

The Boeing 737 MAX Debacle

A white paper on how the 737 MAX was unwisely certified and what needs to be done

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November 5, 2019

Washington, DC

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Introduction

This white paper explains how Boeing and the FAA’s delegation of certification authority caused the 737 MAX crashes. Within the Boeing 737 MAX’s first year of commercial service, two crashes killed 346 people. This is entirely unprecedented in aviation history, at least since the Comet in the 1950s that had three crashes within one year and ended UK leadership of commercial aviation. First, on October 29, 2018, Lion Air Flight 610 crashed into the Java Sea, killing all 189 people on board. On March 10, 2019, Ethiopian Airlines Flight 302 crashed in a field near Bishoftu, Ethiopia, killing all 157 people on board. Ethiopian Airlines immediately grounded its MAX fleet, and China grounded all 737 MAX planes. The European Union grounded the 737 MAX on March 12, followed by Brazil and Canada on March 13. The FAA followed a few hours later, acknowledging, what many already knew: “the possibility of shared causes for the two incidents.”¹ This white paper is dedicated to the grieving families of the victims of the two unnecessary crashes and their incredibly hard work to right the wrongs of Boeing and the FAA.

Boeing’s struggle to fit larger and more fuel-efficient engines on to the 737 MAX airframe caused a chain of events leading to the two crashes. This struggle of fitting a larger engine onto a lower, 1960’s fuselage did not start with the MAX, but actually originated in 1984 with the 737-300. A more rigorous and independent government safety regulation which mandated airframe rather than software changes enabled the 737-300 to fly safely with the larger engines. Critically, changes in delegation and oversight authority between 1984 and 2016 allowed Boeing to hide and obfuscate design details from the FAA and to capture safety regulatory authority from the FAA.

History of Delegation

In the aviation context, delegation is the assignment of safety duties to a private company with subject area expertise. Delegation has occurred throughout much of aviation history. As the private sector will contain many experts and will be on the forefront of innovation, few would argue against some level of delegation. Delegation should occur in a regime where the FAA maintains supervision and authority over the delegated representative.

Starting in the 1940’s, the FAA’s predecessor agency, the Civil Aeronautics Administration (CAA), delegated much of new aircraft testing to “designees”, employees of airplane manufacturers on temporary assignment to the FAA.² In 1958, the FAA enacted the Delegation Option Authorization (DOA) program in response to expansion in the aircraft industry to certify small airplanes, engines, and propellers.³ Congress authorized the FAA to appoint designees to examine, test, or inspect airplanes to support aircraft certification.

¹ <https://www.nytimes.com/2019/03/13/business/canada-737-max.html>

² <https://www.federalregister.gov/documents/2005/10/13/05-20470/establishment-of-organization-designation-authorization-program>

³ <https://www.federalregister.gov/documents/2005/10/13/05-20470/establishment-of-organization-designation-authorization-program>

In the 1960's, the FAA created the Designated Alteration Station (DAS) program, allowing approved engineering employees of repair stations to issue supplemental type certificates (STCs) and related airworthiness certificates.⁴ DAS still allows eligible air carriers to issue STCs and related airworthiness certificates.⁵

In 1975, the Secretary's Task Force recommended continued reliance on the private aviation industry for safety compliance provided that the FAA takes steps to improve its ability to monitor and oversee delegated inspection responsibilities.⁶ The Task Force also recommended that the FAA insist on more comprehensive design reviews for major aircraft and engine certification and that the FAA should conduct audits with the NTSB. With the Airline Deregulation Act of 1978, the FAA's workload expanded significantly when it had to focus on applications for new airlines.⁷

Monumental Shift to Current Delegation System, Organizational Designation Authorization (ODA)

In the 1980s, "Designated Engineering Representatives" (DER) would conduct safety certification for the FAA.⁸ DERs would file documents with the FAA, but the FAA retained final approval authority.

In 1996, Congress eliminated FAA's dual mandate, of regulating safety and promoting the industry.⁹ Safety was established as the FAA's highest priority. Yet, in 2004, the GAO issued a report recommending strengthening FAA's designee programs.¹⁰

Changes in 2005, secretly lobbied by Boeing represented a troubling transformation of the system of delegation.¹¹ The FAA surrendered its direct oversight of Boeing and other companies. In its place, Boeing supervisors had the power to oversee, hire, and fire designated Boeing employees outside of the FAA's purview. These Boeing designees were intended to operate independently from the profit motivations of the company. Instead, the designees "have been quite aggressive in pushing back against the [FAA]."¹² In addition to losing practical authority and oversight over the designated employees for the tasks of aircraft certification that had been historically delegated, the FAA's 2005 policy change ceded further tasks to Boeing.

⁴ <https://www.federalregister.gov/documents/2005/10/13/05-20470/establishment-of-organization-designation-authorization-program>

⁵ <https://www.federalregister.gov/documents/2005/10/13/05-20470/establishment-of-organization-designation-authorization-program>

⁶ https://www.faa.gov/about/history/chronolog_history/media/b-chron.pdf

⁷ https://www.faa.gov/about/history/brief_history/

⁸ <https://www.seattletimes.com/business/delegating-aircraft-safety-assessments-to-boeing-is-nothing-new-for-the-faa/>

⁹ <https://www.congress.gov/104/plaws/publ264/PLAW-104publ264.pdf>

¹⁰ <https://www.gao.gov/products/GAO-05-40>

¹¹ <https://www.nytimes.com/2019/10/27/business/boeing-737-max-crashes.html>

¹² <https://www.seattletimes.com/business/delegating-aircraft-safety-assessments-to-boeing-is-nothing-new-for-the-faa/>

Before Organization Designation Authorization (ODA) was fully enacted, many within the DOT and FAA raised the alarm bell to the FAA's surrender of certification responsibility and oversight. Even after full enactment, many within the FAA, the DOT Inspector General, and three aviation safety specialists' unions continued to sound the alarm before the two Boeing 737 MAX crashes.

