

Boeing 737 MAX groundings

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A parking lot at [Boeing Field](#) in Seattle, Washington, filled with undelivered [Boeing 737 MAX](#) aircraft

Date	<ul style="list-style-type: none">• Lion Air accident: October 29, 2018• Ethiopian Airlines accident: March 10, 2019• First grounding: March 10, 2019 by Ethiopian Airlines (superseded)• First grounding order: March 11, 2019 by the Civil Aviation Administration of China (CAAC) (still in effect)• FAA grounding order March 13, 2019 – November 18, 2020
Duration	<ul style="list-style-type: none">• between accidents: 4 months and 10 days• of grounding by the FAA: 1 year, 8 months and 5 days (619 days)
Cause	Airworthiness revoked after recurring flight control failure
Budget	<ul style="list-style-type: none">• direct costs: US\$20 billion^{[]}• indirect costs: US\$60 billion^{[]}
Deaths	346 total: <ul style="list-style-type: none">• 189 on Lion Air Flight 610• 157 on Ethiopian Airlines Flight 302

The [Boeing 737 MAX](#) passenger [airliner](#) was [grounded](#) worldwide between March 2019 and December 2020 - longer in many jurisdictions - after 346 people died in two crashes, [Lion Air Flight 610](#) on October 29, 2018 and [Ethiopian Airlines Flight 302](#) on March 10, 2019. The [FAA](#) resisted grounding the aircraft until March 13, when it received evidence of accident similarities. By then, most other regulators had already grounded the aircraft. By March 18, all 387 aircraft were banned from service.

In November 2018, a week after the Lion Air accident, Boeing issued a bulletin supplementing the flight operations manual to warn that the MAX could pitch down automatically when a sensor fails and to explain how pilots should respond. The FAA enforced the bulletin with an [Emergency Airworthiness Directive](#). Both avoided mentioning the new [Maneuvering Characteristics Augmentation System](#) (MCAS), which was responsible for the nosedives but had been omitted by Boeing from crew manuals and training. Following intense pressure from pilot unions and customers, Boeing finally revealed the name MCAS in a message to operators. In December 2018, the FAA privately predicted that MCAS could cause 15 crashes over 30 years, but expected Boeing to fix MCAS by April 2019.

FAA [certification of the MAX](#) was subsequently investigated by the [U.S. Congress](#) and multiple U.S. government agencies, including the [Transportation Department](#), [FBI](#), [NTSB](#), [Inspector General](#) and special panels. Engineering reviews uncovered other design problems, unrelated to MCAS, in the flight computers and cockpit displays. The Indonesian [NTSC](#) and the Ethiopian [ECAA](#) both attributed the crashes to faulty aircraft design and other factors, including maintenance and flight crew actions. Lawmakers investigated Boeing's incentives to minimize training for the new aircraft.^[2] The FAA revoked Boeing's authority to issue [airworthiness certificates](#) for individual MAX airplanes and imposed a fine on Boeing for exerting "undue pressure" on its [designated aircraft inspectors](#).

In August 2020, the FAA published requirements for fixing the aircraft and improving pilot training. On November 18, 2020, the FAA cleared the MAX to return to service,^[3] followed by European and Canadian regulators in January 2021.^[4] The 20-month grounding was the longest ever for a U.S. airliner, costing Boeing an estimated US\$20 billion in fines, compensation and legal fees, and indirect losses in the form of 1,200 cancelled orders valued at more than US\$ 60 billion ^{[5][1]} Passenger flights resumed on the MAX in the U.S. and Brazil in December, and Boeing began deliveries of some 400 aircraft in its backlog.



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Timeline^[edit]



This section **may be [too long](#) to read and navigate comfortably**. Please consider [splitting](#) content into sub-articles, [condensing](#) it, or adding [subheadings](#). Please discuss this issue on the article's [talk page](#). *(January 2021)*

2016^[edit]

- March 2016, The General Manager of Boeing's 737 MAX program, and the former Chief Project Engineer on the 737 MAX program, both approved a redesign of MCAS to increase its authority to move the aircraft's stabilizer at low speed, in order to address "stall characteristics" requirements necessary for FAA certification. Just hours after the approval for MCAS's redesign was granted, Boeing sought, and the FAA approved, the removal of references to MCAS from Boeing's FCOM. The FAA officials who authorized this request remained unaware of the redesign of MCAS until after the crash of the Lion Air flight.^[6]

2018^[edit]

