3. LOW FARE AIRLINE OPTIMIZED AIRCRAFT

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3.1 Introduction

The increasing growth of the low cost airline business model around the world comes along with new challenges for aircraft designers. It is crucial for the low cost airlines to have the least possible costs, which is usually achieved at the expense of the passenger services and comfort. A large portion of the cost reduction comes from the operations strategy of the airline, however only if the aircraft itself allows for those specific operational procedures. A B747 simply does not allow for a 20 minute turnaround time regardless of how much it might save in operational cost.

The goal of this project is to design a new aircraft, the A2007, that allows for a 15% reduction in Direct Operating Costs (DOC) of the airline and a 20% reduction in turnaround time compared to its closest competitors, namely the A320 and B737. The A2007 will be developed in a standard range version (1800 nm) as well as an extended range version (3000 nm) and is intended to enter service in 2015.

3.2 Project definition

The project starts with defining the Project Objective Statement. For this project it is defined as follows:

"Create a preliminary design of a successor of the A320 and B737 optimized for low fare airlines with entry into service in 2015, using innovative technologies with a sustainable approach. This is to be achieved by 9 students over 10 weeks."

The Mission Need Statement, which concerns the design itself, is defined as follows:

“Fly 150 passengers over regional distances while reducing Direct Operating Costs by at least 15% and Turn Around Time by 20% with additional optimization for Low Fare Airlines, including minimum emissions and noise.”

3.3 Requirements

The most important requirement, called the killer requirement, is that the A2007 aircraft must enter into service in 2015. This requirement can drive the design to an unacceptable extent if it is not met. The key requirements of the A2007 design are the following:

- Reduce the direct operational cost by 15%
- Reduce the turn-around time by 20%
- The aircraft should be able to transport 150 passengers
- The aircraft should be able to cover 1800 nm (standard range version) or 3000 nm (extended range version)
- The design should be flexible for family design
- The design should be sustainable through minimizing fuel burn, noise and emissions
- The development should be done with a minimum in development cost.
- The aircraft should have a high operational reliability, ensuring high availability

The requirements mentioned above drive the design of the A2007. In order to determine whether the design process has been successful, the design of the A2007 will be evaluated with respect to the requirements mentioned above by means of a compliance matrix. This tool identifies to what extent the design meets the requirements.

3.4 Conceptual Design

The three different concepts are each developed by three members of the group. Some aspects of the design are assigned to the subgroup, such as the fuselage shape, and some aspects are free for choice by the groups themselves, such as the engine location. The parts of the design process that overlap are developed in cooperation between the concept groups. All concepts contain the additional systems of the integrated stairs and autonomous pushback which were derived from the market analysis.

For the first concept two configurations are considered: a conventional low-wing configuration and a canard configuration. From the investigation it turned out that the canard configuration is less suitable for the A2007, because the advantages do not outweigh the disadvantages. Therefore the A2007-I is a low-wing configuration. The exterior configuration of the A2007-I looks very similar to the A320/B737. It has a circular fuselage, low wing, engines below the wing and a standard tail. The fuselage of the A2007-I fits six passengers abreast in a 2-2-2 seating arrangement. This implies that the aircraft has two aisles, which is rather unconventional in this segment. The diameter of the fuselage is therefore somewhat larger. However, the twin aisle configuration should improve the turn-around time, because the passengers have more room to walk around. The concept is designed for minimum seating distances and has overhead stowage compartments.

The second concept which was developed, describes a high wing configuration. By using the high wing, the fuselage can be closer to the ground and therefore the accessibility of the aircraft is improved. The engines of the second concept are placed under the wing and due to the high wing configuration, the A2007-II has a T-tail. The second concept also has a circular cross-section. A feature that is special about this concept is the third door on one side. This should improve the turn-around time, since the passengers will be able to board and exit the aircraft faster. Because the concept has a high wing, the main landing gear cannot be stored in the wings. Therefore it is stored in the fairings which extend the fuselage at that place. The A2007-II has a 3-3 seating configuration, which is designed for minimum seating distances. The seating configuration implies a single aisle and the hand luggage can be stowed in the overhead bins. Because of the third door in the middle of one side, one row of seats is moved to the other side. Therefore the cabin is longer than that of the A2007-I.

