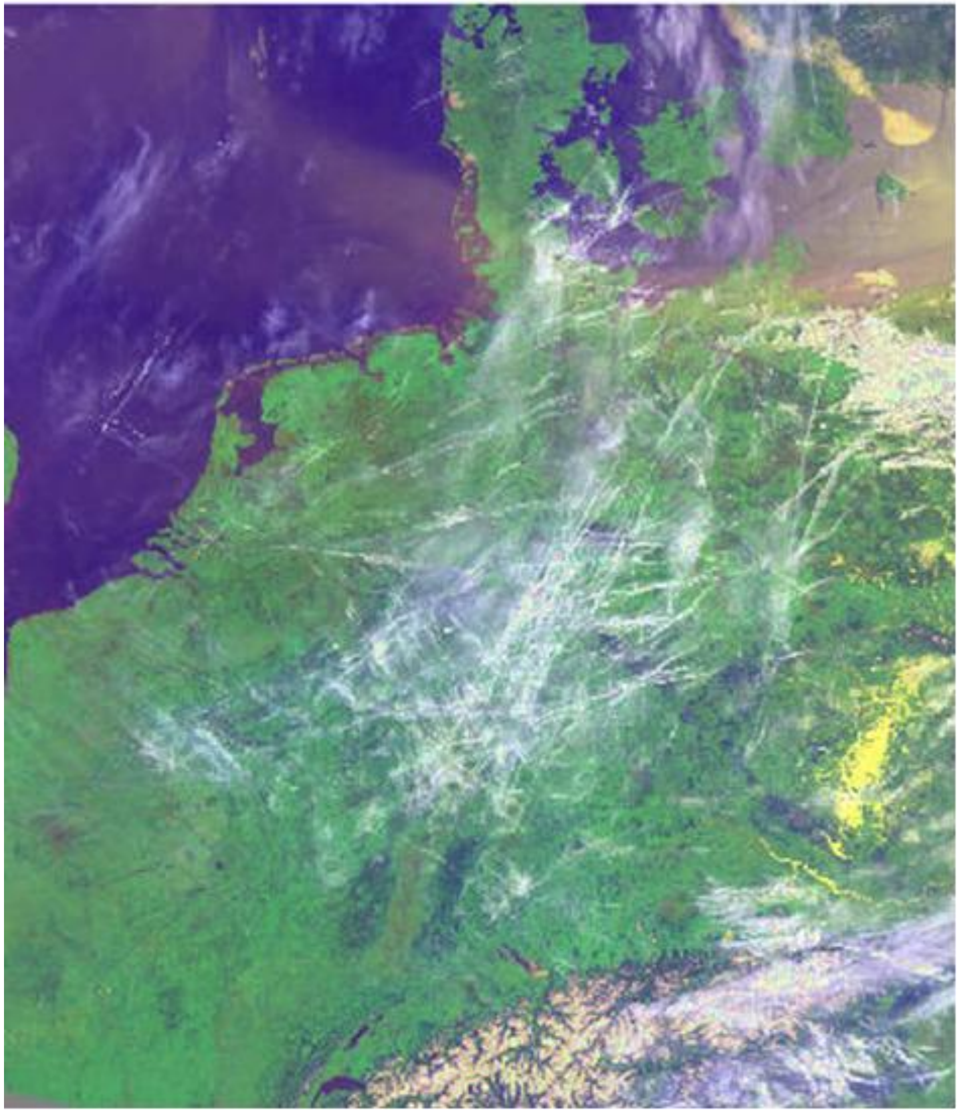
Quelle: Airbus

Effect of cirrus clouds in high altitudes



Depending on day, season and altitude cirrus clouds can have warming and cooling effects!

Contrail - Cirrus



Formation of contrails in supersaturated air and outside temperature T<-40°C

-> conditions typically available in the cruising altitude of 10-13km

Source: DLR

Chapter 10.4

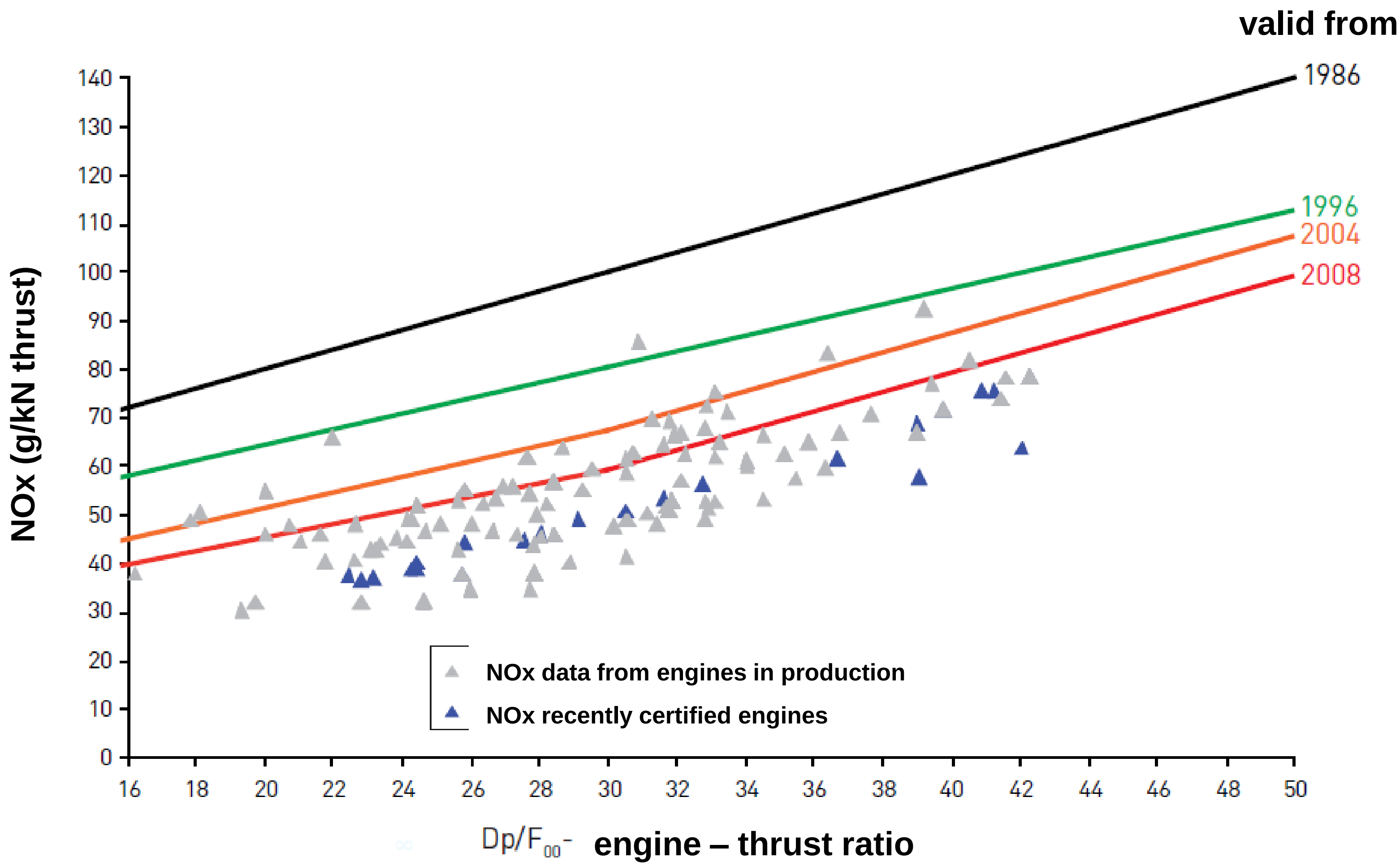
Legal framework

Legal framework - overview

- Approved limit values for aircraft engines according to ICAO Annex 16 Vol II for NOx, CO, HC and soot. The NOx limit values have been tightened several times since 1986.
- Emission dependent landing fee in several European countries (e.g. Switzerland, Sweden, England, Germany)
- ICAO Resolution A 35-5 (October 2004), A36-22 (September 2007)
- Attempts in Sweden to introduce emission charges in addition to the landing fees.
- Environmental fees per passenger in the Netherlands.
- Airlines suggest the passengers voluntary surcharges for compensating the CO2 emission of their flight.
- Implementing aviation into ETS (Emission Trading System) of the European Union from 2012.
- Recurring discussions about the introduction of kerosene taxes.