- January 10, The Operational Evaluation Report of the [National Civil Aviation Agency of Brazil](#) (ANAC) mentions the [MCAS](#).^[7] The FAA had approved Boeing's request to remove MCAS from differences tables and QRH;^{[8][9]} The Operational Evaluation Report prepared by Transport Canada contained the same table as ANAC's, except the reference to MCAS.^{[7][*excessive detail?*]}
- October 29, a 737 MAX 8 operating [Lion Air Flight 610](#) crashed after take-off from Jakarta, killing all 189 on board. Boeing started redesigning the MCAS system right after the accident.^[10]
- November 6, Boeing issued an [Operations Manual Bulletin \(OMB\)](#),^[11] describing a MAX-specific feature of the pitch trim system, warning that with "erroneous AoA data, the pitch trim system can trim the stabilizer nose down in increments lasting up to 10 seconds" which "can be stopped and reversed with the use of the electric stabilizer trim switches but may restart 5 seconds after" and instructed pilots to counteract it by running the [Runaway stabilizer and manual](#)

[trim](#) procedure.^[12] The background introduction of the bulletin states: "This bulletin directs flight crews to existing procedures to address this condition", and reminds operators to use the "existing procedures in the Runaway Stabilizer NNC [Non-Normal Conditions]" when the MAX reacts to a false stall detection.^[13] This was Boeing's first public announcement about MCAS, albeit not by name.^[14]

- November 7, the FAA issued an [Emergency airworthiness directive](#) to owners and operators,^[15] requiring revising the aircraft flight manual (AFM) "to provide the flight crew with runaway horizontal stabilizer trim procedures" when "repeated nose-down trim commands" are caused by "an erroneously high single AoA sensor",^[12] reinforcing the Boeing bulletin.^[16] The FAA directive warned that the problem was an "unsafe condition" that could result in "impact with terrain".^[17] The directive informs pilots of a new function specific to MAX models : "Note: The 737-8/-9 uses a Flight Control Computer command of pitch trim to improve longitudinal handling characteristics. In the event of erroneous Angle of Attack (AOA) input, the pitch trim system can trim the stabilizer nose down in increments lasting up to 10 seconds." The FAA had removed reference to MCAS from its draft EAD.^[18]
- November 10, Boeing referred publicly for the first time to the [MCAS](#) by name in a Multi Operator Message to operators.^{[19][20][21]} The MCAS control law, a few lines of software code in the FCC, could autonomously command [nosedives](#), when even a single sensor failure resulted in bad data; MCAS was omitted from aircraft manuals and training,^[22] therefore flight crews had no knowledge of its existence or functioning until Boeing published a bulletin on November 6.
- November 27, the [Allied Pilots Association](#) of [American Airlines](#) had a meeting with Boeing to express concerns with the MCAS effectiveness, and was unnerved by the airframer's responses. Union president Daniel Carey later said, "The huge error of omission is that Boeing failed to disclose the existence of MCAS to the pilot community. The final fatal mistake was, therefore, the absence of robust pilot training in the event that the MCAS failed".^[23] The Boeing officials acknowledged, that they were considering some changes, for example preventing MCAS's repetitive activation to ensure that it only triggers once.^[24]
- December 3, the FAA Seattle Certification Office reviewed an unpublished quantitative risk assessment [analysis](#) of the MAX, prepared using the "Transport Aircraft Risk Assessment Methodology" (TARAM). The U.S. [House Committee on Transportation and Infrastructure](#) made the report public just over a year later, on December 11, 2019. In the committee's words, the report concluded that "if left uncorrected, the MCAS design flaw in the 737 MAX could result in as many as 15 future fatal crashes over the life of the fleet", predicting 2900 deaths over 30 years.^[25]
- December 17, in a presentation to the FAA, Boeing deflected blame and continued to assert that appropriate crew action would save the aircraft.^[26]

2019^[edit]

- March 10, another 737 MAX 8 operating [Ethiopian Airlines Flight 302](#) crashed shortly after take-off from Addis Ababa airport, killing all 157 on board, due to a similar faulty MCAS, initiating a worldwide flight ban for the aircraft, starting with China.