The third concept is somewhat more unconventional. The A2007-III has a horizontally aligned double-bubble fuselage configuration, with a supporting beam between the intersections of the two circular fuselages. The cabin floor is as low as possible within the fuselage. Since there is hardly any space beneath the floor, the baggage compartment is placed at the back of the aircraft. The width of the fuselage is approximately the same as concepts I and II, but the height is decreased. The A2007-III has a low wing, the engines mounted under the wing and a standard tail. The wing of this concept are slightly bent upwards to ensure clearance for the engines. Since the middle of the cabin cannot be used as an aisle due to the reinforcements, the A2007-III has a twin aisle configuration, with a 2-2-2 alternate seating arrangement. The chairs are not placed right next to each other, but they are staggered. Therefore the seat dimensions can be smaller, while still having the same comfort and space to sit. The hand luggage can be stored under the seats. The third concept also has a self cleaning floor system, which eases the work of the flight attendants.

One of the concepts described above has to be chosen as the final concept. This choice is made in a trade-off process where all concepts are compared to each other based on different criteria. The criteria facilitate the trade-off process by focussing on different aspects. The used criteria are:

- Weight
- Development cost
- Maintainability
- Accessibility
- Risk
- Manufacturer compliance
- Passenger comfort
- Crew friendliness

Each concept is graded per criteria. This grade is then multiplied by the weight factor of each criterion that is based on the importance of that criterion. Adding these values of the different criteria leads to the total score of a concept. The concept with the highest score is the best concept. From the result of the trade-off, the high wing aircraft (second concept) was the most suitable. The good accessibility and the weight of the A2007-II resulted in a high total score against the other concepts. The double hull aircraft appears to be the worst concept, which is mainly due to the weight. The first concept is good as well and has an average score. However it does not beat the second concept in the total sum. As a result the A2007-II is chosen to be further developed in the final phase of the project.

3.5 Final concept

The concept that is further elaborated is the high-wing design. Next to this external configuration the interior dimensions are also designed for low-fare operations. The propulsion system has better environmental characteristics and furthermore there are some other specific features to decrease the turn-around time.

Figure 3.1: The final A2007 design

The A2007 has 150 seats in a 3-3 configuration which means that 25 rows of seats are necessary. By making use of an alternate seating arrangement, the comfort increases while still keeping the very minimum seat width of 16" to maximize capacity for low-fare operations. In the alternate arrangement the seats are staggered instead of placed right next to each other, as shown in figure 3.2. Therefore the passengers have more shoulder space and no extra space is needed in between the seats, because the armrests can overlap. The cabin consists of two toilets at the back and a small galley just before the rear pressure bulkhead, since low-fare airlines only offer some drinks and snacks during flight. The toilets of the designed aircraft are triangular in shape, so the cabin space is then used efficiently based on the seating layout.

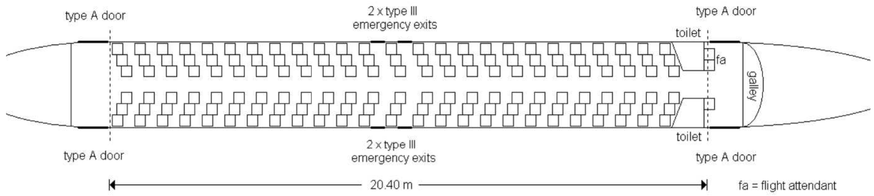

Figure 3.2: Cabin layout of the A2007

Next to the alternate seating arrangement, the seats are designed in such a way that turn-around time will be reduced. In order to limit the aisle congestion which usually occurs because of the passenger use of the overhead bins, the aisle seat is designed intentionally to fold as can be seen in figure 3.3, to allow the person that is loading his luggage to stand in that specific place away from other passengers. This way the aisle remains free for other passengers to walk through, and consequently reduce boarding times.

