Boeing 737 MAX

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Developed from Boeing 737 Next Generation

The Boeing 737 MAX is a narrow-body aircraft series designed and produced by Boeing Commercial Airplanes as the fourth generation of the Boeing 737, succeeding the Boeing 737 Next Generation (NG).

The new 737 series was launched on August 30, 2011.[8] It had performed its first flight on January 29, 2016.[1] The new series gained FAA certification on March 8, 2017.[9] The first delivery was a MAX 8 on May 6, 2017 to Malindo Air,[10] which placed the aircraft into service on May 22, 2017.[2] The 737 MAX is based on earlier 737 designs. It is re-engined with more efficient CFM International LEAP-1B engines, aerodynamic improvements (including distinctive split-tip winglets), and airframe modifications.

The 737 MAX series has been offered in four variants, typically offering 138 to 230 seats and a 3,215 to 3,825 nmi (5,954 to 7,084 km) range. The 737 MAX 7, MAX 8, and MAX 9 are intended to replace the 737-700, -800, and -900, respectively. Additional length is offered with the further stretched 737 MAX 10. As of January 2019, the Boeing 737 MAX has received 5,011 firm orders and delivered 350.[11]

Development

Background

In 2006, Boeing started considering the replacement of the 737 with a "clean-sheet" design that could follow the Boeing 787 Dreamliner.[12] In June 2010, a decision on this replacement was postponed into 2011.[13]

On December 1, 2010, Boeing's competitor, Airbus, launched the Airbus A320neo family to improve fuel burn and operating efficiency with new engines: the CFM International LEAP and Pratt & Whitney PW1000G.[14] In February 2011, Boeing's CEO Jim McNerney maintained "We're going to do a new airplane."[15] At the March 2011 ISTAT conference, BCA President James Albaugh was not sure about a 737 re-engine, like Boeing CFO James A. Bell stated at the JP Morgan Aviation, Transportation and Defense conference the same month.[16] The A320neo gathered 667 commitments at the June 2011 Paris Air Show for a backlog of 1,029 units since its launch, setting an order record for a new commercial airliner.[17]

On July 20, 2011, American Airlines announced an order for 460 narrowbody jets including 130 A320ceos and 130 A320neos, and intended to order 100 re-engined 737s with CFM LEAPs, pending

Boeing confirmation.[18] The order broke Boeing's monopoly with the airline and forced Boeing into a re-engined 737.[19] As this sale included a Most-Favoured-Customer Clause, Airbus has to refund any difference to American if it sells to another airline at a lower price, so the European manufacturer can not give a competitive price to competitor United Airlines, leaving it to a Boeing-skewed fleet.[20]

Program launch

737 MAX 9 mockup at 2012 ILA Berlin

On August 30, 2011, Boeing's board of directors approved the launch of the re-engined 737, expecting a fuel burn 16% lower than the Airbus A320ceo and 4% lower than the A320neo.[8] Studies for additional drag reduction were performed during 2011, including revised tail cone, natural laminar flow nacelle, and hybrid laminar flow vertical stabilizer.[21] Boeing abandoned the development of a new design.[22] Boeing expects the 737 MAX to meet or exceed the range of the Airbus A320neo.[23] Firm configuration for the 737 MAX was scheduled for 2013.[24]

In March 2010, the estimated cost to re-engine the 737 according to Mike Bair, Boeing Commercial Airplanes' vice president of business strategy & marketing, would be $2–3 billion including the CFM engine development. During Boeing's Q2 2011 earnings call, former CFO James Bell said the development cost for the airframe only would be 10–15% of the cost of a new program estimated at $10–12 billion at the time. Bernstein Research predicted in January 2012 that this cost would be twice that of the Airbus A320neo.[6]

Fuel consumption is reduced by 14% from the 737NG.[25] In November 2014, Boeing Chief Executive Officer Jim McNerney said the 737 will be replaced by a new airplane by 2030, slightly bigger and with new engines but keeping its general configuration, probably a composite airplane.[26]

Production

Boeing 737 MAX roll-out in December 2015 with the first 737 MAX 8

On August 13, 2015, the first 737 MAX fuselage completed assembly at Spirit Aerosystems in Wichita, Kansas, for a test aircraft that would eventually be delivered to launch customer Southwest Airlines.[27] On December 8, 2015, the first 737 MAX—a MAX 8 named Spirit of Renton—was rolled out at the Boeing Renton Factory.[28][29]

