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Boeing 737 MAX

The MAX is the latest version of Boeing's highly successful twin-engine 737 aircraft. The newest model is more fuel-efficient than its predecessors and comes in four variants: the MAX 7, MAX 8, MAX 9 and MAX 10. The variants can transport between 138 and 204 passengers and are designed for short- and medium-haul flights. Previous versions of the 737 are considered some of the most reliable commercial aircraft in use.

Boeing was leading the pack in this segment long before Airbus marketed its A320. By 2019, Boeing had sold almost 10,500 of its 737s, the most widely spread plane of the jet era. It had developed a large number of modernized and improved versions over the years, but some 10 years ago, the company realized it had to

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with its A320neo. Boeing found itself under enormous pressure to keep up.

The airplane manufacturer announced 18 July 2019 that its second-quarter earnings for the year would be reduced by $4.9 billion as it compensated airlines for disruptions and plane delivery delays. That figure omits any amounts Boeing may need to pay in the future to compensate families of the victims. Meanwhile, profits would be hit by a further $1.7 billion because of the Max 737's reduced production rate. The passenger jets had been grounded since March after two crashes that killed 346 people, in which software glitches appeared to have played a role. The accidents happened off the coast of Indonesia, where there were 189 fatalities October 2018, and in March 2019 when 157 people died in a crash near the Ethiopian capital, Addis Ababa.

Unlike the A320, which was able to accommodate larger engines under its wings, the Boeing 737 didn't lend itself easily to the same thing, as its wings were a lot closer to the ground. Many airlines had requested a completely new short-haul aircraft, but Airbus and Boeing shied away from the two-digit-billion-dollar investment required, knowing the money would most likely not pay off. Boeing was forced to make compromises and overhaul its old 737 model instead of developing an entirely new one. To make the LEAP engines fit under the wings, the nose landing gear had to be extended to ensure enough distance to the ground. On top of that, the new engines had to be mounted further apart from the outboard wing assembly, and that changed the plane's aerodynamics. This in turn causes the plane to lift its nose, which triggers a compressor stall in the worst case scenario, which in turn can lead to terrain impact.

A pitch augmentation control law (MCAS) was implemented on the 737 MAX to improve aircraft handling characteristics and decrease pitch-up tendency at elevated angles of attack. It was put through flight testing as part of the certification process prior to the airplane entering service. MCAS does not control the airplane in normal flight; it improves the behavior of the airplane

in a non-normal part of the operating envelope. Boeing's 737 MAX Flight Crew Operations Manual (FCOM) outlines an existing procedure to safely handle the unlikely event of erroneous data coming from an angle of attack (AOA) sensor. The pilot will always be able to override the flight control law using electric trim or manual trim.

Boeing's newest family of airplanes - 737 MAX 7, 737 MAX 8 and 737 MAX 9 - build on the Next-Generation 737's popularity and reliability while delivering customers unsurpassed fuel efficiency in the single-aisle market. Development of the 737 MAX was on schedule with firm configuration of the airplane planned for 2013, first flight in 2016 and deliveries to customers beginning in the fourth quarter of 2017. Already a market success, by 2014 the 737 MAX had accumulated more than 1,000 orders and commitments from 16 customers worldwide since its launch Aug. 30, 2011.

The 737 MAX would deliver the big savings in fuel that airlines require for the future. The new-engine variant, powered by CFM International LEAP-1B engines, reduces fuel burn and CO2 emissions by an additional 13 percent over today's most fuel-efficient single-aisle airplanes. Recent design updates, including Boeing's Advanced Technology winglet, would result in less drag and further optimize the 737 MAX performance especially on longer-range missions.

When compared to a fleet of 100 of today's most fuel-efficient airplanes, this new model would emit 286,000 fewer tons of CO2 and save nearly 200 million pounds of fuel per year, which translates into more than $100 million in cost savings*. The 737 MAX 8's fuel burn is expected to be 8 percent per-seat lower than the future competition. The 737 MAX's more efficient structural design, less engine thrust and less required maintenance also would add up to substantial cost advantages for customers. The 737 MAX 8 would have the

lowest operating costs* in the single-aisle segment with an 8 percent per-seat advantage over the A320neo.

