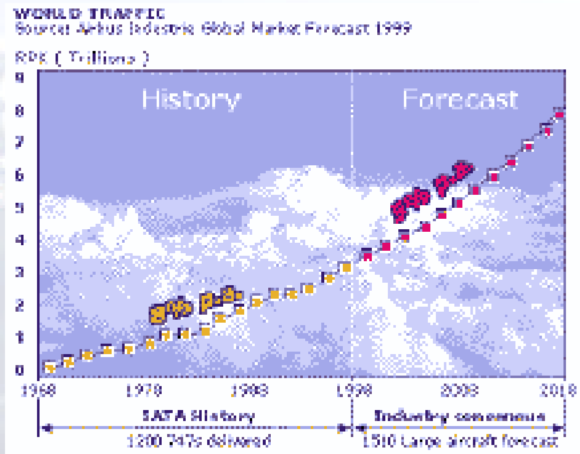
Virginia Tech Aerospace & Ocean Engineering

The Big Guys

by Valerio Viti

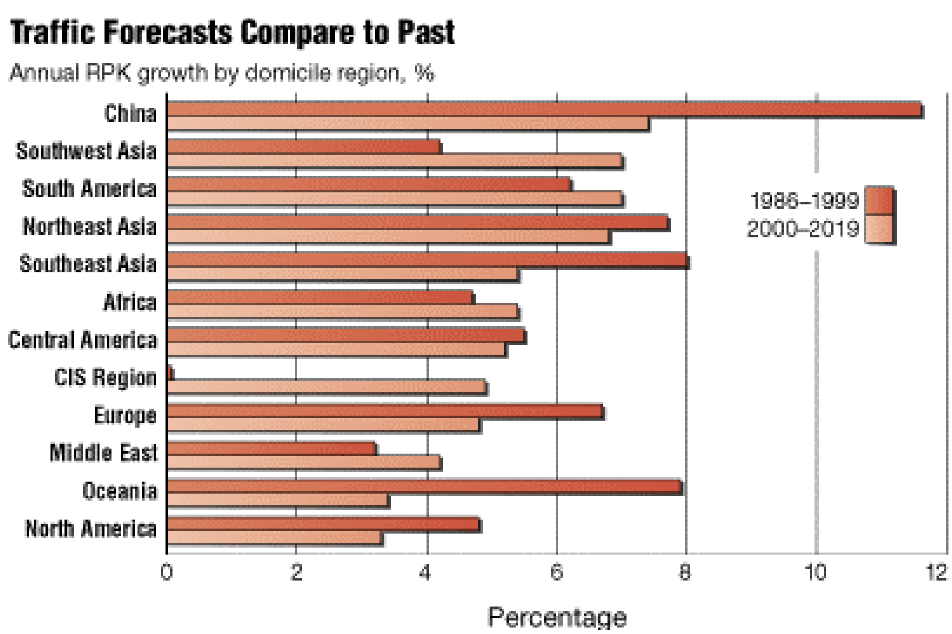
Why do we Need More Airliners in the Next 20 Years?



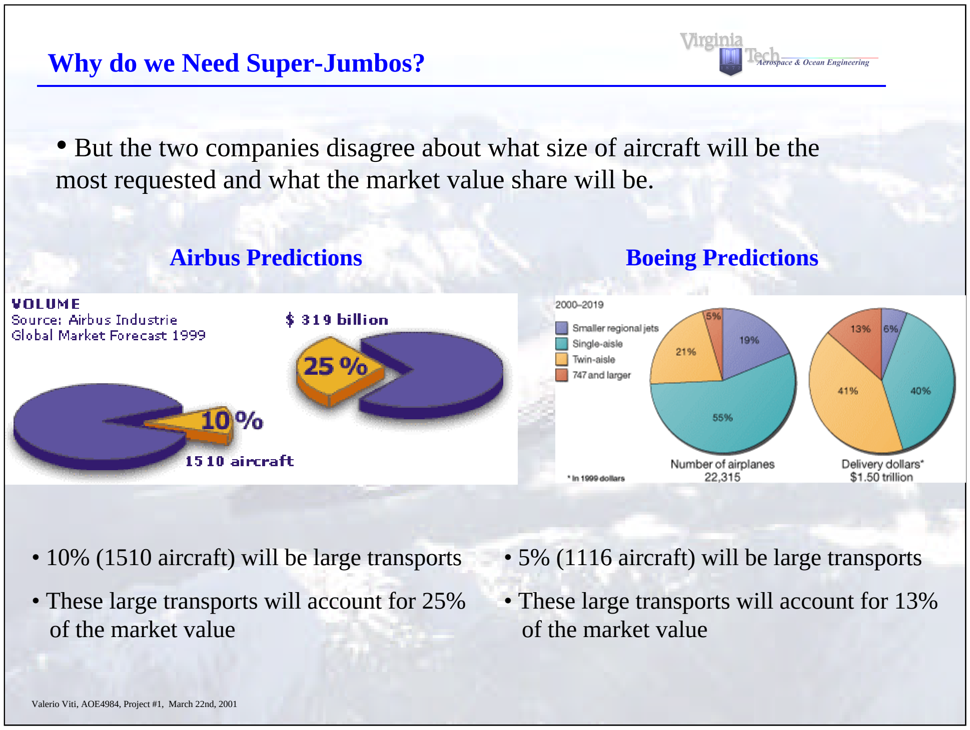
- Both Boeing and Airbus agree that civil air transport will keep increasing at a steady pace of roughly 5% per annum.
- Therefore the world fleet will more than double over the next 20 years from 13,679 airplanes in 1999 to 31,755 in 2019 (Boeing Website)