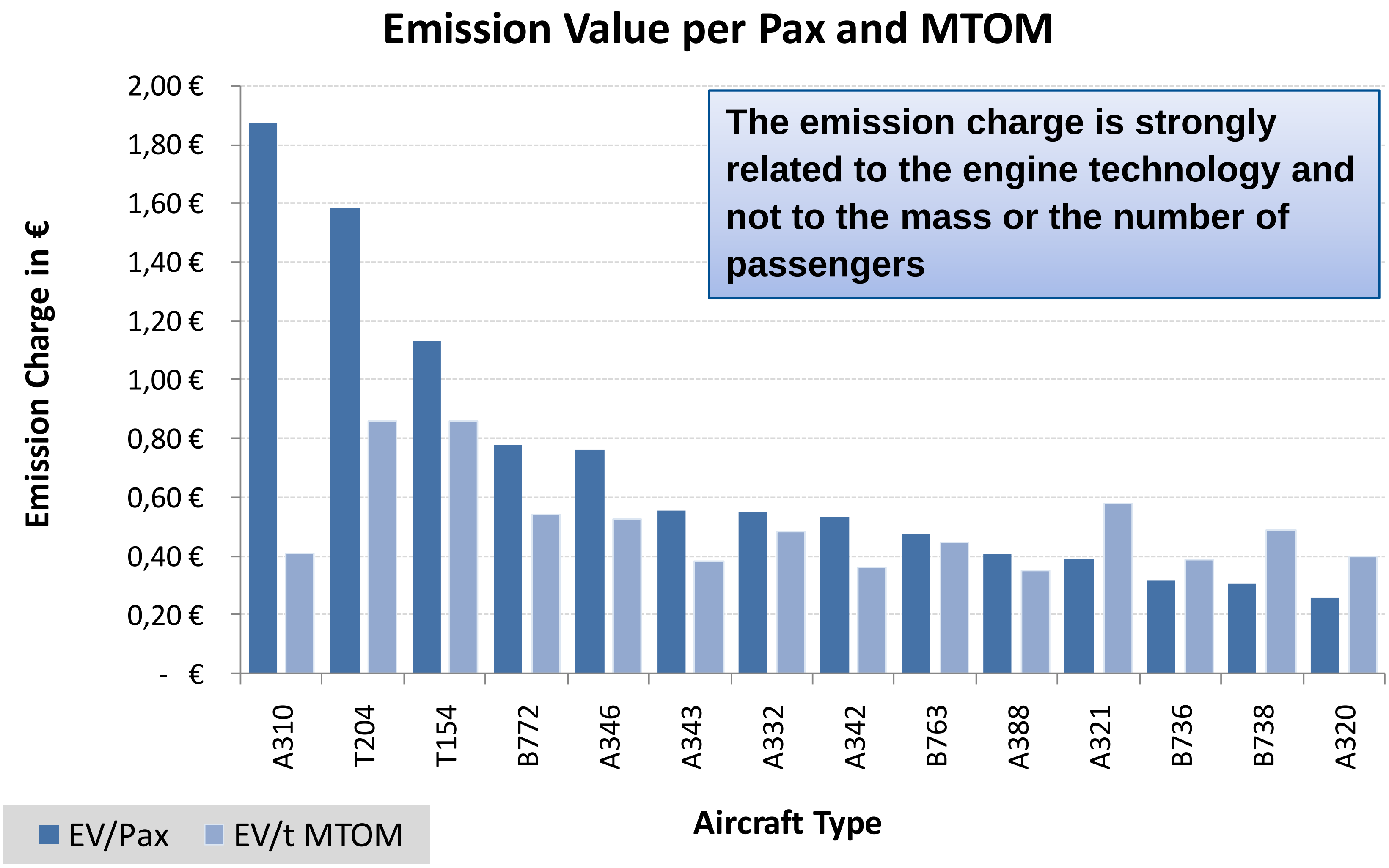
- ICAO ANNEX 16 Volume II – CAEE, CAEP/2, CAEP/4, CAEP/6. Valid for all aircraft engines with Foo (rated output) > 26.7 kN and those manufactured after 1.1. 1983 , excluding turboprops, turboshafts and pistons and turbofan/turbojet engines with Foo < 26,7kN .
- Measurements on engines are run in a special testing environment. The results are referenced on both Sea Level and ISA Atmosphere.
- All member states of the ICAO are required to follow the limit values and the national aviation authorities have to review the engine certificates.
- Through higher efficiency the new engines are tended to have higher pressure conditions and combustion chamber temperatures. This leads to higher nitric oxide NO_x emissions. In order to counter this trend the nitric oxide limits have been incrementally tightened.
  →Altogether 40% limit-reduction since the implementation of CAEP standards.

Tightening of ICAO NOx-limit values since 1986



Source: Unique

Charges per Pax or t MTOM for selected aircraft types



Source: Flughafen Munich GmbH

Decision for emission trading

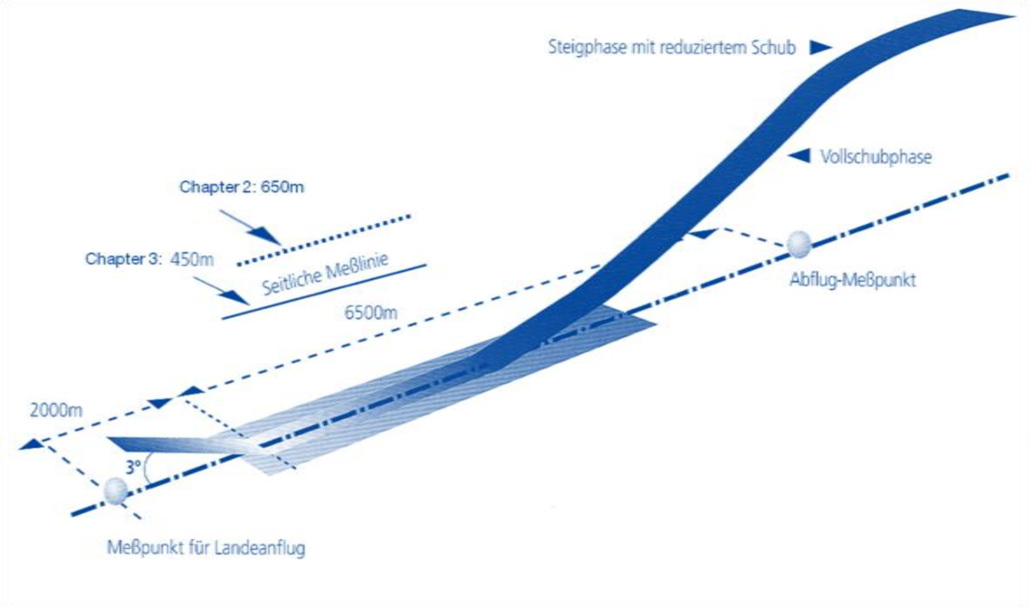
- Decision by the EU-Council on 24.10.2008, to include aviation from 2012 in the european emission trading system. Affacted will be all departing and arriving flights in the EU.
- Semi-open system, meaning the aviation industry can buy certificates from other sectors
- Only CO_2 emissions are considered, no multipliers for nitric oxides or contrails
- The aviation industry will receive a CO_2 budget in 2012, that equals to 97% of the average CO_2 emission output in the reference period of 2004-06. This budget will be cut to 95% in the time 2013-2020.
- In 2008 the USA started planning a CO_2 emission limiting- and tradingsystem. B. Obama plans a market based system where 100% of the certificates are auctioned. The US CO_2 output shall be reduced by 80% of the 1990 levels until 2050. Possibly this could signal the introduction of an international trading system supervised by the ICAO.

Possible effects and sample calculations

- IATA (8.7.2008): Costs for the aviation around 3.4 bn € in the first year with annual increases. In comparison the annual fuel costs are 190 bn €.
- AEA (8.7.2008): Costs for the european airlines around 5.3 bn €.
- DLR: Lufthansa in 2012 can calculate with about 400 Mio. € extra costs, Ryanair with about 270 Mio. €.
- EU-KOM: an outward and return flight within the EU will increase about 9€, one flight to New York around 40€.
- DLR: With a certificate price of 20€ ticket price increases of 1 to 3% are realistic. One Lufthansa flight to London will increase by 3.14€, whereas a flight from Frankfurt to Singapore about 40€.
- MVA Consultancy: With a certificate price of 30€ a KLM flight AMS-LAX will increase in ticket price about 28,10€.
- There is a risk that large airport hubs will be relocated outside of Europe, thus indirectly increasing the climate‘s burden with additional detours.

