A STUDY of AIRBUS A380 (A3XX)
by Serhat Hosder

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March 22, 2001 | *AOE 4984 Configuration Aerodynamics Project 1* | 1

AOE 4984 Configuration Aerodynamics

Project #1

Project title: A study of Airbus A380 (A3XX)

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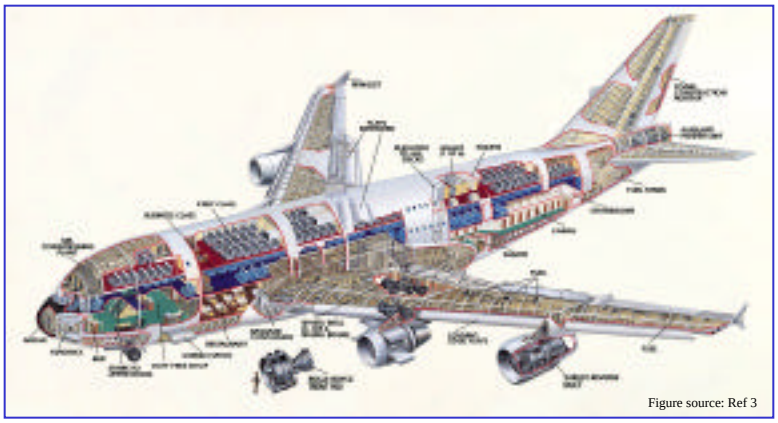
AIRBUS A380-100



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- BIGGEST AIRLINER EVER DESIGNED
- FIRST CIVIL TRANSPORT WITH THREE DECKS
- NEW TECHNOLOGIES

March 22, 2001 *AOE 4984 Configuration Aerodynamics Project 1* 2

Airbus A380 is the biggest airliner ever designed. It will become the first full-triple decked large-body, long-range civil transport. Despite its large size, basic configuration of A380 is similar to a typical civil transport.

Because of the customer imposed constraints, A380 is designed to fulfill current airport gate and runway requirements (80 m gatebox limitation). In the case of A380-100 (baseline configuration), the customers asked for direct operating costs 15% below current 747-400.

Since A380 is a unique design, the production of the airplane depends on the improvements and new technologies in aerodynamics, structures, avionics, material science and system integration.

Motivation for the Development of A380

- World Air Traffic will double in 15 years and nearly triple in 20 years
- First B-747 in 1970
  - Turbofan powered
  - more than twice the size of its predecessors
  - Since then no significant improvement
- Time for a new, larger aircraft to satisfy current and future “market” need

Figure source: Ref 7

MODELS

-50R ……...Shortened model with extended range

-100 ……Basic model with standard range

-100R……..Basic model with extended range

-100S……..Basic model with reduced range

-100C7……Basic model as combi (7 pallets)

-100C11…..Basic model as combi (11 pallets)

-100F……..Basic model as freighter

-200……Stretched model with standard range

-200S……..Stretched model with reduced range

Comparison with the Other Widebody, Long Range Transports

A380-100
First flight: 2004 (expected)
First delivery: 2005 (expected)

B777-300
First flight: 1997
First delivery: 1998

A340-600
First flight: 2001
First delivery: 2002

B747X Stretch
First flight: not available
First delivery: not available

March 22, 2001 *AOE 4984 Configuration Aerodynamics Project 1* 4

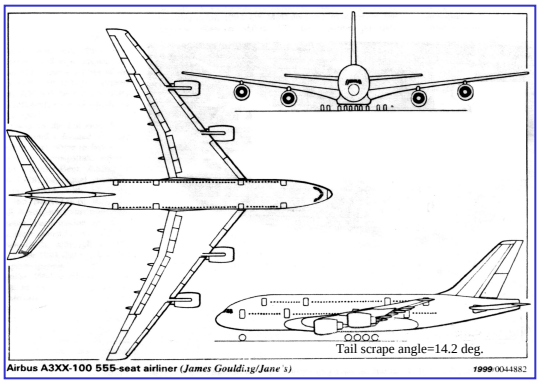
Basic dimensions, configurations, and the performance parameters of A380-100 are compared with the data from the following large-body, long range civil transport aircraft:

Boeing 777-300: Long-range, high capacity, twin-turbofan airliner. First flight was performed in 1997 and first delivery was made in 1998. Compared with first-generation 747s, 777-300 carries the same number of passengers but at two-thirds of fuel cost and with %40 less maintenance.

