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FUTURE REQUIREMENTS AND CONCEPTS FOR CABINS OF BLENDED WING BODY CONFIGURATIONS—A SCENARIO APPROACH

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ABSTRACT

The strong influence of unpredictable factors on the development of future concepts for cabins of Blended Wing Body (BWB) aircraft favors the methodology of scenario techniques. The scenario process performed at Technische Universitat München together with Airbus Deutschland GmbH, DaimlerChrysler Society and Technology Research Group and industrial Design Studio comprises the development of three different scenarios, the implication of specific requirements and the realization of preliminary cabin concepts. On the basis of current cabin standards of the A380, new standards for the BWB cabin designs were quantitatively derived for each scenario. According to these inputs, two-dimensional cabin layouts and specific system solutions have been developed and sketched to visualize the concepts. In a final step, specific requirements and technologies have been evaluated in all scenarios to identify their compatibility in the respective future environments.

Stephan Eelman received a Bachelor's degree in Aerospace Engineering from the Technische Universität München (TUM) in 1997. In the course of his subsequent graduate studies, focusing on commercial aircraft and its interfaces in the air traffic system, he was granted a scholarship at Delft University of Technology, the Netherlands, before receiving a Master's degree in Aeronautical Engineering in June 2000. Continuing at MTU Aero Engines in the Market-Technology-Department, he took an opening as research scientist in 2001 and since 2002 is scientific assistant at the Institute of Aeronautical Engineering, TUM. Since then he has been involved in several scenario projects with partners from aerospace industry.

INTRODUCTION

With a basic scenario of a strong aviation business growth of around 4.7% per year in the next thirty years, passenger volumes will multiply by a factor of at least two-and-one-half until the year 2020 (Airbus, 2002) and almost quadruple by the year 2030 from today's level. Taking into account that capacity in the air and at major and hub airports already is evolving as a limiting factor and that airline efficiencies will have to improve from current levels, aircraft with higher productivity yields may play a major role in the future of the aviation system. This could lead to an additional concentration of large passenger flows through hub airports with little infrastructure capacity on the airport airside (e.g. runways, taxiways, aprons, parking positions) available, especially with regard to long-range routes with significantly longer turn-around times.

Dieter Schmitt completed his mechanical engineering studies in 1968 at Technical University in Darmstadt and continued at the Institute of Aeronautics in Darmstadt as a scientific assistant of Prof. X. Hafer until 1975. He received his Doctorate in 1976, already being involved as a flight engineer at MBB (Messerschmitt Bölkow Blohm) in Hamburg in the tailplane design for A300 B10 and A310 until 1980. As a manager of Aerodynamics he coordinated all aerodynamic aspects of Airbus Industries in Toulouse, France. He served as general manager of Research and Technology, vice president of Future Projects, and chief engineer. In 1996 he was nominated Lead Professor of the TUM Institute of Aeronautical Engineering. Since 2002 he has been vice president of Research and Technology at Airbus.

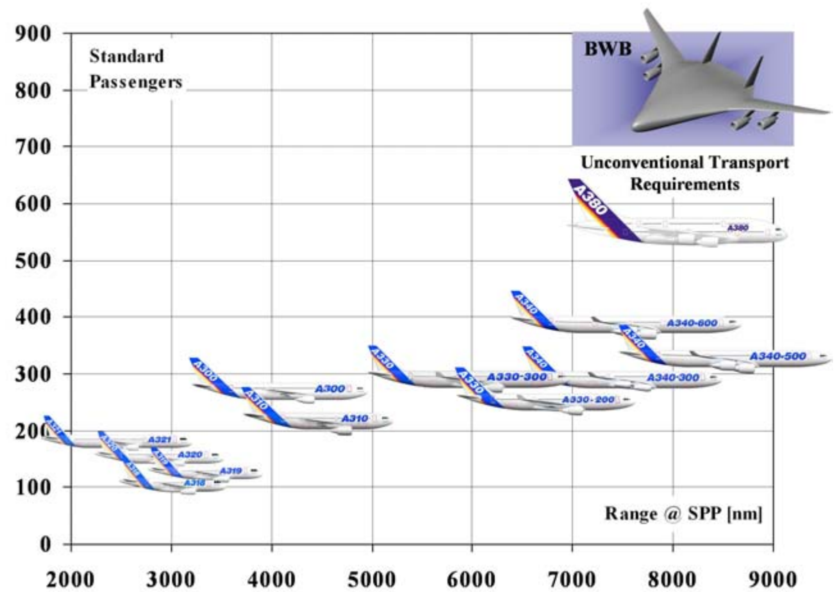
Axel Becker, certified engineer, studied from 1990 to 1996 at the Institute of Aeronautics and Astronautics of the Technische Universität Berlin, putting the main emphasis of his studies on systems dynamics; civil aviation economy and policy; and corporate and innovation management. Since 1991, he has participated in the Society and Technology Research Group of the DaimlerChrysler AG in Berlin. In this he has been co-responsible, among other things, for the conception, moderation and methodical monitoring of different projects such as Civil Aviation and Alternative Drivetrains. Furthermore he is working on the systematic analysis of business and product environments, strategic development and assessment and the further development and application of the scenario method in the context of corporate decision and product development processes.