Valerio Viti, AOE4984, Project #1, March 22nd, 2001

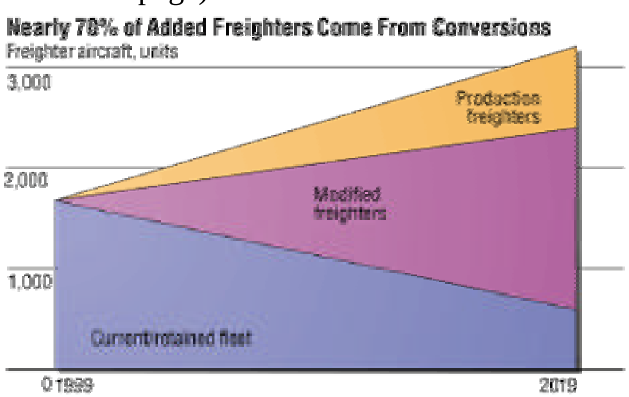
Market Growth varies widely from one region to the other. Here is a chart showing the past and predicted traffic growth according to Boeing.

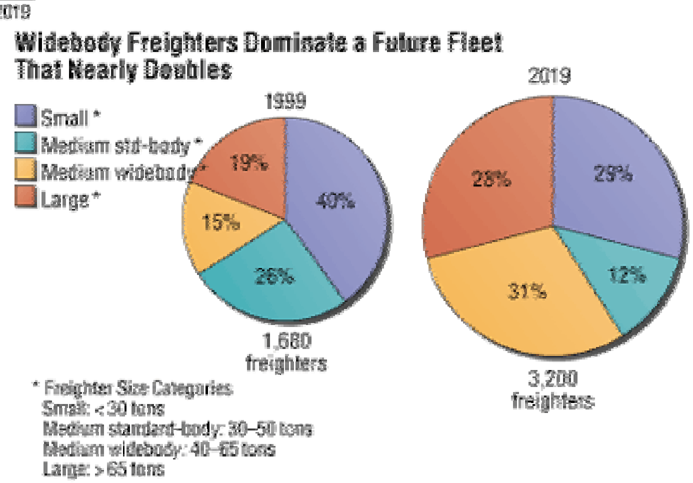


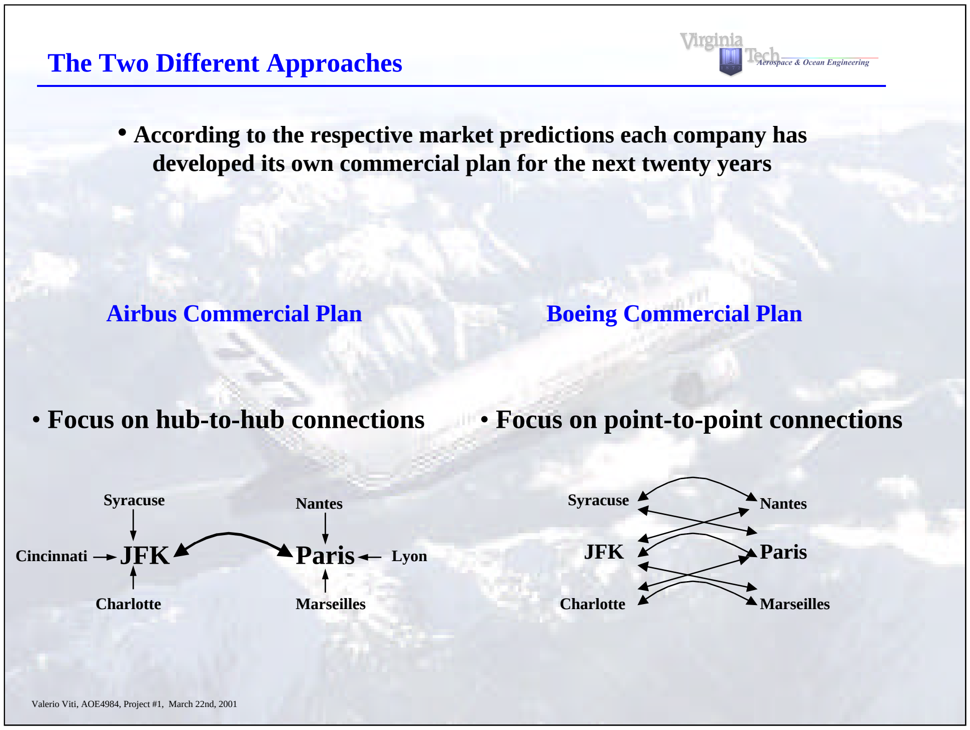
(Boeing web site)



•Freighter deliveries too will influence the market. All predictions indicate a high request for large/medium widebody aircraft in the next 20 years (Boeing webpage)







• Focus on hub-to-hub connections

• Early development (1995) of a completely new very large transport, known since the beginning as A3xx and then named A380.

•Large investments (ca. 12 billion $) in the completely new design will be off-set by large revenues due to an early entry in the market, lack of a strong competition in this sector and the completely new and advanced design.

• Diversification of the A330/340 family to satisfy that portion of the market that do not need extra seat capacity but rather a large range

•Focus on point-to-point connections

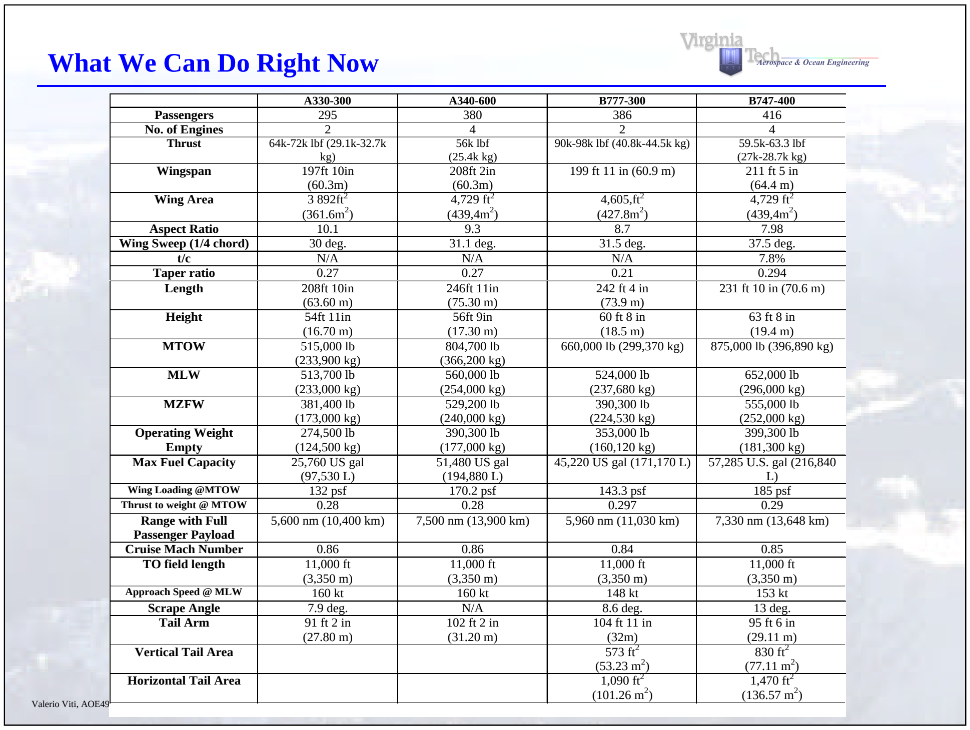
• Development of B747 derivatives in order to guarantee larger payload and a larger range than the -400 model.

•The relatively low investments (ca. 4 billion $) in the development of the B747 derivatives will be offset by a partial dominance of a small market

• Development of the B777 family that will satisfy the market requirement for relatively large, long range, efficient transports that will satisfy the market requirement for poi-to-point routes.

