HIGH CAPACITY AIRCRAFT

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Abstract

Deutsche Airbus have carried out a study on very high capacity aircraft. It is based on the current A330/340 technology standard. Certain design targets were developed after initial airline contacts and the 747-400 is taken to be the yardstick for performance and economic requirements like 10 % improvement in blockfuel and direct operating cost. There are three example aircraft (500/600/700 seats) that are investigated with respect to configurational, infrastructural, and economic aspects of such type of aircraft.

An 11-abreast circular single deck cross-section forms the basis of the 500- to 600-seater family. In this case, part of the cargo holds must be used for galleys and toilets to achieve a larger number of seats on the main deck in order to meet the economic targets relative to a 1 ½ deck 747-400. A 9+6-abreast "Oval" and an 11+7-abreast tri-bubble double-deck cross-section are the basis for the 600- to 700-seater and 700- to 800-seater family respectively. Double-deck fuselages are the solution for large passenger aircraft with fuselage length limits. Such fuselages require deeper cargo holds for acceptable freight volumes and this, in turn, permits the wing box to be installed inside of the normal cross-section and makes the body gear installation easier. Also it helps to achieve acceptable ditching conditions.

First discussions with airport authorities show a certain long-term flexibility with respect to the main dimensions of very large aircraft like length, span, wheel base or wheel track. However, aircraft heights of 22 to 27 m cause problems with existing maintenance hangars. Main deck sill heights of 6 to 7 m and upper deck sill heights of 8.5 to 9.5 m require new concepts for passenger boarding and emergency evacuation. The current noise levels are a function of MTOW up to about 400 t. Beyond this weight the noise levels are constant and hence independent of aircraft size and weight. This is a critical point for large high weight aircraft, and it is doubtful whether a 600- to 800-seater aircraft could meet such requirements. The three example aircraft show a good fuel efficiency. The benefit on an average stage length of 3000 nm is 10.5 % relative to the 747-400 neglecting engine sfc and size effects. So the 10 % target is fulfilled. The double-deck versions show a good cost efficiency. The 600- and 700-seater aircraft are able to meet the target of 10 to 15 % seatmile cost improvement. The 500-seater aircraft shows a seatmile cost benefit of 6 % relative to the 747-400 reference aircraft. A further optimization of fuselage volume utilization will improve this figure. However, a 10 % improvement in seatmile cost is an ambitious target for a 500-seater.

I. Introduction

It is generally expected that air transport capacity will need doubling within the next 10 to 15 years, whereas the relevant infrastructure will not grow accordingly. As ATC overstrain and slot availability do pose problems already today, the obvious solution to a further increase of capacity is introducing larger aircraft. In the near future, new wide-bodies like A330/A340, 777, and MD 11/12 will serve the purpose, at the long run, however, very high capacity aircraft in the 500- to 800-seat-class will be required. Deutsche Airbus (DA) carried out a study on such very high capacity aircraft on the basis of current A330/340 technology standard. It is directed to configurational/infrastructural aspects and to the economy of such type of aircraft.

II. Requirements

FIGURE 1 shows the range and seat targets in the 500- to 800-seater class. This high-capacity market is divided in three segments, and for each of these segments an example aircraft was established. TABLE 1 shows the major design targets which were established after initial airline contacts. The 747-400 is taken to be the yardstick for performance and economic requirements.

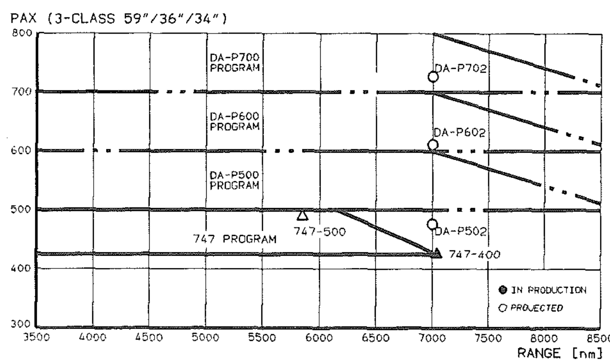


FIGURE 1 - SEAT RANGE FLEXIBILITY TARGET

III. Cross-section Selection

DA has investigated a series of alternative cross-sections for a 500/600/700-seater family. Three main design criteria were used to select adequate fuselages for each aircraft family:

- Minimum wetted area/passenger
- Fuselage length < 80 m
- Freight volume > 10 ft^3/pax

The first step of the cross-section study was based on the following assumptions:

- Design cabin width:	Economy Class
- Underfloor capability:	Standard LD3 Container

FIGURE 2 shows a number of circular, double-bubble and tri-bubble cross-sections. Three cross-sections were identified to give acceptable fuselage length for their respective market segments:

500 - 600 SEATS :	11 abreast, circular, single deck
600 - 700 SEATS :	9 + 6 abreast, double-bubble, double deck
700 - 800 SEATS :	11 + 7 abreast, tri-bubble, double deck

These cross-sections do not yet fully meet the relevant criteria.

DA P 500:

- Excellent freight volume
- Acceptable fuselage length
- Unacceptable fuselage volume utilization
- Unacceptable wetted area/passenger

DA P 600 an DA P 700:

- Minimum wetted area/passenger
- Acceptable fuselage length
- Unacceptable freight volume
- Critical ditching condition
- Critical wing box and body gear installation