Werner Granzeier finished his studies in Industrial Design at the Bergische Universität GHS in Wuppertal. He started as a designer at MBB (Messerschmitt Bölkow Blohm) and later at VFW-Fokker and Airbus. He developed cabins of commercial aircraft, among which for example the A320 basis cabin. In 1984 he founded his own company iDS, industrial Design Studio, in Hamburg and was involved with the design of the Boeing 717 cabin and later the Fairchild Dornier 728Jet program as well as projects together with Airbus Cabin Research. From 1989 on he was assigned as Professor at the Hamburg University of Applied Sciences in the Department of Automobile and Aeronautical Engineering and completed here several exterior and interior designs of aircraft. He is member of DGLR (Deutsche Gesellschaft für Luft- und Raumfahrt) and AIAA (American Institute of Aeronautics and Astronautics).

To cope with these demanding qualities of future air travel, airlines require new aircraft configurations to ensure and improve operational efficiency, productivity and customer value in a highly competitive market environment.

The conventional aircraft configuration is reaching its optimum and even scaling effects with bigger airplanes do not provide the potential for leap improvements. Though claiming superior economics over current large airplanes, the introduction of the Megaliner A380 seems to be the upper limit of size for conventional airplanes and is a probable transition to a next generation of aircraft, which combine extremely low fuel burn with high capacity, high environmental compatibility, low operating costs, and operational flexibility for airlines (see Figure 1).

Figure 1. Airbus product line and blended wing body profile



Besides a number of aircraft configurations being investigated by both large aircraft manufacturers to comply with the strict requirements, the Blended Wing Body (BWB) is closest to realization with a reasonable chance to enter the market by 2030, being discussed by both large aircraft manufacturers. As a compromise between the aerodynamically high performing flying wing and the evolutionary optimized conventional airplane it offers significant advantages for operators, which is especially true for larger sized aircraft.

As the foreseeable entry into service of this type of aircraft is some time into the future, derivation and assessment of requirements reflecting market demands is difficult. This is explicitly the fact for the cabin of the aircraft, as it embodies the direct interface between the operator, customer and manufacturer in a competition driven environment. The importance of an early view of different cabin development paths by derivation of basic cabin requirements in the young stages of BWB development can be underlined with the broad variety of different BWB aircraft designs currently developed at aircraft manufacturers, scientific institutes and universities.

However, to maintain a competitive advantage it is vital for new aircraft characterized by a long life and product cycle to be as attractive as possible over a maximum period of time. Therefore, the identification of robust cabin requirements becomes eminently essential as it determines the main portion of cabin development at the start of the aircraft program and will have major influence on the potential to adapt to modified customer requirements later on in the product life cycle.

APPROACH AND AIM

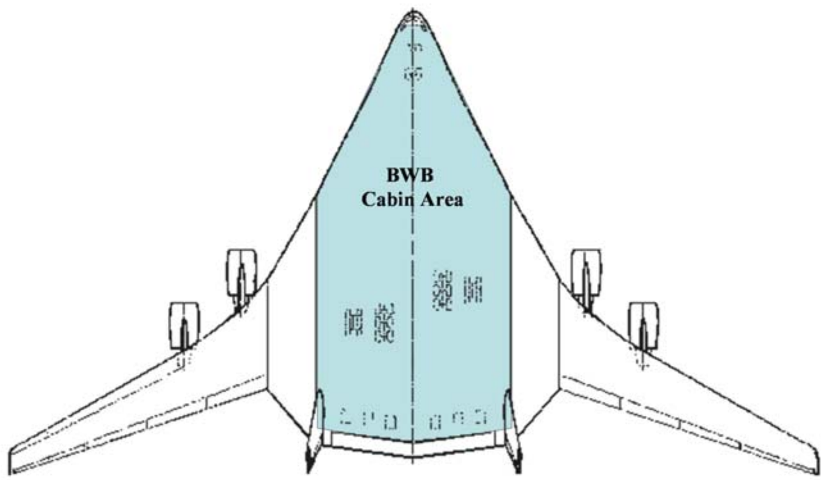
The large number of unpredictable factors from various environments—such as socio-economic; air transport and operation related; and political or technological area—has a great impact, with considerable uncertainty, on the design process. The geometric spacious room inside the BWB fuselage with unknown varieties for new cabin solutions describes a completely different type of product, for which a classical design approach is not convenient anymore. This leaves even more uncertainties for the derivation of BWB cabin requirements. Therefore, scenario techniques, as described by Strohmayer and Schmitt (2000), are applied to work out a qualitative set of comprehensive future product environments which drive the development of the BWB cabin.

The aim of the process has been to derive hard figures for key cabin parameters like seat pitch or number of galleys on the one hand and soft qualities regarding incorporated technology and process profiles on the other. With this approach, the aircraft manufacturer is capable of evaluating basic cabin design variants and options to be prepared for different customer requirements and challenges coming from the operator. This is vital from a technological as well as a marketing point of view. As a consequence, there are no restrictions regarding structural layout of the BWB, for example by concepts of single or double shell or load supporting elements for the inner structure.

The BWB aircraft is an Airbus designed configuration with the performance displayed in figure 1 (ICAS Congress, 2000). The usable cabin area is geometrically given and constant for all scenarios (no scaling). Figure

2 shows the significant difference in cabin area compared to the common cylindrical fuselage of conventional tail-aft configurations.