Also the McDonnelDouglas/Boeing MD-11 could be included in the above list of modern airliners. However the passenger version is not in production anymore.

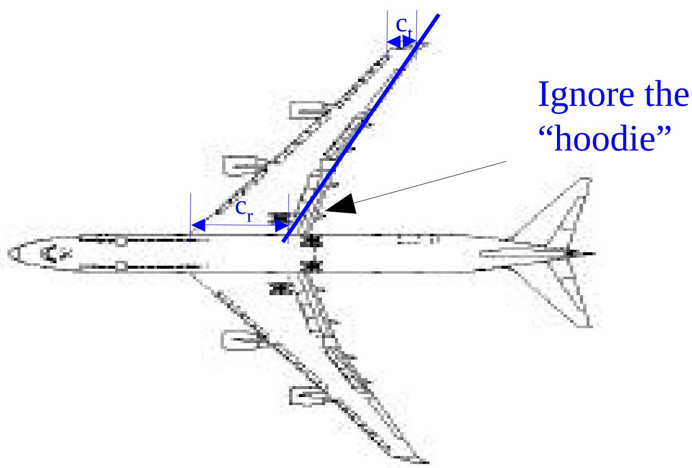
Other common airliners which are not in production anymore are the DC-10, L1011 Tristar, and the 747-classics. Due to the poor fuel efficiency, high maintenace/repair costs and high noise level these airliners are being quickly phased-out or converted to freighters