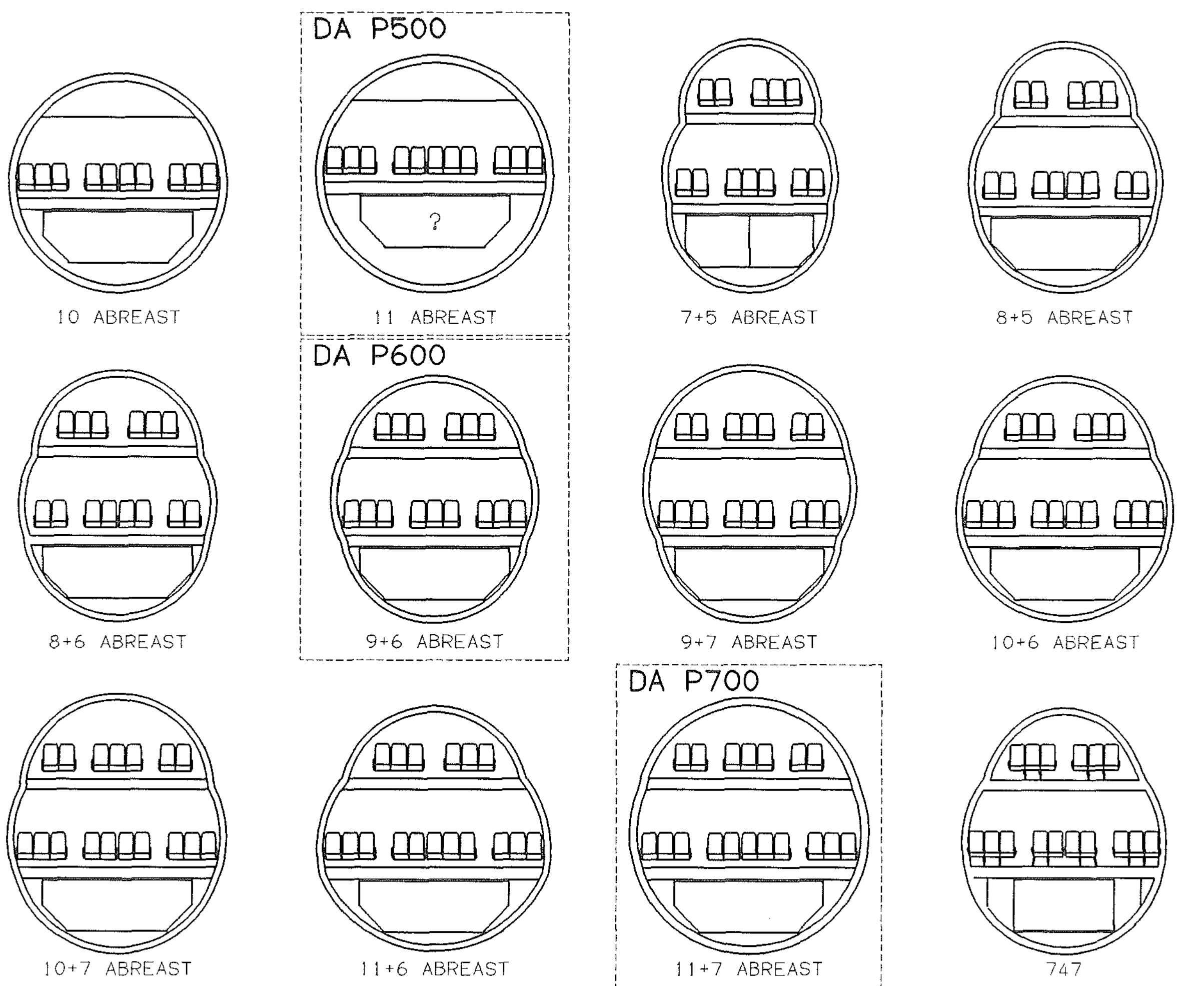


FIGURE 2 - ALTERNATIVE CROSS SECTIONS (LD3 CONTAINER)

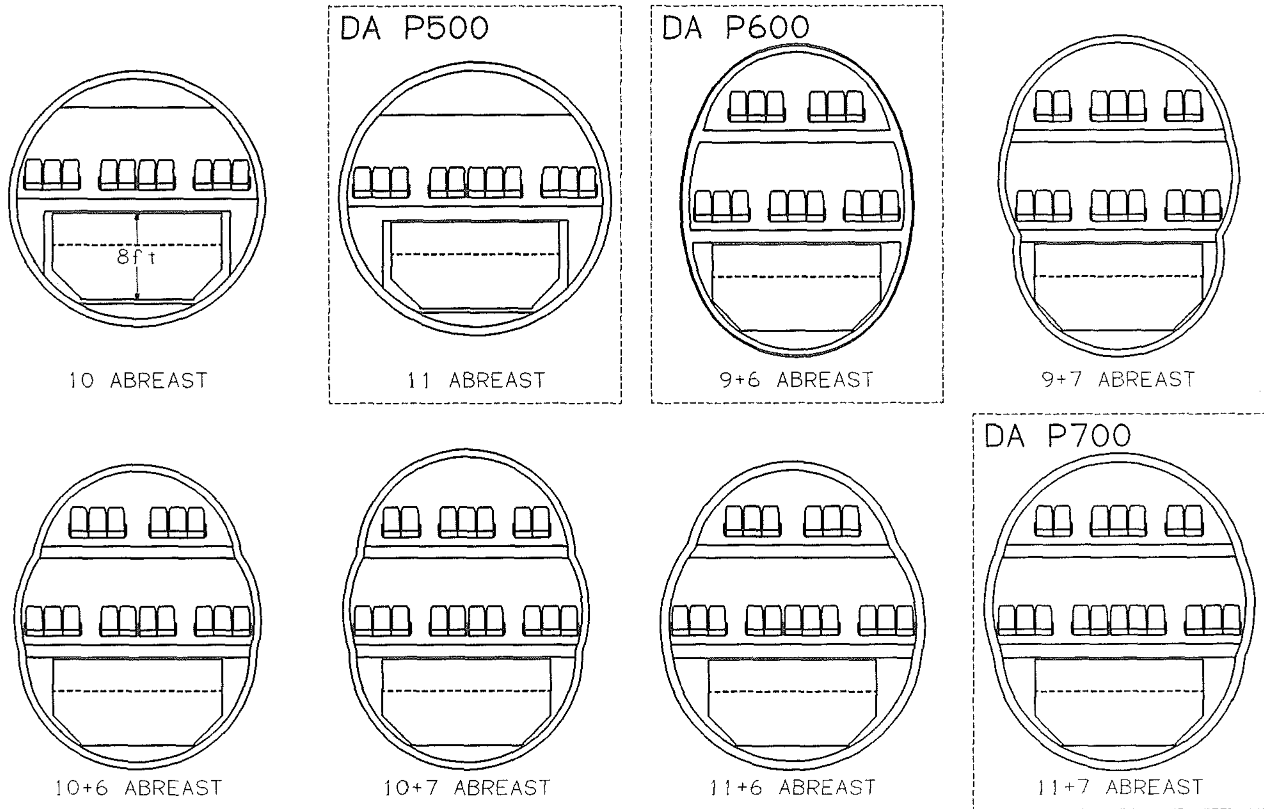


FIGURE 3 - ALTERNATIVE CROSS SECTIONS (8x8 ft CONTAINER)

The second step of the cross-section study was based on deeper cargo holds to solve the a. m. problems. In this context, the use of 8 x 8 ft containers - currently used as main deck ULD's - was a logical step. FIGURE 3 shows a number of cross-sections with improved cargo holds. The three selected cross-sections now do fulfil the vòlume related requirements.

DA P 500:

- Volume utilization "optimized"
- Alternative use of lower holds possible

DA P 600 and DA P 700:

- Acceptble freight volume
- Acceptable ditching situation
- Sufficient space for wing box and body gear installation below passenger floor.

FIGURE 4 shows the standard seat arrangements of the three selected cross-sections. The design case for the cabin width was the tourist class at 11, 15, and 18 abreast. The economy seat width was increased by 1" relative to the current Airbus standard to allow for a better comfort level and to take into account the trend of human growth.

