THE BOEING 737 MAX: EXAMINING THE DESIGN, DEVELOPMENT, AND MARKETING OF THE AIRCRAFT

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THE BOEING 737 MAX: EXAMINING THE DESIGN, DEVELOPMENT, AND MARKETING OF THE AIRCRAFT

WEDNESDAY, OCTOBER 30, 2019

HOUSE OF REPRESENTATIVES,
COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE,
WASHINGTON, DC.

The committee met, pursuant to notice, at 10:05 a.m. in room 2167, Rayburn House Office Building, Hon. Peter A. DeFazio (Chairman of the committee) presiding.

Mr. DEFAZIO. The Committee on Transportation and Infrastructure will come to order.

I ask unanimous consent that the chair be authorized to declare recesses during today's hearing.

Without objection, so ordered.

I also ask unanimous consent that the chair and ranking member of the full committee be recognized for 10 minutes each during the first round of questions.

Without objection, so ordered.

Before I begin I want to explain an administrative matter regarding some of the documents we may use in today's hearing, and that will be entered into the record. I will be making two unanimous consent requests in reference to two documents, list A and list B.

First, the documents contained on list B are marked "export control." We have been advised by the House General Counsel that the Constitution provides ample authority for us to release these documents and the documents from Boeing. Boeing's attorneys agreed to the release of these documents. I see nothing that is export-sensitive in these documents. The FAA stamped every document they sent us as "export control."

However, to prevent confusion with regards to documents with "export control" markings on them, I will be making a unanimous consent request regarding the release of these documents, pursuant to the Export Control Act.

Second, I will be making a unanimous consent request to enter the documents on list A into the hearing record. This list includes the export control documents on list B, as well as additional documents. The ranking member's staff is aware of all these, and has reviewed all these documents that are on both lists.

And with that I ask unanimous consent that the documents on list B be disclosed pursuant to 50 U.S. Code, section——

Mr. GRAVES OF MISSOURI. Mr. Chairman?

Mr. DEFAZIO. Yes?

Mr. GRAVES OF MISSOURI. I want to reserve my right to object at this point.

Mr. DEFAZIO. The gentleman is recognized.

Mr. GRAVES OF MISSOURI. The reason for doing that is we have had two—at least two, that I can remember—hearings noting Chinese infiltration of American industries, and that includes rail, maritime, transit, you name it, and they would love to have the opportunity to get their hands on technology from the aviation industry, as well. And it concerns me in a big way.

We have talked about this and gone over this. These documents have all been made available to everybody on the committee. Making these documents available to the public, or putting them out there in the public domain, I think, is a real problem. I do. And I think we are cutting ourselves off at the legs when it comes to that technology. It concerns me. It concerns me in a big way, and I really want us to think about that, moving forward.

Having said that, I will withdraw my right to object, and allow this to move forward, because I do want to get answers. I think we can get the answers without these, but I do want to get the answers, so will remove that request.

Mr. DEFAZIO. Well, I thank the gentleman. And I didn't take a back seat to anybody in the issues regarding China. I voted against most-favored-nation status, opposed them going into the WTO. I have raised concerns for decades about their theft of U.S. technology, and their unfair trade practices. So I certainly share the gentleman's concerns.

I have reviewed these documents. I don't think there is anything in there that will be of any utility to the Chinese. But in any case, I recognize your concerns. So I just have to finish reading this list B. It will be disclosed pursuant to 50 United States Code section 4820(h)2(b)2, because withholding such information is contrary to the national interest.

Without objection, so ordered.

In addition, I ask unanimous consent to enter all the documents on list A into the hearing record.

Without objection, so ordered.

[The information follows:]

List A and List B, Submitted for the Record by Hon. DeFazio

List A is on pages 119–158. List B is on pages 159–273.

Mr. DEFAZIO. Let's proceed now to the hearing.

I first want to recognize the families who are here today. I have met twice with families. I don't know if have met with all of you who are here today. And I want to convey my utmost condolences. It is 1 year and 1 day after the Lion Air crash, a very somber day. We shouldn't have to be here, but we are. And we are going to get to the bottom of this, and we are going to fix it, and we are going to see it never happens again.

With that, I would thank the witnesses for being here, Mr. Muilenburg, Mr. Hamilton, this is the fourth hearing the committee has held, our first full committee hearing. Given the extraordinary interest of members of the committee, I felt it best to

do it in full committee. I know that Boeing told us that they wanted to wait until the airplane was ungrounded, but I felt it was very important for them to testify before that happened.

We are here today because 346 people—sons, daughters, fathers, mothers—died on two MAX aircraft within a 5-month period. Something went drastically wrong.

As you know, our committee has been conducting a very robust investigation for a long time. We have never undertaken an investigation of this magnitude, to the best of my knowledge, in the history of this committee, which is the second oldest committee in the United States Congress.

And we have received hundreds of thousands of pages of documents from Boeing. They have been cooperative in providing those documents, and agreeing that we could use those documents in the public hearing. And we have received tens of thousands of pages from the FAA. We have conducted some interviews with FAA employees. We have others we wish to interview, and we have requested to interview Boeing employees, but we are told that we have to be in line behind the Justice Department. So those are still forthcoming.

There are a lot of unanswered questions that we need to get to the bottom of. We know that a new and novel system called MCAS took these two planes into an uncontrollable attitude after it repeatedly triggered, having to do with a faulty or missing sensor. The system was wired to one sensor.

And in May, then-Acting Administrator Elwell sat there, and I asked him, was MCAS a safety-critical system? He said yes. Then how could it have been approved to trigger with a single point of failure? He had no answer to that. How could the FAA approve it? How could the manufacturer do that? He had no good answer. We are going to continue to pursue the roots of this problem.

We do know that at one point, Boeing had planned to inform pilots about MCAS. In fact, it was in the first version of the flight manual when it was a relatively benign system. But when it became a radical system which could trigger a catastrophic failure, it came out. Some of that was discussed in the Senate yesterday and it will be discussed here again today, particularly quoting from Boeing's chief test pilot. And his instant messages seem inexplicable.

Secondly, we do know that Boeing engineers actually proposed placing a MCAS annunciator in the cockpit. But again, that came out in later versions, or in the actual production version.

And then it wasn't until after Lion Air that Boeing informed anyone. And still at that point, I think, soft peddling MCAS, that it was in the plane. I have talked to a lot of pissed off pilots. They said, "We were the backup system? How can we be backup, if we don't know something is going to take over our plane?" There is quite a bit of discontent out in the aviation community about that.

We now know that Boeing and the FAA assume pilots would appropriately react in 4 seconds. Four seconds. But Boeing had information, which we will get to a little later in this hearing, that some pilots might react in 10 seconds or longer. And, if that happens, the results would be catastrophic, and result in the loss of the aircraft, as happened twice.

We now know from the very beginning of the plane's development Boeing was—they had a phone call. The phone call was, hey, major customer, we are going to buy Airbus. They have better fuel economy, and the pilots don't need retraining, which is very expensive and disruptive of our schedules. So Boeing, from day one, had to meet that. Instead of a clean sheet airplane, they got the 12th or 13th iteration of the 737 amended type certificate. That meant big engines mounted forward, flies differently.

Then they had to develop a system to make it fly the same as the others, so it wouldn't have to go through pilot training or recertification. And that drove the whole process.

We do know that Boeing offered Southwest Airlines $1 million per plane rebate if the pilots had to be retrained. Imagine what the pressures were from the top on down to mid-level, low-level engineers. You are saying, "What? No, no, no. Can't have that. It has cost us a million bucks a plane, $300 million for that one contract." Maybe other contracts had the same provision. Cost us our marketing advantage. Slow things down.

And then, there has been a lack of candor all through this. Boeing learned that the AOA, angle-of-attack, disagree light, which was a standard feature on all Boeing 737s, did not work on this plane, unless someone bought the upgraded package. We were told that was an inadvertent software error in developing the upgraded package, but—that may be so.

But Boeing decided to delay the fix for 3 years, until 2020. They didn't tell the FAA, they didn't tell the customers, and they didn't tell the pilots about this until after the Lion Air crash. That is inexplicable. They say, "Well, it is not necessary for safe operation of the MAX," but keeping everybody in the dark and having that—there it is, it is there, it is right in front of the pilot, it is not lighting up. Well, it can't light up, even if there is disagreement.

And it was included in the flight manual, unlike MCAS. Wow. So you include something in the manual that doesn't work, but something that is going to work and potentially cause catastrophic issues is not in the manual. What was that all about?

We know there was the tremendous pressure on production. Boeing whistleblowers have contacted us regarding features engineers wanted to put on the MAX, but were denied because of the rush to get this plane out the door and compete.

We have from an internal whistleblower a survey conducted November 2016 that 39 percent of Boeing employees surveyed, they experienced undue pressure. Twenty-nine percent said they were concerned about consequences. Consequences? You might lose your job, I guess, if they reported these incidents.

We now know at least one case where a Boeing manager implored then-vice president, the general manager of the 737 program, to shut down the 737 MAX production line because of safety concerns several months before the first tragic Lion Air crash.

There is a lot we don't know. We don't know what would happen if a different path had been followed here, exactly.

We don't know, if these pilots had had simulator training that replicated this system, what would have happened.

We don't know why Boeing designed a plane with a safety critical system assigned to a single point of failure. Inexplicable, inex-

cusable. And, as far as I know, unprecedented in the history of passenger aviation production.

We do know, and we have seen that pressures from Wall Street, market forces, have a way of influencing the decisions of the best companies in the worst way, endangering the public, jeopardizing the good work of countless, countless hardworking employees on the factory lines. And I hope that is not the story that is ultimately going to be written about this long-admired company.

So we need today, Mr. Muilenburg, Mr. Hamilton, we need answers. But we also know that we need reforms on how commercial aircraft are certified, and how manufacturers—not just Boeing, all—are watched and overseen by the regulators. This hearing today and investigation is not just about getting answers to our questions, but how to make the system safer and prevent future tragedies.

[Mr. DeFazio's prepared statement follows:]

Prepared Statement of Hon. Peter A. DeFazio, a Representative in Congress from the State of Oregon, and Chairman, Committee on Transportation and Infrastructure

Thank you, Mr. Muilenburg and Mr. Hamilton, for being at today's hearing, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft." This is the fourth hearing our committee has held on the 737 MAX since May, but the first full committee hearing on this subject.

I know Boeing wanted to wait to testify until after the airplane was ungrounded, but I thought it was important you appear before our committee before the MAX returned to service.

You are here today because 346 people—sons, daughters, fathers, and mothers—died on two Boeing 737 MAX aircraft in the span of 5 months. If you need a reminder of the lives that have been devastated by these tragedies, you can look to the family members of those on Lion Air flight 610 and Ethiopian Airlines flight 302 who are sitting to your left. Their lives have been forever changed as a result of these two crashes, crashes that could have been avoided.

Something went drastically wrong, a total of 346 people died, and we have a duty to fix it.

As you know, our committee has been conducting a robust investigation of the design, development, and certification of Boeing's 737 MAX since March. In fact, our investigation is the most extensive and important investigation this committee has undertaken during my time on the committee.

Over the last several months, we have received hundreds of thousands of pages of documents from Boeing and others, and our staff is continuing to review those records. Our investigation is not complete, and we will continue to investigate these issues until we have clear answers to our questions. The family members of those who died, many of whom are here today, deserve answers too.

There are areas we are exploring that remain murky, and we need to bring clarity to those issues. But there is a lot we have learned over the past 7 months, and we expect you to answer a number of questions to improve our understanding of what happened and why.

MCAS

We now know that a single point of failure triggered a novel flight control system that put these two flights into unrecoverable dives. As a result of this single point of failure—the angle-of-attack sensor—the maneuvering characteristics augmentation system (MCAS) led to repeated and continuous nose-down trim commands in both accidents, and the chain of events that followed and ultimately led to both aircraft impacting water or terrain.

We now know that at one point Boeing had planned to inform pilots about MCAS in their flight manuals, but then reversed course and removed virtually every reference of MCAS from the pilot operating and training manuals. As if it never existed.

We now know that Boeing engineers proposed placing an MCAS annunciator inside the cockpit itself, but that initial decision failed to materialize in the final versions of the 737 MAX. It was not until after Lion Air flight 610 plunged into the waters off the coast of Indonesia 1 year ago that pilots even became aware of MCAS and its capabilities. Even after these accidents, Boeing attempted to downplay MCAS and its abilities although they knew that a malfunctioning MCAS could lead to catastrophe in certain circumstances

We now know that while Boeing and the Federal Aviation Administration (FAA) assumed pilots would appropriately react to an MCAS malfunction resulting in stabilizer trim run-away within 4 seconds, Boeing had information that some pilots might react in 10 seconds or longer, and that if that happened, the results would be *catastrophic*, resulting in the loss of the aircraft.

PILOT TRAINING

We now know that from the very beginning of the plane's development, Boeing touted the limited training required for pilots to switch from flying the older 737 NG to the new 737 MAX—known as "differences" training. Why is that important? Well, limiting pilot training translated into key marketing incentives to sell the MAX to airlines—it would not only save airlines money on training for their pilots, it would help get the plane approved and to market faster.

We now know that Boeing offered Southwest Airlines a rebate of $1 million per airplane if pilots ended up needing simulator training in order to fly the 737 MAX. By the time of the Lion Air crash, Southwest had already ordered nearly 300 of the aircraft. Failure to ensure the FAA provided Level B, or nonsimulator, training would have cost Boeing hundreds of millions of dollars and given its competitor an advantage.

LACK OF CANDOR

We now know that in *August 2017*, Boeing learned that the angle-of-attack (AOA) disagree alert—a standard, standalone feature on all 737 MAX aircraft that indicates to pilots when the readings from the left and right AOA sensors disagree—did not work on aircraft unless they also purchased an optional AOA *indicator* feature. Despite becoming aware of this issue, Boeing decided to delay a fix for 3 years—until 2020—failing to inform the FAA, its airline customers, and 737 MAX pilots about this flaw until *after* the Lion Air crash.

Even if the AOA disagree alert is not necessary for safe operation of the MAX, as Boeing states, the company kept *everyone*, including regulators, in the dark regarding its inoperability for more than a year. And during this time, Boeing continued delivering new aircraft to customers with nonfunctioning AOA disagree alerts and did not inform airlines or pilots the alerts were not functioning. In fact, the AOA disagree alert was included in the 737 MAX flight crew operating manual, including the one provided to Lion Air in August 2018. The actual fix was relatively simple and a software update could have been done quickly, but it wasn't, and it is still unclear why.

UNDUE PRESSURE

We now know that at least one internal Boeing whistleblower said Boeing sacrificed safety for cost savings on some features that engineers intended to deploy on the MAX during the development process.

We now know from an internal Boeing survey conducted in November 2016, provided to the committee from a whistleblower, that 39 percent of those Boeing employees surveyed said they experienced undue pressure and 29 percent said they were concerned about "consequences" if they reported these incidents.

We now know of at least one case where a Boeing manager implored the then-Vice President and General Manager of the 737 program to shut down the 737 MAX production line because of safety concerns, several months before the Lion Air crash in October 2018.

UNANSWERED QUESTIONS

But there is still a lot that we don't know. We don't know what the results would have been if different actions were taken. We don't know what would have happened if more information was shared with the FAA. We don't know what would have happened if the pilots of these two doomed 737 MAX aircraft had been required to undergo simulator training prior to flying the MAX.

We are still unclear about why Boeing designed the 737 MAX to rely on a single point of failure that the company knew could potentially be catastrophic. This was

inexplicable and inexcusable. We may never know what key steps could have been taken that would have altered the fate of those flights, but we do know that a variety of decisions could have made those planes safer and perhaps saved the lives of those on board.

Mr. Muilenburg, I've worked on consumer and aviation safety issues for a long time, in this very room in fact. And I have seen how pressures from Wall Street have a way of influencing the decisions of the best companies in the worst way, endangering the public and jeopardizing the good work of countless workers on the factory lines. I hope that's not the story that will be written about your long-admired company.

So we need answers from you today, Mr. Muilenburg, but more importantly, I believe the 737 MAX accidents show that we need reforms in how commercial aircraft are certified and how manufacturers, like Boeing, are watched and overseen by the regulator. Our investigation and this hearing are not just about getting answers to our questions, but about making the aviation system safer, for all who travel, and ensuring tragedies like those in Indonesia and Ethiopia never happen again.

Mr. DEFAZIO. With that, I yield time to the ranking member.

Mr. GRAVES OF MISSOURI. Thank you, Mr. Chairman, for holding this hearing.

I do want to extend my condolences to the families and friends of the accident victims. I can't imagine how hard it is to you to sit and go through this process.

I am going to divert from my statement for just a minute and associate myself with a couple of comments that the chairman made. And I, too, as a pilot, having a piece of equipment in an airplane that I don't know about is something that concerns me in a big way. And that comment about pilots saying, "What, we are the backup system," it does concern me.

But I do want to point out, though, as well, when it comes to Airbus—because it was mentioned, too, that there were customers that wanted to look at Airbus as opposed to the Boeing product, but in an Airbus aircraft the pilot is the backup system. You can't shut it off.

The same—similar system, I should say, very similar system in an Airbus that is in a Boeing MAX, MCAS, you can't shut it off. It overrides the pilot. Overrides the pilot, whereas MCAS can be shut off, and that is one of the things about, you know, when it comes to being a pilot, you want to be able to shut a system off that has failed, and be able to fly the airplane. And that is what I have harped on and harped on over and over and over again.

And it is my hope that Mr. Muilenburg's testimony today is going to help us understand the decisions that Boeing made between 2009 and 2017 regarding the design and certification of the 737 MAX. Some of those decisions were reviewed and approved by the Boeing Organization Designation Authorization, or the ODA. We keep using that term, obviously. It is on behalf of the FAA. And while the Boeing ODA was authorized to act for the FAA, as the regulator of the FAA, they retain the ultimate responsibility for overseeing the compliance with all safety regulations. It still lies within the FAA.

And I know the chairman said we have still got a lot of other people to hear from. We are hearing from the Boeing leadership today. At the time of these decisions, to get a complete picture, I would like to hear from the FAA officials that were there at the time, between 2012 and 2017, when these decisions were being

made. And I hope that I can get a commitment—and I am sure you don't have any problem with that—to do that.

Mr. DEFAZIO. I commit that we will be hearing from FAA.

Mr. GRAVES OF MISSOURI. Because we have got to hear from everybody. That is the bottom line. I have said before, many times, the various investigations, they reveal problems.

If these investigations reveal problems with certification, then I think Congress should act to fix those specific and identifiable problems. That is going to be the issue, identifying what those problems are.

But in the aftermath of these accidents, we can't address safety of the aviation system by focusing on one single factor.

And there is never one single factor that contributes to an accident. I have heard safety experts refer to the swiss cheese model of accident causation. In this model, if you use this model, you have layers, many layers of accident protection that are visual. If you visualize them as slices of cheese with holes that represent the weaknesses, some of those weaknesses are due to conditions. Others are due to active failures.

But when an accident occurs, when all of those holes of weaknesses, when they line up, that is when you have a catastrophic failure. And in the context of the 737 MAX, we have to consider all of those layers, all of them, when it comes to the protection and safety, when we try to determine what weaknesses are out there, and try to figure out what those weaknesses are.

So, as an investigator, the Indonesian Government said about the Lion Air accident—and I quote—"If one of those nine contributing factors did not happen, the crash would not have happened." One particular layer, the design and certification of the 737 MAX, that is the focus of a number of investigations.

And earlier this year Boeing took responsibility for the MCAS design weaknesses, and they have been working on a software fix which we are waiting to hear about.

But other weaknesses, Boeing, with the FAA's oversight—we are going to address—they include pilot displays, operation manuals, crew training. Today we are going to hear about the status of all of those efforts.

But I want to hear about how these efforts line up with the recommendations of the Joint Authorities Technical Review, or the JATR. The first completed review of the MAX certification by individuals with vast aviation and technical expertise is due out—is obviously due soon.

But while the JATR didn't call for an end to the FAA's delegation programs, it did highlight some bureaucratic efficiencies in the relationship between Boeing and the FAA, and we have to address those. And I know we will.

The FAA concurred with the JATR's report, and is committed to working on these recommendations, which is good. We, obviously, have to have oversight to make sure that that happens.

But lastly, Mr. Muilenburg, I want to hear about recently shared documents relating to Boeing's former chief technical pilot for the 737. And I am sure you are going to do that.

But other investigations are moving forward, as well. Last month the National Transportation Safety Board, they issued a rec-

ommendation report which largely focused on the assumptions that were made during the design and certification process related to human factors. Design and certification cannot be the sole focus of our efforts, and I have said this before. That is only one layer of that cheese model that I talked about.

In the last few months other weaknesses that appear to have played a role in these accidents have surfaced. Reports earlier this month called into question evidence submitted to the Lion Air investigation, which related to the installation, calibration, and testing of the faulty angle-of-attack sensor.

There has also been whistleblower statements and other reports raising significant concerns with the Lion Air and Ethiopian Airlines operation and maintenance programs.

The former chief engineer for Ethiopian Airlines filed a whistleblower complaint alleging significant problems with that airline's maintenance, training, and recordkeeping.

He also alleges that the air carrier went into the maintenance records of the 737 MAX a day after the accident.

And, unfortunately, operational pressures and lack of robust safety culture can negatively impact aviation safety. That is another layer of that model that I talked about. The NTSB has confirmed that, along with certification, operational factors are going to be the focus of its accident investigations.

In addition, along with its own MAX certification review, the Department of Transportation—their IG, their inspector general, at the request of the committee's leadership—is soon going to begin a review of the international training standards in the impact of automation, which is another thing that I have talked about as a potential problem.

But I want to be crystal clear in reviewing these areas, that this is not an effort to blame the pilots, and I don't blame the pilots, and I don't absolve Boeing of its responsibility.

But a September New York Times magazine article described the changing nature of the airline industry, and the impact it is having on airmanship. And the article refers to a decade-long transformation of the entire business of flying, in which airplanes became so automated and accidents so rare that a cheap air travel boom was able to take root around the world. And this boom in air travel resulted in the need for more and more pilots. But the pool of experienced pilots couldn't keep up.

I remember getting letters from airlines all over the world, just simply because I had ATP on my license, getting letters, offering me jobs to quit what I was doing and come fly for them.

But I will continue to repeat this. Pilots can master cockpit technology. But when the technology fails, they have to be able to fly the plane, not just fly the computer. And to be clear, none of this is a reflection on Lion Air or Ethiopia's pilots' professionalism or character. They were fighting for their lives. That is the bottom line.

But instead, it is a reflection on the broader pressures that are present today in the global aviation economy. And it is incumbent on the airline whose name is on the side of that airplane to ensure that their pilots are properly trained to the level that they need to be, and not rushed into the cockpits to meet those demands.

That is where some of this blame lies, in Ethiopia in particular. The Government owns the airline, and they put pilots in there that—something above their head. It is not the pilot's fault. You have to look at who put them in that position to be responsible for hundreds of lives.

So in line with that swiss cheese model and other layers of protection, such as pilot actions, airline operations, maintenance, training programs, they must also be explored, and all of those weaknesses have to be addressed.

And I still believe that the FAA remains the gold standard in aviation safety. And once the agency certifies the fixes to the MAX, I will gladly volunteer to be the very first person, right alongside Administrator Dickson, in the very first flight of the MAX 8.

In regard to the two 737 MAX accidents, I think all of those issues need to be addressed, but only after we have had the benefit of various investigative work that has yet to be completed. Jumping to conclusions before that work is done only risks more harm than good.

The bottom line is the U.S. safety record speaks for itself. And I will stand up to anybody that tries to question that. The FAA's proven system has made air travel the safest mode of transportation in history.

And with that, I appreciate the opportunity and the deference, Mr. Chairman. And I look forward to today's hearing, and yield back anything I have left.

[Mr. Graves of Missouri's prepared statement follows:]

Prepared Statement of Hon. Sam Graves, a Representative in Congress from the State of Missouri, and Ranking Member, Committee on Transportation and Infrastructure

Thank you, Mr. Chairman. I want to extend my condolences to the families and friends of the accident victims.

It is my hope that Mr. Muilenberg's testimony today will help us understand decisions Boeing made between 2009 and 2017 regarding the design and certification of the 737 MAX. For example, as a pilot, I would also be concerned about having a piece of equipment or software in my cockpit that I didn't know about.

Some of Boeing's decisions were reviewed and approved by the Boeing Organization Designation Authorization, or ODA, Office on behalf of the FAA. While the Boeing ODA was authorized to act for the FAA, as the regulator the FAA retained ultimate responsibility for overseeing compliance with safety regulations.

Mr. Chairman, today we are hearing from Boeing leadership involved at the time of these decisions, but to get a complete picture I hope I can get your commitment to hold a committee hearing in the near future to receive testimony from the FAA officials in charge between 2012 and 2017 when decisions related to the 737 MAX certification were made and approvals granted.

As I've said before, if the various investigations reveal problems with the certification, Congress should act to fix those specific, identifiable problems. But, in the aftermath of these accidents, we can't address the safety of the aviation system by focusing on a single possible cause.

Safety experts often refer to the "Swiss Cheese Model of Accident Causation." In this model, layers of accident protection are visualized as slices of cheese, with holes representing weaknesses. Some weaknesses are due to existing conditions, and others are due to active failures. An accident occurs when holes or weaknesses in the many layers all line up.

In the context of the 737 MAX, we must consider all layers of protection and address all weaknesses discovered. As an investigator for the Indonesian Government said about the Lion Air accident, "If one of the nine contributing factors did not happen, the crash would not have happened."

One particular layer—the design and certification of the 737 MAX—is the focus of a number of investigations. Earlier this year, Boeing took responsibility for MCAS design weaknesses and has been working on a software fix. Other weaknesses Boeing, with the FAA's oversight, will address include pilot displays, operation manuals, and crew training. Today, I look forward to hearing about the status of those efforts.

I also want to hear about how these efforts line up with the recommendations of the Joint Authorities Technical Review (JATR)—the first completed review of the MAX's certification by individuals with vast aviation and technical expertise.

While the JATR did not call for an end to the FAA's delegation programs, it did highlight "bureaucratic inefficiencies" in the relationship between Boeing and the FAA. The FAA concurred with the JATR's report and has committed to working on the recommendations.

Lastly, Mr. Muilenburg, I want to hear about recently shared documents related to Boeing's former Chief Technical Pilot for the 737.

Other investigations are also moving forward, and last month the National Transportation Safety Board (NTSB) issued a Recommendation Report, which largely focused on assumptions made during the design and certification process related to human factors. But, design and certification cannot be the sole focus of our efforts. That's only one layer of the cheese.

In the last few months, other weaknesses that appear to have played a role in the accidents have surfaced.

Reports earlier this month called into question evidence submitted to the Lion Air investigation related to the installation, calibration, and testing of a faulty angle-of-attack sensor. There have also been whistleblower statements and other reports raising significant concerns with Lion Air and Ethiopian Airlines' operations and maintenance programs. The former chief engineer for Ethiopian Airlines filed a whistleblower complaint alleging significant problems with that airline's maintenance, training, and recordkeeping. He also alleges that the air carrier went into the maintenance records of the 737 MAX a day after it crashed.

Unfortunately, operational pressures and lack of a robust safety culture can negatively impact aviation safety—another layer of the cheese. The NTSB has confirmed that, along with certification, operational factors will be a focus of its accident investigations.

In addition, along with its own MAX certification review, the Department of Transportation Inspector General, at the request of this committee's leadership, will soon begin a review of international training standards and the impact of automation.

I want to be crystal clear that reviewing these areas is not an effort to blame pilots or absolve Boeing of its responsibility.

A September New York Times Magazine article describes the changing nature of the airline industry and its impact on airmanship. The article refers to "a decades-long transformation of the whole business of flying, in which airplanes became so automated and accidents so rare that a cheap air-travel boom was able to take root around the world." The boom in air travel resulted in a need for more and more pilots, but the pool of experienced pilots couldn't keep up with demand. In fact, I've gotten letters from airlines offering me jobs because my license has an ATP (airline transport pilot) on it.

I'll continue to repeat this: pilots can master cockpit technology, but when that technology fails, they must be able to fly the plane—not just fly a computer.

To be clear, none of this is a reflection on the Lion Air and Ethiopian pilots' professionalism or character. Instead, it's a reflection on the broader pressures present in today's global aviation economy.

But it is incumbent on the airline whose name is on the side of that airplane to ensure their pilots are properly trained and not rushed into the cockpit to meet those demands.

So, in line with the "Swiss cheese model," other layers of protection—such as pilot actions, airline operations, maintenance, and training programs—must also be explored and any weaknesses must be addressed.

I still believe that the FAA remains the gold standard for safety, and once the agency certifies the fixes to the MAX, I would gladly volunteer to be on the first flight alongside Administrator Dickson.

In regard to the two 737 MAX accidents, any issues should be addressed, but only after we have the benefit of various investigative work yet to be completed. Jumping to conclusions before that work is complete risks doing more harm than good.

Bottom line: the safety record speaks for itself—the FAA's proven system has made air travel the safest mode of transportation in history.

Mr. DEFAZIO. I thank the gentleman. I would now turn to the chairman of the subcommittee, Mr. Larsen.

Mr. LARSEN. Thank you, Chair DeFazio. I will be brief, because I want to get to the reason why we are here today. That is for questions to, and clear and direct answers from, Boeing.

But yesterday I did release a video opening statement, and you can find my full comments there.

But in summary I want to say this, that the 346 lives lost in Lion Air 610 and Ethiopian Airlines 302 crashes are constant reminders of the importance of this committee's work and what is at stake if we do not address systemic safety issues in U.S. aviation today.

Some of the victims' family members are here with us today. Others are watching the livestream. And your presence and tireless advocacy are critical to what we are doing today. I want to thank you for that. You deserve answers, and you rightfully expect Congress to act.

Following the recent release of recommendations from the JATR or the NTSB, the Indonesian authorities, and Boeing itself, though, I do want to say I see one undeniable conclusion: The process by which the Federal Aviation Administration evaluates and certifies aircraft is itself in need of repair.

It is no accident that there are few airplane accidents. It makes it all the more tragic when there is one. It makes it even worse when there are two.

So, as the committee's investigation continues, we should maintain safety as our guiding principle, and use all the tools at our disposal to ensure the safety of the traveling public.

With that I yield back.

[Mr. Larsen's prepared statement follows:]

Prepared Statement of Hon. Rick Larsen, a Representative in Congress from the State of Washington, and Chairman, Subcommittee on Aviation

Thank you, Chair DeFazio.

I will be brief, because I want to get to the reason why we are all here: for questions to and clear, direct answers from Boeing.

Yesterday, I released a video opening statement, where you can find my full comments.

The 346 lives lost in the Lion Air 610 and Ethiopian Airlines 302 crashes are constant reminders of the importance of this committee's work and what is at stake if we do not address the systemic safety issues in U.S. aviation today.

Some of the victims' family members are with us today and others are watching the livestream. Your presence and tireless advocacy are essential to our process.

You deserve answers and rightfully expect Congress to act.

Following the recent release of recommendations from the JATR, NTSB, Indonesian authorities and Boeing itself, I see one undeniable conclusion: The process by which the Federal Aviation Administration evaluates and certifies aircraft is itself in need of repair.

As the committee's investigation continues, we will maintain safety as our guiding principle and use all the tools at our disposal to ensure the safety of the traveling public.

Thank you.

Mr. DEFAZIO. I thank the gentleman. I now turn to the ranking member on the Subcommittee on Aviation, Mr. Graves from Louisiana.

Mr. GRAVES OF LOUISIANA. Thank you, Mr. Chairman, and thank you for holding this hearing today.

Yesterday was 1 year since the Lion Air tragedy. And I, too, want to join everyone sitting up here in offering our condolences to all of the Ethiopian family victims, the Indonesian family victims.

Here we are in Washington. And everybody in this town—everybody, nearly, in this town, you sit up here and you are dealing with billions and trillions of dollars and all these crazy acronyms and processes, and none of it often makes sense, or fits the common sense test. And oftentimes you see people that just forget about objectives. Why are we actually doing this? What is the purpose of this whole process that we go through, the regulations, the procedures? Why?

And at the end, it is always about people. That is what we are here for. We are here for people, for fellow Americans, fellow citizens. And it is amazing to me, just being here, how often that is forgotten.

I am sorry to every one of you, and your pictures are incredibly powerful.

You know, I used to be a rock climbing instructor. And when we would go out there, we would have somebody's son or daughter, somebody's brother or sister. And when you are out there, rock climbing, look, there is no room for error. None. You lose somebody on a rock, there is no room for error. Air travel is the same thing.

There is no room for—you can't, "Oh, we are going to pull over to the side of the road and see what is going on. I hear a noise coming out of the engine." That is not an option. This process has got to stay focused on the risks that air travel poses, the fact that you can't pull over to the side of the road, that you have got to have redundancies.

And look, there is an awful lot going on right now with all of the different reports, investigations that are going on, and I am going to run through those in a minute. But there is an awful lot going on.

But, for example, if there truly was one AOA sensor that could potentially engage MCAS, that is not the proper redundancies. And when you are looking at the risk that is posed in this case, it is unacceptable. It is unacceptable.

A while back I had the chance to represent the State of Louisiana in the *Deepwater Horizon* disaster, and spent a lot of time with the families there, and spent many days in the court, listening to testimony. And I do believe, and I think that the judge found, that there was an inappropriate culture of focusing on the wrong objectives. And oftentimes people can be looking at stock prices, or economics, or how many people can we fit in here, or how fast can this jet travel, or what have you. I am going to say it again: This is 100 percent about people.