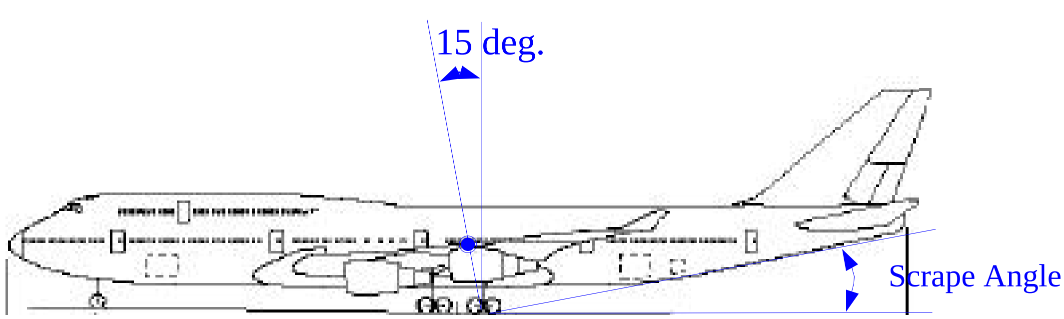
What We Can Do Right Now

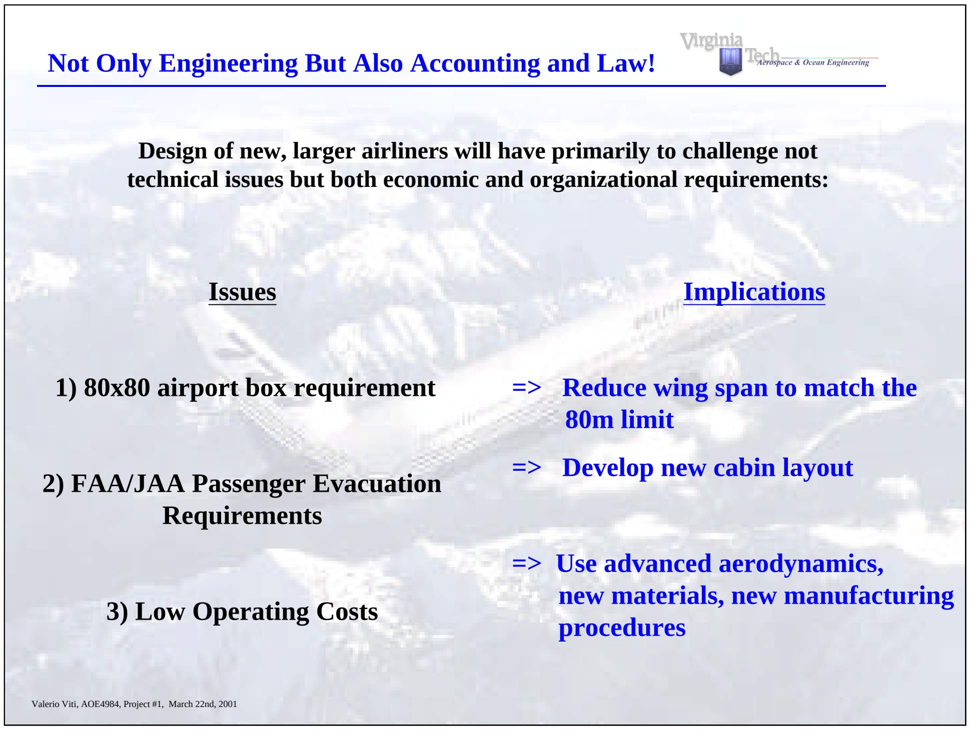
	A330-300	A340-600	B777-300	B747-400
Passengers	295	380	386	416
No. of Engines	2	4	2	4
Thrust	64k-72k lbf (29.1k-32.7k kg)	56k lbf (25.4k kg)	90k-98k lbf (40.8k-44.5k kg)	59.5k-63.3 lbf (27k-28.7k kg)
Wingspan	197ft 10in (60.3m)	208ft 2in (60.3m)	199 ft 11 in (60.9 m)	211 ft 5 in (64.4 m)
Wing Area	3 892ft^2 (361.6m^2)	4,729 ft^2 (439,4m^2)	4,605,ft^2 (427.8m^2)	4,729 ft^2 (439,4m^2)
Aspect Ratio	10.1	9.3	8.7	7.98
Wing Sweep (1/4 chord)	30 deg.	31.1 deg.	31.5 deg.	37.5 deg.
t/c	N/A	N/A	N/A	7.8%
Taper ratio	0.27	0.27	0.21	0.294
Length	208ft 10in (63.60 m)	246ft 11in (75.30 m)	242 ft 4 in (73.9 m)	231 ft 10 in (70.6 m)
Height	54ft 11in (16.70 m)	56ft 9in (17.30 m)	60 ft 8 in (18.5 m)	63 ft 8 in (19.4 m)
MTOW	515,000 lb (233,900 kg)	804,700 lb (366,200 kg)	660,000 lb (299,370 kg)	875,000 lb (396,890 kg)
MLW	513,700 lb (233,000 kg)	560,000 lb (254,000 kg)	524,000 lb (237,680 kg)	652,000 lb (296,000 kg)
MZFW	381,400 lb (173,000 kg)	529,200 lb (240,000 kg)	390,300 lb (224,530 kg)	555,000 lb (252,000 kg)
Operating Weight Empty	274,500 lb (124,500 kg)	390,300 lb (177,000 kg)	353,000 lb (160,120 kg)	399,300 lb (181,300 kg)