The FAA's Risk Based Resource Targeting in 2007 attempted to identify which certification areas presented the highest levels of risk and therefore required more FAA oversight. A 2008 Blue Ribbon Panel, convened by Secretary of Transportation Mary Peters, issued a report warning that differing approaches to safety created the possibility of wide variances and errors in decision making. Despite these concerns, in November 2009, ODA was fully implemented. All delegated organization would now fall under the ODA policy.

Since 2009, manufacturers such as Boeing have used its own employees to certify the safety of its products. In February 2018, an employee designee, Edward Carl Fernandez, pleaded guilty to falsely certifying the airworthiness of aviation parts in exchange for bribes from an aviation repair company.¹³

A 2011 DOT Inspector General report found that the FAA played a significantly smaller role in approving individuals who perform delegated work on the FAA's behalf. The report also found that the FAA's program for assessing engineering project risk was not effective and was based on subjective opinions rather than data. Under ODA, the report found that FAA engineers were receiving inadequate training commensurate to their expanded enforcement responsibilities.

2012 and 2018 FAA Reauthorization Acts directed the agency to make certifications quicker and cheaper without jeopardizing safety. In 2012, FAA employees complained that the new ODA certification process gave Boeing too much control of the process. These complaints led to a DOT investigation, which concluded that FAA had not "[held] Boeing accountable."¹⁴ Meanwhile in 2012, the Aircraft Certification Process Review and Reform Aviation Rulemaking Committee, created by the 2012 law, recommended "maximize[ing] delegation to the greatest extent in current delegation systems," and preparing for future expanded delegation systems.

Critics examined FAA's oversight of ODA holders in 2013 after the Boeing 787 battery fire debacle. Critics said that "FAA's heavy reliance on manufacturers to attest to the safety of their own products has largely relegated the agency to an administrative role—and has left it without the expertise and manpower to adequately challenge and revise safety standards."

In 2013, FlyersRights.org filed an intervention petition, supported by three battery experts, calling for the grounding of the Boeing 787 until the lithium batteries were replaced or conclusively found to be safe. The planes were grounded for 6 weeks, and the FAA's solution was merely to encase the batteries in a steel jacket.

¹³ <https://www.oig.dot.gov/library-item/36596>

¹⁴ <https://www.seattletimes.com/business/delegating-aircraft-safety-assessments-to-boeing-is-nothing-new-for-the-faa/>

Three unions of aviation safety inspectors issued a 2017 report, before the MAX was approved, warning that Boeing was given too much authority to monitor itself and that the MAX had safety flaws. The report claimed that Boeing and the FAA overruled front-line workers on a vulnerable flight control system and on flaws in the fuel tank. FAA Safety Chief Ali Bahrami cited U.S. competitiveness as a reason for maximizing delegation. Boeing executives pushed the same competitiveness rationale to persuade FAA Administrator Michael Huerta and Ranking Member of the Senate Commerce Committee Senator Maria Cantwell to support this Boeing power grab.¹⁵

Acting FAA Administrator Daniel Elwell claimed, without evidence, that eliminating the delegation process and bringing all certification within the FAA would require 10,000 more employees and cost \$1.8 billion. This statement is troubling not only because it ignores the current costs to the private companies for delegation, but it assumes that the FAA cannot or should not exercise more authority and oversight under the current system. An unsubstantiated price tag and self-serving FAA statements that FAA is not permitting Boeing to self-certify should not be impediments to strengthen the FAA's oversight and to bring more certification back within the FAA. Cost is not an impediment; this amount, even if true, could be raised through user fees or appropriations. Air safety is currently funded mainly by excise taxes on airline tickets and aviation fuel.

In 2018, Boeing lobbied for its version of a provision in the 2018 FAA Reauthorization Act mere weeks before the Lion Air crash.¹⁶ The FAA believed the changes would “not be in the best interest of safety.”¹⁷ The 2018 changes made it even harder for the FAA to supervise Boeing's work. As more and more safety certification had been shifted from FAA to Boeing, the 2018 law made it more difficult for the FAA to reclaim certification power over any single process the FAA thought would compromise safety. Under the new law, the FAA would have to conduct a lengthy formal investigation or inspection if it believed a system was unsafe before it could wrestle back control of certification of that system. Doug Anderson, a former attorney in the FAA's Chief Counsel office, explained “[t]he Reauthorization Act mandated regulatory capture.”¹⁸ Congress has been complicit and overly influenced by the commercial aviation industry, willing to take campaign donations and freebies and frequently meeting with Boeing and airline lobbyists.

FAA and Boeing Squeeze One More Variation out of the 737

The 737 design is over 50 years old and has undergone countless changes between its 21 variations. While this may reflect well on the early 737 designs, this fact is a symptom of an aviation system that incentives amendments, grandfathering, and waivers. Boeing consciously acted to minimize changes to the 737-NG variants designs in order to certify the MAX as a 737 instead of under a new type certificate.

¹⁵ <https://www.nytimes.com/2019/10/27/business/boeing-737-max-crashes.html>

¹⁶ <https://www.nytimes.com/2019/10/27/business/boeing-737-max-crashes.html>

¹⁷ <https://www.nytimes.com/2019/10/27/business/boeing-737-max-crashes.html>

¹⁸ <https://www.nytimes.com/2019/10/27/business/boeing-737-max-crashes.html>

The first Boeing 737 design was created in 1965 and had its first commercial flight in April 1967.¹⁹ In the 1960's, stairs were the common method to load and unload passengers. The 737-100 had a set of metal stairs attached to its fuselage.²⁰ This method of loading passengers required that the plane's fuselage be sufficiently low to the ground. The low fuselage did not pose a problem to the relatively small 1960's plane engines. Additionally, the low fuselage allowed bags to more easily be loaded and unloaded without the use of a conveyor.