Because GKN could not produce the titanium honeycomb inner walls for the thrust reversers quickly enough, Boeing switched to a composite part produced by Spirit to deliver 47 MAXs per month in 2017. Spirit supplies 69% of the 737 airframe, including the fuselage, thrust reverser, engine pylons, nacelles, and wing leading edges.[30]

A new spar-assembly line with robotic drilling machines should increase throughput by 33%. The Electroimpact automated panel assembly line sped up the wing lower-skin assembly by 35%.[31] *(Lulay's note: Electroimpact makes electromagnetic riveting systems).* Boeing planned to increase its 737 MAX monthly production rate from 42 planes in 2017 to 57 planes by 2019.[32]

The rate increase strains the production and by August 2018, over 40 unfinished jets were parked in Renton, awaiting parts or engine installation, as CFM engines and Spirit fuselages were delivered late.[33] After parked airplanes peaked at 53 at the beginning of September, Boeing reduced this by nine the following month, as deliveries rose to 61 from 29 in July and 48 in August.[34]

In collaboration with Commercial Aircraft Corporation of China Ltd., Boeing has built a completion and delivery facility for the 737 MAX in Zhoushan, China.[35][36] This facility initially handles interior finishing only, but will subsequently be expanded to include paintwork. The first aircraft was delivered from the facility to Air China on December 15, 2018.[37]

Flight testing

The first flight took place on January 29, 2016, nearly 49 years after the maiden flight of the 737, a 737-100, on April 9, 1967.[1] The first Max 8, 1A001, was used for aerodynamic trials: flutter testing, stability and control, and takeoff performance-data verification, before it was modified for an operator and delivered. 1A002 was used for performance and engine testing: climb and landing performance, crosswind, noise, cold weather, high altitude, fuel burn and water-ingestion. Aircraft systems including autoland were tested with 1A003. 1A004, with an airliner layout, flew function-and-reliability certification for 300h with a light flight-test instrumentation.[38]

The 737 MAX gained FAA certification on March 8, 2017.[9] It was approved by the EASA on March 27, 2017.[39] After completing 2,000 test flight hours and 180-minute ETOPS testing requiring 3,000 simulated flight cycles in April 2017, CFM International notified Boeing of a possible manufacturing quality issue with low pressure turbine (LPT) discs in LEAP-1B engines.[40] Boeing suspended 737 MAX flights on May 4,[10] and resumed flights on May 12.[41]

Introduction

The Boeing 737 MAX 8 entered service with Lion Air's subsidiaries Malindo Air/Batik Air

The first delivery was a MAX 8, handed over to Malindo Air (a subsidiary of Lion Air) on May 16, 2017; it entered service on May 22.[2] Norwegian Air subsidiary Norwegian Air International was the second airline to put a 737 MAX into service, when it performed its first transatlantic flight with a MAX 8 named Sir Freddie Laker on July 15, 2017 between Edinburgh Airport in Scotland and Bradley International Airport in the US state of Connecticut, followed by a second rotation from Edinburgh to Stewart Airport, New York.[42]

Boeing aims to match the 99.7% dispatch reliability of the NG.[43] Southwest Airlines, the launch customer, took delivery of its first 737 MAX on August 29, 2017.[44] Boeing planned to deliver at least 50 to 75 aircraft in 2017, 10–15% of the more than 500 737s to be delivered in the year.[10]

After one year of service, 130 have been delivered to 28 customers, logging over 41,000 flights in 118,000 hours and flying over 6.5 million passengers. flydubai observed 15% more efficiency than the NG, more than the 14% promised, and dependability reached 99.4%. Long routes include 24 over 2,500 nmi (4,630 km), including a daily Aerolineas Argentinas service from Buenos Aires to Punta Cana over 3,252 nmi (6,023 km).[45]

Design

In mid-2011, the objective was to match the A320neo 15% fuel burn advantage, but the initial reduction was 10–12%; it was later enhanced to 14.5%: the fan was widened from 61 inches to 69.4 inches by raising the nose gear and placing the engine higher and forward, the split winglet added 1–1.5%, a relofted tail cone 1% more and electronically controlling the bleed air system improves efficiency.[46]