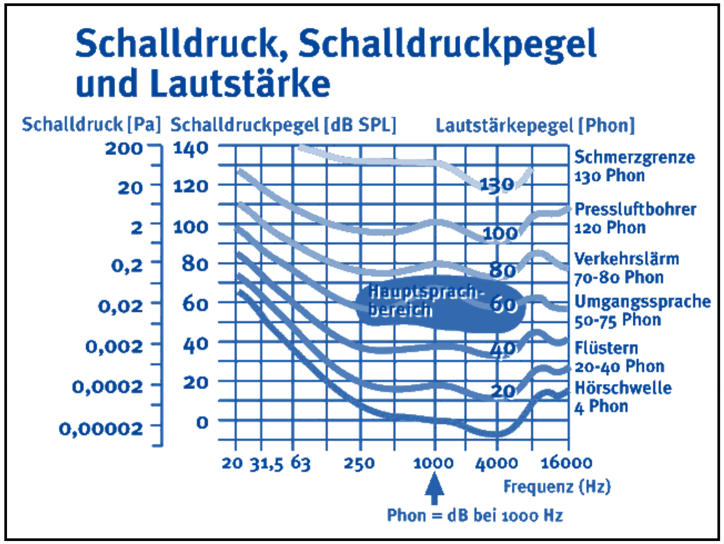
Chapter 10.5

Noise



Chapter 10.6

Definition and correlation
Sound vs Noise



Definitions and correlations by aviation noise (1)

- Soundwaves are vibration of the matter, that can be heard with an ear or verified with physical equipment.
- Sound propagates in the medium (by noise: air) as periodical variation of density in longitudinal waves.
- Soundwaves are characterized in the atmosphere through local sound speed and sound pressure.
- The sound pressure amplitude p of the soundwave is a measurement of the volume:
  - Lowest hearing treshhold: $2 \cdot 10^{-5}$ Pa
  - Hearing pain: $2 \cdot 10^{2}$ Pa

  Sound pressure is generally given in sound pressure level (SPL):

  SPL=20 · log $^{p}/_{p_0}$ [dB] p_0=Reference pressure= $2 \cdot 10^{-5}$ Pa
- Sound intensity (I) is a quantitative physical unit for the energy transport of a soundwave:

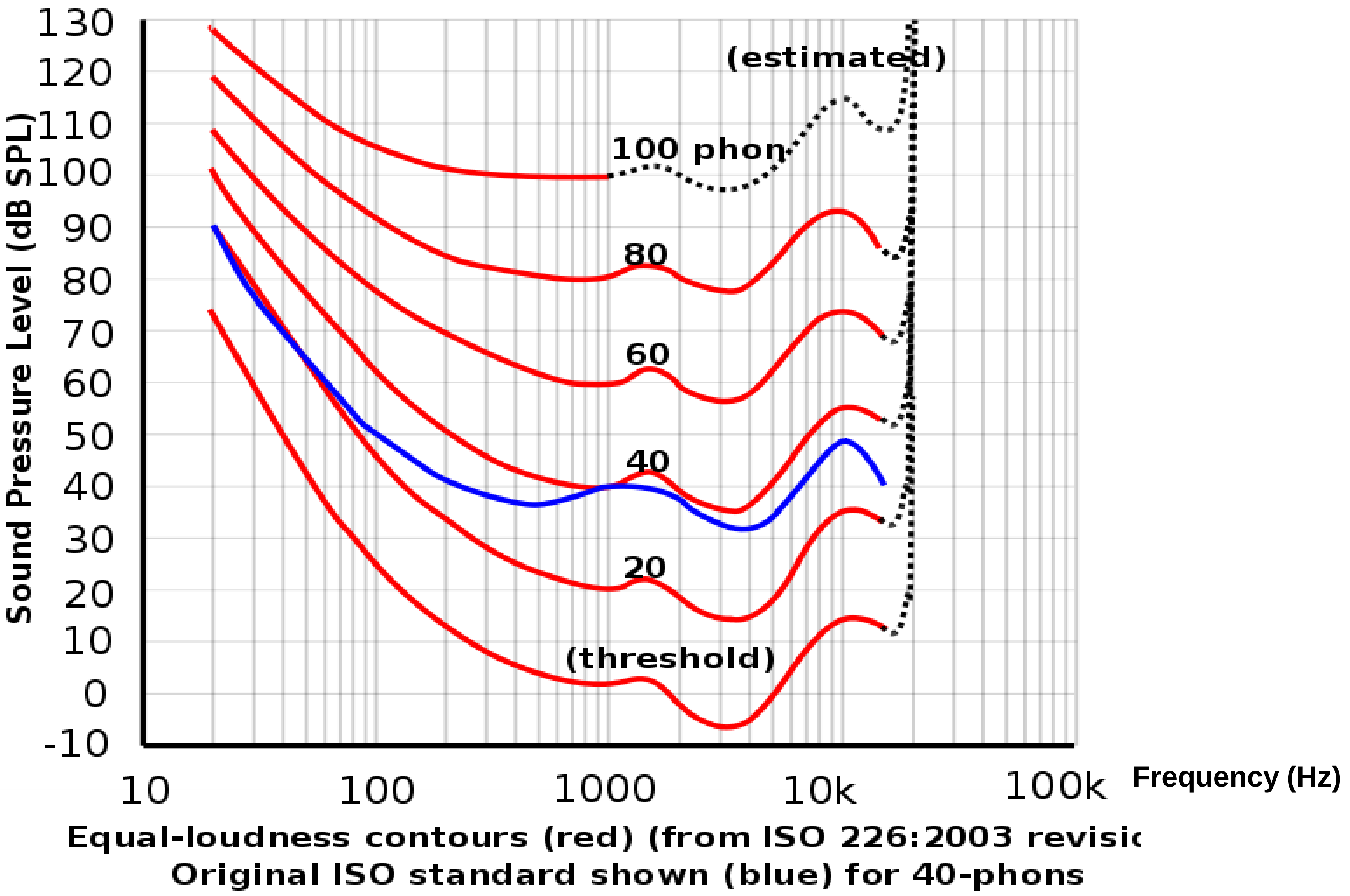
$$I = \frac{P^2}{\rho \cdot c} = \frac{Power}{Area}\left[\frac{Watt}{m^2}\right] \qquad \text{Gauge}: L_I = 10 \log \frac{I}{I_0} = [dB]$$

ρ=Density of the carrier medium

c=Speed of sound in the carrier medium

I_0=Reference intensity=10^{-12} W

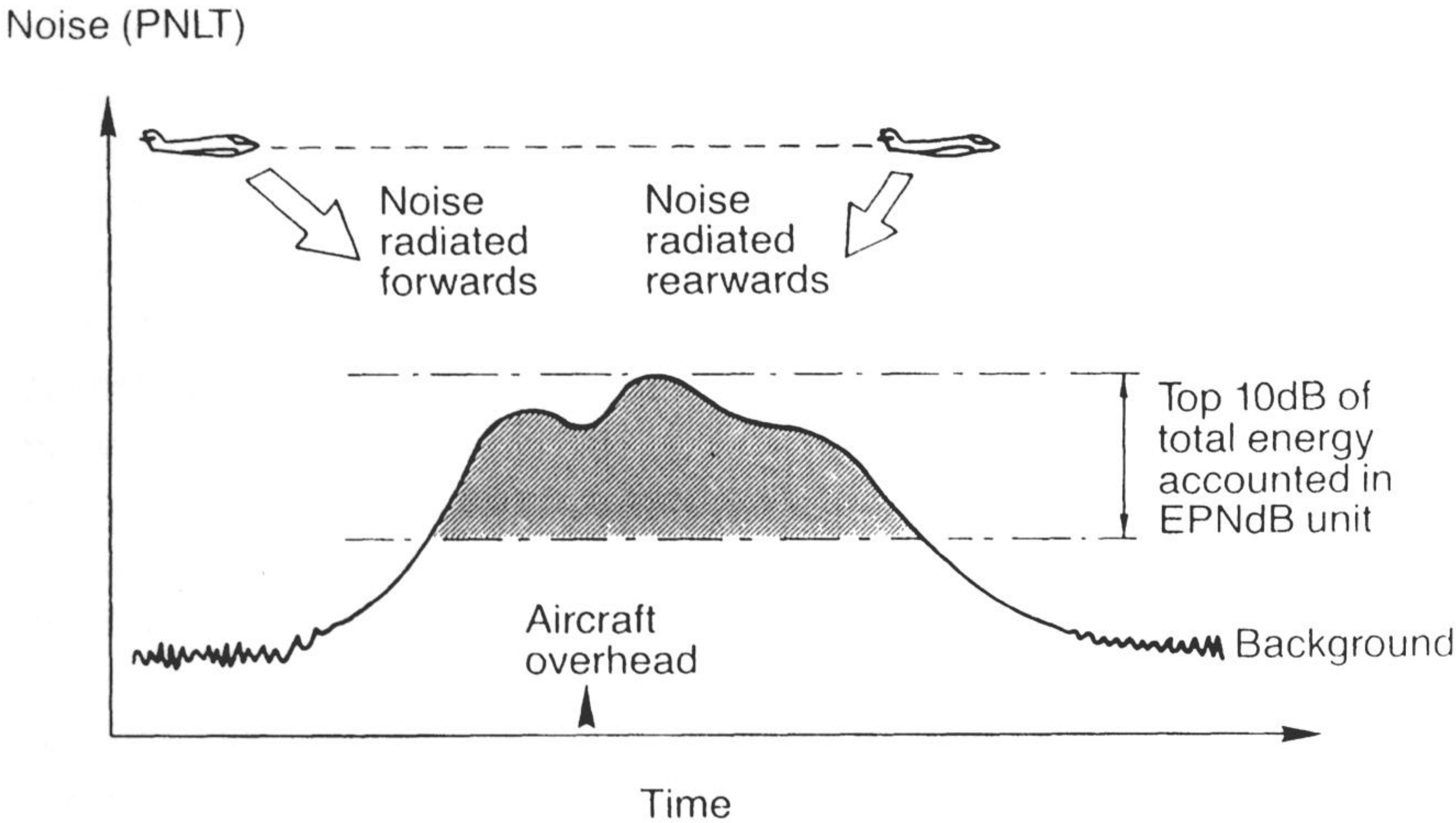
Correlation between sound, frequency and volume



