

FAA, EU finish Boeing 737 Max recertification flights

After two crashes killed 346 people, the Boeing 737 Max is getting close to carrying passengers again. Plus: Everything you need to know about the plane's other issues.



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Two Boeing 737 Max 8s crashed, killing 346 people.

After a pair of crashes of its 737 Max 8 in 2018 and 2019 that killed 346 people, [Boeing](#) continues to work to get its grounded aircraft back in the air. Investigators in [Indonesia](#) and [Ethiopia](#) have largely blamed the accidents on a faulty sensor and problems with a flight control system while other reports have identified potential problems with the airliner's [flight control computer](#), [wiring and engines](#).

The developments have been a huge blow to Boeing, which has thousands of 737 Max orders on its books. The company said it's completed the necessary changes to repair the plane, which has been grounded since March, 2019, and has conducted recertification flights with the US

It's still unclear when the Max could return to service -- after piloting the plane himself on September 30 the FAA administrator says the process is in "the home stretch" -- but here's everything else we know in the meantime.

What happened in the two crashes?

In the first crash, on Oct. 29, 2018, [Lion Air flight 610](#) dove into the Java Sea 13 minutes after takeoff from Jakarta, Indonesia, killing 189 people. The flight crew made a distress call shortly before losing control. That aircraft was almost brand-new, having arrived at Lion Air three months earlier.

The second crash occurred on March 10, 2019 when Ethiopian Airlines flight 302 departed Addis Ababa Bole International Airport bound for Nairobi, Kenya. Just after takeoff, the pilot radioed a distress call and was given immediate clearance to return and land. But before the crew could make it back, [the aircraft crashed](#) 40 miles from the airport, six minutes after it left the runway. Aboard were 149 passengers and eight crew members. The aircraft involved was only four months old.

What is the Boeing 737 Max?

Built to compete with the Airbus [A320neo](#), the 737 Max is a family of commercial aircraft that consists of four models. The Max 8, which is the most popular version, made its first flight on Jan. 29, 2016, and entered passenger service with Malaysia's Malindo Air on May 22, 2017. (Malindo [no longer flew the plane](#) by the time of the first crash.) [Seating between](#) 162 and 210 passengers, depending on the configuration, it's designed for short- and medium-haul routes, but also has the range (3,550 nautical miles, or about 4,085 miles) to fly [transatlantic](#) and between the [mainland US and Hawaii](#). The larger [Max 9](#) first flew in 2017, and the Max 10 has yet to fly ([it made its formal debut Nov. 22](#), 2019). The smaller 737 Max 7 [flew for the first time](#) in May 2018.

A 737 history

- [Boeing 737: Much more than just the Max](#)

The design of the 737 Max series is based on the Boeing 737, an aircraft series that [has been in service since 1968](#). As a whole, the 737 family is the best-selling airliner in history. At any given time, thousands of some version of it are airborne around the world and some airlines, like Southwest and Ryanair, have all-737 fleets. If you've flown even occasionally, you've most likely flown on a 737.

What's different about the 737 Max series compared with earlier 737s?

The 737 Max can fly farther and carry more people than the [previous generation of 737s](#), like the 737-800 and 737-900. It also has improved aerodynamics and a [redesigned cabin interior](#) and flies on bigger, more powerful and more efficient CFM LEAP engines.

Those engines, though, required Boeing to make critical design changes. Because they're bigger, and because the 737 sits so low to the ground (a deliberate 737 design choice to let it serve small airports with limited ground equipment), Boeing moved the engines slightly forward and raised them higher under the wing. (If you place an engine too close to the ground, it can suck in debris while the plane is taxiing.) That change allowed Boeing to accommodate the engines without completely redesigning the 737 fuselage -- a fuselage that hasn't changed much in 50 years.

But the new position of the engines changed how the aircraft handled in the air, creating the potential for the nose to pitch up during flight. A pitched nose is a problem in flight -- raise it too high and an aircraft can stall. To keep the nose in trim, Boeing designed software called the Maneuvering Characteristics Augmentation System, or MCAS. When a sensor on the fuselage detects that the nose is too high, MCAS automatically pushes the nose down. (For background on MCAS, read these in-depth stories from [The Air Current](#) and [The Seattle Times](#).)