- March 13, the [U.S. FAA](#) was among the last to order the grounding of the 737 MAX, after claiming there was no reason: China had the most aircraft in service, 96, followed by the U.S. with 72, Canada with 39 and India with 21. The FAA issued an Emergency Order of Prohibition grounding Boeing 737 MAX airplanes, followed by a CANIC.^[27]
- March 20, EASA and Transport Canada indicated that they would conduct their own reviews of Boeing's proposed software update.^[28]
- March 27, Boeing unveiled a [software update](#) to avoid MCAS errors, already developed and tested it in-flight, to be certified.
- April 5, Boeing announced it was cutting 737 production by almost a fifth, to 42 aircraft monthly, anticipating a prolonged grounding, and had formed an internal design review committee.
- May 13, Republican [Congressman Sam Graves](#) at the [House Aviation](#) subcommittee hearing, blamed the 737 MAX crashes on poor training of the Indonesian and Ethiopian pilots; he stated that "pilots trained in the U.S. would have been successful" in handling the emergencies on both jets.^{[29][30]}
- June 18, [IAG](#) signed a [letter of intent](#) for 200 737 MAXs at the [Paris air show](#), followed by Turkish [SunExpress](#) and [Air Astana](#) later in the year.
- June 26, flight tests for the FAA uncovered a data processing issue affecting the pilots' ability to perform the "runaway stabiliser" procedure to respond to MCAS errors.
- October 30, Boeing CEO [Dennis Muilenburg](#) testified before [U.S. Congress](#) committees, defending Boeing's [safety culture](#) and denying knowledge of internal messages in which Boeing's former chief technical pilot said he had unknowingly lied to regulators, and voiced its concerns on MCAS.
- November 22, Boeing unveiled the first [737 MAX 10](#) flight-test aircraft.^[22]
- November 26, the FAA revoked Boeing's [Organization Designation Authorization](#) to issue [airworthiness certificates](#) for individual MAX airplanes.^[31]
- December 17, Boeing confirmed the suspension of 737 MAX production from January 2020.
- December 23, Dennis Muilenburg resigned, to be replaced by board chairman [David Calhoun](#).^[22]

2020^[edit]

- January 7, Boeing recommended "simulator training in addition to computer based training".^[32]
- January 9, Boeing released previous messages in which it claimed no [flight simulator](#) time was needed for pilots, and distanced itself from emails mocking airlines and the FAA, and criticising the 737 MAX design.
- January 13, David Calhoun became CEO, pledging to improve Boeing's commitment to safety and [transparency](#), and estimating the return to service in mid-2020.
- January 21, Boeing estimated the ungrounding could begin in mid-2020.^[22]
- May 27, Boeing resumed production of the MAX at a "very gradual pace".^[33]

- June 28 to July 1, the FAA conducted flight tests with a view to recertification of the 737 MAX.^[34]
- September 16, the [U.S. House of Representatives](#) releases its concluding report, blaming Boeing and the FAA for lapses in the design, construction and certification.^[35]
- September 30, a Boeing 737 MAX test aircraft was flown by FAA administrator [Stephen Dickson](#).^[36]
- October 16, Patrick Ky, the executive director of the European Union Aviation Safety Agency, claimed that the updated 737 Max reached the level of safety "high enough" for EASA.^[37]
- November 18, the FAA issued a [CANIC](#), subject to mandatory updates on each individual aircraft^[a].^[38] Other regulators are expected to follow.^{[3][39]}
- December 9, Brazilian low-cost carrier [Gol Transportes Aéreos](#) was the first airline to resume passenger service.^[40]
- December 29, [American Airlines](#) is the First US airline to resume commercial operations.^[41]

2021^[edit]

- January 7, Boeing [settled](#) to pay over \$2.5 billion after being charged with [fraud](#) over the company's hiding of information from safety regulators: a [criminal monetary penalty](#) of \$243.6 million, \$1.77 billion of [damages](#) to airline customers, and a \$500 million crash-victim beneficiaries fund.^{[42][43]}
- January 18, Transport Canada authorized the MAX to resume flights in Canadian airspace.^[44] Canadian operators must modify the aircraft to enable pilots to disable the [stick shaker](#) when it is erroneously activated, if they are certain that they understand the underlying cause.^[45]
- January 27, EASA cleared the MAX to resume service in Europe, subject to additional restrictions similar to those mandated by Transport Canada.^[46] Certain approaches requiring precision navigation are however not yet approved as EASA is awaiting data from Boeing as to the aircraft's ability to maintain the required performance in the event of sensor failures.^[47]
- February 26, the Australian Civil Aviation Safety Authority lifted its ban on the MAX, accepting the return-to-service requirements set by the FAA. Australia is the first nation in the Asia-Pacific region to clear the aircraft to return to service.^[48]

Groundings^[edit]



Five [Shenzhen Airlines](#) 737 MAX 8s (foreground, red livery) grounded at the [Shenzhen Bao'an International Airport](#), March 2019