Noise: subjective evaluation of the sound disturbance

- **Momentarily Maximum Level:**
  - **Perceived Noise Level (PNL):**
    Measurement for the momentarily perceived noise, determined by empirical weighting of the intensity of specific frequencies to the total perceived noise.
  - **Tone Corrected Perceived Noise Level (PNLT):**
    Adding a tone correction C for tone noise in the frequency spectrum:
    PNLT=PNL + C
  - **A – Evaluated noise level (L_A):**
    Evaluating of the momentarily perceived noise after the A-evaluation curve. This frequency evaluation is used for multiple noise sources.
- **Maximum Level for an event:**
  - **Effective Perceived Noise Level (EPNL):**
    Measurement of perceived noise considering the progression of the event in time. Adding a permanent correction D through integration of the momentarily maximum level PNLT over time. All levels are considered that are higher than $PNLT_{MAX}$-10 dB:
    EPNL=PNLT + D [EPNdB]

Assessment of EPNL

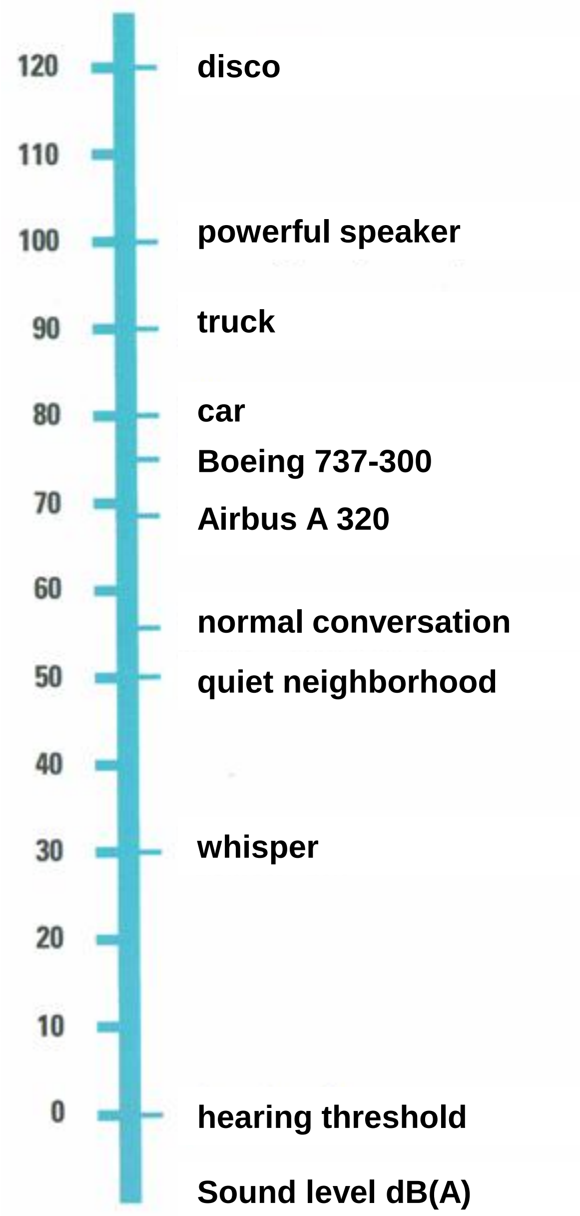


- **Sound Exposure Level (SEL):**
  Measurement of momentarily perceived noise while considering the progression of the event in time. Analogous to the calculation of EPNL, only without the tone correction and with the A-evaluated noise level as basis.

Level for multiple events

- **Weighted Equivalent Continous Perceived Noise Level (WECPNL):**
  Measurement of the noise pollution at an airport through integration of the measured EPNL for one year. This unit is barely in use.
- **Energy equivalent Continuous Sound Level (L_{eq})**:
  Metric for the noise emission during a day on the basis of SEL. Often used in Europe for noise assessment.
- **Day-Night Level (DNL):**
  Measuring noise emission on one day based on SEL. Often used in the US. During the night noises are valued 10 dB higher than during daytime.

Noise values



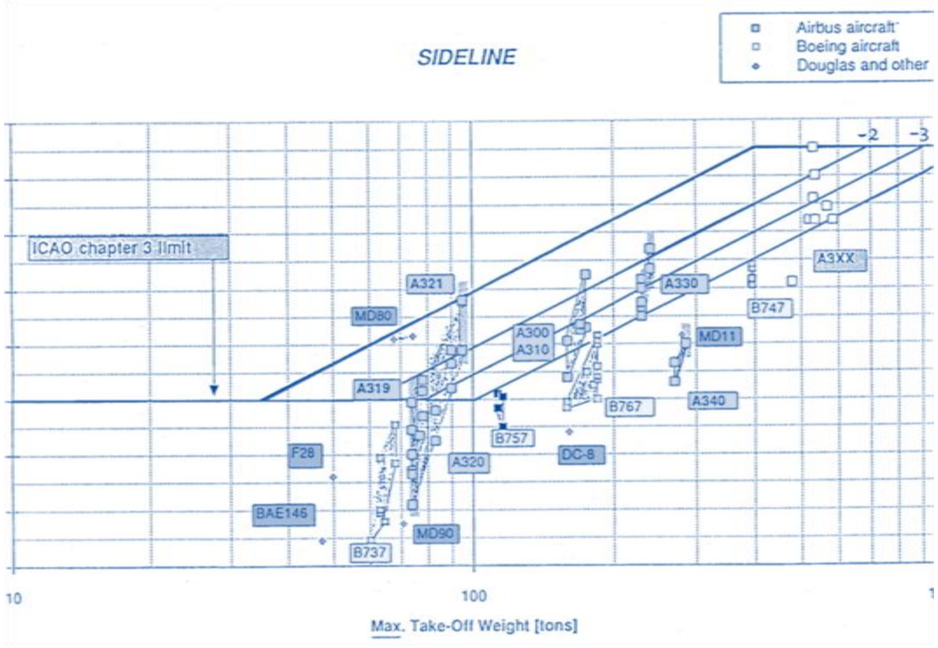
The values have been measured in the following distance:

- **Aircrafts at the 6500 meter extension of the runway**
- **Road vehicles 7,5 meter**
- **Speakers 2 meter away from the soundsource.**