However, in the 45 years after the launch of the first Boeing 737, the desire for more fuel-efficient engines would require Boeing to make a major change to keep up with its competition, as the larger engines would not fit on the airframe, and Boeing would realize it had exhausted all solutions based on modifications to the airframe. Since 1984, Boeing has had problems fitting larger engines, then the CFM56, onto the 737-300.²¹ To make the engines fit, Boeing had SNECMA make a custom version of the engine with a smaller fan, and Boeing relocated engine accessories and had to use non-round engine inlets.²² After Airbus announced a more fuel-efficient version of the A320, the A320neo, on December 1 2010,²³ Boeing rushed to develop a more fuel efficient 737.²⁴

To compete, Boeing focused its efforts to persuade the FAA to certify the MAX quickly and to reduce costs for air carriers. In contrast, the A320 started life designed around larger engines, specifically a full-sized version of the CFM56. Adding large, high-bypass, turbofans to the A320 did not entail anything similar to the engineering and design effort of fitting similar engines to the 737.²⁵

The situation was dire for Boeing, as American Airlines positioned itself to order hundreds of Airbus jets. To win American Airlines' order, American Airlines CEO Gerard Arpey told Boeing it would have to "act aggressively." Bowing to financial pressure, Boeing scrapped its plan to build an entirely new plane.²⁶ Instead, Boeing embarked on yet another version of the 737.²⁷ Boeing CEO Albaugh promised the 737 MAX would be ready in six years, and Boeing and Airbus shared American Airlines' new order.²⁸

But initially, Boeing did not feel threatened by the A320neo. Boeing believed it could wait 10 years to produce a new jet. Boeing CEO Jim Albaugh predicted that Airbus' decision to install larger, more fuel-efficient engines would "be a design change that will ripple through the

¹⁹ <https://www.airliners.net/aircraft-data/boeing-737-100200/91>

²⁰ <https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html>

²¹ <https://www.airspacemag.com/history-of-flight/how-737-got-its-hamster-mouth-180952391/>

²² <https://www.airspacemag.com/history-of-flight/how-737-got-its-hamster-mouth-180952391/>

²³ <https://www.airbus.com/newsroom/press-releases/en/2010/12/airbus-offers-new-fuel-saving-engine-options-for-a320-family.html>

²⁴ <https://www.nytimes.com/2019/02/03/world/asia/lion-air-plane-crash-pilots.html?action=click&module=RelatedCoverage&pgtype=Article®ion=Footer>

²⁵ <https://www.cfmaeroengines.com/engines/cfm56/>

²⁶ <https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html>

²⁷ https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html?rref=collection%252Ftimestopic%252FBoeing%2520Company&action=click&contentCollection=business®ion=stream&module=stream_unit&version=latest&contentPlacement=50&pgtype=collection

²⁸ <https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html>

airplane.”²⁹ Albaugh, in what would more aptly summarize the Boeing 737 MAX debacle, predicted, “I think [Airbus will] find it more challenging than they think it will be.” Indeed, incorporating larger and more fuel-efficient engines would ripple throughout the Boeing 737 MAX, ultimately requiring the fatal and now infamous Maneuvering Characteristics Augmentation System (MCAS).

Captain Chesley B. (Sully) Sullenberger succinctly connected the accidents to Boeing’s profit focused decision, “Accidents are the end result of a causal chain of events, and in the case of the Boeing 737 MAX, the chain began with decisions that had been made years before, to update a half-century-old design.”³⁰

Campaign to Minimize or Conceal Changes to the 737 to Rush the Certification

In order to win American Airlines’ order, Boeing had to minimize certification time, certification costs, and any training and costs for airlines and pilots. Boeing had to convince the FAA that few enough changes were made in order to justifying certifying the MAX as a 737. Second, Boeing had to convince FAA that the changes made to the MAX would require little, if any, additional differential training for 737 NG pilots. Ultimately, these two shortcuts would not be enough for Boeing.

Rick Ludtke, an engineer who participated in the design of the 737 MAX cockpit, relayed that Boeing created a rule for engineers that changes had to be limited in order to avoid FAA mandated simulator training for pilots.³¹ “There was so much opportunity to make big jumps, but the training differences held us back,” according to Ludtke. Boeing “wanted the minimum change to simplify the training differences, minimum change to reduce costs, and to get it done quickly.”

Andrew Skow and his firm, Tiger Century Aircraft, developed a cockpit display system, known as Q-Alfa, which would have identified the angle of attack sensor failure and allowed the crew to abort the takeoff.³² As seen with the 787 Dreamliner battery controversy, Boeing went with the path of least resistance rather than seeking the outside expert opinions that could have prevented the problem altogether.

Boeing admitted their motivation was to limit changes and training requirements. Boeing CEO Dennis A. Muilenburg conceded “[p]art of what we wanted to accomplish was seamless

²⁹ https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html?ref=collection%252Ftimestopic%252FBoeing%2520Company&action=click&contentCollection=business®ion=stream&module=stream_unit&version=latest&contentPlacement=50&pgtype=collection

³⁰ <http://www.sullysullenberger.com/my-testimony-today-before-the-house-subcommittee-on-aviation/>

³¹ https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html?ref=collection%252Ftimestopic%252FBoeing%2520Company&action=click&contentCollection=business®ion=stream&module=stream_unit&version=latest&contentPlacement=50&pgtype=collection

³² <https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html>

training and introduction for our customers, so we purposely designed the airplane to behave in the same way.”³³

Boeing engineers rushed to submit technical drawings at twice the normal speed.³⁴ FAA engineers were also pressured to approve designs quickly. When a review would take too much time, FAA managers would either sign off on the approval or delegate the review back to Boeing.³⁵ “There wasn’t a complete and proper review of the documents...Review was rushed to reach certain certification dates.”³⁶ The rush to get the plane certified and the corresponding mandate to minimize or conceal any changes that would require pilot simulator training would spell disaster. A functioning system of safety oversight would have blocked Boeing’s proposed changes. The pressure to approve designs quickly was made clear with publication of Mark Forkner’s comments. According to Forkner, then the FAA’s chief technical pilot, test pilots “[are] all so damn busy, and getting pressure from the program.”³⁷

The 737 MAX’s LEAP-1b engines have a diameter of 69 inches. These new engines did not fit on the 737’s 1965 fuselage. Rather than recognizing that enough changes had been made to the 737 design and that safety would dictate a new type certificate, Boeing pigeonholed the new engines on by extending the pylons farther forward and higher to give the engines the needed clearance. Boeing also installed higher nose landing gear.³⁸ The higher and more forward position of the engines generated greater lift for the aircraft, creating a tendency for the nose to pitch up.