Max Fuel Capacity	25,760 US gal (97,530 L)	51,480 US gal (194,880 L)	45,220 US gal (171,170 L)	57,285 U.S. gal (216,840 L)
Wing Loading @MTOW	132 psf	170.2 psf	143.3 psf	185 psf
Thrust to weight @ MTOW	0.28	0.28	0.297	0.29
Range with Full Passenger Payload	5,600 nm (10,400 km)	7,500 nm (13,900 km)	5,960 nm (11,030 km)	7,330 nm (13,648 km)
Cruise Mach Number	0.86	0.86	0.84	0.85
TO field length	11,000 ft (3,350 m)	11,000 ft (3,350 m)	11,000 ft (3,350 m)	11,000 ft (3,350 m)
Approach Speed @ MLW	160 kt	160 kt	148 kt	153 kt
Scrape Angle	7.9 deg.	N/A	8.6 deg.	13 deg.
Tail Arm	91 ft 2 in (27.80 m)	102 ft 2 in (31.20 m)	104 ft 11 in (32m)	95 ft 6 in (29.11 m)
Vertical Tail Area			573 ft^2 (53.23 m^2)	830 ft^2 (77.11 m^2)
Horizontal Tail Area			1,090 ft^2 (101.26 m^2)	1,470 ft^2 (136.57 m^2)

1) Measurement of taper ratio: 747X Stretch



1) Measurement of scrape angle and CG position

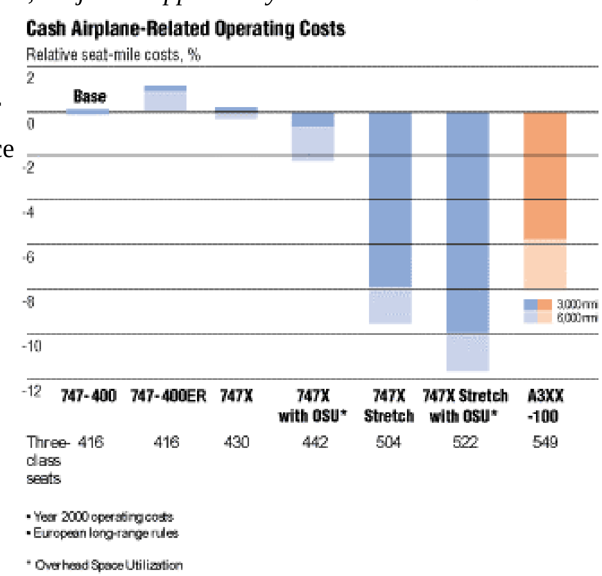




1) This “box” rule has been in use for seeral years. A change in these dimensions would require major modifications to all of the existing airports thus making the launch of the airliner impracticable.