DA P 502 Cross-Section

A circular cross-section with a diameter of 7.82 m is the result of an 11-abreast (3/5/3) economy seating with 21" wide seats. The basic aircraft uses underfloor toilets and galleys to achieve an acceptable passenger/freight relationsship. The underfloor galley arrangement results in an increased number of trolley movements on the main deck. The possibility of trolleys passing each other requires 25" aisles. The standard business class is 10-abreast (3/4/3) with 23" wide seats and 25" aisles. A 9-abreast (3/3/3) business class with more comfortable 26" seats is possible as an alternative. The standard first class is a very comfortable 7-abreast (2/3/2) with 29" wide seats and 35" aisles. One centre seat is separated to avoid an uncomfortable triple seat. Reducing the aisles to 25" permits an alternative 8-abreast (2/4/2) seating.

DA P 602 Cross-section

An "OVAL" cross-section at a height of 8.76 m and a width of 6.54 m is the basis for the 600- to 700-seater family. The main deck has a 9-abreast economy seating similar to the 777 at 9-abreast. The upper deck has a very comfortable 6-abreast economy seating, which is about 15" wider than A320 (today's best 6-abreast). The standard business class is 8-abreast (2/4/2) with 23" wide seats and 23" aisles. The optional 7-abreast business class (2/3/2) accommodates the more comfortable 26" seats. The standard first class is a conventional 6-abreast (2/3/2) with 29" seats and 25" aisles.

DA P 702 Cross-section

A tri-bubble cross-section at a height of 8.94 m and a width of 7.7 m is the basis for the 700- to 800-seater family. The main deck has a 9-abreast economy seating similar to DA P 502. A twin aisle 7-abreast economy seating similar to 767 was used for the upper deck. The 10-abreast business class and the 7-abreast first class is comparable to the DA P 502 arrangements.