And I have heard people talk about this whole process and say that, well, this process was short-circuited. Well, you know, you can look back, and you can look at the 737–6. –7, –8, –9, you can look at the A319, A320, A321, the E190, E195, the C919, and many versions of those aircraft. And you know what? Every single one of those actually was certified or approved in a shorter period of time

than the MAX. So it is not just about how long, it is what we actually do during that process.

What are we doing during the process to make sure that this is a safe aircraft, to make sure that we are not putting folks at undue risk?

Now, I have heard a lot of people talk about a lot of different ideas, and solutions, and things that they want to do as we move forward, and people posing solutions right now. And certainly we need to extract every single lesson learned that we can.

But right now—and I somehow ditched my list—right now we have investigations, the Indonesian authorities, the Ethiopian authorities, the NTSB, we have the JATR, we have the Technical Advisory Board, the TAB. We have the Office of Special Counsel that is working with the whistleblower complaint. We have the Secretary of Transportation that set up a special committee. Boeing is doing an internal investigation. We have so many different investigations that are going on.

One thing that we have got to make sure that we do is focus on facts. One thing that I have seen in this body in the 4½ years that I have been here is us responding emotionally to things, and not responding to facts. And we will go and do something that may make us feel good, but does not—does not—actually respond to the facts.

And so, as we move forward—and I am sure I left out some of the investigations that are ongoing—but as we move forward, we have got to make sure that we are acting on the facts. And every single outcome, every single problem that we have identified, we have got to make sure that we truly base our solutions on those facts to where this doesn't happen again.

Lastly, Mr. Chairman, the families shared a number of concerns that I think are right on. And I do want to ask that Boeing get back to us on these. And it was things like fully disclosing the MCAS fix before the plane is allowed to fly, if it is allowed to fly again; fully defining the role of the MCAS system. All right, all right, I will submit——

Mr. DEFAZIO. I would suggest——

Mr. GRAVES OF LOUISIANA. I will.

Mr. DEFAZIO. You could submit those for the record, or you could ask during the question period.

Mr. GRAVES OF LOUISIANA. Thank you. I yield back.

[Mr. Graves of Louisiana's prepared statement follows:]

Prepared Statement of Hon. Garret Graves, a Representative in Congress from the State of Louisiana, and Ranking Member, Subcommittee on Aviation

Thank you, Mr. Chairman.

Yesterday was the anniversary of the Lion Air tragedy, and I want to let the families of those lost in that incident and in the Ethiopian crash know that I'm keeping their loved ones in mind as I sit here today.

Here in Washington, we all regularly talk about budgets in the billions of dollars, and a soup of acronyms, processes, and programs. Sometimes it can be easy to forget why we're really here—what all these processes and programs are for. This is about people. That's truly why we are here, and we can't lose sight of that throughout this process.

So it's thinking of those we lost that motivates me to ensure that we, as members of both this committee and of the Congress, are thoughtful about our role in the aftermath of these incidents.

I'm pleased that Boeing is here today to tell us how the development of MCAS evolved, and the flaws in that process. We know from NTSB's preliminary recommendations that certain incorrect assumptions and incomplete reviews of how multiple systems interact allowed those flaws to become fatal. We know this from the results of some of the expert investigative work that has been completed to date.

In air travel, there is no room for error, and that's why it's critical to have safety redundancies. We are closely reviewing the results and recommendations from the investigations which have already wrapped: FAA's Joint Authorities Technical Review (JATR); NTSB's, which has issued preliminary recommendations; Boeing's internal review, which yielded recommendations that are already being implemented; and the Indonesian accident report, released late last week.

It's my hope that the committee will hear from and consider the findings of the yet-to-be-concluded certification and accident investigations so that we can make sure we know what went wrong and leverage those findings and recommendations to ensure something like this doesn't happen again.

I also hope we hear from FAA officials who were in charge of the agency when the certification process for this aircraft was conducted and its type certificate approved. This information will crucially inform the committee on our next steps.

We certainly need to extract every single lesson learned so far, but it's critical that we also take into consideration the many ongoing investigations into these accidents when we have their results: the Ethiopian accident report, Secretary Chao's special committee, the DOT Inspector General's reports, and several other international reviews.

It is very important that we wait for these experts to complete their work and carefully review their findings and recommendations. Once we have a better understanding of what happened and all the factors involved, we will ask ourselves: what changes do we need to make to ensure the highest levels of safety and prevent future accidents?

As Congress, we have to act on facts—not on emotion—to address every single problem identified so that this doesn't happen again. But acting before we know the whole picture is both a disservice to those we lost and dangerous to those who will fly in the future.

Mr. DEFAZIO. I thank the gentleman.

With that we will turn to the witness for an opening statement.

TESTIMONY OF DENNIS MUILENBURG, PRESIDENT AND CHIEF EXECUTIVE OFFICER, THE BOEING COMPANY; ACCOMPANIED BY JOHN HAMILTON, CHIEF ENGINEER, BOEING COMMERCIAL AIRPLANES

Mr. MUILENBURG. Chairman DeFazio, Ranking Member Graves, Congressman Larsen, Congressman Graves. Thank you. And to the whole committee, we appreciate the opportunity to be here today, and we are going to do our best to answer all of your questions.

Before we get started, I too would like to acknowledge the families that are here with us today and, again, wanted to tell you I am sorry. And I have had the opportunity to talk with some of you and hear your stories, and we are deeply, deeply sorry, and we will never forget. And I want you to know that. And we are committed to making the improvements that we need to make. We are committed.

And I had the chance to hear some of those stories, and see the photos, and listen to the personal stories, and it does get to a business that is about people. And I think Congressman Graves said it well. That is where our hearts will always be. And I know all of Boeing, our 150,000 people, feel the same way, and they think about this every day. We will carry the memories——

Mr. LYNCH. Can you speak a little closer into your microphone?

Mr. MUILENBURG. Yes, sir.

Mr. LYNCH. Just so—a little more audible. Thank you.

Mr. DEFAZIO. Yes, again, just pull it toward you, Mr. Muilenburg.

Mr. MUILENBURG. Is that better? Thank you. Sorry. Please know that we carry the memories of these accidents with us, and the loved ones, the memories of them, they will never be forgotten. And their memories will drive us every day to make our airplanes safer and make this industry safer. And we are committed to doing that.

I am grateful to have the opportunity to be here today to say this to the families personally. And I want to let you all know that we are dedicated to learning. We are learning. We still have more to learn. We have work to do to restore the public's trust, and we will do everything possible to prevent accidents like this from ever happening again.

Mr. Chairman, I know this committee has many questions about the MAX, and we will do our best to answer those today.

And while investigations are still underway, we note both accidents involved the repeated activation of a flight control software system called MCAS, which we have already talked about. That system responded to erroneous signals from the angle-of-attack sensor.

Based on that, we have enhanced MCAS in three ways. First, it will now compare information from both sensors, instead of one, before activating. Second, MCAS will only activate a single time. And third, MCAS will never provide more input than the pilot can counteract using the control column alone. Pilots will also continue to have the ability to override MCAS at any time.

We have brought the best of Boeing to this effort. We have spent over 100,000 engineering and test hours. We have flown more than 800 test flights. And we have conducted simulator sessions with 545 participants from 99 customers and 41 global regulators. I have flown on a couple of flights myself. This has taken longer than expected, but we are committed to getting it right.

During this process we have worked closely with the FAA and other regulators. We have provided them with documentation, had them fly the simulators, answered their questions. And regulators around the world should rigorously scrutinize the MAX and only approve its return when they are completely satisfied with its safety. The public deserves nothing less.

Mr. Chairman, today and every day, over 5 million people will board a Boeing airplane and fly safely to their destination. Decades of cooperation and innovation by industry and regulators and the rigorous oversight of this committee have reduced accidents by more than 95 percent over the last 20 years. But no number other than zero accidents is ever acceptable. We can and must do better.

We have been challenged and changed by these accidents. We have made mistakes, and we have learned, and we are still learning. And we are improving. We established a permanent aerospace safety committee for our board. We have stood up a new safety organization, and we strengthened our engineering organization so that all 50,000 engineers now report up through Boeing's chief engineer.

We are also helping to rebuild the communities and the families impacted by these accidents. We have pledged $100 million to this effort. We have hired renowned experts in this area to ensure families can access these funds as quickly as possible. No amount of money can bring back what was lost. But we can at least help the families meet their financial needs.

Mr. Chairman, I started at Boeing more than 30 years ago as a summer intern in Seattle. I was a junior at Iowa State University studying engineering, and I had grown up on a farm in Iowa. My parents taught me the value of hard work and integrity. I was awestruck to work at the company that brought the jet age to the world and helped land a person on the moon. Today I am still inspired by what Boeing does, and by the remarkable men and women who are committed to continuing its legacy. But these heartbreaking accidents and the memories of the 346 lives lost are now a part of that legacy. It is our solemn duty to learn from them, and we will.

Recently there has been much criticism of Boeing and our culture. We understand and deserve this scrutiny. But I know the people of Boeing. They are more than 150,000 of the hardest working, most dedicated, honest people you will ever meet. And their commitment to safety, quality, and integrity is unparalleled, and it is resolute. We will stay true to those values because we know our work demands it. It demands the utmost excellence.

So thank you for this opportunity to convey to the world that we are committed to changing, and to making sure that accidents like these never happen again.

Mr. Chairman, thank you for listening. And I look forward to your questions.

[Mr. Muilenburg's prepared statement follows:]

Prepared Statement of Dennis Muilenburg, President and Chief Executive Officer, The Boeing Company

Chairman DeFazio, Ranking Member Graves, members of the committee: good morning and thank you for inviting me to be here today.

I'd like to begin by expressing my deepest sympathies to the families and loved ones of those who were lost in the Lion Air Flight 610 and Ethiopian Airlines Flight 302 accidents, including those who are here in the room today. I wanted to let you know, on behalf of myself and all of the men and women of Boeing, how deeply sorry I am. Please know that we carry the memory of these accidents, and of your loved ones, with us every day. They will never be forgotten, and these tragedies will continue to drive us to do everything we can to make our airplanes and our industry safer.

Mr. Chairman, I know that you and your colleagues have many questions about the 737 MAX. My colleague John Hamilton, Chief Engineer for Boeing Commercial Airplanes, and I will do our best today to answer them. While the Ethiopian Airlines accident is still under investigation by authorities in Ethiopia, we know that both accidents involved the repeated activation of a flight control software function called MCAS, which responded to erroneous signals from a sensor that measures the airplane's angle of attack.

Based on that information, we have developed robust software improvements that will, among other things, ensure MCAS cannot be activated based on signals from a single sensor, and cannot be activated repeatedly. We are also making additional changes to the 737 MAX's flight control software to eliminate the possibility of even extremely unlikely risks that are unrelated to the accidents.

We have brought the very best of Boeing to this effort. We've dedicated all resources necessary to ensure that the improvements to the 737 MAX are comprehensive and thoroughly tested. That includes spending over 100,000 engineering and

test hours on their development. We've also flown more than 814 test flights with the updated software and conducted numerous simulator sessions with 545 participants from 99 customers and 41 global regulators. This process has taken longer than we originally expected, but we're committed to getting it right, and return-to-service timing is completely dependent on answering each and every question from the FAA.

I have flown on two of the demonstration flights myself and seen first-hand the expertise and professionalism of our teams. Mr. Chairman, I could not be more confident in our solutions—and I could not be more grateful to the men and women who have worked so hard to develop and test these improvements always with safety at the forefront. When the 737 MAX returns to service, it will be one of the safest airplanes ever to fly.

During this process we have been working closely with the FAA and other regulators. We've provided documentation, had them fly the simulators, and helped them understand our logic and the design for the new software. All of their questions are being answered. Regulators around the world should approve the return of the MAX to the skies only after they have applied the most rigorous scrutiny, and are completely satisfied as to the plane's safety. The flying public deserves nothing less.

We know that it's not just regulators that need to be convinced. We know the grounding of the MAX is hurting our airline customers, their pilots and flight attendants, and most importantly, the people who fly on our airplanes. Our airline customers and their pilots have told us they don't believe we communicated enough about MCAS—and we've heard them. So we have partnered with customers and pilots from around the world as we've developed our solutions. We have welcomed and encouraged their questions and given them opportunities to test those solutions firsthand in simulators. And subject to regulatory approval, additional and enhanced training and educational materials will be available for pilots who fly the MAX.

We have learned and are still learning from these accidents, Mr. Chairman. We know we made mistakes and got some things wrong. We own that, and we are fixing them. We have developed improvements to the 737 MAX to ensure that accidents like these never happen again. We also are learning deeper lessons that will result in improvements in the design of future airplanes. As painful as it can be, the process of learning from failure, and even from tragedies like these, has been essential to the advances in airplane safety since the industry began roughly a century ago. And it is one of the reasons that travel on a large commercial airplane is the safest form of transportation in human history.

Mr. Chairman, this is something we must not lose sight of. Today and every day, over 5 million people will board a Boeing airplane and fly safely to their destination. Whether it's their first flight or their millionth mile, we want it to be a great experience—and most importantly, a safe one. Decades of work and innovation throughout the industry, as well as the oversight of the FAA, this committee, and regulators around the world have reduced the risks of air travel by more than 95 percent over the last twenty years. But no number, other than zero accidents, is ever acceptable.

For 103 years, Boeing has been dedicated to making the world a safer and better place. Our founder, Bill Boeing, established our first safety council in 1917, the first full year of the company's existence, beginning a commitment to safety that we have carried forward as a core value ever since. The engineers who design our airplanes, the machinists who work in our factories, and the many others who contribute to the extraordinarily complex work of building and maintaining commercial airplanes do so with pride and honor. Ensuring safe and reliable travel is core to who we are. Our customers and the traveling public, including our own families, friends, and loved ones, depend on us to keep them safe. That's our promise and our purpose.

But we also know we can and must do better. We have been challenged and changed by these accidents, and we are improving as a company because of them. We established a permanent aerospace safety committee of our Board of Directors; stood up a new Product and Services Safety organization that will review all aspects of product safety and provide streamlined reporting and elevation of safety concerns; and strengthened our Engineering organization by having all engineers in the company report up through Boeing's chief engineer. We also are investing in advanced research and development in new safety technologies and are exploring ways to strengthen not just the safety of our company but our industry as a whole. We have a shared bond of safety across the entire aerospace community.

We recognize it is not just our airplanes and our company that needs to be supported and strengthened. We also must help rebuild the communities and families affected by these accidents. Our first step was our pledge of $100 million to them. We hired Ken Feinberg and Camille Biros, renowned experts in this area, to ensure families can access this money as quickly as possible. Of course, no amount of

money can bring back what has been lost. But we can at least help families meet their financial needs. Our people also have donated more than $750,000 of their own money to these funds—a tremendous example of the giving spirit our teams consistently display in the communities where they live and work across the globe.

Mr. Chairman, I've worked at Boeing my entire career. It started more than 30 years ago when Boeing offered me a job as a summer intern in Seattle. I was a junior at Iowa State University studying engineering, having grown up on our family farm in Iowa. It's beautiful land with rolling hills where my siblings and I milked cows and baled hay. Our parents taught us the value of hard work, integrity, and respect for others. Back then, I drove my 1982 Monte Carlo from Iowa to Boeing's operations in Seattle, crossing the Rocky Mountains for the first time. I was awestruck at the opportunities I had to work on projects that mattered at the company that brought the Jet Age to the world and helped land a person on the moon. I was amazed by the people of Boeing. Today, I'm still inspired every day by what Boeing does and by the remarkable men and women who are committed to continuing its legacy.

These heartbreaking accidents—and the memories of the 346 lives lost—are now part of that legacy as well. It's our solemn duty to learn from them and change our company for the better. I can assure you that we have learned from this and will continue learning. We have changed from this and will continue changing. The importance of our work demands it.

In the months since the accidents, there has been much criticism of Boeing and its culture. We understand and deserve this scrutiny. But I also know the people of Boeing, the passion we have for our mission, and what we stand for. There are over 150,000 dedicated men and women working for Boeing around the world—and their commitment to our values, including safety, quality, and integrity, is unparalleled and resolute. No matter what, we will stay true to those values because we know our work demands the utmost excellence.

Over the last few months, I've had the opportunity to visit many of our Boeing teams, talk about our safety culture, and gain ideas for how we can be better still. Last week, I saw our team in San Antonio—made up of 40 percent veterans—beaming with pride as they support the C-17 fleet for our men and women in uniform. Earlier, I talked with our people in Philadelphia building Chinook helicopters; in St. Louis testing F/A-18 Super Hornets; and in Charleston, South Carolina, and El Segundo, California, connecting the world with the 787 Dreamliner and advanced satellites. I've also met with our people in Huntsville, Alabama, and New Orleans, Louisiana, who are building the rocket that will return humans to the moon and then travel on to Mars and those at Kennedy Space Center, Florida, who are preparing to launch the CST-100 Starliner that will commercialize space travel. I've spent time also with our teams in Everett, Washington, who are testing the new 777X long-range jet and in Renton, Washington, where 12,000 amazing people pour their hearts into building the 737 MAX. These are the people of Boeing. I wish you could all meet them. They change the world. They are Boeing.

I'm here today, honored to serve as the leader of this incredible team—talented engineers, machinists and all those who design, build and support our products. I want to answer all of your questions and convey to the world that we are doing everything in our power to make our airplanes and our industry safer and prevent an accident like this from ever happening again.

And, Mr. Chairman, you have my personal commitment that I will do everything I can to make sure we live up to that promise.

Thank you for listening, and I look forward to your questions.

Mr. DEFAZIO. I thank the gentleman. As I stated at the outset, with consultation with the minority, both myself and Mr. Graves will open with 10 minutes, and then we will move to other Members for 5 minutes in the usual order.

Mr. Muilenburg, it is clear, obviously, from everything we know, and the Lion Air report now, that MCAS was a major factor that contributed. But Boeing's position, at least prior to these crashes, was it was an autonomous system and it operated in the background. Is that correct?

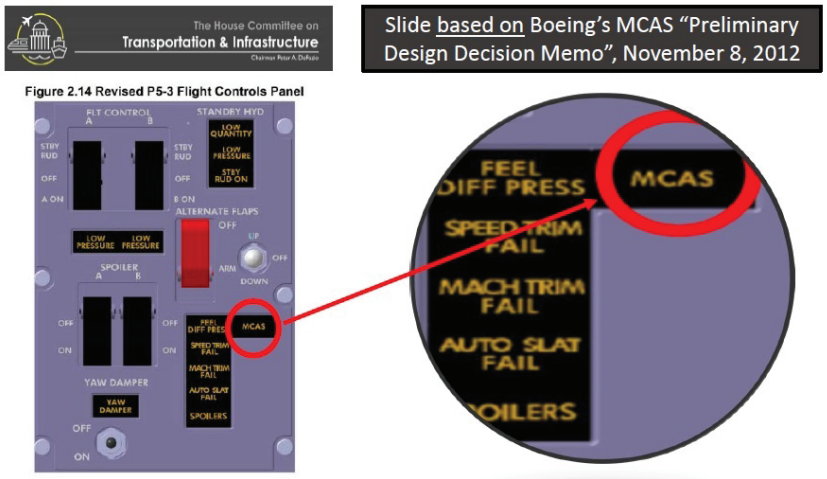
Mr. MUILENBURG. Mr. Chairman, that was the design approach, yes.

Mr. DEFAZIO. Yes. So—but the question is, how do we get to that?

And we have a slide. You will be able to see it right in front of you.

Staff?

[Slide]



Mr. DEFAZIO. Yes, this was a concept design for the flight deck in 2012. And, as you can see in the bottom, right-hand corner, there was an MCAS alert indicator. So at least at some point some on the engineering and design staff felt it would be important to make the pilots aware of the system, and to have an indicator light. Do you agree that that was originally proposed?

Mr. MUILENBURG. Congressman, understand that was part of an early trade study at that point, and very, very common that early in the design stage we would evaluate different flight deck systems.

Mr. DEFAZIO. OK, thank you. So—but obviously, the final version did not have that. That light was—I mean there was no indication, either in the manual or on the flight deck, of the presence of MCAS.

Mr. MUILENBURG. Congressman, John can answer that question.

Mr. HAMILTON. Yes, Chairman. The MCAS light issue pointed out, the intent of it was to signal an MCAS failure. It is important to note that in these accidents the MCAS system did not fail.

Mr. DEFAZIO. Right, it triggered.

Mr. HAMILTON. And it would not have lit up.

Mr. DEFAZIO. So—but it was——

Mr. HAMILTON. But the functionality of the MCAS light was actually—the reason it was deleted was because the functionality was incorporated into the speed trim fail light, which——

Mr. DEFAZIO. Right.

Mr. HAMILTON [continuing]. You can see just adjacent to that.

Mr. DEFAZIO. Right.

Mr. HAMILTON. The MCAS is a——

Mr. DEFAZIO. OK. Thank you.

Mr. HAMILTON [continuing]. Extension of a speed——

Mr. DEFAZIO. Thank you. Thank you for that. But when it was a relatively benign system, .6 degrees, it was in the manual. And then when it went to a repeated 2½ degrees, it came out of the manual. Is that correct?

I have seen very early versions of the manual that indicate that you had MCAS in the manual. Your test pilot asked FAA to take it out, and it came out.

Mr. MUILENBURG. Congressman, if I could try to clarify, because you are asking questions that span into a couple of areas, just if I could clarify——

Mr. DEFAZIO. Well——

Mr. MUILENBURG. So there was—the intent—the MCAS inclusion in the training manual, that was an iterative process that was occurring in parallel to the extension of MCAS to low-speed operation, which I believe is what you are referring to.

Mr. DEFAZIO. Right.

Mr. MUILENBURG. So the extension of MCAS to low-speed operation, that was done and flight tested from a period of around the middle of 2016——

Mr. DEFAZIO. Right. Yes, we understand that, and we understand some of the problems in the way it was tested, and it wasn't tested with the AOA failure. But that is good for now.

A key assumption was reaction time. And, with the AOA failure, the MCAS activates, and it is 2.5 degrees every 10 seconds, pretty radical. And Boeing assumed it would take pilots 4 seconds to recognize and react to runaway stabilizers, is that correct?

Mr. MUILENBURG. Mr. Chairman, again, this—we do what we call hazard analysis for the airplane design.

Mr. DEFAZIO. Four seconds was the assumption.

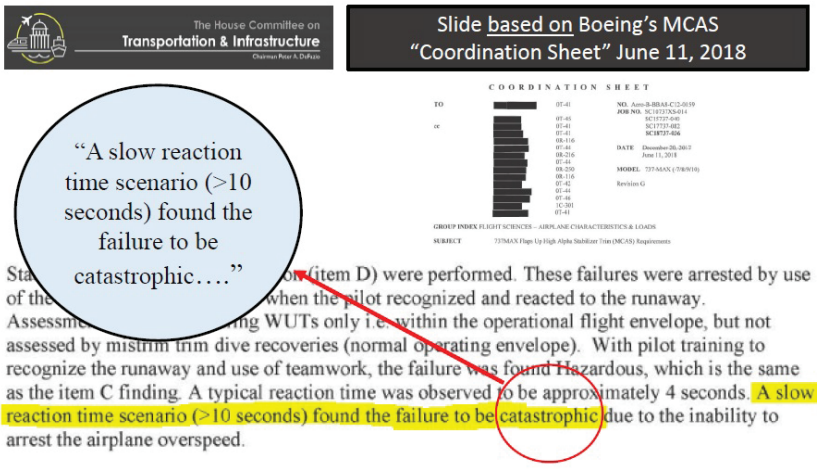
Mr. MUILENBURG. In this particular case that was the assumption. That is a——

Mr. DEFAZIO. OK.

Mr. MUILENBURG [continuing]. Longstanding industry assumption for systems like this.

Mr. DEFAZIO. Right. Lion Air reports—says it took pilots 8 seconds to react. And then we have information provided to the committee by Boeing, which will now be the second slide.

[Slide]



Mr. DEFAZIO. And it says there a slow reaction time scenario, 10 seconds, found the failure to be catastrophic. Do you think that was clearly—was this document ever clearly communicated to the regulators, that a 10-second delay, which doesn't seem like a lot of time to me, particularly when you look at the NTSB report and the cacophony going on on the flight deck, and particularly in the case of Lion Air, when they didn't even know the system existed, did—was the FAA aware of this, this document?

Mr. MUILENBURG. Chairman, I can't speak to this specific document.

Mr. DEFAZIO. OK.

Mr. MUILENBURG. John may be able to.

But I do think it is important to note that, as part of the design process, we use a set of industry standard practices on these timelines. This is a common part of our hazard analysis——

Mr. DEFAZIO. Yes, but you——

Mr. MUILENBURG. That was shared with the FAA——

Mr. DEFAZIO. Right. I understand. And I understand what the industry standard was. But, I mean, it does cause a little concern. Ten seconds. I mean, you can say, "Gee, really good pilots can do it in less than 10 seconds." Pilots aren't at the top of their game every day, and particularly in the first iteration, at least, when they weren't even aware of the system. I think that assumption should have rung some alarm bells.

Do you think, in retrospect, it was a mistake to not inform pilots of the existence of the MCAS system?

Mr. MUILENBURG. Congressman, a few things on that. And I agree, we made some mistakes on MCAS. And as we have gone back and taken a look at this, moving from a single sensor to a dual sensor feed is an important part of that. Providing additional training information——

Mr. DEFAZIO. Right.

Mr. MUILENBURG. Which—the feedback we have gotten from the pilots, as you noted, is part of that. And then revisiting these dec-

ades-long industry standards. I think you see a similar recommendation out of the——

Mr. DEFAZIO. Right. Of course——

Mr. MUILENBURG. We believe——

Mr. DEFAZIO. The question would be why was it just originally wired to one sensor, which—again, single point of failure. As then-Acting Administrator Elwell said in May, a safety critical system, that is just not done.

As the NTSB said, multiple alerts and indication can increase pilots' workload. The combination of the alerts and indications did not trigger the accident pilots to immediately perform the runaway stabilizer functions.

OK. Mr. Hamilton, are you aware of any other aircraft out there that has a safety critical system that is dependent upon a single point of failure?

Mr. HAMILTON. Chairman, single-point failures are allowed in airplane design. Regulation 25.1309 actually discusses that, and talks about different hazard categories. And——

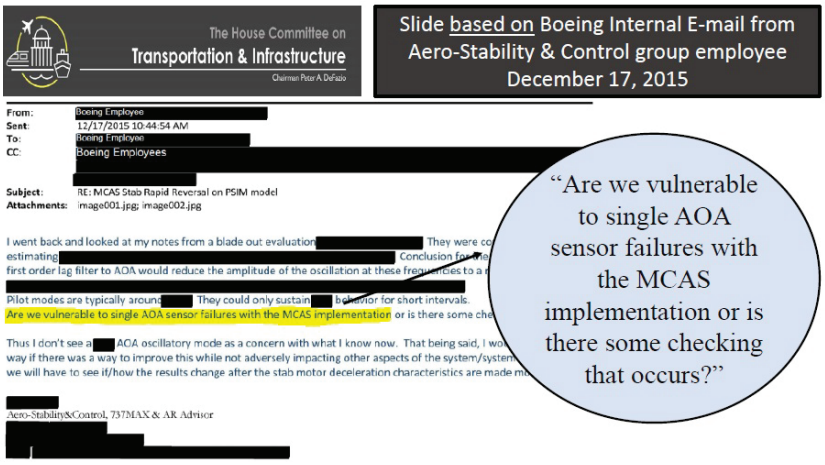
Mr. DEFAZIO. And this one——

Mr. HAMILTON. We have——

Mr. DEFAZIO. This one was deemed to be catastrophic. I know there are three categories. You didn't deem it to be catastrophic, although, in looking at the 10 seconds, you said it was catastrophic. It was classified as major, as I recall.

Mr. HAMILTON. Yes, catastrophic is one category. And so when we test out systems, we do look at their impact on the airplane when there are failures. And we did look at 10 seconds, but we also then took it into the simulator with pilots, and the typical reaction time was 4 seconds——

[Slide]



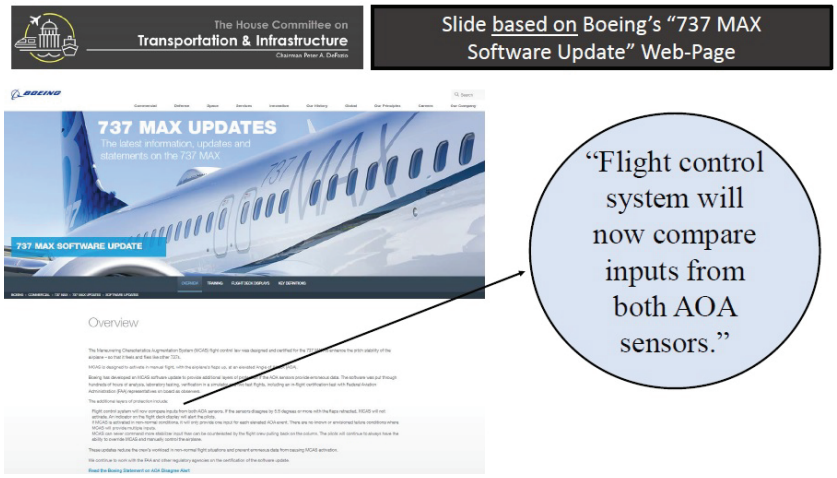
Mr. DEFAZIO. I put up another document. It is right in front of you there. And 12–17–2015, I don't know if you are aware of this, but this was raised by one of your engineers. "Are we vulnerable to single AOA sensor failures with the MCAS implementation or is there some checking that occurs?"

Did you ever receive this communication, and did you respond to that engineer?

Mr. HAMILTON. Chairman, I did not actually receive this communication, but I am aware of the communication recently as it surfaced. In talking with the engineer, I think it highlights that our engineers do raise questions in an open culture. They question things. But it also followed our thorough process, and was determined that the single sensor, from a reliability and availability standpoint, met the hazard category and the safety——

Mr. DEFAZIO. Well, of course, we don't know what happened in Ethiopia, but there is some speculation a bird sheared it off. They are pretty delicate little things out there, actually. I have seen them.

[Slide]



Mr. DEFAZIO. And now, of course—a final slide here is now, as you emphasize, flight control will now compare inputs from both AOA sensors. And I guess the question is why wasn't it that way from day one?

Mr. MUILENBURG. Mr. Chairman?

Mr. DEFAZIO. Why wasn't it that way from day one? If you can do it now, with an extra wire, or a software fix, or whatever, why didn't you do it from day one? Why not have that redundancy?

Mr. MUILENBURG. Mr. Chairman, we have asked ourselves that same question over and over. And if back then we knew everything that we know now, we would have made a different decision.

The original concept, from a safety standpoint, was to build the MCAS, extend the current speed trim system on the previous generation of 737. That is a system that had about 200 million safe flight hours on it. So one of our safety principles is to take safe systems, and then incrementally extend them. That was the safety concept behind the original decision.

Mr. DEFAZIO. All right. Well, thank you.

Mr. MUILENBURG. We learned since then.

Mr. DEFAZIO. Right.

Mr. MUILENBURG. And that is——

Mr. DEFAZIO. My time——

Mr. MUILENBURG [continuing]. When we moved to this new design.

Mr. DEFAZIO. Sure. My time has expired, and I want to turn to the ranking member.

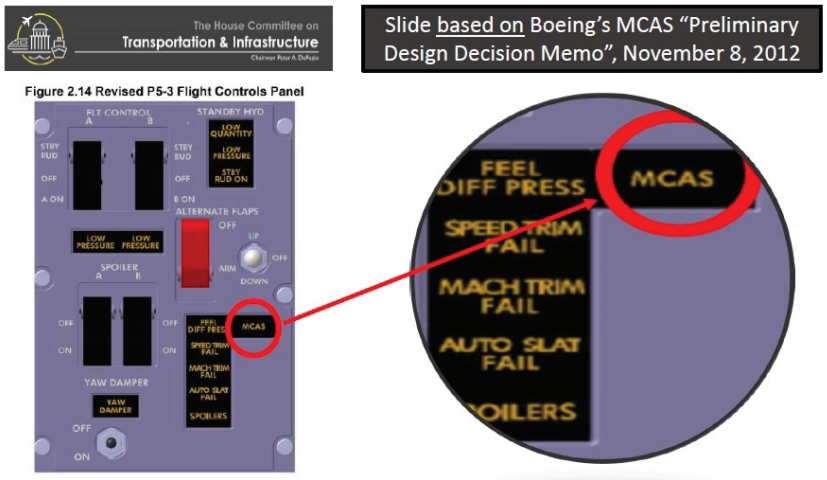
The ranking member, Mr. Graves, is recognized.

Mr. GRAVES OF MISSOURI. It is hard to know where to start.

Now I want to go back to the—just kind of for clarification—to that first slide with the MCAS, can we bring that up?

Mr. DEFAZIO. Just bring that first slide back up, please, for Sam, the one that shows the flight deck with the MCAS.

[Slide]



Mr. DEFAZIO. There.

Mr. GRAVES OF MISSOURI. The MCAS warning light, to me, would be—this is, I guess, more of an editorial comment. Have you ever been in your car and the check engine light comes on? And we are—"What the heck?" OK. So what is it? Is it the oil pressure? Is it the oil temperature? Is it the vacuum? I don't know what it is. It is just a general check engine.