What caused the crashes?

On Oct. 25, 2019, the Indonesian National Transportation Safety Committee [published its final report](#) on the Lion Air crash. The report identifies nine factors that contributed to the crash, but largely blames MCAS. Before crashing, the Lion Air pilots were unable to determine their true airspeed and altitude and they struggled to take control of the plane as [it oscillated](#) for about 10 minutes. Each time they pulled up from a dive, MCAS pushed the nose down again.

"The MCAS function was not a fail-safe design and did not include redundancy," the report said. Investigators also found that MCAS relied on only one sensor, which had a fault, and flight crews hadn't been adequately trained to use the system. Improper maintenance procedures, confusion in the cockpit and the lack of a cockpit warning light (more on that in a minute) contributed to the crash, as well.



Compared with previous versions of the 737, the Max's engines sit farther forward and higher up on the underwing pylons. Andrew Hoyle/CNET

More on the Lion Air accident report

- [Report on 737 Max 8 crash blames Boeing design, Lion Air staff](#)

Ethiopian investigators haven't completed their final report. But on March 9, 2020, almost one year to the day since the crash in Addis Ababa, the country's Aircraft Accident Investigation Bureau [published an interim analysis](#). Like the Indonesian findings, it cites design flaws with MCAS such its reliance on a single sensor. It also blamed Boeing for providing inadequate training to crew on using the Max's unique systems. (The Seattle Times [has a great deep dive](#) on the report.)

Unlike their Indonesian counterparts, the Ethiopian investigators do not mention maintenance problems with the plane nor does it blame the flight crew. "The aircraft has a valid certificate of airworthiness and maintained in accordance with applicable regulations and procedures," the report said. "There were no known technical problems before departure."

While [we wait for the final Ethiopian report](#), remember that crash investigations are tremendously complex -- it takes months to evaluate the evidence and determine a probable cause. Investigators must examine the debris, study the [flight recorders](#) and, if possible, check the victims' bodies to determine the cause of death. They also involve multiple parties including the airline, the airplane and engine manufacturers, and aviation regulatory agencies.

What was the problem with the warning light?

[The Air Current](#) reported March 12, 2019 that the Lion Air plane lacked a warning light designed to alert pilots to the faulty sensor and that Boeing sold the light as part of an optional package of equipment. When asked about the warning light, a Boeing spokesman gave CNET the following statement:

"All Boeing airplanes are certified and delivered to the highest levels of safety consistent with industry standards. Airplanes are delivered with a baseline configuration, which includes a standard set of flight deck displays and alerts, crew procedures and training materials that meet industry safety norms and most customer requirements. Customers may choose additional options, such as alerts and indications, to customize their airplanes to support their individual operations or requirements."

But on April 29, 2019, [The Wall Street Journal](#) reported that even for airlines that had ordered it, the warning light wasn't operating on some Max planes that had been delivered (a fact the Indonesian accident report confirmed). Then on June 7, 2019, Reps. Peter DeFazio, a Democrat from Oregon, and Rick Larsen, a Democrat from Washington, said [they'd obtained information](#) suggesting that even though the plane maker knew the safety alert wasn't working, it decided to wait until 2020 to implement a fix.

Boeing responded to DeFazio and Larsen in a statement sent to CNET the same day.

"The absence of the AOA Disagree alert did not adversely impact airplane safety or operation," the statement read. "Based on the safety review, the update was scheduled for the MAX 10 rollout in 2020. We fell short in the implementation of the AoA Disagree alert and are taking steps to address these issues so they do not occur again."



The original version of the 737 first flew in 1967. Boeing

What kind of MCAS training did 737 Max pilots receive?

Not much, which was a factor cited in both crash reports. As the report said, "The absence of guidance on MCAS or more detailed use of trim in the flight manuals and in flight crew training, made it more difficult for flight crews to properly respond."

Though MCAS was new to the Max, existing 737 pilots didn't have to train on a simulator before they could start flying the Max. Instead, they learned about the differences it brought through [an hour's worth of iPad-based training](#). MCAS received scant mention. The reason? It was because Boeing, [backed by the FAA](#), wanted to minimize the cost and time of certifying pilots who'd already been trained on other 737 versions. To do so, Boeing and the FAA treated the Max as just another 737 version, rather than a completely new airplane.