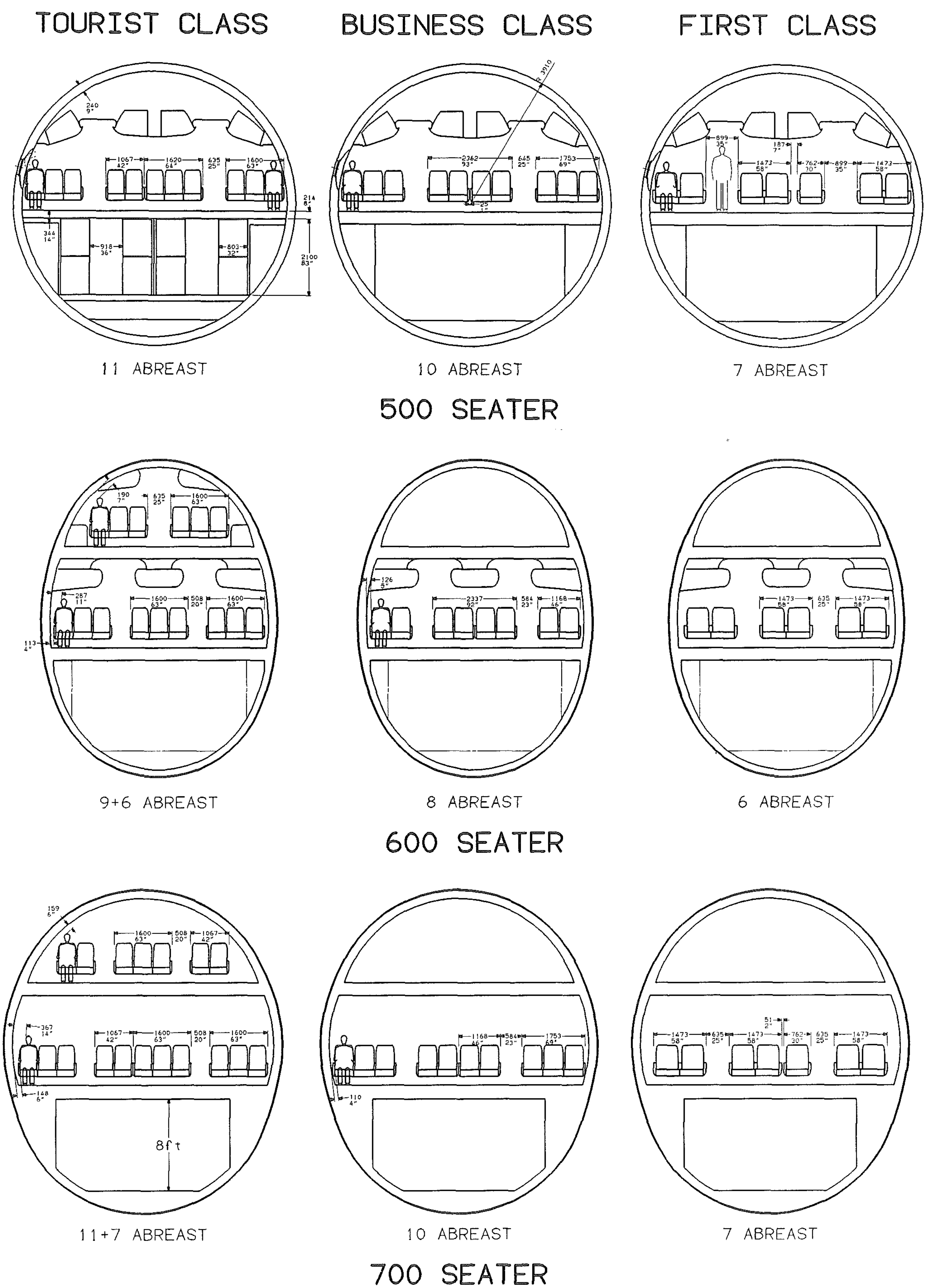


FIGURE 4 - CROSS SECTIONS

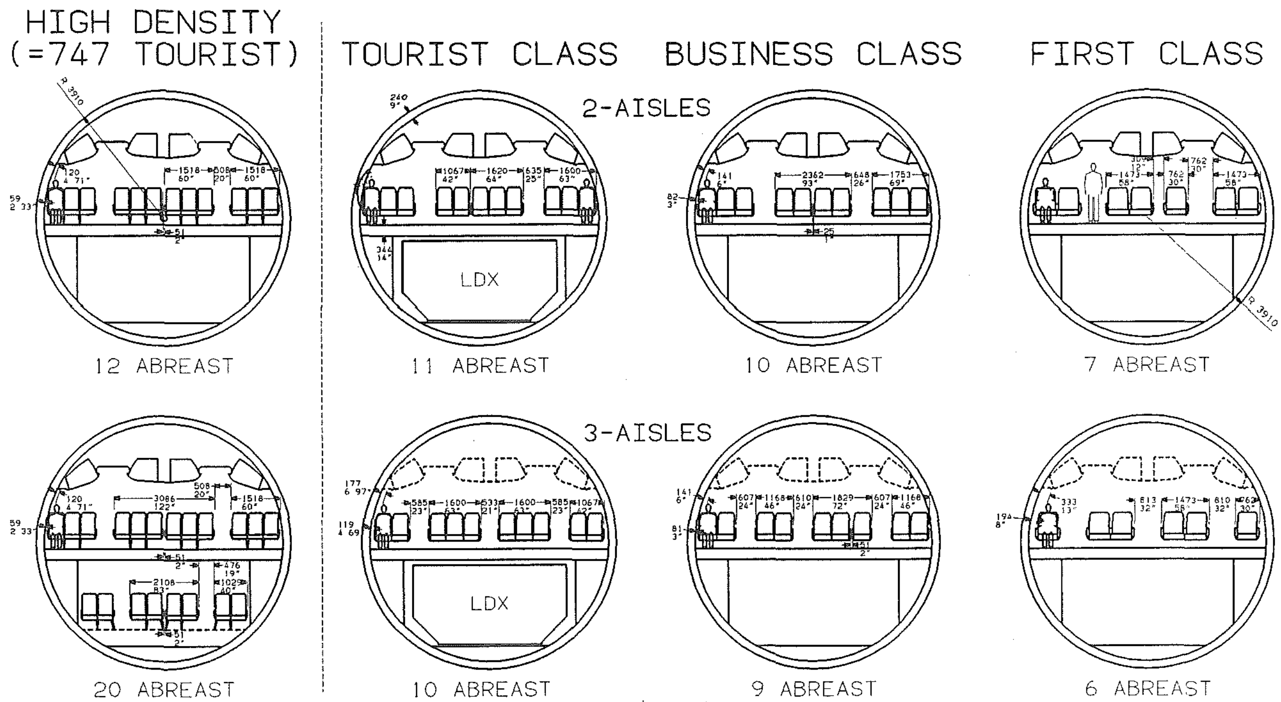


FIGURE 5 - CROSS SECTION FLEXIBILITY

CROSS-SECTION FLEXIBILITY

FIGURE 5 shows the layout flexibility by example of a DA P 502 cross-section. The standard twin aisle seating arrangements in some cases have an uncomfortable 2-seat distance to the nearest aisle:

11-abreast economy:	Window seats/centre seat
10-abreast business:	Window seats
7-abreast first class:	Uncomfortable centre seat

The alternative 3-aisle seating arrangements have an excellent comfort level. The maximum distance to the nearest aisle is only 1 seat. All first class passengers are sitting next to an aisle. The penalty is the loss of 1 seat per seat row and, therefore, a capacity loss of about 9 %.

The high density seating arrangements are shown on the left side of FIGURE 5. The 12-abreast high density seating on the main deck is the maximum number of seats abreast with 2 aisles. The aisle and seat dimensions are comparable to the current 747 tourist standard. With a raised lower floor the number of passengers can be increased by an 8-abreast underfloor seating. Raising the floor gives the following advantages:

- Increased floor area
- Acceptable cabin height (2 to 2.1 m)
- Increased crash resistance
- Additional system installation volume

Alternatively, the underfloor hold can also be used for rest facilities.

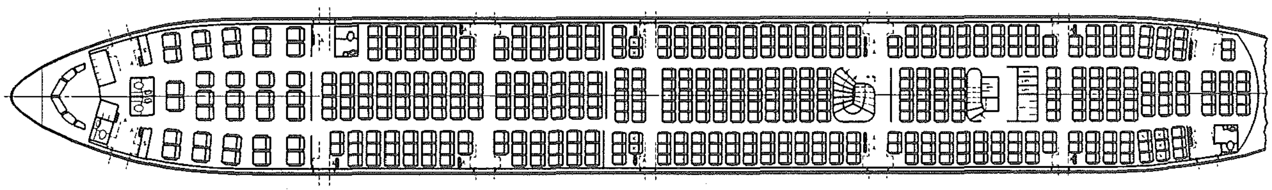
IV. Example Aircraft Configuration

Seat Layouts/Freight Holds

The cabin arrangements of the three example aircraft are based on a set of Airbus Industrie rules like the repartition of classes, the number of galleys and toilets and the seat pitch.

747-400 (Reference Aircraft)

The 747-400 reference aircraft accommodates 421 passengers in a typical standard three-class layout. The underfloor capacity of the 747-400 with five 96" x 125" pallets forward (2212 ft^3) and 14 LD3 containers aft (2212 ft^3) is the yardstick for the freight requirement of 10 ft^3/passenger.



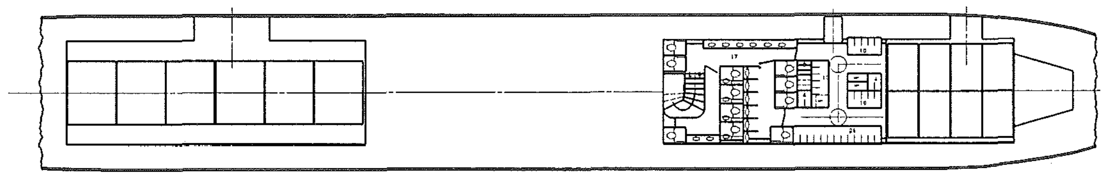


FIGURE 6 - DA P502 SEAT LAYOUT/FREIGHT HOLD

DA P 502 (FIGURE 6)

The standard three-class layout of the DA P 502 with 476 passengers has business and economy class galleys and toilets in the rear part of the underfloor hold. Only the larger toilets for handicapped people of both classes are positioned on the main deck. First class galleys and toilets are also installed there.

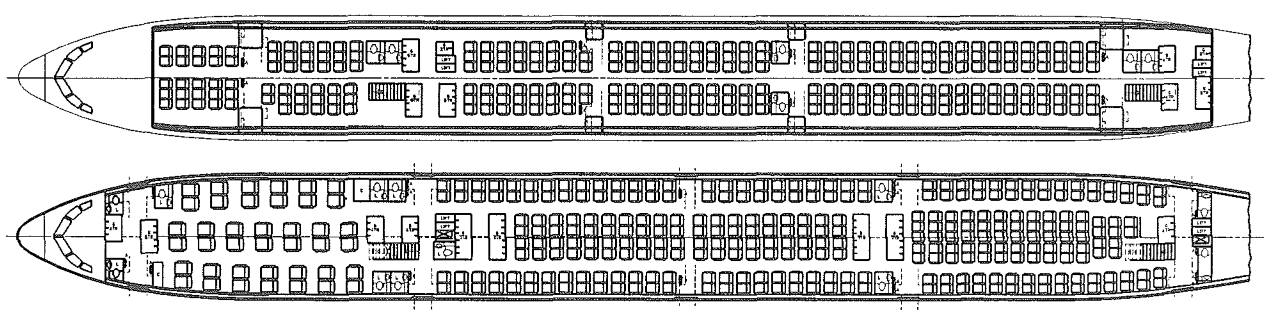
Three lifts of the main deck galley plus a separate staircase connect main deck and lower deck galley facilities. A large double staircase leads to the lower deck toilet area. Any requirement concerning minimum main deck galley/toilet capacity may slightly change the seat layout.