And the stuff that is more important to me, you know, is the stuff that is on the left, because MCAS manifests itself as a trim issue. It is a runaway trim issue, which, again, I go back to training.

And you have memory items. Every pilot is—I shouldn't say that—in the United States, pilots are taught to have memory items. You instantly go through those when you have a failure. You start through that checklist in your mind. And we have—some of them are even goofy little rhymes, or whatever, to help you remember. And you go through each one of these processes.

In the case of Ethiopian Air—I still come back to this, too—they never retarded the throttles. They set the throttles for takeoff, and they never pulled them back. They went right through the maximum certified speed of 736 or 737 MAX 8, right on through, right up to 500 miles per hour, way beyond the maximum certified

speed. That is the reason they can't manually trim the airplane, is because it is going so fast.

And I have used that analogy, too. Go down the road at 70 miles an hour. Try opening the door. See if you can open the door, and see what the pressures are against the door of your car. The more pressure there is, the faster you are going, the more pressure there is, and the harder it is to try to reverse those pressures.

But you go through those memory items, and you immediately start ticking down. And the chairman is right, in terms of, what is the average, you know? Is it 4 seconds to react, 10 seconds to react?

And I guess that is one of the flaws that we need to be thinking about is, I guess we are going to have to start building airplanes to the least common denominator in terms of—and that is a poor choice of words, I guess you might say, but the least common denominator in terms of, internationally, we have got to start thinking about—if we are going to export, we are going to have to start thinking about international training standards.

And I know that is one of the things that is being looked at, in how they train. Did they have those memory items? Could they tick them off? Most pilots will sit there, and they will do it in the shower. You go through your memory items. I do it all the time in the shower, just sit there and tick through my memory items on engine failure, trim failure, whatever those might be.

But I guess we are making assumptions, and the FAA is making assumptions, manufacturers are making assumptions about pilot training experience. And in the aftermath of these two accidents—and I am going to—this question is for Mr. Muilenburg—do you believe that these assumptions, particularly for aircraft that are going to be operated outside of the United States, do we need to revisit those assumptions?

Mr. MUILENBURG. Congressman, we believe we need to go take a look at those longstanding industry assumptions. As you well point out, those are used across manufacturers, not just Boeing. And these are things that have produced safe airplanes for decades. But we do believe that it is appropriate to go take a hard look at those. We may need to make some revisions.

I think the JATR report has identified the same thing, and we think that would be a good area for us all to look at on behalf of aviation safety. We are committed to doing that and supporting that study.

And one of the areas for the future that we are investing in is we think about pilot-machine interface, and how to do that most effectively. And, as you pointed out earlier, a large generation of new pilots will be needed over the next 20 years, and we need to be thinking about designing our airplanes for that next generation.

Mr. GRAVES OF MISSOURI. With the benefit—and it is always dangerous to—because hindsight is always 20/20, but knowing what you know now, would the Boeing Company have done things differently? Would you have done things differently, in terms of certification of the 737 Max?

Mr. MUILENBURG. Congressman, yes, we would have. We have learned, as I mentioned earlier, we made some mistakes. We discovered some things we didn't get right. And we own that. We are

responsible for our airplanes. Any accident with one of our airplanes is unacceptable. And that is our responsibility. We own it. We are going to fix it. We know what needs to be done. And that is where we are focused, going forward.

Mr. GRAVES OF MISSOURI. I am going to make a comment here, and this is—it is as a result of this. And the unfortunate part is we lost life. We lost loved ones, friends, and life was lost as a result of these accidents. And, you hope that it is never going to happen again. The unfortunate reality is one of these days it will happen again.

But I have harped on this, and this is something that concerns me. And I have talked, too, about the difference in the United States in pilot training, and pilot training in other countries. But something that concerns me, and I want everybody to hear this. In the United States, what I am afraid of is we are going down the same direction that we are seeing in other countries when it comes to getting pilots to the point where they can fly.

No matter what, we can build the most perfect airplane that is never going to cause a problem, or it is never going to get itself into a bad situation. And sure enough, sooner or later, it is going to get into a bad situation, and it is going to require a pilot to figure out what is wrong, and then to come back and fly that airplane.

But here in the United States, I think we are dumbing down. And again, this is a criticism of our system, because this is what I am afraid we are going to. And I want to think about this as we move forward, because I think it needs to be addressed. But in the United States, we taught spin training and stall training in your basic piloting skills for your private pilot's license. Before you get commercial, before you get your airline transport rating, you are taught—or you were taught—basic stall characteristics and how to get out of a spin.

Today you can't do that. An instructor is not allowed to let a stall fully develop. At the first warning—this is what it states in the book—at the first warning of a stall, they have to recover or they fail their check ride immediately. That means if the light comes on, or if the buzzer goes off, they have to recover immediately. They can't let that stall develop.

So we're teaching them how to—and this is happening in other countries, because many countries do base their system off our system, as well, but sooner or later you are going to get an airplane into a stall. But we are not teaching anybody how to get out of that stall and how to recognize it. We are teaching them how to not get into it. Well, that is never going to happen. Sooner or later, you are going to get into a problem.

And this concerns me because we have changed. We have rewritten our—and I have got a problem with the FAA allowing this, but we have rewritten our instruction manuals to not allow this to happen, to not allow these items that will ultimately happen. We aren't teaching pilots how to fix them, how to correct them, how to get out of them, how to save the people that are in the plane with them, heaven forbid that should happen. Again, that is me harping because it concerns me, and it concerns me in a big way. The United States is behind other countries in, ultimately, going down that road. And I think we have to get back to basic piloting.

And there is nothing wrong with technology. I think technology is great. But the most important safety component in any airplane is a pilot that can fly the damn plane, and not just fly the computer.

I think I have got a minute left. Actually, I will just yield back.

Mr. DEFAZIO. OK, I thank the gentleman. I now recognize the—how do we do this, in order of—OK. We do this in order of seniority and appearance. And so first would be Ms. Norton.

Ms. NORTON. Thank you very much, Chairman DeFazio. I can't say enough about the importance of this hearing.

I appreciate you, Mr. Muilenburg, being here. Ranking Member Graves asked had you flown—I think you even said in your testimony that you had flown on the 737 MAX since the fixes or corrections have been made. That is your testimony?

Mr. MUILENBURG. Ma'am, yes. I have flown on a couple of test flights as part of that——

Ms. NORTON. Test flights. I understood those to be test flights.

But the chairman mentioned that we are trying to get to the roots of the problem so it doesn't happen again, so the FAA—so that airlines like Boeing—and so my questions really go to penalties, whether they have made any difference, penalties paid or outstanding—essentially, to compliance, so the Congress can decide what, if anything, it can do. Everybody has an obligation here. Boeing, to be sure, but so does Congress.

So the record I have—and I ask you, Mr. Muilenburg, did Boeing enter into a settlement agreement with FAA in an effort to resolve what were then multiple enforcement cases against Boeing that were either pending or under investigation? That was in 2015.

Mr. MUILENBURG. Congresswoman, I am not familiar with the details of that, although I am aware——

Ms. NORTON. I simply asked did you enter into settlement agreements. Surely you know whether you entered into settlement agreements.

Mr. MUILENBURG. John, you——

Ms. NORTON. I didn't ask you about the details.

Mr. HAMILTON. Congresswoman, that is correct. We did enter a settlement agreement in 2015.

Ms. NORTON. Thank you. Is it also true that Boeing had to immediately pay $12 million into the U.S. Treasury as a result?

Mr. HAMILTON. That is correct.

Ms. NORTON. Continuing, is it true that Boeing faced up to $24 million in additional penalties through 2020, if certain conditions were not met?

Mr. HAMILTON. Yes, Congresswoman. In working with the FAA, they were really looking for creating a longstanding agreement with us to build a good foundation on elevating compliance——

Ms. NORTON. I am just asking you about the $24 million.

Mr. HAMILTON. And——

Ms. NORTON. My time is limited—in additional penalties through 2020 if the conditions were not met.

Mr. HAMILTON. There was——

Ms. NORTON. Wasn't that the agreement, the understanding?

Mr. HAMILTON. There was a—yes, there was a deferred penalty.

Ms. NORTON. Now I am just going to list quickly the obligations: improve management and accountability, internal auditing, supplier management, more stringent quality and timeliness of regulatory submissions, simplify specifications. I could go on. Surely, you understood that that was the agreement, those were the agreement.

Yet in designing and developing and manufacturing the 737 MAX, Boeing has run into issues, problems—characterize them as you will—in meeting the obligations in most of these categories. Would you agree, Mr. Muilenburg?

Mr. MUILENBURG. Congresswoman, we have identified many of those challenges through the MAX development program, and some of those are in the areas that——

Ms. NORTON. And you have had issues in meeting them. Some of this has resulted in the problems that bring us here today.

Mr. MUILENBURG. Congresswoman, I can't give you any specific examples that link the two.

I don't know, John, if you have got any——

Ms. NORTON. I didn't ask you that.

Mr. MUILENBURG [continuing]. Thoughts on that?

Mr. HAMILTON. Yes, the—some of these agreements were agreements that you would make over the course of the 5 years. Each year we provide a progress report to the FAA on our progress on that. And there is still——

Ms. NORTON. Yes. And so you—I am not saying you are not making progress. I am saying the issues——

Mr. HAMILTON. There are still——

Ms. NORTON [continuing]. As you say, are in black and white.

Mr. HAMILTON. There is still opportunity in the time remaining to meet all obligations of the settlement agreement.

Ms. NORTON. Within the last decade Boeing has had two worldwide groundings of relatively new airplanes, the 787 Dreamliner, the 737 MAX, and encountered many compliance issues in the time since Boeing paid that $12 million settlement payment. And I am assuming it was paid.

Has the FAA assessed any additional financial penalties on Boeing to the 2015 agreement?

Mr. HAMILTON. No, we are not aware of any additional penalties.

Mr. DEFAZIO. OK. The time of the gentlelady has expired. It would be, first, Mr. Crawford.

Mr. CRAWFORD. Thank you, Mr. Chairman.

Mr. Muilenburg, are you aware of any aviation accident that can be attributed to a single factor?

Mr. MUILENBURG. Congressman, no. I think the history of aviation shows that these accidents are very—and they are very unfortunate, but in many cases they involve multiple factors.

Mr. CRAWFORD. Mr. Hamilton, do you agree with that?

Mr. HAMILTON. Yes. As Ranking Member Graves pointed out, James Reason's swiss cheese model, all accidents are typically due to a number of contributing causes.

Mr. CRAWFORD. The Indonesian National Transportation Safety Committee recently issued its final report into the Lion Air 610 flight, finding nine contributing factors for the crash. Other than the design of the aircraft, those factors include the miscalibration

of sensors during repairs, a lack of flight and maintenance documentation, and failure by the flight crew to appropriately respond to an emergency situation. To quote one of the Indonesian flight investigators, "The nine factors have to happen together. If one of these nine contributing factors did not happen, the crash would not have happened."

Mr. Chairman, I have a copy of that report here, and I ask for unanimous consent that it be included in the record.

Mr. DEFAZIO. Without objection.

[The information follows:]

"Final Aircraft Accident Investigation Report KNKT.18.10.35.04," Submitted for the Record by Hon. Crawford

The document is retained in the committee files and available at: https://www.flightradar24.com/blog/wp-content/uploads/2019/10/JT610-PK-LQP-Final-Report.pdf

Mr. CRAWFORD. Thank you, Mr. Chairman, and I will yield back.

Mr. DEFAZIO. I thank the gentleman. Next on our side would be Representative Eddie Bernice Johnson.

Ms. JOHNSON. Thank you, Mr. Chairman. And thank our witnesses for being here.

I would like to ask unanimous consent to put an opening statement in the record.

Mr. DEFAZIO. Without objection.

[Ms. Johnson's prepared statement follows:]

Prepared Statement of Hon. Eddie Bernice Johnson, a Representative in Congress from the State of Texas

I thank the chairman and ranking member for having this hearing today, as it allows us to examine the current priorities and critical concerns with the Boeing 737 MAX aircraft. I am eager to hear from Mr. Muilenburg, the president and CEO of the Boeing Company.

My interests are specific as to how we as a legislative body can adequately address the promotion of aviation safety; potential avenues of reform in the agency certification processes; and long-term influences on consumer flight experiences.

As to safety, the Boeing 737 MAX was marketed as a safe, modernairplane; however, after two major failures and hundreds of people losing their lives, we now know that the 737 MAX is not a safe plane and consequently has been grounded.

As to the agency certification process, we must ensure that the planes that are certified to fly go through the most comprehensive certification process modernly available, so that we may avoid these tragic failures in flight. We are experiencing a serious crisis of trust in aviation safety. The importance of an appropriate certification process for large aircraft in the United States is now more pertinent than ever. If the safety certification process merits reexamination and reform, we must advocate for transparency. This will avert not only the reduction of the United States position of authority on aviation safety, but also the endangerment of hundreds of lives in preventable accidents.

My district in Texas is a major hub for aviation, and with the significance of this industry and the jobs that the airline industry provides, I am dedicated to addressing the imminent and long-term concerns regarding the grounding and ensuing safety concerns of the 737 MAX aircraft. This is of significant concern to me, as both American Airlines and Southwest Airlines are prominent entities at the Dallas Fort Worth International Airport and the Dallas Love Field Airport and had previously employed a significant number of this aircraft model.

Therefore, the operational implications of the grounding and safety certification of the Boeing 737 MAX are literally a matter of life and death.

Again, I look forward to the testimony of Mr. Muilenburg and the answers to my questions. With this hearing, I join the efforts of my colleagues in Congress to meaningfully and comprehensively address these urgent concerns on both the national and global scale.

Ms. JOHNSON. Mr. Muilenburg, Mr. Mark Forkner's position as chief technical pilot on the 737 MAX was in place at the time of the accident. Who did he report to?

Mr. MUILENBURG. Congresswoman, he was an engineer in our Commercial Airplanes division. I am not sure who he reported to directly, but he reported up through our engineering team.

John, if you——

Mr. HAMILTON. Actually, he was in the training department, so he worked through the training organization.

Ms. JOHNSON. OK. So there was a chain of command in some way?

Mr. MUILENBURG. Yes.

Mr. HAMILTON. Yes.

Ms. JOHNSON. OK. In March of 2016 he asked the FAA if it was OK to remove all references to the MCAS in the flight crew operations manual and training materials. When he made this request,

was he acting on his own, outside the scope of what he was supposed to be doing as the chief technical pilot?

Mr. MUILENBURG. Congresswoman, part of Mr. Forkner's responsibility included discussions on training with the FAA, but that is more than a single individual. There is a large team that does that work, together with the FAA and other stakeholders. And typically, they will discuss the contents of the training manual and make iterations on that manual over time to try to optimize it for the pilots.

Ms. JOHNSON. Was there some way that it was called to his attention, this request was made? And what was the inside discussion?

Mr. MUILENBURG. Congresswoman, I apologize, I could not hear your question.

Ms. JOHNSON. The first question you responded to, which is related to the second one, and that is when he made the request to remove all references to the MCAS and the flight crew operations manual and training materials, when he made that request, was he acting on his own? And you said that it was a number of people.

So I am saying was he just—talked a—did he have any reprimand in any way for this request being made, or was it a group request?

Mr. MUILENBURG. Congresswoman, part of that discussion on whether to include MCAS in the training manual, that was an iterative process over several years, and included many people beyond Mr. Forkner.

And typically, what we do is we want to include in the training manuals the items that the pilots need to fly the airplane. I think Ranking Member Graves described it well earlier. We don't want to put more information in the training manual than required. We want to focus on the information that is needed to fly the airplane.

And so, typically, over a multiyear timeframe, we will make decisions on whether to include things or not, depending on whether they meet our criteria for what is beneficial to the pilots.

Ms. JOHNSON. Was he or anybody else in Boeing rewarded in any financial way for removing this requirement, and making it simpler for you?

Mr. MUILENBURG. Congresswoman, no. That is part of our obligation. Our responsibility is to provide the best training manuals we can.

I know the discussion around MCAS has included a—there has been a lot of discussion about whether to include it or not. But again, our focus has been on providing the information the pilot needs to fly the airplane, rather than the information that would be used to diagnose a failure. And that difference between flying the airplane and diagnosing a failure is a really important safety concept in our training manuals.

Ms. JOHNSON. Well, do you recall any discussion that was made around anybody objecting to this decision to remove this MCAS from pilot training materials?

Mr. MUILENBURG. Congresswoman, I can't point you to a specific document, but I know there were discussions, debates on whether to include MCAS or not. That is part of our healthy engineering culture. We bring up ideas, we debate. We encourage that open dis-

cussion. That is how we ultimately optimized the content of the training manual.

Ms. JOHNSON. Have you reconsidered the removal of this material from your training manual, operational manual?

[No response.]

Ms. JOHNSON. Have you had any discussion to reconsider removal of that material?

Mr. MUILENBURG. There were discussions and debates amongst the team. Again, that was happening during that multiyear timeframe as MAX was being developed.

I don't know, John, if you want to add to that.

Mr. HAMILTON. No, I agree. But I would say, since these accidents, we understand that pilots do want more information, and we are going to incorporate that in our flight crew training manual and flight crew operations manual.

Mr. MUILENBURG. That has been——

Ms. JOHNSON. Thank you. My time——

Mr. MUILENBURG [continuing]. One of our key learnings——

Mr. DEFAZIO. The time of the gentlelady has expired. Just a quick interjection in reference to the single point of failure.

I mean there was Turkish Airlines flight 981, where a DC–10 went down because the rear cargo door blew out. There was USAir flight 427, the rudder problem that we had, which was the subject of hearings in this committee. It was ultimately determined that the rudder hardovers—we had two of those single point of failure. And then we had the jack screw on the Alaska flight. You know, the—so there have been a number. And in this case MCAS was a major factor. It wasn't the only factor.

With that, Representative Gibbs.

Mr. GIBBS. Thank you, Chairman. My condolences to the families, too, prayers as you struggle through this very difficult time.

On the MCAS, the sensor—and my understanding is on the angle-of-attack sensors there is actually two sensors, but only one was tied into the MCAS system. Is that correct?

Mr. MUILENBURG. Congressman, that is correct. Depending on sequencing of the flight control computers, one sensor would feed MCAS. But on different flights it could be either sensor. But one sensor at a time.

Mr. GIBBS. OK, because—one thing, I am not a pilot. I fly, obviously, frequently. But, you know, when my friend down here, Garret Graves, talks about how important it is, you can't just pull off to the side of the road—redundancy.

So I don't know what you guys were thinking, because sensors, I know from my background in agriculture, a lot of times when we have problems, it is usually a sensor failure that, you know, shuts the system down, because the sensor is failing. Just an analogy. And an airplane, I think redundancies really would be key.

And so I think we have all learned a lesson there, that we are going to not just depend on one sensor. Correct? You have learned that?

Mr. MUILENBURG. Congressman, that is one of the lessons learned here. We tried to rely on a previous architecture. We have learned, and we are moving to a two-sensor architecture.

Mr. GIBBS. Now, the MCAS system, I am old school, I guess. Maybe my kids and my grandkids might see it different. But every once in a while on stuff that I operate—on your phone or whatever, you got to reboot it. And so I have to agree with, I believe, the chairman, but definitely Ranking Member Graves talks about make sure we have the pilots be able to fly the plane. I know these systems have added safety, overall, we have less issues and tragedies because of the systems. But we have got to make sure humans have to be able to override it.

So that is really concerning to me, when I heard that the Airbus doesn't have that ability to override. I think that is something the FAA ought to be looking at. I don't know. That just raises a question with me.

But pilot training, testing. And I know we talked about these two catastrophic accidents happened in Lion Air and Indonesia and Ethiopia. And my understanding is—nothing against the pilots, I know they were trying to save their lives and everything, that is no doubt. But their training maybe wasn't what it should have been, reports I have read.

I guess, if I was Boeing, a large manufacturer of very sophisticated pieces of equipment, aircraft—what was Boeing's plan in the future—you sell these sophisticated aircraft around the world—to make sure, other than just relying on their Government regulators—because I think I want to make sure that the people that are maintaining them, the people that are flying them have the training and the knowledge and the ability, continuing training.

Moving forward, because this is one area I think we can make sure we prevent things like this happening, and not rely totally on the infrastructure itself, the asset itself, the technology itself, but make sure we got the human technology, the human behind that.

So I guess I would hear your comments on what, going forward, what is Boeing going to do when they make these sales, to make sure that you are confident that the people that maintain the aircraft and fly the aircraft have the training and the ability—what Boeing's role would be, moving forward.

Mr. MUILENBURG. Congressman, I think you raise a very good point. And that broader area of comprehensive global aviation safety is an area where we are going to make additional investments, going forward. An element of that is helping to build the talent pipeline. By most estimates, the world will need about 44,000 new commercial airplanes over the next 20 years, and about 1.5 million new pilots and aviation technicians. So we have a responsibility to help build that talent pipeline.

We are also going to take a look at the pilot machine interface on our airplanes, and designing that for the next generation, as technology is rapidly evolving. We are investing heavily in that area, future flight deck design.

We are also investing in additional simulation infrastructure around the world to provide additional training capacity, working with airline customers around the world.

Those are just a few examples of what we are doing.

Mr. GIBBS. I am just curious on the case of the two cases here, the Ethiopian and Lion Air, you know, the two cases, did you have

simulators over there, training? Or how has that worked here in the past? What has been the involvement of Boeing?

Mr. MUILENBURG. John, are you aware of exactly what training capacity they have?

Mr. HAMILTON. I am not specifically aware of what Ethiopia has, from a simulator standpoint.

Mr. MUILENBURG. Congressman, if we could take that question, we will follow up with the details there. I know we have a team that is locally engaged with both airlines, and we will follow up with the details on simulation infrastructure——

Mr. GIBBS. Yes, I appreciate that, because I think, moving forward, we rely too much on our computers and our—all that. And we know that machines do break, too.

So I yield back. Thank you, Mr. Chairman.

Mr. DEFAZIO. I now turn to the chair of the subcommittee, Mr. Larsen.

Mr. LARSEN. Thank you, Mr. Chair.

Mr. Muilenburg, as we are looking forward prospectively, we need to do our job looking retrospectively a little bit to understand the certification process. That has been the focus of this committee's long-term investigation since March. And so I want to touch on that a little bit.

You said today and you said yesterday at the Senate hearing that "We," that is Boeing, "We have made mistakes and we got some things wrong." Can you name three specific mistakes Boeing made in this process?

Mr. MUILENBURG. Congressman, I would point out implementation of the angle-of-attack disagree alert. We got that wrong, upfront. The implementation was a mistake, and we have subsequently fixed that, going forward.

Mr. LARSEN. Second?

Mr. MUILENBURG. Secondly, we have learned about the MCAS architecture, the changes that we have already talked about. Clearly, we have some areas to improve there.

Mr. LARSEN. And third?

Mr. MUILENBURG. And thirdly, I would say, in the broader area of communication, documentation across all of the stakeholders, and doing that in an efficient and comprehensive manner, we have identified some improvements we need to make there.

Mr. LARSEN. Can you identify individuals, then, who made these mistakes within Boeing?

Mr. MUILENBURG. Congressman, across all three of those areas, these are large teams that work together across our company, our supply chain. We have about 900 supplier companies that work in our 737 supply chain alone: the FAA, other global regulators, airlines. So in each of these three areas, there are broad, integrated teams. There is no one individual that makes decisions within these. These generally are engineering teams that build consensus with all of the stakeholders.

Mr. LARSEN. So does that make this an organizational or cultural problem, as opposed to an individual problem and that led to these mistakes?

Mr. MUILENBURG. Congressman, I think it is important, from an accountability standpoint—you know, my company and I are ac-

countable. That accountability starts with me. And our board recently took some actions regarding my position.

Mr. LARSEN. I was going to ask.

Mr. MUILENBURG. Yes.

Mr. LARSEN. How have you been held accountable through this?

Mr. MUILENBURG. Yes. So, Congressman, to your question, our board has recently taken some actions on my position, and I fully support that. That will allow me again to focus even more on safety in our internal operations. And these decisions are directed at safety.

I have also taken some management actions. We know there are still a number of other reviews underway. And as those reviews are completed, if we need to take additional actions, we will. And those will be firm. And in some cases, they are not individual actions, but to—as you pointed out, they are organizational or structural actions. And these are equally important.

And we have recently announced changes to our safety review board structures to elevate them and make them more transparent. I now receive weekly data reports, very detailed level, on our safety review boards. We stood up a new safety organization under Beth Pasztor. She now reports directly to our chief engineer, who reports to me, instead of being down in the businesses.

Our board has set up a new aerospace safety committee that is chaired by Admiral Giambastiani. Just Friday we announced the addition of Admiral Richardson, who has a deep, deep background in safety. He will be a member of that committee.

And then we have also realigned our entire engineering organization, roughly 50,000 engineers now all report directly to our chief engineer, who reports to me. And again, this will create additional transparency, visibility, and independence, all with a focus on safety.

Mr. LARSEN. So I can't help but think, when I hear that, and when I read the JATR report, and read the NTSB recommendations from September, and read the Indonesian accident investigation report, that there are changes that we need in how we certify aircraft and components in the FAA process, that what we have now went too far, and that we don't have a handle.

We hold the FAA accountable. The FAA is supposed to then hold the OEMs, the original equipment manufacturers, accountable. I am not convinced, based on reading these reports and looking at Boeing's own actions, that that is being done adequately. And I would like to hear your view on what—well, do you agree with me or not?

Mr. MUILENBURG. Congressman, we believe there are also improvements we can make to that process. And as you are very, very familiar with the delegated authority process, that process, we do think, is very important to fundamental safety. It broadly—it contributes to the 95-percent improvement in safety we have seen over the last two decades. But we need to make sure we have the balance right, and we support the reviews that have been announced on that. I think that——

Mr. LARSEN. Well, if I could just—and I will finish here, Mr. Chair—if the bookends on this are what former—well, Acting Administrator Elwell said at one time it would be $2 billion and

10,000 more inspectors. If that is one bookend, and the other bookend is what we have today, I think that we ought to be pulling out a book somewhere between those two bookends. And right now we are—we have gone too far.

And with that I yield back.

Mr. DEFAZIO. I thank the gentleman. Representative Davis?

Mr. DAVIS. Thank you, Mr. Chair. And, as a matter of fact, I want to kind of add to what my colleague from the State of Washington was asking about, and it is about the certification process.

As he just asked, there is one bookend of what the FAA actually believes could be done with billions more dollars in inspectors. We have the current certification process. I don't want to see a knee-jerk reaction here.

Look, it breaks my heart, and everybody's heart in this room, to look over and see those pictures. And I know it does yours, too. These are real people who were affected by tragic accidents that we are here to get answers for. But we also want to make sure that we don't see any more in rooms like this.

I have many of my constituents who work at your facilities in St. Louis and in Mascoutah, Illinois. I know every one of those constituents that put on that Boeing uniform and go to work every day, it breaks their heart when they see accidents and tragedies like we have witnessed. They want to do the best job they can to put a safe plane in the air. They want to make sure no one cuts corners.

So this certification process, tell us, so we don't have that knee-jerk reaction, what do you think the sweet spot is from those bookends that Mr. Larsen was talking about?

Mr. MUILENBURG. Congressman, I applaud the focus on safety and people. As you point out, we always have to remember what we are doing here is providing safe travel for people around the globe, and lives depend on what we do. So we have to get it right.

I think the certification system that we have today is a solid system that has been built up over decades. We have seen very significant improvements in safe travel over the last two decades—as I mentioned, about a 95-percent improvement. That is a result of the current certification system. So we need to maintain what is good in that current system. There is, clearly, a lot of goodness.

I think we have identified a couple of areas where we could look at refinements. And one of the areas we talked about is standards, these longstanding industry standards around pilot-machine interface, and the assumptions behind that. I think we are all eager to take a look at that as a potential area of reform.

And I think, as John has well pointed out, there are some aged regulations on the books that could be updated to represent current technology, and that would also be beneficial.

Mr. DAVIS. Well, that is good to hear. And I certainly hope all of us here, we as policymakers, can ensure that we don't have that knee-jerk reaction. Because we all have the same goal. And there is probably not many more in the country that fly as much as we do. So we understand the safety of the aviation industry. But it is those instances where safety might have been compromised, which is why you are here.

And I appreciate Boeing, and I appreciate you admitting mistakes and talking about the administrative decisions that you are making as a team at Boeing to ensure that those mistakes aren't made in the future.

We have seen some disturbing whistleblower complaints, complaints from former Boeing executives and workers about processes and the culture that may exist at certain facilities. What are you doing to address some of those to ensure that the culture at Boeing, at all of their facilities, is up to par with the facilities that I know my constituents work at in St. Louis and in Mascoutah?

Mr. MUILENBURG. Yes. Well, Congressman, you raise a very good point. And we want our employees to speak up. When they have concerns, issues, we want a culture where they are willing to speak up. So I encourage those reports. We want to hear what our employees' concerns are.

We conduct surveys to bring those up, as well, and we provide reporting channels where, if employees want to bring up anonymous concerns, they can. And those get immediate followup action. And I think it is important, when you take a look at those—the whistleblower complaints, other points that you have brought up, this is part of our culture of providing visibility on issues. That is how we get better, as a company.

And I can also tell you, as you know, I know the 150,000 people of Boeing. You know them from St. Louis and Mascoutah. I know them, as you do. These are honest, hardworking, dedicated people that know the work they do directly affects lives. And they want to do it right, and they want to do it with excellence. And we want a culture where people can bring up concerns.

And my commitment, the culture of our company—I know John shares this, as does the rest of my team—is to be responsive to those inputs, to hear our employees, to take action, and to do that consistent with our values.

Mr. DAVIS. Well, I hope the message you take from today's hearing when you go back is thank you for the good job that many of your employees do on a daily basis, but we also expect results. And we want to see those results in all of your facilities.

And my time is up. I yield back, and I thank you both for being here.

Mr. DEFAZIO. I thank the gentleman. The Representative from California, Mrs. Napolitano.

Mrs. NAPOLITANO. Thank you, Mr. Chairman. Our collective prayers are with the families on their tremendous loss, and I am glad you are here, showing us—keeping us aware of it.

Mr. Muilenburg, my question is regarding FAA's organization delegation authority, known as ODA, that allows your company to oversee certain FAA certification activities. The FAA's Boeing Aviation Safety Oversight Office, or BASOO, not only oversees the Boeing 737 MAX program, but it also oversees other Boeing commercial transport aircraft programs, including the 777 and the 787 Dreamliner.

There are approximately 45 FAA employees that work in BASOO, but there are 1,500 Boeing employees that work in the organization, ODA, program. These Boeing employees have a dual

role of working for Boeing and representing the Government's interests through the FAA.

Mr. Muilenburg, do you believe that having 45 FAA employees overseeing all of the critical safety decisions Boeing makes every day regarding commercial aircraft is adequate? Yes or no?

Mr. MUILENBURG. Congresswoman, I can't give you what would be the exact right number. We do respect the FAA's oversight authority. We think——

Mr. DEFAZIO. Well, she didn't—sir, she did ask for a yes-or-no answer. Do you believe that is an adequate number, given the scope of their duties?

Mr. MUILENBURG. Mr. Chairman, I can't answer that specifically.

Mr. DEFAZIO. OK, all right.

Mr. MUILENBURG. I think that is the FAA's call. All I want to say is we fully support the FAA's oversight. We think strong oversight——

Mrs. NAPOLITANO. Thank you, sir.

Mr. MUILENBURG [continuing]. Is part of what makes the system safe.

Mrs. NAPOLITANO. Thank you. I think the tragedy of Boeing 737 MAX doesn't just highlight cultural problems at Boeing regarding production and Boeing's commitment to safety, but I think also highlighted a failure by the FAA to provide appropriate oversight of critical issues that impacted safety and ultimately led to the accidents of both Lion Air and Ethiopian Airlines.

I think the current oversight structure is a critical—very critical—issue, and one that Congress is going to have to need to evaluate in the wake of these accidents.

Thank you, Mr. Chairman. I yield the remaining time to you.

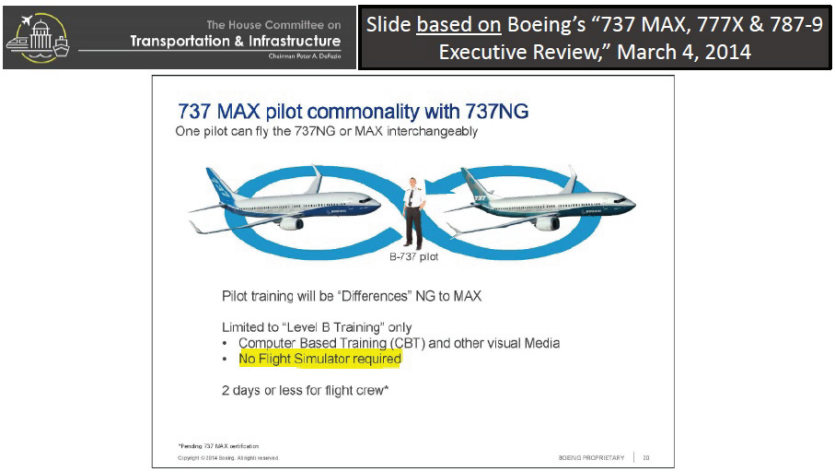
Mr. DEFAZIO. Thank you, Mrs. Napolitano.

