FINAL COMMITTEE REPORT

THE DESIGN, DEVELOPMENT & CERTIFICATION OF THE

BOEING 737 MAX

SEPTEMBER 2020

PREPARED FOR:

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The House Committee on
Transportation & Infrastructure

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Related Documents

Transcripts of the transcribed interviews and other documents referenced in this report can be accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

References to Senior Boeing Officials

During design, development, and certification of the 737 MAX, the following individuals held senior positions at Boeing and are referred to in Boeing documents that are linked to this report by their titles.

- Keith Leverkuhn served as Vice President (VP) and General Manager (GM) of the 737 MAX Program from April 2013 to April 2018. In Boeing documents, references to "Former 737 MAX VP/GM" are references to Mr. Leverkuhn.

- Michael Teal served as Vice President and 737 Chief Project Engineer from August 2011 to March 2017. In Boeing documents, references to "Former 737 MAX Chief Project Engineer" are references to Mr. Teal.

- Mark Forkner served as 737 Technical Pilot from 2011 to 2015 and as 737 Chief Technical Pilot from 2015 until 2018 when he left Boeing to work at Southwest Airlines. In Boeing documents, references to "Former 737 Chief Technical Pilot" are references to Mr. Forkner.

- Elizabeth "Beth" Pasztor served as Vice President (VP) of Boeing Commercial Airplanes (BCA) Safety, Security and Compliance and in this role was the ODA Lead Administrator. In Fall 2019, Ms. Pasztor became Vice President and General Manager of Product & Services Safety. In Boeing documents, references to "VP BCA Safety, Security and Compliance" are references to Ms. Pasztor.

Abbreviations

737 NG	Boeing 737 Next Generation Airplane
AAR	Airplane Assessment Report
ACO	Aircraft Certification Office
AD	Airworthiness Directive
AEG	Aircraft Evaluation Group
AFSCME	American Federation of State, County and Municipal Employees
AIA	Aerospace Industries Association
AIR	Aircraft Certification Service
AR	Authorized Representative
APA	Allied Pilots Association
ATC	Amended Type Certificate
ATP	Airline Transport Pilot
AVS	Aviation Safety Organization
BASOO	Boeing Aviation Safety Oversight Office

BCA	Boeing Commercial Airplanes
CARB	Corrective Action Review Board
CAS	Commercial Aviation Services
CBT	Computer Based Training
CEO	Chief Executive Officer
DER	Designated Engineering Representative
DOT	Department of Transportation
DR	Deficiency Report
EASA	European Union Aviation Safety Agency
EBAW	Enhanced Bank Angle Warning
ECS	Environmental Control System
EDFCS	Enhanced Digital Flight Control System
EICAS	Engine Indicating and Crew Alerting System
EU	European Union
FAA	Federal Aviation Administration
FBW	Fly-by-wire
FCC	Flight Control Computer
FCOM	Flight Crew Operations Manual
FSB	Flight Standardization Board
FTD	Fleet Team Digest
GAO	Government Accountability Office
GM	General Manager
IEEE	Institute of Electrical and Electronics Engineers
IPT	Integrated Product Team
ISS	International Space Station
JATR	Joint Authorities Technical Review
LAM	Landing Attitude Modifier
LGW	London Gatwick Airport
MCAS	Maneuvering Characteristics Augmentation System
MOM	Multi Operator Message
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NNC	Non-normal Checklist
NTSB	National Transportation Safety Board
ODA	Organization Designation Authorization
OIG	Office of Inspector General
OMB	Operations Manual Bulletin
PASS	Professional Aviation Safety Specialists
PSSA	Preliminary System Safety Assessment
QFR	Questions for the Record
RCAS	Roll Command Alerting System
R-TARA	Random Transport Airplane Risk Analysis
SCD	Specification Control Drawing
SME	Subject Matter Expert
SSA	System Description and Safety Analysis
STC	Supplemental Type Certificate
STS	Speed Trim System

SWA	Southwest Airlines
TARAM	Transport Airplane Risk Assessment Methodology
TCBI	Tutorial Computer-Based Instruction
TIA	Type Inspection Authorization
VP	Vice President

1. Introduction

-Introduction-

On the evening of March 9, 2019, Paul Njoroge was up late, tracking a flight from Toronto, Canada to Addis Ababa, Ethiopia. It was the first leg of his family's journey to visit relatives in Kenya for what was to be the trip of their lifetimes. After his family arrived safely at their layover in Addis Ababa, Mr. Njoroge went to bed, expecting to check in again the next day.

As he slept, his wife Carolyne, their three children—6-year-old Ryan, 4-year-old Kelli, and 9-month-old Rubi—and his mother-in-law, Ann, continued their journey by boarding Ethiopian Airlines flight 302 from Addis Ababa, Ethiopia, to Nairobi, Kenya. It was a crystal-clear day, but within minutes of take-off the unthinkable happened: the Boeing 737 MAX, a brand new aircraft with 157 passengers and crew members on board, began to dive back towards the ground as the pilots fought to force the plane's nose back up toward the sky. The battle did not last long. Six minutes after take-off, Ethiopian Airlines flight 302 crashed. The jet's impact left a massive crater in a field just a few miles from the airport. Not a single soul survived.

Over one year later, Mr. Njoroge testified before the U.S. House Committee on Transportation and Infrastructure that he is still haunted by the image of his young children's final moments. "I have nightmares about how they must have clung to their mother, crying, seeing the fright in her eyes as they sat there helplessly. And there was nothing I could do to save them," he said. "I miss their laughter, their playfulness, their touch."

Mr. Njoroge would soon learn that his family members were the victims of not the first, but the second Boeing 737 MAX aircraft that was involved in a catastrophic, fatal crash killing everyone on board—an extraordinary fact given the significant advances in aviation safety over the last two decades, and the fact that the 737 MAX was a newly certified aircraft.

The story of the Boeing 737 MAX was never expected to be associated with catastrophe. It was supposed to be a story of American ingenuity and technological success—a modern, more fuel-efficient airplane that had already become the manufacturing giant's best-selling jet in its storied history prior to the first MAX crash of Lion Air flight 610 in Indonesia on October 28, 2018. Ethiopian Airlines flight 302 crashed on March 10, 2019, just two years and two days after the Federal Aviation Administration (FAA) had certified the new 737 derivative aircraft as safe to fly. Clearly it was not.

The Boeing 737 MAX is now the subject of multiple investigations and lawsuits around the world and will be forever associated with the tragic deaths of 346 people killed in two separate crashes within five months of each other, as well as one rescue diver who died attempting to recover bodies from the Lion Air crash in the Java Sea.

-FINAL COMMITTEE REPORT: BOEING 737 MAX-

1. Introduction

This report concludes the U.S. House Committee on Transportation and Infrastructure's 18-month long investigation of the design, development, and certification of the 737 MAX aircraft, and related matters. The Committee's investigation has revealed multiple missed opportunities that could have turned the trajectory of the MAX's design and development toward a safer course due to flawed technical design criteria, faulty assumptions about pilot response times, and production pressures. The FAA also missed its own opportunities to change the direction of the 737 MAX based on its aviation safety mission. Boeing failed in its design and development of the MAX, and the FAA failed in its oversight of Boeing and its certification of the aircraft.

At the direction of Committee Chair Peter DeFazio and Subcommittee on Aviation Chair Rick Larsen, this report is being released to help inform the public's understanding of what went so horrifically wrong and why. Despite the sweeping and substantive problems that have been identified by this Committee's investigation as well as various other investigations, both Boeing and the FAA have suggested that the certification of the 737 MAX was compliant with FAA regulations. 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.

2. Executive Summary

-Executive Summary-

Technical design flaws, faulty assumptions about pilot responses, and management failures by both The Boeing Company (Boeing) and the Federal Aviation Administration (FAA) played instrumental and causative roles in the chain of errors that led to the crashes of Lion Air flight 610 in October 2018,[1] and Ethiopian Airlines flight 302 in March 2019,[2] that resulted in the tragic and preventable deaths of 346 people. Both crashes involved Boeing 737 MAX airplanes.

On March 8, 2017, the FAA granted an amended type certificate to Boeing for the 737-8 aircraft, the first of the 737 MAX family.[3] The MAX is the 4th generation 737 model airplane[4] and is the successor to the company's 737 Next Generation (NG) family of aircraft.[5] The 737 MAX was the 12th derivative model of the 737 aircraft,[6] which was first certified half a century earlier in 1967.[7] In May 2017, the 737 MAX first entered revenue passenger service with Malindo Air, a Malaysian air carrier, two months after its FAA certification.[8] Seventeen months later the 737 MAX suffered its first fatal crash.[9]

On October 29, 2018, Lion Air flight 610 flying from Soekarno–Hatta International Airport in Jakarta, Indonesia, to Depati Amir Airport in Pangkal Pinang, Indonesia, crashed into the Java Sea 13 minutes after takeoff, killing all 189 passengers and crew.[10] One Indonesian rescue diver also died

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[1] Barbara S. Peterson, "How Could a Brand New Boeing Jet Crash Without Warning?," *Popular Mechanics*, October 31, 2018, accessed here: https://www.popularmechanics.com/flight/airlines/a24405573/indonesia-boeing-737-max-jet-crash

[2] Hadra Ahmed, Norimitsu Onishi, Dionne Searcey and Hannah Beech, "Ethiopian Airlines Plane Is the 2nd Boeing Max 8 to Crash in Months," *New York Times*, March 10, 2019, accessed here: https://www.nytimes.com/2019/03/10/world/africa/ethiopian-airlines-plane-crash.html

[3] "Type Certificate Data Sheet A16WE," Federal Aviation Administration, Department of Transportation, March 8, 2017, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/0970d54d00efbb9a862580de006a83cc/$FILE/A16WE_Rev_58.pdf

[4] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report No. AV2020037, June 29, 2020, p. 5, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[5] "Type Certificate Data Sheet A16WE," Federal Aviation Administration, Department of Transportation, March 8, 2017, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/0970d54d00efbb9a862580de006a83cc/$FILE/A16WE_Rev_58.pdf

[6] The 737 MAX was the 12th "derivative" of the original 737-100 aircraft certified in 1967, making it the 13th 737 model produced by Boeing. See: "Type Certificate Data Sheet A16WE," Federal Aviation Administration, Department of Transportation, March 8, 2017, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/0970d54d00efbb9a862580de006a83cc/$FILE/A16WE_Rev_58.pdf

[7] Ibid.

[8] Firdaus Hashim, "Malindo operates world's first 737 Max flight," *FlightGlobal,* May 22, 2017, accessed here: https://www.flightglobal.com/orders-and-deliveries/malindo-operates-worlds-first-737-max-flight/124109.article

[9] James Griffiths, Steve George, Kathy Quiano and Helen Regan, "Lion Air crash: Indonesia to inspect all Boeing 737 Max 8 planes," *CNN*, November 1, 2018, accessed here: https://www.cnn.com/2018/10/30/asia/lion-air-plane-crash-intl/index.html

[10] "Final KNKT.18.10.35.04 Aircraft Accident Investigation Report, PT. Lion Mentari Airlines, Boeing 737-8 (MAX); PKLQP, Tanjung Karawang, West Java, Republic of Indonesia, 29 October 2018," Komite Nasional Keselamatan Transportasi (KNKT), Republic of Indonesia, issued October 25, 2019, pp. 19-27 (hereafter referred to as: "Lion Air

during recovery efforts.[11] Less than five months later, on March 10, 2019, in strikingly similar circumstances, Ethiopian Airlines flight 302 crashed six minutes after takeoff on a flight from Addis Ababa, Ethiopia, to Nairobi, Kenya, killing all 157 passengers and crew, including eight U.S. citizens.[12]

In March 2019, within days of the crash of Ethiopian Airlines flight 302, the House Committee on Transportation and Infrastructure (Committee), under the leadership of Chair Peter A. DeFazio and Subcommittee on Aviation Chair Rick Larsen, launched an investigation into the design, development, and certification of the 737 MAX aircraft and related matters that led to these crashes.[13] Since then, the Committee has held five hearings on issues related to the 737 MAX program;[14] written 23 oversight letters, including 12 records request letters; received an estimated 600,000 pages of records from Boeing, the FAA, airlines, and others; and conducted two dozen official interviews with current Boeing and FAA employees and others. This included transcribed interviews with Michael Teal, former vice president, chief project engineer and deputy program manager of the 737 MAX program;[15] Keith Leverkuhn, former vice president and former general manager of Boeing's 737 MAX program;[16] and Ali Bahrami, the FAA's current Associate Administrator for Aviation Safety. Committee staff have also spoken with a wide range of aviation experts, engineers, software developers, and former FAA and Boeing employees. In addition, the Committee's investigation has been informed by records and information provided by numerous whistleblowers who have contacted the Committee directly with their concerns.