Figure 2. Blended wing body configuration of very efficient larger aircraft



DEVELOPED SCENARIOS

The analysis comprises the development of three different scenarios to cover a relevant range of potential evolutions. The following general assumptions are used as a basis for all of the scenarios since they characterize the development of the air transport system until 2030 and justifies the introduction of BWBs (Strohmayer & Becker, 2001):

1. Global economic growth of over 3% per year on average;
2. Global strong growth of air traffic volume of at least 4.7% per year on average;
3. Share of hub and spoke connections increases;
4. Long haul routes are predominantly served by very large aircraft;
5. Long routes are basically operated by full service carriers.

Parallel to these market conditions, the following factors have also been considered throughout the entire process;

1. Importance of flight time increases;
2. Information technology continues to propagate globally into society;
3. Anthropometric dimensions of human beings are larger;
4. Cabin safety improves; and
5. Medical care in aircraft evolves further.

The relevant scenarios, all of which have been treated equally, are presented hereunder.

“Chief Pax” Scenario

This positive reference scenario describes an optimistic environment in which political and socio-cultural stability ensures steady economic growth with a steadily increasing standard of living. Further cornerstones of this scenario are as follows:

1. Growing wealth in most of the global regions create passengers with high demands for comfort and service. This is addressed by airlines with an enhanced supply of in-flight values, covered by higher air fares. However, the relative value per price increases, resulting in profit margins comparable to current values.
2. The variety of different nationalities traveling the air and the distinctive individuality of the passenger as a result of higher living standards turns religious and cultural issues into key factors.
3. Conventional aircraft classes are refined into more and smaller user groups to react to individual needs. Passenger convenience is realized by both personal assistance by the crew and onboard systems.
4. Extensive advances in innovative technologies and processes permit a high constructional flexibility to facilitate quick and efficient changes in cabin layouts.
5. Growing restrictions from environmental issues and certification are addressed by new technologies.
6. Awareness of health issues related to air travel (e.g. the growing incident of deep vein thrombosis) increases.
7. BWB airplanes meet the expectations of airlines and passengers leading to more favorable perception of the aircraft by the public.

“Slow Motions” Scenario

As a projection of today’s trend to rationalize, this scenario of slow development shows little motivation for leap innovations, and is founded in deeper society problems which affect airline strategies, as well.

1. Despite economic growth, society is split into a small wealthy group and a large population stratum with a stagnating standard of living. The gap between the lower/middle and upper class widens which leads to social inequities and is especially a phenomenon of the economic triad (USA, Europe, Japan).

2. Due to strong competition, airlines continue to be under pressure to operate with low fares and high productivity, leaving small profit margins per seat sold. Passengers have not been able to organize themselves into a powerful entity expressing their needs towards the airlines, while dragging certification processes hinder operators to introduce new standards. The evolution is inert and moving slowly, resulting in conventional cabin designs with few classes.
3. The widespread application of information technology has overtaken many procedures in daily life, leaving many people, especially older, overstrained. The development into a two-class society results in a general decline of educational and intellectual standards. Still attracted by low ticket prices, this produces a significantly higher number of passengers requiring support and assistance. The demand for help services grows because of a lack of understanding of onboard processes and technologies by many groups of the flying society.
4. The BWB convinces airlines but only receives moderate acceptance from the passenger.

"Flying Heavenly Peace Square" Scenario

The metaphoric title aims at a specific Asian market development ascending up to 2030 which is taken as a major force for this scenario.

1. Economic growth pushes the Asian countries to a similar living standard as in the western world, leading to a long-running boom in air traffic both in and with this region.
2. A steady technological evolution leads to high standards and is the basis for sophisticated technological solutions.
3. Airlines face declining profit margins with a higher demand for in-flight conveniences and can only react with highly operationally efficient cabin layouts and concepts. The need for a single class layout is one of the measures taken, evolving from a gradual transition in the Asian market towards fewer classes, which started with the advent of high passenger volumes on shorter hub routes aimed to achieve throughput and efficiency.
4. To minimize operational cost, extensive aircraft cabin reconfigurations during down-time periods or even turn-arounds (e.g. changes of passenger classes, reallocation of cabin elements, interior modifications) are not wanted by operators.

5. To attract passengers, cabin design, functionality and quality is emphasized—along with the impression of the cabin's appearance—as a premium product. Because of substantial differences in culture, it is a priority to address special considerations to the development of an adequate traveling environment.
6. Ticket price mix and marketing options for airlines are realized by seat-individual service concepts sold at travel agents, airlines or operators, in which both the technological facility standard and the in-flight comfort service can be booked.
7. The awareness for health issues on long range flights increases throughout society.

BWB CABIN STANDARDS

The derivation of key requirements for cabin development from the specific scenarios follows the methodology as described in figure 3.

Taking cabin standards of the A380 as a reference, standards for the BWB cabin are tailored according to the requirements of the specific scenario. The main geometric standards are class ratios, seat pitch, seat width, aisle width, toilets/passengers, trolleys/passengers and stowage spaces. These are influenced by both the specific characteristics of the different scenarios and the general premises of all the scenarios. These latter are the continuous growth of the average dimensions of a human being (known as acceleration; Bauch, Schmitt, and Kasch, 2001); and the need for enhanced in-flight safety and medical facilities. Acceleration, for instance, is causing an increase in body height of about 1.5 centimeters over the next 30 years, justifying a seat pitch gain of one inch, as the operational life of an aircraft is 30 years. Accordingly, the need for an additional one inch in pitch results in a reduction of at least one row in the given BWB aircraft, and has a direct impact on capacity and productivity, especially because of the shape of the cabin area.