[Slide]

Mr. DEFAZIO. I want to return to the market pressures, the fact that you had to design a plane that was more economical and couldn't require pilot training, and I would, you know, refer to—the first slide here is during an executive review of, unfortunately,

it is an Ethiopian Airlines plane, talking about the MAX advantage. And it was just relentless pressure.

[Slide]



Mr. DEFAZIO. And the next slide, which is, you know, no flight simulator required. We have had questions about the communications of your test pilot, and we have the polling from your own employees about the pressures.

There is going to be, ultimately, a determination whether you directly concealed, inadvertently concealed, provided in a fragmented manner the full MCAS in its radical form, information to the regulators, and that is something we are also going to pursue with the regulators, what their understanding was.

Let me just ask a quick question.

I know you know why we are here today: 346 people died on 2 of your airplanes in 5 months. And you are helping us to try and delve into what we need to fix, because we need to change the law.

But part of this process, really, is taking full accountability for what went wrong, for the death of 346 innocent people on two 737 MAX flights. So my question is a simple one, and I hope you can give me a direct response.

Who bears the principal responsibility at Boeing for the cascading events that resulted in the crash of Lion Air flight 610 and Ethiopian Airlines flight 302?

I know that you have lost your board chair. You are still CEO, you still serve on the board. I did happen to look at your compensation last year. You received after that crash a $15 million bonus.

What are the consequences? Who is taking principal responsibility? Who is going to be held accountable, fully accountable? I know you fired one person.

Mr. MUILENBURG. Mr. Chairman, my company and I are responsible. We are responsible for our airplanes. And we know there are things we need to improve. We own that. We are going to fix it, and we are responsible. I am responsible.

Mr. DEFAZIO. OK.

Mr. MUILENBURG. I am also accountable.

Mr. DEFAZIO. All right.

Mr. MUILENBURG. And I described the actions that we took earlier. And, as additional reviews are completed, as additional studies are completed, we will take additional action.

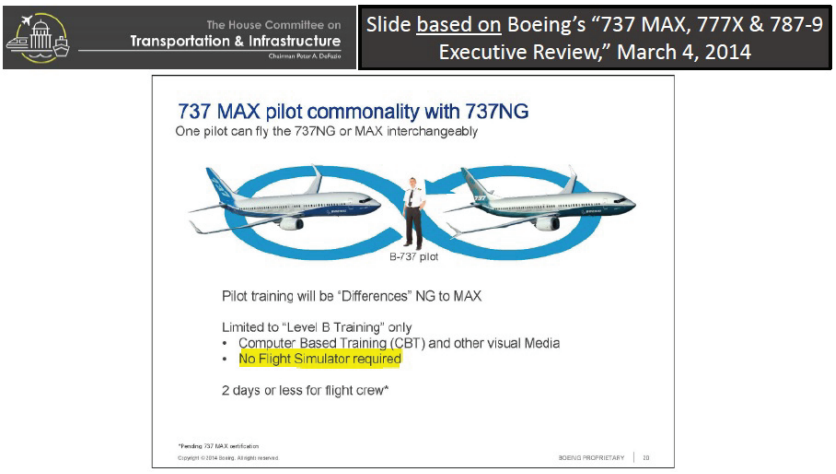
But I am accountable, my company is accountable. The flying public deserves safe airplanes. That is our business.

Mr. DEFAZIO. Thank you.

Mr. Woodall?

Mr. WOODALL. Thank you, Mr. Chairman. I wanted to pick up where the chairman left off with the no flight simulator required slide.

[Slide]



Mr. WOODALL. I am a lawyer, I am not an engineer. But I don't understand the regulatory distinction between a derivative type and a new type.

Is the requirement of a new flight simulator a disqualifier to fit in under a derivative certificate?

Mr. HAMILTON. No, let me explain. The 737 is a family of airplanes. It is one of the safest family of airplanes flying in the world today. And many pilots will fly an NG first flight in the morning, they could fly a MAX as the second flight of the day, back in the NG on the third flight of the day.

And so one of the market requirements the customers want is to be able to make it a seamless transition from an NG to a MAX.

Mr. WOODALL. Well, let me go back, then, because the New York Times reported in 2011, as competition grew with Airbus, that it was Boeing's position that we didn't want a derivative type, that it was a brandnew, clean-sheet design that is what customers wanted.

And so, was the presumption at that time that you were going to do a brandnew, clean-sheet design, going to create a brandnew type certificate, and no new flight simulator was going to be required?

Mr. HAMILTON. Congressman, I was actually the chief engineer of the 737 at that time, and we had actually had product studies, as we normally do, looking at reengining, since 2007.

We also had a product development organization that was looking at a new airplane. And just like any good company, we were looking at both options, and competing them internally about what made sense to bring to the market. At the end of the day, what the customers really wanted was to have an airplane they could seamlessly transition from their 737s into this future airplane. They——

Mr. WOODALL. Well, when we talk about who takes responsibility, candidly, I am concerned that we may have created a regulatory environment that makes it so difficult for you to get a new type certificate that you try to stuff all of these changes that should never be stuffed in under a derivative certificate.

But what you are telling me is, no, it is your customers who demand that you get derivative certificates, and we, from a regulatory perspective, are not complicit in making it too hard to declare that new model.

Mr. HAMILTON. I would say that a derivative type cert is not necessarily any easier than a new type cert. I think, as someone alluded to, we took over 5 years to do the derivative type cert, which is very consistent with what we do for a new type cert.

So they are actually very complementary. And if you look at the MAX's certification, it was very comprehensive.

Mr. WOODALL. All right. So when we go back to the IG's report that quotes an FAA official as saying, "The 737 MAX is not a simple derivative of its previous models, it is a very complex modification incorporating many new and novel features. Boeing is doing everything it can to be exempt from the new certification rules and keep the aircraft the same type rating with minimal training differences," that has nothing to do with the length of the approval process, that has everything to do with the economic pressures Boeing is under to meet customer demand of pilot similarity in a continuing model?

Mr. HAMILTON. Yes, the MAX was—with technology we determined that we could get the same amount of fuel efficiency, the same amount of carbon dioxide reductions, the same amount of noise reductions that we pretty much could with a new type—a new airplane. And it was a desire from the customers.

So, yes, that informed some of the decisions we made, but it wasn't about—how we approached certification. It was about design choices we made.

Mr. WOODALL. Let's go back to the FAA partnership, then, because I—and I appreciate what you said yesterday in your Senate testimony, Mr. Muilenburg, about ODA making American aviation and world aviation safer. I believe that to be true, and I very much worry that, in every tragedy, that the tendency is to swing the pendulum back too far the other direction.

When an FAA official says the MAX is not a simple derivative, it is a very complex modification, it does incorporate new and novel features, what role does Boeing have in requiring the FAA to go ahead and sign off on that derivative type, instead of saying, "No,

we have now looked at your engineering, this is not a derivative type, you must go back and begin this process again"?

Is ODA implemented in FAA's decision of whether to certify a new type or not?

Mr. HAMILTON. Congressman, I used to run the ODA, and I was actually leading the ODA at the time. This is not an ODA function at all.

This is Boeing as—the applicant, the OEM, we go discuss with the FAA what the certification basis should be for the airplane. And it is—ultimately, it is the FAA's decision. They set the requirement, they set the cert basis. And then we, as a company, as the applicant, we have to follow that. It is not an ODA function at all in establishing the cert basis.

Mr. WOODALL. I hope we will bring those FAA officials in, Mr. Chairman, so that we can ask that question, because that is the point of failure, if there is a point of failure in this regulatory process.

Mr. DEFAZIO. OK.

Mr. WOODALL. I yield back.

Mr. DEFAZIO. I thank the gentleman. Mr. Lipinski is next.

Mr. LIPINSKI. This is not a court, and this is not a criminal hearing, but 346 people died in 2 crashes of Boeing 737 MAX planes that should not have been certified to fly by the FAA.

I said at a hearing earlier this year, "Something went wrong in the certification process of this plane. Either the FAA certification process itself is at fault, Boeing is at fault in their role in the process, or both." After I made this statement, I was upbraided by some in the industry for questioning the process.

But this committee has a responsibility to get to the bottom of what went wrong in the certification process for the 737 MAX so we can make changes to that process and assure the public, especially those in this audience and everyone who lost loved ones, assure them that they will not be flying in unsafe planes again.

Now, sitting here, we heard about accountability. I am not sure what accountability means if accountability means, Mr. Muilenburg, you received a $15 million bonus after these planes crashed. I am not sure who has been held accountable here for this.

Two planes crashed. Even after the first plane crashed, I still don't really understand how you have—I am an engineer, but I am asking a lot of questions back here. People who are more expert than me—I don't understand how you have this single point of failure. Chairman DeFazio went through that, but it was raised, as the chairman mentioned.

There is also another case. There was an internal ethics complaint that alleged that an engineer recommended the synthetic airspeed system be put in, which is in the 787 Dreamliner, and was rebuffed because of "cost and potential pilot training impact."

There is a lot of reasons mistakes are made. The problem, the bigger problem, is if mistakes were made for financial reasons. And there are a lot of things that seem to point to that in this whole process, and that is what is so concerning. And how did that happen in Boeing? How did Boeing allow that to happen? How did the certification process allow that to happen?

In order to get a new type certificate, it takes, generally, a longer amount of time. I think most people will agree, Mr. Hamilton, it takes a longer amount of time. It also risks having—most likely you are going to have to require pilot training.

So all these point back to ways of saving money, and that is a big problem. How do we stop that?

Now, I want to ask—the JATR team found that MCAS was not evaluated—and this is something—I was listening to the Senate testimony yesterday, Mr. Muilenburg, and you didn't seem to agree with this. And I want to get your—what you say here: The JATR team found that MCAS was not evaluated as a complete and integrated function in the certification documents that were submitted to the FAA. Is that true?

Mr. MUILENBURG. Congressman, the MCAS system was certified with the FAA.

Mr. LIPINSKI. Was it evaluated as a complete and integrated function, or was it step by step without ever having FAA look at it as a complete and integrated system? Because that is what is the important piece of this.

Mr. MUILENBURG. Yes, I think what the JATR report points out—and this is an area where we support further looks, as well—is when we think about what we call a cross-system integration, and how we do certification of that.

So, for example, a multiple failure mode analysis, high pilot workload conditions, we do think that is an area where we want to look more deeply.

The MCAS system and the MAX were certified to our current standards for how we do those analyses. But, as the JATR points out——

Mr. LIPINSKI. Well, it was a completely—it was a very different system. I think that is very, very important, and that is something that FAA should have required, and I think it should have been provided.

But in my last few seconds here I want to ask. As the 737 MAX reenters service, will Boeing require airlines to conduct similar training on MCAS for all pilots?

Mr. MUILENBURG. Congressman, those decisions are the purview of the regulatory authorities around the world. And we will respect their——

Mr. LIPINSKI. Will Boeing lose——

Mr. MUILENBURG [continuing]. Their decisions.

Mr. LIPINSKI. Will Boeing have to give money back to any of the airlines if that is the case?

Mr. MUILENBURG. Congressman, money doesn't factor into this decision. It is about safety. So we——

Mr. LIPINSKI. But if it is in the contract, that is a question.

My time is up.

Mr. DEFAZIO. I thank the gentleman. Representative Katko?

Mr. KATKO. Thank you, Mr. Chairman. And I thank all of my colleagues for all these questions today.

In my previous life I was an organized crime prosecutor, and routinely had to sit with victims—and victims' families, more often. And the pain I see on your faces is exactly the pain I saw on those victims' faces. So I just want to recognize that, and recognize

that—I hope you understand we are taking this very, very seriously.

And I understand, Mr. Muilenburg, last night they had an opportunity to meet with the victims' families. I would like to—I know what—it always had a huge impact on me and how I carried out my cases, and it motivated me to do better, and to get to the bottom of the problem. So I want to hear what it was like for you, and what was discussed.

Mr. MUILENBURG. Congressman, I want to respect the privacy of the families, but I can perhaps, if you will allow me, just broadly describe our discussion.

We wanted to listen. And each of the families told us the stories about the lives that were lost. And those were heartbreaking. I will never forget that.

So we talked about their stories, we listened. And we, further into the conversation, you know, talked about safety, talked about changes, talked about what my company has learned, what I have learned. We talked about our commitment to never letting this happen again, to preventing any future accidents like this. You know, it was—one thing I wanted to convey to the families.

But, you know, these stories, they are always going to be with us. And I wish we could change that. And all we could do is—we have to remember these people. It brought me back to remembering that, you know, lives literally depend on what we do at the Boeing Company. That is why I came to this company as a farm kid from Iowa, right? That is what I wanted to work on. And these stories brought that all back.

Mr. KATKO. Well——

Mr. MUILENBURG. So we are never going to forget that, and the commitments we shared with the families, and working in their communities going forward, that is very important to us. And we are going to follow up.

Mr. KATKO. I can tell you I never forgot any of those conversations with the victims of—murder victims, and what have you, their families. I can remember it like it was yesterday. And I hope you remember that, and it motivates you and your company, going forward, to do better than you have done.

Mr. Hamilton, from an engineering standpoint, I want to switch gears a bit. My colleagues have done a terrific job of asking about this particular issue. But I am concerned about other things with respect to air safety, as well.

And with my work on the Committee on Homeland Security, I am—and my chairmanship on the Subcommittee on Cybersecurity, Infrastructure, Protection, and Innovation, very, very, very concerned about supply chain anywhere in public transit. We have made a lot of noise in this committee about what New York City was doing with their subway systems, and we made noise with Metro here, as well. And so I am concerned that, you know, what you are doing to ensure that the supply chain is good, and is sound, and you are not getting it from bad actors?

And also, what you are doing to ensure that the ever-spreading and ever-metastasizing cybersecurity problem doesn't infect the airlines themselves.

Mr. HAMILTON. Certainly. You know, we do have a global supply chain, and we carefully do audits of our suppliers to determine, first of all, should we get something from that supplier or not, and then we have robust followup processes, both looking at their quality controls, their producibility, and oversight of our supply chain. And this is one of the things that the FAA has asked us to strengthen. And we are doing that. We have taken some actions on that, as well.

And every day we get reports in on how the suppliers are doing, and whether or not we need to invest and put more actions to improve their operations.

Do you want to talk cybersecurity, overall?

Mr. MUILENBURG. Yes.

Mr. HAMILTON. Yes.

Mr. MUILENBURG. In addition to that, as John well pointed out, we have got about 12,000 companies in our supply chain here in the U.S., mostly mid- and small-sized businesses. So, in many cases, we assist them with their cybersecurity infrastructure, as well. That is a very important infrastructure to us across our Boeing enterprise. And my CIO, who reports directly to me, is responsible for that.

We also have a continuous effort on the cybersecurity of not only our systems, but our products. So cyber-hardening our airplanes for the future, ensuring that nobody can gain access to those airplanes, is a very important safety design principle for us. And our engineering team spends time on that every day.

Mr. KATKO. Thank you very much. I am out of time.

I yield back, Mr. Chairman.

Mr. DEFAZIO. I thank the gentleman. With that I recognize Representative Cohen.

Mr. COHEN. Thank you, Mr. Chair.

Mr. Hamilton, on the 30th of March in 2016, Boeing asked the FAA if it was OK to remove all references to MCAS from the flight crew operations manual and training material. That request was based, in part, on Boeing's representation that MCAS "only operates way outside of the normal operating envelope." Is that not true?

Mr. HAMILTON. I believe that is true, that we—I can't verify the date, but I believe——

Mr. COHEN. Right.

Mr. HAMILTON [continuing]. What you are saying is true.

Mr. COHEN. So let me suggest this to you, or ask you. On March the 30th, the same day, Boeing's chief technical pilot at the time, Mark Forkner, emailed the FAA with the following request, "Are you OK with us removing all reference to MCAS from the operating manual and the training as we discussed, as it's completely transparent to the flight crew and only operates way outside of the normal operating envelope?" The "normal operating envelope" being the term the flight conditions a commercial airline passenger might reasonably experience. Is that correct?

Mr. HAMILTON. As Mr. Muilenburg has discussed, it is an iterative process that we go back and forth with the FAA on what needs to be in the training manual and what doesn't. And collec-

tively, the FAA and Boeing reached an agreement that the description of the MCAS did not need to be in the training manual.

Mr. COHEN. And Mr. Forkner requested that. Is that correct?

Mr. HAMILTON. Yes, and Mr. Forkner's role, as chief technical pilot, would be the prime interface with the FAA on that.

Mr. COHEN. So he said it was way outside the normal operating envelope, talking about conditions or airplane maneuvers that are beyond what a commercial airline passenger would normally experience. Right?

That is right, isn't it, Mr. Hamilton, that Mr. Forkner said that it was outside the normal procedures, you normally wouldn't have that occur on a commercial airline.

Mr. MUILENBURG. Referring to the MCAS envelope being outside?

Mr. HAMILTON. Yes, MCAS should have been transparent to the pilots and assist them only as they approached what we refer to as high alpha, or high attitude-type conditions.

Mr. COHEN. All right. MCAS didn't activate outside the normal operating envelope on Lion Air. In fact, MCAS activated within the normal operating envelope on that flight. Is that not correct?

Mr. HAMILTON. Yes, MCAS reacted to a faulty sensor input, and operated as it was designed, yes.

Mr. COHEN. So Captain Forkner repeated this representation to the FAA as late as January of 2017 after Boeing had changed MCAS to operate at lower speeds, and just a few short months before the FAA finally certified the plane.

In a recently released email exchange in which he was discussing changes that were needed for MAX pilot training, he reminded the FAA, "Delete MCAS, recall we decided we weren't going to cover it in the flight crew operating manual or the CBT, since it's way outside the normal operating envelope." Let's get it out of the flight crew operations manual and outside the computer-based training.

In hindsight, would you not agree that Captain Forkner either, one, did not understand; two, downplayed; or, at worst, three, concealed the fact that, under a scenario that—known to Boeing, the failure of a single angle-of-attack sensor, MCAS could activate within the normal operating envelope?

Mr. HAMILTON. Again, I was not part of those conversations. You know, I think that was part of the—was leading up to the fleet standardization board meeting, and understanding what needed to be presented in that meeting.

Mr. COHEN. You might not have been part of it, but you are an expert. You are an engineer. You are a vice president of Boeing.

Mr. HAMILTON. That is correct.

Mr. COHEN. Would you not agree, in hindsight, that Forkner either did not understand; downplayed it; or concealed a fact that, under a scenario known to Boeing, failed to tell—to talk to—MCAS to—acted about what would go on?

Mr. MUILENBURG. Congressman——

Mr. COHEN. Mr. Hamilton, would you answer my question?

Mr. HAMILTON. Absolutely. Congressman, you know, I don't know what was going through Captain Forkner's mind, what he knew, what he didn't know, I don't want to speculate on that.

Mr. COHEN. Mr. Muilenburg, do you want to respond?

Mr. MUILENBURG. Congressman, the only point I was adding is that the MCAS is originally designed—the idea is for it to operate outside the normal envelope. And then the extension to the low-speed envelope, which I think you are referring to, again, that was something that was tested and certified with the FAA from roughly mid-2016 to early 2017.

Mr. COHEN. Let me ask you this, Mr. Muilenburg. You said you are accountable. What does accountability mean? Are you taking a cut in pay? Are you working for free from now on until you can cure this problem?

These people's relatives are not coming back. They are gone.

Mr. MUILENBURG. Yes.

Mr. COHEN. Your salary is still on. Is anybody at Boeing taking a cut, or working for free to try to rectify this problem, like the Japanese would do?

Mr. MUILENBURG. Congressman, it is not about the money for me. That is not why I came to Boeing——

Mr. COHEN. Are you giving up any money?

Mr. MUILENBURG. Congressman, my board will conduct a comprehensive review. That——

Mr. COHEN. So you are saying you are not giving up any compensation at all. You are continuing to work and make $30 million a year after this horrific two accidents that caused all of these people's relatives to go, to disappear, to die? You are not taking a cut in pay at all?

Mr. MUILENBURG. Congressman, again, our board will make those determinations——

Mr. COHEN. You are not accountable, then. You are saying the board is accountable.

Mr. MUILENBURG. Congressman, I am accountable, sir.

Mr. DEFAZIO. The gentleman's time has expired. With that we would turn to Representative Graves.

Mr. GRAVES OF LOUISIANA. Mr. Muilenburg, did you fly on a 737 MAX prior to these disasters?

Mr. MUILENBURG. Congressman, I don't recall flying on a MAX prior to, no.

Mr. GRAVES OF LOUISIANA. Mr. Hamilton?

Mr. HAMILTON. Yes.

Mr. GRAVES OF LOUISIANA. Do you have any idea how many times?

Mr. HAMILTON. I don't recall the exact number, no.

Mr. GRAVES OF LOUISIANA. Once? Ten times? Any ballpark?

Mr. HAMILTON. Yes, it was probably—I could count on one hand.

Mr. GRAVES OF LOUISIANA. I flew on one. I don't know how many times, but I know at least once before.

My point is that I am—there are all sorts of things that have come out, including the text messages and other things that some folks have said, "This is a smoking gun." I am going to assume that you all wouldn't have ridden on an airplane if you believed that something was wrong. Is that a safe assumption?

Mr. HAMILTON. Yes.

Mr. GRAVES OF LOUISIANA. All right. So here is where I want to transition, all right?

So I talked earlier about all the reports that I did from memory. I think the only one I left out was the Department of Transportation's inspector general report. We have got outcomes of a number of reports, including NTSB, Indonesian accident report. We have got the Boeing board and others that have come out.

How do we know that this new process is actually going to have the integrity to where you don't just feel it is right, FAA doesn't just feel it is right, that it actually is right? Does that question make sense?

Mr. MUILENBURG. When you say "new process," Congressman——

Mr. GRAVES OF LOUISIANA. So my point is that, before, you flew. I flew.

Mr. MUILENBURG. Yes.

Mr. GRAVES OF LOUISIANA. We all believed that it was right. Now we are potentially going to unground this craft at some point. How do we know that this new process is actually going to work and yield the right outcome?

Mr. HAMILTON. You know, I would say that, number one, the software changes we are making are going to prevent our pilots from ever being in this condition again.

But also, the FAA is doing a very robust, thorough review of all our documentation, of all our testing, and that is partially why it is taking this long.

But I feel that, very confidently, that when we get through this, the FAA will clearly say that this airplane is safe.

Mr. GRAVES OF LOUISIANA. As I mentioned, you have got outcomes, at least preliminary outcomes, from NTSB, Indonesia, from the Boeing board and others. Based on what you have seen so far, are there any of these expert recommendations that you disagree with?

Mr. HAMILTON. You know, I think the NTSB recommendations, the JATR recommendations, they are all—and even the Indonesians' recommendations, I think, you know, we are still reviewing all of them.

But I would say, after my initial look at them, I think there are some very good recommendations, and we are looking forward to working with the FAA and the industry to address those, yes.

Mr. GRAVES OF LOUISIANA. Are you implementing those recommendations now on your efforts on the 777X as it goes through certification?

Mr. HAMILTON. I would say absolutely, based on the lessons learned coming out of the MAX, we are absolutely applying those to the 777–9.

Some of the recommendations, though, we need to work with the FAA on how they want to respond to some of those.

Mr. GRAVES OF LOUISIANA. I would appreciate if you could come back to the committee after looking through some of the recommendations of NTSB and others and advise us of any recommendations that you do not concur with.

Secondly, if you could provide the committee and follow up with—just helping us to better understand what changes Boeing is making. And, look, I understand you are part of the system. The airlines play an important role, the FAA plays an important role,

and others. But what changes you are making to where—you felt it was right, OK, before—and making sure that there are changes.

Lastly, I was going through five recommendations from some of the families, and I want to ask that you follow back up with us: publicly disclose the MCAS fix; clearly define the utility of MCAS; address the concern of the culture within Boeing that might have been prioritizing the wrong things; ensuring that there were not efforts to conceal the MCAS and its role, which I think goes back to defining; and also ensuring that the entire plane is viewed as an integrated system, as opposed to components, individually, that may not recognize their role in the larger system.

Mr. MUILENBURG. Congressman, we will follow up on all those.

Mr. GRAVES OF LOUISIANA. Thank you very much. I yield back.

Mr. DEFAZIO. I thank the gentleman. We are going to recognize—what? Yes, one more Member, and then the panel has requested a break, which I think is quite reasonable, of 15 minutes.

So I will recognize Representative Sires, and then we will have a 15-minute break, and then we will return.

Mr. SIRES. Chairman, thank you for holding this hearing. It is very important.

Mr. Muilenburg, in the spring and summer of 2018, did the former general manager of the 737 program ever raise safety concerns with you about production pressure on Boeing's employees who were involved in the final assembly of the 737 MAX at Boeing's Renton, Washington, facility? Yes or no?

Mr. MUILENBURG. Congressman, yes, I am aware of some concerns that were raised——

Mr. SIRES. So yes?

Mr. MUILENBURG [continuing]. In that time period.

Mr. SIRES. OK. I would like to read from an email that was sent to the general manager of the 737 program in June 2018, 4 months before the Lion crash, and 2 months before the plane was delivered to Lion Air.

The email comes from a senior manager on the final assembly team for the 737 MAX, and it reads like this: "I have some safety concerns that I need to share with you, as the leader of the 737 program," he wrote. . . . "Today we have 38 unfinished airplanes located outside the factory. The following concerns are based on my own observations and 30 years"—30 years—"of aviation safety experience. . . .

"My first concern," he states, "is that our workforce is exhausted. Employees are fatigued from having to work at a very high pace for an extended period of time. . . . Fatigued employees make mistakes. . . .

"My second concern is schedule pressure is creating a culture where employees are either deliberately or unconsciously circumventing established processes. These process breakdowns come in a variety of forms adversely impacting quality. . . .

"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."

The employee was so concerned that he recommended shutting down the production. And he states, "I don't make this rec-

ommendation lightly," he wrote. "I know this would take a lot of planning, but the alternative of rushing the build is far riskier.

"Nothing we do is so important that it is worth hurting someone."

Mr. Muilenburg, I know this employee also wrote to you, personally, in December 2018, after the Lion Air crash, as he spoke with Boeing's assistant general counsel several times after that.

My question is what have you done to ensure the safety issues Boeing employees raised are properly addressed?

I mean you went through before a whole litany of what you do with employees. It seems that this one must have escaped somewhere.

Mr. MUILENBURG. Yes, Congressman, I am familiar with that last communication that you referenced, where the employee sent—or I believe he was a previous employee, a retired employee——

Mr. SIRES. He is retired, yes.

Mr. MUILENBURG. I will double check that.

Mr. SIRES. He went on to retire after 30 years.

Mr. MUILENBURG. He—I recall his email. And we did have several followup sessions with him. I told him I appreciated the fact that he brought up those issues and concerns.

We do know that our team, who, at that point, was running a production line that was operating at 52 737s a month—it was a high-rate line at that point, as we had been ramping up production from 42 to 47——

Mr. SIRES. So what did you do about it?

Mr. MUILENBURG. We took a number of actions on taking a look at each of the work locations within the factory, each of the production stops. We implemented some additional quality checkpoints in the process.

We also just took a look at his concerns, because he was not actually in the factory at that point, but he raised some good concerns, so we went back and took a look at his concerns. And in some cases we identified areas where we thought his issues had already been addressed, and we provided that information back to him.

But this is part of our continuous process in our factories. It is very, very important that we set up a culture where, again, safety is first in the factories. And that comes with quality, as you well pointed out. And safe work is also work that is done in position. And that is one of the big focus areas for us.

What happens in high-rate factories like ours, if—in the production factory, if they have work that gets behind, and it gets out of position, that is when injuries can happen. So our objective is to make sure work can happen in position. That is a safer work environment. And that is an area where we have been very, very focused in our safety efforts, and we will continue to be.

So we take those inputs seriously. We evaluated them, we responded, and we are continuing to take action.

Mr. SIRES. My time is up, and I thank you.

Mr. DEFAZIO. Just one quick followup. Did you reduce the rate of production at that point in time, given his concerns, from 52?

Mr. MUILENBURG. Congressman, we are currently running the 737——

Mr. DEFAZIO. No, at that time. I mean at that time. Did you reduce it——

Mr. MUILENBURG. Sir——

Mr. DEFAZIO [continuing]. Given the concerns he expressed?

Mr. MUILENBURG. Sir, we did not change the production rate.

Mr. DEFAZIO. OK, all right, thank you.

Mr. MUILENBURG. Again, I think it is very important that, when you change a production rate in a line like ours, any change up or down——

Mr. DEFAZIO. Sure, I understand there is a whole supply chain. That is good.

Mr. MUILENBURG. Stability is preferred.

Mr. DEFAZIO. If you want your 15 minutes we are going to have to break now. So we will recess the committee for 15 minutes.

[Recess.]

Mr. DEFAZIO. OK, the committee will come back to order. Which side are we on? We are on this side, right?

So Representative Babin?

Dr. BABIN. Yes, sir, Mr. Chairman. Thank you very much.

I would like to join the others in acknowledging those in attendance here today who lost loved ones in the accidents, and offer my very sincerest condolences to you, and thank you for being here today.

In the interest of time, I would like to get right to it. Instead of directing my questions to one of you, specifically, I would like to address these to both of you, and let you decide who is best fit to answer.

I think there is a feeling out there that, after the Lion Air crash in Indonesia, Boeing sat back and did nothing in terms of addressing the causes of the accident. And since the second crash in Ethiopia, we have heard a lot from Boeing and the rest of the industry about how the information gleaned from these tragic accidents helped to ensure that they are not repeated.

With that in mind, what did Boeing do after the Lion Air crash to ensure that those circumstances were not repeated? And do you have any specific examples of lessons learned that you can share with all of us that have positively impacted the entire commercial aviation arena beyond just Boeing or the MAX, specifically?

If you can, give that to me, one of you, as quickly as possible.

Mr. MUILENBURG. Yes, Congressman, I am going to ask Mr. Hamilton to answer that.

Dr. BABIN. OK.

Mr. MUILENBURG. But if I could, just very quickly, I also need to correct a statement I made on a question from Congressman Sires, where he referenced a concern that had been brought up by a retired employee. I responded to a question about whether the vice president, GM, of the program, had talked to me. And I said yes to that. That was incorrect.

My initial reception of that input was direct from the employee, and I just wanted to clarify that to make sure it was right. We did follow up, and I referenced several actions that were ongoing in our factory concurrently. And the letter from the employee addressed several of those topic areas, but I just wanted to clarify that was separate from the actions that we were taking. And——

Dr. BABIN. OK, thank you. Just very, very quickly, Mr. Hamilton, because I have got some other things I want to say.

Mr. HAMILTON. Certainly. In the—so I—in my previous role I led our accident investigation teams to some of the accident sites, including some of the ones that the chairman announced earlier, and I have led the corrective actions.

In the hours following the Lion Air accident, we convened a group of experts from around the company and started postulating on what possibly could have happened, given the limited data that was available. We quickly identified that this MCAS activation could have been a scenario. We started running that through our labs, running scenario planning. And once the flight data recorder came up later in the week, and it verified what we had, we went—started working on a software change immediately to start working that.

Dr. BABIN. OK.

Mr. HAMILTON. And separately, convened a safety board and determined that that was not enough, just a software change, to mitigate the risk. And we determined that, while the crew—the captain of Lion Air was trimming out the airplane as it was getting MCAS when he handed over the control, it didn't quite follow the assumptions that we had based the design on. So we knew we needed to put an operation manual bulletin out to remind crews——

Dr. BABIN. OK, let me interrupt you because I have got some other——

Mr. HAMILTON. OK.

Dr. BABIN [continuing]. Other things I want to have, but I think I will just submit those for the record.

But I do want to use my remaining time to be perfectly clear about something. As unfortunate as these tragedies are, systems sometimes fail. And we will continue to learn from them until they don't fail. In the meantime, we need highly trained humans in the loop to make judgment calls when things go awry. That means ensuring that the operators of these complex systems know how to triage problems in order to put a plane safely on the ground in the case of an emergency.

The day before the Lion Air crash, when the identical problem occurred, an off-duty pilot riding in the cockpit correctly identified the problem and guided the crew to disable the MCAS and save the airplane. Let me be clear: This plane absolutely should not have been in the air on October the 29th in 2018, another human error.

But this is an indicator that a well-trained crew potentially could have averted this disaster, and all that to say that there are plenty of things that Boeing should have done better. Also, human errors.

And I am sorry to say that even on this committee there are those who claim that Boeing's decisions are made only with the almighty dollar in mind. Are we under the illusion that Boeing makes money when tragedies like these occur? Hard to imagine that Boeing would intentionally suppress information that would make the public safer and their product ultimately better.

We should be using these opportunities to seek out solutions, not trying to hang blame on a company that has as much desire to keep their passengers safe as we do. Let's not forget that more than 5 million people fly safely on Boeing planes every single day.

We must be very careful not to erode American leadership when it comes to safety in aviation. America is unquestionably the gold standard when it comes to commercial aviation, and Boeing has played a major role in getting us to that point.

And, just for the record, I serve no parochial interest in Boeing's commercial aviation program in my District 36 in the State of Texas.

So I would yield back, and I will submit my questions—further questions, then. Thank you, Mr. Chairman.

Mr. DEFAZIO. I thank the gentleman.

Mr. Muilenburg, since you just made a clarification about your response to Representative Sires, I just want to get this straight. You heard directly from this individual, the individual who, 4 months before Lion Air, said that he was hesitant about putting his family on a Boeing airplane after he complained about schedule pressure, exhaustive workforce, et cetera? He corresponded with you directly?