Pilot [complaints about the lack of training](#) emerged quickly after the Lion Air crash. On Nov. 12, 2018, [The Seattle Times reported](#) that Max pilots from Southwest Airlines were "kept in the dark"

about MCAS. [The Dallas Morning News found](#) similar complaints from American Airlines pilots four months later.



The previous model, the 737-900ER, doesn't have the MCAS flight control system. Boeing/Ed Turner

Are there any other issues with the aircraft besides MCAS?

There are a few.

- In December, 2019, the FAA said [it was looking at a potential problem](#) with two bundles of wiring that power control surfaces on the aircraft's horizontal stabilizer. Because the bundles are close together, there's a remote possibility that they could short-circuit and (if not noticed by the flight crew) send the plane into a dive. Boeing, however, is arguing [a fix isn't necessary](#), since earlier 737s have the same wiring design, and has proposed [leaving the bundles as they are](#).
- The same month, the FAA said [it was investigating software](#) in monitors that verify whether key systems on the aircraft are functioning correctly.

- Then in February, Boeing [notified the FAA of a malfunction with an indicator light](#) for the stabilizer trim system, which raises and lowers the Max's nose. The indicator, which notifies pilots of a malfunction, was turning on when it wasn't supposed to. Boeing also is investigating whether [it needs to better insulate the engine cowlings](#) from lightning strikes in flight.
- Separately, CFM International said there [may be a potential weakness](#) with a rotor on the Max's engines.
- In April, the FAA instructed Boeing [to make two additional computer fixes](#) to the airplane beyond MCAS. One, a possible fault in a flight control computer, could lead to a loss of control from the horizontal stabilizer, while the second could lead the autopilot feature to potentially disengage during final approach.
- Aviation safety regulators in Europe and Canada have asked [for additional changes to the Max's avionics](#) beyond MCAS.
- in June, the FAA said Boeing had [to fix engine coverings](#). The defect could lead to a loss of power during flights.

Have any other reports been issued?

On Oct. 11, 2019, an international flight safety panel issued a [Joint Authorities Technical Review](#) that [faulted both the FAA and Boeing](#) on several fronts. For the FAA, it said the agency needs to modernize its aircraft certification process to account for increasingly complex automated systems by ensuring that aircraft incorporate fail-safe design principles that don't rely too heavily on pilot input.

For Boeing's part, the report cited the company's "inadequate communications" to the FAA about MCAS, inadequate pilot training and shortage of technical staff. The review was conducted by representatives from NASA, the FAA and civil [aviation](#) authorities from Australia, Canada, China, Europe, Singapore, Japan, Brazil, Indonesia and the United Arab Emirates.

When was the Max grounded?

Most operators [quickly grounded](#) their planes in the days following the second crash. That list includes both Ethiopian Airlines and Lion Air, but also AeroMexico, Aerolíneas Argentinas, GOL Linhas Aéreas (Brazil), Turkish Airlines, S7 Airlines (Russia), FlyDubai, Air Italy, Cayman Airways, Norwegian, China Eastern Airlines, Fiji Airways and Royal Air Maroc.

More than 40 countries have also banned the 737 Max from flying in their airspace. China (a huge Boeing customer and [a fast-growing commercial aviation market](#)) led the way and was joined by Indonesia, Thailand, Malaysia, Australia, India, Oman, the European Union and Singapore. Canada initially hesitated, but soon [reversed course](#).

Up until March 13, 2019, the FAA also declined to issue a grounding order, saying in a statement [tweeted the previous day](#) that there was "no basis to order grounding the aircraft." That was despite a public outcry from [a group of senators](#) and [two flight attendant unions](#). But following President Trump's [decision to ground](#) the Max that day, the agency cited [new evidence](#) it had

collected and analyzed. Southwest and American quickly grounded their planes. Trump also grounded the 737 Max 9, currently in service with United Airlines.

Older [737 models](#), like the 737-700, 737-800 and 737-900, don't use the flight control system under investigation and aren't affected.

How has Boeing responded?

