BOEING 787 DREAMLINER AIRCRAFT DEVELOPMENT AND OPERATION

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The thesis presents aquired knowledge about the development and introduction into operation of new super modern and highly economic B787 Dreamliner aircraft, developed and manufactured by the Boeing Company. This work documents the birth of B787 Dreamliner aircraft and continues in comparing it with the Airbus Company conventional aircraft, agelong Boeing´s rival.

K e y w o r d s: Development, Operation, Aircraft Operators, Technical Dala, Economy of Operation, Competition

1 INTRODUCTION

After twelve years, American Boeing introduced the brand new B787 Dreamliner aircraft, on which the future of the company depends. Dreamliner 787 experienced a very good start. The manufacturer introduced his "Dream Aircraft" as a halfly solid plastic machine with the fuel consumption of a fifth lower than other aircrafts´. Traditional alluminium was replaced by a solid plastic, thanks to which the aircraft weight and maintenance costs associated with the rust removal decreased. New material enabled the creation of innovative design features, such as unusually large windows next to the passenger seats. During flight, passengers can feel a higher air pressure and humidity, so as lightning that imitates natural day and night cycle. Dreamliner 787 is designed to long-distance flights.

Before its full production started, the aircraft had become known as the most ecological and yet most comfortable had reached 677 orders. Boeing hopes to deprive the European Airbus of the leadership position in the large transport aircraft market already five years after the start of its production. Airbus aims to reaffirm its position by the future superjumbo A380 that is going to alleviate the passengers´ strain on the largest airports of the world. Different policy was chosen by the Boeing that believes the future growth of air transport lays in the mid-size aircrafts that can use smaller airports. Airbus is also working on the model similar to 787. Whereas Dreamliner entered commercial service on October 26, 2011, the European A350 has still to wait for its debut.

2 BOEING 787 DREAMLINER

Boeing 787 Dreamliner is a long-range, mid-size wide-body aircraft that seats 210 to 290 passengers, depending on the variant. Boeing states that it is the company's most fuel-efficient airliner and the world's first major airliner to use composite materials as the primary material in the construction of its airframe. Boeing has managed to meet project goals and Dreamliner really shows to be 20% more fuel efficient than the Boeing 767. The Dreamliner's distinguishing features include mostly electrical flight systems, a four-panel windshield, noise-reducing chevrons on its engine nacelles, and a smoother nose contour.

2.1 Design

B787 was designed to be the first production airliner with the fuselage assembled with one-piece composite barrel sections instead of the multiple aluminum sheets and some 50,000 fasteners used on existing aircraft. Boeing selected two new engine types to power the 787, the General Electric GEnx and Rolls-Royce Trent 1000. The company stated the 787 would be approximately 20 percent more fuel-efficient than the 767, with approximately 40 percent of the efficiency gain from the engines, plus gains from aerodynamic improvements.

Obr. 1 Assemblage of B787 Fuselage

During the design phase, the 787 underwent extensive wind tunnel testing. The final styling of the aircraft was more conservative than earlier proposals. By the end of 2004, customer-announced orders and commitments for the 787 reached 237 aircraft. Boeing initially priced the 787-8 variant at US$120 million, a low figure that surprised the industry. In 2007, the list price was US$146–151.5 million for the 787-3, US$157–167 million for the 787-8 and US$189–200 million for the 787-9.

2.2 B 787 Dreamliner Development and Production

During the late 1990s, Boeing began considering replacement aircraft programs as sales for the Boeing 767 and 747-400 slowed. The company proposed two new aircraft, the 747x, which would have lengthened the 747-400 and improved efficiency, and the Sonic Cruiser, which would have achieved 15% higher speeds (approximately Mach 0.98) while burning fuel at the same rate as the existing 767. Market interest for the 747X was

tepid, but the Sonic Cruiser had brighter prospects. Several major airlines in the United States, including Continental Airlines, initially showed enthusiasm for the Sonic Cruiser concept, although they also expressed concerns about the operating cost.

Changing course after the Sonic Cruiser unsuccess and the innovative B747 production delay, the company announced an alternative product using Sonic Cruiser technology in a more conventional configuration, the 7E7, on January 29, 2003. Original futuristic design was eventually changed several times until it reached the existing, more standard design and was renamed 787. The new aircraft manufacturer used the same technology as did the Sonic Cruiser´s. The 787 development and production has involved a large-scale collaboration with numerous suppliers around the globe. Final assembly is at the Everett Factory in Washington and in North Charleston, South Carolina.