Mr. MUILENBURG. Congressman, as I recall, the—it was via a letter that I received. I am not sure if it was electronic or physical, but it was via a letter from him. I did talk to him——

Mr. DEFAZIO. Right. And in response to my followup you said you didn't reduce production at that point in time, despite having an exhausted workforce, despite all the other concerns he raised. You didn't reduce production because you were concerned about your supply chain.

Now, this—just reflect on this for a second. You talked about your upbringing, modest upbringing. But now, you know, you are a very highly paid CEO of a vaunted American institution, the Boeing Company. And as Mr. Cohen pointed out, and I pointed out at the beginning, after Lion Air you get a $15 million bonus. And you say people are being held accountable.

This gentleman quit the company after 30 years in the industry because his concerns weren't being addressed. But you are leading us to believe that they were significantly addressed. I am sorry, I just don't buy that.

And with that I recognize Mr. Mitchell.

Mr. Garamendi? John, sorry.

Mr. GARAMENDI. No need. You were carrying on a line of questions that I want to pursue.

Mr. Muilenburg, you are the chief executive officer. Do you set the pace for the company? Do you set the standards? Do you set the purpose and goal for the company?

Mr. MUILENBURG. Congressman, that is part of my responsibility.

Mr. GARAMENDI. So the answer is yes, you do those things?

Mr. MUILENBURG. Yes, sir.

Mr. GARAMENDI. Good. And as the chairman just said, did you receive a $30 million remuneration from the company in 2018? Stock, wages, et cetera?

Mr. MUILENBURG. Congressman, I recall my salary was roughly $23 million that year.

Mr. GARAMENDI. Then I suppose this is incorrect. It came from Seattle Times. It says $30 million.

You have at least three employees that have left the company—Adam Dickson, Rick Ludtke, and also a whistleblower in Char-

lotte—all of which said the company's goal is profit over quality. Are they correct?

Mr. MUILENBURG. Those comments are not accurate.

Mr. GARAMENDI. Then what is the company's standard for quality over profit?

Mr. MUILENBURG. Our core values as a company, top of that list: safety, quality, and integrity.

Mr. GARAMENDI. I see. So in 2016, when Boeing started asking for time and cost reductions as part of a manager's performance evaluation, the gentleman that said that, Mr. Dickson, is he incorrect? That is not what happened in 2016?

Mr. MUILENBURG. Congressman, I am not familiar with the specific communication, but it is true that we incentivize our team to perform from a cost and schedule standpoint, as well.

Mr. GARAMENDI. Is that contrary to quality and safety?

Mr. MUILENBURG. Congressman, no, it is not.

Mr. GARAMENDI. So which is most important?

Mr. MUILENBURG. Most important, clearly, safety comes first.

Mr. GARAMENDI. And we have the——

Mr. MUILENBURG. And quality.

Mr. GARAMENDI [continuing]. 737 MAX to prove that that is incorrect.

Mr. MUILENBURG. Congressman, I disagree with that premise, respectfully.

It is very true that we operate in a competitive environment around the world. We are the last remaining big, commercial airplane builder in the U.S. It is a competitive environment.

Mr. GARAMENDI. And you are the most recent to have lost 2 airplanes and 346 people dying as a result of a problem with your quality and your airplane. Is that correct?

Mr. MUILENBURG. Congressman——

Mr. GARAMENDI. It is correct.

Mr. MUILENBURG. As I said, safety and quality are our top priorities.

Mr. GARAMENDI. I see.

Mr. MUILENBURG. And safety and quality go hand in hand with operational——

Mr. GARAMENDI. Would you like to talk to me about the quality of the KC–46? Would you like to go into detail about the abject lack of quality in an airplane that the U.S. Government is purchasing, or wants to purchase from you, the KC–46? You want to talk about the boom? You want to talk about the inability to keep cargo in place? Shall we talk about the quality there?

Or would you like to talk about the quality of the Dreamliner?

Mr. MUILENBURG. Congressman, I agree that we have——

Mr. GARAMENDI. You got a problem.

Mr. MUILENBURG. We have had some improvements to make on quality.

Mr. GARAMENDI. You have a systemic problem in your company. You are reaching for profit, which, incidentally, was very, very significant in 2018. Was it not? Fifteen billion dollars of cash, plus a significant increase in the profit.

You are driving profit, you are not driving quality, and you sure as heck are not driving safety.

Mr. MUILENBURG. Congressman——

Mr. GARAMENDI. I just gave you three examples.

Mr. MUILENBURG. Congressman, I disagree with your premise. Our business model is safe airplanes. That is the only sustainable business model for Boeing. We work in a long-cycle business. It takes 5 to 10 years to bring a new product to the market. When those products come to market, they are typically used by our customers for decades, both military and commercial customers. The only sustainable business model for our company is safety. That is what we are built on. That is why we have lasted 103 years.

Mr. GARAMENDI. Yes, well——

Mr. MUILENBURG. That is why we are the only U.S. builder of big, commercial airplanes remaining today.

Mr. GARAMENDI. Three of your principal product lines—the MAX, 737 MAX; the KC–46; and the Dreamliner—all have quality issues. They certainly all—certainly the case of the MAX, they have a serious safety issue. And I would posit the reality that you are pushing profits over quality and safety.

And those three examples of three of your main product lines—and I see I am out of time, so I have to yield back.

Mr. DEFAZIO. I thank the gentleman. And now I would turn to Mr. Mitchell.

Mr. MITCHELL. Thank you, Mr. Chair. We are talking about 346 lives here. And we refer to it as an accident. It is not an accident. It reflects a failure. It reflects multiple failures. And I think we need to stop talking about accidents. It is a tragedy. Accidents are mistakes on the road that people make, a bad choice, and it is a fender-bender. This is far from that.

Safety begins at design. That is where it starts. I met individually with the FAA, the safety people there. I have met with some of your folks, as you are well aware. And here is one of the things that troubles me. The word "assume" was used way too often for my comfort level.

I was CEO of a business much smaller than yours. We didn't build aircraft. Making assumptions, we know the old saying about assume—I won't use it here, but we know what it means.

You talk about changing your culture. I challenge the FAA to change how they approach thinand when they are dealing with assumptions, they have a separate team, what I will refer to as a red team, or something, to test the assumptions. The worst thing in the world are assumptions.

You have talked about restructuring your team and what you are doing with safety. Who is going to test assumptions in your organization, given the assumptions killed people?

Mr. MUILENBURG. Congressman, that is a responsibility that I count on for—what we call our engineering function. So, as we have recently announced, we have realigned all of our engineers to report directly to chief engineer, as opposed to the programs——

Mr. MITCHELL. Let me stop you, because time is limited. I appreciate it.

But you are—unless you have a separate group doing that independently, outside of the other decisionmaking—you—literally, there is pollution there. There is impact on that. They have got to

do it totally independently. How are you doing that? Or are you doing that?

Mr. MUILENBURG. Congressman, in addition to the realignment internally, typically, in all of our design programs we bring in external experts. We often bring in senior advisory groups. We will bring in what we call nonadvocate groups. Sometimes we will tap a team from another part of Boeing to do what we call a nonadvocate review of other parts of Boeing to get cross checks. So we use resources from a number of different areas.

Mr. MITCHELL. I would ask, if you would, that, for the sake of the committee here, that you explain how it is you are going to go forward with testing your assumptions under—given—in light of where we are at now, not how it has been in the past—what are we going to do about it? Because we have to look forward. We have to look forward, based upon the experience you have had.

And I would challenge that assumptions in the FAA, they assumed MCAS—said MCAS was going to operate in the background. Well, it certainly didn't when things went awry. And in this circumstance we had, it wasn't in the background. It was pretty much in the foreground.

A question for you, an additional question real quickly, if I can.

The March 4, 2014, slide that was shown earlier about the commonality between the NG and the MAX, it said 2 days or less of training would be required. The problem with that is that MCAS wasn't referenced in the training manual. So it just didn't matter. Right? It wasn't in the training——

Mr. MUILENBURG. Congressman, again, the training was focused on trying to respond to the effects of a failed MCAS, which is what we call a runaway stabilizer——

Mr. MITCHELL. But that is what we got.

Mr. MUILENBURG [continuing]. Training, and that is what is included in the training, is how the pilot will respond to a runaway stabilizer.

Mr. MITCHELL. Well, that wasn't in the manual, nor was it—based on talking with a variety of the pilots—was it covered prior to the Lion Air crash.

So, in fact, they didn't know it was there. How do you train on something you don't know is there, that hasn't said upfront, "Here is what is going to happen under these circumstances"? How do you train for that? You don't.

Mr. MUILENBURG. Congressman, as I mentioned, we—one of the things we have learned is we need to provide more MCAS documentation, which we are doing. The intent was that the training for MCAS was to train on the failure mode, runaway stabilizer, as opposed to training on—diagnosing the system itself.

But we have learned that we need to provide more information on MCAS, and that is what we are doing, going forward.

Mr. MITCHELL. Let me in the last 50 seconds or so I have—I am not operating on the basis—or I am not—that profit is somehow evil. I was a CEO of a for-profit company. I don't believe that that incentivized Boeing to do things that are adverse. I think you had competitive pressures you were dealing with from Airbus, and it had impact.

I don't care about your or any of your management team's bonuses. What you are compensated is up to your board. I will say, again, it was a much smaller company I was CEO of, but if I was CEO of a company that I led into—I was responsible for that was mine, and in this set of circumstances, and I owned 38 percent of the company, I would be submitting my letter of resignation to the board of directors. Because I am responsible for it, ultimately.

So one last question. This is a simple yes or no, Mr. Muilenburg. Have you submitted or offered your letter of resignation to your board of directors?

Mr. MUILENBURG. Congressman, I have not. I am responsible. These two accidents happened on my watch. I feel responsible to see this through.

As I mentioned earlier, I grew up on a farm in Iowa. My dad taught me that you don't run away from challenges. And this is a challenging situation. My responsibility is to stick to it, and to help our team work through it, and to get Boeing ready for the future. I feel a keen sense of responsibility to do that. And I am confident that that is what we are going to do, as a company.

Mr. MITCHELL. Thank you.

Mr. DEFAZIO. Mr. Johnson would be next.

Mr. JOHNSON. Thank you, Mr. Chairman. I would like to extend my heartfelt condolences to the families affected by these two tragedies. Looking at the faces of the deceased, their lively, smiling faces, I am deeply saddened that they are no longer with you. But my sadness can in no way match the grief that you must feel. And thank you all for being here.

Mr. Muilenburg, I trust you would agree that the crews of Lion Air flight 610 and Ethiopian Airlines flight 302 were faced with multiple alerts and indications during the accident sequences, correct?

Mr. MUILENBURG. Congressman, my understanding of the accidents is that is correct.

Mr. JOHNSON. And you would agree that they received air speed disagree indicators, correct?

Mr. MUILENBURG. Congressman, I believe, from what we understand, they had air speed disagree, as well as other——

Mr. JOHNSON. Altitude——

Mr. MUILENBURG [continuing]. Flight deck alerts occurring.

Mr. JOHNSON. Altitude disagree indications, correct?

Mr. MUILENBURG. That, and also, I believe, stick shaker alerts, as well.

Mr. JOHNSON. And you would agree that they received various other cautions and warnings during that period, correct?

Mr. MUILENBURG. Congressman, that is my understanding, yes.

Mr. JOHNSON. The National Transportation Safety Board reported in October, in reference to these tragedies, that "multiple alerts and indications can increase pilots' workload." Do you agree with that statement?

Mr. MUILENBURG. Congressman, yes, that statement makes sense. Yes.

Mr. JOHNSON. And the NTSB further observed that "industry experts generally recognize that an aircraft system should be de-

signed such that the consequences of any human error are limited." Do you agree with that statement, as well?

Mr. MUILENBURG. Congressman, I believe that is consistent with our design approaches, yes.

Mr. JOHNSON. And the NTSB went on to note that "the industry challenge is to develop airplanes and procedures that are less likely to result in operator error, and that are more tolerant of operator errors when they do occur." Do you agree with that statement?

Mr. MUILENBURG. Congressman, I think that is one area where we have learned from both of these accidents, is an area that we need to revisit some of our longstanding principles and design guidelines around that. I believe that is an important area for us to address, going forward.

Mr. JOHNSON. So you would agree that, in terms of the design of the 737 MAX and the 730 MAX, MCAS and angle-of-attack sensing systems were not designed such that the consequences of human error were limited. You would agree with that, correct?

Mr. MUILENBURG. Congressman, on the MCAS, as we said, we have identified some areas where we need to improve. And it is related——

Mr. JOHNSON. That is one of them, correct?

Mr. MUILENBURG [continuing]. To pilot workload.

Mr. JOHNSON. That is one of them, correct, the sequence that was not designed to accommodate—well, let me put it like this.

In other words, you would agree that the 737 MAX's MCAS and angle-of-attack sensing systems were not designed such that the consequences of any human error were limited. You would have to agree with that statement.

Mr. MUILENBURG. Congressman, again, from that standpoint, we designed the system to longstanding industry standards. But one of the——

Mr. JOHNSON. But it was——

Mr. MUILENBURG [continuing]. Things we have learned from these accidents is we need to change——

Mr. JOHNSON. This one was not designed so as to accommodate the possibility of human error, in terms of dealing with the MCAS system.

But let me move on. The company has indicated in court filings that you intend to try to stop all litigation in the United States, and ensure that, as far as the Indonesian crash. Any litigation would be confined to Indonesia, and not in the court system of the United States. Correct?

Mr. MUILENBURG. Congressman, I can't comment on that. I am just not familiar with the details of that.

Mr. JOHNSON. Well, so are you here to say that your company would not take efforts to protect itself from the U.S. court system, insofar as the victims of these air crashes are concerned? You trying——

Mr. MUILENBURG. Congressman, if I could take that question, we will get back to you. I don't know the answer.

Mr. JOHNSON. Well, you are attempting to settle things out of court with a $100 million fund available for claimants. Correct?

Mr. MUILENBURG. Congressman, I believe the $100 million fund that you are referring to is one that we recently set up that is com-

pletely separate from any legal proceedings. And it is being administered by Mr. Feinberg. That is intended to be completely separate from any legal proceedings, with the idea that we can more quickly assist the families and communities. So I believe——

Mr. JOHNSON. Participation in that system caused the aggrieved individual's family, next of kin, to then waive their ability to go to court later?

Mr. MUILENBURG. Congressman, the $100 million fund that you are referring to, if I am understanding what you are referring to——

Mr. JOHNSON. Yes.

Mr. MUILENBURG [continuing]. Is completely separate from any legal proceeding.

Mr. JOHNSON. Participating in the $100 million fund would not bar them litigation thereafter?

Mr. MUILENBURG. That is correct. They are completely separate.

Mr. JOHNSON. Thank you.

Mr. DEFAZIO. However, I will say, Mr. Muilenburg, I am incredulous that you don't know whether or not your company is attempting to avoid the U.S. courts for liability regarding Lion Air. Seriously? You don't know that, as a fact? You know nothing about that? You know nothing—that would seem to me it would be a pretty damn big thing. Like, U.S. courts—oh, let's go over to Indonesia.

We go through this with the maritime industry, where mariners on these foreign-flagged ships aren't allowed access to U.S. courts. And you are telling me that this—you are not aware of your legal strategy regarding Indonesia? You really aren't?

Mr. MUILENBURG. Congressman, I am not familiar with that strategy. I do have a legal team with the responsibility——

Mr. DEFAZIO. Well, I——

Mr. MUILENBURG. Congressman, my focus has been on safety.

Mr. DEFAZIO. Yes. Well, we will get back to that.

With that, Mr. Palmer.

Mr. PALMER. Thank you, Mr. Chairman.

Mr. Muilenburg—and, Mr. Hamilton, you may want to comment on this—but the Indonesian Government's final accident report identified nine contributing factors that resulted in the crash of Lion Air flight 610. One of those factors was the absence of guidance on the MCAS, or more detailed use of trim in the flight manuals and the flight crew training that made it difficult for the flight crews to properly respond to the uncommanded MCAS.

And I bring this up in the context that it was reported that, after the initial certification—and I guess this was discovered, obviously, after the plane was certified—that the adjustment in the horizontal tail was greater by a factor of 4 than what was certified. Can either of you address that?

Mr. HAMILTON. I think you are referring to the MCAS authority with low speed versus the high speed. So originally, we did wind tunnel testing back in 2011, and determined we were going to need to do something for the handling characteristics for high-speed windup turns. And that is where we developed the original MCAS.

During flight testing in 2016 we identified that there was some additional work we had to do to satisfy for low speed. And that is where we used the MCAS, to address that.

There is a difference in the authority, but that is partially because, when you are going low speed, you need to move the stabilizer a little bit more to get the pitching moment you need to address the handling quality.

Mr. PALMER. Well, my——

Mr. HAMILTON. But that was all part——

Mr. PALMER. My question here is, in the training—according to what the Indonesian Government found—was the training based on the original certification, or did it take into account both certifications?

Mr. HAMILTON. So——

Mr. PALMER. Were the flight manuals and the crew training adequate to address both situations?

Mr. HAMILTON. Yes, sir. We were open and transparent with the FAA on the authority between the high speed and the low speed, all the way through the certification development. And they understood that prior to certification. And the decision on——

Mr. PALMER. That is not the question. The question is did you provide adequate, detailed instructions for both situations for——

Mr. HAMILTON. When we were having conversations with the FAA about what should be in the training manual, we were accounting for both the high speed and low speed, yes.

Mr. PALMER. But was it adequate?

Mr. HAMILTON. We believed it was sufficient, as Mr. Muilenburg has said, because we wanted to train pilots on how to react to the behavior of the airplane, regardless of what is causing it. And a runaway stabilizer is a memory item that we expected crews would be able to react to and take action.

We have learned since these accidents that we need to take further action.

Mr. PALMER. There is also some criticism that has been reported about the fact that Boeing tends to use the same design for planes, rather than build a new plane. And in the case of the 737 MAX, you were basically using an old design and—that required the MCAS system, because you used larger engines and moved them more forward on a plane. Is that also accurate?

Mr. HAMILTON. We evolved the 737 family through the years, but we have also updated the safety requirements that it is certified to through the years.

And it is not uncommon, as you are developing a new type design airplane, that you find things in flight tests and have to make a software change, or some other control law change to address that.

Mr. PALMER. Yes. But more specifically, you were in the process of a totally new design. And these were on parallel paths, weren't they, for this 737 MAX? You—I mean it—that is what has been reported, I believe.

Mr. MUILENBURG. John, you referenced the early trade studies?

Mr. HAMILTON. Yes, the early trade studies were—we were looking back in 2007 of reengining, and also looking at a brandnew airplane. And those were both being developed and looked at, and we made a decision back in 2011 to proceed forward with the——

Mr. PALMER. OK. Was the decision based on what is the best, safest design, or based on what you could get to market?

Mr. HAMILTON. You know——

Mr. PALMER. In a timely manner.

Mr. HAMILTON. Safety guided the decision. And, you know, pilots fly the family of airplanes. And, from a safety standpoint, it is important that crews are able to transition from one airplane to the next without having to think about "Am I in a MAX or an NG?" They want them to feel and operate the same way. And that is——

Mr. PALMER. Well, that is a matter of time.

Mr. HAMILTON [continuing]. The highest safety issue.

Mr. PALMER. And training. That is a matter of time and training.

I want to say this, that—hearing some of the questions that have been directed toward you today, I do not think that Boeing in any way intends to produce an unsafe product. I do think, though, having worked in engineering, mistakes are made. I think sometimes people make decisions that have very bad outcomes. And I think that might be an issue here.

I have children who fly. I fly every week. And I think everybody in this room probably flies in a Boeing product. And when they put on that seatbelt, they want to know the plane is going to take off safely, fly safely, and land safely. And that ought to be the sole point of this hearing. Retribution and any other thing that comes after that, I think, will be handled in the courts of law. But from the perspective of transportation safety, we want safe planes.

I yield back.

Mr. DEFAZIO. I thank the gentleman.

Mr. Muilenburg, this took me 30 seconds with a Google search. June 10th, Business Insider: "The company is arguing for the cases to be moved from the U.S. to Indonesia." And you would have us believe that you are not aware that your legal team—they are so far distant from you, you don't talk to them, this hasn't been discussed on the board?

You know, my wife was the risk manager for the city of Eugene, Oregon, for a long time. She had to pay the claims. When a big claim came, just a couple of million bucks, against the city, she was involved, the city manager was involved, the legal team was involved, everybody was involved.

You are looking at hundreds of millions, billions of dollars of claims you are trying to move to a country, and this expert says having a trial in another country with a different legal—less scope for close scrutiny of Boeing would render the cases worthless. And you don't know that that is happening, that you are making that pleading?

Mr. MUILENBURG. Congressman, I am aware of those articles. But as I stated earlier——

Mr. DEFAZIO. OK.

Mr. MUILENBURG. I am not——

Mr. DEFAZIO. Would you then please——

Mr. MUILENBURG. I am not——

Mr. DEFAZIO [continuing]. Tell us—would you please respond to the committee after you consult with your lawyers? Have they filed to move these cases to Indonesia in any court in the United States, or do they intend to?

Mr. MUILENBURG. Mr. Chairman, we will follow up with that information.

Mr. DEFAZIO. Thank you.

Ms. Titus?

Ms. TITUS. Thank you, Mr. Chairman. Well, like my colleagues, I have been concerned about some of the text messages and emails that have come out in the documents for this case, especially some of those by your chief technical pilot. I believe his name is Mark Forkner. So let me ask you about those.

As I understand it, Boeing has nearly 5,000 737 MAX orders pending. Is that correct?

Mr. MUILENBURG. Congresswoman, I believe we have 4,400 aircraft in backlog.

Ms. TITUS. And many of those are to airlines that operate outside the United States.

Mr. MUILENBURG. The majority of the backlog is outside of the United States, yes.

Ms. TITUS. Well, I want my constituents to feel safe, whether they are getting on one of your planes in Las Vegas or Las Palmas. So let me ask you about some of these emails that Captain Forkner sent.

We know that he sent these at the same time that he was discussing some of the concerns about the MCAS system. He talks about flying around the world—and this is a quote—"Jedi mind-tricking" foreign customers into purchasing your aircraft. I am not quite sure what Jedi mind-tricking is, but he uses it frequently.

In one of the emails he says, "It is 6:30 a.m. here. Just getting ready to hit breakfast, then try and Jedi mind-trick these people into buying some airplanes!"

Here is another one: "No, I have been working to certify the new 737–8 MAX with all the regulators all over the world, led by the AEG. It was a huge deal, but I got what I wanted, at least so far. You know me, I usually get what I want."

Then a little later he says, "Things are calming down a bit for my airplane cert, at least for now. I am doing a bunch of traveling through the next few months, simulator validations, Jedi mind-tricking regulators into accepting the training that I got accepted by FAA."

So I would ask you what Jedi mind-tricking is, and, if—given these comments, would it be fair to state that your company misled foreign regulators to get your aircraft certified?

Mr. MUILENBURG. Congresswoman, I am not quite sure what Mr. Forkner meant in those emails. We haven't been able to talk to him, given he has departed the company and has legal representation. But any thought that we would try to trick customers or deceive customers is just not consistent with our values. And that would not be tolerated.

So I am not sure what he meant, but that is not our approach.

Ms. TITUS. Well, what is your approach when it comes to international customers? What do you think is your responsibility, especially those that have less stringent pilot training requirements, when you sell a new aircraft abroad?

Mr. MUILENBURG. Congresswoman, we work with regulatory authorities around the world. So typically, those decisions are made

by the authority in that jurisdiction. And we, with the FAA and other regulators, support that.

We also work with the airlines in those other countries. And together we work on training standards. Ultimately, those are decisions that are made by the regulatory authority in that jurisdiction.

Ms. TITUS. Well, since that captain is no longer with you, have you kind of changed or modified in any way your engagement with foreign regulators, or are you still just using the Jedi mind-tricking approach?

Mr. MUILENBURG. Congresswoman, I appreciate your question. I can tell you, again, I am not quite sure what Mr. Forkner meant, but that does not represent the people of Boeing. It does not represent the people who work with our international regulators.

Ms. TITUS. And you are not trying to Jedi mind-trick us here today on this committee?

Mr. MUILENBURG. Congresswoman, I am telling you the truth.

Ms. TITUS. Thank you. I yield back my time to the chairman.

Mr. DEFAZIO. I thank the gentlelady. There is little time remaining. I am a "Star Wars" fan, so I know what Jedi mind-tricking means. Perhaps you watched "Star Wars," too.

But here is one other observation I would like to make. We have brought up your $15 million bonus after the Lion Air tragedy, and Boeing has established a fund of $100 million. And I just did the math. That means that each of the 436 families would receive 1 percent of your compensation that you got last year. You know, that does not seem to be—you know, and—but you are telling us there have been consequences, you are responsible. And yet, these families will get 1 percent of what you got paid.

And you talk a lot about your upbringing as a farm boy. I appreciate that. I grew up a little different. My dad was a teacher. He ran a camp for inner-city kids in the summer. I carried golf clubs for rich people. You are no longer an Iowa farm boy. You are the CEO of the largest aircraft manufacturer in the world. You are earning a heck of a lot of money. And so far the consequence to you has been, oh, you are not chairman of the board any more. I don't know what extra bonus the chairman gets. I know the members of the board get one-quarter-million bucks a year.

So I haven't seen, convincingly, that there have been consequences, except one guy got fired and the chief, the leader of the 737 program, retired in disgust because he wouldn't want to put his family on the airplane.

With that, who am I recognizing? Mrs. Miller.

Mrs. MILLER. Thank you, Chairman DeFazio. And to all of you, my heart absolutely goes out to you. Having lost a family member in a horrible crash, while it was not an airplane, I do know the consequences to children that don't have a parent, and spouses that are missing their loved ones. And it is so hard. And my heart does go out to you.

Also, I think it is very important that safety and quality should always be the highest priority for airline manufacturers. We need to be prepared if technology fails us. With the new technological advancements in all of our industries, it is a possibility that one day there might be a time when we have to decide whether to put

our faith in our training and our intuition, or on a machine. Millions of people fly every day. And while there is new technology in the aviation industry, it is critical that pilots be prepared if a mechanical problem occurs.

With that being said, as we move forward into the future, it is of the utmost importance that we continue to advance and perfect technology before introducing new equipment into the market. We can support innovating and new technology as an added benefit, but we also cannot overlook safety, efficiency, or quality in the aviation industry.

Restoring confidence in air travel is not a political issue. It is a societal issue. Our world has become so much smaller, once we were able to fly. And it is imperative that the airline manufacturers perfect new technology and guarantee safe, flawless, and exceptional airplanes.

Mr. Muilenburg, can you quickly walk us through the safety assessment evaluation Boeing conducted for the MCAS?

Mr. MUILENBURG. Congresswoman, I will attempt to do that. John will be more familiar with the details.

Mrs. MILLER. Well, do it together, if you need to.

Mr. MUILENBURG. We conducted our typical safety review boards and safety system analyses as part of that development. So safety is one of the core parameters that we look at throughout the design, test, and certification process. And that ultimately leads to the certification by the FAA. So that was a very disciplined process, consistent with our normal procedures.

I don't know, John, if you want to add detail to that.

Mr. HAMILTON. Any time we bring forward a new system or something to that effect we do a failure effects analysis of, when something is going to fail, what is the effect of that.

We separately then do a fault hazard assessment, where we then look at all the different faults, and we make an assessment based on what is the hazard category, per regulations.

Then we build a fault tree, which is a top-down look at what is the probability of these events happening. And, again, this is all built to meet regulations.

And then we put together a system safety assessment, which culminates all the information from these different actions, and that is the compliance deliverable that we submit to the FAA for——

Mrs. MILLER. Did Boeing evaluate pilot response to erroneous MCAS activation?

Mr. HAMILTON. Yes, we evaluated, if the MCAS operated uncommanded, what the pilot response would be.

Mrs. MILLER. Did it also show if it could trigger other alarms?

Mr. HAMILTON. We considered that in the analysis.

Mrs. MILLER. OK. In your testimony, Mr. Muilenburg, you mentioned your dedication to safety and culture, and the time you spent traveling to visit different Boeing teams. How can we restore confidence in our air travel, and guarantee industry transparency and communication from top to bottom?

Mr. MUILENBURG. Congresswoman, I believe those changes start with us: my company, myself, and our structure. I mentioned a number of changes we have made internally around safety structures: a new safety organization, a new board, safety committee, re-

aligning our engineering workforce. Those are all actions we are taking to increase focus on safety, and increase transparency. And I believe that is part of rebuilding confidence.

We are also paying close attention to all the independent reviews that are being done, the Government reviews, any other actions we might take together to improve the certification process. I think those are actions that will help, as well.

And then, frankly, we still have a lot of work to do to rebuild the public's trust. And we are going to make sure that the changes we are making to the MAX today will prevent accidents like this from ever happening again. That is our focus. And it is going to take time to rebuild the public's confidence, once we get the airplane back up for the fleets. And we are going to be working side by side with our airline customers, and side by side with the flying public to help rebuild that confidence.

Mrs. MILLER. Thank you. I yield back my time.

Mr. DEFAZIO. I thank the gentlelady.

Mr. Lowenthal?

Mr. LOWENTHAL. Thank you, Mr. Chair. And I, too, join with my colleagues in offering our sympathy and our concern. And, as Representative Graves said right at the beginning of this hearing, this is all about you, the people. I can't imagine what you are going through, but I am so glad you are here to keep us focused that it is all about the people who have been impacted.

So my questions, or my concerns, Mr. Muilenburg, really have to do with the certification process. You know, the JATR, that report, the technical review, found that, despite significant advances being made since the MAX was originally certificated in 1967, these advances, which have led to significant improvements in the safety of air transportation, the MAX failed to incorporate many of these designs and technology advancements, as they were deemed impractical.

What is the reason Boeing failed to include the latest safety features in the MAX, like those Boeing included in other aircrafts like the 787 Dreamliner?

Mr. HAMILTON. Congressman, I want to take an attempt at that.

So, as we are developing a product—and again, I want to go back to—one of the biggest ways we can have safety is—the pilots to be able to transition from one airplane to the next and not have to have a big difference. Whether it is the crew alerting system, or how the systems operate——

Mr. LOWENTHAL. So what you are—excuse me. So what you are saying is you did not include these improvements because it was difficult for the pilots to transition?

Mr. HAMILTON. It is not a question of if it is difficult. It is we want the crews to not have to think about which model they are in, so that they are—the training that they have gone through applies to either model, and they handle each airplane exactly—because the—when you walk on the airplane, you want the pilots to be comfortable flying that product.

Mr. LOWENTHAL. So the question is, then, as you point out, this is an aircraft that was originally certificated—certified in 1967, has not had a full certification since, and the reason had to do with the

ease in which pilots could move between different aircrafts of the same family.

I want to go on. The JATR report found that there were no Federal criteria for determining "when the core attributes of an existing design make it fundamentally incapable of supporting the safety advancements introduced by the latest amendments to airworthiness standards."

So for the FAA, they don't have a Federal criteria when you have to go to a full assessment versus this. What criteria does Boeing use to decide when it is time to upgrade the original design and have a recertification?

Mr. HAMILTON. So, Congressman, there is actually regulations in part 21 of the FARs that defines when you need to do a new type cert, versus an amended type cert. And we follow that process. We have conversations with the FAA about——

Mr. LOWENTHAL. Well, the FAA has no specific standard. You are saying Boeing just follows that the FAA—what the FAA—there is no specific criteria that you use, independent of the lack of standards that the FAA actually specifies?

Mr. HAMILTON. We follow the FAA regulations on new types of——

Mr. MUILENBURG. The standard you just mentioned.

Mr. HAMILTON. Yes.

Mr. LOWENTHAL. OK. Last question. So I am very unclear on what that answer means.

The JATR report also found that the requirements of an amended type certificate certification process, like the MAX went through, focuses only on change and areas affected by the change, which may fail to recognize the whole aircraft system which could be affected by seemingly small changes. Do you agree with the assessment by the JATR report?

Mr. MUILENBURG. Congressman, we are taking a look at all of the recommendations from that report. I believe there are 12 recommendations that are being considered. And one of those areas is this systemwide analysis——

Mr. LOWENTHAL. Right.

Mr. MUILENBURG [continuing]. Failure mode analysis. And we have identified that as a potential area for improvement, going forward. So that is an action that we look forward to supporting, and making appropriate changes. I think it is an area worth looking at.

Mr. LOWENTHAL. So your—you have not—or you are looking at the report—decided how in the future aircraft designs that seek to fall under an amended type certificate, rather than a new type certification—you are discussing, and you will be looking at when an amended type or a full certification is going to be needed?

Mr. HAMILTON. We look forward to working with the FAA and the rest of the industry on any changes that may be required to part 21 on when you apply for one, versus the other.

But you know, the amended type cert is still—you upgrade to the later amendments, later safety requirements, as you make changes to the airplane. So I just want to imply that, you know, the MAX—the requirements that the MAX is certified to, even though it is an amended type cert, it is meeting some later safety requirements than earlier versions of the 737.

Mr. LOWENTHAL. And—thank you, and I yield back.

Mr. DEFAZIO. Oh, well—Mr. Brown?

Mr. BROWN. Thank you, Mr. Chairman. First, let me offer my——

Mr. DEFAZIO. I don't know.

Mr. BROWN [continuing]. My condolences to the families, friends, the communities of the 346 men, women, and children who lost their lives in this tragedy.