For every scenario a set of basic technologies is identified to establish a general level from which the different scenario implications develop. The common ones are summarized in the following list:

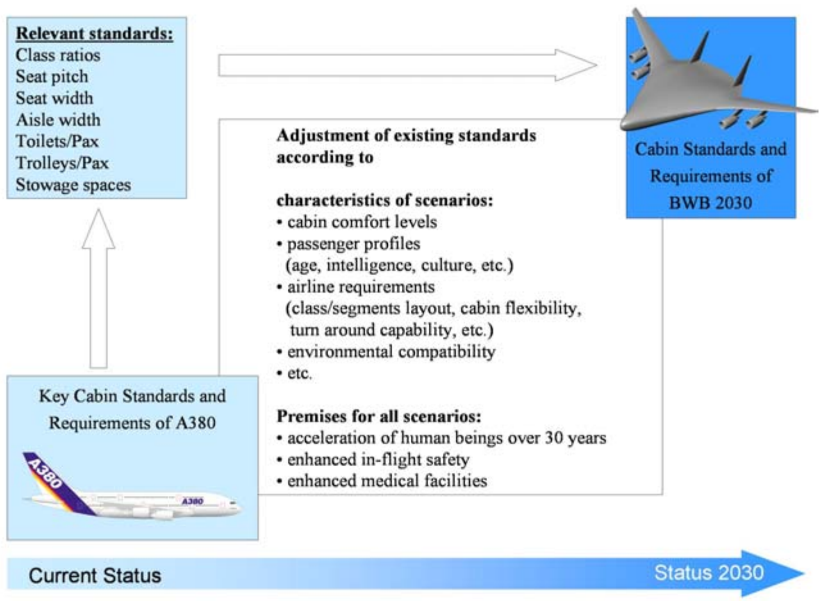
1. Communication with broad band internet;
2. Wireless blue tooth-like support of mobile equipment (phones, laptops, pagers, etc.);
3. Online information systems (passengers, cabin systems, stock data) for the crew; and
4. Intelligent boarding/deboarding systems optimizing on-board processes.

Generation of two-dimensional layouts

With these scenario-specific new standards, the number of seats in the BWB cabin is calculated. The procedure is shown in Figure 4. First, the seat areas within the BWB cabin are determined according to the given ratio of the absolute seat area and total cabin area of current aircraft (Figure 5), which is typically up to 55%. Second—with the given fuselage and unaffected by the need to scale the aircraft for a dedicated number of passengers—aisles, galleys and other remaining surface areas are determined according to the scenario needs. Also door positions, sizes and emergency evacuation paths are planned as part of the total cabin concept.

Along with consequent and logical rationales, the following scenario-specific standards for different cabin and operational concepts have been developed.

Figure 3: Derivation of blended wing body cabin standards



"Chief Pax" Scenario

The standard cabin dimensions developed for this scenario are noted in Table 1. The high standard of living and individuality combined with powerful communities of interest in this scenario enforces the influence of passengers as a prime stakeholder in the airline business. Airlines have to react to this demand with a personalized offer to defined passenger groups like families, older people, youths or different business passenger clienteles. This is reflected by airlines with the creation of additional segments within the classical classes, especially in the economy class. As can be seen in Table 1, the class layout has been adjusted to meet different demands, which are related to ticket price and offered service. The two-dimensional layout with emergency exits can be seen in Figure 6.

Figure 4: Generation of two-dimensional layouts

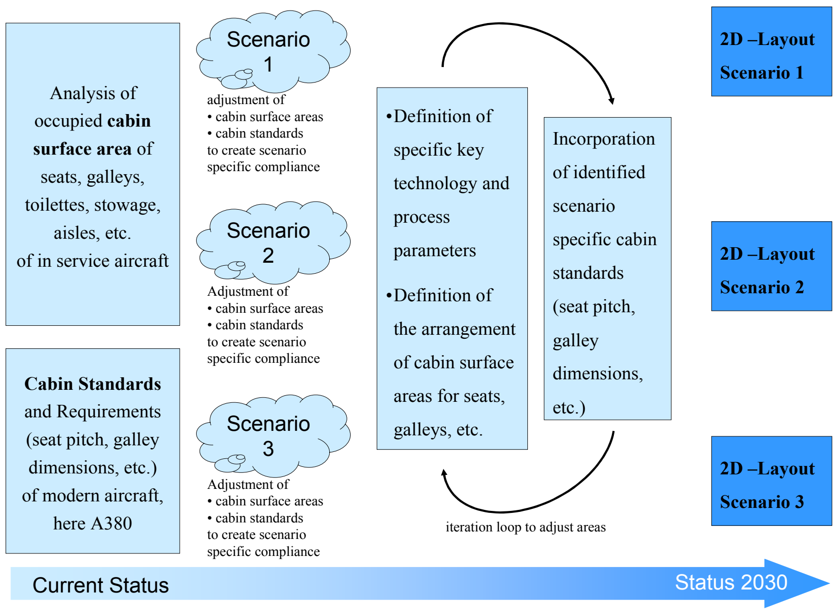
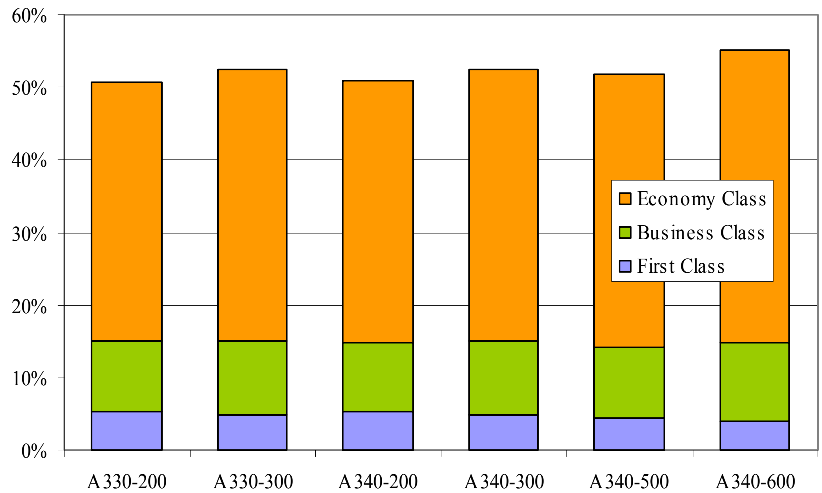