To make the 737 MAX “feel” similar to the older 737s,³⁹ Boeing installed MCAS, Maneuvering Characteristic Augmentation System. Boeing contracted the development of software systems to a firm that employed Indian software graduates at rates as low as \$9 per hour.⁴⁰ MCAS may have been only one of the software systems contracted out in this manner, given Boeing’s decision at the time to lay off experienced engineers.⁴¹ Boeing’s previous versions of the 737 had similar pitch-up problems, but those problems were solved with changes to the

³³ <https://www.nytimes.com/2019/02/03/world/asia/lion-air-plane-crash-pilots.html?action=click&module=RelatedCoverage&pgtype=Article®ion=Footer>

³⁴ https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html?rref=collection%252Ftimestopic%252FBoeing%2520Company&action=click&contentCollection=business®ion=stream&module=stream_unit&version=latest&contentPlacement=50&pgtype=collection

³⁵ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

³⁶ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

³⁷ https://www.washingtonpost.com/local/trafficandcommuting/text-messages-show-boeing-employees-knew-in-2016-of-problems-that-turned-deadly-on-the-737-max/2019/10/18/8578c990-f1ca-11e9-89eb-ec56cd414732_story.html

³⁸ <https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html>

³⁹ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁴⁰ <https://www.bloomberg.com/news/articles/2019-06-28/boeing-s-737-max-software-outsourced-to-9-an-hour-engineers>

⁴¹ <https://www.bloomberg.com/news/articles/2019-06-28/boeing-s-737-max-software-outsourced-to-9-an-hour-engineers>

airframe rather than with software.⁴² At times throughout the certification process, Boeing withheld the existence of and the actual nature and strength of MCAS from the FAA and pilots.⁴³ Administrator Elwell was unaware that pilots did not know about MCAS, saying that the revelation caused his “pilot juice [to] start flowing.”⁴⁴

Boeing’s System Safety Analysis of MCAS contained at least three major flaws and misled the FAA and pilots. First, the analysis understated MCAS’ power by a factor of 4. The analysis stated that MCAS could only move the tail more than 0.6 degrees down. But in reality, MCAS could move the horizontal stabilizer more than four times as far, 2.5 degrees, each activation.⁴⁵ Boeing programmed this higher limit after flight tests revealed that a stronger MCAS would be required. But the FAA “believed the airplane was designed to the 0.6 limits, and that’s what the foreign regulatory authorities thought, too.”⁴⁷

Second, the analysis also classified the failure rating as “hazardous”, one step below “catastrophic.”⁴⁸ A hazardous danger level requires input from more than one sensor. However, the 737s legacy autopilot architecture did not allow the operating Flight Control Computer (FCC) ready access to the other FCC’s angle of attack sensor. As a result, the original MCAS implementation relied on just one angle of attack sensor. AOA sensors have high rates of failure, evidenced by the more than 216 reports of faulty AOA sensors reported to FAA since 2004.⁴⁹

A major failure requirement may rely on a single input sensor. These have a failure rating of less than one in 100,000.⁵⁰ When the consequences of failure are deemed costlier, a hazardous failure requirement needs a failure rate of less than one in 10 million. Typically, this requires two separate sources of input.

Boeing could have required MCAS to compare two angle of attack sensors. Or if using just one sensor, the sensors could be tested on the ground before takeoff. This simple change appears apparent to many observers, and in fact may represent a large portion of Boeing’s proposed solution. Many experts were incredulous when they found out that MCAS relied on a single sensor.⁵¹

⁴² <https://www.airspacemag.com/history-of-flight/how-737-got-its-hamster-mouth-180952391/>

⁴³ <https://www.apnews.com/822e02570983487f8cac3b43fd9defcb>

⁴⁴ Pilots learned of MCAS after the Lion Air Crash.

⁴⁵ <https://www.seattletimes.com/business/boeing-aerospace/faa-chief-defends-system-that-delegated-certifications-to-boeing/>

⁴⁶ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁴⁷ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁴⁸ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁴⁹ <https://edition.cnn.com/2019/04/30/politics/boeing-sensor-737-max-faa/index.html>

⁵⁰ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁵¹ <https://www.seattletimes.com/business/boeing-aerospace/a-lack-of-redundancies-on-737-max-system-has-baffled-even-those-who-worked-on-the-jet/>

Boeing's prioritization of profit over safety directed MCAS to take input from only a single sensor. Boeing shortsightedly concluded it was too costly to take input from two sensors. After the two crashes, Boeing has now agreed to take input from two sensors in order to return the 737 MAX to service. The original Boeing autopilot architecture consists of two separate system of sensors and two separate systems of autopilot controllers (FCCs in Boeing's terms). The systems did not originally communicate with each other in any way and were not digital. When they were changed to digital in the early 2000s, the inability of the two systems to communicate was retained. MCAS ran on one FCC without access to the sensors of the other FCC. The process to have the FCCs communicate would be time consuming and costly.

Third, Boeing failed to address how MCAS would reset itself after each activation.⁵² This granted MCAS "unlimited authority" according to Peter Lemme, a former Boeing flight control engineer.⁵³ In the Lion Air crash, MCAS triggered a 2.5 degree drop 23 or 24 times.⁵⁴ Pilots had no reason to know why the plane was pitching so sharply and in ten second intervals.⁵⁵ Boeing installed a similar MCAS on the KC-46 Pegasus military tanker, but that version only allowed one movement of the horizontal stabilizer and allowed the pilot to fully override MCAS when controlling the stick.

Failure to Notify FAA or Pilots of MCAS

The European Union Aviation Safety Agency (EASA) determined that MCAS did not need to be included in the flight operations manual.⁵⁶ Brazil, however, identified MCAS as a significant change that needed to be flagged.