This report was produced by Democratic staff of the Committee and is the culmination of the Committee's investigative efforts assessing the costs, consequences, and lessons from the design, development, and certification of Boeing's 737 MAX aircraft. The report reveals several unmistakable facts. The MAX crashes were not the result of a singular failure, technical mistake, or mismanaged event. They were the horrific culmination of a series of faulty technical assumptions by Boeing's engineers, a lack of transparency on the part of Boeing's management, and grossly insufficient oversight by the FAA—the pernicious result of regulatory capture on the part of the FAA with respect to its responsibilities to perform robust oversight of Boeing and to ensure the safety of the flying public. The facts laid out in this report document a disturbing pattern of

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Flight 610 Final Aircraft Accident Investigation Report"), accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[11] "Lion Air: Indonesian rescue diver dies while searching for victims of jet crash near Jakarta," *ABC Australia*, November 3, 2018, accessed here: https://www.abc.net.au/news/2018-11-03/indonesian-rescue-diver-dies-in-lion-air-jet-crash-search/10463266

[12] "Interim Investigation Report on Accident to the B737-8(MAX) Registered ET-AVJ operated by Ethiopian Airlines on 10 March 2019," Federal Democratic Republic of Ethiopia, Ministry of Transport, Aircraft Accident Investigation Bureau, released March 9, 2020, pp. 11-18 (hereafter referred to as: "Ethiopian Airlines Flight 302 Interim Investigation Report"), accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[13] "As Part of Investigation into Boeing 737 MAX Certification Process, Committee Sends Records Requests to FAA, Boeing," Press Release, Committee on Transportation and Infrastructure, U.S. House of Representatives, April 1, 2019, accessed here: https://transportation.house.gov/news/press-releases/as-part-of-investigation-into-boeing-737-max-certification-process-committee-sends-records-requests-to-faa-boeing

[14] See: "Boeing 737 MAX Investigation," Committee on Transportation and Infrastructure, U.S. House of Representatives, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

[15] In November 2017, Mr. Teal was named to the position of vice president and chief project engineer for the Boeing 777X program.

[16] In July 2018, Mr. Leverkuhn was named to the position of vice president of Supply Chain Propulsion for Boeing Commercial Airplanes. He retired from Boeing this year.

technical miscalculations and troubling management misjudgments made by Boeing. It also illuminates numerous oversight lapses and accountability gaps by the FAA that played a significant role in the 737 MAX crashes.

-The MAX Crashes-

Ethiopian Airlines, which is wholly owned by the government of Ethiopia,[17] has flourished over the last two decades as it has capitalized on a strategy to connect primary and secondary markets across the African continent with North American, European, and Asian destinations via its hub in Addis Ababa.[18] The carrier's pilot training programs and facilities have garnered praise from seasoned American pilots.[19] Before the crash of flight 302, Ethiopian Airlines' last major accident occurred in January 2010 and involved a Boeing 737-800 departing Beirut at night bound for Addis Ababa; it was determined that the flight crew likely experienced spatial disorientation during climb out over the Mediterranean Sea in the darkness, and that the crew failed to manage the flight path of the airplane and lost control, leading to an impact with the sea. All 90 passengers and crew died.[20]

Lion Air is an Indonesian airline which provides fast, inexpensive travel across the massive Indonesian archipelago.[21] Unfortunately, Lion Air has a checkered safety record and has earned a reputation among some observers of hiring inexperienced pilots and working them hard.[22] For example, before the crash of flight 610, Lion Air airplanes had been involved in 10 accidents that led to the death of 25 people since the company's founding in 1999.[23] Moreover, between 2007 and 2016, the European Union (EU) blacklisted the carrier, prohibiting it from operating into EU member states.[24]

In November 2011, Lion Air signed a $22 billion order with Boeing for 230 units of the 737—including 201 737 MAX aircraft—the largest single order in Boeing's history.[25] However, while Lion Air's business model was built around the use of the Boeing 737 and its pilots were used

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[17] "Corporate Overview," Ethiopian Airlines, accessed here: https://corporate.ethiopianairlines.com/AboutEthiopian/Overview

[18] Omar Mohammed and Maggie Fick, "Ethiopian Airlines steps up hunt for African connections," *Reuters*, November 23, 2018, accessed here: https://www.reuters.com/article/us-ethiopia-airlines-africa/ethiopian-airlines-steps-up-hunt-for-african-connections-idUSKCN1NS0X3

[19] Prepared statement of Captain Daniel F. Carey, President, Allied Pilots Association, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/CA%20Carey%20Hearing%20testimony%20.pdf

[20] See: "ASN Accident Database: ET409," Flight Safety Foundation Aviation Safety Network, accessed here: https://aviation-safety.net/database/record.php?id=20100125-0

[21] William Langewiesche, "What Really Brought Down the Boeing 737 MAX?," *The New York Times Magazine*, September 18, 2019, accessed here: https://www.nytimes.com/2019/09/18/magazine/boeing-737-max-crashes.html?action=click&module=Top%20Stories&pgtype=Homepage

[22] Ibid.

[23] "ASN Aviation Safety Database: Lion Air accidents and incidents," Flight Safety Foundation Aviation Safety Network, accessed here: https://aviation-safety.net/database/dblist.php?sorteer=datekey_desc&kind=%&cat=%&page=1&field=Operatorkey&var=5758

[24] "Lion Air," Flight Safety Foundation Aviation Safety Network, accessed here: https://aviation-safety.net/database/operator/airline.php?var=5758

[25] "Boeing, Lion Air Announce Historic Commitment for up to 380 737s," Boeing Press Release, November 17, 2011, accessed here: https://boeing.mediaroom.com/2011-11-17-Boeing-Lion-Air-Announce-Historic-Commitment-for-up-to-380-737s and Kevin Voight, "Lion Who? What record Boeing-Indonesia deal means," *CNN Business*, November 18, 2011, accessed here: https://www.cnn.com/2011/11/18/business/boeing-lion-air-indonesia-analysis/index.html

to flying the airplane, the 737 MAX contained a new feature in its flight control computer—the Maneuvering Characteristics Augmentation System (MCAS)—that has become the center of scrutiny for both MAX crashes.[26] The new system had the ability to trigger non-pilot-commanded flight control movements that could place the airplane into a dangerous nose-down attitude that challenged the pilots' ability to control the aircraft.[27] In addition, the MCAS software operated on input from one of the two angle-of-attack (AOA) sensors[28] externally mounted on the fuselage on either side of the airplane.[29]

The day before the crash of Lion Air flight 610, a mechanic in Denpasar, Indonesia, replaced the AOA sensor on the left side of the accident airplane, prior to its 90-minute flight from Denpasar to Jakarta.[30] The mechanic used a refurbished AOA sensor that had previously been used on a Boeing 737-900ER (NG) aircraft operated by Lion Air's Malaysian sister company, Malindo Air,[31] and rebuilt in late 2017 by Xtra Aerospace in Miramar, Florida.[32]

On the flight to Jakarta, MCAS activated based on an erroneous reading from the newly installed AOA sensor and commanded the airplane's horizontal stabilizer[33] to push the nose down while the pilots struggled against it to stabilize the airplane.[34] In this case, a third "deadheading" pilot who occupied the jump seat inside the flight deck[35] recognized what was occurring and provided

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[26] Chris Brady, "Maneuvering Characteristics Augmentation System (MCAS)," The Boeing 737 Technical Guide, Updated April 18, 2020, accessed here: http://www.b737.org.uk/mcas.htm

[27] Ibid.

[28] Angle of Attack (AOA) sensors are sometimes referred to as AOA vanes. Throughout this report we refer to them as AOA sensors. See: "Angle of Attack (AOA) Systems," UTC Aerospace Systems, accessed here: https://utcaerospacesystems.com/wp-content/uploads/2018/04/Angle-of-Attack-AOA-Systems.pdf and "Angle of Attack Vane," Basic Air Data, accessed here: https://www.basicairdata.eu/knowledge-center/design/angle-of-attack-vane

[29] Ibid.

[30] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," pp. 36, 174, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[31] Ibid., pp. 37-38.

[32] In October 2019, the FAA issued an order revoking Xtra Aerospace, LLC's repair station certificate. According to the FAA, which launched an investigation of the company after the Lion Air crash, it "determined that from November 2009 until May 2019, Xtra failed to complete and retain records in accordance with procedures in its repair station manual to support parts on its capability list. The company also did not substantiate that it had adequate facilities, tools, test equipment, technical publications, and trained and qualified employees to repair parts on its capability list." See: "FAA Revokes Repair Station Certificate of Xtra Aerospace of South Florida," Press Release, Federal Aviation Administration (FAA), October 25, 2019, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24314 and Dominic Gates, "FAA shuts down Florida repair firm that supplied faulty Lion Air sensor on Boeing 737 MAX," *Seattle Times*, October 25, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/faa-shuts-down-revokes-certificate-of-florida-repair-firm-that-supplied-faulty-lion-air-sensor/

[33] The horizontal stabilizer is a movable part at the back of the aircraft that provides stability for the aircraft by pitching the plane up or down, to keep it flying straight. Because of the faulty AOA readings MCAS erroneously tried to push the nose of the aircraft down. See: https://howthingsfly.si.edu/ask-an-explainer/what-horizontal-stabilizer-modern-commercialairplanes#:~:text=What%20is%20a%20horizontal%20stabilizer%20in%20modern%20commercial%20airplanes%3F,-A%3A&text=A%20horizontal%20stabilizer%20is%20a,down%20motion%2C%20of%20the%20aircraft.

[34] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," pp. 174-176, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[35] Throughout this report we use the term "flight deck" instead of "cockpit" in regard to the 737 MAX. According to Aviation Stack Exchange, "A cockpit is a hole with a seat that you strap into for the entire flight. A flight deck is a larger version of a cockpit, where you can at least leave your seat and walk behind it." Access here:

instructions to the two active pilots that enabled them to regain control of the airplane and fly it safely to Jakarta by depressing two "stabilizer trim cutout" switches, thereby removing electrical power from the flight control that MCAS was erroneously activating.[36]

Upon landing in Jakarta, the captain made entries in the airplane's maintenance log about cautions and warnings that appeared during the flight. However, he did not report the flight crew's use of the stabilizer trim cutout switches to address the unexpected horizontal stabilizer movement.[37]

On the following day, October 29, 2018, Lion Air flight 610 departed Jakarta. Again, the AOA sensor provided inaccurate information to the flight control computer which triggered MCAS to move the horizontal stabilizer which pushed the airplane's nose down.[38] This occurred more than 20 times as the pilots fought MCAS while struggling to maintain control of the aircraft.[39] Unfortunately, because the previous flight crew did not document its use of the stabilizer trim cutout switches to address the same condition, the new flight crew did not have an important piece of information that could have helped them to identify and respond to the problem.[40] Amid a cacophony of confusing warnings and alerts on the flight deck, the horizontal stabilizer ultimately forced the airplane into a nose-down attitude from which the pilots were unable to recover.[41]

Nearly five months later, on March 10, 2019, once again a faulty AOA sensor and subsequent triggering of MCAS led to the downing of Ethiopian Airlines flight 302. As opposed to the Lion Air accident airplane on which cautions and warnings on its earlier flights had given some indication of a problem, the 737 MAX operated by Ethiopian Airlines had no known technical troubles.[42] However, after a normal takeoff, the left AOA sensor began producing erroneous readings.[43] Over the approximately six minutes that Ethiopian Airlines flight 302 was airborne following its departure from Addis Ababa, Ethiopia, MCAS triggered four times as a result of the false AOA readings and caused the airplane's horizontal stabilizer to force the airplane into a nose-

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https://aviation.stackexchange.com/questions/66094/cockpit-vs-flight-deck#:~:text=A%20cockpit%20is%20a%20hole,the%20top%20of%20the%20ship

[36] Ibid.