Engines

LEAP mockup

Nacelle with chevrons for noise reduction

Main article: CFM International LEAP

In 2011, the Leap-1B was initially 10–12% more efficient than the previous 156 cm (61 in) CFM56-7B of the 737NG.[47] The 18-blade, woven carbon-fiber fan enables a 9:1 bypass ratio (up from 5.1:1 with the previous 24-blade titanium fan) for a 40% smaller noise footprint.[25] The CFM56 bypass ranges from 5.1:1 to 5.5:1.[48] The two-shaft design has a low-pressure section comprising the fan and three booster stages driven by five axial turbine stages and a high-pressure section with a 10-stage axial compressor

driven by a two-stage turbine.[25] The 41:1 overall pressure ratio, increased from 28:1, and advanced hot-section materials enabling higher operating temperatures permit a 15% reduction in thrust specific fuel consumption (TSFC) along with 20% lower carbon emissions, 50% lower nitrogen-oxide emissions, though each engine weighs 849 lb (385 kg) more at 6,129 lb (2,780 kg).[25]

In August 2011, Boeing had to choose between 66 in (168 cm) or 68 in (173 cm) fan diameters necessitating few landing gear changes to maintain a 17 in (43 cm) ground clearance beneath the new engines; Boeing Commercial Airplanes chief executive officer Jim Albaugh stated "with a bigger fan you get more efficiency because of the bypass ratio [but also] more weight and more drag", with more airframe changes.[49] The smaller Leap-1B engine will weigh less and have a lower frontal area but a lower bypass ratio leading to a higher thrust specific fuel consumption than the 78 in (200 cm) Leap-1A of the A320neo.[citation needed]

In November 2011, Boeing selected the larger fan diameter, necessitating a 6–8 in (150–200 mm) longer nose landing gear.[50][51] In May 2012, Boeing further enlarged the fan to 69.4 in (176 cm), paired with a smaller engine core within minor design changes before the mid-2013 final configuration.[52]

The nacelle features chevrons for noise reduction like the 787.[53] A new bleed air digital regulator will improve its reliability.[54] The larger engine is cantilevered ahead of and slightly above the wing, and the laminar flow engine nacelle lipskin is a GKN Aerospace one-piece, spun-formed aluminum sheet inspired by the 787.[31]

The new Maneuvering Characteristics Augmentation System accommodates the forward placement of the new engines while still retaining commonality (similar flying characteristics) with the Boeing 737NG family.

Aerodynamic improvements

Boeing's new "split tip" winglet on the 737 MAX

The split tip wingtip device is designed to maximize lift while staying in the same ICAO Aerodrome Reference Code letter C gates as current 737s. It traces its design to the McDonnell Douglas MD-12 1990s twin-deck concept, proposed for similar gate restrictions before the Boeing merger.[55] It should deliver at least 1.5% improvements in fuel economy or even more if the proposed laminar flow surface treatment meets expectations. A MAX 8 with 162 passengers on a 3,000 nmi (5,600 km) mission will have up to a 1.8% better fuel burn than a blended-winglet-equipped aircraft and even 1% over 500 nmi (930 km) at Mach 0.79.[55]

The new winglet is 9 ft 6 in (2.90 m) high.[31] Other improvements include a re-contoured tail cone, revised auxiliary power unit inlet and exhaust, aft-body vortex generators removal and other small aerodynamic improvements.[25] Aviation Partners offers a similar "Split-Tip Scimitar" winglet for previous 737NGs.[56] It resembles a three-way hybrid between a blended winglet, wingtip fence, and raked wingtip.

Structural changes and other improvements

3-3 Economy Cabin

The 8 in (20 cm) taller nose-gear strut keeps the same 17 in (43 cm) ground clearance of the engine nacelles.[25] New struts and nacelles for the heavier engines add bulk, the main landing gear and supporting structure are beefier, and fuselage skins are thicker in some places for a 6,500 lb (2,900 kg) increase to the MAX 8's empty aircraft weight.[25] To preserve fuel and payload capacity, its maximum takeoff weight is 7,000 lb (3,200 kg) heavier.[25]

Rockwell Collins will supply four 15.1-inch (380 mm) landscape liquid crystal displays (LCD), as used on the 787 Dreamliner, to improve pilots' situational awareness and efficiency.[57] Boeing plans no major modifications for the 737 MAX flight deck, as it wants to maintain commonality with the 737 Next Generation family. Boeing Commercial Airplanes CEO Jim Albaugh said in 2011 that adding more fly-by-wire control systems would be "very minimal".[58] Most of the systems are carried from the 737NG for a short differences-training course to upgrade flight crews.[25]

The 737 MAX extended spoilers are fly-by-wire controlled.[31] As production standard, the 737 MAX will feature the Boeing Sky Interior with overhead bins and LED lighting based on the Boeing 787's interior.[59]

For further details, see: https://en.wikipedia.org/wiki/Boeing_737_MAX