Source: Lufthansa

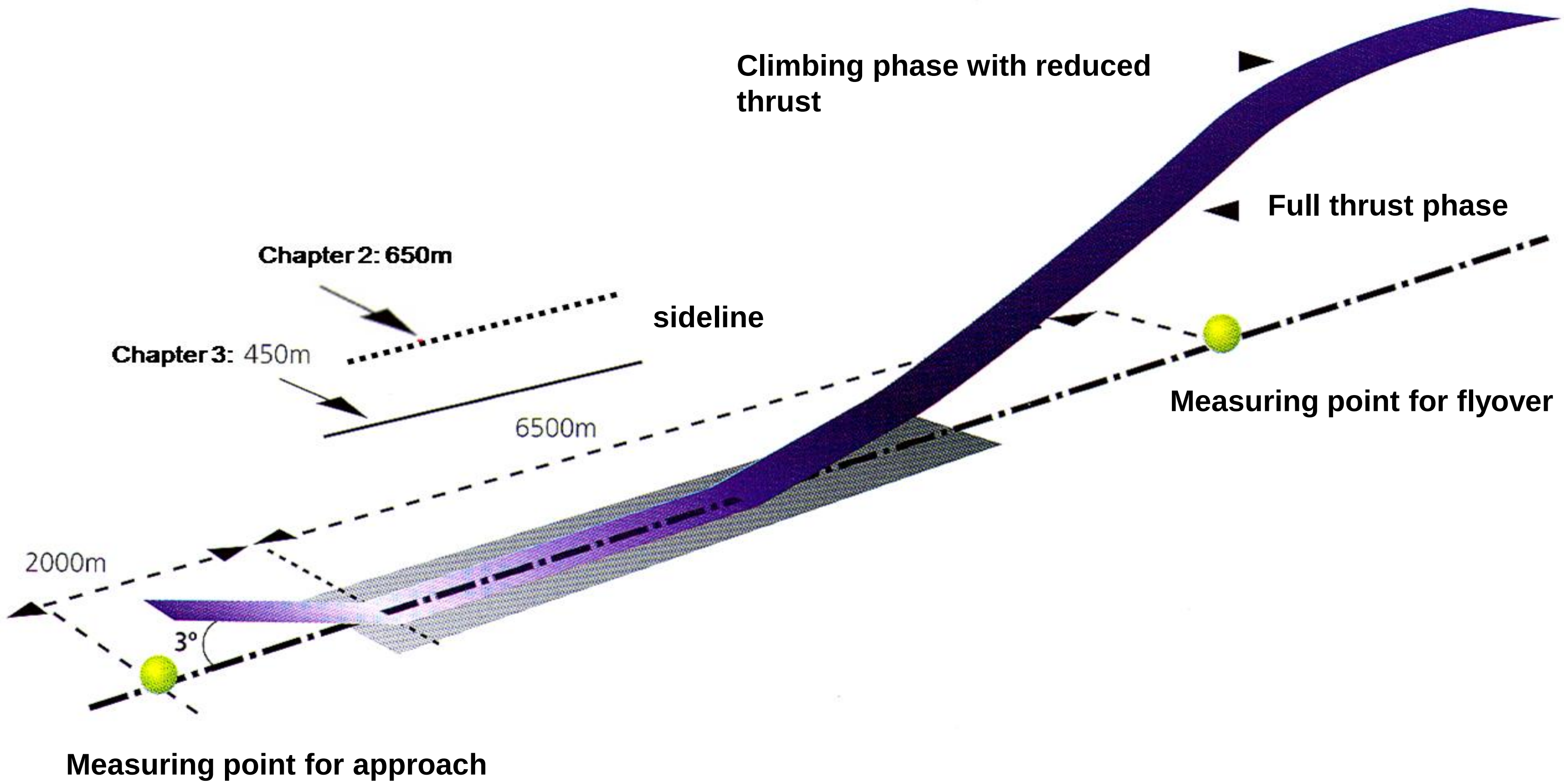
Chapter 10.7

Noise -
Laws and regulations



Differentiation of two categories of regulations and restrictions:

- **Noise certification / authorization of aircrafts according to ICAO Annex 16.**
- **Operational restrictions at airports.**



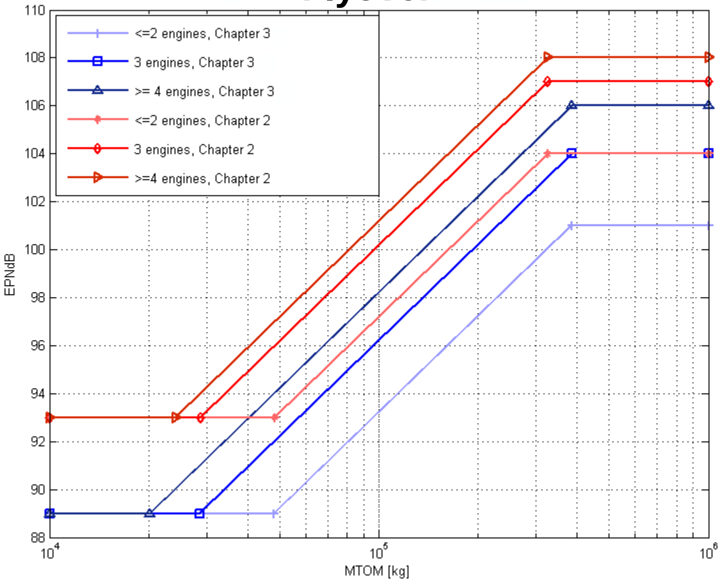
By noise certification the sound pressure is measured at 3 location:

- **Approach**
- **Flyover**
- **Sideline**

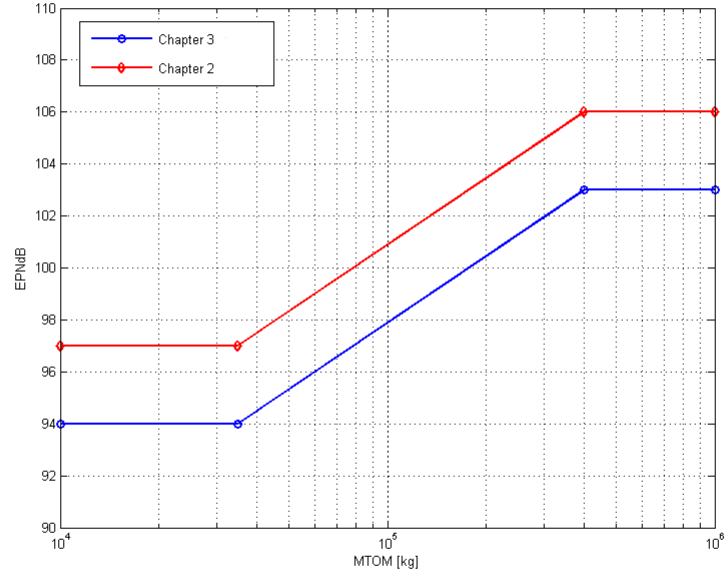
Each point has its maximal allowed noise level.

Source: EADS

Flyover



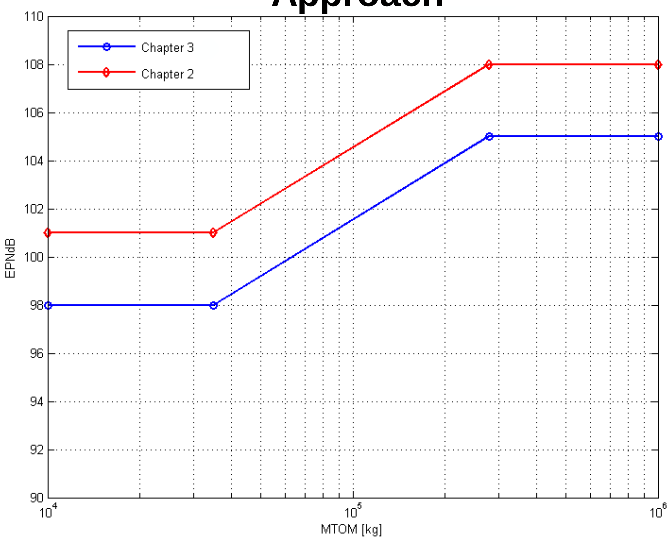
Sideline



Chapter 2

Chapter 3

Approach



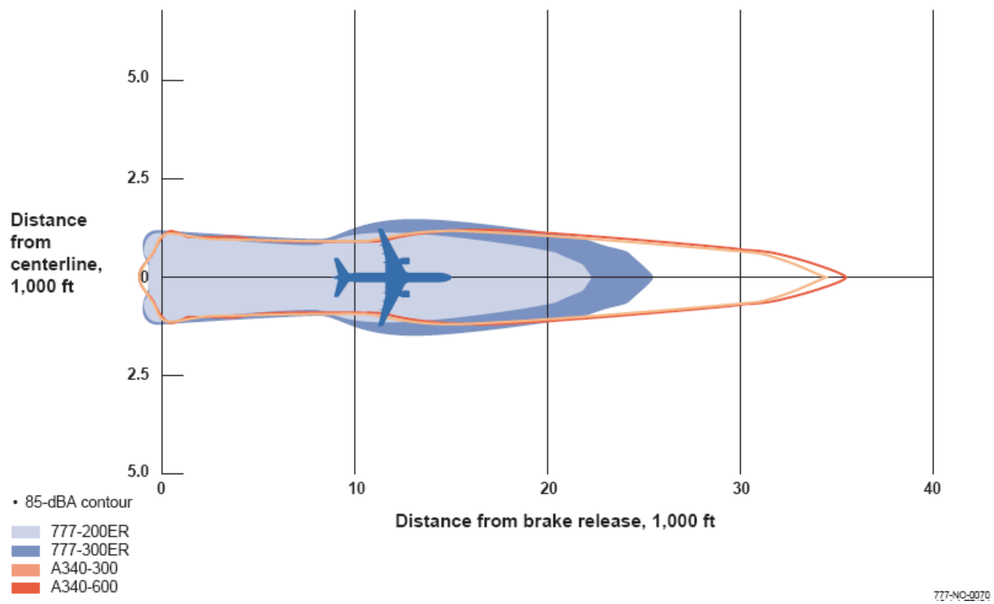
Definition Chapter 4:

The cumulated distance of all 3 noise values from chapter 3 limits shall not be smaller than 10 EPNdB.