Table 1. Two-dimensional layout dimensions for the Chief Pax scenario

Cabin BWB 2030	Standard 2000 (A380)			Standard 2030 (BWB)				
	FC	BC	EC	FC	BC	EC1	EC2	EC3
Class ratios in %	4	16	80	5	12	83		
Seat pitch	62"	40"	32"	64"	42"	35"		
Seat width	30"	27,5"	25"	32"	30"	27"		
Aisle width	min 500 mm			min 570 mm				
Toilets / Pax	1 / 10	1 / 25	1 / 45	1 / 10	1 / 21	1 / 30		
Trolleys / Pax (*	1 / 2	1 / 4	1 / 10	1 / 2	1 / 4	1 / 10		
- Stowage space / Pax	25"x2"	25"x1,5"	1 Tray	25"x2"	25"x1,5"	25"x1"	1 Tray	1 Tray
- Hand luggage	2	2	1	3	2	1		

Figure 5. Absolute seat area as a portion of total cabin area



With aisle widths orientating at conventional dimensions, the cabin layout has to be designed attractively to achieve a favorable perception from the passenger. An unconventional approach of a bended main broad aisle (2 meters) assures quick boarding and deboarding in the critical entrance areas. The familiar approach of a cabin divided into classes, with first class in the front, is maintained. High service levels are addressed with additional facilities in the lower deck compartments with crew rest rooms, fitness and children areas and a social meeting point (with bar). Assistance for the passenger is obtained in the front and the middle **i**nformation desk to explore the full range of service supply during flight (indicated by "i" on Figure 6). Two additional **s**ervice points (indicated by "s" on Figure 6) in the economy classes underline the higher-quality traveling level.

Emergency exits are provided all around the cabin area with wing and aft exits according to FAR 25.807 of type B dimensions (75 passengers per minute), two type A doors per side in the front (110 passengers per minute) and the main entrance with a new standard type 0 door (double Type A with 200 passengers per minute). The design ends up with 730 passengers in a standard layout. Some artist impressions of the cabin are elaborated in figures 7 and 8.

Figure 6. Two-dimensional layout with emergency exits, Chief Pax scenario with 730 passengers

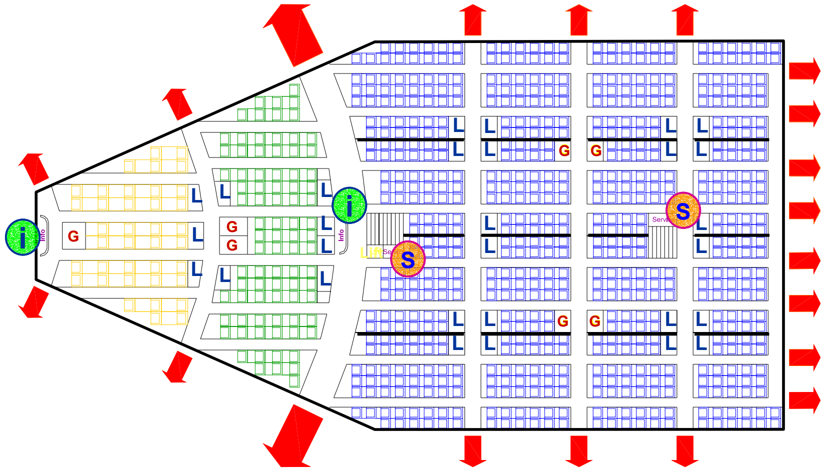


Figure 7. Three-dimensional impression of main aisle, Chief Pax scenario

Figure 8. Three-dimensional impression of lower deck facilities, Chief Pax scenario