The large depth of the "new type" of freight holds leads to four different underfloor compartments: a forward and a rearward 8 x 8 ft container compartment, a rear LD 3 container and a bulk cargo compartment. The freight holds have a capacity of six 8 x 8 ft containers and 8 LD 3 containers with a total volume of 4888 ft^3 (10.3 ft^3/pax). Alternatively, the forward part of the rear cargo compartment can carry four 8 x 8 ft containers. The associated loss of passengers is 33.

DA P 602 and DA P 702

FIGURES 7 and 8 show the seat layouts and freight holds of the double deck versions. On the upper deck there are only economy class seats (274/326). First class, business class and a certain number of economy class seats are on the main deck (40 + 172 + 125 = 337)/(51 + 202 + 148 = 401). The access to the upper deck is via staircase and two trolley lifts in the forward and rear part of the cabin. A total number of 611/727 passengers requires 87/105 trolleys with an equivalent number of 2436/2940 meals. It is doubtful whether the current catering and trolley concept is still valid for very large aircraft.

The 15-abreast DA P 602 has an advantageous underfloor capacity. Nine 8 x 8 ft ULD's and 8 LD 3 containers with a total volume of 6700 ft^3 result in a specific value of 11 ft^3/passenger. The cargo capacity of the DA P 702 is marginal. Ten 8 x 8 ft ULD's and 6 LD 3 containers have a total volume of 6988 ft^3 and a specific value of only 9.6 ft^3/pax. The 18-abreast cross-section has freight volume problems even with the deeper cargo holds.



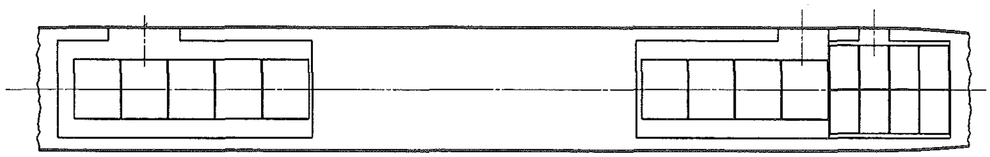


FIGURE 7 - DA P602 SEAT LAYOUT/FREIGHT HOLD

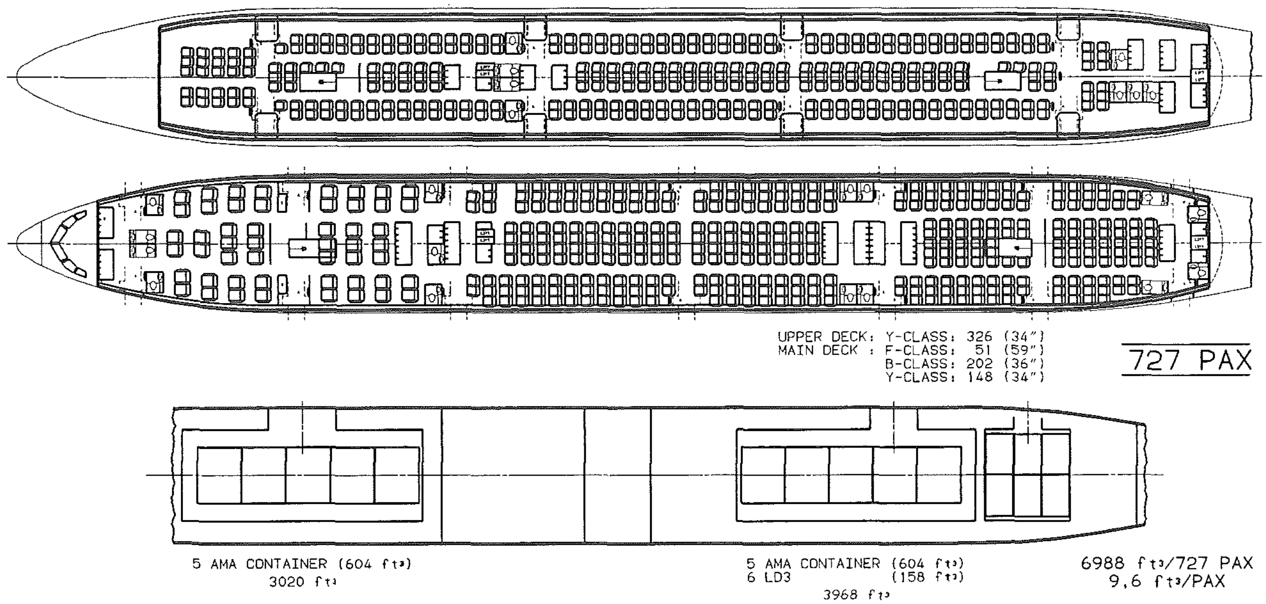


FIGURE 8 - DA P702 SEAT LAYOUT/FREIGHT HOLD

<u>DA P 502 (FIGURE 9)</u>

In the first step of iteration, a wing area of 592 m² was used for the DA P 502 (FIGURE 9). The 7000 nm mission with 476 passengers requires a maximum take-off weight of 410 t. The engines are rated at 56000 lb SLST with a 10 % bump rating for climb and cruise to achieve the intial cruise altitude of 35000 ft. A 20-wheel main undercarriage and a 3-wheel nose gear is required for acceptable ACN values. The undercarriage length depends on the rotation angle of the stretched 600-seater, which will have a fuselage insert of about 10 m. The door concept covers the high density case with a 17-abreast all-tourist layout (30" seat pitch). With 6 pairs of type A exits and one type C overwing exit the door limit is at 715 passengers. The forward cargo hold has a cargo door, which is similar to current upper deck combi doors. The rear cargo hold has a catering door only. Its sill height is only 4.2 m compared to 6.5 m for the main deck doors.

<u>GENERAL ARRANGEMENTS</u>

The general arrangements of the three example aircraft are based on essentially the same wing parameters, i. e. 33° sweep and an aspect ratio of about 8.6. The wing size allows for an initial cruise altitude of 35000 ft and a growth of 100 passengers at a design range of 7000 nm.

Leading edge slats and double slotted trailing edge flaps are required for an approach speed target of 140 kts. The fuel volume of the wing is not critical.

The tailplanes are sized with regard to wing area, tail arms, engine thrust and engine arms.

The engine characteristics are scaled on the basis of a GE 90. Engine size depends on cruise and climb thrust requirements, a typical situation for 4-engined aircraft with M = 0.85 cruise speed capability.