Boeing 747 X Stretch: Extended version of Boeing 747-400 X which would carry 500 passengers in typical three class configuration. In terms of the mission profile, size and configuration this aircraft is comparable to A380.

Airbus A340-600: Derivative of A340-300 with fuselage stretch. Designed as Boeing 747 replacement with significantly lower costs and fully communality with A330/340 family, A340-600 has improved aerodynamic design and additional fuel capacity compared to A340-300.

Basic Dimensions



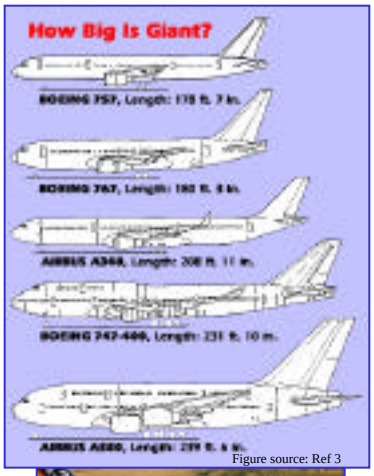


Figure source: Ref 3

	A380-100	*B777-300*	*B747 X Stretch*	*A340-600*
Overall Length	**239 ft 6 in (73 m)**	242 ft 9 in (73.9 m)	263 ft (80.2 m)	247 ft (75.30 m)
Overall Height	**79 ft (24.1 m)**	61 ft (18.6 m)	65 ft 2 in (19.9 m)	58 ft 5 in (17.8 m)

• Fuselage shape: *Vertical Ovoid* *max width=7.14 m*
max depth=8.69 m

- 10 passengers on main deck, 8 on upper deck (cross-section)
- Greater space per passenger than Boeing-747

Figure source: Ref 3

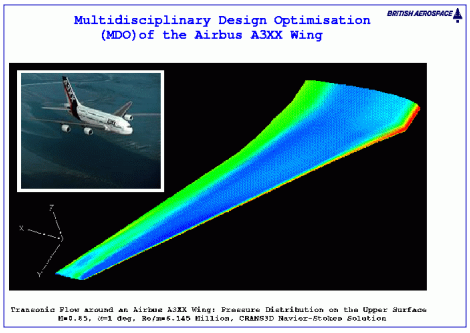
March 22, 2001 *AOE 4984 Configuration Aerodynamics Project 1* 5

Tail scrape angle has been measured by using the layout figure of A380-100. Since the height of the landing gears is not specified, this approximation may not be accurate enough.

Wing Configuration

	A380-100	B777-300	B747 X Stretch	A340-600
Wing Span (b)	**261 ft 9in (79.8 m)**	212 ft 7 in (64.8 m)	229 ft (69.8 m)	208 ft 2 in (63.45 m)
Reference Wing Area (S)	**9,095 ft^2 (845 m^2)**	4,605 ft^2 (428 m^2)	6,824 ft^2 (634 m^2)	4,729 ft^2 (437 m^2)
Wing Aspect ratio (AR)	**7.53**	8.7	7.62	9.21
Sweep angle at quarter chord	**33.5 deg. (outboard)**	31.5 deg. (outboard)	37.5 deg. (outboard)	31.1 deg.
*Taper Ratio **	**~ 0.3**	~0.26	~ 0.3	~0.28
Mean chord length	**34 ft 10 in (10.6 m)**	21 ft 8 in (6.6 m)	29 ft 11 in (9.1 m)	22 ft 7 in 6.9 m

- Low wing configuration
- Large wing area and mean chord length
- Considerations on the wing design:
  - 80 m gatebox limitation (short span length and lower AR)
  - Transonic and subsonic performance, low drag
  - More sweep compared to A340 & B777
  - Enough space for fuel
  - Vortex wake



* Based on trapezoidal wing, see notes for details

The taper ratio for each plane has been determined by using layout figures, and due to the measurement errors, the results may not be accurate.

Airport compatibility is one of the main driving factors that has strong influence on the wing design. 80 m gatebox requirement puts a limitation on the span length. This requirement and the weight of the aircraft forces a large wing area. Fuel space is also another factor. 80 m span constraint results in an AR of 7.53 which is lower than the A330/340.

The cruise Mach is 0.85 for A380. For this reason, wing has more sweep compared to A340.

Another key issue in the wing design is the vortex wake. Despite the size of A380, the flap design, engine location, and pylon design play an important role on the vortex wake, and proper design may reduce the effect of the size of the aircraft on the wake formation.