[37] According to the "Lion Air Flight 610 Final Aircraft Accident Investigation Report," p. 176, the captain reported problems experienced during the flight that had been displayed in messages on the Primary Flight Display and overhead flight controls panel. These problems were the IAS DISAGREE (indicated airspeed disagree) and ALT DISAGREE (altitude disagree) warnings and the illumination of the FEEL DIFF PRESS (feel differential pressure) light. The captain did not mention the activation of the stick shaker or the runaway stabilizer and the use of the STAB TRIM CUTOUT guarded switches that disabled MCAS and caused the flight crew to use manual trim for the majority of the flight and the landing.

[38] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," p. xviii, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[39] Ibid., pp. 19-28, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and Sinead Baker, "This timeline shows exactly what happened on board the Lion Air Boeing 737 Max that crashed in less than 13 minutes, killing 189 people," *Business Insider*, October 29, 2019, accessed here: https://www.businessinsider.com/lion-air-crash-timeline-boeing-737-max-disaster-killed-189-2019-10

[40] Ibid.

[41] Ibid.

[42] "Ethiopian Airlines Flight 302 Interim Investigation Report," pp. 130-132, accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[43] Ibid.

down attitude from which the pilots were unable to recover.[44] Faulty AOA data that erroneously triggered MCAS to repeatedly activate played critical roles in both MAX crashes.

There have been some allegations made against both Lion Air and Ethiopian Airlines regarding poor maintenance and even cover-ups. For example, investigators determined that photos provided by the Lion Air mechanic that purported to document the AOA sensor repair on the accident airplane depicted a different airplane and dismissed the photos as invalid evidence.[45] In addition, a whistleblower with knowledge of Ethiopian Airlines' actions in the aftermath of the March 2019 crash alleged that staff of the carrier accessed the airplane's maintenance records the day after the accident.[46] Such action is contrary to protocols that call for records to be immediately sealed following a crash.[47] However, while it is not known how, if at all, the records were altered, the whistleblower contends that this action was part of a pattern of faulty repairs and erroneous records that call into question the reliability of Ethiopian Airlines' maintenance practices.[48]

In addition to maintenance concerns, some negative aspersions have arisen about the abilities of the pilots who commanded the ill-fated Lion Air and Ethiopian Airlines flights. While Lion Air has a reputation for hiring inexperienced pilots and quickly promoting them, the 31-year-old captain of Lion Air flight 610 had accumulated over 5,100 hours of flight time on Boeing 737 airplanes, and the 41-year-old first officer had more than 4,200 hours on Boeing 737 models, indicating that they were seasoned pilots.[49] Further, while the 29-year-old captain of Ethiopian Airlines flight 302 had reportedly not received training on the airline's 737 MAX simulator—even though Ethiopian Airlines was one of the first airlines worldwide to purchase a 737 MAX specific simulator[50]—the young pilot had amassed over 5,500 flying hours on Boeing 737 airplanes, including 103 hours on the 737 MAX.[51] Even the 25-year-old first officer of flight 302—who was the least experienced of the pilots—had accumulated 207 hours flying Boeing 737 airplanes since obtaining his commercial pilot's license in December 2018, just three months before the fatal crash.[52]

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[44] Ibid.

[45] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," p. 185, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[46] Bernard Condon, "Whistleblower complaint alleges corruption in Ethiopian Airlines," *USA Today*, October 7, 2019, accessed here: https://www.usatoday.com/story/news/2019/10/07/ethiopian-airlines-whistleblower-alleges-corruption-after-737-crash/3898991002

[47] Ibid.

[48] Ibid.

[49] William Langewiesche, "What Really Brought Down the Boeing 737 MAX?" *The New York Times Magazine*, September 18, 2019, accessed here: https://www.nytimes.com/2019/09/18/magazine/boeing-737-max-crashes.html?action=click&module=Top%20Stories&pgtype=Homepage and "Lion Air Flight 610 Final Aircraft Accident Investigation Report," pp. 28-30, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[50] Selam Gebrekidan, "Ethiopian Airlines Had a Max 8 Simulator, but Pilot on Doomed Flight Didn't Receive Training On It," *New York Times,* March 20, 2019, accessed here: https://www.nytimes.com/2019/03/20/world/africa/ethiopian-airlines-boeing.html

[51] "Ethiopian Airlines Flight 302 Interim Investigation Report," pp. 18-21, accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[52] Ibid.

Addressing the qualifications of these pilots at a June 2019 Subcommittee on Aviation hearing, Captain Dan Carey, a 35-year career pilot and then president of the Allied Pilots Association, which represents 15,000 American Airlines pilots, said in his written statement:

> To make the claim that these accidents would not happen to U.S.-trained pilots is presumptuous and not supported by fact. Vilifying non-U.S. pilots is disrespectful and not solution-based, nor is it in line with a sorely needed global safety culture that delivers one standard of safety and training. Simply put, Boeing does not produce aircraft for U.S. pilots vs. pilots from the rest of the world.[53]

Retired airline captain Chesley B. "Sully" Sullenberger III, who landed U.S. Airways flight 1549 on the Hudson River in 2009 saving all 155 people on board in what came to be known as the "Miracle on the Hudson," also testified at that hearing. He offered similar sentiments about the qualifications of these pilots as part of his remarks about the two crashes.[54] In his prepared testimony Captain Sullenberger wrote:

> These crashes are demonstrable evidence that our current system of aircraft design and certification has failed us… It is obvious that grave errors were made that have had grave consequences, claiming 346 lives… 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… We owe it to everyone who flies, passengers and crews alike, to do much better than to design aircraft with inherent flaws that we intend pilots will have to compensate for and overcome. Pilots must be able to handle an unexpected emergency and still keep their passengers and crew safe, but we should first design aircraft for them to fly that do not have inadvertent traps set for them.[55]

For two brand-new airplanes, of a brand-new derivative model, to crash within five months of each other was extraordinary given significant advances in aviation safety over the last two decades.[56] While certain facts and circumstances surrounding the accidents differed, a common

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[53] Prepared statement of Captain Daniel F. Carey, President, Allied Pilots Association, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/CA%20Carey%20Hearing%20testimony%20.pdf

[54] Robert D. McFadden, "Pilot Is Hailed After Jetliner's Icy Plunge," *New York Times*, January 15, 2009, accessed here: https://www.nytimes.com/2009/01/16/nyregion/16crash.html and Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/status-of-the-boeing-737-max-stakeholder-perspectives

[55] Prepared statement of Chesley B. "Sully" Sullenberger III, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/Sully%20Sullenberger%20Testimony.pdf

[56] See: "Fact Sheet – Out Front on Airline Safety: Two Decades of Continuous Evolution," Federal Aviation Administration, August 2, 2018, accessed here: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22975; "Safety Record of U.S. Air Carriers," Airlines for America, accessed here: https://www.airlines.org/dataset/safety-

component in both of the accident airplanes was the new flight control feature: MCAS. Boeing developed MCAS to address stability issues in certain flight conditions induced by the plane's new, larger engines, and their relative placement on the 737 MAX aircraft compared to the engines' placement on the 737 NG.[57] On March 13, 2019, the FAA grounded the 737 MAX three days after the Ethiopian Airlines crash, following similar actions taken by China, the EU, and Canada, among others.[58] Despite optimistic predictions at the time—that a simple software fix for MCAS would allow the 737 MAX to return quickly to service[59] —the aircraft has been grounded for 18 months, with even more, newly discovered safety issues emerging since.[60] *(See "New Issues Emerge" below).*

This report identifies the key technical flaws and management failures the Committee has discovered at both Boeing and the FAA during its investigation of the design, development, and certification of the 737 MAX, and related issues. We anticipate that the factual evidence our investigation has uncovered and the findings we present in this report will help the Members of the Committee as they consider legislative actions to (1) rectify the problems our investigation has revealed, (2) create a more robust FAA oversight structure and improved certification process, and (3) enhance the safety of the flying public.

-Investigative Themes-

The Committee's investigative findings identify five central themes that affected the design, development, and certification of the 737 MAX and FAA's oversight of Boeing. Acts, omissions, and errors occurred across multiple stages and areas of the development and certification process of the 737 MAX. These themes are present throughout this report. They include:

1) Production Pressures. There was tremendous financial pressure on Boeing and the 737 MAX program to compete with Airbus' new A320neo aircraft.[61] Among other things, this pressure resulted in extensive efforts to cut costs, maintain the 737 MAX program schedule, and avoid

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record-of-u-s-air-carriers; and "Air Traffic By the Numbers," (Commercial Flight and Available Seat Mile (ASM) Trends), Federal Aviation Administration, June 2019, accessed here: https://www.faa.gov/air_traffic/by_the_numbers/media/Air_Traffic_by_the_Numbers_2019.pdf

[57] Ralph Vertabedian, "How a 50-year-old design came back to haunt Boeing with its troubled 737 MAX jet," *Los Angeles Times,* March 15, 2019, accessed here: https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html

[58] "Emergency Order of Prohibition: Operators of Boeing Company Model 737-8 and Boeing Company Model 737-9 Airplanes," Federal Aviation Administration, Department of Transportation, March 13, 2019, accessed here: https://www.faa.gov/news/updates/media/Emergency_Order.pdf and Luz Lazo, Michael Laris, Lori Arantani and Damian Paletta, "FAA's emergency order grounding Boeing jets came after the agency identified similarities between crashes in Ethiopia, Indonesia," *Washington Post*, March 13, 2019, accessed here: https://www.washingtonpost.com/local/trafficandcommuting/canada-grounds-boeing-737-max-8-leaving-us-as-last-major-user-of-plane/2019/03/13/25ac2414-459d-11e9-90f0-0ccfeec87a61_story.html

[59] See: Dawn Gilbertson, "Boeing 737 MAX: How will airlines convince skittish passengers it's safe to fly again," *USA Today*, April 7, 2019, accessed here: https://www.usatoday.com/story/travel/flights/2019/04/06/boeing-737-max-8-passengers-return-airlines-safety-crashes-fix-airplanes/3376865002/ and Sam Roecker, "Boeing 737 MAX MCAS Update Ready For Certification," *Simple Flying,* April 18, 2019, accessed here: https://simpleflying.com/boeing-737-max-update-complete

[60] Natalie Kitroeff and David Gelles, "It's Not Just Software: New Safety Risks Under Scrutiny on Boeing's 737 Max," *New York Times*, January 29, 2020, accessed here: https://www.nytimes.com/2020/01/05/business/boeing-737-max.html

[61] David Gelles, Natalie Kitroeff, Jack Nicas, and Rebecca R. Ruiz, "Boeing Was 'Go, Go, Go' to Beat Airbus With the 737 MAX," *New York Times*, March 29, 2019, accessed here: https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html

slowing the 737 MAX production line. The Committee's investigation has identified several instances where the desire to meet these goals and expectations jeopardized the safety of the flying public.