Boeing has been fully involved with both investigations since early on. On Nov. 6, 2018, just eight days after the first crash, [the company issued a safety warning](#) advising 737 Max operators to deactivate MCAS if a flight crew encountered conditions like the Lion Air pilots experienced. It also [expressed sympathy](#) for victims' families and [pledged \\$100 million](#) in support, and [it quickly backed](#) the US grounding order.

"There is no greater priority for our company and our industry," Boeing said in a March 13, 2019 statement. "We are doing everything we can to understand the cause of the accidents in partnership with the investigators, deploy safety enhancements and help ensure this does not happen again."

As is common after a crash, [Boeing didn't comment](#) on preliminary findings of either investigation, but the day after the Ethiopian crash the company [said it would](#) issue a software update that would include changes to MCAS, pilot displays, operation manuals and crew training.

Following the Lion Air accident report, then CEO Dennis Muilenburg said the company was "addressing" its safety recommendations. "We commend Indonesia's KNKT for its extensive efforts to determine the facts of this accident, the contributing factors to its cause and recommendations aimed toward our common goal that this never happens again," he said.

Did Boeing know about Max problems before the crashes?

There is some evidence that it did. On Oct. 17, 2019, Boeing revealed [it revealed text messages](#) between two of the company's top pilots sent in 2016, which indicated the company knew about problems with the MCAS system early on. In one of the messages, a former chief technical pilot for the Boeing 737 described the MCAS' habit of engaging itself as "egregious."

Later that month, [as he appeared before](#) two congressional committees, Muilenburg admitted Boeing [knew of the test pilot concerns](#) in early 2019. "I was involved in the document collection process, but I relied on my team to get the documents to the appropriate authorities," he said. "I didn't get the details of the conversation until recently."

Then on Jan. 10, 2020 Boeing [released a series of explosive emails](#) and instant messages to Congress in which Boeing employees discussed the 737 Max. Though [some expressed regret for the company's actions](#) in getting the aircraft certified -- "I still haven't been forgiven by God for the covering up I did last year," one employee wrote in 2018 -- others openly discussed the 737 Max's flaws [and joked about the FAA's approval process](#). "This airplane is designed by clowns

who in turn are supervised by monkeys," another employee wrote. (The New York Times [has compiled the documents online](#).)

Did Boeing change its leadership?

Yes, but it didn't happen quickly. Though Muilenburg [apologized](#) to the victims' families in an interview with [CBS News](#) (CNET News is published by CBS Interactive, a unit of ViacomCBS) in May, 2019, he came under sharp criticism for his response to the crashes. On Oct. 11, 2019, Boeing announced it had [taken away his role as chair](#) so that as CEO, Muilenburg could "focus full time on running the company as it works to return the 737 Max safely to service."

Muilenburg spent the next two months [resisting calls](#) for his resignation from his other position, but on Dec. 23, 2019 the company announced that he had stepped down. "The Board of Directors decided a change in leadership was necessary to restore confidence in the company moving forward as it works to repair relationships with regulators, customers, and all other stakeholders," Boeing [said in a statement](#). Chairman David Calhoun [officially replaced](#) Muilenburg on Jan. 13, 2020.

Calhoun had defended Muilenburg before taking the top role, but in a March 5, 2020 interview [with the New York Times](#) he said his predecessor had needlessly rushed production of the Max before the company was ready. "I'll never be able to judge what motivated Dennis, whether it was a stock price that was going to continue to go up and up, or whether it was just beating the other guy to the next rate increase."

Separately, on Oct. 22, 2019, the company [said it replaced](#) Boeing Commercial Airplanes CEO Kevin McAllister, the official overseeing the 737 Max investigation, with Stan Deal, former president and CEO of Boeing Global Services.

How has the FAA responded?

The agency quickly came [under fire](#) on multiple fronts over the crashes. [Congress](#), the [FBI](#), [the Justice Department's criminal division](#) and Secretary of Transportation Elaine Chao all [called for investigations](#) of the FAA's [certification process](#). Under an FAA program, Boeing was allowed to participate in the process, meaning that it inspected its own plane.