"Slow Motions" Scenario

The standard cabin dimensions developed for this scenario are noted in Table 2. The scenario is based on a two class society and, thus, has two levels of treatment of passengers during flight (Figure 9). With declining profit margins, the inert evolution of innovative cabin ideas together with the low paying traveler leads to a conventional standard class system. The lack of airline demand for conversion of cabin elements in or during aircraft operation entail limited flexibility for cabin elements. Major cabin reconfigurations can only be realized at C or larger maintenance checks during aircraft overhaul. The scenario is characterized by the strong differentiation between standards of high revenue (first and business) class and low revenue (economy) class, which is, for example, obvious with the number of galleys and toilets per passenger. Service as well as supplied technology levels is significantly down-graded in economy class, focusing on efficiency and productivity for the airline. However, the larger share of older, immobile (wheelchairs) and larger passengers demands larger aisles. The service concept ensures convenient and quick operation through an automatic trolley distribution system with elevators which are integrated in the emergency stairs leading to the roof. The highly cost-efficient systems for simple operation limit the comfort of the passenger. On the other hand, first and business class have an optimized traveling environment and high-end service standards. Sophisticated comfort levels with on-seat climate, individual ergonomic adjustable seats, sound and light surround the high yield passengers that generate the major part of the airlines' revenues.

Table 2. Two-dimensional layout dimensions for the Slow Motions scenario

Cabin BWB 2030	Standard 2000 (A380)			Standard 2030 (BWB)		
	FC	BC	EC	FC	BC	EC
Class ratios in %	4	16	80	4	16	80
Seat pitch	62"	40"	32"	65"	42"	33"
Seat width	30"	27,5"	25"	32"	29"	26"
Aisle width	min 500 mm			1m	0,95m	0,9 / 0,6m
Toilets / Pax	1 / 10	1 / 25	1 / 45	1 / 10	1 / 25	1 / 45
Trolleys / Pax (*	1 / 2	1 / 4	1 / 10	1 / 2	1 / 4	1 / 10
- Stowage space / Pax	25"x2"	25"x1,5"	1 Tray	25"x2"	25"x1,5"	1 Tray
- Hand luggage	2	2	1	3	2	1

The location of crew rest compartments as well as the accommodation of trolleys in galleys at the lower deck realizes more productive seat area on the main deck. The design ends up with 808 passengers in a standard layout. Some views of the cabin are sketched in figures 10 and 11.

Figure 9. Two-dimensional layout with emergency exits, Slow Motions scenario with 808 passengers

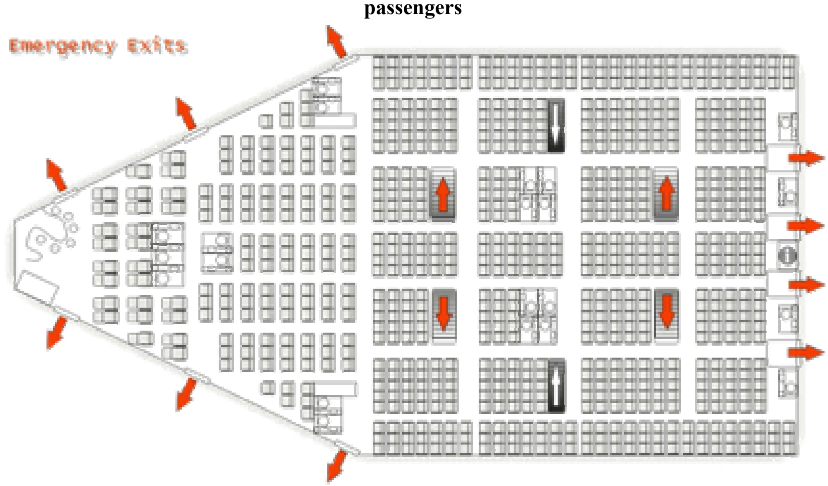


Figure 10. Three-dimensional sketch of emergency stairs, Slow Motions scenario

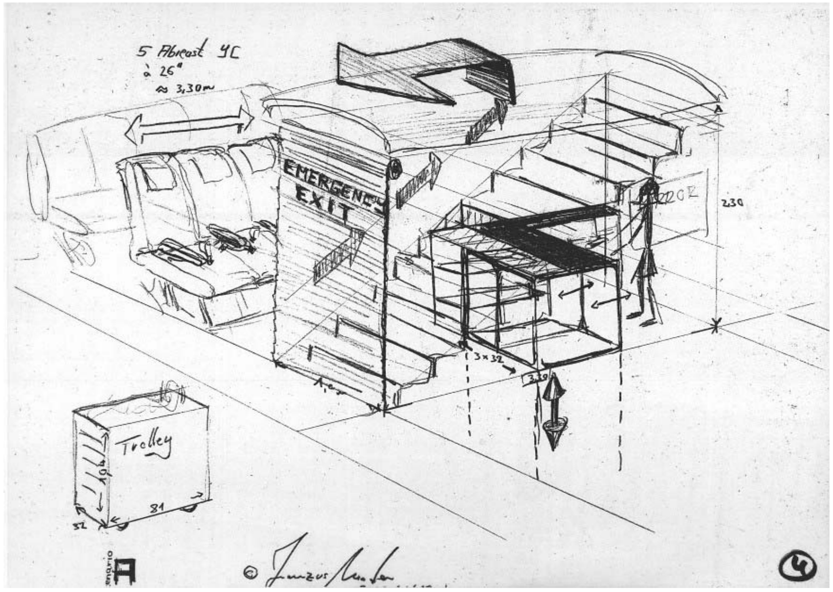
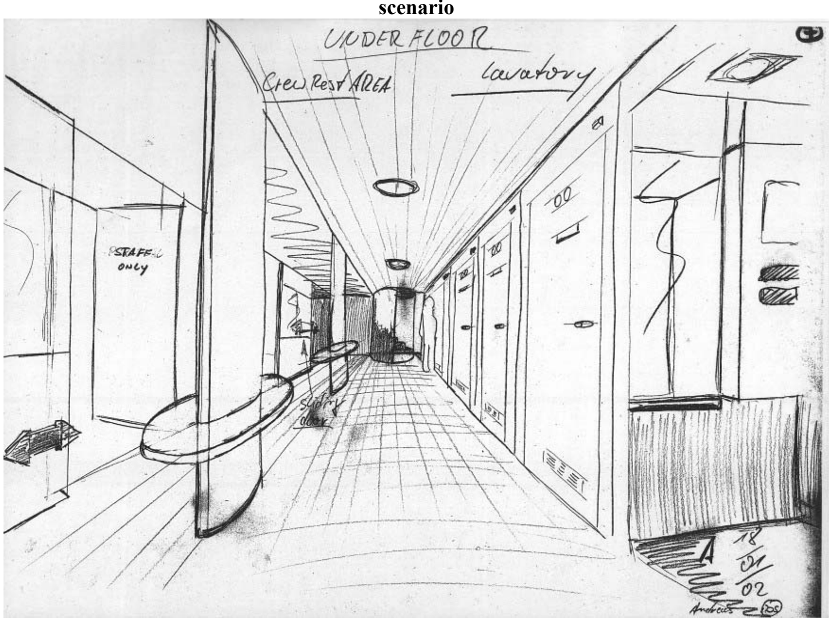