The 737 MAX incorporates the latest quiet engine technology to reduce the operational noise footprint of the airplane by 40 percent. Emissions would be reduced by 50 percent below the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP)/6 limits for nitrogen oxides (NOx).

The 737 MAX built on the best reliability record of any airplane, with a world-beating 99.7 percent of Next-Generation 737 flights ready to depart within 15 minutes of schedule. On-time performance is the major positive influence on passengers' perception of their experience on short flights and saves operators maintenance, flight and crew costs. The design superiority of the 737 translates into fewer passengers being inconvenienced every year when flying on a Boeing 737 versus the competition. For a fleet of 100 Next-Generation 737 airplanes flying five flights a day, the 737s would have 590 fewer delays and avoid disrupting 66,600 fewer passengers when compared to a fleet of A320s. While Boeing is making the upgrades necessary to give customers the fuel savings they need for the future, the 737 MAX would retain the superior design reliability of the Next-Generation 737.

As of 2014 the first flight of a Boeing 737 MAX (in the form of a 737 MAX 8) was scheduled in 2016, with deliveries to customers beginning in 2017. The 737 MAX had accumulated firm orders for more than 1,700 aircraft to date. Boeing claims the 737 MAX family would have 8 per cent lower operating costs per seat than the future competition, which would mainly be the Airbus A320neo family but would also include the Bombardier CSeries, China's Comac C919 and Russia's Yakovlev Yak-242, previously known as the Irkutsk MS-21. The A320neo family has outsold the 737 MAX family to date, with more than 2,500 ordered. Independent industry analysts, such as the AirInsight group of consultants, strongly contest Boeing's claim, saying all indications to date were that the members of the A320neo family would be as fuel-efficient per seat as the equivalent 737 MAX models.

On 08 December 2015 thousands of Boeing employees in Renton, WA, celebrated the completion of final assembly of the first 737 MAX 8, the precise date determined when the MAX development schedule was defined more than four years earlier. The 737 MAX 8 is the first member in Boeing's new family of single-aisle airplanes – the 737 MAX 7, MAX 8, MAX 200 and MAX 9 – to begin production. With the second and third 737 MAX 8 flight test airplanes in final assembly and the fourth (and final) in sub-assembly, the 737 MAX remained on track for first delivery to launch customer Southwest

Airlines in the third quarter of 2017. The 737 MAX family had nearly 3,000 orders from 60 customers worldwide.

Deliveries of the 737 MAX 8 was scheduled to begin in the first half of 2017. Malaysia-based Malindo Air took the first delivery in May 2017. By the end of 2018, more than 200 MAX jets have been delivered to airlines around the world. By March 2019 the Boeing Company Model 737-8 and 737-9 airplanes (737 MAX) U.S.-registered fleet was 74 airplanes; and the worldwide fleet: 387 airplanes.

The MAX aircraft, the latest version of Boeing's popular 737 jetliner, includes a "Maneuvering Characteristics Augmentation System" (MCAS) for the 737 Max models, which can detect critical flight situations and intervene in the event of an imminent stall, but only when the autopilot is switched off. This automated system pushes the nose down if a sensor detects that the nose is pointed so high that the plane could go into an aerodynamic stall. The Maneuvering Characteristics Augmentation System (MCAS) automatically lowers the nose to head off a compressor stall. But Boeing failed to comprehensively communicate this system to pilots and encorporate it into regular training programs.

If an erroneously high single angle of attack (AOA) sensor input is received by the flight control system, there is a potential for repeated nose-down trim commands of the horizontal stabilizer. This condition, if not addressed, could cause the flight crew to have difficulty controlling the airplane, and lead to excessive nose-down attitude, significant altitude loss, and possible impact with terrain.

A new Boeing 737 MAX 8 operated by Lion Air of Indonesia plunged into the Java Sea on 29 October 2018, killing all 189 people on board. Lion Air pilots struggled to maintain control of the Boeing jet as its automatic safety system repeatedly pushed the plane's nose down. Here it was apparently not the Pitot tubes that were faulty, but the sensors that determine the angle of attack of the wings. The two sensors deviated from each other by up to 20 degrees. The pilots failed to recognize what was happening and follow the known procedure for countering incorrect activation of the automated safety system.