2)FAR 25 Airworthiness Standard: Transport Category Aircraft, Appendix J states: “*Not more than 50 percent of the emergency exits in the sides of the fuselage of an airplane that meets all of the requirements applicable to required emergency exits for that airplane may be used for the demonstration. Exits that are not to be used in the demonstration must have the exit handle deactivated or must be indicated by red lights, red tape, or other acceptable means placed outside the exits to indicate fire or other reason why they are unusable. The exits to be used must be representative of all the emergency exits on the airplane and must be designated by the applicant, subject to approval by the Administrator. At least one floor level exit must be used.*”

3) Seat-mile (or km) costs are one of the major parameters for an airline. Also low maintenance costs and long time between overhauls are determining parameters in the choice of an airliner. This is an example of an economic performance chart that Boeing is using on its web site to show the economic superiority of the 747x Stretch over the competition



The Near Future

Airbus A380

Boeing B747X

Airbus A380-100

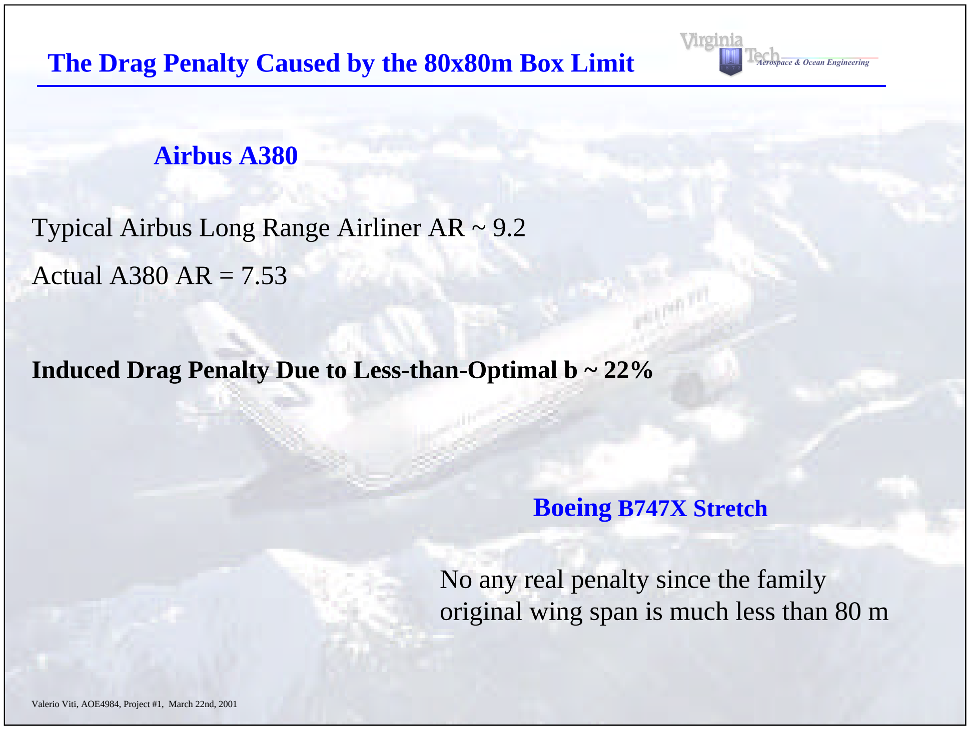
Planned Entry into Service: 2006
Max 3-class Passenger Load: 555
Range with Max Passengers: 8150 nm

Boeing 747X Stretch

Planned Entry into Service: 2005
Max 3-class Passenger Load: 522
Range with Max Passengers: 7785 nm