Figure 11. Three-dimensional sketch of lower deck crew rest and lavatory, Slow Motions scenario



"Flying Heavenly Peace Square" Scenario

The standard cabin dimensions developed for this scenario are noted in Table 3. The proposed single class layout has been worked out along with the demand for high profitability (Figure 12). Two versions are presented by the manufacturer to the airline: (a) a standard configuration with a larger seat pitch of 36 inches and 768 passengers and (b) a high density configuration with a reduced 34 inches pitch and 871 passengers to comply with the greater traffic volume on inner Asian routes. As the technologically most innovative scenario, a passenger container system is developed to achieve short turn-arounds (higher frequency) and high operational efficiency. The dashed line shows the outline of a container, which is boarded in the airport area, transported to the aircraft and loaded into it from the tail. The inner service area with galleys and toilets are built-in elements with a high degree of automation. Intelligent robot trolleys assist the crew with cabin operations, for instance, and take over major parts of the food and beverage service. More toilets, vending machines and trolley transport systems are installed in the lower deck. A highly sophisticated virtual reality environment with 3D-glasses and head sets is adjusting to the demands of the individual passenger and succeeds to shorten the subjective flight time.

In case of emergency, in contradiction to current certification rules, wing emergency exits are blasted away after intelligent hazard detection systems decide the safest way of evacuation. If necessary and possible, the big tail doors are opened to quickly evacuate the plane. Some views of the cabin are sketched in figures 13 and 14.

Table 3. Two-dimensional layout dimensions for the Flying Heavenly Peace Square scenario

Cabin BWB 2030	Standard 2000 (A380)			Standard 2030 (BWB)	
	FC	BC	EC	Standard config.	High density config.
Class ratios in %	4	16	80	100	100
Seat pitch	62“	40“	32“	36“	34“
Seat width	30“	27,5“	25“	27“	27“
Aisle width	min 500 mm			1,0 / 0,6m	
Toilets / Pax	1 / 10	1 / 25	1 / 45	1 / 32	1 / 42
Trolleys / Pax (*	1 / 2	1 / 4	1 / 10	1 / 6	1 / 8
- Stowage space / Pax	25“x2“	25“x1,5“	1 Tray	1 Tray	1 Tray
- Hand luggage	2	2	1	2	2

(* Trolleys for 40 / 60 / 80 tablets; dimensions standard trolley: width: 12“ / depth: 32“ / height: 41“)

Figure 12. Two-dimensional layout with emergency exits, Flying Heavenly Peace Square scenario in standard layout with 768 passengers

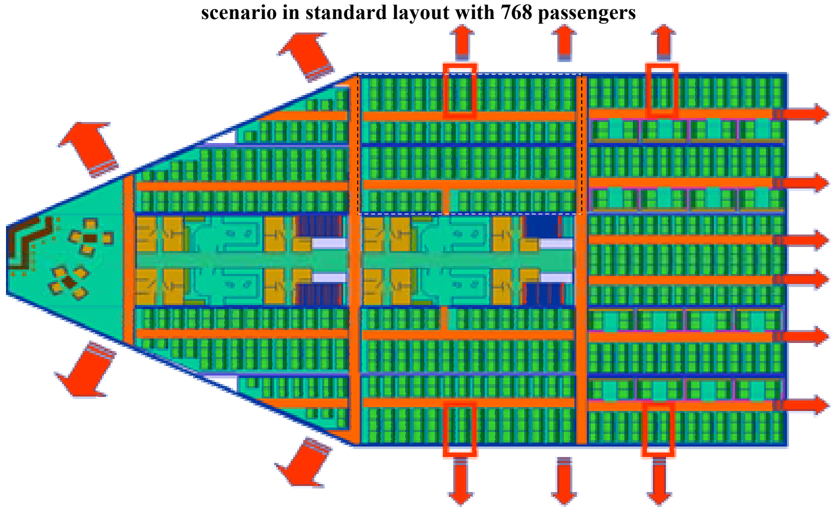


Figure 13. Three-dimensional sketch of tail container loading, Flying Heavenly Peace Square scenario