2) Faulty Design and Performance Assumptions. Boeing made fundamentally faulty assumptions about critical technologies on the 737 MAX, most notably with MCAS. Based on these faulty assumptions, Boeing permitted MCAS—software designed to automatically push the airplane's nose down in certain conditions—to activate on input from a single angle of attack (AOA) sensor. It also expected that pilots, who were largely unaware that the system existed, would be able to mitigate any potential malfunction. Boeing also failed to classify MCAS as a safety-critical system, which would have attracted greater FAA scrutiny during the certification process. The operation of MCAS also violated Boeing's own internal design guidelines related to the 737 MAX's development which stated that the system should "not have any objectionable interaction with the piloting of the airplane" and "not interfere with dive recovery."[62]

3) Culture of Concealment. In several critical instances, Boeing withheld crucial information from the FAA, its customers, and 737 MAX pilots. This included concealing the very existence of MCAS from 737 MAX pilots[63] and failing to disclose that the AOA Disagree alert was inoperable on the vast majority of the 737 MAX fleet,[64] despite having been certified as a standard aircraft feature.[65] The AOA Disagree alert is intended to notify the crew if the aircraft's two AOA sensor readings disagree, an event that can occur if one sensor is malfunctioning or providing faulty AOA data. Boeing not only concealed this information from both the FAA and pilots, but also continued to deliver MAX aircraft to its customers knowing that the AOA Disagree alert was inoperable on most of these aircraft. Further, Boeing concealed internal test data it had that revealed it took a Boeing test pilot more than 10 seconds to diagnose and respond to uncommanded MCAS activation[66] in a flight simulator, a condition the pilot found to be "catastrophic[.]"[67] While it was not required to share this information with the FAA or Boeing customers, it is inconceivable and inexcusable that

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[62] Boeing Coordination Sheet, Revision G, June 11, 2018, TBC-T&I 30584 – 30592 at TBC-T&I 30588, at p. 170, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[63] Benjamin Shang, "Boeing's CEO explains why the company didn't tell 737 Max pilots about the software system that contributed to 2 fatal crashes," *Business Insider*, April 29, 2019, accessed here: https://www.businessinsider.com/boeings-ceo-on-why-737-max-pilots-not-told-of-mcas-2019-4

[64] Alan Levin, "Boeing Failure to Fix 737 Max Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty

[65] See: Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, July 11, 2019, (On file with the Committee), and Julie Johnsson, Ryan Beene and Mary Schlangenstein, "Boeing Held Off for Months on Disclosing Faulty Alert on 737 Max," *Bloomberg*, May 5, 2019, accessed here: https://www.bloomberg.com/news/articles/2019-05-05/boeing-left-airlines-faa-in-dark-on-737-alert-linked-to-crash

[66] The Maneuvering Characteristics Augmentation System (MCAS) was designed to activate automatically without any pilot command. To the extent this report uses the term "uncommanded" in connection with MCAS activation, it is for consistency with Boeing's own Functional Hazard Assessments which measured "Uncommanded MCAS function operation to pilot reaction[,]" and determined that a pilot reaction time of greater than 10 seconds could be "catastrophic[.]"

[67] "Coordination Sheet, Subject: 737 MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, BATES Number TBC-T&I 29160 – 29166 at p. 164, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

Boeing withheld this information from them. It also argues strongly for a disclosure requirement. Federal guidelines assume pilots will respond to this condition within four seconds.[68]

4) Conflicted Representation. The Committee found that the FAA's current oversight structure with respect to Boeing creates inherent conflicts of interest that have jeopardized the safety of the flying public. The Committee's investigation documented several instances where Boeing Authorized Representatives (ARs)—Boeing employees who are granted special permission to represent the interests of the FAA and to act on the agency's behalf in validating aircraft systems and designs' compliance with FAA requirements—failed to disclose important information to the FAA that could have enhanced the safety of the 737 MAX aircraft.[69] In some instances, a Boeing AR raised concerns internally in 2016 but did not relay these issues to the FAA, and the concerns failed to result in adequate design changes. Some of the issues that were raised by the AR and not thoroughly investigated or dismissed by his Boeing employees, such as concerns about repetitive MCAS activation and the impact of faulty AOA data on MCAS, were the core contributing factors that led to the Lion Air and Ethiopian Airlines crashes more than two years later.

5) Boeing's Influence Over the FAA's Oversight Structure. Multiple career FAA officials have documented examples where FAA management overruled a determination of the FAA's own technical experts at the behest of Boeing. In these cases, FAA technical and safety experts determined that certain Boeing design approaches on its transport category aircraft were potentially unsafe and failed to comply with FAA regulations, only to have FAA management overrule them and side with Boeing instead.[70] These incidents have had a detrimental impact on the morale of FAA's technical and subject matter experts that compromises the integrity and independence of the FAA's oversight abilities and the safety of airline passengers. A recent draft internal FAA "safety culture survey" of employees in the agency's Aviation Safety Organization (AVS) drew similar conclusions. "Many believe that AVS senior leaders are overly concerned with achieving the business-oriented outcomes of industry stakeholders and are not held accountable for safety-related decisions," the survey observed.[71]

These five recurring themes point to a troubling pattern of problems that affected Boeing's development and production of the 737 MAX and the FAA's ability to provide appropriate

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[68] JATR Report p.14, accessed here: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf and FAA Advisory Circular 25.1329-1C, October 27, 2014, p. 78, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1329-1C.pdf

[69] For example, a June 7, 2013, email described an internal Boeing meeting that showed an AR concurred with Boeing's plan to describe MCAS as part of the speed trim function to avoid greater FAA certification requirements and pilot training impacts. See: Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, at p. 93, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[70] "Amid Committee's Ongoing Investigation into the Certification of the 737 MAX, Chairs DeFazio and Larsen Raise New and Serious Concerns to FAA About Other Safety-related Issues," Press Release, Committee on Transportation and Infrastructure, U.S. House of Representatives, November 7, 2019, (hereafter referenced as T&I Committee Press Release, November 7, 2019) accessed here: https://transportation.house.gov/news/press-releases/amid-committees-ongoing-investigation-into-the-certification-of-the-737-max-chairs-defazio-and-larsen-raise-new-and-serious-concerns-to-faa-about-other-safety-related-issues-

[71] "Safety Culture Assessment Report," Federal Aviation Administration, Aviation Safety Organization (AVS), conducted and prepared by The MITRE Corporation, (DRAFT) February 28, 2020, (Hereafter referred to as "FAA Safety Culture Survey"). (On file with the Committee).

oversight of Boeing and the agency's certification process. These issues must be addressed by both Boeing and the FAA in order to correct poor certification practices that have emerged, reassess key assumptions that affect safety, and enhance transparency to enable more effective oversight.

-Investigative Findings-

Listed below are the Committee's investigative findings grouped into six distinct categories: 1) FAA oversight, 2) Boeing production pressures, 3) Maneuvering Characteristics Augmentation System (MCAS), 4) AOA Disagree alert, 5) 737 MAX pilot training, and 6) Post-accident responses by Boeing and the FAA.

FAA Oversight –*The FAA failed to ensure the safety of the traveling public.*

- The FAA's recent draft "safety culture survey" has made it clear that the agency is struggling to effectively fulfill its core regulatory and oversight mission to enhance aviation safety. According to the survey results, 49 percent of the FAA employees responding said they believe "safety concerns/incidents" will not be addressed, 43 percent believe the FAA delegates too many certification activities to industry and 34 percent said "fear of retribution" is one reason employees don't report safety issues.[72] These results correspond with many of the Committee's own investigative findings.

- Excessive FAA delegation to Boeing has eroded FAA's oversight capabilities.

- Boeing's Authorized Representatives (ARs) may be impaired from acting independently.

- A 2016 Boeing internal survey of its ARs, who are supposed to represent the interests of the FAA, conducted at the height of the 737 MAX's certification activities, and provided to the Committee from a whistleblower, found that 39 percent of Boeing ARs that responded perceived "undue pressure" and 29 percent were concerned about consequences if they reported potential "undue pressure."[73]

- The Committee has documented four instances in Boeing's 737 MAX program where Boeing ARs failed to represent the interests of the FAA in carrying out their FAA-delegated functions. In one instance, in 2013, an AR concurred on a decision **not** to emphasize MCAS as a "new function" because of Boeing's fears that doing so would increase "costs"[74] and lead to "a greater certification and training impact" on the 737 MAX program.[75] The Committee has no evidence that the AR shared this information with the FAA. In addition, the Committee found no evidence that any of the four Boeing ARs who knew that Boeing

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[72] Ibid.
[73] "Undue Pressure: Key Learnings and Next Steps," Boeing Commercial Airplanes, November 2016, at p. 145, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[74] Boeing "ITRACS" report, "Title: MCAS/Speed Trim," 37MAXFCI-PDR_AI22, Item entered: May 21, 2013, Item closed: June 27, 2013, BATES Number TBC-T&I 549172 – 548173. (On file with the Committee).
[75] Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," Sent: June 7, 2013, at p. 93, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf (The issues surrounding this June 2013 meeting regarding MCAS, and Boeing's position on it, are discussed at length in the *MCAS section* of this report).

had evidence demonstrating that in 2012 it took a Boeing test pilot more than 10 seconds to respond to uncommanded MCAS activation in a flight simulator, a condition the pilot found to be "catastrophic[,]" informed the FAA of this critical information. In 2016, a Boeing AR also raised concerns regarding the ability of MAX pilots to respond to repetitive MCAS activation and the impact of faulty AOA data on MCAS. Those concerns were not properly addressed, and the AR did not inform the FAA of the concerns. The Committee also discovered that one AR who was aware that Boeing knowingly delivered aircraft with inoperable AOA Disagree alerts to its customers in 2017 and 2018 took no action to inform the FAA.

- Not all of these instances violated FAA regulations or guidance. However, every one of them indicates that Boeing ARs are not communicating fundamentally important information about safety, certification or conformity-related issues to the FAA that could drastically enhance the agency's oversight functions and greatly improve its understanding of potential safety issues on aircraft it is obligated to certify as safe.

- FAA management has undercut the authority and judgment of its own technical experts and sided with Boeing on design issues that failed to adequately address safety issues and appear to have violated FAA regulations or guidance, in some instances. These issues go beyond the 737 MAX program. The Committee is aware of at least one example where FAA technical experts were overruled by FAA management regarding a lightning protection safety feature on another Boeing aircraft, the 787 Dreamliner.[76]

- The FAA's oversight was hampered by poor, disjointed FAA communication among the agency's own internal offices responsible for certifying new critical 737 MAX systems, such as MCAS. This lack of information impeded the ability of FAA employees to make fully informed decisions about the MAX. From FAA leadership down, ineffective communication and lack of coordination on key certification and safety issues jeopardized the safety of the flying public.

- The FAA failed to fully exercise its oversight authority and this failure adversely affected safety. The agency did not ask enough questions or sufficiently scrutinize Boeing responses regarding critical certification-related issues involving pilot training and technical design.

- The FAA has, for instance, as of the publishing of this report, failed in its duty to hold Boeing accountable for delivering airplanes with non-functioning AOA Disagree alerts that Boeing knew were inoperable.[77] According to then-Acting FAA Administrator Dan Elwell, Boeing was required to deliver airplanes with functioning AOA Disagree alerts because they were part of the 737 MAX's approved type design.[78]

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[76] T&I Committee Press Release, November 7, 2019, accessed here: https://transportation.house.gov/news/press-releases/amid-committees-ongoing-investigation-into-the-certification-of-the-737-max-chairs-defazio-and-larsen-raise-new-and-serious-concerns-to-faa-about-other-safety-related-issues-

[77] Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, July 11, 2019, (On file with the Committee).

[78] Ibid.