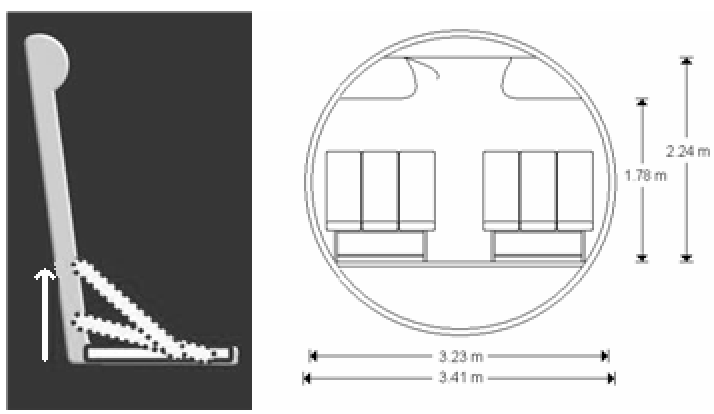

Figure 3.3: The foldable seat and cross-section with the overhead bins

A special feature integrated in the A2007 that is part of this exterior design is the integrated stairs. The A2007 will have two integrated stairs (one at the front and one at the back) that slide directly under the door as depicted in figure 3.4. Therefore the choice of making use of either the air bridge or the integrated stairs is up to the airlines themselves. However low-fare airlines can now operate independently, since airport stairs are not necessary anymore. This reduces airport fees and can also contribute to a decrease in turn-around time.

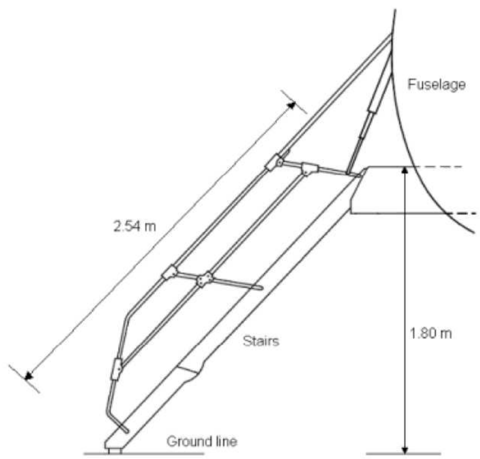

Figure 3.4: Integrated stairs.

The A2007 will be powered by two LEAP56 engines with ducted counter- rotating fans. The LEAP56 will have a 10-15% improvement in specific fuel consumption compared to the current CFM series engines. To achieve this SFC of 14.43 mg/Ns, CFM has selected a bypass ratio of 9:1 without an increase in total engine dimensions. Furthermore the LEAP56 has the following characteristics as compared to the CFM56-7 series:

- 15-25% reduction in maintenance, repair and overhaul costs
- 25% increase in on-wing life
- At least 50% lower emissions (including 50% lower NOx)
- 15 dB more reduction in effective perceived noise (stage 4 requirements of FAA)
- Lighter engine mainly due to the use of composites

The main landing gear retracts into the fuselage. Because the space below the floor is not sufficient, fairings are added on both sides of the fuselage which give some additional drag. The nose landing gear retracts forward in the nose. To speed up the turn-around time an autonomous push-back system (APS) is installed on this nose landing gear as can be seen in figure 3.5. This system will consist of an electric engine integrated in the nose-wheel which is connected to the auxiliary power unit (APU). The APS can also be used for taxiing as well as for pushback. This will result in less fuel burn and less emissions next to the reduction in turn-around time.

Figure 3.5: Autonomous push-back system integrated in the nose wheel

The APS needs additional support for the pilots for guidance when reversing. The A2007 will have both visual and computer controlled systems to monitor the push-back.

Because of the demand of the market for Carbon Fibre Reinforced Plastics (CFRP) aircraft, it was decided to use CFRP in most of the A2007 structure. CFRP will be used in two forms on the A2007: CFRP laminate and CFRP sandwich. The sandwich structure will be used on the control surfaces of the horizontal and vertical stabilizer. Besides CFRP also Glass Fibre Reinforced Plastics (GFRP) will be used on the A2007, which is better at impact than CFRP. Therefore GFRP is considered for the nose radome, the leading edge of the main wing, horizontal stabilizer and vertical stabilizer and also for insulation of connections between CFRP and aluminium. Finally it will be used on the landing gear doors. Aramid Fibre Reinforced Plastics (AFRP) will not be used because of the high costs and production difficulties. The overall result of the use of composites on the A2007 will be around 10% weight reduction in comparison to a full aluminium design.