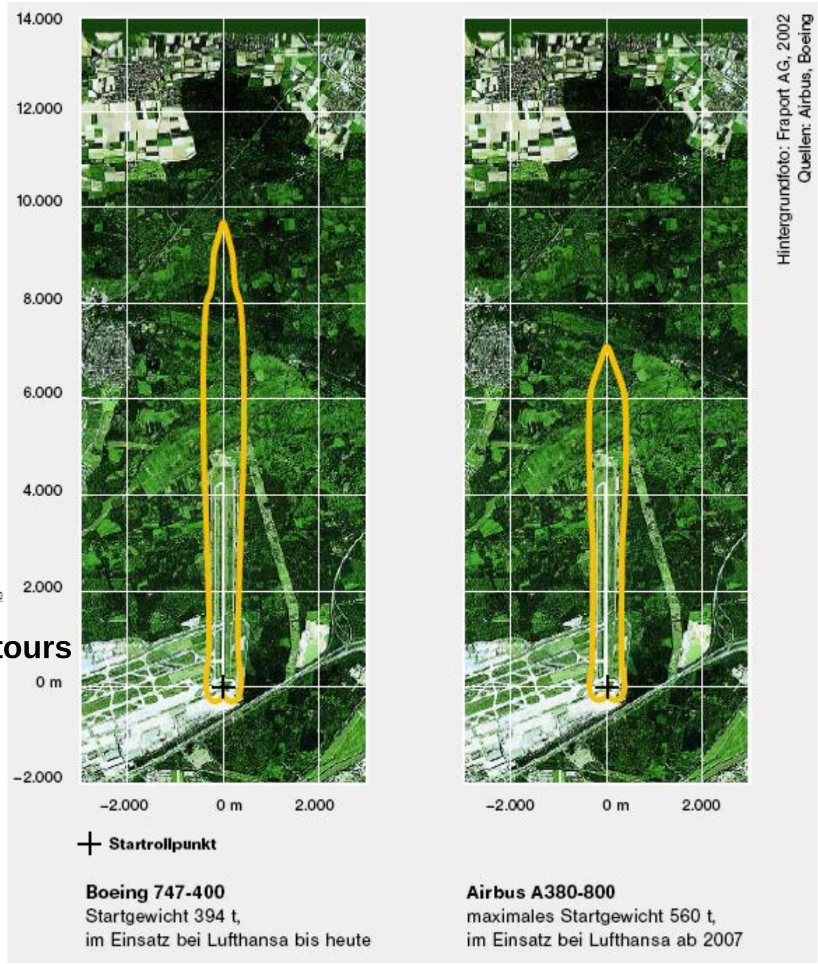
The sum of the difference from two noise values compared to Chapter 3 limit must be at least 2 EPNdB.

Chapter 4 limits have to be applied for new designs since 1.1.2006

Source: ICAO Annex 16



Comparison of Boeing 777 and Airbus A340 Take-off 85 dB(A) contours



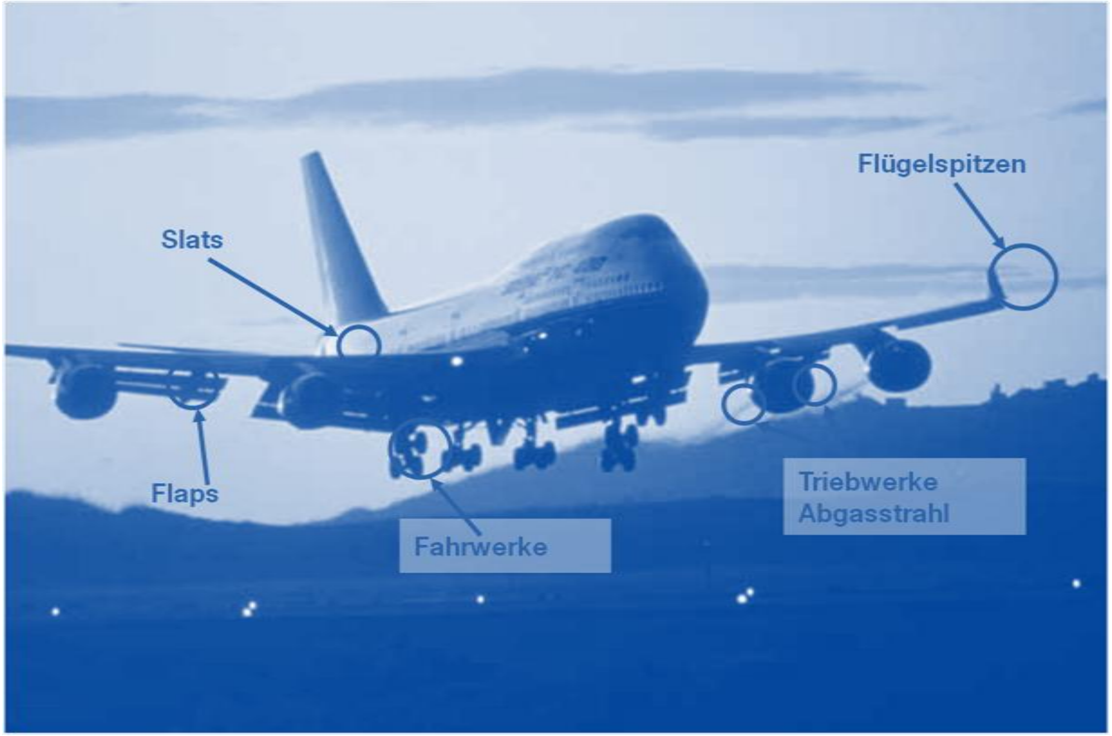
Source: Lufthansa

Comparison of Boeing 747-400 and Airbus A380-800, L_{Amax} Contour 85 dB(A) Take-off

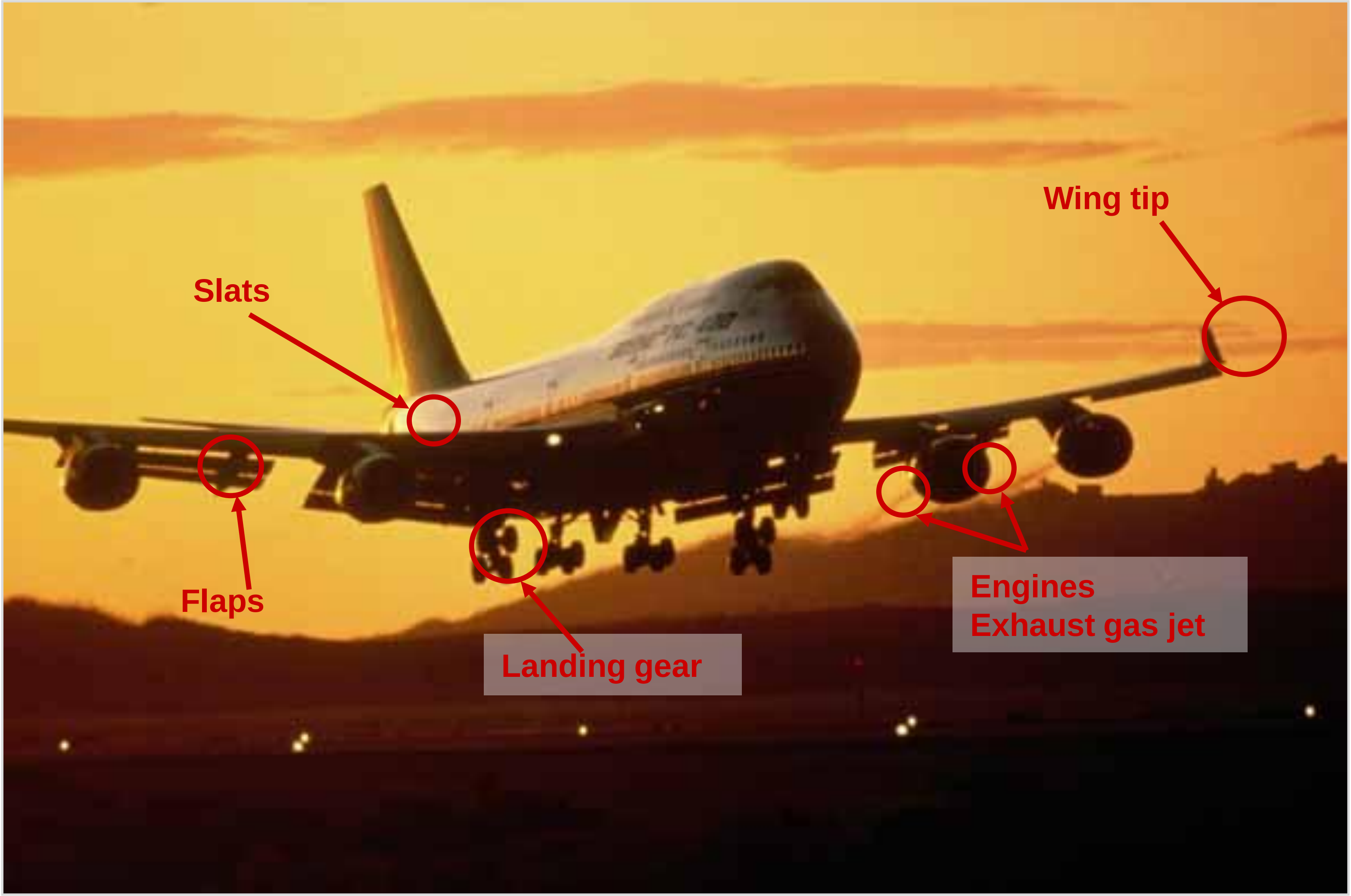
- The noise of an aircraft is not evenly distributed in all directions
- Each aircraft has a characteristic noise-contour (Lines of constant dB- Values).