- Boeing received an FAA exception to allow the company to **not** install on the 737 MAX an Engine Indicating and Crew Alerting System (EICAS)—a system common in newly type certificated aircraft since 1982 that displays for pilots aircraft system faults and failures and helps pilots prioritize their response to multiple or simultaneous indications, warnings, and alerts. The FAA accepted Boeing's argument about the impracticality and the economic expense of installing EICAS on the 737 MAX.[79] The 737 family, including the 737 MAX, is the only Boeing commercial aircraft line that does not have an EICAS installed, which may have helped to alleviate pilot confusion in both the Lion Air and Ethiopian Airlines accidents.[80]

Boeing Production Pressure – *Costs, schedule, and production pressures at Boeing undermined safety of the 737 MAX.*

- Schedule pressure was visible to all Boeing employees working on the 737 MAX program.

- To emphasize the significance of the 737 MAX program's schedule to Boeing employees, the Committee learned that senior program officials kept a "countdown clock" in their conference room. Keith Leverkuhn, the former Vice President and General Manager of the MAX program, described the clock as an "excitement generator" for Boeing's staff. But he also acknowledged it was to remind staff about the MAX's schedule. "One of the mantras that we had was the value of a day," he said, "and making sure that we were being prudent with our time, that we were being thorough, but yet, that there was a schedule that needed to be met…."[81] He said the countdown clock was used to mark two major milestones: power on, when the MAX was powered up for the first time in the factory, and first flight.[82]

- In 2012, in order to lower costs of the 737 MAX program, Boeing reduced the work hours involved in avionics regression testing on the 737 MAX by 2,000 hours. It also examined other reductions to save costs, including a reduction to flight test support by 3,000 hours and a reduction to the engineering flight deck simulator (E-CAB) by 8,000 hours.[83]

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[79] See: "Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board (NTSB), September 19, 2019, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf; Boeing slide presentation to FAA, "BCA Airplane Programs Organization Designation Authorization (ODA) Technical Review Board 737 MAX Impractical Exception Proposal – Flight Crew Alerting, 25.1322(b)(2), (b)(3), (c)(2), (d)(1), and (d)(2)," June 7, 2013, FAA-DEFAZIO-000032891 (On file with the Committee); and Dominic Gates, Steve Miletich, & Lewis Kamb, "Boeing pushed FAA to relax 737 MAX certification requirements for crew alerts," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-pushed-faa-to-arelax-737-max-certification-requirements-for-crew-alerts

[80] Dominic Gates, Steve Miletich, & Lewis Kamb, "Boeing pushed FAA to relax 737 MAX certification requirements for crew alerts," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-pushed-faa-to-arelax-737-max-certification-requirements-for-crew-alerts

[81] Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

[82] Ibid.

[83] Boeing internal power-point presentation, "FCOI Model Leads Meeting – 737 MAX," July 12, 2012, TBC-T&I 011072 - 011073 (On file with the Committee).

- In 2013, a Boeing engineer raised the issue of installing on the 737 MAX a synthetic airspeed indicator—a computer-based indicator of speed that can be compared to actual airspeed measures—as had been done on the 787 Dreamliner. However, this request was rejected by Boeing management due to cost concerns and because adding synthetic airspeed could have jeopardized the 737 MAX program's directive to avoid pilot simulator training requirements.[84]

- The Committee has learned that to thank him for keeping to the MAX's production schedule, Boeing gave Michael Teal, the former Chief Project Engineer on the 737 MAX program, restricted stock options after the airplane's first flight in 2016 to show its appreciation for his work.[85]

- In June 2018, Ed Pierson, a senior Boeing plant supervisor at the company's Renton, Washington 737 MAX production factory, emailed Scott Campbell, the 737 General Manager, requesting a meeting about "safety concerns."[86] Mr. Pierson described multiple concerns about production and schedule pressures that were impacting quality control and safety issues. "As a retired Naval Officer and former Squadron Commanding Officer," wrote Pierson, "I know how dangerous even the smallest of defects can be to the safety of an airplane. Frankly right now all my internal warning bells are going off. And for the first time in my life, I'm sorry to say that I'm hesitant about putting my family on a Boeing airplane."[87]

- In July 2018, five weeks after Mr. Pierson's email, he finally met with Mr. Campbell in Mr. Campbell's office. According to Mr. Pierson's testimony to the Committee, he told Mr. Campbell that in the military they would temporarily halt production if they had the kinds of safety problems that Mr. Pierson was seeing on the MAX factory floor. Mr. Campbell allegedly responded: "The military is not a profit-making organization."[88] Rather than heeding Mr. Pierson's dire warnings and thoroughly evaluating his safety concerns, Boeing continued to ramp up production on the 737 MAX[89] and rehired retired Boeing employees

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[84] See: Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, at p. 1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf, Natalie Kitroeff, David Gelles and Jack Nicas, "Boeing 737 Max Safety System Was Vetoed, Engineer Says," *New York Times*, October 2, 2019, (Updated 29, 2019), accessed here: https://www.nytimes.com/2019/10/02/business/boeing-737-max-crashes.html and Dominic Gates, Steve Miletich and Lewis Kamb, "Boeing rejected 737 MAX safety upgrades before fatal crashes, whistleblower says," *Seattle Times*, October 2, 2019 (Updated October 3, 2019), accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblowers-complaint-says-737-max-safety-upgrades-were-rejected-over-cost

[85] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

[86] Email from Ed Pierson to Scott A. Campbell, "Subject: Recovery Operations & Safety Concerns," Saturday, June 9, 2018 1:32 PM.

[87] Ibid.

[88] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, 116th Congress, First Session, U.S. House of Representatives, December 11, 2019, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[89] The Boeing Company, Q2 2018 Earnings Call, July 25, 2018, p. 6, accessed here: https://s2.q4cdn.com/661678649/files/doc_financials/quarterly/2018/q2/2Q18-Earnings-Call-Transcript-Final.pdf

to keep the production lines moving at the Renton plant.[90] Lion Air flight 610 crashed three months later in October 2018.

Maneuvering Characteristics Augmentation System (MCAS) – *Boeing failed to appropriately classify MCAS as a safety-critical system, concealed critical information about MCAS from pilots, and sought to diminish focus on MCAS as a "new function" in order to avoid increased costs, and "greater certification and training impact."*

- Both Boeing and the FAA failed to appropriately designate MCAS a safety-critical system. In May 2019, then-Acting FAA Administrator Dan Elwell acknowledged this point at a hearing before the Committee.[91]

- In 2012, Boeing developed initial concepts for an MCAS annunciator to inform pilots when MCAS failed to activate, but never implemented it.[92] Instead, Boeing designed the "speed trim fail" alert to incorporate the MCAS failure functionality.[93] Human factors experts have argued that an MCAS-specific display that went beyond just indicating MCAS's "failure" could have helped to negate pilot confusion in the MAX accidents.[94]

- In June 2013, Boeing employees formulated a plan to help avoid increased "cost,"[95] and "greater certification and training impact" for the 737 MAX by describing MCAS as "an addition to [the existing] Speed Trim [system]."[96] The Boeing meeting minutes warned: "If we emphasize MCAS is a new function there may be a greater certification and training

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[90] "Boeing 737 MAX: Retired former employees come back to help with production," *Traveller,* September 12, 2018, accessed here: https://www.traveller.com.au/boeing-737-max-retired-former-employees-come-back-to-help-with-production-h157in

[91] Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, pp. 28-29, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf

[92] "Preliminary Design Decision Memo," High Speed Pitch-Up, Revision A, November 8, 2012, BATES Number TBC-T&I 010920, TBC-T&I 010926, accessed at p. 119 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[93] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 20, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[94] Dr. Mica Endsley, a Committee Chair at the Human Factors and Ergonomics Society and a former Chief Scientist of the U.S. Air Force testified before the Transportation and Infrastructure Committee in December 2019. She pointed out: "It is critical that the automation mode and status be clearly and saliently displayed. In this case a display showing that the MCAS was on and each time it engaged, as well as its effect on aircraft trim, would have provided key input to the pilots as to what the system was doing. If the MCAS is overridden by the pilot and turned off, this should be displayed as well to provide clear feedback to the pilots on its state." See: Dr. Mica R. Endsley, Prepared Testimony, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/the-boeing-737-max-examining-the-federal-aviation-administrations-oversight-of-the-aircrafts-certification

[95] Boeing ITRACS Item, "MCAS/Speed Trim," 37MAXFCI-PDR AI22, BATES Number TBC T&I 549172-549173. (On file with the Committee).

[96] Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, at p. 93, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

impact."[97] According to the email that summarized the meeting minutes, a Boeing AR concurred with this plan.[98]

- In 2015, a Boeing AR raised the question of whether MCAS was "vulnerable to single AOA sensor failures…."[99] Despite this, the aircraft was delivered with MCAS dependent on a single AOA sensor. Boeing's decision to allow MCAS to operate off of a single AOA sensor has been roundly criticized by a wide range of aviation safety experts.[100]

- In March 2016, the General Manager of Boeing's 737 MAX program, Keith Leverkuhn, and Michael Teal, 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.[101]

- 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 Flight Crew Operations Manual (FCOM)[102]—a document that provides procedures, performance, and systems information to flight crews to enable their safe and efficient operation of the airplane.[103] As a result, 737 MAX pilots were precluded from knowing of the existence of MCAS and its potential effect on aircraft handling without pilot command. Meanwhile, the FAA officials who authorized this request remained unaware of the redesign of MCAS until **after** the crash of the Lion Air flight. Although Boeing's approval of the redesign of MCAS and its efforts to remove references to MCAS from pilot training material occurred nearly simultaneously it is unclear if these actions were coordinated.

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[97] Ibid.

[98] Ibid. (The issue regarding this June 2013 meeting, and Boeing's response to it, are discussed at length in the *MCAS section* of this report.)

[99] See Boeing internal email, AOA Sensor email string – TBC-T&I 10584-10585, December 17, 2015, p. 121, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[100] See: Peter Cohan, "MIT Expert Highlights 'Divergent Condition' Caused By 737 MAX Engine Placement," *Forbes*, April 2, 2019, accessed here: https://www.forbes.com/sites/petercohan/2019/04/02/mit-expert-highlights-divergent-condition-caused-by-737-max-engine-placement/#7c4f24d040aa; Jack Nicas, Natalie Kitroeff, David Gelles, & James Glanz, "Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change," *New York Times*, June 1, 2019, accessed here: https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html?searchResultPosition=1; and Gregory Travis, "How the Boeing 737 Max Disaster Looks to a Software Developer," *IEEE Spectrum*, April 18, 2019, accessed here: https://spectrum.ieee.org/aerospace/aviation/how-the-boeing-737-max-disaster-looks-to-a-software-developer

[101] See: Boeing presentation, "737 MAX: SMYD (EFS) & FCC (MCAS) FT Validation, Basic Stall Characteristics," Compilation of previous presentations S&C, April 7, 2016, BATES Number TBC T&I 257428-257439, at TBC T&I 257430 (On file with Committee); Boeing presentation, "737 MAX / Stall Characteristics – Mitigation," Aero S&C, March 30, 2016, BATES Number TBC T&I 046618-046682 (On file with the Committee); and Boeing internal email, "Subject: FW: 737MAX Stall Chars Meeting Summary 3-30-16," Sent: March 30, 2016, 12:46:55 PM, BATES Number TBC T&I 257421-257422 (On file with the Committee). See also, Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020 and Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.

[102] Email from Mark Forkner to FAA, "Subject: MCAS lives in both FCCs," Sent: March 30, 2016 11:16:45 (On file with the Committee).