Pic. 2 Existing Standard Form of B787 Dreamliner

After countless problems accompanying the 787 development and leading to the multiple postponement initial launch date, the first 787 was unveiled in a roll-out ceremony on July 8, 2007, at Boeing's Everett assembly factory, by which time it had reached 677 orders; this is more orders from launch to roll-out than any previous wide-body airliner.

But only well-informed people knew that demonstrated prototype´s major systems had not been installed at that time and many parts were attached with temporary non-aerospace fasteners requiring their later replacement with flight fasteners. Mentioned facts caused the first launch delay. Originally planned to enter service in May 2008, the project has suffered from multiple delays. The airliner's maiden flight took place on December 15, 2009, and completed flight testing in mid-2011. Final Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) type certification was received in late August 2011 and the first model was delivered in late September 2011. It entered commercial service on October 26, 2011.

2.2.1 Time Path of the B787 Development and Production

Right after the a roll-out ceremony, works on the prototype finalization were launched. However, similarly to the previous development, the producer had to deal with many problems, namely unsufficient manufacturing and technical documentation, subjects of cooperation, building components not supplied in time and employees strike. All mentioned negatively affected keeping of the original schedule flight tests, certification of B787 and its entry into the regular operation. Despite these difficulties, a majority of customers did not cancel their orders and Dreamliner´s reputation of the fastest selling jet airliner in the history remained undamaged.

2.3 B787 Dreamliner Assemblage

Boeing announced on December 16, 2003, that the 787 would be assembled in its factory in Everett. Instead of building the complete aircraft from the ground up in the traditional manner, final assembly would employ 800 to 1,200 people. Boeing assigned its global

Pic. 3 Boeing 747-400 Dreamlift

subcontractors to do more assembly themselves and deliver completed subassemblies to Boeing for final assembly. This approach was intended to result in a leaner and simpler assembly line and lower inventory, with pre-installed systems reducing final assembly time by three-quarters to three days. To speed up delivery of the 787's major components, Boeing modified four used 747-400s into 747 Dreamlifters to transport 787 wings, fuselage sections, and other smaller parts.

2.4 Dreamliners Fly

On December 15, 2009 Boeing conducted the supermodern Boeing 787's long awaited maiden flight , originating from Snohomish County Airport in Everett, Washington, at 10:27 am PST, and landing at Boeing Field, Seattle, at 1:33 pm PST. Dreamliner departed before an estimated crowd of more than 12,000 employees, guests and media representatives, and millions of viewers around the world watched its maiden flight via live telecast. Trial crew of this historical flight consisted of 787 Chief Pilot Michael "Mike" Carriker and Capt. Randall "Randy" Lee Neville who tested some of the airplane's systems and structures, as on-board equipment recorded and transmitted real-time data to a flight-test team at Boeing Field. Carriker and Neville took the new Boeing (ZA001, N787BA, v.č 40690/1) to an altitude of

13,200 feet (4,023 meters) and an air speed of 180 knots, or about 207 miles (333 kilometers) per hour, customary on a first flight. After the landing, both pilots stated that in terms of aircraft handling and board systems monitoring, 787 has fully met expectations. One week later, on December 22, the second Boeing (ZA002, N787EX, v.č. 40691/2), also powered by Rolls-Royce Trent 1000, completed its first flight. The airplane took off at 9:09 a.m. PST and landed at 11:10 a.m. PST. Captain Randy Neville was at the controls for the flight, with Chief Pilot Mike Carriker operating as co-pilot.

Pic. 3 Maiden flight Crew at Press Conference, 787 Chief Pilot M.H.Carriker on the Left and Pilot R.L.Neville on the Right

The all-new airplane, which features the livery of the Dreamliner's launch customer, ANA (All Nippon Airways) of Japan, reached an altitude of 13,000 feet (3,962 m) and an airspeed of 200 knots, or about 230 miles (370 km) per hour. During the flight, pilots and ground control evaluation centre technicians focused on systems performance. Subsequently, flight test program was launched (with a special focus on the composite structures), which should be completed in the fall of 2010 granting European Aviation Safety Agency (EASA) type certification. The 787 flight test program was composed of 6 Dreamliners, four of them with Rolls-Royce Trent 1000 engine, the rest two with General Electric Genx engine. It was assumed that during the last quarter the first aircrafts would be delivered to their users. At the date of B787´s first flight, 840 aircrafts were ordered by 56 customers, making this machine the fastest selling airline in the history. Acquisition prices of particular models were determinated followingly: B787-3 from 150,0- to 155,5mil.; B787-8 from 161,0- to 171,5 mil and B787-9 from 194,0-do 205,5 million dollars.