Main article: [List of Boeing 737 MAX groundings](#)

After the Ethiopian Airlines crash, China and most other [aviation authorities](#) preceded the U.S. [Federal Aviation Administration](#) (FAA) in grounding the airliner over perceived safety risks. The FAA issued a [Continued Airworthiness Notification to the International Community](#) on March 11 and resisted pressure from U.S. lawmakers to ground the aircraft.^{[49][50]} Boeing CEO [Dennis Muilenburg](#) called President [Donald Trump](#) on March 12 to assure him the airplane was safe.^[51] On March 13, 2019, the FAA found similarities between the two accidents and grounded the plane.^[52] About 30 MAX aircraft were flying in U.S. airspace at the time and were allowed to reach their destinations.^[53] By March 18, regulators grounded all 387 MAX aircraft in service with 59 airlines worldwide and making 8,600 flights each week.^[54] Several [ferry flights](#) were operated with flaps extended to circumvent MCAS activation.

The grounding subsequently became the longest ever of a U.S. airliner.^[55] As of January 2020, another 400 newly-manufactured aircraft await delivery to airlines pending the aircraft's [return to service](#).

Accident investigations^[edit]

Lion Air Flight 610^[edit]

Main article: [Lion Air Flight 610](#)



PK-LQP, the aircraft involved in the crash of [Flight 610](#)

Preliminary investigations revealed serious [flight control](#) problems that traumatized passengers and crew on the aircraft's previous flight, as well as signs of [angle-of-attack](#) (AoA) sensor and other instrument failures on that and previous flights, tied to a design flaw involving the [Maneuvering Characteristics Augmentation System](#) (MCAS) of the 737 MAX series. The aircraft maintenance records indicated that the AoA Sensor was just replaced before the accident flight.^[56] The report tentatively attributed the accident to the erroneous angle-of-attack (AoA) data and automatic nose-down [trim](#) commanded by MCAS.^{[57][58]}

The NTSC final report, published on October 23, 2019 was prepared with assistance from the U.S. NTSB. NTSC's investigator Nurcahyo Utomo identified nine factors to the accident, saying:

"The nine factors are the root problem; they cannot be separated. Not one is contributing more than the other. Unlike NTSB reports that identify the primary cause of

accidents and then list contributing issues determined to be less significant, Indonesia is following a convention used by many foreign regulators of listing causal factors without ranking them".^{[59][60]}

The final report has been shared with families of Lion Air Flight 610, then published on October 25, 2019.^{[61][62][63][64]}

Ethiopian Airlines Flight 302^[edit]

Main article: [Ethiopian Airlines Flight 302](#)



ET-AVJ, the [Ethiopian Airlines](#) aircraft that crashed as [Flight 302](#)

The initial reports for Flight 302 found that the pilots struggled to control the airplane in a manner similar to the Lion Air flight 610 crash.^[65] On March 13, 2019, the FAA announced that evidence from the crash site and satellite data on Flight 302 suggested that it might have suffered from the same problem as Lion Air Flight 610 in that the [jackscrew](#) controlling the pitch of the horizontal stabilizer of the crashed Flight 302, was found to be set in the full "nose down" position, similar to Lion Air Flight 610.^[66] This further implicated MCAS as contributory to the crash.^{[67][68][69]}