[103] "Development of Aircraft Operating Manuals," SKYbrary, accessed here: https://www.skybrary.aero/index.php/Development_of_Aircraft_Operating_Manuals

- After Boeing redesigned MCAS in 2016 to increase its authority to move the aircraft's stabilizer at lower speeds, Boeing failed to reevaluate the system or perform single- or multiple-failure analyses of MCAS.[104]

- In June 2016, a Boeing AR raised concerns following a test flight of the 737 MAX during which MCAS countered the pilot's attempts to trim the airplane, including concerns related to the vulnerability caused by faulty AOA readings.[105] These concerns were discounted by the AR's Boeing colleagues, particularly Boeing's test pilots.[106] However, faulty AOA data that resulted in uncommanded MCAS activation was a significant contributing factor in the crashes of both the Lion Air and Ethiopian Airlines flights.[107]

- Following the same test flight, another Boeing engineer asked if repetitive MCAS activation was a safety issue.[108] A colleague responded: "I don't think this is safety, other then (sic) the pilot could fight the MCAS input and over time find themselves in a large mistrim."[109] In both the Lion Air and Ethiopian Airlines flights, the pilots struggled to overcome MCAS, partly because of MCAS's repetitive activations that forced the airplanes into a nose-down configuration from which the pilots were unable to recover.[110]

- In a transcribed interview with Committee staff, Michael Teal, the former Chief Project Engineer on the 737 MAX program, acknowledged that when he approved the MCAS redesign in March 2016 he was unaware: 1) that MCAS operated from a single AOA sensor, 2) that MCAS could activate repeatedly, or 3) that Boeing had internal test data showing that one of its own test pilots took more than 10 seconds to react to uncommanded MCAS activation in a flight simulator, and described the results as "catastrophic."[111]

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[104] See Boeing presentation to FAA, "MCAS Development and Certification Overview," December 17, 2018, (updated and transmitted to FAA on March 1, 2019), TBC-T&I130073, TBC-T&I130111, pp. 178 - 201 at p. 198, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[105] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 10:23 AM, BATES Number TBC-T&I 246488 – TBC-T&I 246493 at TBC-T&I 246490 and Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC-T&I 246488 – TBC-T&I 246493 at TBC-T&I 246489.

[106] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 1:43 PM, BATES Number TBC-T&I 246488 – 246493 at TBC-T&I 246489 and Boeing internal email, "Subject: RE: Discussion of MCAS Characteristics," Sent: June 22, 2016, 1:59 PM, BATES Number TBC-T&I 292457 – 292458. (On file with the Committee).

[107] See: "Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and "Ethiopian Airlines Flight 302 Interim Investigation Report," accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[108] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," Sent: Thursday, June 16, 2016, 2:49 PM, BATES Number TBC-T&I 220826 (On file with the Committee).

[109] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," Sent: June 20, 2016, 6:38:08 AM, BATES Number TBC-T&I 220826 (On file with the Committee).

[110] See: "Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and "Ethiopian Airlines Flight 302 Interim Investigation Report," accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[111] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.

- Mr. Teal defended his lack of awareness of these key attributes on a system he approved saying he relied on the advice of the engineers on the MAX program. Although Mr. Teal was the program's Chief Project Engineer responsible for signing off and approving of key design decisions on the MAX, he did not actually supervise any engineers. "[Y]ou could say that none of them worked for me but all of them worked for me," he said.[112] This reporting structure contributed to an overall lack of accountability on the MAX program.

- The operating parameters of the MCAS system eventually placed on the 737 MAX aircraft violated Boeing's own internal design requirements which demanded that MCAS "not have any objectionable interaction with the piloting of the airplane" and "not interfere with dive recovery," which occurred in both 737 MAX crashes.[113]

AOA Disagree Alert – ***Boeing concealed information from the FAA, its customers, and pilots that the AOA Disagree alerts were inoperable on most of the 737 MAX fleet, despite their operation being "mandatory" on all 737 MAX aircraft. To date, FAA has failed to hold Boeing accountable for these actions.***

- Boeing has publicly blamed its software supplier for an issue that tied the AOA Disagree alert, which was supposed to be standard on all 737 MAX aircraft, to an optional AOA Indicator display,[114] the result of which was to render the AOA Disagree alert inoperable on more than 80 percent of the MAX aircraft. However, the Committee has learned that in July 2015, Boeing tested this software and failed to detect the problem.[115]

- In August 2017, five months after the 737 MAX was certified by the FAA and three months after it entered revenue service, Boeing issued a problem report to its supplier complaining that the 737 MAX's AOA Disagree alert was tied to the optional AOA Indicator and therefore was not functioning on the vast majority of the 737 MAX fleet worldwide.[116] Yet Boeing had previously approved of the version of the software that tied the AOA Disagree alert to the optional AOA Indicator display in July 2015.[117]

- Rather than immediately informing the FAA and Boeing customers about this issue when it was discovered in August 2017, and advising Boeing to fix the problem via a software update as soon as possible, a Boeing AR consented to Boeing's plan to postpone the software

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[112] Ibid.
[113] Boeing Coordination Sheet, Revision G, June 11, 2018, TBC-T&I 30584 – 30592 at TBC-T&I 30588, at p. 170, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf.
[114] "Boeing Statement on AOA Disagree Alert," Press Release, The Boeing Company, May 5, 2019, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130431
[115] "AOA DISAGREE Displayed with AOA Fail Flag," Problem Report (PR) 195, PR opened: May 14, 2015, PR closed: July 29, 2015, BATES Number TBC T&I TBC 267345-267346. (On file with the Committee). (Hereafter referred to as "AOA Disagree Alert Problem Report #195").
[116] See: Boeing AOA Disagree Alert Narrative. TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267830 (On file with the Committee). and Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty
[117] Letter to Chair DeFazio and Subcommittee on Aviation Chair Larsen from attorney for Rockwell Collins, June 20, 2019, p. 9. (On file with the Committee).

update until 2020, three years later, so it could be done in conjunction with the rollout of Boeing's planned 737 MAX-10 aircraft.[118]

- Although Boeing prepared a "Fleet Team Digest" to inform its customers about the inoperable AOA Disagree alert, Boeing never sent it, keeping Boeing's customers in the dark about the inoperable alert until **after** the Lion Air crash.[119]

- Boeing's software supplier, Collins Aerospace, also falsely believed that Boeing had communicated the AOA Disagree alert issue to its 737 MAX customers.[120]

- Boeing provided Lion Air with a Flight Crew Operations Manual (FCOM) for its 737-8 MAX aircraft dated August 16, 2018, one year after learning that the AOA Disagree alert was not functioning on most 737 MAX aircraft, including those operated by Lion Air. The FCOM explained how the AOA Disagree alert was intended to work and provided absolutely no indication that Boeing was fully aware that the AOA Disagree alert on the Lion Air 737 MAX aircraft was not operational.[121] As a result, Lion Air pilots who referenced Boeing's FCOM would have falsely believed that the AOA Disagree alert was functioning properly and would reliably warn them of a malfunctioning AOA sensor. Boeing knowingly deceived these pilots and its customer airlines.

- Boeing did not acknowledge that the AOA Disagree alerts on more than 80 percent of the 737 MAX fleet were inoperative until **after** the Lion Air crash in October 2018.[122]

- By the time of the Lion Air crash, Boeing had knowingly delivered approximately 200 MAX aircraft to customers around the world with non-functioning AOA Disagree alerts.[123]

- In July 2019, then-Acting FAA Administrator Dan Elwell informed the Committee that "[a]lthough an AOA Disagree message was not necessary to meet FAA safety regulations, once it was made part of the approved type design, it was required to be installed and functional on all 737 MAX airplanes Boeing produced."[124]

- Although the AOA Disagree alert was not considered a safety critical component, Boeing knowingly delivered 737 MAX aircraft to its customers with inoperable AOA Disagree alerts that did not conform to the airplane's amended type certificate. As far as the Committee understands, the FAA has failed to take any measures whatsoever to hold Boeing

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[118] Boeing AOA Disagree Alert Narrative, TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267830 - TBC-T&I 267831. (On file with the Committee).
[119] Boeing AOA Disagree Alert Narrative, TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267831. (On file with the Committee).
[120] Committee staff interview with Rockwell Collins employee, September 11, 2019.
[121] Lion Air Flight Crew Operations Manual, August 16, 2018, accessed at pp. 175-177 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[122] Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty
[123] "737 MAX: Deliveries Report," The Boeing Company, accessed here: http://www.boeing.com/commercial/#/orders-deliveries
[124] Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, regarding the mandatory installation of functional AOA Disagree alerts on all Boeing 737 MAX aircraft, July 11, 2019. (On file with the Committee).

accountable for knowingly delivering aircraft with non-functioning AOA Disagree alerts to their customer airlines and failing to inform MAX pilots or the FAA that an item that was supposed to be a standard feature in the cockpit was inoperable.

737 MAX Pilot Training – *Boeing's economic incentives led the company to a significant lack of transparency with the FAA, its customers, and 737 MAX pilots regarding pilot training requirements and negatively compromised safety.*

- Boeing had tremendous financial incentive to ensure that no regulatory determination requiring pilot simulator training for the 737 MAX was made. Under a contract signed in December 2011 with Southwest Airlines, the U.S. launch customer for the 737 MAX, Boeing was financially obligated to have discounted the price of each MAX airplane it delivered to Southwest by at least $1 million if the FAA had required simulator training for pilots transitioning from the 737 NG to the 737 MAX.[125]

- Southwest had 200 firm orders for the MAX with the option to purchase an additional 191 MAX aircraft.[126] Thus, if Boeing failed to obtain Level B (non-simulator) training requirements or less from the FAA it would have owed Southwest between $200 to nearly $400 million.[127] This helped incentivize Boeing and its leadership to forestall any simulator training for 737 MAX pilots. This had the impact of evading and averting the inclusion of at least one technology that could have affected Boeing's directive to avoid simulator training.

- In November 2012, for instance, it took a Boeing test pilot more than 10 seconds to respond to uncommanded MCAS activation during a flight simulator test, a condition the pilot found to be "catastrophic[.]"[128] The FAA has provided guidance that pilots should be able to respond to this condition within four seconds.[129] This event should have focused Boeing's attention on the need for enhanced pilot training for MAX pilots. It didn't.

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[125] See: Letter from Southwest Airlines' Drew Richardson to Chair DeFazio and Subcommittee on Aviation Chair Rick Larsen, July 26, 2019, (On file with the Committee), and David Shepardson and Tracy Rucinski, "U.S. lawmakers question Boeing's $1 mln rebate clause for Southwest 737 MAX orders," *Reuters,* October 30, 2019, accessed here: https://www.reuters.com/article/us-boeing-airplane-southwest/u-s-lawmakers-question-boeings-1-mln-rebate-clause-for-southwest-737-max-orders-idUSKBN1X92D4

[126] "Southwest Airlines Reports Fourth Quarter And Record Annual Profit; 44th Consecutive Year Of Profitability," Southwest Airlines Company, January 26, 2017, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={55E44CBF-22E3-41F5-84EF-B3EDAB030B07}

[127] In January 2017, Southwest had 200 firm 737 MAX orders with the option to purchase 191 additional MAX aircraft. In October 2019, one year after the Lion Air crash, Southwest had 246 firm MAX orders, 34 of its MAX aircraft were grounded and it had the option to purchase 115 additional MAX aircraft. See: "Southwest Airlines Reports Fourth Quarter And Record Annual Profit; 44th Consecutive Year Of Profitability," Southwest Airlines Company, January 26, 2017, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={55E44CBF-22E3-41F5-84EF-B3EDAB030B07}; "Southwest Corporate Fact Sheet," Southwest Airlines Company, 2020, accessed here: https://www.swamedia.com/pages/corporate-fact-sheet#fleet and "Southwest Reports Record Third Quarter Net Income And Earnings Per Share," Southwest Airlines Company, October 24, 2019, accessed here: http://www.southwestairlinesinvestorrelations.com/news-and-events/news-releases/2019/10-24-2019-112936719

[128] Internal email from Boeing engineer to two Boeing test pilots, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 2:40 PM, BATES Number TBC T&I 131226 – 131227 (On file with the Committee).

[129] See: JATR Report p.14 and FAA Advisory Circular 25.1329-1C, October 27, 2014, p. 78, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1329-1C.pdf

- From 2015 to 2018, the information regarding the fact that Boeing's own test pilot took more than 10 seconds to respond to uncommanded MCAS activation in a flight simulator leading to potentially "catastrophic" consequences was included in at least six separate internal Boeing Coordination Sheets on MCAS's requirements.[130] This indicates Boeing's keen awareness of the importance of this information.