In the event of erroneous AOA data, the pitch trim system can trim the stabilizer nose down in increments lasting up to 10 seconds. The nose down stabilizer trim movement can be stopped and reversed with the use of the electric stabilizer trim switches but may restart 5 seconds after the electric stabilizer trim switches are released. Repetitive cycles of uncommanded nose down stabilizer continue to occur unless the stabilizer trim system is

deactivated through use of both STAB TRIM CUTOUT switches. Initially, higher control forces may be needed to overcome any stabilizer nose down trim already applied.

An Ethiopian Airlines plane en route to Nairobi crashed shortly after takeoff on 10 March 2019, with the airline confirming that there were no survivors. The pilot had reported difficulties and asked for permission to turn back. The Ethiopian Airlines Max 8 was the same model as the one that crashed into the Java Sea in October 2018.

Australia and Singapore suspended the Boeing 737 Max 8 passenger jet from operating in their respective airspaces, joining a growing list of countries taking precautionary measures involving the troubled plane after its second fatal crash in five months. Airlines in countries across the globe, including China, Indonesia, Brazil and Mexico, grounded all the 737 Max 8 jets in their respective fleets. The European Aviation Safety Agency (EASA) said it would be grounding all flights involving the plane, widening to prohibition to all EU member states. Belatedly following the lead of more than 30 other countries, the U.S. Federal Aviation Administration on 13 MarCH 2019 ordered the immediate grounding of the entire Max series of Boeing jetliners. The action to halt all flights of the new planes in American airspace was a quick and sudden reversal of the stance taken by the manufacturer, the U.S. airlines flying them and the administration of Donald Trump that there was no reason to order a grounding despite fatal nose-dive crashes of the Max planes in Indonesia and Ethiopia.

Boeing’s completion of the flight control system enhancements provide reduced reliance on procedures associated with required pilot memory items. The FAA anticipated mandating these design changes by AD no later than April 2019. Federal Aviation Administration officials told The Wall Street Journal on Tuesday that a fix to the software problem with the Boeing 737 Max's MCAS flight-control feature was expected in January 2019, but that the shutdown "halted work on the fix for five weeks."

The fixes include updates to the Maneuvering Characteristics Augmentation System (MCAS) flight control law, pilot displays, operation manuals and crew training. The enhanced flight control law incorporates angle of attack (AOA) inputs, limits stabilizer trim commands in response to an erroneous angle of attack reading, and provides a limit to the stabilizer command in order to retain elevator authority.

The first fuselage for the first 737 MAX 9, the second and largest member of Commercial Airplanes' new single-aisle airplane family, has arrived at the Final Assembly site in Renton, Wash. The 737 MAX is being assembled exclusively in Renton, Wash. At 138 feet, 4 inches, the 737 MAX 9 fuselage is 8 feet, 8 inches longer than the 737 MAX 8, which was the first family member produced and is currently undergoing flight testing. Two other models — the 737 MAX 7 and the 737 MAX 200 — would come later.

The fuselage, like all those for the 737 program, was produced by Spirit AeroSystems in Wichita, Kan., and shipped to Renton by rail. After going through Final Assembly, it is scheduled to roll out of the factory and take its first flight in the first quarter of next year. With a two-class seating configuration for 178 passengers and a range of 3,280 nautical miles (3,775 miles, 6,075 kilometers), the 737 MAX 9 was scheduled to enter service with Indonesia-based launch customer Lion Air in 2018.