Mr. Muilenburg, I believe that you are sincerely sorry, as well. I also know that you wake up every day with the responsibility and the accountability for a large organization. And while your values may be on safety, often in a large organization there are interests like profits, and production rates, promoting that product, and also personal incompetence among the 150,000 people. Not all of them are the most proficient and competent. And those factors can eat away at times at your ability to achieve that most important value of safety.

Mr. Muilenburg, according to the Indonesia Air report, during discussions and communications with the FAA beginning in March 2016, Boeing proposed removing MCAS from the flight crew operator's manual and differences tables, and you have been asked about that. That has been brought to your attention.

I too am a pilot. I flew in the Army. A much simpler airframe, never a commercial aircraft. And what I valued was information, the operator's manual, even technical manuals. My emergency checklist, which is a quick reference handout. It is all important information. Sometimes I would look and I would say, "It is a lot of information," but I knew it was my professional responsibility to prioritize that information.

And my concern here is that Boeing did not give the pilots the information that they needed. And what makes it particularly troubling is sort of like the environment in which this is happening. And a lot of this has already been raised and brought to your attention.

An environment in which your chief technical pilot talks about Jedi mind tricks to convince regulators to accept a lower level of training, I don't know what a Jedi mind trick is, but I know what a trick is. And it is particularly troubling when Boeing has the expertise, you have the data, far superior to what the regulators have, and the chief guy on your team that is interfacing with the regulator is playing tricks to negotiate down training levels, coupled with the fact that—and as the chairman put on the screen, your promotional material as you build your 737 MAX fleet.

Millions of dollars will be saved because of the commonality with the next generation 737, rebates and contracts with Southwest. If you don't have to use a simulator, which is much more expensive to train a pilot, if you have to use a simulator, a $1 million rebate on the airframe. So this is the environment that we are observing in Boeing, and it questions whether or not that profit and promotion is undermining safety.

I want to ask you this question. Mr. Cohen was asking you about—from the same line—Indonesia Air report: "Boeing also considered that the procedure required to respond to any MCAS function was no different than the existing procedures and that crews

were not expected to encounter MCAS in normal operation." I don't want to ask you about the normal operation; Mr. Cohen did.

Existing procedures, that is the runaway——

Mr. HAMILTON. Runaway stabilizer.

Mr. BROWN [continuing]. Stabilizer trim.

Mr. HAMILTON. Yes.

Mr. BROWN. But they are not the same procedure, are they?

Mr. HAMILTON. No, it is a common procedure between the NG and the MAX.

Mr. BROWN. When you have an MCAS failure, it is not really a failure. But when the MCAS is defective, it is not the same emergency procedure as a runaway stabilizer trim.

Mr. HAMILTON. Actually, when it—when the MCAS were to fail, or if a motor were to fail, there is various causes of runaway stabilizer——

Mr. BROWN. OK, let me ask you this. Stabilizer trim fails. I can use a manual trim button, or I can control the column. And if it is a true runaway stabilizer trim, I won't be able to disrupt that failure. Is that correct?

Mr. HAMILTON. No. With a runaway stabilizer, you can—as you say, you can counter it with the——

Mr. BROWN. If I counter it, and I don't get the result that I want, then I go to the cutoff. Is that correct?

Mr. HAMILTON. You go to the cutoff procedure.

Mr. BROWN. Right.

Mr. HAMILTON. Yes.

Mr. BROWN. However, with the MCAS failure, I can actually interrupt the stabilizer trim failure. Isn't that correct?

Mr. HAMILTON. That is true.

Mr. BROWN. Because it happened 15-plus times in the Indonesia Air, didn't it?

Mr. HAMILTON. Yes, the——

Mr. BROWN. Right. So you are saying that you don't put it in the documentation because the emergency procedure is the same. But, in fact, it is not.

And what I am wondering is, when you look particularly at the Indonesia Air, the very first time that the MCAS fails is when the flaps go to zero, full retraction. And you provided no information in any of these manuals that said, hey, you know what, when you go to full flap retraction, you are activating this new system.

Isn't that right, that there is nothing in the manuals that tells a pilot when they have activated the system? Is that right?

Mr. HAMILTON. That was correct, and we are making changes now to add that material to the training manual and the operations manual——

Mr. BROWN. And the MCAS was probably the first computer, right, software system that manipulated a primary flight control in the 737. Isn't that right? The first—not a pilot-induced flight control, change in a flight control, the first computer software system that actually manipulated a primary flight control. That is MCAS, isn't it?

Mr. HAMILTON. Well, actually, the auto pilot that——

Mr. BROWN. OK, OK, OK. Everyone knows the auto pilot. Aside from the auto pilot, right? Isn't that right? MCAS was the very

first computer software that actually manipulated primary flight control?

[No response.]

Mr. BROWN. Yes or no? Or you don't know? Chief engineer?

Mr. HAMILTON. I guess, with the words you are using, I would say that the auto pilot does satisfy that.

Mr. BROWN. OK. Second, then, would be—the MCAS would be the second one, right?

Mr. HAMILTON. There is a yaw damper function on the rudder that moves independent of the pilots.

Mr. BROWN. Do you have—in the quick reference handbook, do you have a procedure for addressing a failure in that?

Mr. HAMILTON. I——

Mr. BROWN. You probably do.

Mr. HAMILTON. I would have——

Mr. BROWN. You probably do. But you don't have it for the MCAS. That is the—as a pilot, you didn't give them the information they needed.

Mr. MUILENBURG. Congressman, as we said, that is one area where we have learned, and we are coming back, and we are adding that information to the manual.

Mr. BROWN. Thank you, Mr. Chairman.

Mr. DEFAZIO. Mr. Mitchell?

Mr. MITCHELL. Thank you, Mr. Chair. Boeing and Boeing aircraft is an iconic brand in this country. I have been asked by a number of constituents and people, "Will you fly the 737 MAX? Will you take that flight?"

I will say publicly I will—given the scrutiny, I will fly it as soon as it is allowed to go back in the air, because I believe it will be the most scrutinized aircraft in the history of this country.

I do want to talk to you a little bit about some of the continuing questions that Mr. Garamendi had. Boeing's tanker they are supplying to the military, it has some significant issues. However, when a similar system was put on it to the MCAS, the Pentagon required that it fire only once. Only once.

Why on the 737 MAX was another approach taken, where it could—and did—fire repeatedly? As my colleague says, significantly, what was the—why the difference in approach, given a similar issue with the aircraft, or similar concern with the aircraft?

Mr. HAMILTON. So the MCAS was—again, it was designed for—as you approached a stall. When pilots do fly into stall, oftentimes they may overcorrect and fly back into a stall. But it was intended that, if you were in a stall condition, and——

Mr. MITCHELL. Let me stop you. I understand stall. I am—had flight instruction, I understand. But you haven't answered my question.

Why the difference between the tanker, where the Pentagon required it only fire once—that was the criteria put forth as they are going through the—taking that aircraft—and the commercial aircraft had a repeated and, in fact, accentuated—you changed the standard on it, it went to a more powerful motion. Ultimately, why the difference? What motivated that?

Mr. HAMILTON. Well, the Air Force set some of the requirements for the tanker that we followed.

Mr. MUILENBURG. Congressman, if I could just add——

Mr. MITCHELL. Sure, please.

Mr. MUILENBURG [continuing]. Add a bit to that. John is correct. The concept behind MCAS on the tanker was for a different purpose, a different part of the flight envelope, as I understand it. We can provide additional details on that, but the reason the design requirements are different is that it was designed for a different part of the flight envelope, and for a different handling qualities purpose. But we will——

Mr. MITCHELL. I appreciate that——

Mr. MUILENBURG. If we could follow up with the details, we will.

Mr. MITCHELL. I would appreciate that. But I think, just to be honest about it, I think we may—we, collectively, the FAA and Boeing, made an error in understanding where it would apply in the flight envelope, in terms of the MCAS, because it clearly occurred within the flight envelope, and it occurred catastrophically. So we are back to my earlier question about assumptions, because they failed.

Question two for you. When doing the simulator testing, I saw some documentation that it wasn't possible to simulate no angle-of-attack data or flawed angle-of-attack data to test pilot response, that, in fact, it wasn't included as part of the simulator. So, therefore, there was no way to figure out whether 4 seconds would work, or 10 seconds, never mind all the other things that may happen.

Can you shed some light on that?

Mr. HAMILTON. Yes. When we evaluated the MCAS failure, we did not actually input a faulty AOA sensor input, because the simulators didn't—couldn't simulate that. But we simulated the actual MCAS failure.

Mr. MITCHELL. Well, let me ask you a question.

Mr. HAMILTON. We have subsequently——

Mr. MITCHELL. I understand——

Mr. HAMILTON [continuing]. Gone forward and actually updated the——

Mr. MITCHELL. Let me ask you a question. You have got how many other sensors on the aircraft? Are there any others that you didn't simulate in order to test the—what would happen, in terms of aircraft performance or pilot response?

Mr. HAMILTON. I can't answer that question off the top, but we could follow up with you on that.

Mr. MITCHELL. I would like you to answer for the committee, because I am astonished, not only with information which I have raised, as well, to the pilots, training requirements for the pilots regarding MCAS.

Then, in fact, in your—it appears to me in your testing process you didn't test whether or not flawed data from a single AOA would, in fact, cause catastrophic problems, which, in fact, it did. They couldn't test it on a simulator. They didn't see it, because they didn't have it. They had other problems, but they didn't see that, your pilots, which are more experienced than some that are flying this aircraft. So I would appreciate that information.

I will yield back. Thank you, Mr. Chair.

Mr. DEFAZIO. I thank the gentleman. Just—you did raise a point that Mr. Hamilton responded to about why the repeated actuation

at a very radical angle, and he said, "Well, sometimes pilots tend to overcorrect, and they can fall back into a stall again."

Well, that kind of contradicts your whole reasoning that they are going to figure this all out in 4 seconds and fly perfectly. I mean I think you have just created something that goes back to your other study, which said if it takes as long as 10 seconds, the plane is going in.

With that I would recognize Mr. Espaillat and then Malinowski.

Mr. ESPAILLAT. Thank you, Mr. Chairman. I first want to extend my condolences to the families that are here today. My district suffered a similar tragedy with flight 587 back in 2001, which, unfortunately, went down in Rockaway of New York City, and I know the kind of hurt that many of you are going through. So my heart goes out to you, my condolences and sympathies to you all.

Mr. Muilenburg, the National Transportation Safety Board recommended that the Federal Aviation Administration develop standards for improved aircraft system diagnostic tools to help the pilots better identify and respond to the kind of failures they met. Will you provide this committee with your absolute assurance that any future Boeing airplane will include such a system?

Mr. MUILENBURG. Congressman, I am not exactly sure what system you are referring to. I am familiar with the NTSB recommendation, and it is one that we are taking a look at. But there are many——

Mr. ESPAILLAT. And are you committed to following those recommendations provided by the NTSB to upgrade and improve your Boeings so that in the future you will not have these kinds of tragedies?

Mr. MUILENBURG. Congressman, we are currently evaluating those recommendations. We think that topic area is certainly one we want to look at. We will get into the details, but we——

Mr. ESPAILLAT. You cannot give us any assurance whatsoever that any of those recommendations that are given by NTSB you, as of today, you are completely sure that you will include them in any future Boeing production?

Mr. MUILENBURG. Congressman, our intent here is to evaluate all of those recommendations. We haven't completed those evaluations yet, but any opportunity we have there to improve safety is certainly——

Mr. ESPAILLAT. And what is the timeline for the evaluation? When do you think you will be completed with those evaluations?

Mr. HAMILTON. Congressman, those recommendations are made to the FAA. So we will have to work with the FAA on how they want to move forward with adopting those recommendations.

Mr. ESPAILLAT. There is—from this entire horrible experience there is not one modification, there is not one single meritorious change that you will make in the production of a Boeing as of today, right now?

Mr. HAMILTON. Well, I think, as a result of these accidents, we are making changes to the software of the airplane, we are making changes to the training, to the procedures.

Mr. ESPAILLAT. What kind of changes have you made for the airplanes?

Mr. HAMILTON. For the airplanes?

Mr. ESPAILLAT. Yes.

Mr. HAMILTON. So we are making three changes to the software that address the MCAS issue. We are making additional changes that further address pilots flying towards stall, and addressing some of those issues, as well.

Mr. ESPAILLAT. Are any of those changes included in these recommendations by the National Transportation Safety Board?

Mr. HAMILTON. I think, when you look at the first recommendation that talks about the MAX, I think it does address that first one, yes.

Mr. ESPAILLAT. OK, thank you. My next question, really quickly, is, Mr. Muilenburg, the Joint Authorities Technical Review report states that the MCAS "used the stabilize trim to change the column force feel, not trim the aircraft . . . and that this is a case of using the control surface in a new way that the regulations never accounted for."

While I understand that you personally maintain that the MAX was designed and certified to the company's standards, will you agree that this is an example of where the regulations have not kept pace with changes in the industry?

Mr. MUILENBURG. Congressman, I don't know if I would characterize it as not keeping pace. It is true that the MCAS implementation is new and different, and we are evaluating what lessons learned we have from that.

So again, all of the JATR recommendations are currently being evaluated, and we are going to take a hard look at all of them.

Mr. ESPAILLAT. Just let me conclude by saying that I know that all of this has to be assessed. I remember back when we had flight 587, the length of time that it took. But there are particular changes that could be adopted immediately that are no-brainers, and that these families, I think, deserve to hear from you with regards to what kind of improvements you will make.

As passengers may consider getting on a Boeing in the future, I think it is incumbent upon you to give responses to these families, and this Congress.

Mr. HAMILTON. Yes, so we are making a number of software changes, as I mentioned, that will prevent the pilots from ever getting into this situation ever again.

But also, I would tell you that, as the FAA is diligently going through all the documentation, they are taking lessons learned from these accidents and applying criteria to us that goes above and beyond what the current guidance and regulatory standards are. And so I would say we are working to a higher level of standard already with that.

Mr. ESPAILLAT. Thank you to both of you.

Thank you, Mr. Chairman. I yield.

Mr. DEFAZIO. The gentleman—Mr. Balderson is recognized.

Mr. BALDERSON. Thank you, Mr. Chairman.

First I want to thank the families and loved ones of the victims that are in attendance today. Your strength does not go unnoticed by everyone in this room and those watching on TV. So my thoughts and prayers are with all of you, and thank you so much for being here.

Mr. Muilenburg, thank you for being here. Following the grounding of 737 MAX, Boeing stated in a CBS news report, "Safety and quality are absolutely at the core of Boeing's values. Speaking up is a cornerstone of that safety culture, and we look into all issues that are raised."

When the 737 MAX was being certified, what procedures were in place to ensure the safety concerns from designers, engineers, test pilots, or mechanics were properly investigated and addressed by Boeing?

Mr. MUILENBURG. Congressman, in addition to the specific updates that John well described on software and training, which are an important part of that answer, we are also making significant restructuring of how we do our work. We have set up a new safety organization that will report to a new vice president, reporting to our chief engineer, creating a direct line of communication back to me.

We have restructured all of our safety review boards within the company, so that they are elevated and, again, provide more ready access, detailed access to safety data. Any safety concerns that our employees might raise will also come through this new organization.

That includes setting up an updated anonymous reporting system. So if we have any employees that have a safety concern, if they wish to remain anonymous, they can report it up through that system. That will come directly to me, and it will also independently go to our aerospace safety committee inside of our board of directors to make sure all of those get the right response.

Mr. BALDERSON. Thank you. My followup would be did Boeing have a process to ensure these safety concerns or whistleblower reports were made available to the FAA during its certification of the plane?

Mr. MUILENBURG. Congressman, yes. Our intent is to share this information. Again, as we gather data, safety concerns are raised, our intent is always to try to share information with the FAA. That is——

Mr. BALDERSON. And I know you have answered some of that, so thank you.

You have discussed some recent actions from Boeing to enhance safety. These include having all Boeing engineers report to Boeing's chief engineer, as well as new anonymous reporting systems. You just talked about that. Can you provide more information on how this anonymous reporting system will work?

Mr. MUILENBURG. Congressman, I will be happy to follow up with the information. It will be modeled after our existing ethics hotline structure, which has proven to be very effective. And our intent is to have a similar model here.

Mr. BALDERSON. OK.

Mr. MUILENBURG. And, if helpful, we can provide additional details on how it is structured and how it works.

Mr. BALDERSON. Yes, please, thank you very much.

Do you believe it should be mandatory for aircraft manufacturers like Boeing to immediately provide the FAA with safety reports or safety concerns that have been filed through the company's internal channels?

Mr. MUILENBURG. John, you could comment on that.

Mr. HAMILTON. So we actually have a bulletin board, an electronic bulletin board, where we take all the fleet data that comes in, anything that meets the criteria that the FAA established on reporting to them. We post it to that, they have total visibility of that.

If we have potential safety issues that—we can post those to the board, as well. So the FAA then can do an independent review of that.

Mr. BALDERSON. OK. Thank you, Mr. Hamilton.

Mr. Chairman, I yield back my remaining time. Thank you very much.

Mr. DEFAZIO. I thank the gentleman. Now Mr. Malinowski.

Mr. MALINOWSKI. Thank you, Mr. Chairman.

Mr. Muilenburg, we have been over a lot of this, but just to be clear, it is fair to say that Boeing pushed the FAA and regulatory agencies around the world to not require simulator training to fly the MAX.

Mr. MUILENBURG. Congressman, our design objective was level B training.

Mr. MALINOWSKI. Understood. And, of course, we have been over the issues with the manual not including information on the MCAS system.

With all of that in mind, let me ask you, just very simply, was Boeing aware that MCAS could pose, under realistic, real-world circumstances, a catastrophic risk?

Mr. MUILENBURG. Congressman, as part of that broader hazard analysis that John described earlier, we evaluate a broad set of scenarios. And that is included in that system safety assessment document.

John, is that——

Mr. HAMILTON. FHA, FHA.

Mr. MUILENBURG. In the FHA?

Mr. HAMILTON. Yes.

Mr. MUILENBURG. OK.

Mr. MALINOWSKI. OK. Well, we have another slide, I think, that may be worth looking at, if folks could put it up.

[Slide]

Mr. MALINOWSKI. OK, thank you. This is from a presentation that Boeing developed for the FAA in December of 2018, after the Lion Air accident, before the Ethiopian Airlines crash. And, as you will see, the slide states that if there were the loss of one angle-of-attack sensor, and the other received a bad reading, the situation was "potentially catastrophic before crew recognition of issue."

And underneath it states, "Crew training supports recognition and appropriate flight crew action." And so it does appear from this and other evidence we have seen that Boeing understood how important crew training would be to prevent these kinds of crashes within a month of the first crash.

And given how quickly Boeing came to that answer, and before many details of the first crash were available, I have to assume that you were aware before the first crash, as well. And yet you actively worked against simulator training. Do you have an explanation for this?

Mr. MUILENBURG. Congressman, I will try to answer that.

And I don't know, John, if you have—you want to jump in on that?

Mr. HAMILTON. So——

Mr. MUILENBURG. Go ahead.

Mr. HAMILTON. The training that we recognize on this is—when you transition from an NG to a MAX—you do simulator training in the original NG training. And that same basic training would apply here.

If you were new to the MAX, there would be simulator training that would be required as part of that. And so that is how that item got addressed.

Mr. MALINOWSKI. Let me also ask you this. Going back a little bit in time, did Boeing lobby for the provisions in the 2003 aviation bill that established this ODA program, which has delegated so many of these basic decisions about whether a plane is safe to fly to industry? Did Boeing lobby for those provisions?

Mr. MUILENBURG. Congressman, I am not familiar with the details back in that timeframe. But you know, Boeing has been engaged in the ODA process and discussions over that time period.

Mr. MALINOWSKI. And it is probably—is it fair to say that, since that time period, Boeing has vigorously lobbied the FAA, and lobbied Congress to lobby the FAA to speed up the certification process?

Mr. MUILENBURG. Congressman, we have advocated efficiency in certification, and trying to do things efficiently across all the stakeholders where we can provide better interfaces and exchange of data. So——

Mr. MALINOWSKI. Well, that is——

Mr. MUILENBURG. Efficiency in the process has been——

Mr. MALINOWSKI. Very bureaucratic language, but I think that means yes. And I think it is something worth reflecting on, because I think this is—there is a larger story here. There is a reflexive tendency among corporate lobbyists in this town to always lobby for streamlined and faster provisions, and less regulation.

And here we have a case—because they see it as in the company's interest. And here we have a case where 346 people died, number one, most important. And in terms of the company's interest, how much money did Boeing lose in the second quarter of 2019?

Mr. MUILENBURG. Congressman, we wrote off billions of dollars.

Mr. MALINOWSKI. Yes. Can you reflect a little bit on this? Is this one of the lessons you have learned, that perhaps this reflexive pattern of lobbying for faster and faster procedures to make it easier for you to get planes to market is not necessarily in the company's best interest?

Mr. MUILENBURG. Congressman, I have to disagree with the premise under the question. We never lobby for something that is going to harm safety. If there are places where we can gain efficiency, the idea is to always enhance the safety of the regulatory system. That is our intent. We have no desire to reduce safety. Our business model is about safe airplanes. And that is the only sustainable approach.

So I understand the point you are making, but our intent is to try to be part of the regulatory system that drives safety.

Mr. MALINOWSKI. I yield back.

Mr. DEFAZIO. I thank the gentleman. We would now go to Representative Stanton.

Mr. STANTON. Thank you very much, Mr. Chairman.

It is clear that during your tenure, Mr. Muilenburg, the top brass at Boeing too often put shareholders before safety, profit before people's lives. And, as a result of the singular focus in getting the MAX to market as quickly as possible, and the actions that were taken, and many that were not taken, 346 innocent people lost their lives.

Today we have heard a lot about the MCAS and its role in these tragedies. The evidence our committee has outlined today and in the months leading up to this hearing shows that Boeing did not even follow its own design requirements when it created this MCAS system and put it on the MAX.

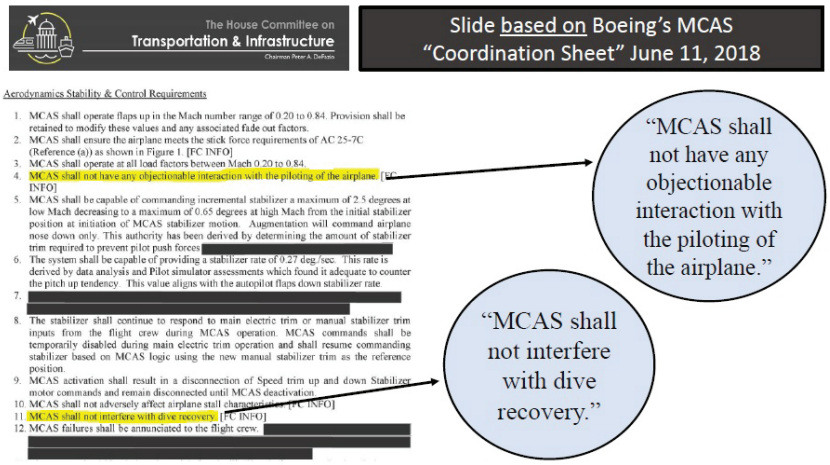
Here is what deeply troubles me: Not only did you fail to follow your own design requirements for MCAS, but you also went to great lengths to hide the existence of MCAS from your customers, and even from pilots, who are absolutely vital to the safe operation of the MAX.

Mr. Hamilton, you are Boeing's chief engineer. It is your job to make sure MCAS works properly. I want to ask you a few questions about Boeing's internal MCAS requirements. Those design requirements were described in detail in Boeing's own coordination sheets.

These coordination sheets were updated as MCAS moved through the design process. But two sheets—one from March 2016, one from June 2018—did not change. Even after Boeing started using a newer, more powerful version of MCAS, these two sheets were never changed. Even more than a year after the 737 MAX entered service, there were still no changes.

First slide, please.

[Slide]



Mr. STANTON. I would like to focus on this slide on two specific design requirements of MCAS.

Design requirement number 4—and you can see it highlighted on the screen—states, "MCAS shall not have any objectionable interaction with the piloting of the airplane."

My time is short, so I need yes-or-no answers, Mr. Hamilton. Did MCAS affect the piloting of Lion Air flight 610?

Mr. HAMILTON. The crew has always had the ability to override MCAS with the trim switches on the wheel.

Mr. STANTON. Let me ask it another way. Did the pilots in the Lion Air flight struggle to counteract the activation of the MCAS system?

Mr. HAMILTON. As the captain was flying the airplane, as you look at the flight data recorder, the captain continually trimmed out the MCAS inputs for multiple times.

Mr. STANTON. Did MCAS affect the piloting of Ethiopian Airlines flight number 302?

Mr. HAMILTON. That accident is still under investigation. I think we will need to——

Mr. STANTON. Mr. Muilenburg, you are the CEO. The buck stops with you. You are ultimately responsible for making sure that you adhere to your design requirements. That didn't happen here, did it?

Mr. MUILENBURG. Congressman, again, we have learned some things from these accidents. We are coming back and we are updating the MCAS design and the training materials.

As we went through our process, we, at each step, tried to make the decisions that are consistent with our process and the data we had. But clearly, we didn't get it all right.

Mr. STANTON. Mr. Muilenburg, are you willing to give a yes-or-no answer to that direct question? You didn't—that didn't happen here, did it?

That is really a yes-or-no question. It is a tough question, but it deserves a fair and direct response.

Mr. MUILENBURG. Congressman, I tried to give you my direct response. It is a complicated question with a——

Mr. STANTON. Thank you.

Mr. MUILENBURG [continuing]. An answer that we——

Mr. STANTON. Reclaiming my time, Mr. Hamilton, design requirement number 11—you can also see it on this slide—it says, "MCAS shall not interfere with dive recovery." Did MCAS affect the dive recovery of Lion Air Flight number 610?

Mr. HAMILTON. Ultimately, after multiple MCAS inputs that——

Mr. STANTON. That was really intended as a yes-or-no question. You have had plenty of time—it is a tough one, but it deserves a yes-or-no answer. Did MCAS affect in any way the dive recovery of Lion Air flight number 610?

Mr. HAMILTON. When the MCAS wasn't trimmed out, as we assumed it would be, it caused the airplane to go into a dive that the crews were not able to recover from.

Mr. STANTON. Mr. Hamilton, was MCAS a contributing factor into the dive, as noted in the final accident report released by Indonesian investigators?

Mr. HAMILTON. Yes.

Mr. STANTON. Did MCAS affect the dive recovery of Ethiopian Airlines flight number 302?

Mr. HAMILTON. Yes.

Mr. STANTON. Mr. Muilenburg, as CEO, I am going to ask you the same question. Did MCAS affect the dive recovery of Lion Air flight number 610 and Ethiopian flight number 302?

Mr. MUILENBURG. Congressman, we know MCAS was a factor in both accidents, and there were a number of things occurring in both accidents. We know MCAS was a contributing factor, and we know we need to make some updates to it, and that is what we are doing.

Mr. STANTON. Mr. Hamilton, I appreciate your direct answer to that question.

Did you—this is back to Mr. Muilenburg.

Did Boeing fail to meet your own design requirements, as it relates to MCAS?

Mr. MUILENBURG. Congressman, we are still evaluating everything we have learned from those accidents. I think what you see here is that there are cases where we have implemented against a requirement set where we have learned we need to make some improvements. And that is what we are doing with the updates.

Mr. STANTON. It is clear that the design to the MCAS stabilization system was fundamentally and tragically fatally flawed. The Lion Air and Ethiopian Airlines tragedies don't just show the fault of the MCAS design, they also show that the system did not even meet Boeing's own design criteria.

It is crystal clear to me, through the course of this investigation, that relinquishing approval of MCAS by the FAA was a grave mistake with severe consequences.

Safety must be our top priority, and Congress must act. We owe nothing less to the victims and their families. I yield back.

Mr. DEFAZIO. We will now move on to Ms. Mucarsel-Powell.

Ms. MUCARSEL-POWELL. Thank you, Mr. Chairman. I have been sitting here, listening to the testimony, and I think that it is clear to me that so much of what we have heard today, and also some of the testimony from yesterday, is that, to a large extent, this is a story about a company cutting corners, taking shortcuts, sacrificing safety to achieve maximum profits.

And at the end, what is it that we have to show for it? Three hundred and forty-six lives were lost, due to the negligence of what happened in those two flights.

Mr. Muilenburg, for me it is very important to focus on the families of the victims that, as you see, are sitting right here. I know that the company started the Boeing financial assistance fund, which provides $50 million in financial assistance to the families of the victims, and $50 million to support education and economic empowerment. So, by my calculation, that comes out to $144,500 to each of the families of the 346 people that were killed in those two flights.

My question, my first question, have you—did you ever reach out to the families before Boeing made this announcement in July, Mr. Muilenburg?

Mr. MUILENBURG. Congresswoman, I did not reach out personally before that——

Ms. MUCARSEL-POWELL. Thank you. How did you communicate about this fund with the families, that you had created this fund for them?

Mr. MUILENBURG. Congresswoman, our reach out to the families is an area where I think we clearly needed to improve. I feel terrible about these two accidents. And having spent time talking with the families the last——

Ms. MUCARSEL-POWELL. But my question is how did——

Mr. MUILENBURG [continuing]. Couple of days——

Ms. MUCARSEL-POWELL. How did you do that? How did you communicate with the families about this fund?

Mr. MUILENBURG. Our Boeing global engagement team reached out. We had connections back into the—into both the—Ethiopia and Indonesia, working with our airline customers——

Ms. MUCARSEL-POWELL. So you never personally reached out to any of the families.

Mr. MUILENBURG. I did not personally. And again, that is something I regret, and I wish I had done——

Ms. MUCARSEL-POWELL. Mm-hmm, thank you.

Mr. MUILENBURG [continuing]. I had done that earlier.

Ms. MUCARSEL-POWELL. How did you and how are you now working with the families to determine the best way to use these funds?

Mr. MUILENBURG. Congresswoman, a couple of things. One, for the first $50 million that you identified, we have asked Mr. Ken Feinberg, an expert in this area, to administer that fund. So he is already, you know, making progress with many of the families. We will continue that.

On the second $50 million——

Ms. MUCARSEL-POWELL. And——

Mr. MUILENBURG [continuing]. We have engaged with the families. That was one of the topics of discussion at our meeting last evening, and we are going to continue that, going forward——

Ms. MUCARSEL-POWELL. Thank you, Mr. Muilenburg. And it was reported in this article that—by CNBC—that the families of the 737 MAX have only until December 31st, 2019, to file a claim with Boeing, with the Boeing compensation fund. Is that correct?

Mr. MUILENBURG. Congresswoman, I am not sure if that is the deadline. But my expectation is that it——

Ms. MUCARSEL-POWELL. Why put a deadline?

Mr. MUILENBURG. Congresswoman, it is not something that I have——

Ms. MUCARSEL-POWELL. I mean there are so many families——

Mr. MUILENBURG [continuing]. Established——

Ms. MUCARSEL-POWELL [continuing]. That are here, just trying to seek basic justice. I want you to take a look at them, just for 1 second, because, obviously, you haven't spoken to them.

Mr. MUILENBURG. Well, Congresswoman, I——

Ms. MUCARSEL-POWELL. So I am going to continue, thank you, Mr. Muilenburg.

Can you assure us today that if these families accept these funds, they will not in any way hinder anybody's ability to sue or take any legal action against the company?

Mr. MUILENBURG. Yes, Congresswoman. This fund is completely separate from any legal activities.

Ms. MUCARSEL-POWELL. So you give me that assurance today?

Mr. MUILENBURG. Yes.

Ms. MUCARSEL-POWELL. Thank you. Now I want to ask for unanimous consent to introduce this article that I found, "FAA Discovers New Safety Concern During Boeing 737 MAX Test."

Mr. DEFAZIO. Without objection.

[The information follows:]

Article entitled, "FAA Discovers New Safety Concern During Boeing 737 MAX Test," Submitted for the Record by Hon. Mucarsel-Powell

https://www.washingtonpost.com/local/trafficandcommuting/faa-discovers-new-safety-concern-during-boeing-737-max-test/2019/06/26/6ebfacf2-9868-11e9-830a-21b9b36b64ad__story.html

FAA DISCOVERS NEW SAFETY CONCERN DURING BOEING 737 MAX TEST

By Michael Laris
June 26, 2019 at 7:57 p.m. EDT

The Federal Aviation Administration has discovered a potential problem connected to the flight control computer on Boeing's 737 Max jets that, in rare circumstances, could force the plane to dive in a dangerous, uncontrolled fashion.

Highly experienced FAA test pilots were concerned that they could not "quickly and easily follow the required recovery procedures," according to a person familiar with the testing who spoke on the condition of anonymity to discuss the findings Wednesday.

The problem is not the same as the faulty data issue that investigators say contributed to the crashes of 737 Max planes in Indonesia and Ethiopia.

In each of those two crashes, investigators say bad information from an external sensor caused an automated feature known as the Maneuvering Characteristics Augmentation System (MCAS) to automatically push the planes' noses down.

In the latest case, the problem "was traced to how data is being processed by the flight control computer" itself, according to the person familiar with the findings.

The aircraft has been grounded since March.

"The FAA recently found a potential risk that Boeing must mitigate," the agency said in a statement. "The FAA will lift the aircraft's prohibition order when we deem it is safe to do so."