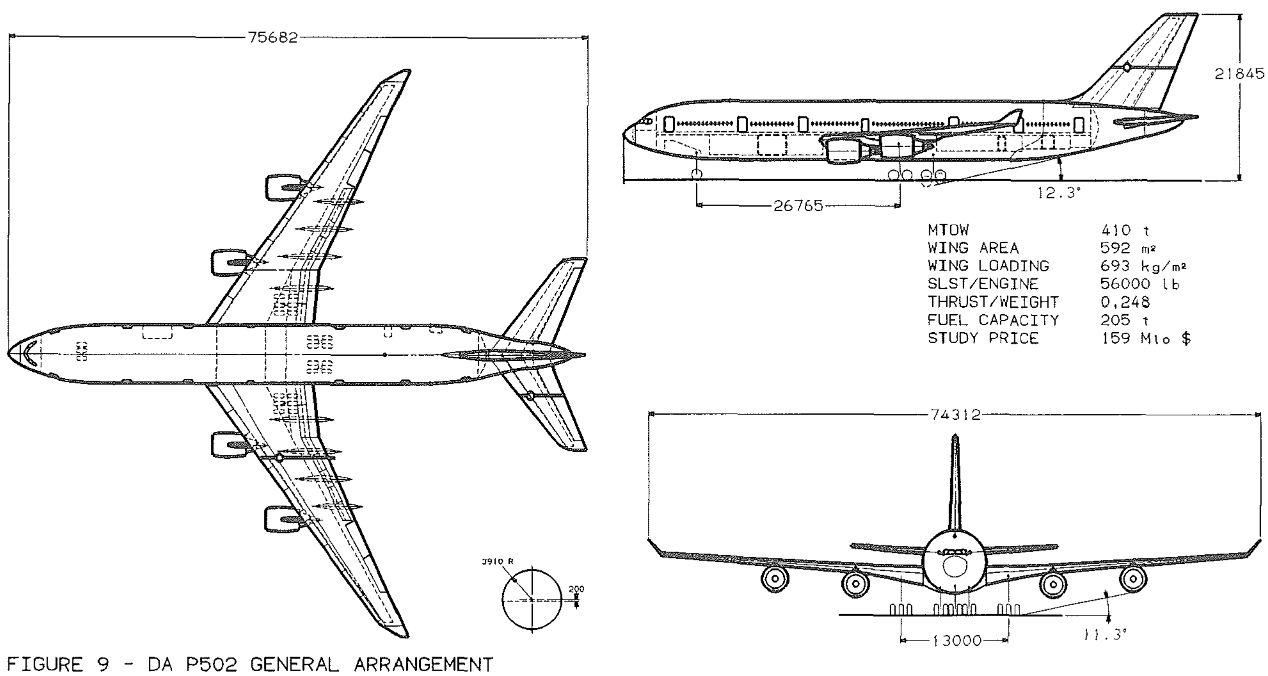


FIGURE 9 - DA P502 GENERAL ARRANGEMENT

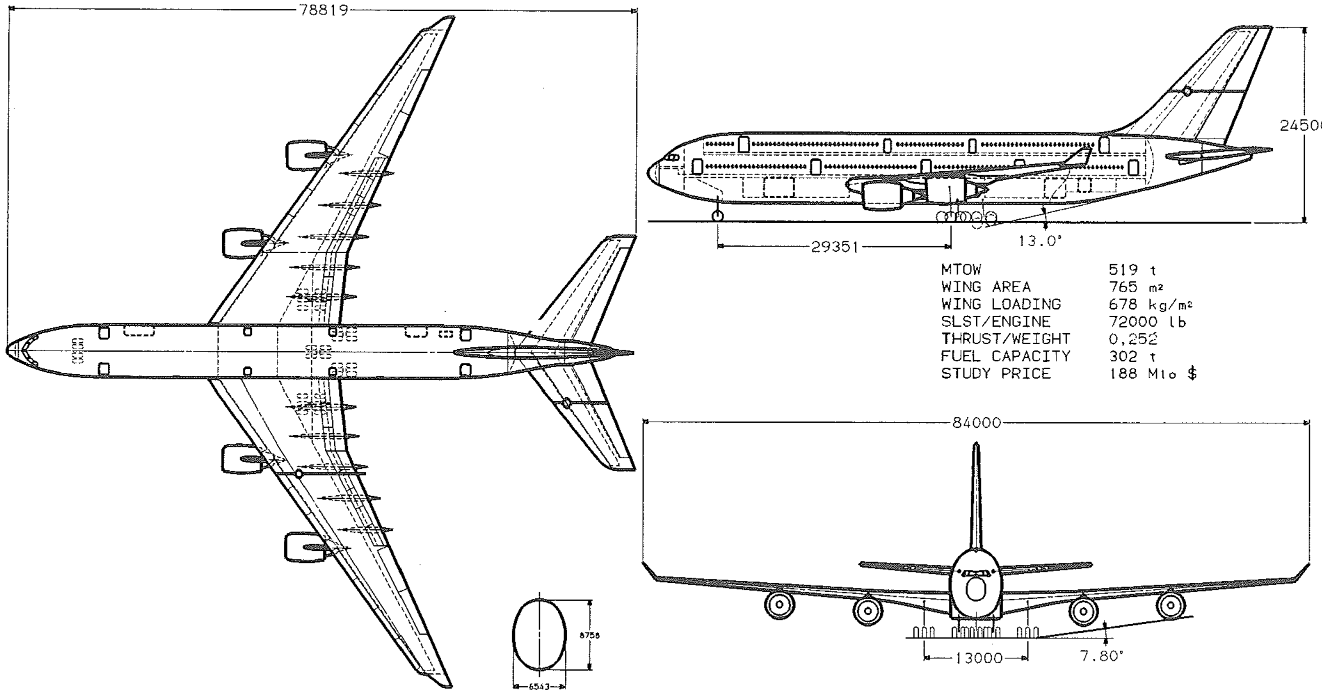


FIGURE 10 - DA P602 GEN.

DA P 602 and DA P 702

The DA P 602/702 have a wing area of 765/902 m² (FIGURE 10/11). The 7000 nm mission with 611/727 passengers requires a maximum take-off weight of 519/614 t. The engines are rated at 72000 lb and 88000 lb respectively.

The 5-leg main gears have 24/30 wheels for acceptable ACN values and there is a 4-wheel nose gear.

The door concept covers the high density case with 16/20-abreast all-tourist layouts (30" pitch). The door limit is at 880/1210.

The underfloor holds have two large cargo doors and one LD3 container door. A bulk hold can be offered as an option.