The Near Future

	A380-100	B747X
Passengers	555	522
No. of Engines	4	4
Thrust	68k-75 lbf (30.9k-34.1k kg)	68k lbf (30.9k kg)
Wingspan	261 ft 10 in (79.8 m)	228 ft 9 in (69.6 m)
Wing Area	9,100 ft^2 ($842.1m^2$)	6,820 ft^2 ($633.6m^2$)
Aspect Ratio	7.53	7.68
Wing Sweep (1/4 chord)	33.5 deg.	37.5 deg.
t/c	N/A	9.44%
Taper ratio	0.28	0.26
Length	239 ft 6 in (73 m)	264 ft 3 in (80.6 m)
Height	79 ft 1 in (24.1 m)	65 ft 2 in (19.9 m)
MTOW	1,235,000 lb (560,000 kg)	1,043,000 lb (473,500 kg)
MLW	844,000 lb (383,000 kg)	725,000 lb (328,850 kg)
MZFW	789,000 lb (358,000 kg)	680,000 lb (308,440 kg)
Operating Weight Empty	606,000 lb (275,000 kg)	495,000 lb (224,730 kg)
Max Fuel Capacity	85,900 U.S. gal (325,000 L)	72,573 U.S. gal (267,000 L)
Wing Loading @MTOW	136 psf	156 psf
Thrust to weight @ MTOW	0.24	0.26
Range with Full Passenger Payload	8,150 nm (14,670 km)	7,785 nm (14,000 km)
Cruise Mach Number	0.85	0.86
TO field length	11,000 ft (3,350 m)	11,000 ft (3,350 m)
Approach Speed @ MLW	145 kt	N/A
Scrape Angle	14.1 deg.	12.7 deg.
Tail Arm	102 ft 2 in (31.20 m)	101 ft 1 in (30.80 m)



Following the Airbus Company trend to use relatively high AR for its long-range airliners the A380 should have had an AR of roughly 9.2. The A380 AR is instead 7.53. The penalty in Induced Drag can then be computed from:

$$Cdi = \frac{Cl^2}{\pi e AR} = \frac{Cl^2}{\pi e (b^2/S)}$$

Then:

$$\Delta Cdi = \frac{Cdi_{Ideal}}{Cdi_{Actual}} = \frac{AR_{Actual}}{AR_{Ideal}} = \frac{9.20}{7.53} = 1.22$$

So that:

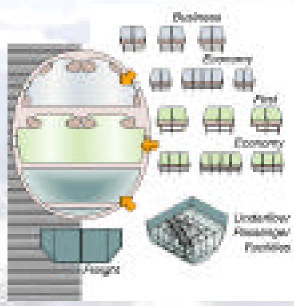
$$\Delta Cdi = 22\%$$

Optimize The Cabin Layout

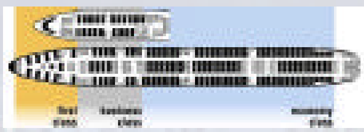
Airbus A380

Two full-length passenger floors. Each floor is roughly the same size as a A330-class aircraft interior.

Third full-length cargo floor.



Typical Cabin Layout for a 747-400. The 747X Stretch cabin should be comparable to this one, with an extended overhead section



Boeing B747X Stretch

Extend the overhead floor

Modify the distribution of passenger space/galleys/crew rest area to maximize efficiency

Improve Aircraft Efficiency

Airbus A380

•Use MDO methods to optimize aerodynamic/propulsion/structure integration

•Reduced CG margin that allows a 10% reduction in horizontal tail surface; software does the job.

•Extensive use (40% by weight) of carbon-based materials (for wing center-box) and lightweight metal alloys (Glare for skin panels)

•Use of advanced manufacturing methods (laser welding instead of riveting) that reduce weight and maintenance costs.

(Source: WichiteEagle web site)

Boeing B747X Stretch

•Use of 777-type supercritical airfoils for the full span and of blended wing-tips that should boost the aerodynamic efficiency of the wing by 3%