But on Jan. 16, 2020, an independent panel set up by the Department of Transportation (the FAA is a division of the DOT) [dismissed that criticism](#). In its report, the committee found no significant problems with how the Max was cleared to fly. Though the committee said the FAA could improve the certification process, it saw no need for substantial changes.

Outside of the certification process, the FAA has slapped Boeing with two fines for installing substandard or unapproved equipment in some Max planes. With the first fine, [which the FAA proposed](#) in January, 2020 for \$5.4 million, the agency said Boeing used improper equipment to guide the slats on 178 Max planes. Positioned at the leading edge of each wing, slats are deployed at take-off and landing to provide more lift. [The FAA also accused Boeing](#) of installing a guidance

system on 173 Max planes that used sensors that hadn't been properly tested. The proposed penalty is \$19.68 million.

And that's not all. According to The Wall Street Journal, both the FAA and the DOJ [are investigating whether Boeing workers mistakenly left debris](#) in fuel tanks or other interior spaces of completed aircraft.

Has Congress gotten involved?

Yes. In March 2020, the House Committee on Transportation and Infrastructure [released a report](#) on the design, development and certification of the 737 Max and the FAA's oversight of Boeing. It said "acts, omissions, and errors occurred across multiple stages and areas of the development and certification of the 737 MAX." The report went on to identify five specific issues.

- Production pressures: There was tremendous financial pressure on Boeing and the 737 Max program to compete with the A320neo, leading the company to rush the plane into service.
- Faulty assumptions: Boeing made fundamentally faulty assumptions about critical technologies on the 737 Max, most notably with MCAS.
- Culture of concealment: In several critical instances, Boeing withheld crucial information from the FAA, its customers and 737 Max pilots.
- Conflicted representation: The FAA's current oversight structure regarding Boeing creates inherent conflicts of interest that have jeopardized the safety of the flying public.
- Boeing's influence over the FAA's oversight: Multiple career FAA officials documented examples of FAA management overruling the determination of the agency's own technical experts at the behest of Boeing.

On Sept. 16, the House Transportation Committee issued [a report](#) that [blamed the crashes on](#) a "horrific culmination" of failures at Boeing and the FAA. "In several critical instances, Boeing withheld crucial information from the FAA, its customers, and 737 MAX pilots," the report said. And as for the FAA, "the fact that a compliant airplane suffered from two deadly crashes in less than five months is clear evidence that the current regulatory system is fundamentally flawed and needs to be repaired."

What has to happen before the Max can fly again?

Aviation safety agencies around the world need to approve [Boeing's fixes](#) as safe, and airlines would need to implement them and conduct more pilot training.

On May 16, 2019, Boeing said the update [was largely complete](#) after more than [135 test flights](#). Five months later, on Oct. 22, the company [said it had made](#) "significant progress" toward that goal by adding flight control computer redundancy to MCAS and three additional layers of protection. It's also completed a dry run of a certification flight test and conducted simulator tests for 445 participants from more than 140 customers and regulators. Boeing [provided a further progress report](#) Nov. 11.

Boeing and the FAA finally began the recertification flights on June 29. The flights attempted to trigger the steps that led to the two crashes and confirm that MCAS isn't activating erroneously. The FAA also reviewed pilot training materials. After the flights, the agency released [a list of changes](#) (PDF) it says Boeing must make to the Max before it can return to service.

On Sept. 30, FAA Administrator Steve Dickson piloted the plane on a test flight to evaluate Boeing's changes. Speaking to reporters after the flight he said he "liked what I saw" and that the FAA's recertification process was in "the home stretch." Dickson declined, however, to predict an approval date.

But that's just in the US. Aviation regulatory agencies around the world, like the [European Aviation Safety Agency](#), also need to approve the fix before they'll let the Max fly to the countries they oversee. Traditionally, they've followed the FAA's lead on such matters, but both [Transport Canada](#) and the [EU](#) conducted independent tests of the plane while working with the FAA.

Will pilots have to train in a simulator before they can fly the Max again?

After Boeing announced it was ready to deploy the MCAS software update in April, the FAA initially said that simulator training still [wouldn't be required](#). But some pilots and regulatory officials from other countries, like Canadian Transport Minister Marc Garneau, quickly disagreed with that decision. They won an influential supporter on June 19, 2019, when "[Miracle on the Hudson](#)" Capt. Chesley B. "Sully" Sullenberger argued before a congressional committee that simulator training [should be required](#) before pilots take the Max back into the air. He [also said the original design](#) of MCAS was "fatally flawed and should never have been approved."