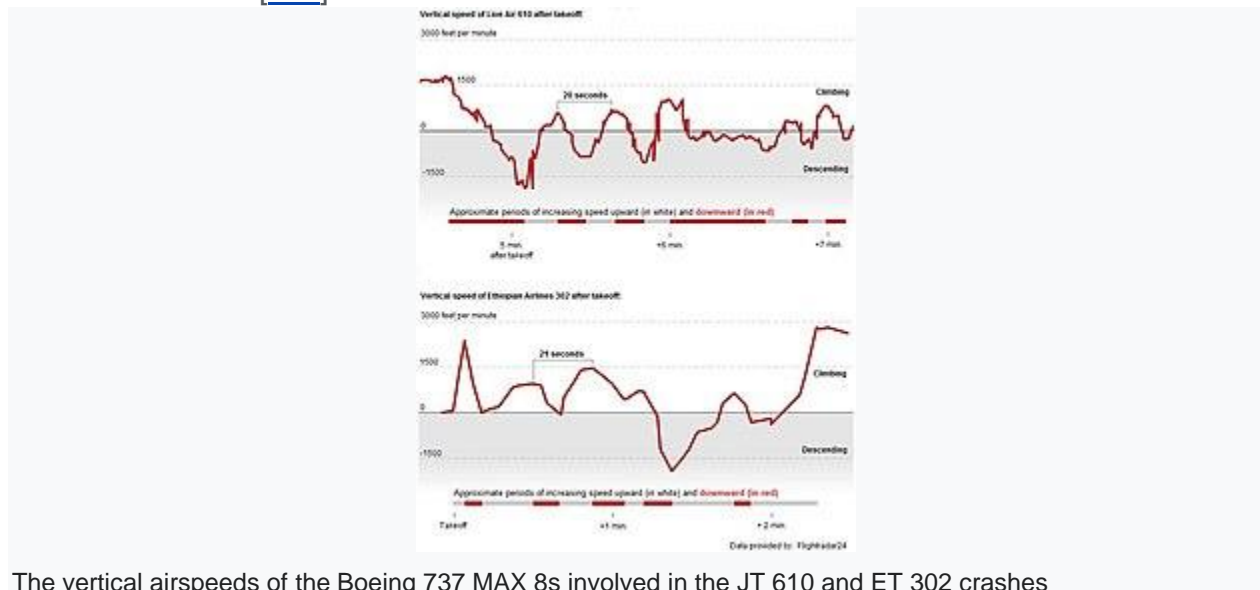
Ethiopian Airlines spokesman Biniyam Demssie said that the [procedures for disabling MCAS](#) had just been incorporated into pilot training. "All the pilots flying the MAX received the training after the Indonesia crash," he said. "There was a directive by Boeing, so they took that training."^[70] Despite following the procedure, the pilots could not recover.^[71]

The [Ethiopian Civil Aviation Authority](#) (ECAA) is leading investigations for Flight 302. The United States Federal Aviation Administration will also assist in the investigation.^[72] Both [flight recorders](#) (voice and data) were recovered from the crash site on March 11, 2019.^[73] The French aviation accident investigation agency [BEA](#) announced that it would analyze the flight recorders from the flight.^[74] BEA received the flight recorders on March 14, 2019.^[75]

On March 17, 2019, [Dagmawit Moges](#), [Ethiopia's transport minister](#), announced that the black box had been found and downloaded, and that the preliminary data retrieved from the flight data recorder show a "clear similarity" with those of Lion Air Flight 610 which crashed off Indonesia.^{[76][77]} Due to this finding, some experts in Indonesia suggested that the NTSC should cooperate with Flight 302's investigation team.^[78] Later on the evening, the NTSC offered assistance to Flight 302's investigation team, stating that the committee and the [Indonesian Transportation Ministry](#) would send investigators and representatives from the government to assist with the investigation of the crash.^[79]

The [Ethiopian Civil Aviation Authority](#) published an interim report on March 9, 2020, one day before the March 10 anniversary of the crash.^[80] Investigators have tentatively concluded that the crash was caused by the aircraft's design.^{[81][82]} As of March 2021, the final report has not yet been published.^[83]

United States^[edit]



The vertical airspeeds of the Boeing 737 MAX 8s involved in the JT 610 and ET 302 crashes

On November 6, 2018, four days before it identified MCAS by name, Boeing published a supplementary service bulletin prompted by the first crash. The bulletin describes warnings triggered by erroneous AoA data, and referred pilots to a "non-normal runaway trim" procedure as resolution, specifying a narrow window of a few seconds before the system would reactivate and pitch the nose down again.^[84] The FAA issued an [emergency airworthiness directive](#), 2018-23-51, on November 7, 2018 requiring the bulletin's inclusion in the flight manuals, and that pilots immediately review the new information provided.^{[85][86]} On March 11, FAA defended the aircraft against groundings citing these emergency procedures ([Continued Airworthiness Notification to the International Community](#)) for operators.

In December 2018, a month after the Lion Air accident, the FAA had conducted an internal safety risk analysis predicted fifteen more crashes with no repairs to MCAS, but that report was not revealed until the [U.S. House hearing](#) in December 2019. FAA's administrator, Stephen Dickson, who assumed the position during the accident investigations, said in retrospect that "the result was not satisfactory".