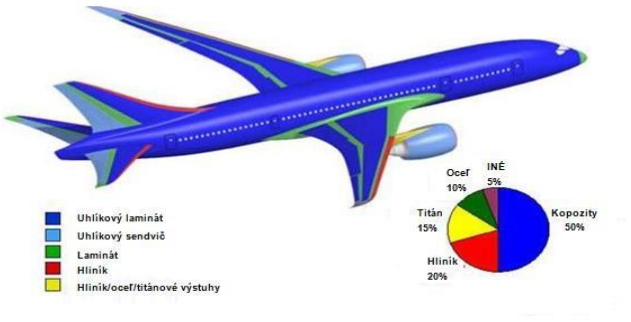
3 SERVICE ENTRY

The first B787 Dreamliner was officially delivered to All Nippon Airways on September 25, 2011, at Boeing's facilities in Everett, Washington. A ceremony to mark the occasion was also held the next day. On October 26, 2011, Dreamliner flew to the Haneda airport in Japan and un October 26flew its first commercial flight from Narita to Hong Kong. The airliner was planned to enter service some three years prior. Tickets for the flight were sold in an online auction, with the highest bidder paying $34,000 for a seat.

3.1 Supermodern, Highly Economic

Boeing 787 Dreamliner is the result of the cooperation of 44 companies from USA, Japan, Spain, Great Britain and other countries. 787 brings to its prospective users and passengerss the best that current knowledge and technical capabilities of the air construction services allow, including composite materials used in such extent for the first time in history. Modern engines and excellent aerodynamic properties of the machine, carefully verified in wind tunnels and laboratories testing, all this contributes significantly to the high performance economy, especially on the lines connecting smaller airports anywhere on the globe. Compared with the existing airline types, B787 would be 20 percent more fuel-efficient and would have 45 percent higher freight earning capacity at the flying speed M = 0,85.

Boeing´s composite construction is aerodynamically cleaner more sophisticated, as well as specially designed, highly flexible wing with 32^0 arrow, and raked wingtips (analogic to e.g. B767-400), which together with a smaller rail dampers overlap contribute to the reduction of the machine´s harmful resistance. Composite materials were used as the basic building material for the fuselage and wing parts (carbon fiber), movable tail surfaces, spoilers, wing tips, engine cowlings



Pic. 4 B787 Dreamliner - Graphical Display of the Materials Used in the Aircraft Construction

(carbon sandwich), and for the wings cover (other composites). Alluminium is used for the end face leading edges, titanium is used on the fuselage part.

4 B787 DREAMLINER DRIVE UNITS

4.1 New Engines

Boeing 787 Dreamliner is powered by General Electric GEnx engines. 787 deliveries were delayed, but the new engines development went according to the plan. Its tests were conducted quite successfully. First of the

tested engines reached 358 kN thrust at standard day according to ISA. During the test, engine worked more than 100 hours, including 146 starts with specially ordered starter - generator. The second engine test started in the rural neighborhood laboratory, Peeble, Ohio. The engine went through the emissive, operational and cyclic endurance test. The third engine had to undergo endurance test for vibration resistance. First test of the unstuck vane blower in its package was successful. First of all, special test equipment was tested and the engine test was repeated afterwards. GEnx was ready for certification with a maximum take-off thrust 334 kN. By the end of 2007, seven test engines, were in operation. Boeing 747 GEnx tests were successfully completed. Tensile characteristics in actual flight conditions were confirmed, so as avian ingestion.