Weights and Loadings

	A380-100	B777-300	B747 X Stretch	A340-600
Max. Takeoff Weight (MTOW)	**1,190,500 lb (540,000 kg)**	660,000 lb (299,379 kg)	1,043,000 lb (473,100 kg)	804,675 lb (365,000 kg)
Max. Landing Weight (MLW)	**839,950 lb (381,000 kg)**	524,000 lb (237,680 kg)	725,000 lb (328,850 kg)	529,100 lb (240,000 kg)
Max. Zero Fuel Weight (MZFW)	**784,850 lb (356,000 kg)**	495,000 lb (224,530 kg)	680,000 lb (308,440 kg)	529,100 lb (240,000 kg)
Operating Weight Empty (OWE)	**588,625 lb (267,000 kg)**	353,000 lb (160,120 kg)	495,000 lb (224,532 kg)	390,220 lb (170,000 kg)
Fuel Capacity	**85,900 US gal (325,000 L)**	47,890 US gal (181,280 L)	72,853 US gal (275,780 L)	51,480 US gal (194,880 L)
Max. Wing Loading (W/S)	**130.8 psf (639 kg/m^2)**	143.3 psf (699.8 kg/m^2)	153 psf (746.2 kg/m^2)	171.1 psf (835.2 kg/m^2)
Max. Span Loading (W/b)	**4,542 lb/ft (6,767 kg/m)**	3,104 lb/ft (4,617 kg/m)	4,554 lb/ft (6,778 kg/m)	3,868 lb/ft (5,753 kg/m)

Figure source: Ref 3

Figure source: Ref 4

- MTOW twice as much of B777-300's
- Low Wing Loading
- High Span Loading ==> increase in induced drag D_i

  fi $D_i \sim (W/b)^2$
- Drag penalty due to reduced span ~ 22%† increase in D_i

† See notes for the calculation details and the assumptions

March 22, 2001 | *AOE 4984 Configuration Aerodynamics Project 1* | 7

Calculation of drag penalty due to reduced span:

1. Assume without the 80 m gatebox limitation, the AR will be 9.21 (same as the AR of A340-600, typical AR for a civil transport)

2. Assume the wing area and MTOW does not change. Then for AR=9.21, the new span length would be 290 ft.

3. New span loading (W/b) is approximately 4105. This would give a D_i that is 82% of the initial one.

4. Thus the increase in the induced drag is approximately 22%.

Performance Parameters

	A380-100	B777-300	B747 X Stretch	A340-600
Number of Passengers	**555 (3-class)**	365 (3-class)	500 (3-class)	380 (3-class)
Cruise Mach	**0.85**	0.84	0.87	0.83
Range w/ full passenger payload	**7,650 nm (14,167 km)**	5,720 nm (10,593 km)	7,820 nm (14,484 km)	7,500 nm (13,890 km)
Approach Speed at MLW	**<145 kt (268 km/h)**	148 kt (274 km/h)	153 kt (284 km/h)	160 kt (296 km/h)

- Lower approach speed compared to B747 X Stretch
- New Improvements in the wing design of B747 X Stretch allows cruise Mach 0.87
  - Old wing planform
  - New airfoil with increased t/c

Propulsion

	A380-100	B777-300	B747 X Stretch	A340-600
Number of Engines	**4**	2	4	4
Max. Thrust per Engine (at sea level, STP)	**67,000 lb (298 kN)**	90,000 lb (400 kN)	68,000 lb (302 kN)	56,000 lb (249 kN)
Thrust to Weight Ratio @ MTOW (T/W)	**0.23**	0.27	0.26	0.28

- Engine Type: Rolls-Royce Trent RB-967 or Engine Alliance GP-7267 turbofan
- High bypass ratio and reduced noise compared to today's turbofans (110 in. fans)

Stall Speed and CL_{max}

	A380-100	*B777-300*	*B747 X Stretch*	*A340-600*
Stall Speed (Vstall)	**121 kt (224 km/h)**	123 kt (228 km/h)	128 kt (237 km/h)	133 kt (246 km/h)
CL_{max}	**2.6**	2.8	2.8	2.9

- Assume Vstall= Vapp/1.2
- Low Wing Loading ==>
  - Lower Vstall and CL_{max}
  - Simple one-segmented slotted flap

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March 22, 2001 *AOE 4984 Configuration Aerodynamics Project 1* 9

Due to large wing area and low wing loading, both stall speed and CL_{max} are lower than the other planes which have higher wing loading.

Low wing loading also allows the use of simple one-segment slotted flap system.

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