On September 26, 2019, the NTSB released the results of its review of potential lapses in the design and approval of the 737 MAX.^{[87][88](p1)[89]} The NTSB report concludes that assumptions "that Boeing used in its functional hazard assessment of uncommanded MCAS function for the 737 MAX did not adequately consider and account for the impact that multiple flight deck alerts and indications could have on pilots' responses to the hazard". When Boeing induced a stabilizer trim input that simulated the stabilizer moving consistent with the MCAS function, "... the specific failure modes that could lead to unintended MCAS activation (such as an erroneous high AOA input to the MCAS)

were not simulated as part of these functional hazard assessment validation tests. As a result, additional flight deck effects (such as IAS DISAGREE and ALT DISAGREE alerts and stick shaker activation) resulting from the same underlying failure (for example, erroneous AOA) were not simulated and were not in the stabilizer trim safety assessment report reviewed by the NTSB."^{[88][90]}

The NTSB questioned the long-held industry and FAA practice of assuming the nearly instantaneous responses of highly trained test pilots as opposed to pilots of all levels of experience to verify [human factors](#) in aircraft safety.^[91] The NTSB expressed concerns that the process used to evaluate the original design needs improvement because that process is still in use to certify current and future aircraft and system designs. The FAA could for example randomly sample pools from the worldwide pilot community to get a more representative assessment of cockpit situations.^[92]

Responsible states^[edit]

See also: [Aviation accident analysis](#)

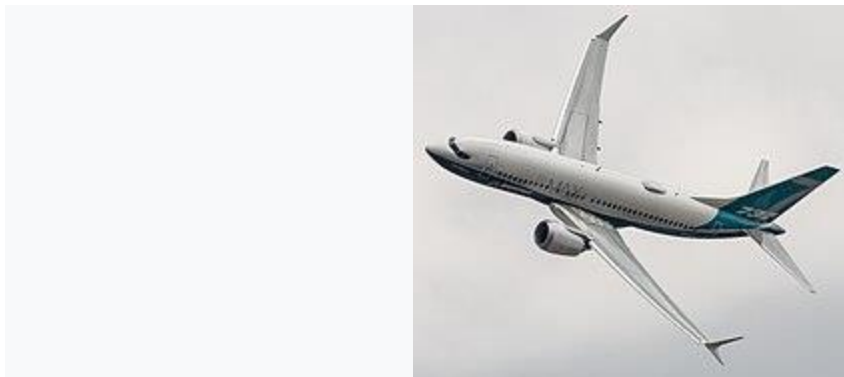
[ICAO](#) regulations Annex 13, "Aircraft Accident and Incident Investigation", defines which states may participate in investigations. For the two MAX accidents these are:^[93]

1. Indonesia, for Lion Air Flight 610 as state of registration, state of occurrence and state of operator.
2. Ethiopia, for Ethiopian Airlines Flight 302, as state of registration, state of occurrence and state of operator.
3. The United States, as state of manufacturer and issuer of the type certificate.

The participating state or national transportation safety bureaus are the NTSB for the US and the NTSC for Indonesia. Australia and Singapore also offered technical assistance, shortly after the Lion Air accident, regarding data recovery from the new generation [flight recorders](#) (FDR).^[needs update] With the exception of Ethiopia, the officially recognised countries are members of the [Joint Authorities Technical Review](#) (JATR).

Type certification and return to service^[edit]

Main article: [Boeing 737 MAX certification](#)



The [Boeing 737 MAX](#) was initially certified in 2017.

The [Boeing 737 MAX](#) was certified in March 2017 by the U.S. [Federal Aviation Administration](#) (FAA) and the [European Union Aviation Safety Agency](#) (EASA). After two fatal crashes, [Lion Air Flight 610](#) and [Ethiopian Airlines Flight 302](#), global regulators grounded the MAX in March 2019. Both crashes were linked to the [Maneuvering Characteristics Augmentation System](#) (MCAS), a new [flight control law](#).

Investigations determined that Boeing and the FAA favored cost-saving solutions, but ultimately produced a flawed design.^[94] The FAA's [Organization Designation Authorization](#) program, allowing manufacturers to act on its behalf, was also questioned for weakening its oversight of Boeing. The MAX was given the same [type certificate](#) as previous 737 generations to reduce pilot training and save money for its airline customers, a major selling point. For [fleet commonality](#), MCAS was added so that the MAX would handle similar to earlier 737 versions. Boeing convinced the FAA that MCAS could not fail hazardously or catastrophically, and that existing procedures were effective in dealing with malfunctions. The MAX was exempted from certain newer safety requirements, saving Boeing billions of dollars in development costs.^[95]