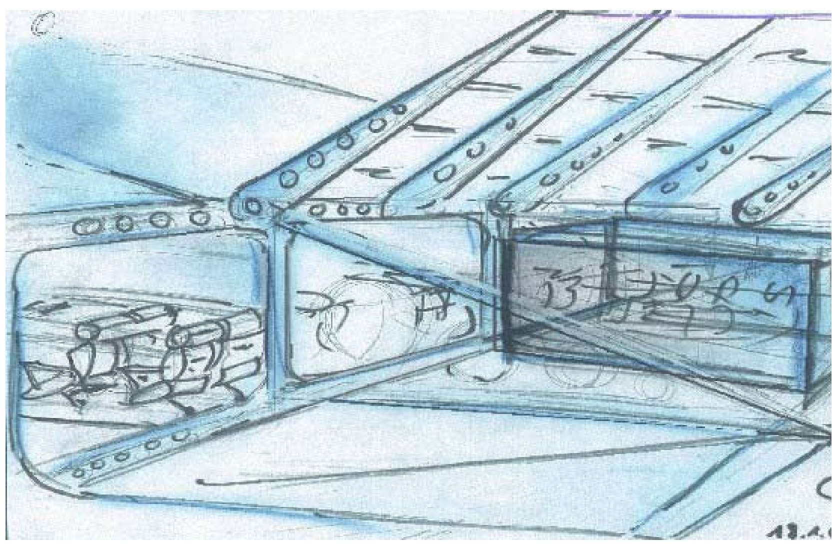
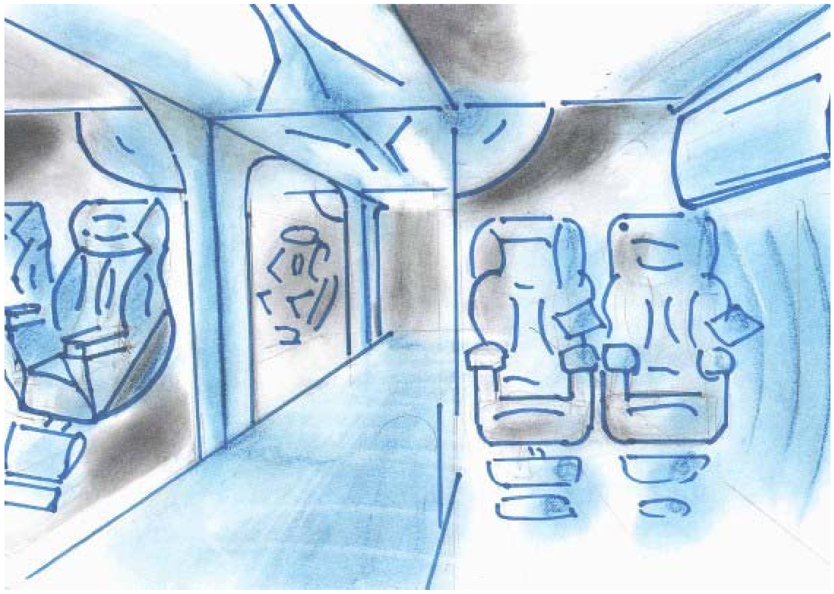


Figure 14. Three-dimensional sketch of container interior design, Flying Heavenly Peace Square scenario



Evaluation of requirements

The different scenarios developed a range of scenario-specific requirements of the cabin layout and development as well as primary cabin systems. To evaluate the robustness of these requirements, they have been introduced into all three scenarios and assessed for their fit with the particular scenario. The main results of this comparison are listed below:

1. Increase in seat pitch despite the fact that adjustments are a matter of airlines;
2. Standardization of broader aisles (defining cabin layouts significantly!);
3. Development of enhanced boarding and seat allocation systems with intelligent passenger flow control;
4. Utilization of the lower deck area: a major factor dependent on how strict regulations are towards passengers in the future;
5. Availability of wireless communication technologies inside the cabin (passenger on-board system);
6. Lobbying for enhanced certification rules;
7. Alternative and decentralized on-board high power generation (e.g. fuel cells) for a more electrical aircraft configuration

(substitution of pneumatic and hydraulic systems by electric ones, e.g. electric air conditioning, requiring high electric power)
8. Use of easy-to-clean materials (similar to lotus flower effect);
9. Recycling of operating supply items (water, oil, etc.);
10. Availability of computer-aided direct view video system (passenger control during take-off and landing, monitor surveillance by crew);
11. Intuitive emergency procedures; and
12. Intelligent escape slides.

CONCLUSIONS

With the help of scenario methodologies a consistent and structured approach towards the derivation of cabin requirements were found, adopted and validated through three scenario-specific and independent cabin concepts. Economic, socio-cultural and technologic objectives were considered throughout the process, leading to different cabin layouts and models driving future designs. In a final step, robust requirements were formulated by qualitatively evaluating the scenario evolved from the respective future environments. With the proposed methodology, strategic recommendations for the aircraft manufacturer are presented which can be adopted for other BWB configurations as well.

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