Chapter 10.8

Noise sources on the aircraft

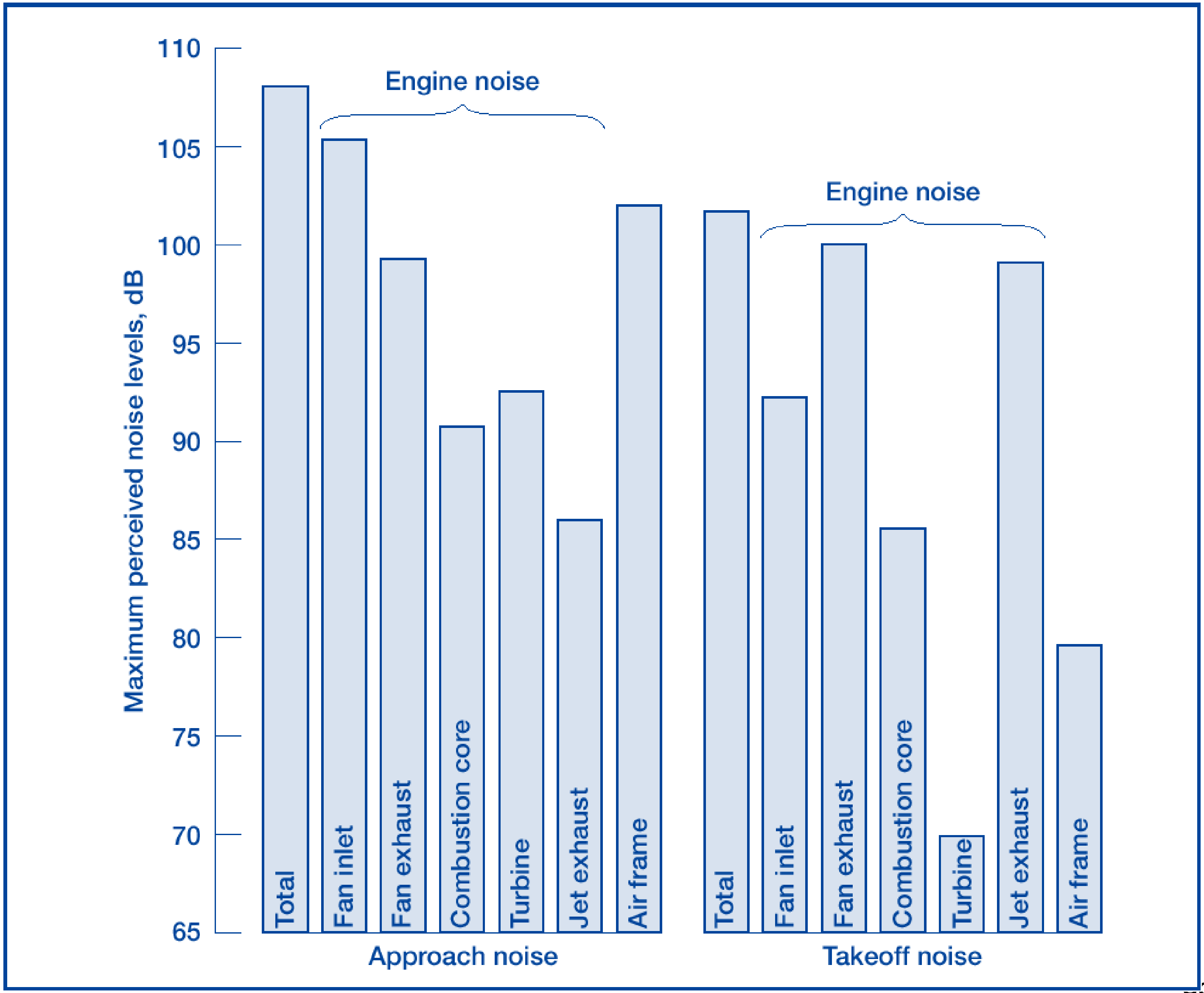


Noise source on the aircraft



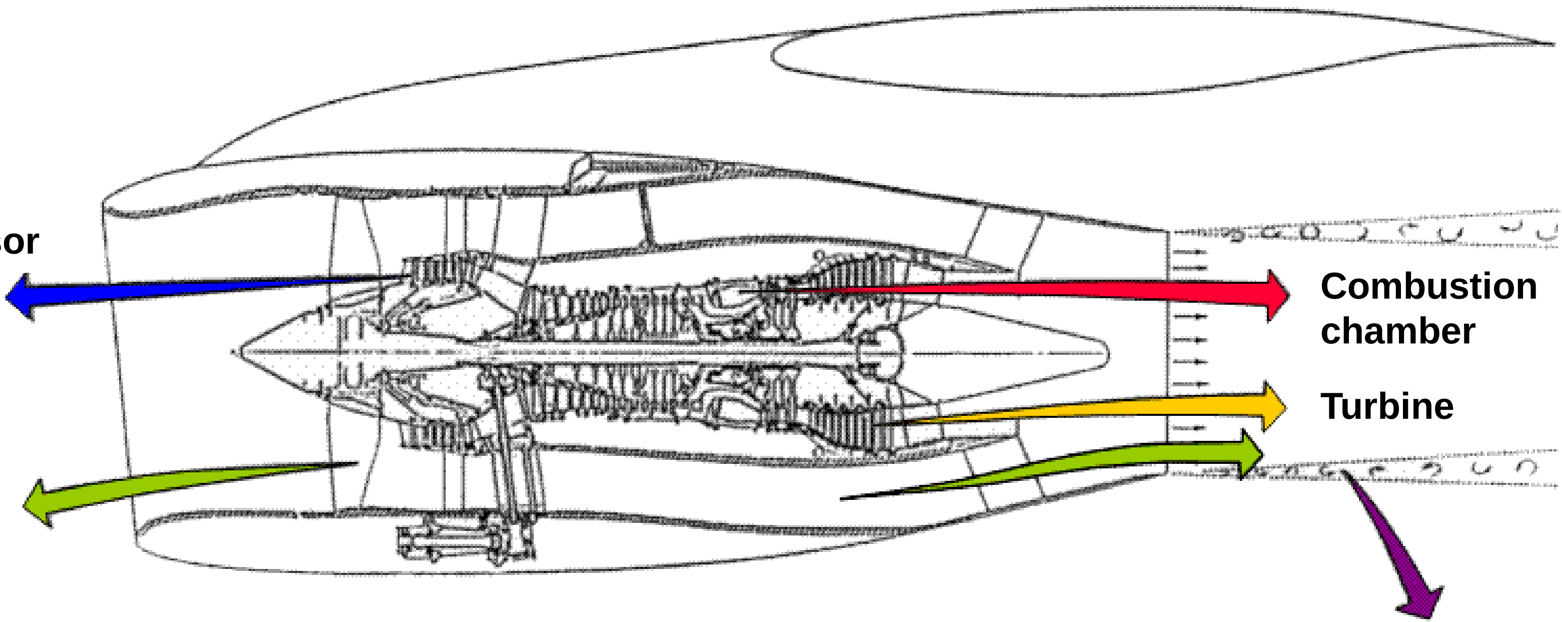
- During take-off engine noise is dominant.
- While landing the structural noises play a considerable role.