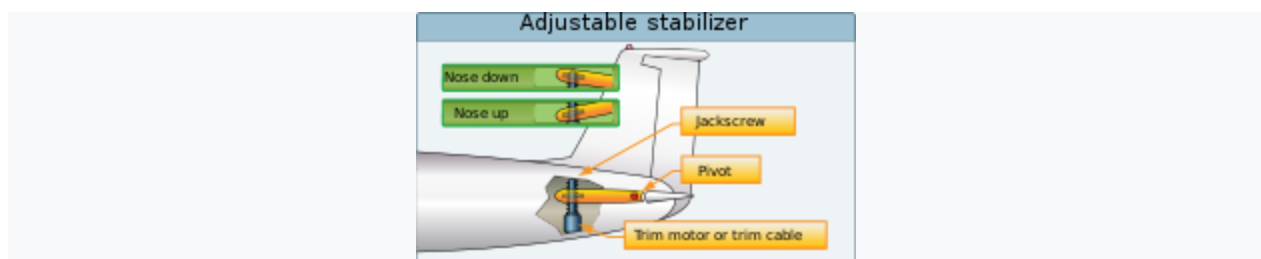
In February 2020, the [DOJ](#) investigated Boeing's hiding of information from the FAA, based on the content of internal emails.^[96] In January 2021, Boeing [settled](#) to pay over \$2.5 billion after being charged with [fraud](#).

In June 2020, the [U.S. Inspector General](#)'s report revealed that MCAS problems dated several years before the accidents.^[97] The FAA found several defects that Boeing deferred to fix, in violation of regulations.^[98] In September 2020, the House of Representatives concluded its investigation and cited numerous instances where Boeing dismissed employee concerns with MCAS, prioritized deadline and budget constraints over safety, and where it lacked transparency in disclosing essential information to the FAA. It further found that the assumption that simulator training would not be necessary had "diminished safety, minimized the value of pilot training, and inhibited technical design improvements".^[99]

In November 2020, the FAA announced that it had cleared the aircraft type to return to service.^[100] Various system, maintenance and training requirements are stipulated, as well as design changes that must be implemented on each aircraft before the FAA issues an [airworthiness certificate](#), without delegation to Boeing. Other major regulators worldwide are gradually following suit: Transport Canada and EASA both cleared the MAX in late January 2021, subject to additional requirements.^{[44][46]}

Maneuvering Characteristics Augmentation System^{[[edit](#)]}

Main article: [Maneuvering Characteristics Augmentation System](#)



The MAX uses an adjustable stabilizer, moved by a jackscrew, to provide the required pitch trim forces. Generic stabilizer illustrated.

The **Maneuvering Characteristics Augmentation System (MCAS)** is a [flight control law](#) first introduced on the Boeing [KC-46](#) Air Force tanker, but became notorious on the [Boeing 737 MAX](#) as a hidden feature that caused two fatal accidents. MCAS was intended on the MAX to mimic [pitching](#) behavior of the previous generation of the series, the [Boeing 737 NG](#), correcting an elevated [angle of attack](#) (AoA) situation by electronically adjusting the [horizontal stabilizer](#) and [trim tab](#) to push the nose down. A description of MCAS did not exist in the flight manuals during [certification](#), leaving pilots unaware of the system when the airplane entered service.^{[101][102]}

Twelve days after the Lion Air accident, on November 10, 2018, Boeing publicly revealed MCAS in a message to airline operators, noting that the system operates "without pilot input."^{[103][104]} Pilots were advised to perform a recovery procedure to reverse the nose down commands caused by MCAS in the event of a malfunction. The procedure could not prevent the March 2019 crash of [Ethiopian Airlines Flight 302](#), which occurred while a fix to MCAS was under development,^{[105][106]} thus the aircraft was grounded worldwide.

In April 2019, Boeing admitted that the MCAS played a role in both accidents, where it acted on false indications from exterior sensors. Boeing said that MCAS's functions were distinctly not an anti-[stall](#) system. Then reports emerged that Boeing knowingly withheld, for at least a year before the Lion Air crash, that a key sensor warning system did not function as advertised.^[107] Repairs to the aircraft included an overhauled [computer architecture](#), accurate [simulation](#) of forces potentially resisting [manual trim](#), and other electromechanical defects.

In late 2020, an FAA [Airworthiness Directive](#)^[108] approved design changes for each MAX aircraft, requiring input from two AoA sensors for MCAS activation, elimination of the system's ability to repeatedly activate, and allowing pilots to override the system if necessary. For each aircraft, the FAA will issue an [airworthiness certificate](#), without delegation to Boeing, upon completion of an AoA sensor system test and a validation test flight.^[109] The FAA began requiring all MAX pilots to undergo MCAS-related training in flight simulators.