The A2007 makes use of a fly-by-wire system to control the aircraft and advanced displays in the cockpit. All necessary systems to ensure a safe, healthy and comfortable flight for the passengers are also installed, together with protection systems in case an accident will occur. The cockpit layout will also be standard to the manufacturer to allow for lower pilot training costs and allow pilots to quickly adapt to the new aircraft.

The most important sustainability aspects in aircraft design are noise and emissions. Next to these also aircraft lifetime, maintenance and weight play a significant role in the sustainability of an aircraft. The noise levels of the A2007 during three different flight phases are as follows:

- Fly-over:79 dB (engine)
- Sideline:93 dB (engine)
- Approach:94 dB (engine and airframe)

These values for the produced noise by the A2007 have a margin of about 5 dB and are well below the noise requirements. The emissions of the A2007 are minimal due to the use of the LEAP56 engine described above.

3.6 DOC and turnaround time

The DOC calculation was made using a combination of the Association for European Airlines (AEA) and the Roskam methods for estimating the operating costs of the aircraft. These methods use a set of equations that estimate the costs based on several inputs, among which the MTOW, stage length, and aircraft price. Compared to the A320-200, the A2007 reaches 15.05% reduction in DOC per trip on the Extended Range based on the total finance, flight, fuel and maintenance costs. The Short range reduces DOC by 17.3% because of its lighter weight.

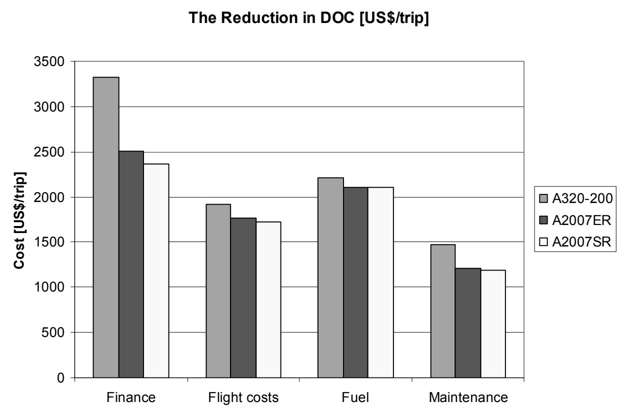

Figure 3.6: The DOC calculation of the A2007 compared to the A320-200

The turnaround time of the A2007 is compared to the A320 and the B737. The average current turnaround time of the latter is approximately 30 minutes. The A2007 gains time reduction mainly during pushback and passenger boarding times, and its design is capable of reaching a turnaround time of 20 minutes, thus a 30% reduction. Although the design of the aircraft is capable of reaching these milestones, the reduction in time is highly dependant on operational procedures and airport facilities.

3.7 Conclusions and recommendations

As from the previous it can be concluded that a preliminary design has been completed by the project group in the assigned time of 10 weeks. With that the project objective has been met. The designed successor of the A320 and B737, the A2007 is able to enter into service in 2015 because of its smart combination of already existing designs such as the high wing where many manufacturers already have plenty of experience with. The design features some innovative technologies, like the autonomous pushback system. The specifications of the engines, the lower noise and emissions, confirm that a sustainable approach is used for the A2007. This is enhanced by the fact that the aircraft is designed to be lightweight compared to other aircraft.

The design of the A2007 meets the key requirements set forth by the project. The direct operating costs are reduced by 15.05% for the extended range and 17.3% for the Short range. In addition to that, the A2007 is capable of a turnaround time reduction of more than 20% as required. All other requirements such as the performance requirements were also met in the A2007 design.

In the future it is recommended to investigate the use of propeller engines for a design in the segment of the A2007. Propeller engines operate at lower specific fuel consumption than jet engines. However, propeller engines are not yet able to operate at Mach 0.8 efficiently. Flying at a lower Mach number would then be a solution. Nowadays it does not make a big difference in direct operating costs when flying at Mach 0.7 with propeller engines or flying at Mach 0.8 with jet engines. This is due to additional travel time that is required for the aircraft with propeller engines. However, when fuel prices increase significantly it can make a difference.