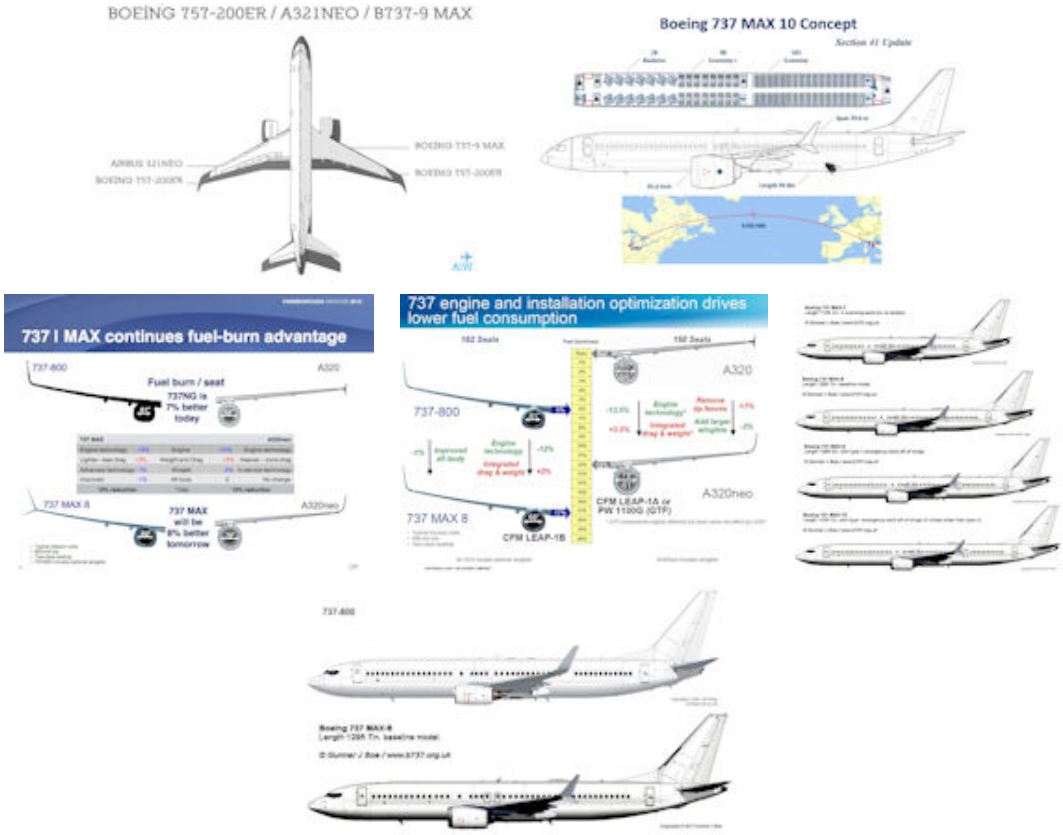
737-10 / Max 10

By 2016 Boeing was considering stretching their 737-9 MAX to counter the market being flooded by A321s. This reflects not only the seriousness of the threat posed by the better-selling Airbus A321neo but also the company's belief in the growth potential of its seemingly ever-flexible 737 design. By 2016 Airbus had more than 4,515 orders for the A320neo family, of which 1,117 are for the A321neo. Boeing was believed to have accrued fewere than 500 orders for the competing 737-9.

Boeing was studying two designs for its so-called Max 10, a potential stretch of its largest 737 aimed at matching Airbus Group SE's longest single-aisle jet. One option Boeing has discussed with airlines and lessors was a simple lengthening of the 737 Max 9 that would offer much of the range and payload of Airbus's A321neo. The company was also examining an alternative, more elaborate revamp that would feature the larger engines developed for the Airbus jet.

Although the engine is unchanged, the fuselage is lengthened so the main landing gear must be modified to enable adequate clearance of the longer body for rotation on takeoff and landing and to ensure the aircraft remains stall rather than pitch-limited. If Boeing offered a PW1000/LEAP-A sized turbofan, the company would have to redesign much of the inner 737 wing and central wingbox. The Leap-1A has a 78-in.-dia. fan and a maximum nacelle height of 93 in. while the -1B, with a maximum thrust rating at takeoff of just over 29,000 lb, has a 69-in.-dia. fan and a nacelle just under 89 in. in height at its deepest point. Boeing managed to get the Leap-1B under the

wing of the MAX by extending the nose leg 8 in., and cantilevering the engine forward and upward of the wing leading edge. The company faced a bigger challenge with the Leap-1A.



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