Rolls-Royce consortium also intensivelly worked on the alternative engine Trent 1000 for Boeing 787. Two such engines were ready for one of the prototypes and flight tests have already been launched on Boeing 747 aircraft, treated as a flying laboratory. Engine thrust is in the range of 334 - 423 kN; ISA +15 oC. The engine has tri-shaft arrangement, air blower with six-speed turbine, eight-speed low-pressure compressor and single-stage high-pressure turbine. Engine bypass ratio is at least 8 and overall compression 40. The engine output control and the aircraft systems cooperation testing showed good results from the beginning, and such good results could serve for certification purposes. Further tests have been carried out on the engine to verify the safe operation in icing conditions and the stopped engine activation during various flight conditions.

Pic.5 GEnx Engine – Engine Assembling

5 B787 DREAMLINER AND CONVENTIONAL AIRCRAFTS COMPARISON

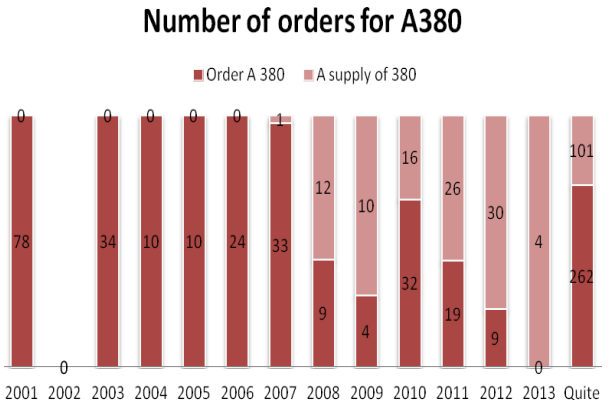
5.1 Big A380 or Small B787?

World´s two largest airliner producers after years of similar strategies grew apart completely. The European Airbus staked on the mammoth A 380, whereas Boeing completed conventional and in all respects more efficient B 787 Dreamliner. The two companies have different philosophies on what airlines and people will want in the next generation of aircraft.

Pic.6 Airbus A 380 on the Right , B787 on the Left

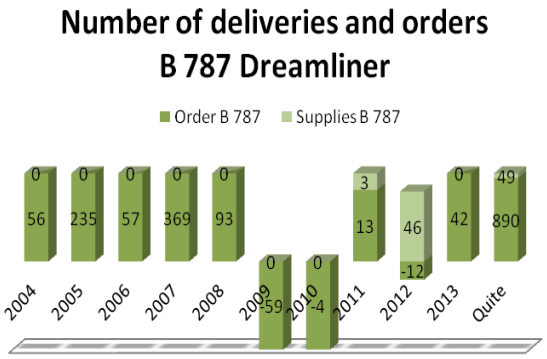
5.1.2 Unclear Marketing Speech

Thanks to the unprecedented media development in the last years are A 380 and B787 models the most marketing-promoted machines of both producers. For example, Boeing diligently attacks A380 with one reputable company´s marketing study, which claims that 80 % of economy class passengers prefers small and fast airlines and non-stop flight to the large machines with one or two interlandings. In contrast, Airbus counters with the fact that only 6% of passengers chooses the flight on the basis of the aircraft, thus the previous argument has no value. Both producers constantly publish quite contradictory predictions about the market development and their products expectations. Time will show if „hub and spoke“ or „point to point“ will win. On the basis of orders, it is certain that Boeing leads in the number of ordered machines (890 to 262), Airbus clearly wins in the number of delivered aircrafts (101). Although both



Pic. 7 A380-800 Orders Graphic Chart

producers consider different philosophies to be the key, the aircraft availability and on-time delivery are more important for the customer. This is also one of the reasons why Boeing´s number of deliveries is decreasing. More and more airlines rather cancel aircraft orders with an uncertain delivery date and search for alternatives. Although B787 has been ordered by higher number of airlines, Airbus achieves profit with a smaller number of aircrafts.



Pic. 8 B787 Dreamliner Orders Graphic Chart

A 380 is almost twice more expensive than B 787. The cost of both machines development is estimated to cost roughly the same. For economic balance, Airbus needs to deliver at least two hundred aircraft to the market, and Boeing is going to need to deliver almost twice as much. Airbus seems not to be hurt by the recession. The majority of A 380 users chose a three-class configuration, where first class occupies only minimum seats that are easy to be filled. It is hard to identify the winner of Boeing and Airbus competing philosophies and time will show the direction of civil aviation.