Boeing admitted that it was aware of issues with the angle of attack sensors on the MAX two years before the crashes.⁵⁷ Angle of attack (AOA) sensors were a known problem generally for Boeing planes. A 2013 FAA directive ordered inspections of AOA sensors on Boeing planes.⁵⁸ A 2016 FAA directive ordered AOA sensors to be modified on Boeing MD-90-30s.⁵⁹

Angle of attack sensors, the input for MCAS, can provide erroneous readings so often that manufacturers make an AOA sensor disagree display to notify pilots when one of the

⁵² <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁵³ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁵⁴ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁵⁵ <https://www.nytimes.com/2019/09/18/magazine/boeing-737-max-crashes.html>

⁵⁶ <https://www.nytimes.com/2019/02/03/world/asia/lion-air-plane-crash-pilots.html?action=click&module=RelatedCoverage&pgtype=Article®ion=Footer>

⁵⁷ <https://www.npr.org/2019/05/06/720553748/boeing-knew-about-737-max-sensor-problem-before-plane-crash-in-indonesia>

⁵⁸ <https://www.federalregister.gov/documents/2013/10/02/2013-23084/airworthiness-directives-the-boeing-company-airplanes>

⁵⁹ <https://www.federalregister.gov/documents/2016/12/29/2016-30279/airworthiness-directives-the-boeing-company-airplanes>

readings is erroneous. Boeing waited 13 months before notifying the FAA that its sensor disagree display feature, believed to be a standard feature, was in practice an optional upgrade.⁶⁰

After Boeing notified the FAA in November 2018 that the standard feature was not in fact standard. Even after the Lion Air crash, FAA agreed with Boeing that the AOA Disagree alert was not necessary for safe operations. However, this failure caused pilot confusion and false confidence. Boeing likely exposed itself to criminal and civil liability for declining to notify the FAA for 13 months. While the criminal investigation is on-going, it appears the FAA has taken no civil action.

FAA decided that 737 pilots only needed a one-hour iPad training course for the 737 MAX instead of any hands-on simulator training. More troubling, Boeing made the decision that pilots did not even need to know about MCAS.⁶¹ Jon Weaks, the president of the Southwest Airlines Pilots Association said that pilots “were kept in the dark” about MCAS.⁶² Capt. Mike Michaelis, Chairman of the Allied Pilots Association (APA) Safety Committee, told American Airlines pilots after the Lion Air Crash “[t]his is the first description you, as 737 pilots, have seen...It is not in the American Airlines 737 Flight Manual...nor is there a description in the Boeing FCOM (Flight Crew Operations Manual).”⁶³

Emphasizing how few changes were made to the 737 design enabled the MAX to earn a common type rating. This has the effect of reducing the training costs for pilots and accelerating the certification process. Boeing’s own website boasts “millions of dollars will be saved because of [the MAX’s] commonality with the Next Generation 737.”⁶⁴

Post-Accident Actions

After the Lion Air Crash on October 29, 2018, Boeing, on November 6, and then the FAA, on November 7, notified pilots that MCAS was a feature of the 737 MAX. Boeing inaccurately pushed the narrative that the Lion Air pilots should have been able to correct the problem without knowing that MCAS was a feature of the 737 MAX.

In December, an Ethiopian Airlines pilot told managers that more training and better communication to crew members was needed to avoid a repeat of the Lion Air crash.⁶⁵ Bernd Kai von Hoesslin wrote “[i]t will be a crash for sure.”⁶⁶ In December, FlyersRights.org wrote to

⁶⁰ <https://www.reuters.com/article/us-ethiopia-airplane-boeing/boeing-did-not-disclose-737-max-alert-issue-to-faa-for-13-months-idUSKCN1SB0JC>

⁶¹ <https://www.seattletimes.com/business/boeing-aerospace/u-s-pilots-flying-737-max-werent-told-about-new-automatic-systems-change-linked-to-lion-air-crash/>

⁶² <https://www.seattletimes.com/business/boeing-aerospace/u-s-pilots-flying-737-max-werent-told-about-new-automatic-systems-change-linked-to-lion-air-crash/>

⁶³ <https://www.seattletimes.com/business/boeing-aerospace/u-s-pilots-flying-737-max-werent-told-about-new-automatic-systems-change-linked-to-lion-air-crash/>

⁶⁴ <https://www.seattletimes.com/business/boeing-aerospace/failed-certification-faa-missed-safety-issues-in-the-737-max-system-implicated-in-the-lion-air-crash/>

⁶⁵ <https://www.bloomberg.com/news/articles/2019-05-29/long-before-crash-ethiopian-air-pilot-warned-bosses-of-dangers>

⁶⁶ <https://www.bloomberg.com/news/articles/2019-05-29/long-before-crash-ethiopian-air-pilot-warned-bosses-of-dangers>

Boeing inquiring why Boeing had not grounded the MAX. Boeing replied by stating it was cooperating with investigations and could not say anything more. Boeing promised a software fix by January 2019 and delivered its first of multiple MCAS software fixes in January 2019.⁶⁷ This MCAS fix was not installed on the Ethiopian Airlines' 737 MAX that crashed on March 10, 2019.⁶⁸

Rush to Blame Pilots

With most plane crashes, incentives line up to place the blame on pilot error. Plane manufacturers do not want to take blame for a design defect, just as they do not want to blame a customer airline either. Pilots, in many crashes, are dead and therefore cannot defend against such allegations. On May 15, 2019, the House Aviation Subcommittee convened a hearing on the 737 MAX with the Acting FAA Administrator and the NTSB Chairman.