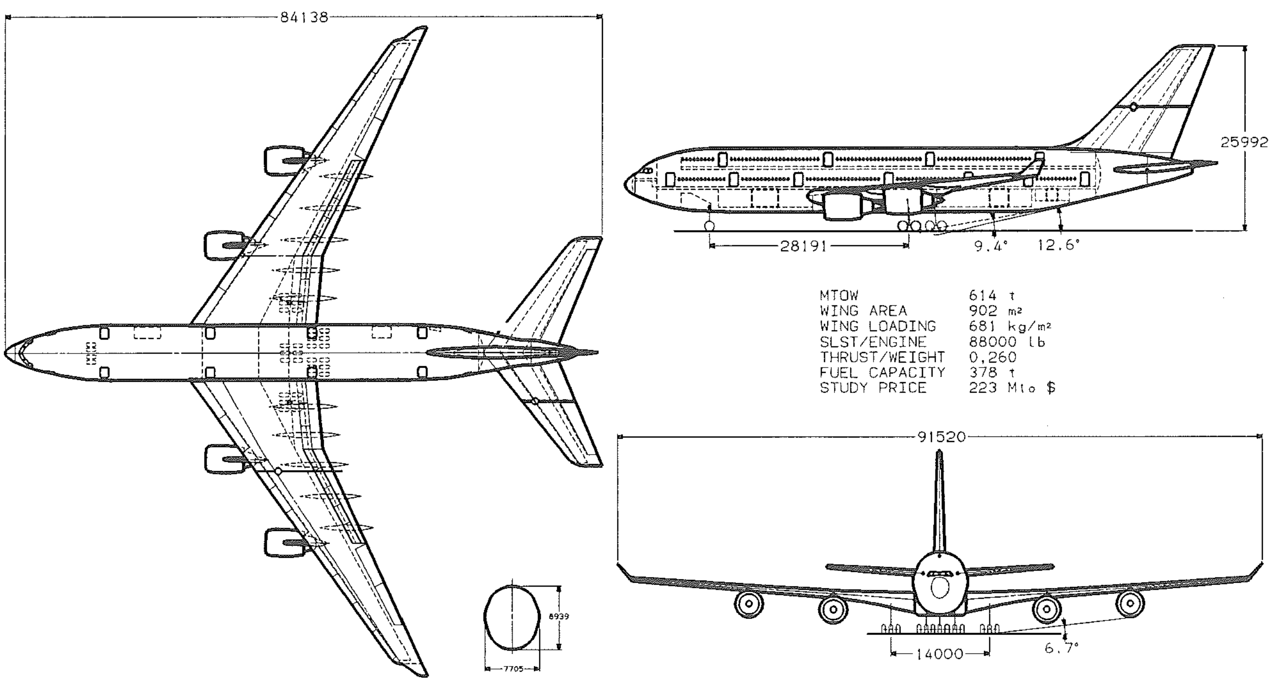


FIGURE 11 - DA P702 GENERAL ARRANGEMENT

Wetted Areas

FIGURE 12 shows a comparison of wetted areas relative to the 747-400 reference aircraft.

The lower comfort standard of the 747-400 results in a wetted area benefit of about 10 % relative to the example aircraft.

The double deck aircraft DA P 602/702 are very effective in terms of wetted area/pax (incl. size effect). The penalty increases to unacceptable 10 % when toilets and galleys are on the main deck instead of the rear freight hold. A pure single deck aircraft is unable to meet the economic targets compared to a 1½ deck 747-400 or new double deck aircraft.

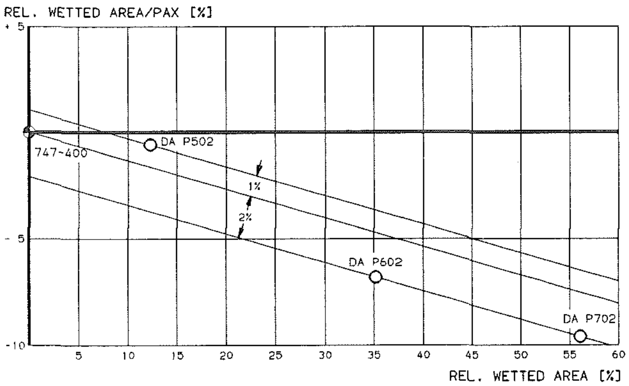


FIGURE 12 - WETTED AREA COMPARISON

V. Airport Development

The long-term planning of airports does already include new high capacity aircraft. The International Industry Working Group (IIWG) for instance is responsible for compatible development of aircraft, airlines, and airports worldwide. The "New Lancer Aircraft Study Group", a sub-group of the IIWG has summarized the findings of an initial European airport survey concerning high capacity aircraft at their 34th meeting in Dallas/Fort Worth. The introduction of larger geometric boundaries for aircraft being introduced within the next 10 to 13 years were discussed and laid down. These boundaries are used as a yardstick for the example aircraft.

Aircraft Length

Aircraft length discussions are concentrating on 80 to 90 m overall length for new large aircraft. FIGURE 13 compares the 747-400 with DA P 502/602/702 and its stretched derivatives. The stretched versions of DA P 502 and 602 are very similar in length (~ 86 m) and well within the area of discussion. The 800-seater DA P 702 will have a length of about 91 m which is slightly outside the 90 m boundary. The comparison shows that the 80 to 90 m length band is a relaistic approach for future large aircraft.

Wheel Base

The wheel base of the initial aircraft is below the critical 30 m margin. The stretched versions are between 31 and 33 m which requires taxi way fillet modifications and/or steerable body gears.

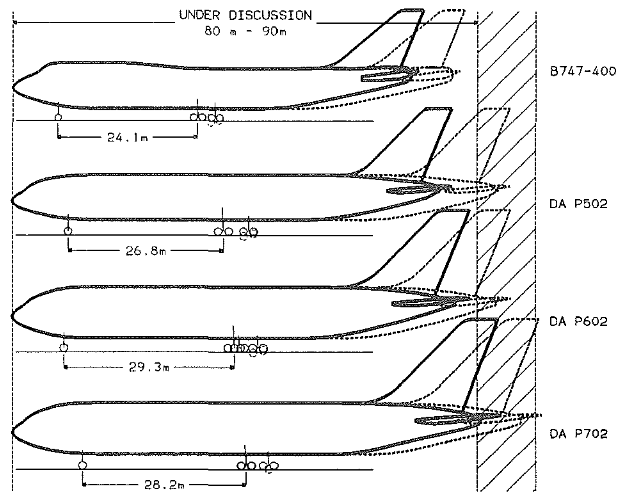


FIGURE 13 - LENGHT/BASE

Wing Span

The current span limit of 65 m (ICAO CODE E) is based on the 747-400. The wing layouts of the three example aircraft do not take into account any constraints by the airports.

FIGURE 14 shows the 600-seater in the centre of the 77 to 90 m span band. The 500-seater is just below and the 700-seater just above these margins. Folding wings could be avoided if airports in the US and Pacific Rim showed a similar 90 m flexibility as the European airports.