On Jan. 7, 2020, Boeing reversed course when it issued a recommendation that pilots receive simulator training on MCAS before the Max returns to service, an action that aviation safety agencies will support. Simulator sessions will require extra time and expense for airlines struggling to get their Max fleets back in the air, steps [Boeing originally wanted to avoid](#).



A Boeing 737 Max 7 lands at Boeing Field in Seattle after a test flight to evaluate the MCAS software fix.

Paul Christian Gordon/Boeing

Are airplanes now too complicated?

On March 12, 2019, Trump [tweeted](#) that airplanes are "becoming far too complex to fly." The reality isn't quite that simple. Commercial airliners have used automated systems for decades (that's what an automatic pilot is). The Lockheed L-1011, introduced in 1972, [could land itself](#). Most airliners flying today also are "fly by wire," meaning that a pilot's commands are carried as electronic signals (rather than over hydraulic lines) to an aircraft's control services. Flight computers also continually stabilize an aircraft during flight without input from the flight crew. Boeing and Airbus [have different philosophies](#) for this interaction, but explaining those could take a book.

So the basic concept of MCAS is nothing new. But crews need to be properly trained to use automated systems, recognize when they may be at fault and override them if necessary. As the accident reports have indicated, a lack of training about MCAS contributed to the Max 8 crashes. Airline pilots are thoroughly trained to fly an aircraft under extraordinary circumstances, but they need accurate information about factors like airspeed and altitude to be able [to make quick decisions](#) in an emergency.

Has a commercial aircraft been grounded before?

Yes. In the most recent example, the FAA [grounded the Boeing 787](#) for three months in 2013 after a series of nonfatal [battery fires](#). Before that, the FAA [grounded the Douglas DC-10](#) for a month in 1979 after a crash near Chicago O'Hare Airport killed 271 people on board, plus two on the ground. (Outside of the Sept. 11, 2001, terrorist attacks, that remains the deadliest airplane crash on US soil.) The Chicago crash was ultimately attributed to improper maintenance. The crash of a DC-10 in 1974 in France, killing 346 people, was caused by a design flaw on a cargo hold door latch.

Outside the US, both Qantas and Singapore Airlines voluntarily grounded their Airbus A380s for a couple of days after [a Qantas flight](#) from Singapore to Sydney in 2010 had [an uncontained engine failure](#).

How important is the Max series to Boeing?

Hugely important. The battle for the 150- to 200-seat aircraft market between Boeing and Airbus is fierce. As of May 31, 2020, Boeing had [4,232 firm 737 Max orders](#), making [it the fastest-selling airplane](#) in its history. But two crashes in five months is a troubling record for a plane that entered service barely three years ago, and airlines will have to reassure passengers the planes are safe.

Not surprisingly, the grounding has been an anchor on Boeing's financials, costing it almost \$19 billion so far. On Jan. 29, 2020, [the company reported a loss](#) of \$636 million for 2019, its first annual loss since 1997. In the report, Boeing said its "financial results continue to be significantly impacted by the 737 MAX grounding."

As of June 30, 2020, the company had [delivered 387 Max aircraft](#) to [more than 50 airlines](#). Currently, the three largest customers (in order) are Southwest Airlines, American Airlines and Air Canada. Following the second crash, airlines stopped ordering the aircraft and some airlines [have canceled](#) or [delayed](#) Max orders, a trend only hastened by the [travel slowdown](#) from the [coronavirus](#) pandemic. Boeing also [halted production of the Max in January 2020](#) and then [resumed it in May](#).

New orders, however, could still come. On June 18, 2019, at the Paris Air Show, International Airlines Group said [it would consider buying](#) 200 737 Max 8s and 10s. And at the Dubai Air Show in October 2019, Boeing reported 737 Max orders from [Air Astana](#) and [SunExpress](#).

Correction, Jan. 10, 1:54 p.m. PT: This story initially misstated the status of Malaysia's Malindo Air at the time of the first crash.

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