In his first Congressional testimony after the grounding of the 737 MAX, Acting Administrator Daniel Elwell attempted to place the blame on the pilots by explaining “what concerns me about the data from the flight data recorder is the apparent lack of recognition of runaway stab trim...is taught at the earliest stages of aircraft that have stab trim motors. It is so important that you don't pull out a checklist, you don't open...it's memorized, you're tested on it all the time.”⁶⁹

Rep. Sam Graves declared in the exchange with Elwell, “they kept on accelerating throughout the entire process...pilot training and this is what worries me more than anything else, and I hate to disparage another country and what their pilot training is but that's what scares me: climbing on an aircraft or airline that is outside U.S. jurisdiction. It just bothers me we continue to tear down our system based on what has happened in another country...and particularly given the qualifications and what we're learning about the training standards.”⁷⁰ The Ethiopian Airlines pilots turned off the stab trim⁷¹, as Admin. Elwell said they should have, but when the plane was not responding, the pilots turned it back on.

After the Lion Air crash, in a closed-door meeting on November 27, 2018, American Airlines pilots urged Boeing executives to make changes to MCAS and to explore grounding the plane.⁷² Boeing refused, believing that pilots could handle the software defects and even doubting what really caused the Lion Air crash. Mike Sinnott, a Boeing vice president, stated, “No one has yet to conclude that the sole cause of this was this function on the airplane.”⁷³

⁶⁷ <https://www.wsj.com/articles/faa-finds-new-software-problem-in-boeings-737-max-11561596917>

⁶⁸ <https://www.seattletimes.com/business/boeing-aerospace/faa-had-initial-version-of-boeings-proposed-software-fix-seven-weeks-before-the-ethiopian-crash/>

⁶⁹ <https://transportation.house.gov/committee-activity/hearings/aviation-subcommittee-hearing-status-of-the-boeing-737-max>

⁷⁰ <https://transportation.house.gov/committee-activity/hearings/aviation-subcommittee-hearing-status-of-the-boeing-737-max>

⁷¹ The horizontal stabilizer maintains the aircraft in trim (in longitudinal balance) and provides longitudinal static stability, ensuring the aircraft maintains a constant attitude and pitch without active input from the pilot.

⁷² <https://www.nytimes.com/2019/05/14/business/boeing-737-max-ethiopian-plane-crash.html>

⁷³ <https://www.nytimes.com/2019/05/14/business/boeing-737-max-ethiopian-plane-crash.html>

Captain Chesley B. (Sully) Sullenberger refuted these claims of pilot error, “I know firsthand the challenges the pilots on the doomed accident flights faced, and how wrong it is to blame them for not being able to compensate for such a pernicious and deadly design. These emergencies did not present as a classic runaway stabilizer problem, but initially as ambiguous unreliable airspeed and altitude situations, masking MCAS.”⁷⁴

Post-Accident Revelations

A number of whistleblowers have spoken out at great risk to themselves and deserve to be commended. According to whistleblowers in April 2019, employees for the FAA Aircraft Evaluation Group and the FAA Flight Standardization Board did not have proper training or proper certifications.⁷⁵ Both then-Acting FAA Administrator Dan Elwell and DOT General Counsel Steven Bradbury denied the April 2019 whistleblowers’ contention that anyone certifying the MAX lacked proper qualifications. Senator Wicker, Chairman of the Senate Commerce Committee, wrote on April 2, 2019 that the FAA “may have been notified about these deficiencies as early as August 2018.”

In response to the Wicker letter, Acting Administrator Daniel Elwell replied, “we can confirm that all of the flight inspectors who participated in the Boeing 737 MAX Flight Standardization Board certification activities were fully qualified for these activities.”⁷⁶ One month later, Elwell insisted, “It is not accurate...to suggest that this whistleblower disclosure and investigation implicated the qualifications of the Boeing 737 MAX Flight Standardization Board and the FSB’s evaluation of the Maneuvering Characteristics Augmentation System.”

One month later, on June 3, General Counsel Steven Bradbury, who later would be elevated to Acting Deputy Secretary of Transportation, wrote to Henry J. Kerner, of the Office of Special Counsel, that the “FAA has confirmed” there were no deficiencies with the qualifications of MAX inspectors, and attempted to preempt the Special Counsel investigation by proffering that the whistleblowers’ allegations “have already been investigated.”

But the Office of Special Counsel in September 2019 revealed that it uncovered information raising “serious concerns” that the FAA misled the Senate Commerce Committee.⁷⁷ Special Counsel Henry J. Kerner wrote to President Trump to say “FAA’s official responses to Congress appear to have been misleading in their portrayal of FAA employee training and competency.” The misleading responses “[diverted] attention away from the likely truth of the matter: that they were neither qualified under agency policy to certify pilots flying the 737 MAX nor to assess pilot training on procedures and maneuvers.” The Special Counsel obtained internal FAA communications and FAA employee interview responses during their investigation. Highlighting the sham Office of Audit and Evaluation report that General Counsel Bradbury

⁷⁴ <http://www.sullysullenberger.com/my-letter-to-the-editor-of-new-york-times-magazine/>

⁷⁵ https://www.washingtonpost.com/local/trafficandcommuting/faa-misled-congress-on-inspector-training-for-boeing-737-max-investigators-say/2019/09/23/05e9f986-de08-11e9-be96-6adb81821e90_story.html

⁷⁶ https://www.washingtonpost.com/local/trafficandcommuting/faa-misled-congress-on-inspector-training-for-boeing-737-max-investigators-say/2019/09/23/05e9f986-de08-11e9-be96-6adb81821e90_story.html

⁷⁷ https://www.washingtonpost.com/local/trafficandcommuting/faa-misled-congress-on-inspector-training-for-boeing-737-max-investigators-say/2019/09/23/05e9f986-de08-11e9-be96-6adb81821e90_story.html

claimed exonerated the FAA, the Special Counsel revealed that the Office of Audit and Evaluations “determined” that MAX safety inspectors did not meet official qualification standards, and that another FAA division agreed with that assessment. The Special Counsel noted, however, that this information did not make it into the Office of Audit and Evaluation’s report. Acting Administrator Elwell defended this discrepancy by appealing to “ambiguities in the FAA’s policy.” Ali Bahrami, the FAA’s top safety official, wrote a memo to Elwell that “the current guidance language allows either formal training” or on-the job training.⁷⁸

The FAA’s Flight Standardization Board proposed no simulator training. The draft report had been removed and re-added to the FAA’s website a few times. The original comment period was extended beyond its 14-day period because of pressure from FlyersRights.org and victims’ families. FlyersRights.org filed comments in opposition to the FSB’s proposed amendments.