The FAA made the discovery during simulator sessions meant to test the plane's overall flight control software and Boeing's proposed fixes to its MCAS feature. Its testing procedures are designed to find and "highlight potential risks," the FAA said.

"Boeing agrees with the FAA's decision and request, and is working on the required software," the company said in a statement.

A company spokesman declined to answer questions about how long it will take to address the new issue or why Boeing itself had not discovered the risk earlier.

Boeing said addressing the issue "will reduce pilot workload by accounting for a potential source of uncommanded stabilizer motion."

"Uncommanded stabilizer motion" is a reference to an automatic adjustment in the position of the horizontal stabilizer on the plane's tail, which can make the aircraft ascend or descend.

The person familiar with the testing said the FAA pilots were unable to quickly follow the steps Boeing and the FAA have described when pilots experience a "runaway" horizontal stabilizer.

The FAA discovery raises the potential for a lengthy delay if Boeing is unable to address the problem by making software changes and instead has to consider hardware upgrades. The agency has instructed Boeing to come up with a plan for fixing the issue, which it will evaluate.

Boeing has been working on a fix to its MCAS software for eight months, the company said. That update makes the MCAS system reliant on two external sensors, rather than just one, and prevents the feature from firing repeatedly, as occurred in the two crashes, which killed more than 300 people.

"Boeing will not offer the 737 Max for certification by the FAA until we have satisfied all requirements for certification of the Max and its safe return to service," the company said in its statement.

Ms. MUCARSEL-POWELL. Thank you. Changing subjects for a second, are you expecting this aircraft, the 737 MAX, to fly any time in the near future?

Mr. MUILENBURG. Congresswoman, we are working with the FAA on that. We have currently set a baseline for——

Ms. MUCARSEL-POWELL. When——

Mr. MUILENBURG [continuing]. Our purposes of——

Ms. MUCARSEL-POWELL. When is that date expected?

Mr. MUILENBURG. The fourth quarter, this——

Ms. MUCARSEL-POWELL. So——

Mr. MUILENBURG. Before the end of the year.

Ms. MUCARSEL-POWELL. So soon? So you are going to feel—because I have lost all confidence, Mr. Muilenburg. I sit on the Transportation and Infrastructure Committee. I have been listening to your testimony and heard some of your testimony yesterday, and I think many of the families have asked for your resignation.

And I have thought for a long time I don't want to blame you. But at some point you have to take full responsibility of the negligence of these two flights. And I want to ask you. Are you going to be stepping down as CEO of Boeing?

Mr. MUILENBURG. Congresswoman, I—no.

Ms. MUCARSEL-POWELL. No?

Mr. MUILENBURG. Congresswoman——

Ms. MUCARSEL-POWELL. It doesn't surprise me.

Mr. MUILENBURG. It is important——

Ms. MUCARSEL-POWELL. Because I saw something else. Boeing increases CEO's pay 27 percent to $23.4 million last year. This was last year.

Mr. MUILENBURG. Congresswoman——

Ms. MUCARSEL-POWELL. So, obviously, you don't want to step down.

Mr. MUILENBURG. My company——

Ms. MUCARSEL-POWELL. But I think that, at some point, to build trust and confidence in your company—because I do agree with you there are thousands of employees that work in this company that don't deserve to be put through this. But it is you, as the CEO, that takes full responsibility for what happened. And I have not heard you doing that.

Mr. MUILENBURG. Congresswoman——

Ms. MUCARSEL-POWELL. And with that, thank you, I yield back my time.

Mr. MUILENBURG. Congresswoman, if I could respond to that, I am responsible. I take responsibility for these two accidents that occurred on my watch. I feel responsible to carry that through.

As I mentioned earlier, I grew up on a farm in Iowa. My dad taught me responsibility, and he asked—what he told me is to—when they are faced with challenges, to carry through. And I don't want to run away from challenges. My intent is to see this through. I think that is part of my responsibility——

Ms. MUCARSEL-POWELL. Mr. Muilenburg, if you had an ounce of integrity you would know that the right thing to do is to step down.

Mr. DEFAZIO. OK, the gentlelady's time has expired. I would now recognize the ranking member, Mr. Graves.

Mr. GRAVES OF MISSOURI. Would you like to finish what you were saying?

Mr. MUILENBURG. Well, Congressman, thank you. Again, I understand the congresswoman's view here, and I respect those inputs. But, as I said, the way I was brought up, when faced with a tough challenge like this, something that occurred on my watch, I have a keen sense of responsibility to see it through. And I think that is part of what I owe to these families, and to their memories. And I am committed to doing that.

To me this is about being responsible and ensuring safe travel for the future. That is my focus.

Mr. GRAVES OF MISSOURI. Thank you. I yield back.

Mr. DEFAZIO. Mr. Allred?

Mr. ALLRED. Thank you, Mr. Chairman. I want to begin by offering my sincerest condolences to the families who are here today. As the father of an 8-month-old child, I am particularly devastated to see the babies in these pictures.

I do believe that Boeing is a great American company, and that is part of why I am so frustrated that we are here today.

I also want to say that the FAA has failed in its duty to make sure that we fix—and we must ensure in this committee that we fix—this process to make sure that this never happens again.

Industry capture of safety regulation in any area is not only dangerous to the public, it is bad business. This has cost Boeing dearly, and it has cost our airlines dearly. That is why it is so important that we get this right.

Mr. Muilenburg, I hope that you are gathering from today's hearing that our concern isn't with the mistakes that were made. We are certainly concerned about that, but we understand that mistakes happen. Even the greatest companies make mistakes. It is the concealment, it is the purposeful concealment that bothers so many of us, with an obvious financial drive behind it.

That the pilots didn't know about this is unacceptable. That you implemented this new system and had airlines rely on you to deliver a safe and reliable aircraft, and you did not do that, it is unacceptable.

And that we in this committee only are finding out some of this information last month, you come here and you are telling us how sorry you are about what has happened, but yet we have to have whistleblowers tell us some of this information about what is going on inside Boeing. We only got some of this information on October 18th about these texts that are going on with some of your people. You have not fully complied with us. We have had to fight and scratch for all the information that we have to try and fix this system. And that makes me angry, and it makes me feel like your use of the word "accountability" has a very different meaning than mine.

Now, this is not about pilot error. I have heard some of my colleagues mention pilot error. This is about catastrophic design flaw, and regulatory failure that has caused us to lose hundreds of lives. Two of your aircraft, sir, have gone down.

In Dallas, where I represent, we have two airlines, Southwest Airlines and American Airlines, both of which have extensive hubs in my area. They have invested heavily in your aircraft. This

grounding and these catastrophes have cost them over $1 billion. They have canceled 9,500 flights in the last quarter alone—that is American, alone. And their hardworking employees are feeling the financial effects of your negligence.

Now, when the 737 MAX flies again, after it has gone through the needed changes that are just now being done, which I think some of this process has shown that you knew should have been done in the first place, it will be a profitable aircraft for your company.

And so, my question to you is how will you compensate the airlines and their employees who have lost so much due to your negligence?

Mr. MUILENBURG. Congressman, we have been working with a number of airlines, including American and Southwest. As you might have seen in our last quarterly report, we took charge of several billion dollars associated with what we call customer compensation. Those discussions with those two airlines and many others around the country and around the world are ongoing. And our intent is to make things right with our customers.

We feel terrible about the impact it has had. We know the flying public has been affected, we know these airlines have been affected. We know their communities have been affected. And we have a deliberate engagement approach with each and every airline, and we are working our way through that. And we have set aside a financial impact associated with that that you have seen in our public reports.

Mr. ALLRED. Well, we are going to be following this closely, because there are hardworking employees of both these airlines who have no role in this, who are doing their best, who have been impacted by this.

I fly Southwest twice a week. Every time I get on a plane someone asks one of the flight attendants whether or not it is a MAX. You have a lot of work to do, sir.

I yield back.

Mr. DEFAZIO. Ms. Davids would be next, the vice chair of the subcommittee.

Ms. DAVIDS. Thank you. Well, first I would like to again extend my condolences to the families that are here. And I appreciate your continued willingness to show up and be a part of this process.

Aviation is extremely important to Kansas, the State that I hail from. And our State has a strong aviation history, and it is vital to my State's economy. And it is vital to the U.S. economy. I think you know that already.

Mr. Muilenburg, to piggy-back off of so much of the questioning we have heard today, and what we heard from you today, and what we heard from you yesterday in the Senate, you have reiterated time and time again Boeing's commitment to safety and pilot training. But we have seen a number of documents, the committee has reviewed a number of documents with an emphasis on an effort to minimize pilot training requirements for the 737 MAX.

My interest is having you provide some clarity on the apparent inconsistencies that we are hearing and seeing. Would you agree that pilot training is important to Boeing?

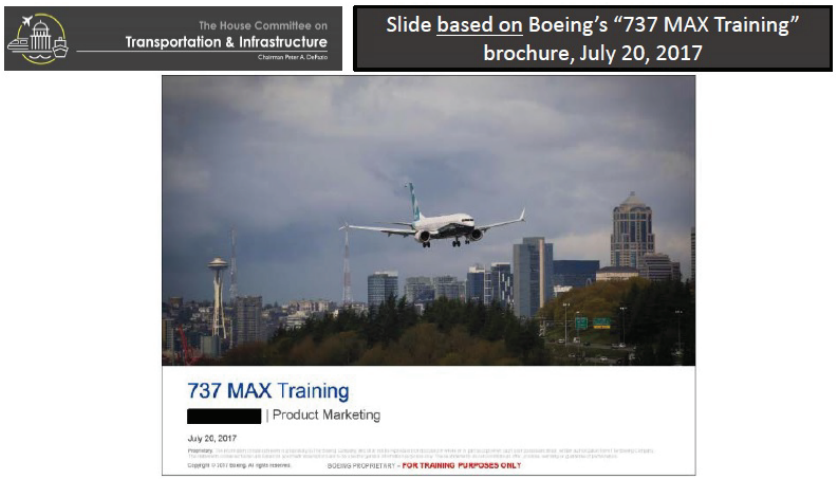
Mr. MUILENBURG. Yes.

Ms. DAVIDS. And when Boeing marketed the MAX to potential airline customers, did they assure the customers that, if they purchased the MAX, it would be unlikely that they would need to put their pilots through timely and costly simulator training?

Mr. MUILENBURG. One of our design requirements that we worked with our airline customers was to do what we call level B training, computer-based training, as a design objective.

Ms. DAVIDS. OK. I have some slides.

[Slide]



Ms. DAVIDS. So this—I have a PowerPoint presentation from a 737 MAX training that one of the marketing officials provided from July 2017, which was a few months after the FAA certified the MAX.

Can you go to the second slide, please?

[Slide]

Ms. DAVIDS. This graphic shows a quote, if you will look in the box here. "We had marketed 2 days previously. A 3- to 4-hour course has now been approved."

Mr. Muilenburg, after FAA's 2017 certification, did Boeing's marketing representatives emphasize to potential customers that FAA had reduced the length of pilot training that Boeing had originally expected?

Mr. MUILENBURG. Congresswoman, I am not familiar with those discussions.

I don't know, John, if you have any awareness——

Mr. HAMILTON. No, I do not.

Mr. MUILENBURG. We can certainly follow up on that question.

Ms. DAVIDS. OK. Well, it is clear from this slide that Boeing had expected a different number of days of training than what it ultimately ended up with.

[Slide]

"This culminates more than 3 years of tireless and collaborative efforts across many business units. Flight Technical, Flight Technical Data, Training Development, Flight Deck Crew Ops, ALL MAX engineering teams, Flight Test Engineering and . . . [the] Engineering Test Pilot team should all be commended for their efforts in getting us to the finish line." -- Boeing 737 Chief Technical Pilot Mark Forkner, August 2016

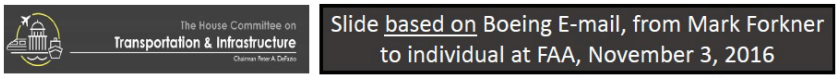
Ms. DAVIDS. So this slide here contains text from an email chain on August 2016 from chief technical pilot Mark Forkner, which announces to a large group at Boeing that the FAA approved the level B training, and that it was—first of all, it—the entire email contains a lot of exclamation points. He was very enthusiastic. And he noted that, "This culminates more than 3 years of tireless and collaborative efforts across many business units." You can see the rest of the text here.

Mr. Muilenburg, level B designation means the 737 MAX was subject to computer-based pilot training requirements, and not more extensive simulator requirements, correct?

Mr. MUILENBURG. Congresswoman, that is correct for the differences training between the models. The baseline training for the 737 MAX is a 20-plus-day training program that includes significant simulator time.

Ms. DAVIDS. So, in a separate email chain—can you bring up the next slide, please?

[Slide]



Ms. DAVIDS. We are very familiar with this quote by this time in the day. Mr. Forkner, in November 2016, tells an FAA official that he was working on "Jedi mind-tricking regulators into accepting the training" that he got accepted by the FAA.

Mr. Muilenburg, the push across Boeing to limit cost of pilot training requirements on the MAX, despite the company's commitment to safety and pilot training, is clear. From the questions we have heard today, the slides we have heard, what is up here right now, this is your chance to provide some clarity on how you mesh all of this information with your continued statements about commitment to safety.

Mr. MUILENBURG. Yes. Congresswoman, I think it is a very good question. And the idea here is that incremental training adds to safety.

We don't make training decisions based on economics. We try to make training decisions based on safety. And as John pointed out earlier——

Ms. DAVIDS. If it wasn't based on economics, what was it based on, that you were trying to push to reduce——

Mr. MUILENBURG. On safe operations for our airlines.

So many of our airline customers who received the 737 MAX, they also fly 737 NGs. And a typical pilot, in a given day, may have a flight on an NG and a flight on a MAX. And it is——

Ms. DAVIDS. What you are saying right now sounds inconsistent with the information that we have been seeing, that you are committed to safety, and that you are not taking into account the economic impacts of the pilot training that people would have to do.

Mr. MUILENBURG. Could——

Ms. DAVIDS. The last thing I want to say is, based on what Congresswoman Mucarsel-Powell said, can you tell us right now, if this article is correct in that December 31st, 2019, is the last chance that families are able to file a claim for the Boeing compensation fund, that you will extend that? Because that is only 2 months from now, and that seems completely ridiculous, that people only have until December 2019.

Mr. MUILENBURG. So, Congresswoman, I—until that was mentioned earlier, I just hadn't recalled that deadline. But I can tell you that is something that we can extend, and I would be—I will give my team that direction. If——

Ms. DAVIDS. Thank you.

Mr. MUILENBURG. If there are families that we can help, and more time is needed, we will take the time. Our commitment here is to try to help the families. And I know, you know, monetary help never relieves the pain, it never will, but hopefully we can help in the communities.

And I don't want to put any kind of artificial timeline on that. So if that is the constraint, we will remove it.

Ms. DAVIDS. Thank you. I yield back.

Mr. DEFAZIO. Mr. García?

Mr. GARCÍA. Yes. Thank you, Mr. Chairman. To the families and friends of those who perished, thank you for bearing witness to what was really lost in the catastrophes.

I would like to explore with you, Mr. Muilenburg, some of the financial forces that may have contributed to the catastrophe, as it relates to the corporation. If you would, answer some simple questions in a yes-or-no format.

One of your primary duties as CEO is to focus on increasing the price of the company's stock. Is that right? One of your duties?

Mr. MUILENBURG. Congressman, one of our objectives——

Mr. GARCÍA. OK.

Mr. MUILENBURG [continuing]. Is to increase the shareholders value, yes.

Mr. GARCÍA. I will take that as a yes. Is your total compensation or realized gains tied to Boeing's stock performing well?

Mr. MUILENBURG. That is one component of it, yes.

Mr. GARCÍA. OK. Mr. Muilenburg, do you know what the stock price was when you became CEO?

Mr. MUILENBURG. Congressman, I do not.

Mr. GARCÍA. It was $140 a share. That is a June 5, 2015, number.

What was the stock price at the last trading day before the Ethiopian Air accident this year, would you know that?

Mr. MUILENBURG. I don't know.

Mr. GARCÍA. Let me help you. It was $422 a share on March 8.

So in a little over 4 years your company's stock rose. It tripled. From 1999 to 2009 it went from $42 to $49 a share. But from 2015 to 2019 it tripled, from $140 per share to $422 a share. Very significant.

In fact, you and your board authorized a $20 billion stock buyback program in December of 2018, 2 months after the Lion Air incident, that helped drive up the price of Boeing stock.

You own shares of company stock, correct?

Mr. MUILENBURG. That is correct.

Mr. GARCÍA. So, in short, you benefitted personally from increasing the stock price. In fact, a report from the American Prospect, shows you made over $95 million from 2015 to 2018. You were pocketing almost $2 million a month, almost half from stock dividends.

The way I see it, your relentless focus on stock price and your company's bottom line may have negatively affected employee performance. Would you agree?

Mr. MUILENBURG. Congressman, I don't agree with that. Our business model is about safe airplanes. It is a——

Mr. GARCÍA. So you don't think that——

Mr. MUILENBURG [continuing]. Long-cycle business.

Mr. GARCÍA. You don't think that employees felt pressured to perform?

Mr. MUILENBURG. Congressman, the realities of the competitive environment, the pressure to perform, is there. But that is never——

Mr. GARCÍA. Well——

Mr. MUILENBURG [continuing]. Equal to safety. Safety——

Mr. GARCÍA. But in November——

Mr. MUILENBURG [continuing]. Is very——

Mr. GARCÍA [continuing]. Of 2016 Boeing conducted an internal survey which—in which over 40 percent of employees stated they felt undue pressure.

Curtis Ewbank, a Boeing employee, said, "Boeing management was more concerned with cost and schedule than safety and quality."

Another, Adam Dickson, said—a Boeing engineer said his managers warned in "very directly and threatening ways" that pay was at risk if targets weren't met.

It is pretty clear there has been a culture of greed and compromising safety at Boeing.

Mr. Muilenburg, you did everything to drive profits over safety. You skirted recertification requirements or regulators at every corner, and your employees even admit to lying to the FAA.

There are basically two ways that this plays out. You either truly didn't realize you had a defective plane, which demonstrates gross incompetence and/or negligence, or you did know you had a defective plane, but still tried to push it to market, in which case it is just clear corruption. Either way, Mr. Muilenburg, you are the captain of this ship. A culture of negligence, incompetence, or corruption starts at the top, and it starts with you. You padded your personal finances by putting profit over safety. And now 346 people, including 8 Americans, are dead on your watch.

Today you said you made mistakes and you are accountable. If Ex-Im Bank isn't reauthorized and the MAX is left grounded, you might be asking us for a bailout. That bill—the Ex-Im Bank is before the Financial Services Committee. I think it is time that you submitted your resignation, don't you?

Mr. MUILENBURG. Congressman, I respectfully disagree with your premise on what drives our company.

Mr. GARCÍA. OK. Well, whether or not you or your colleagues are incriminated in the ongoing criminal investigation, the facts remain. It was either gross negligence, incompetence, or corruption. You are at the top. I think it is pretty clear to me, to the families of the victims, and the American public that you should resign and do it immediately.

I yield back, Mr. Chairman.

Mr. DEFAZIO. Next would be Mrs. Fletcher.

Mrs. FLETCHER. Thank you, Mr. Chairman. Thank you very much for being here today, and thank you for holding this very important hearing. I join my colleagues in expressing my deepest condolences to the families and the friends who are here with us today, and those who can't be here with us. And, of course, they

are in our minds and—as are the victims. And I think that that really needs to remain our focus as we are here today.

We convened this hearing to get the facts and to understand better what we can do, as Members of Congress, to prevent a tragedy like this from ever happening again. And we understand that these are real people whose lives have been affected, lives have been lost, and lives have been forever changed. And so I remain aware of that. And we want to do what we can.

And so, one of the things that has been an issue that we have touched on a little bit earlier today, but I want to follow up on, is this delegation of certification authority. I think this is a critical place where Congress really needs to reassess whether this is a program that should continue.

And I understand—and there have been questions about this earlier—that Boeing was really able to avoid installing some of the latest safety features by using this amended certification. And I think both Boeing and the FAA failed to evaluate the impacts of the MCAS on the whole aircraft system because of this.

So, Mr. Muilenburg, my question is for you, first. The JATR recommends that the FAA needs to ensure that engineers have open lines of communication to the FAA certification engineers without fear of punitive action or process violations. Do you agree with that recommendation?

Mr. MUILENBURG. Congresswoman, we agree with having those open communications, yes.

Mrs. FLETCHER. And what changes, if any, has Boeing made to improve the relationship and ensure that Boeing employees have the access they need to make safety determinations?

Mr. MUILENBURG. Congresswoman, one of the big changes we announced roughly 2 weeks ago now was a standup of a new safety organization. It is centralized within Boeing, a direct reporting line to our chief engineer, who reports to me. That will include our ODA representatives, the delegated authority representatives. I think that will enhance transparency, directness of communication lines with the FAA, and also increase independence from our airplane programs to create that functional strength.

So those are changes we have announced, and are now implementing.

Mrs. FLETCHER. And are other changes under consideration, or is that the extent of your recommendation at this time?

Mr. MUILENBURG. We have multiple recommendations or actions that are underway. That includes the standup of a new aerospace safety committee for our board that is headed up by Admiral Giambastiani that includes a restructuring of all of our safety review boards across the company, so they now are integrated, companywide.

We are standing up a new design requirements organization that, as technology continues to evolve, we can do a better job of sharing those technologies and requirements across the company.

And we have realigned our engineering organization structure so all—roughly 50,000 Boeing engineers now report directly to our chief engineer.

Mrs. FLETCHER. OK, thank you.

Mr. MUILENBURG. There are additional actions underway, and investments for the future. So that list I just gave you is——

Mrs. FLETCHER. OK, sure.

Mr. MUILENBURG. Consider that a set of initial actions with more to follow.

Mrs. FLETCHER. Thank you. I want to move on to a couple more things before my time expires.

Were any Boeing employees subject to punitive action during the development of the 737 MAX for reporting issues to FAA staff?

Mr. MUILENBURG. Congresswoman, I am not aware of any such cases. If there were cases like that, we don't accept retaliation. There is no tolerance for retaliation. So I can't personally say I am aware of any. But let me check the records to see if there are any there.

Mrs. FLETCHER. Thank you, I would appreciate that.

Mr. MUILENBURG. But I can tell you, from a policy standpoint, we do not tolerate retaliation.

Mrs. FLETCHER. I would appreciate if you could get back to the committee on whether any employees were subjected to punitive action. I understand that you don't know that, sitting here today, for a fact.

Another recommendation is that the JATR recommends increased FAA involvement in safety critical areas that are currently delegated to Boeing. I understand Boeing has implemented these changes to internal processes. Have you identified any changes to the delegation process that Congress can help with, as we evaluate these issues?

Mr. MUILENBURG. Congresswoman, we are starting to evaluate those opportunities. So discussions are ongoing with the FAA and others. We think the area of human-machine interface, and how we set those industry standards and the requirements for how pilots operate in a high-workload environment, that is a place where we can work together on new standards.

There are also some older regulations that are currently on the books that could be updated to take advantage of new technologies, and we are identifying a specific list in that area.

So those are two examples. And I would anticipate there will be more.

Mrs. FLETCHER. Thank you. I see I have exceeded my time. But if you could send those recommendations to this committee, that would be much appreciated. Thank you.

And I yield back.

Mr. DEFAZIO. The gentlelady, Delegate Plaskett.

Ms. PLASKETT. Thank you very much.

Good afternoon, everyone, and thank you all for your patience in being here today to hear some of the answers from Boeing. Thank you, those of you who are in the audience, and condolences to your families, as well as to those, I guess, and others in the airline industry who are really looking very closely at what we all have here to say.

Mr. Muilenburg, I wanted to ask you some questions particularly about MCAS.

Following the Lion Air flight 610 accident last year, Boeing issued a bulletin for the 737 MAX. The subject concerned

"Uncommanded nose down stabilizer trim due to erroneous angle of attack (AOA) during manual flight." While this bulletin describes in detail what can occur during an AOA failure, including nose down trim in increments lasting up to 10 seconds, and that "repetitive cycles . . . continue to occur unless the stabilizer trim system is deactivated," I note that not once does the bulletin mention by name what, in fact, causes such a nose down command, which is MCAS.

And I have a copy of a Boeing flight crew operations manual bulletin number TBC–19, page 51. I would ask that this be entered into the record.

Mr. DEFAZIO. Without objection.

[The information follows:]

Flight Crew Operations Manual Bulletin for The Boeing Company, No. TBC–19, Issued Nov. 6, 2018, Submitted for the Record by Hon. Plaskett

BOEING

Flight Crew Operations Manual Bulletin for The Boeing Company

The Boeing Company
Seattle, Washington 98124-2207

737

Number: TBC-19
IssueDate: November 6, 2018

Airplane Effectivity: 737-8 / -9

Subject: Uncommanded Nose Down Stabilizer Trim Due to Erroneous Angle of Attack (AOA) During Manual Flight Only

Reason: To Emphasize the Procedures Provided in the Runaway Stabilizer Non-Normal Checklist (NNC).

Information in this bulletin is recommended by The Boeing Company, but may not be FAA approved at the time of writing. In the event of conflict with the FAA approved Airplane Flight Manual (AFM), the AFM shall supersede. The Boeing Company regards the information or procedures described herein as having a direct or indirect bearing on the safe operation of this model airplane.

THE FOLLOWING PROCEDURE AND/OR INFORMATION IS EFFECTIVE UPON RECEIPT

Background Information

The Indonesian National Transportation Safety Committee has indicated that Lion Air flight 610 experienced erroneous AOA data. Boeing would like to call attention to an AOA failure condition that can occur **during manual flight only.** This bulletin directs flight crews to existing procedures to address this condition.

In the event of erroneous AOA data, the pitch trim system can trim the stabilizer nose down in increments lasting up to 10 seconds. The nose down stabilizer trim movement can be stopped and reversed with the use of the electric stabilizer trim switches but may restart 5 seconds after the electric stabilizer trim switches are released. Repetitive cycles of uncommanded nose down stabilizer continue to occur unless the stabilizer trim system is deactivated through use of both STAB TRIM CUTOUT switches in accordance with the existing procedures in the Runaway Stabilizer NNC. It is possible for the stabilizer to reach the nose down limit unless the system inputs are counteracted completely by pilot trim inputs and both STAB TRIM CUTOUT switches are moved to CUTOUT.

Additionally, pilots are reminded that an erroneous AOA can cause some or all of the following indications and effects:

- Continuous or intermittent stick shaker on the affected side only.
- Minimum speed bar (red and black) on the affected side only.
- Increasing nose down control forces.
- Inability to engage autopilot.
- Automatic disengagement of autopilot.
- IAS DISAGREE alert.
- ALT DISAGREE alert.
- AOA DISAGREE alert (if the AOA indicator option is installed)
- FEEL DIFF PRESS light.

Operating Instructions

In the event an uncommanded nose down stabilizer trim is experienced on the 737-8 /-9, in conjunction with one or more of the above indications or effects, do the Runaway Stabilizer NNC ensuring that the STAB TRIM CUTOUT switches are set to CUTOUT and stay in the CUTOUT position for the remainder of the flight.

Note: Initially, higher control forces may be needed to overcome any stabilizer nose down trim already applied. Electric stabilizer trim can be used to neutralize control column pitch forces before moving the STAB TRIM CUTOUT switches to CUTOUT. Manual stabilizer trim can be used after the STAB TRIM CUTOUT switches are moved to CUTOUT.

Administrative Information

Insert this bulletin behind the Bulletin Record page in Volume 1 of your Flight Crew Operations Manual (FCOM). Amend the FCOM Bulletin Record page to show bulletin TBC-19 "In Effect" (IE).

This Bulletin remains in effect until Boeing provides additional information on system updates that may allow this Bulletin to be canceled.

Please send all correspondence regarding Flight Crew Operations Manual Bulletin status, to the 737 Manager, Flight Technical Data, through the Service Requests Application (SR App) on the MyBoeingFleet home page.

Ms. PLASKETT. Thank you.

Sir, why was MCAS not mentioned in the November 6 bulletin?

Mr. MUILENBURG. Congresswoman, I am going to ask John to add to this one, but it is—what we were attempting to do with that bulletin was to, again, remind pilots of that existing emergency procedure around runaway stabilizer. And the reference to multiple inputs is the behavior that you would expect the airplane to see as a result of MCAS.

So the idea is, again, provide the pilots information about the behavior of the airplane, as opposed to diagnosing the specific system. So that was the intent——

Ms. PLASKETT. So you—the intent was which one?

Mr. MUILENBURG. The intent was to inform them of the failure mode that MCAS could cause.

Ms. PLASKETT. OK.

Mr. MUILENBURG. Rather than try to provide details on MCAS.

Since then, again, feedback from the pilots, we know we need to provide more information on MCAS itself, in addition to the effects of MCAS, and that is part of the update we are making to the training manual.

Ms. PLASKETT. In providing the effects of MCAS, would it have been easier—or to summarize it by using the term "MCAS"?

Mr. MUILENBURG. It perhaps could have. I think that is one of the things we have learned now, is the pilots would like to have additional information on just the definition of MCAS, itself, in addition to the effects of its failure modes.

Again, our goal is to optimize what is in the training manual, so we don't add more information than what is useful for the pilots. Clearly——

Ms. PLASKETT. How large are your training manuals?

Mr. MUILENBURG [continuing]. We could have done better here.

Ms. PLASKETT. How large are the training manuals?

Mr. MUILENBURG. I can't comment on that. I don't know, John, have you got a——

Ms. PLASKETT. They are pretty substantive, aren't they?

Mr. HAMILTON. They are very substantive, yes.

Ms. PLASKETT. So why would that have been any more of a difference to add that?

I saw you nodding your head, sir. Did you want to add anything?

Mr. HAMILTON. Well, they are very substantial in size. But we do go through a process of trying to evaluate what is the right level of information to be in there. We can incorporate all kinds of information.

In hindsight, you know, and in response to the pilots' requests, we are going to put the material in the training manuals on MCAS. We are going to tell them exactly what the need—we are going to have a lot more information there to address this.

Ms. PLASKETT. So is that the decision as to why it was ultimately excluded, because it was seen as, what, not something that the pilots would have——

Mr. MUILENBURG. Again, our intent was to provide information on how to fly the airplane, not necessarily diagnose the system failures. And that is always a balance that we try to get in our training materials.

And clearly, here, we need to provide more information for the pilots——

Ms. PLASKETT. So the reference to MCAS was excluded. Was the reference to MCAS excluded in order to not bring attention to the system—pilots were unaware about it? No?

Mr. MUILENBURG. Congresswoman, the intent was to provide the training materials that the pilots would need to fly the airplane, rather than try to educate them on the system details.

And again, that is an area where we fell short, and we need to provide additional information. And we are going to——

Ms. PLASKETT. So in that same bulletin, just very quickly, Boeing describes how erroneous AOA can cause, potentially, many indications, and as many as four different alerts or lights: IAS disagree, ALT disagree, et cetera.

Do you believe, if several of these indications went off simultaneous in a cockpit, a pilot would be confused about how to respond?

Mr. HAMILTON. So, Congresswoman, when you have an AOA—in the case of Lion Air, where it was miscalibrated, once it got to a certain threshold, and you—you had a difference in altitude, then it would trigger that altitude disagree. When it got to a certain airspeed disagree, then—so they would—they might not come all on at the same time, but they are probably fairly closely linked together on that.

Ms. PLASKETT. OK, so the question was would a pilot be confused on how to respond. And then I yield back.

Mr. HAMILTON. Yes. So the OMB was really about, if you have an AOA issue, it can trigger a number of different indications on the flight deck, and—to help you identify what could be going on. And if you have the stabilizer moving, then perform the runaway stabilizer procedure.

We subsequently went out, at the request of our customers, with a detailed message about MCAS, and explained what it was.

Mr. DEFAZIO. Mr. Carbajal?

Mr. CARBAJAL. Thank you, Mr. Chair. And I want to start by also offering my condolences to the families that are here, and those that—loved ones that have been mourning all of those that were lost in these unfortunate tragedies.

Mr. Muilenburg, I want to dispense with a lot of what my colleagues have already touched on, and just dive into some really poignant, specific questions. So a very brief answer is what I am looking for.

Boeing did not consider erroneous MCAS activation to present a catastrophic risk, correct?

[No response.]

Mr. CARBAJAL. Let me repeat that. Boeing did not consider erroneous MCAS activation to present a catastrophic risk. Correct?

Mr. MUILENBURG. Congressman, I believe the hazard analysis, if that is what you are referring to, we—John, help me out.

Mr. HAMILTON. Yes, that is correct.

Mr. MUILENBURG. We had a——

Mr. HAMILTON. A single MCAS event——

Mr. CARBAJAL. So is that correct or not?

Mr. HAMILTON. A single MCAS event was not considered, I think you used the word, "catastrophic"?

Mr. CARBAJAL. Yes.

Mr. HAMILTON. Yes, that is correct.

Mr. CARBAJAL. Thank you. And as a result of that lower classification of risk, Boeing did not perform detailed evaluations—failure modes, effect analysis, and fault tree analysis—to fully understand the effects of erroneous MCAS activation, correct?

[No response.]

Mr. CARBAJAL. I am just looking for yes or no.

Mr. HAMILTON. We did a thorough analysis of it using our processes that we have used, and we did consider multiple inputs into MCAS.

Mr. CARBAJAL. But did you do the failure modes and effect analysis and the fault tree analysis? Yes or no?

Mr. HAMILTON. No.