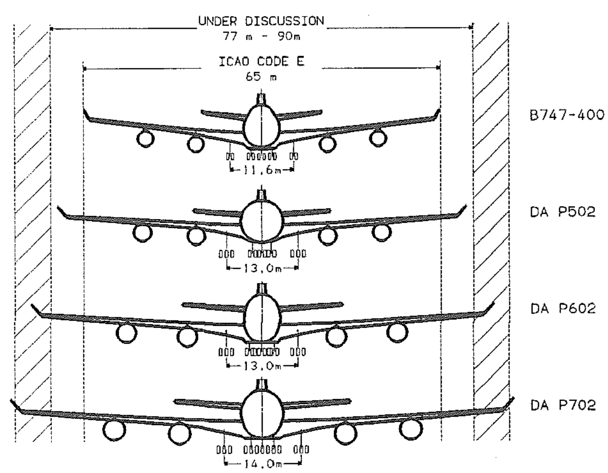


FIGURE 14 - SPAN COMPARISON

Wheel Track

The wheel track is in the order of 13 to 14 m, the corresponding wheel span is 15.6 to 16.6 m. These values are well within the long-term planning.

Runway Loading

FIGURE 15 shows the main undercarriage footprints of the three example aircraft. The increased height of the cargo hold/undercarriage bay allows for a 6-wheel triple tandem wing gear. The body gears are retracted forward and the bogies are stored almost vertically in the undercarriage bays. The current ACN method gives no reasonable figures for heavy weight multi-geared aircraft on flexible pavements. Therefore, there are discussions to replace it with a so-called "slope method" which is based on subgrade deflection slope rather than vertical deflection. This method shows much better agreement with Multi-Wheel-Heavy-Gear-Load test results conducted in the early 1970's. The lower ACN values (FIGURE 15) for DA P 602/702 are valid for one gear, the larger values are valid for all gears. The one gear level gives an indication for the results of the "slope method".

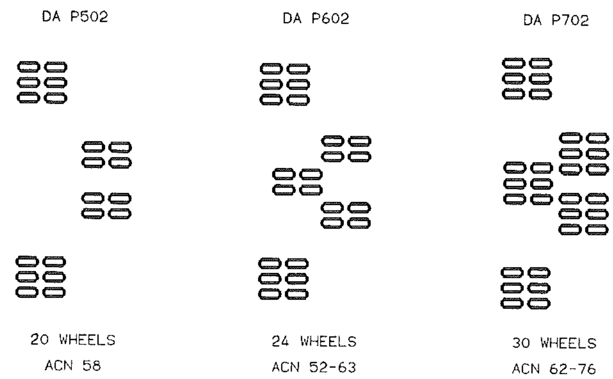


FIGURE 15 - UNDERCARRIAGE SITUATION

The DA P 702 does not achieve the ACN target of 55 The body gears have to be re-arranged which might result in a loss of freight capacity.

Aircraft Heights

Aircraft height is growing beyond 20 m: DA P 502/602/702 ~ 22/25/26.5 m. These dimensions are not in accordance with existing maintenance hangars and may require alternative technical solutions.

The main deck sill heights vary between 6 and 7 m. Only the DA P 502 lower deck galley with 4.2 m can be served by the existing equipment. The sill heights of the upper decks vary between 8.5 and 9.5 m. These heights require new concepts for passenger boarding and emergency evacuation.

Aircraft Noise

The FAR noise regulation PART 36 stage 3 shows MTOW independent levels for large aircraft (4-eng.):

Take-off:	MTOW > 385 t	= 106 EPNdB
Approach:	MTOW > 280 t	= 105 EPNdB
Sideline:	MTOW > 400 t	= 103 EPNdB

A further noise reduction of 3 EPNdB from 1995 onwards is under discussion. First MTOW estimates for DA P 502/602/702 are 410 t/519 t/614 t and hence all aircraft are in the area of constant noise limits. It is doubtful whether the above noise levels can be met by 600- to 800-seaters. Therefore, it is recommended to take into consideration these very large aircraft aspects in future noise level certification requirements.

VI. Economics

The blockfuel and operating cost calculations are based on an average stage length of 3000 nm.

Blockfuel

The blockfuel target is a 10 % improvement over the 747-400 excluding engine sfc effects. The blockfuel improvement of a GE 90 type engine alone is estimated to be about 6 %.

The blockfuel comparison (FIGURE 16) shows the three example aircraft nearly on a straight line with a shallow slope. The aircraft size effect in terms of blockfuel/seat is very small (only - 3 % for + 250 passengers). The DA P 602/702 wetted area benefit is balanced off by the weight penalty of large structures. However, the blockfuel benefit of the three example aircraft is 10.5 % neglecting size and engine effects. Hence the target is about met.

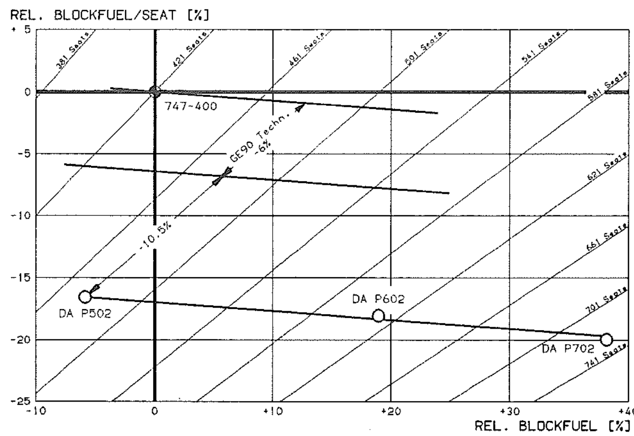


FIGURE 16 - BLOCKFUEL

Direct Operating Cost (FIGURE 17)

The DOC calculation is based on an Airbus Industrie method.

It is assumed that the price effect of the GE 90 type engines does balance off the blockfuel advantage. The airframe prices are size-dependent. So the DA P 702 price/seat level is about 9 % below the DA P 502. For the derivative type 747-400 aircraft a 5 % airframe price reduction is assumed.

The 600- to 700-seater double deck versions are able to meet the target of 10 to 15 % seatmile cost improvement.

The 10 % seatmile cost target is very ambitious for the smaller DA P 502. It achieves only 6 %. A further optimization of fuselage volume utilization will increase the number of passengers (target: 500 seats) and will bring the aircraft nearer to the DOC target.

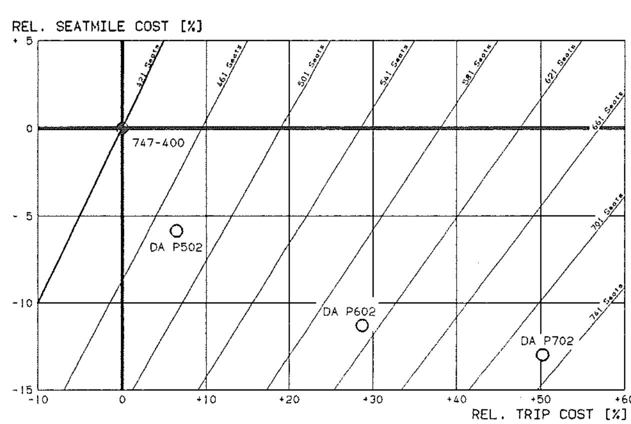


FIGURE 17 - DOC COMPARISON