Part of the opposition to mandated simulator training, outside the incentives to keep costs down and to insist that the MAX represents only a limited change from its predecessor, is the fact that only 3 full motion 737 MAX simulators exist.

FAA has ignored FlyersRights.org and others’ FOIA requests and refuses to release technical details of Boeing’s software changes. FAA, continuing with its longstanding practice, provides no evidentiary support to back up Boeing’s claims of trade secrets and proprietary information. As the FAA receives criticism for its handling of the 737 MAX situation, the FAA has also resisted transparency with respect to Congress’ 2018 mandate to review emergency evacuation demonstration procedures and seat sizes. FlyersRights.org, as the consumer representative on the FAA’s Aviation Rulemaking Advisory Committee, has requested that 737 MAX safety be placed on the committee’s agenda, but all requests have been denied.

In October 2019, text messages between Boeing employees revealed that a Boeing test pilot misled the FAA.⁷⁹ The test pilot explained to a fellow employee in 2016 that “[MCAS is] running rampant on me...the plane is trimming itself like crazy [sic]. I’m like, WHAT?...Granted, I suck at flying, but even this was egregious.”⁸⁰ A source speculates that Boeing did not provide FAA with these emails and texts because they were a subject of an ongoing FBI criminal investigation, which itself for months was unsuccessful in obtaining information from the test pilots as to the meaning and context of the messages.⁸¹ The June 27 simulator flight series revealed a microprocessor failure.⁸² Pilots were unable to recover in a matter of seconds.⁸³

⁷⁸ https://www.washingtonpost.com/local/trafficandcommuting/faa-misled-congress-on-inspector-training-for-boeing-737-max-investigators-say/2019/09/23/05e9f986-de08-11e9-be96-6adb81821e90_story.html

⁷⁹ <https://www.seattletimes.com/business/boeing-aerospace/explosive-text-messages-reveal-boeing-knew-of-mcas-aggression-in-2016-and-misled-faa/>

⁸⁰ <https://www.seattletimes.com/business/boeing-aerospace/explosive-text-messages-reveal-boeing-knew-of-mcas-aggression-in-2016-and-misled-faa/>

⁸¹ <https://www.seattletimes.com/business/boeing-aerospace/explosive-text-messages-reveal-boeing-knew-of-mcas-aggression-in-2016-and-misled-faa/>

⁸² <https://www.seattletimes.com/business/new-problem-discovered-in-boeings-troubled-737-max-jet/>

⁸³ <https://www.cnn.com/2019/06/26/politics/boeing-737-max-flaw/index.html?no-st=1572047855>

Investigations

While many investigations are in progress, including a certification audit by DOT IG and investigations by several Congressional committees, DOT has indicated that it will not wait for the conclusion of each investigation before ungrounding the MAX. Steven Bradbury, General Counsel and Acting Deputy Secretary of Transportation, revealed to a meeting among consumer groups that Administrator Steve Dickson would have the final say on ungrounding with respect to technical questions, and that the FAA was coordinating with but not relying on synchronizing the ungrounding with other authorities such as EASA (EU) and Transport Canada. As a consequence, the FAA is likely planning to unground the 737 MAX before the other leading authorities. This reflects the loss of trust in the FAA from the rest of the world and will create uncertainty when civil aviation authorities will differ on whether they allow 737 MAX flights within their jurisdictions.

FAA created the JATR⁸⁴, the Joint Authorities Technical Review, which was comprised of civil aviation authorities from 9 countries, including Canada, the European Union, and Brazil. The group was chaired by Former NTSB Chairman Chris Hart and also included FAA and NASA officials.⁸⁵ However, the group's individual members were never disclosed, and all meetings were closed to the public. JATR's October 11, 2019 report concluded that FAA did not have adequate oversight and involvement in the 737 MAX certification. The report hypothesized that the current system of organizational delegation does not necessarily compromise safety if the FAA is properly conducting oversight. However, JATR concluded that the FAA did not have sufficient human resources to oversee Boeing, and that Boeing unduly pressured its own employees. JATR concluded that Boeing and the FAA did not evaluate MCAS in a holistic, integrated aircraft-level approach.⁸⁶ Changes to MCAS during the certification process were not reflected in certification documents, and "the design assumptions were not adequately reviewed, updated, or validated."⁸⁷

⁸⁴ The nine countries comprising the JATR were Australia, Brazil, Canada, China, European Union, Indonesia, Japan, Singapore, and United Arab Emirates.

⁸⁵ https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

⁸⁶ https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

⁸⁷ https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

Congress has held six hearings^{88 89 90 91 92 93} on the 737 MAX, none involving consumer advocates. Victims' family members and an independent expert, Captain Chesley B. (Sully) Sullenberger have testified at only one hearing. At the most recent hearing, Boeing CEO Muilenberg stated he was taking responsibility and was very sorry. Other than offering \$100 million to the victims, he did not have any particular recommendations for substantive changes that Boeing will make or any delegation or oversight changes that FAA should make.

FAA's Reputational and Leadership Loss and the Risk to Boeing

The FAA has long held the reputation of the gold standard for aviation safety. This reputation was seriously challenged when the FAA was slow to ground the 737 MAX, waiting until after many aviation authorities around the world to ground the plane, including the European Union and Canada, after a second crash. Two flight attendants' unions, AFA and APFA, called on the FAA and American Airlines, respectively, to ground the 737 MAX before the FAA ultimately acted.⁹⁴ As time passed, more and more revelations cast doubt on the FAA's oversight and delegation. If the FAA now rushes to unground the 737 MAX before other authorities are satisfied, before the systemic problems are fixed, and before the FAA can reassure the public that it has the resources, capability, and desire to act independently and place safety as its first priority, the FAA's reputation may be permanently damaged. Without full transparency, Boeing and the FAA cannot restore public confidence. Should another MAX crash occur, Boeing would likely be destroyed, and FAA's status as a credible safety regulator would end.