Technical Data A 380 and B 787		
Type	A 380	B 787-8
Crew	2	2
Maximum Passengers Number	853	242
Fuselage Lenght	72,73m	56,7 m
Wingspan	79,75 m	60,0 m
Height	24,45 m	16,9 m
Maximum Take-off Weight	569 000kg	170 000 kg
Operating Empty Weight	276 000 kg	101 000 kg
Engines Type	GEnX	Trend 970
Engines Number	4	2
Engines Thrust	4 x 355 kN	2 x 285 kN
Maximum Speed	1020 km/h	954 km/h
Maximum Operating Speed	945 km/h	913 km/h
Flying Range	15 200 km	15 200 km
Ceiling	13 115 m	13 100 m

Tab. 1 B787-8 vs. A380 Technical Data

5.2 A350 Xtra Wide Body versus B787 Dreamliner

Airbus initially rejected Boeing's claim that the launched 7E7 development project, known today as 787 Dreamliner, would make it a serious threat to the Airbus A330. Boeing claimed the 787 has been designed to be 20% more fuel efficient than the A330, but Airbus stated that the 787 was just a reaction to the A330, and that no response was needed. When airlines pushed Airbus to provide a competitor, Airbus initially proposed the A330-200Lite, a simple derivative of the A330, which would feature improved aerodynamics and more powerful engines. The airlines were not satisfied, and Airbus committed €4 billion to a new airliner design known as A350 that superficially resembled the A330 due to its common fuselage. It had 250-300 seats capacity, a new wing, engines and a horizontal stabiliser were to be coupled with new composite materials and production methods applied to the fuselage to make the A350 an almost all-new aircraft.

The A350 XWB was built on the technologies developed for Airbus A380 and has a similar cockpit and fly-by-wire systems layout. The A350 XWB is made out of 62 % lithium-aluminum or aluminum materials, fulfilling high demands on hardness, and is 12 % lighter than B787 construction, or 14 % compared to B777-200.

Boeing 787-8		versus	Airbus A350-800	
56,70 m	186 ft 0 v	lenght	60,54 m	198 ft 0 v
60,00 m	196 ft 10 v	wingspan	64,80 m	212 ft 10 v
347,00 m^2	3735 ft^2	wing surface	443,00 m^2	4768 ft^2
16,90 m	55 ft 5 v	height	17,05 m	55 ft 11 v
2		engines	2	
285 kN	64 000 libier $_f$	engines thrust	334 kN	75 000 libier $_f$
570 kN	128 000 libier $_f$	overall thrust	668 kN	150 000 libier $_f$
228 000 kg	503 000 libier	MTOW	248 000 kg	547 000 libier
15 200 km	8208 nm	range	15 400 km	8316 nm
M=0,85		operating speed	M=0,85	
242 passengers		capacity	270 passengers	

Tab. 2 Basic TTD B787-8 vs. A350-800

CONCLUSION

This work was dealing with Boeing 787 Dreamliner. Aluminum used for the fuselage and wings of the new technologically most advanced machine was replaced by the composites and thus the new era in the transport aircraft design has began. Boeing states its materials by weight to 50% composite that help to make the 787 a 20% lighter aircraft. This fact, together with new engines and aerodynamic improvements enables a 20% lower fuel consumption, which is very important regarding current high fuel prices and low ticket prices pressure. Dreamliner is an aircraft on intercontinental

routes with a range of at least 12 thousand kilometers, seating about 250 passengers, with more comfortable cabin and presents an economical replacement for the aging Boeing models.

Because the composites are lighter than aluminum, B-787 weighs about 15-20 tons less in comparison to its European competitor A330-200, made of more traditional construction materials. That is the reason why Airbus launched the new A350 XWB aircraft development. A350 XWB can easily become new Boeing´s main competitor. With a new wing that improves the aerodynamics and new engines, it is designed to be 8% more fuel efficient than the B787.

In the thesis, individual production and development philosophies of Boeing and Airbus companies are analysed. Airbus believes in the "hub and spoke" strategy, which has been effective for last 30 years, will continue into the future. They see the world as a network of interconnected "hubs" handling huge volumes of intercontinental passengers. Airbus associates its future with the mammoth A380 model, which will unload at the largest airports of the world. Boeing pursues the strategy of providing a mid-size airplane for the forecasted increasing point-to-point traffic on long haul. It is difficult to determine the winner between Boeing and Airbus individual philosophies and only time will show the direction of civil aviation.

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