- The Committee has found no evidence that Boeing shared this information with the FAA, its customers, or 737 MAX pilots and Boeing has confirmed to the Committee that it found no record showing it shared any of these MCAS Coordination Sheets with the FAA because they were not required to do so.

- At least four Boeing ARs were aware of these findings and never reported them to the FAA.

- One of Boeing's key goals for the 737 MAX program was that simulator-based training would not be required for pilots transitioning to the 737 MAX from the 737 NG.[131] That goal undermined appropriate pilot training requirements, hampered the development of safety features that conflicted with that goal and created management incentives to downplay the risks of technologies that jeopardized that goal.[132]

- Early in the 737 MAX program, for instance, Boeing recognized that the addition of MCAS to the pilot's flight controls system posed a risk to qualifying for Level B (non-simulator) training.[133]

- However, the chief project engineer on the MAX program told Committee staff that obtaining Level B (non-simulator) pilot training requirements from the FAA was a "design objective" of the MAX program.[134] That directive demanded that differences training for

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[130] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision B, July 8, 2015, TBC T&I 191227 – TBC T&I 191232 at TBC T&I 191231 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision C, October 19, 2015, TBC T&I 253262 - TBC T&I 253268 at TBC T&I 253267 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf; Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision E, July 5, 2016, TBC T&I 129776 - TBC T&I 129782 at TBC T&I 129782 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision F, December 20, 2017, TBC T&I 037449 - TBC T&I 037457 at TBC T&I 037457 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[131] Boeing internal email, "Subject: 737 MAX Firm Configuration Status/Help Needed," Sent: May 4, 2013 11:35 AM, BATES Number TBC-T&I 048706 – 048707, at pp. 128-129 accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[132] Ibid.

[133] Ibid.

[134] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.

pilots transitioning from the 737 NG to the 737 MAX would be limited to 16 hours—or less—of computer based training requirements.[135]

- In July 2014, two years before the FAA made a determination regarding pilot training requirements for the 737 MAX, and at a time when the FAA was actively questioning Boeing on its presumption that no simulator training would be required, Boeing issued a press release asserting: "Pilots already certified on the Next-Generation 737 will not require a simulator course to transition to the 737 MAX."[136] Boeing made similar claims in marketing materials it provided to potential customers.[137]

- In February 2015, Boeing's 737 Chief Technical Pilot wrote that MAX simulator training would be "unrecoverable" for some Boeing customers due to the lack of simulators.[138]

- In August 2016, the FAA granted provisional approval for Level B (non-simulator) differences training requirements for pilots transitioning between the 737 NG and the 737 MAX.[139] The FAA estimated that its approved computer-based training for the MAX could be completed in approximately two hours, a drastic reduction from the 16 hours Boeing was anticipating.[140]

- The following month, in September 2016, Boeing granted its team of technical pilots the company's Commercial Aviation Services (CAS) Service Excellence Award for their role in "developing the MAX Level B [non-simulator] differences training...."[141]

- In March 2017, the month the 737 MAX was certified by the FAA, Boeing's 737 Chief Technical Pilot responded to colleagues about the prospects of 737 MAX simulator training, writing: "Boeing will not allow that to happen. We'll go face to face with any regulator who tries to make that a requirement."[142]

- In May and June 2017, as some foreign carriers asked Boeing about providing simulator training for their pilots transitioning to the 737 MAX from the 737 NG, emails show

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[135] Boeing internal email, "Subject: 737MAX Firm Configuration Status/Help Needed," May 4, 2013, (see "Differences Pilot Training" section), TBC-T&I 048706-048708, at pp. 128-130, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[136] "Boeing Selects Supplier for 737 MAX Full-Flight Simulator," Boeing Press Release, July 11, 2014, accessed here: https://boeing.mediaroom.com/2014-07-11-Boeing-Selects-Supplier-for-737-MAX-Full-Flight-Simulator

[137] Slide presentation to Ethiopian Airlines—TBC-T&I 001999– TBC T&I 002000 at TBC T&I 002018, at pp. 124-126, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[138] Boeing internal email from 737 Chief Technical Pilot to Former 737 MAX VP/GM, Former 737 MAX Chief Project Engineer and others, "Subject: HELP NEEDED Request: 737 CL Program decision, RCAS/MAX training," Friday, February 27, 2015, 3:29 PM, BATES Number TBC T&I 552664-552666 (On file with the Committee).

[139] FAA letter to The Boeing Company, "Subject: Boeing 737 MAX Pilot Qualification Plan (PQP) Gate 4," August 17, 2016, BATES Number TBC-T&I 010895. (On file with the Committee).

[140] See: "FAA Responses to Follow-Up Questions from House T&I Staff," Sent: September 6, 2019, BATES Number FAA-T&I-000031938 – 000031939 (On file with the Committee).

[141] Boeing internal email, "Subject: RE: Weekly inputs," September 21, 2016, 4:26 PM, BATES Number TBC T&I TBC-T&I 552192. (On file with the Committee).

[142] Boeing internal email, "Subject: RE: Flight Transition costs," Sent: March 28, 2017, 9:00:58 AM, accessed at p. 28 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

Boeing's 737 Chief Technical Pilot strongly opposed such training, and in one case even successfully talked a carrier out of using such training for its pilots on the 737 MAX.[143]

- In December 2017, the Chief Technical Pilot referring to his efforts to talk airlines out of the need for simulator training wrote to a Boeing colleague: "I save this company a sick amount of $$$$."[144]

- Even after the fatal Lion Air crash, Boeing maintained that its "rationale" for removing references to MCAS from the 737 MAX training manual was still "valid,"[145] and Boeing asserted that the addition of MCAS on the 737 MAX did "not affect pilot knowledge, skills, abilities, or flight safety."[146]

- After the Lion Air crash, Boeing also recommended that FAA only require Level A training on MCAS.[147] This is the training level with the fewest obligations, and would only require pilots to review printed materials that described MCAS as part of their transition from the 737 NG to the 737 MAX.[148]

- On March 1, 2019, the FAA reminded Boeing that the original level of differences training proposed in 2016 by Boeing—**before** the Lion Air crash—was Level B.[149] The FAA informed Boeing that the software changes to MCAS "may not meet the definition of Level

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[143] See: Boeing internal email, "Subject: RE: 737 MAX ATB/RTL FOTB" Sent: Monday, June 5, 2018, 8:01 PM (p. 14); Boeing Email to airline customer, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Tuesday, June 6, 2017 11:01:40 AM (p. 34); Airline customer Email to Boeing, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Wednesday, June 7, 2017, 12:12 AM (p. 32); and Boeing internal email, "Subject: FW: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Wednesday, June 7, 2017, 10:01:41 AM (p. 32); accessed here (at page numbers indicated in parenthesis): https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[144] Boeing internal instant message, December 12, 2017, at p. 87, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[145] Boeing Letter to FAA's Seattle Aviation Evaluation Group (AEG), January 30, 2019—TBC-T&I 297017–297018, at pp. 134-135, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[146] Ibid.

[147] Ibid. FAA has defined five training levels, in order of increasing requirements identified as A through E, that describe acceptable training and checking methods that are appropriate to the degree of difference between the base aircraft and the variations. See: FAA Flight Standards Information Management System, 8900.1 Contents, Volume 3 General Technical Administration, Chapter 19 Flightcrew Member Training and Qualification Programs, Section 9 Safety Assurance System: Differences Training—All Training Categories, accessed here: http://fsims.faa.gov/wdocs/8900.1/v03%20tech%20admin/chapter%2019_03_019_009.htm

[148] FAA Flight Standards Information Management System, 8900.1 Contents, Volume 3 General Technical Administration, Chapter 19 Flightcrew Member Training and Qualification Programs, Section 9 Safety Assurance System: Differences Training—All Training Categories, accessed here: http://fsims.faa.gov/wdocs/8900.1/v03%20tech%20admin/chapter%2019_03_019_009.htm

[149] FAA letter to Boeing 737 Chief Technical Pilot, "Subject: Boeing 737-8 Maneuver Characteristic Augmentation System (MCAS) Evaluation Letter of Proposal RA-19-0029 FAA Response Letter," March 1, 2019, BATES Number TBC-T&I 297019 – 297020, at pp. 136-137, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

A differences" training and advised Boeing that the company's "evaluation is proceeding at risk."[150] Nine days later, Ethiopian Airlines flight 302 crashed.

Post-Accident Response - ***Both Boeing and the FAA gambled with the public's safety in the aftermath of the Lion Air crash, resulting in the death of 157 more individuals on Ethiopian Airlines flight 302, less than five months later.***

- After the Lion Air crash, Boeing and the FAA failed to take the actions needed to avert a second crash. In November 2018, days after the Lion Air crash, both Boeing and the FAA issued advisories for 737 MAX pilots that failed to even mention the existence of MCAS by name.[151] Only after receiving inquiries about MCAS from airlines did Boeing describe MCAS in a Multi Operator Message (MOM), on November 10, 2018, that went to Boeing's MAX customers but was not otherwise made public.[152]

- The FAA acknowledged to the Committee that it had drafted—and then deleted—reference to MCAS that had originally appeared in a draft of its Emergency Airworthiness Directive (AD).[153]

- There were multiple red flags and clear data points that should have informed the FAA's decision-making after the Lion Air crash. The FAA learned, for instance, that not only had Boeing failed to fix an inoperable AOA Disagree alert on more than 80 percent of the 737 MAX fleet, but that it had also decided not to inform the FAA or its customers about the non-functioning alert for more than 14 months – until **after** the Lion Air crash.[154]

- Moreover, in December 2018, the FAA received a briefing from Boeing in which the company acknowledged that prior to certification, Boeing had not evaluated the effects of a combination of failures leading to unintended MCAS activation in simulator tests nor their combined flight deck effects on pilots.[155] Boeing also acknowledged that it did not reevaluate

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[150] Ibid.

[151] Flight Crew Operations Manual Bulletin for the Boeing Company, Number TBC-19, 737-8/-9, Uncommanded Nose Down Stabilizer Trim Due To Erroneous Angle of Attack (AOA) During Manual Flight Only, November 6, 2018, accessed here at pp. 95-96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and FAA Emergency Airworthiness Directive # 2018-23-51, November 7, 2018, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgad.nsf/0/83ec7f95f3e5bfbd8625833e0070a070/$FILE/2018-23-51_Emergency.pdf

[152] The Boeing Company Multi Operator Message (MOM), Subject: Information – Multi-Modal Stall Warning and Pitch Augmentation Operation, MOM-MOM-18-0655-01B, November 10, 2018, p. 290, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[153] Questions from Hon. Peter A. DeFazio for Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration, Hearing titled: "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 243-244: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[154] Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty and "Boeing Statement on AOA Disagree Alert," Press Release, The Boeing Company, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130431

[155] MCAS Development and Certification Overview—TBC-T&I 130073–130074; 130075–130117, at pp. 178-179, 180-201, at p. 185, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

its single- and multiple-failure assessments of MCAS after its engineers made design changes to the MCAS software in 2016.[156] Further, because Boeing determined that the loss of one AOA sensor followed by erroneous readings from the other AOA sensor to be extremely improbable, it did not analyze this failure scenario even though it had determined that delayed pilot reaction in this situation was "potentially catastrophic."[157]

- These issues should have raised warning signs for the FAA, but none of these issues were deemed noncompliant with FAA regulations by the FAA.[158]

- In December 2018, the FAA conducted a risk assessment based on its Transport Aircraft Risk Assessment Methodology (TARAM) and estimated that without a fix to MCAS, during the lifetime of the 737 MAX fleet, there could potentially be 15 additional fatal crashes resulting in over 2,900 deaths.[159]

- Despite that assessment, the FAA permitted the 737 MAX to continue flying while Boeing and the FAA worked on designing and validating, respectively, a fix to the MCAS software. During the period between the crashes, the FAA repeatedly justified its decision not to ground the 737 MAX saying that it did not have appropriate data to make that determination.[160] That judgment proved tragically wrong.