Recommendations

1. In the next 10 days, Boeing and the FAA must release the technical details of Boeing's proposed fixes to outside experts and the public for review and critique. There should be a 60-day public comment period and a full report to Congress prior to any possible decision to unground the MAX. This is necessary because

⁸⁸ Senate Commerce, Science, & Transportation Committee, Aviation and Space Subcommittee Hearing, March 27, 2019. <https://www.commerce.senate.gov/2019/3/the-state-of-airline-safety-federal-oversight-of-commercial-aviation>

⁸⁹ House Transportation & Infrastructure Committee, Aviation Subcommittee Hearing, May 15, 2019. <https://transportation.house.gov/committee-activity/hearings/aviation-subcommittee-hearing-status-of-the-boeing-737-max>

⁹⁰ House Transportation & Infrastructure Committee, Aviation Subcommittee Hearing, June 19, 2019. <https://transportation.house.gov/committee-activity/hearings/the-subcommittee-on-aviation-hearing-on--status-of-the-boeing-737-max-stakeholder-perspectives>

⁹¹ House Transportation & Infrastructure Committee, Aviation Subcommittee Hearing, July 17, 2019. <https://transportation.house.gov/committee-activity/hearings/the-subcommittee-on-aviation-hearing-on--state-of-aviation-safety>

⁹² Senate Commerce, Science, & Transportation Committee Hearing, October 29, 2019. <https://www.commerce.senate.gov/2019/10/aviation-safety-and-the-future-of-boeing-s-737-max/dd0f5a92-0362-45e8-bab1-957d0e82f168>

⁹³ House Transportation & Infrastructure Committee, Aviation Subcommittee Hearing, October 30, 2019. <https://transportation.house.gov/committee-activity/hearings/full-committee-hearing-on-the-boeing-737-max-examining-the-design-development-and-marketing-of-the-aircraft>

⁹⁴ <https://www.bloomberg.com/news/articles/2019-03-12/largest-flight-attendant-unions-back-grounding-of-boeing-737-max>

⁹⁵ <https://www.cbsnews.com/news/boeing-737-max-8-safety-pilots-flight-attendants-react-to-flying-planes-after-ethiopia-arlines-crash/>

the policies and practices of Boeing self-classify all submissions to the FAA as proprietary or trade secrets and therefore exempt from public view must be terminated for the 737 MAX. Given Boeing's misleading statements and FAA's delegation of authority to Boeing, this is essential.

2. If Boeing and FAA will not agree to this, Congress should mandate this through its pending appropriations bill.
3. The FAA, in cooperation with other civil aviation authorities, must evaluate MCAS changes from an integrated whole aircraft system perspective. The 737 MAX is a complex system, and any change could have unintended interactions with other parts of the system. The FAA and Boeing did not evaluate MCAS as a complete and integrated function in the original certification documents.
4. Congress must immediately repeal Boeing's secretly lobbied changes to the 2018 FAA Reauthorization Act that granted near total control of aviation safety regulation to the industry and made the regulatory capture of FAA a fait accompli.
5. The FAA should immediately suspend ODA (Organization Designation Authorization) for Boeing in light of its demonstrated lack of trustworthiness that is essential for such delegation, and return to the pre-2005 program of DER (Designated Engineering Representatives).
6. The FAA must promptly civilly prosecute Boeing and its employees who hid or misrepresented dangerous conditions. FAA should impose fines and suspensions in accordance with the law. The U.S. Department of Justice (DOJ) should criminally prosecute those responsible for knowingly or recklessly approving the MAX as safe to fly with life threatening conditions.
7. The FAA officials who certified the 737 MAX as safe to fly should be totally excluded in the decision-making for ungrounding the plane. Accordingly, all Boeing officials responsible for concealing MCAS from the FAA must be identified and terminated before Boeing formally requests ungrounding for the 737 MAX.
8. The FAA must mandate hands-on simulator training for all pilots of the 737 MAX, and Boeing must provide sufficient simulators.
9. The FAA must place maximum reliance on a stable airframe, without having to rely on software and pilot training to compensate for deficiencies in the airframe.
10. Congress should fully fund the increased safety oversight by FAA that must be recaptured from Boeing. Congress should provide funding to improve the qualifications and to increase number of FAA safety personnel. Congress must restore the FAA's ability to independently evaluate aircraft safety. Congress should hold new hearings prior to any move by Boeing or the FAA to unground the 737 MAX to follow up on previous hearings and to evaluate Boeing's software fixes, and should include consumer organizations, victims' families, and independent experts.
11. Any industry personnel to whom safety regulation authority has been delegated should take an oath of office and receive federal government whistleblower protections. Delegated personnel must be free of undue pressure from industry

management, and any undue pressure exerted from industry must be reported to FAA and Congress.

Conclusion

The Boeing 737 MAX situation is not an aberration. It is the logical result of a corporate strategy to take control of safety certification regulation from the FAA. Boeing chose this strategy to increase profits and maintain its competitive position as the top airline manufacturer.

Boeing persuaded Congress to incrementally grant Boeing more control over safety certification, touting a safety record built upon decades of strong government regulation. Instead of recognizing this key role of government regulation, Boeing took it for granted and falsely argued that giving it control over its own safety regulation would cut delays and expenses while not harming safety.

The MAX should never have been certified as safe to fly. 50 years of changes to the original 737 design led Boeing to the situation where a single sensor controlled a critical system without pilots or the FAA knowing the existence of the system or its full capabilities.

The Boeing corporate strategy to avoid government regulation has backfired in a horrible and tragic way. The 737 MAX profits have turned to losses. Thousands of jobs have been lost. Boeing's safety reputation has been ruined, dragging FAA's down with it. Three hundred forty-six innocent lives have been lost in two crashes in six months due to Boeing and FAA greed and incompetence. The entire U.S. commercial aviation industry has been placed at risk.