Intensity distribution of noise sources at the aircraft



Source: NASA

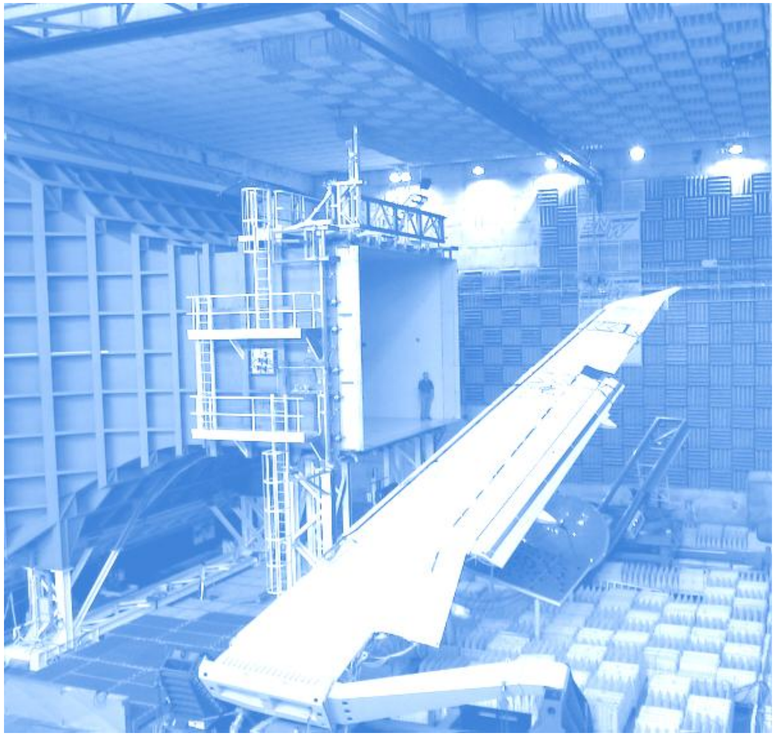
Engine noise sources



Source: MTU

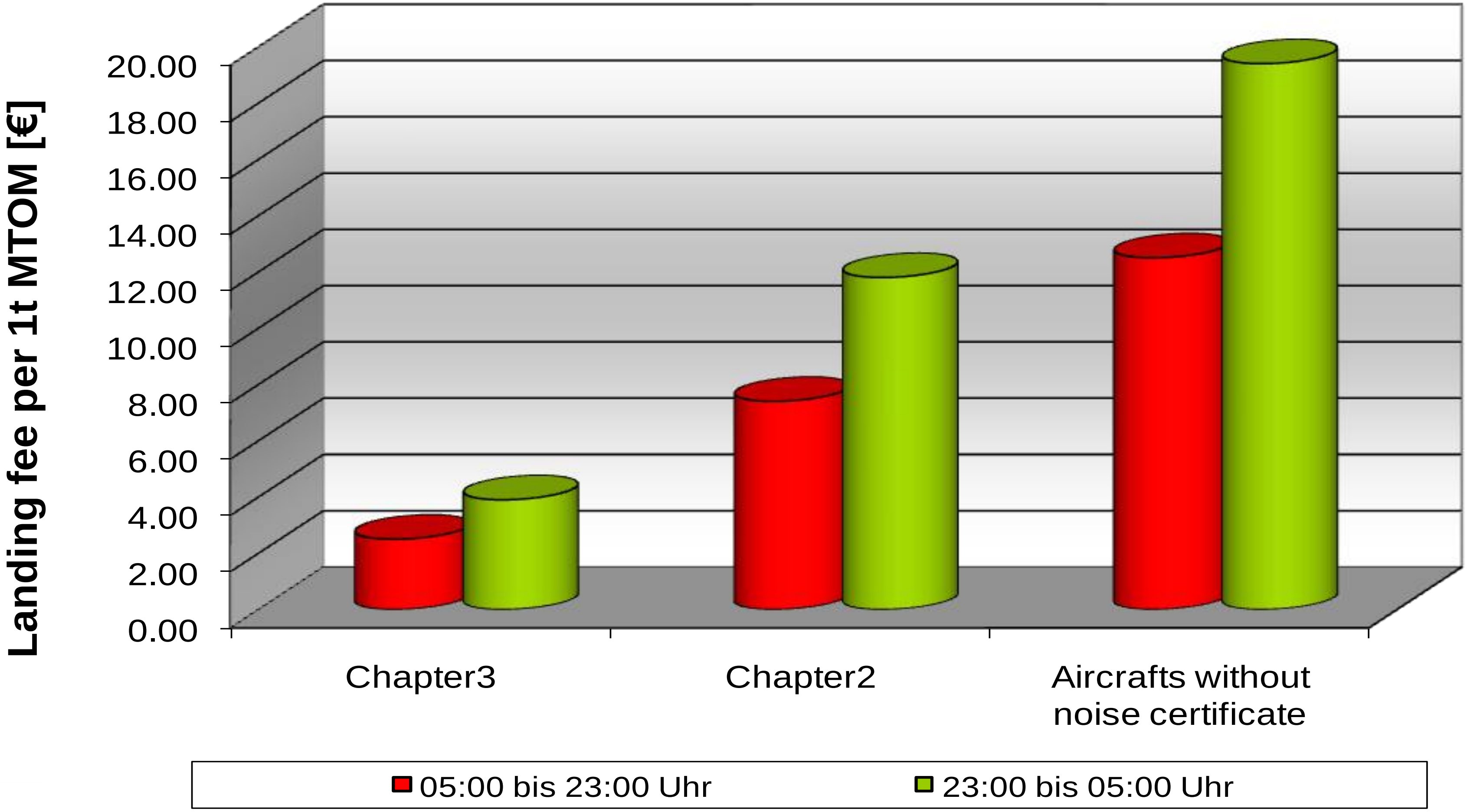
Chapter 10.9

Methods of noise reduction



- **Nightflight restriction:**
  - **Mostly on european airports.**
  - **Applications: only one runway closed, general nightflight ban, operation time with maximal noise level.**
- **Limiting the noise level:**
  - **Flight ban when exceeding noise level.**
  - **Penalty fees when exceeding noise level.**
- **Quota regulation:**
  Maximum number of flights per airline or per time intervall and slot allocation by noise.
- **Noise fees:**
  Influencing factors are noise level, start or landing time and the season.
- **Noise reducing flight methods:**
  - **Vertical and horizontal flight methods.**
  - **Noise reduction through thrust cutback**
  - **Through steep approach and take-off the noise level on the ground is considerably reduced.**

Landing fees according to noise levels



Source: Flughafen Hahn

Summary

- The aviation sector is closely observed by the general public with respect to noise and exhaust gas emissions.
- New climate guidelines are competing with other design requirements.
- Reliable metrics need to be developed for exhaust emission, noise and their effects, in order to value their importance
- Expanding technical progress allows legislation to reduce the allowed noise levels. An aircraft has to meet several requirements and limit values according to FAR-36 and ICAO Annex 16 Chapter 3 in order to achieve authorization.
- The landing fees at most airports are calculated according to the noise level of the affected airplane.
- Analogous to noise limits the ICAO has defined limits for exhaust gas emission. Some airports even introduced landing fees depending on exhaust emission.
- Different engine and aircraft improvements, as well as new operational methods lead to reduction of noise and pollutant emissions.

Bibliography

[1] Airbus,
http://www.airbus.com
[2] Anderson, J.,
Introduction to Flight, McGraw-Hill Book Company 1989
[3] Ashford, N. et al.,
Airport Engineering, Toronto 1992
[4] Ashford, N. et al.,
Airport Operations, Toronto 1996
[5] Boeing,
http://www.boeing.com
[6] Federal Aviation Administration,
http://www.faa.gov
[7] ICAO Accident/Incident Reporting Manual,
http://www.icao.int
[8] Jane´s,
All the Worlds Aircraft, London yearly
[9] Joint Aviation Authorities,
http://jaa.nl
[10] National Transport Safety Board,
http://www,ntsb.gov/aviation/aviation.htm
[11] Jenkinson, L.R., Simpkin, P., Rhodes, D.,
Civil Jet Aircraft Design, London 1999
[12] Toorenbeek, E. ,
Synthesis of subsonic airplane design, 1986 , Delft University Press

Bibliography (2)

[14] IATA
http://www.iata.org
[15] Airport Council International
http://www.aci.aero
[16] Eurocontrol
http://www.eurocontrol.int
[17] Association of European Airlines
http://www.aea.be
[18] Lawrence, Ph., Braddon, D.
Aerospace Strategic Trade
Ashgate 2001, UK
[19] Schmitt D./Gollnick V.
Air Transport System
Springer 2013