•Use of single element flaps to reduce weight, complexity and cost of wing

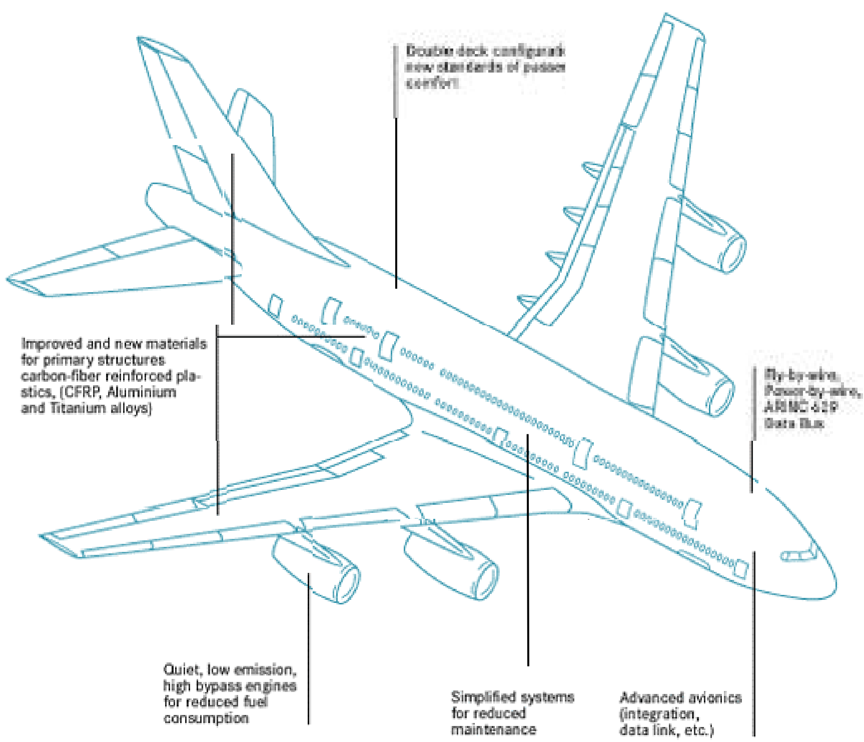
•Use of composite materials and one-piece machined aluminum structures

•Use of advanced manufacturing methods (laser welding instead of riveting) that reduce weight and maintenance costs.

(Source: Aviation Week, March 12, 2001)

Valerio Viti, AOE4984, Project #1, March 22nd, 2001

Schematic of the new technologies used on the A380 according to EADS



(Source: EADS web site)

High Lift Devices

	B777-300	B747-400
Passengers	386	416
No. of Engines	2	4
Thrust	90k-98k lbf (40.8k-44.5k kg)	59.5k-63.3 lbf (27k-28.7k kg)
Wingspan	199 ft 11 in (60.9 m)	211 ft 5 in (64.4 m)
Wing Area	4,605,ft^2 (427.8m^2)	4,729 ft^2 (439,4m^2)
Aspect Ratio	8.7	7.98
Wing Sweep (1/4 chord)	31.5 deg.	37.5 deg.
MTOW	660,000 lb (299,370 kg)	875,000 lb (396,890 kg)
MLW	524,000 lb (237,680 kg)	652,000 lb (296,000 kg)
Wing Loading @MTOW	143.3 psf	185 psf
Thrust to weight @ MTOW	0.297	0.29
Range with Full Passenger Payload	5,960 nm (11,030 km)	7,330 nm (13,648 km)
Cruise Mach Number	0.84	0.85
TO field length	11,000 ft (3,350 m)	11,000 ft (3,350 m)
Approach Speed @ MLW	148 kt	153 kt
Scrape Angle	8.6 deg.	13 deg.
High Lift Device Type	1 element slotted flap	3 element slotted flaps
TE flaps Area	67.13 m^2	78.69 m^2
LE flaps Area	36.84 m^2	43.85 m^2
Tot. Flap Area/Wing Area	24.3%	27.9%

Vertical and Horizontal Tail Volume Coefficient

	B777-300	B747-400
Passengers	386	416
No. of Engines	2	4
Thrust	90k-98k lbf (40.8k-44.5k kg)	59.5k-63.3 lbf (27k-28.7k kg)
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TO field length	11,000 ft (3,350 m)	11,000 ft (3,350 m)
Approach Speed @ MLW	148 kt	153 kt
Scrape Angle	8.6 deg.	13 deg.
Average Chord	7.02 m	6.82 m
Tail Arm	104 ft 11 in (32m)	95 ft 6 in (29.11 m)
Vertical Tail Area	573 ft^2 (53.23 m^2)	830 ft^2 (77.11 m^2)
Horizontal Tail Area	1,090 ft^2 (101.26 m^2)	1,470 ft^2 (136.57 m^2)
Vertical Tail Volume Coefficient	0.065	0.079
Horizontal Tail Volume Coefficient	1.08	1.33

Valerio Viti, AOE4984, Project #1, March 22nd, 2001

The tail coefficients are defined as:

$$C_{vt} = \frac{L_{vt} S_{vt}}{b_w S_w}$$

$$C_{ht} = \frac{L_{ht} S_{ht}}{c_{avg} S_w}$$

High Lift Devices

Valerio Viti, AOE4984, Project #1, March 22nd, 2001