- In December 2019, in a transcribed interview with Committee staff, Ali Bahrami, the FAA's Associate Administrator for Aviation Safety, seemed unaware of key issues related to the 737 MAX accidents.[161] For instance, he said he had not seen Boeing's November 6, 2018 Flight Crew Operations Manual Bulletin that Boeing had provided as an update to flight crews following the Lion Air crash. He said he was not familiar with the details of FAA's post Lion Air TARAM analysis that predicted 15 more fatal accidents without a fix to MCAS over the lifetime of the MAX fleet. He was also unaware of the fact that Boeing had conducted its own tests that showed it took a Boeing test pilot 10 seconds to respond to uncommanded MCAS activation in a flight simulator, which the pilot described as "catastrophic," despite

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[156] Ibid., p. 191
[157] Ibid., pp. 191-192.
[158] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report" February 8, 2019, Prepared by: FAA AIR-860 BASOO, (Draft), Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA) (Hereafter referred to as "FAA MCAS Oversight Report (draft)."') This document was reviewed remotely by Committee staff on May 1, 2020.
[159] "Quantitative Risk Assessment, Random Transport Airplane Risk Analysis (R-TARA) Version 2.42," Aircraft Certification Service, Transport Airplane Directorate (TAD), Federal Aviation Administration (FAA), FAA-DEFAZIO-000028836, part of TAD Corrective Action Review Board (CARB) Presentation Form: CARB 1- Unsafe Condition Determination," December 11, 2018, see: page 167, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[160] Robert Wall, Andrew Tangel, and Andy Pasztor, "The FAA Has No Current Plans to Ground Boeing's 737 MAX After Deadly Crash," *Wall Street Journal*, March 11, 2019, accessed here: https://www.wsj.com/articles/the-faa-has-no-current-plans-to-ground-boeings-737-max-11552341654 and Prepared Statement of Daniel K. Elwell, Acting Administrator, Federal Aviation Administration (FAA), Hearing before the Subcommittee on Aviation of the House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, p. 24, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf
[161] Committee staff transcribed interview of Ali Bahrami, Associate Administrator for Aviation Safety, Federal Aviation Administration (FAA), December 5, 2019, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

the fact that this information had been made public at a high profile Committee hearing on the 737 MAX on October 30, 2019, and widely covered by the media.[162]

- Separately, Mr. Bahrami claimed he could not recall a single conversation with Boeing officials about the MAX in between the Lion Air and Ethiopian Airlines crashes. The FAA's head of aviation safety said, "I don't recall a conversation about that between the two accidents."[163]

- Despite that, documents Boeing provided to the Committee show that recollection was not accurate. On January 24, 2019, Elizabeth ("Beth") Pasztor, Boeing's ODA Lead Administrator, and one of Boeing's most senior officials regarding FAA regulatory compliance, emailed Mr. Bahrami about setting up a phone call.[164] "I would appreciate a few minutes of your time, the topic is Lion Air," wrote Pasztor.[165] According to Mr. Bahrami's response, the two planned to speak the following day.[166] It is unclear if the call ultimately took place and if it did, what was discussed, and who else, if anyone from FAA or Boeing was on the call. However, one week after that email requesting the call with Mr. Bahrami, Ms. Pasztor's deputy wrote to the FAA's Aircraft Evaluation Group (AEG) on Ms. Pasztor's Boeing letterhead arguing that the FAA should grant Boeing Level A training for MCAS in its post Lion Air evaluation.[167]

- The Department of Transportation (DOT) has provided the Committee with substantial FAA records in response to Chair DeFazio and Subcommittee Chair Larsen's original April 2019 records request.[168] However, this process has been inexplicably slow, seemingly incomplete and it is still unclear to the Committee—17 months later—where the agency is in its response since it has repeatedly and consistently refused to provide the Committee with clear updates on the status of these requests.[169] The Senate Committee on Commerce,

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[162] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, at p. 22, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[163] Committee staff transcribed interview of Ali Bahrami, Associate Administrator for Aviation Safety, Federal Aviation Administration, December 5, 2019.

[164] Email from Vice President, Boeing Commercial Airplanes Safety, Security, and Compliance to FAA Associate Administrator for Aviation Safety, Sent: January 24, 2019, 3:48 PM, BATES Number TBC-T&I 552822. (On file with the Committee).

[165] Ibid.

[166] Email from FAA Associate Administrator for Aviation Safety to Vice President, Boeing Commercial Airplanes Safety, Security, and Compliance, "Subject: Re: Request for brief phone call," Sent: January 24, 2019, 1:01 PM, Bates Number TBC-T&I 552822. (On file with the Committee).

[167] Boeing letter from ODA Deputy Lead Administrator to FAA SEA AEG, "Subject: Boeing Response to Transport AEG letter," RA-19-00269, January 30, 2019, TBC-T&I 297017 – 297018 (On file with the Committee).

[168] See: "As Part of Investigation into Boeing 737 MAX Certification Process, Committee Sends Records Requests to FAA, Boeing," Press Release, Committee on Transportation and Infrastructure, U.S. House of Representatives, April 1, 2019, accessed here: https://transportation.house.gov/news/press-releases/as-part-of-investigation-into-boeing-737-max-certification-process-committee-sends-records-requests-to-faa-boeing

[169] In June 2019, DOT/FAA informed the House Committee on Transportation and Infrastructure that, regarding the Committee's investigation of the 737 MAX, it had between 592,915 and 92,265 potentially responsive emails to just a few of the Committee's April 1, 2019, records requests. The FAA acknowledged they had 592,915 emails with the term "MCAS" or "AOA Sensors," for instance, between March 2014 and April 25, 2019. This included 338,074 emails with the terms "MCAS" or "AOA Sensors" and the terms "development" or "testing" or "fielding" or "certification." For the period between March 2014 and October 29, 2018 the number of emails that the FAA identified with the term

Science, and Transportation has experienced remarkably similar problems according to public statements from that Committee's Chairman, Senator Wicker.[170]

- After the Lion Air crash, the FAA's Boeing Aviation Safety Oversight Office (BASOO) started an internal review of its MCAS certification process on the 737 MAX. The review was the first time FAA performed its own detailed analysis of MCAS and the first time FAA received a complete picture of how MCAS operated, according to the Department of Transportation Office of Inspector General (DOT OIG).[171]

- The draft report, titled, "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," concluded that Boeing was compliant with FAA regulations in the certification of the 737 MAX aircraft. "The oversight activity did not reveal any noncompliances," the report said, "but did observe some assumptions used by the Applicant and accepted by the FAA."[172] The report implied that these "assumptions" by both Boeing and the FAA regarding pilot reaction time, for instance, were faulty. The FAA review also found that there was nothing discovered that required "corrective action," although they cited some areas for potential "improvement."[173] The draft report's analysis showed that the MAX was compliant with FAA regulations, raising serious questions about the FAA certification process and its oversight of Boeing.

- This internal FAA review of MCAS began on January 9, 2019,[174] and the last version of the draft report was dated February 8, 2019.[175] The FAA never finalized this report. The FAA told the DOT OIG that the report was going through management review at the time of the Ethiopian Airlines accident and that it was simply overtaken by events.[176]

"MCAS" or "AOA Sensors" was 234,425. In relation to the terms "MCAS" or "AOA Sensors" and the terms "development" or "testing" or "fielding" or "certification," for that same time period, the FAA had identified 92,265 emails. See: "FAA Responses to Follow-Up Questions from House T&I Staff," June 7, 2019, BATES Number FAA-T&I-000192. In addition, in November 2019, in order to help DOT manage the scope of the Committee's requests and at the specific suggestion of DOT, the Committee provided DOT with a list of 13 specific searches of 27 current and former FAA officials. The Committee has received several productions of records related to this request. However, DOT has been unable or unwilling to inform the Committee which of these 13 searches have been performed or which of the 27 individuals' records have been searched.

[170] Prepared Statement, Chairman Roger Wicker, Hearing titled, "Examining the Federal Aviation Administration's Oversight of Aircraft Certification," Senate Committee on Commerce, Science & Transportation, June 17, 2020, accessed here: https://www.commerce.senate.gov/2020/6/examining-the-federal-aviation-administration-s-oversight-of-aircraft-certification

[171] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report No. AV2020037, June 29, 2020, p. 32, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[172] "FAA MCAS Oversight Report (draft)." This document was reviewed remotely by Committee staff on May 1, 2020.

[173] Ibid.

[174] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report No. AV2020037, June 29, 2020, p. 32, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[175] FAA MCAS Oversight Report (draft), February 8, 2019.

[176] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report

- The metadata of this report showed that the report was accessed and printed by an FAA employee on March 11, 2019, the day after Ethiopian Airlines flight 302 crashed.

- Because this report was a "draft" and a final copy was never produced the DOT refused to provide a copy to the Committee. However, Committee staff were given the opportunity to review the document.

-Investigative Findings Conclusion-

Boeing's design and development of the 737 MAX was marred by technical design failures, lack of transparency with both regulators and customers, and efforts to downplay or disregard concerns about the operation of the aircraft. During development of the 737 MAX, a Boeing engineer raised safety concerns about MCAS being tied to a single AOA sensor.[177] Another Boeing engineer raised concerns about not having a synthetic airspeed system on the 737 MAX.[178] Concerns were also raised about the impact of faulty AOA data on MCAS[179] and repetitive MCAS activations on the ability of 737 MAX pilots to maintain control of the aircraft.[180] Ultimately, all of those safety concerns were either inadequately addressed or simply dismissed by Boeing.

In the wake of the Lion Air and Ethiopian Airlines tragedies, Boeing has now acknowledged some of these issues through its actions. For instance, Boeing now plans to have two AOA sensors feed into MCAS.[181] Boeing has also said that MCAS will no longer activate repeatedly.[182] In January 2020, Boeing dramatically reversed course yet again, by recommending that pilots undergo simulator training on the 737 MAX once the airplane returns to service.[183] That decision violated one of the premier principles of the MAX program, to avoid pilot simulator training. Unfortunately, Boeing's responses to safety issues raised in the 737 MAX program have consistently been too late.

No. AV2020037, June 29, 2020, p. 32, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[177] Boeing employee email, "MCAS Stab Rapid Reversal on PSIM Model," December 17, 2015, BATES Number TBC-T&I 010584 - TBC-T&I 010586 at TBC-T&I 010584, released at Hearing before the House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 121, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[178] Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, at p. 1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[179] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOC 2]," Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC T&I 246488 – T&I 246493 at T&I 246489. (On file with Committee) .

[180] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," June 20, 2016, BATES Number TBC T&I 220826 - TBC T&I 220827 at TBC T&I 220826. (On file with the Committee).

[181] "737 MAX Software Update," The Boeing Company, accessed here: https://www.boeing.com/commercial/737max/737-max-software-updates.page

[182] Ibid.

[183] "Boeing Statement on 737 MAX Simulator Training," The Boeing Company, January 7, 2020, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130596 and Natalie Kitroeff and David Gelles, "In Reversal, Boeing Recommends 737 MAX Simulator Training for Pilots," *New York Times,* January 8, 2020, accessed here: https://www.nytimes.com/2020/01/07/business/boeing-737-max-simulator-training.html

The Committee's investigation has also found that the FAA's certification review of Boeing's 737 MAX was grossly insufficient and that the FAA failed in its duty to identify key safety problems and to ensure that they were adequately addressed during the certification process. The combination of these problems doomed the Lion Air and Ethiopian Airlines flights.

The following pages detail the factual evidence gathered by the Committee during its investigation that highlight the actions and events that undermined the design, development, and certification of the 737 MAX aircraft and led to the tragic death of 346 people.