Reactions^[edit]

Main article: [Reactions to the Boeing 737 MAX groundings](#)

The Boeing 737 MAX groundings drew mixed reactions from multiple organizations. The first authority to ground the MAX, [Civil Aviation Administration of China](#) said the accidents "had certain similarities" because both aircraft were newly delivered and crashed shortly after takeoff.^[110]

[Boeing](#) expressed its sympathy to the relatives of the [Lion Air Flight 610](#) and [Ethiopian Airlines Flight 302](#) crash victims, while simultaneously defending the aircraft against any faults until rebutted by evidence. Boeing provided several outdated return to service timelines, the soonest of which was "in the coming weeks" following the March 2019 grounding. On October 11, 2019, [David L. Calhoun](#) replaced [Dennis Muilenburg](#) as

chairman of Boeing, then succeeded Muilenburg's role as chief executive officer in January 2020.

Rep. Congressman [Sam Graves](#) of the [House Transportation Committee](#) had blamed the 737 MAX crashes on substandard-quality training of the Indonesian and Ethiopian pilots; stating that "pilots trained in the U.S. would have been successful" in handling the emergencies on both jets, at the House Aviation subcommittee hearing in Washington D.C.^{[111][112]} [Airbus](#) downplayed that it is "winning" in any way due to the MAX grounding, citing its own logistical and supplier capacity to fulfill orders for the A320 family aircraft.

Pilots and flight attendants opinions are mixed as some expressed confidence in the certification renewal, while others are disappointed as Boeing had hidden an important safety feature to their knowledge. [Mica Endsley](#) of the [Human Factors and Ergonomics Society](#) testified that "The cues received by the pilots [...] were significantly different than the cues received with a runaway stabilizer trim".

Most [airlines](#) seek compensation from Boeing to cover costs of the disruption, while the 737 MAX received some support when [International Airlines Group](#) (IAG) announced at the June 2019 [Paris Air Show](#) it could order 200 jets. Opinion polls suggested most passengers are reluctant to fly again aboard the 737 MAX when it will be reintroduced, while most should be comfortable boarding it again after some time passes to prove its safe operations. [Chesley Sullenberger](#) commented upon the "cozy relationship" that exists between the industry and its regulators.

Financial and economic effects^[edit]

Main article: [Financial impact of the Boeing 737 MAX groundings](#)

The Boeing 737 MAX groundings have had a deep financial effect on the aviation industry and a significant effect on the national economy of the United States. No airline took delivery of the MAX during the groundings. Boeing slowed MAX production to 42 aircraft per month until in January 2020, when they halted until the airplane is reapproved by regulators. Boeing has suffered directly through increased costs, loss of sales and revenue, loss of reputation, victims litigation, client compensation, decreased credit rating and lowered stock value. In January 2020, the company estimated a loss of \$18.4 billion for 2019, and it reported 183 canceled MAX orders for the year.

In February 2020, the global [coronavirus pandemic](#) and the resulting travel bans created further uncertainty for Boeing. In March 2020, news that Boeing was seeking a \$60 billion [bailout](#) caused a steep drop in its stock price, though Boeing eventually received \$17 billion in funds from the [coronavirus stimulus](#).^[113] Its extensive supply chain providing aircraft components and flight simulators suffered similar losses, as did the aircraft services industry, including crew training, the aftermarket and the aviation insurance industry. At the time of the recertification by the FAA in November 2020, Boeing's net orders for the 737 MAX were down by more than 1,000 aircraft,^[5] 448 orders canceled and 782 orders removed from the backlog because they are no longer certain enough to rely on; the total estimated direct costs of the MAX groundings were US\$20 billion and indirect costs over US\$60 billion.^[114] On January 7, 2021, Boeing [settled](#) to pay over \$2.5 billion after being charged with [fraud](#).

See also^{[[edit](#)]}



• [Aviation portal](#)

- [Qantas Flight 72](#): data failure causing pitch down, severely injuring passengers
- [Air France Flight 447](#): fatal accident following data and pitot tube failure and autopilot disablement
- [Turkish Airlines Flight 1951](#): Dutch authorities have reopened the accident probe into this 2009 accident involving the prior generation 737-800 series aircraft.^[115]
- [Boeing 787 Dreamliner battery fires](#): the aircraft was grounded in 2013 for modifications to mitigate or contain risk of inflight fire.

Notes^{[[edit](#)]}

1. [^] install new flight control computer software and new display system software; incorporate certain Airplane Flight Manual flightcrew operating procedures; modify horizontal stabilizer trim wire routing installations; conduct an angle of attack sensor system test; and conduct an operational readiness flight


References^{[[edit](#)]}

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