Mr. CARBAJAL. Thank you. In fact, in simulator tests, Boeing didn't even simulate erroneous MCAS activation to the full 2.5 degrees of stabilizer motion, correct?

Mr. HAMILTON. Congressman, I think I will have to follow up with you, because I believe we did go to beyond 2.5. I think we went to 3.0.

Mr. CARBAJAL. If you could follow up, that would be great.

Boeing didn't consider repetitive, erroneous MCAS activations in those tests, did it?

Mr. HAMILTON. Could you——

Mr. CARBAJAL. Boeing didn't consider repetitive, erroneous MCAS activations in these tests.

Mr. HAMILTON. We did consider multiple MCAS inputs.

Mr. CARBAJAL. Did Boeing assume pilots would be the redundancy to save the airplane during an erroneous MCAS activation?

Mr. HAMILTON. We assumed that pilots could recognize it and trim it out, and——

Mr. CARBAJAL. So is that a yes?

Mr. HAMILTON. Yes.

Mr. CARBAJAL. In retrospect, given that the erroneous activation of MCAS played a critical role in both 737 MAX crashes, would you agree that this was a flawed assumption that the pilots were the backup?

Mr. HAMILTON. We used an industry standard that has been around for a long time, and—around pilots' actions. And in these cases, that assumption did not play out in these accidents——

Mr. CARBAJAL. So is that a yes or a no?

Mr. HAMILTON. It is an assumption that didn't play out, and I think it is one of the things that we need to address, going forward.

Mr. CARBAJAL. So that would be a yes.

Mr. HAMILTON. If you could restate your question, I will——

Mr. CARBAJAL. In retrospect, given the erroneous activation of MCAS played a critical role in both 737 MAX crashes, would you agree that this was a flawed assumption that the pilots were the backup?

Mr. HAMILTON. Yes, I would say that the assumption needs to be addressed.

Mr. CARBAJAL. So yes?

Mr. HAMILTON. Yes.

Mr. CARBAJAL. Thank you.

Mr. HAMILTON. Yes.

Mr. CARBAJAL. Mr. Chair, I yield back.

Mr. DEFAZIO. I thank the gentleman. We begin what will hopefully be a brief second round. I appreciate the witnesses and the members of the committee who have hung in here.

Mr. Muilenburg, do you know how many 737 MAX aircraft Southwest Airlines had ordered from Boeing, prior to the Lion Air crash?

Mr. MUILENBURG. Congressman, I don't know the exact number——

Mr. DEFAZIO. OK.

Mr. MUILENBURG [continuing]. But we can find it for you.

Mr. DEFAZIO. Well, we were told it was 280. And do you contest the fact that Southwest Airlines would have gotten a $1 million rebate per plane, had the pilots had to go through a simulator training?

Mr. MUILENBURG. Chairman, I believe that was part of the contract structure——

Mr. DEFAZIO. OK.

Mr. MUILENBURG [continuing]. We had with Southwest.

Mr. DEFAZIO. Did you have contracts like that with other customers?

Mr. MUILENBURG. Congressman, I don't know if there are any other customers with that specific clause, but it is not uncommon for us to have incentive clauses in these——

Mr. DEFAZIO. Right.

Mr. MUILENBURG [continuing]. Contracts.

Mr. DEFAZIO. So that would have totaled, obviously, $280 million that would have had to have been paid. Because I think a real key issue is how we got to this point, and how MCAS was not in the manual. That has been my question since way back when.

Let's move on to undue pressure, key learnings, and next steps. Slide?

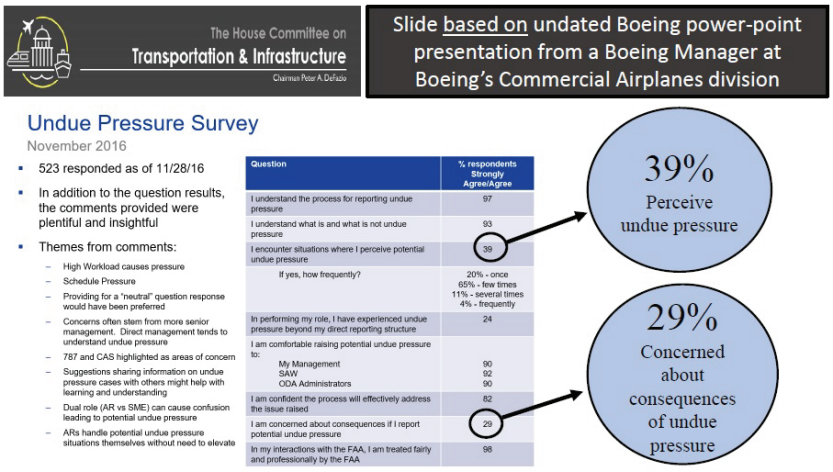
[Pause.]

Mr. DEFAZIO. Slide?

[Slide]

Mr. DEFAZIO. There it goes. This was a survey, which was provided to us by a whistleblower. It was in 2016.

[Slide]



Mr. DEFAZIO. If we go to the next slide, "I am concerned about consequences if I report potential undue pressure, 29 percent."

Then, if we go to the next slide, "When these engineers are also ARs, lines are frequently blurred between when the engineer is acting in an applicant SME role and when they are in an AR role." That was 2016.

And I will give you, in a minute, a chance to respond, but it seems like you didn't pay much attention to the survey and the undue pressure because we then have—and I may have read it improperly before, but he says he was the leader of the 737 program. He was writing to the general manager. He talks about workforce exhausted, schedule pressure. "I am sorry to say I am hesitant about putting my family on a Boeing airplane." That is 2 years later.

It doesn't seem like anything was done to relieve the undue pressure in this culture where people were afraid for their jobs, and there was confusion, you know, which also points to why we need to change this process between, you know, SMEs and ARs and—wait, wait a minute, which hat do I have on, and they are switching hats.

In 2003 I said I don't understand how this is going to work when I voted against this process. I said so someone works for Boeing, gets paid from Boeing, and then someone else works for Boeing and is paid from Boeing, but this person is totally stovepiped over here, and firewalled. They are not responsive to Boeing, they are just responsive to the regulator, but that is not true, because apparently they go back and forth between being a development engineer or being, you know, the AR.

I mean what happened between 2016 and 2018? Apparently not much. Can you point to any significant steps that were taken to change the culture and relieve this undue pressure?

Mr. MUILENBURG. Congressman, I can. And John will feel free to add in, as well.

Mr. HAMILTON. Yes.

Mr. MUILENBURG. First of all, this survey is a survey that we proactively do with our ODA team. The goal here is to identify any sources of undue pressure.

So, in this case, these are the survey results that we proactively sought. We gathered all of these results. We have shared them with the FAA, and we have taken followup actions associated with these inputs.

Mr. DEFAZIO. But then——

Mr. MUILENBURG. The——

Mr. DEFAZIO. That is good, but I am asking for, like, really concrete examples. When you have the leader of the 737 team, 2 years later, workforce exhausted, schedule pressure, it doesn't sound like those things were effective.

Mr. MUILENBURG. Yes, Congressman, if I could, I am attempting to answer the question, and I——

Mr. DEFAZIO. Yes, go ahead.

Mr. MUILENBURG. A very important topic.

Mr. DEFAZIO. Sure.

Mr. MUILENBURG. You will also see on this survey data here that over 90 percent of our employees are comfortable raising issues. And I think the number is 97 percent understand the process for doing so. Those are very high scores. We would still want them higher. But we try to create a culture where employees can speak up and raise issues, so we can take action in response. So that is the culture we are trying to incentivize.

Now, I will say it is true that we have competitive pressures every day. We operate in a tough, globally competitive world. But that never, never takes priority over safety.

And I know we have had this discussion, but I could tell you our culture, as a company, the only long-term sustained business model is safety. And that is because our airplanes last for decades. And having a culture where people are willing to speak up, including the people that responded to this survey, is part of creating that culture.

Now, John, you might be able to comment on specific actions we have taken.

Mr. HAMILTON. Yes, I think there are actually two separate things.

So this was actually looking at the ARs, and the undue pressure. And that is a defined area that the FAA has us act on. We do do recurrent training with the managers in engineering, manufacturing, and quality about how they deal with ARs, and how they need to be treated, and what is undue pressure. And we do take followup actions.

We do audits, and the FAA has come in and actually audited what we did, and they have agreed with what actions were taken.

I think, you know, the other pressures that were alluded to later, 2 years later, it was not an AR, to my understanding. And I think that just—it talks about more the pressures that——

Mr. DEFAZIO. Well, the——

Mr. MUILENBURG. Yes, and again, as I mentioned earlier, I did receive a letter from that individual. And I think he raised some good points, things that we want our people to raise.

We, subsequent to that, evaluated those. We talked to our 737 team——

Mr. DEFAZIO. But you didn't reduce the production rate, as you said earlier. You stated——

Mr. MUILENBURG. Yes.

Mr. DEFAZIO. If I could—I don't want to prolong this too much——

Mr. MUILENBURG. Well, production rate stability, again, sir, is actually better for safety. Consistency in the factory is safer for our workers.

Mr. DEFAZIO. Unless it is moving a little too quick.

So just to go back to the issue of how this all happened, and it started with a phone call in 2011. I brought that out at the beginning. You had an exclusive Boeing customer who called and said, "Can't match Airbus fuel economy and no pilot retraining necessary. We are buying all Airbus."

And then you—you know, I mean, the story is that we didn't rush, except you were looking at—I mean you have a 50-year-old airframe here, some of which—some of the reasons—the problems we had and, you know, why you had to develop MCAS, as opposed to a more stable platform, was because we are dealing with a 50-year-old airframe.

You have still got hydraulic controls. In the newer planes, my understanding is, when you have something serious going on, you actually get prioritization in a more visible way. The disagree light didn't even work.

But we are being told that safety was always paramount, people didn't feel pressure, things weren't rushed. I just don't buy that. And instead of building a clean-sheet design, you might have lost market share for a year or two to Airbus, but then you would have come along with a fabulous, 21st-century airplane that probably would have been better than the Airbus, and you wouldn't be going through what you are going through today.

That was a critical mistake that was made back then, and I believe it exerted pressure throughout the organization from the top down, and it is going to be very hard—very hard—to restore confidence.

And again, when you have the guy who was the leader of the 737 program saying, "I am sorry to say I am hesitant of putting my family on a Boeing airplane," that is a very sad comment on what has happened to the culture of the company.

With that, Representative Brown?

Mr. BROWN. Thank you, Mr. Chairman. I just want to ask a question to clarify my question about computer software. You may recall that question.

I do want to preface first by saying that, look, I know the difference between hindsight and at-the-moment. In hindsight, everything is clear. Today we see MCAS as a much more significant part of the flight control system.

But I still believe that MCAS, at the moment, while you were designing, developing, and promoting it, I think it was a big deal that

you actually just underappreciated. So let me just ask this question here.

So you have the flight control system, a number of components are in it: flight control surfaces, like the stabilizer, and controls, right, cockpit controls, like the yoke or the control arm. You have linkages between the two.

On the 737, all of the flight control surfaces operate by a cockpit control, input by a crew.

The MCAS, as I understand it, is the only computer software that actually operates a flight control surface without crew input. Is that true?

Mr. HAMILTON. No, sir.

Mr. BROWN. You say yes or no?

Mr. HAMILTON. I said no, sir.

Mr. BROWN. OK.

Mr. HAMILTON. As I mentioned earlier, the yaw damper is—operates independent of the crew, and it moves the rudder surface in response to wind gusts. And so—up to 3 degrees. And so crews don't put any input on that, it just happens automatically, based on——

Mr. BROWN. OK. Fair enough, and I appreciate that clarification.

The emergency procedures. I am—you know, and I think, Mr. Muilenburg, you have mentioned this in testimony, I have heard it before from Boeing, and even when Mr. Carbajal was asking questions. The emergency procedure for a runaway stabilizer, first of all, the condition is an uncommanded stabilizer trim movement occurs continuously, which means—let's say the stabilizer goes down, which means the nose is going to go down. You try to make the correction, either the trim button or the yoke, and you are not getting any relief, right? That is a runaway stabilizer trim, right?

Mr. HAMILTON. To do——

Mr. BROWN. Yes or no?

Mr. HAMILTON. That could be a—how it might behave.

Mr. BROWN. Uncommanded stabilizer trim movement occurs continuously. Stabilizer goes down, the nose goes down, right?

Mr. HAMILTON. Right.

Mr. BROWN. Right, OK. So now, if it is continuous, which means I do the control—either the trim button or the control yoke—I don't get any relief, and then the quick reaction handbook says do the runaway cutoff, right?

Mr. HAMILTON. Well, when you say you don't get any relief from the——

Mr. BROWN. Which means if I do either the trim button or the control column, and I were to take my hands off, it would still be going down.

Mr. HAMILTON. So then that sounds like you have multiple failures going on. You have something that is driving the stabilizer in the initial spot, and now you have something else that is causing——

Mr. BROWN. No, I am talking about an uncommanded stabilizer trim movement occurs continuously, and that trim movement causes a nose down.

Mr. MUILENBURG. In which case you trim with the thumb——

Mr. BROWN. Right, but if I trim and nothing happens, that is a runaway stabilizer trim, isn't it?

Mr. HAMILTON. That would be a runaway stabilizer trim, but I am saying that is two different failures that could potentially——

Mr. BROWN. OK. So if I have a runaway stabilizer trim, OK, it is continuous. But with the MCAS activation, it is not continuous.

Mr. HAMILTON. Correct. It moves to a certain position and it stops.

Mr. BROWN. It stops, and I can do some correction, like they did on Lion Air. And then 5 seconds later on Lion Air, MCAS activated again.

So the concern I have is when you say that the emergency procedure should be the same, but the conditions are different. One is continuous and one is intermittent. It happens, it stops when I provide input, and then it kicks in again.

And I know you have got litigation pending, and maybe that is why you don't want to answer the question. But that is——

Mr. MUILENBURG. Congressman, let me try. And John can——

Mr. BROWN. Yes.

Mr. MUILENBURG [continuing]. Help me here, but—so the runaway stabilizer procedure, whether it is caused by MCAS or some other failure mode, the procedure is to trim the airplane, manage your power, and then hit the cutout switch if it continues. So——

Mr. BROWN. But as a pilot, don't you recognize it because, like it says in the QRH, it is continuous?

Mr. MUILENBURG. So——

Mr. BROWN. Right? Is that right?

Mr. MUILENBURG. I think——

Mr. BROWN. It is continuous?

Mr. MUILENBURG. I think the difference you are pointing out is that there is some runaway stabilizer modes where it is one continuous——

Mr. BROWN. Right.

Mr. MUILENBURG. And in the case of MCAS, it is still a continuous movement, but it can happen multiple times.

Mr. BROWN. Right. And——

Mr. MUILENBURG. But——

Mr. BROWN. And here is the point. Here is the point.

Mr. MUILENBURG [continuing]. Multiple time——

Mr. BROWN. There is nothing in the documentation, though, that says to the pilot what continuous is. The pilot is thinking, like, hey, continuous means I try to change it and it ain't changing. That is continuous. But if it changes, but then comes back, that is not really continuous. That is intermittent.

Mr. HAMILTON. Yes, I think——

Mr. BROWN. And this is where—and so, with the Lion—you said you are making changes in documentation.

Mr. HAMILTON. Yes.

Mr. MUILENBURG. Yes, sir.

Mr. BROWN. I really hope that you are looking at an emergency procedure, a quick reaction procedure, OK, that expressly addresses MCAS and the intermittent nature of MCAS, if it continues to be intermittent.

Mr. MUILENBURG. And, Congressman, to that point, that is one of the software changes we made. It is no longer intermittent. It can only operate once.

Mr. BROWN. Got it.

Mr. HAMILTON. Yes.

Mr. BROWN. Thank you, Mr. Chairman. I yield back.

Mr. DEFAZIO. Mr. Larsen?

Mr. LARSEN. Thank you.

Mr. Muilenburg, yesterday, in response to some media reports and a question about them, you denied media reports that say that there were significant changes to MCAS low-speed extension that were not fully vetted by the FAA. You said they were fully vetted.

But the Indonesian accident authorities found FAA's response to the revised system safety assessment was simply to accept the submission. It seems to me there is a difference between the FAA accepting the submission, versus the FAA fully vetting the changes.

So if that was the case, do you—and this gets to the—kind of the heart of some of these certification questions, on whether enough or too much has been given through the authority to Boeing, or to any other manufacturer.

Can you help me score that circle, what "fully vetted" by FAA means, versus what simply——

Mr. MUILENBURG. Yes, sir.

Mr. LARSEN [continuing]. "Accepting the submission" means? Because it seems like there is no way to score that circle.

Mr. MUILENBURG. Congressman, let me try. And then, John, if you want to——

Mr. HAMILTON. OK.

Mr. MUILENBURG. Or do you have a comment you wanted to——

Mr. HAMILTON. Yes, Congressman. I think, you know, there has been some implications here about the ODA and what the role was.

The system safety assessment, the certification deliverable, was retained by the FAA. It was not delegated to the ODA until the very end, after the FAA had reviewed it and provided comments back to the ODA and said, "If these comments are incorporated in the system safety assessment, then the AR is delegated to fly in compliance." But the FAA had reviewed that document for several months.

Mr. MUILENBURG. And Congressman, if I could just add in, just to try to square this off with the comments you heard yesterday, what I was referring to is that, during that time period from—it was mid-2016 to early 2017—the fact that we extended MCAS to the low-speed operation——

Mr. LARSEN. Right.

Mr. MUILENBURG [continuing]. Envelope, that was discussed with the FAA in many ways. We conducted multiple flight tests. Some of those included FAA pilots on board the aircraft. And that ultimately led to the certification of the airplane with the MCAS software, including the extension to low-speed operations.

And that—we are talking about two ends of the same equation there.

Mr. LARSEN. Yes. So—and I appreciate that. I know you won't mind, though, that we are going to continue to go through the doc-

uments you have provided us, and go through FAA documents, as well, to clear that up from our end of things.

Mr. MUILENBURG. And Congressman, I do think we have also identified some areas where we need to improve the documentation in some cases, recording of decisions and making sure those were communicated——

Mr. LARSEN. Yes.

Mr. MUILENBURG [continuing]. To all parties. And that is one of the areas of improvement that we have also identified, and working that jointly with the FAA.

Mr. LARSEN. And related to that, sort of the paper trail side of things, Mr. Hamilton, in October, on October 20th a statement from Boeing referenced that—back to Mr. Forkner—his comments in these text message exchanges reflected a reaction to a simulator program that wasn't functioning properly, as opposed to how many of us read it, that being an MCAS not functioning, and then him making his comments that it did.

However, if it is only—from my understanding, if it was—does it matter if it was just a simulator problem, or if it was deeper MCAS?

There is no paper trail that I am aware of yet that tells me anything was fixed, whether it was an MCAS problem that was fixed, or if it was a simulator problem that was supposed to be fixed. If we are using the simulators that are supposed to be fixed in order to test the—a 737 MAX, I don't feel any better about that, either.

Mr. MUILENBURG. OK——

Mr. LARSEN. So is there a paper trail? To whom did Forkner report this? Who is ultimately responsible for fixing the simulator, if that, in fact, is what it was? And can we—and I hope that we can get those documents.

As well I am going to ask—I want to ask the FAA the same thing, not just how far up the ladder did he have to report, but across to the FAA, and letting them know about the simulator.

Mr. MUILENBURG. Congressman, again, we are not completely sure what he meant in that message——

Mr. LARSEN. Well, join the crowd.

Mr. MUILENBURG [continuing]. That he talked about, but it appears he was working on a simulator, and he is referencing the low-speed extension of MCAS.

Mr. LARSEN. Right.

Mr. MUILENBURG. We need to confirm that. We do know that he was working at that time on a simulator. At least our best understanding is that he was at that time working on what we call an unqualified simulator. So it was a newer simulator that was being brought up to standard. It was not yet at a position where it fully represented the airplane, itself. And——

Mr. LARSEN. Would he have known that? Was he supposed to have known that?

Mr. MUILENBURG. He——

Mr. LARSEN. Why——

Mr. MUILENBURG. Yes——

Mr. LARSEN. And why was he——

Mr. MUILENBURG. He knew that he was——

Mr. LARSEN. Why was——

Mr. MUILENBURG [continuing]. He was operating—again, our understanding here; we haven't talked directly to him—our understanding is that he was in a simulator development process. And it appears from his comments that he was surprised about some feature. Having spent some time in simulators, it is not uncommon for us to have to work on the software to get it to be fully representative of the airplane, over time.

Now, regarding the paper trail on that simulator, I don't know if we have any details on that, but we can follow up.

Mr. LARSEN. And we will follow up. I am over my time, and there are other Members. We will follow up with that.

Mr. MUILENBURG. I——

Mr. LARSEN. So thank you. I got to say thanks.

Mr. DEFAZIO. I would like to recognize——

Ms. DAVIDS. Thank you, Chairman.

Mr. Muilenburg, I would like to talk to you about the AOA disagree alert, and that Boeing recently admitted that the AOA disagree alert on the 737 MAX that was supposed to be a standard feature on all MAX planes was inoperable on MAXes where they didn't purchase the optional AOA indicator.

And it seems as though about 20 percent of the MAX airplanes purchased, the AOA indicator—so the AOA disagree alert was inoperable on 80 percent of the aircrafts. Does that sound right to you?

Mr. MUILENBURG. Congresswoman, I can't give you the exact number, but it was correct that it was not implemented correctly. We made a mistake on that, and we discovered that. Our engineers discovered it, and we have subsequently——

Ms. DAVIDS. OK, that is——

Mr. MUILENBURG [continuing]. Made that fix.

Ms. DAVIDS. That is good for now.

Mr. MUILENBURG. And all our airplanes will have that standard, going forward——

Ms. DAVIDS. When did Boeing learn that the AOA disagree alert wasn't operable on that 80 percent of the aircrafts?

Mr. MUILENBURG. Congresswoman, I can get back to you with the exact timelines, but it was—I don't want to guess on the exact timelines, but it was——

Ms. DAVIDS. OK, when did you personally——

Mr. MUILENBURG [continuing]. Discovered by our engineers, and then it was——

Ms. DAVIDS. When did you personally learn about it?

Mr. MUILENBURG. I just don't recall the exact timelines. I do know that there was a lag between our discovery and it being reported to the FAA. And again, that is——

Ms. DAVIDS. Was there a lag between the discovery and your finding out, and then the FAA finding out?

Mr. MUILENBURG. Congresswoman, the communication timeline on the AOA disagree alert was too long. The communications were not done the way we should have done them. And that is one of the reasons we have revised our review board structures.

Ms. DAVIDS. So—I agree with you, that it was too long.

I also want to just note the issue of candor that Congressman Allred brought up as it relates to the communications that Boeing

had with the regulators and its customers and, thus, the flying public.

So it was only after the Lion Air accident, as I understand it, when Boeing learned of the defect. It waited 3 years—you waited 3 years, until 2020, to actually fix the problem.

Mr. HAMILTON. So, Congresswoman, in 2017 is when we identified the discrepancy. We immediately convened a review board to understand whether or not it was a safety issue or not. We analyzed it, and determined it was not critical for safety of flight. We notified the FAA just after, I believe, the Lion Air accident. The FAA independently convened their own safety board, and——

Ms. DAVIDS. So before you—you continued to manufacture the MAX and distribute it to the customers. Did you—at that time were you providing these MAX aircraft to—with a known defect to your customers without telling them that?

Mr. HAMILTON. Congresswoman, yes, the airplane did not conform to the spec that—the disagree was not working. I am not sure why we didn't notify the customers of that. But we——

Ms. DAVIDS. Who would have been the one to decide not to notify the customers?

Mr. HAMILTON. The——

Ms. DAVIDS. Was it your marketing team?

Mr. HAMILTON. No, it would have been——

Ms. DAVIDS. Was it——

Mr. HAMILTON. It probably would have been somebody on the engineering team on the 737 program.

Ms. DAVIDS. OK. So it might not be a safety critical thing, according to you, but this certainly raises ethical issues, I would say, and issues of candor, which we have been talking about.

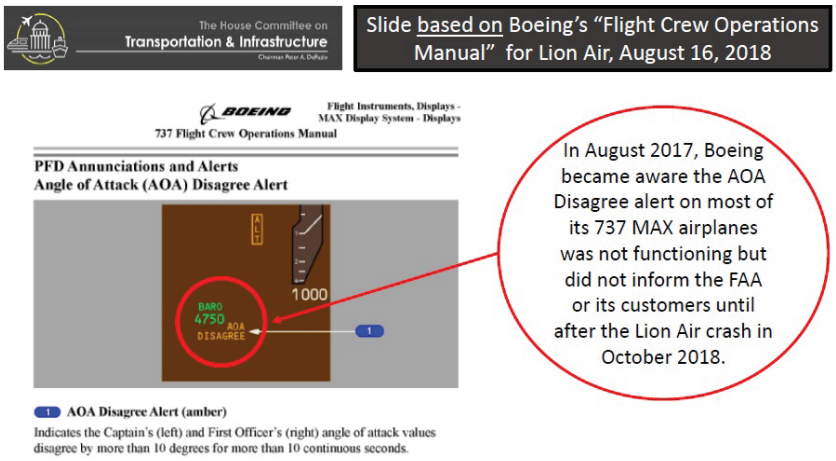
And I want to bring up—I think we have got a couple of slides here.

[Slide]

Ms. DAVIDS. OK, so this is the cover of the flight crew operations manual, or FCOM—lots of acronyms here—delivered to Lion Air in August of 2018. I want to note that this is 1 full year after Boeing

learned that the AOA disagree alert on the 737 MAX airplanes—that it didn't—which they didn't purchase the AOA indicator on, that it wasn't fully functioning, and that Lion Air didn't purchase the indicator on the disagree—I think I need the next slide.

[Slide]



Ms. DAVIDS. The disagree alert was inoperative. So this shows the August 2017—that Boeing became aware that the disagree alert wasn't working. And it wasn't until after the Lion Air crash in October 2018 that they let the FAA know.

I guess, regardless of whether or not you classify the AOA disagree alert as a safety feature or—a critical safety feature, it was required on the aircraft, was it not?

Mr. HAMILTON. It was part of our configuration spec. But there was no crew action associated when you get the disagree message. So it was for crew awareness.

Ms. DAVIDS. So you are saying it—so it was part of your what?

Mr. MUILENBURG. Congresswoman, it was part of the airplane baseline. It should have been implemented on the airplanes. It was not correctly implemented. We made a mistake.

A sister safety review board was brought together, as John described. They came to the conclusion that they could implement that in the 2020 timeframe, in the next software cycle, as you referenced.

Ms. DAVIDS. How do you decide——

Mr. MUILENBURG. That did not get——

Ms. DAVIDS. How do you decide which things are baseline that you are not going to adhere to, and which ones you are?

Mr. MUILENBURG. Yes, Congresswoman, we missed on this one. We made a mistake. We made a mistake. And we have owned up to that. We need to fix it.

Ms. DAVIDS. OK.

Mr. MUILENBURG. One of the reasons——

Ms. DAVIDS. My time has expired. Hopefully we will get to ask you another question, because we, at some point, need to get to how we make sure, as legislators, that this doesn't happen again.

I yield back.

Mr. DEFAZIO. Representative Fletcher?

Mrs. FLETCHER. Thank you, Chairman DeFazio. I want to circle back to another topic that is related to information given to the operators, which is the pilot training following the Lion Air crash once there was a determination to work on the fix to the MCAS system.

There is an ongoing conversation about what additional pilot training, if any, would be required. So I just want to make sure that I understand. I have a couple quick questions.

Following the Lion Air crash, Boeing began developing a software update for MCAS, correct?

Mr. HAMILTON. Correct.

Mrs. FLETCHER. OK. And, as part of the software update process, does Boeing need approval of associated pilot training standards by the FAA's flight standard service?

Mr. HAMILTON. Not necessarily for that specific change at the time.

Mrs. FLETCHER. Well, it is my understanding that in December of 2018 Boeing met with the FAA's transport aircraft evaluation group to discuss and plan, evaluate, and validate——

Mr. HAMILTON. That was——

Mrs. FLETCHER [continuing]. The MAX, the system enhancements, correct?

Mr. HAMILTON. That was subsequent, yes.

Mrs. FLETCHER. And part of that conversation was that the FAA tasked Boeing with proposing pilot training related to the MCAS software fix that would be evaluated and documented in the FAA's flight standardization board report.

What level of pilot training did Boeing propose to the FAA?

Mr. HAMILTON. That would have been level B training, which is a classroom or CBT, computer-based training, training.

Mrs. FLETCHER. Would it surprise you to learn that Boeing recommended level A training at that time?

Mr. HAMILTON. I am not aware of that.

Mrs. FLETCHER. You are not aware that Boeing recommended level A pilot training, instead of level B?

Mr. HAMILTON. No, I am not aware.

Mrs. FLETCHER. OK. Mr. Muilenburg, are you aware that Boeing recommended level A training instead of level B?

Mr. MUILENBURG. No, I am not aware of that.

Mrs. FLETCHER. Well, according to a letter from Boeing to the FAA, Boeing represented that, for the MCAS enhancement, level A training would only be required. And Boeing stated in the letter that its position, which—I have the letter here in front of me, and I am happy to present to you all—that Boeing believes that the rationale for the original recommendation was still applicable, and that Boeing believes there isn't a difference relating to the MCAS flight control law doesn't affect pilot knowledge, skills, abilities, or flight safety.

Do you still believe that statement is true?

Mr. HAMILTON. With the software changes being made, it was going to prevent the MCAS from operating like it did in the accident flight. So yes.

Mrs. FLETCHER. You still believe that level A training would be the appropriate level of training?

Mr. HAMILTON. It—the software changes will prevent the pilots from ever seeing that type of condition again.

Mrs. FLETCHER. Do you understand that the FAA responded to that by saying that they didn't—they cautioned Boeing that level A training might not be the appropriate level of training, and that, while they were willing to evaluate the proposal, that Boeing was proceeding at its own risk?

Mr. HAMILTON. I am not familiar with that.

Mrs. FLETCHER. Mr. Muilenburg, are you familiar with that recommendation from the FAA, that to proceed with only level A training, Boeing would be proceeding at its own risk?

Mr. MUILENBURG. Congresswoman, I am not. But we can certainly follow up on that, and we will.

Mrs. FLETCHER. Thank you. It is my understanding that, following that exchange between the FAA and Boeing, that the FAA said that it would be OK to proceed with scheduled flight simulation tests.

Are you aware of that part of the process, that flight simulator tests were scheduled?

And do you know when those were, earlier this year?

Mr. HAMILTON. What timeframe are you referring to?

Mrs. FLETCHER. Well, the simulator tests were scheduled for March 13th, 2019. Are you familiar with those tests?

Mr. HAMILTON. I recall that there were some simulator tests done in Miami around that time, yes.

Mrs. FLETCHER. And what date did the Ethiopian Airlines crash take place?

Mr. HAMILTON. It was March—it was in March of——

Mrs. FLETCHER. March 10th, 2019, before the simulator tests.

Thank you, Mr. Chairman. I yield back.

Mr. DEFAZIO. I thank the gentlelady.

I just want to—in response to a previous question I believe Mr. Hamilton said that the FAA was completely aware of the much-enhanced MCAS system.

But the finding of the JATR was finding F2.7–A, "The FAA was not completely unaware of MCAS; however, because the information and discussions about MCAS were so fragmented and were delivered to disconnected groups within the process, it was difficult to recognize the impacts and implications of this system. If the FAA technical staff had been fully aware of the details of the MCAS function, the JATR team," an independent group, "believes the agency likely would have required an issue paper for using the stabilizer in a way that it had not been previously used. MCAS used the stabilizer to change the column force feel, not trim the aircraft. This is a case of using the control surface in a new way that the regulations never accounted for and should have required an issue paper for further analysis by the FAA. If an issue paper had been required, the JATR team believes it likely would have identified the potential for the stabilizer to overpower the elevator."

So there is a breakdown there, and we have just got to determine whether it was intentional, unintentional, how much of it lays on

Boeing, and how much of it lays on the FAA. But in this case, they seem to be laying a lot of it on Boeing, and the communications.

Mr. Brown had a quick clarification.

Mr. BROWN. Thank you, Mr. Chairman, I really appreciate it.

Mr. Hamilton, again, you know, in my response to the questions about the flight control systems and the role of computer software, you offered up two examples: one is the yaw damper and the other is the auto pilot.

These systems, both of them, as you know, are engaged by switches on the flight deck by the pilot. The switches and the operations are clearly documented in flight and training manuals. The crew knows when they are activated. In fact, I know that, at least in the case of the yaw damper, and maybe even the auto pilot, there is a warning light when it fails. Those systems are not in the same category as MCAS, which operates behind the scene.

So I will just conclude by saying, at the moment, during the design, development, and promotion of MCAS, MCAS was the only computer software that operated the flight control systems without knowledge from the pilots or pilot input. And, for me, as a pilot, that is a big deal, and not just in hindsight, but at the moment, during the design, development, and promotion. It should have been a big deal to everybody involved.

Thank you, Mr. Chairman. I yield back.

Mr. DEFAZIO. I thank the gentleman, and I recognize the ranking member, Mr. Graves.

Mr. GRAVES OF MISSOURI. Thanks. I want to—just a point of clarification, as well, because there has been a lot of emphasis put on the AOA indicators in the cockpit, whether they should be in the cockpit or not in the cockpit.

And there is a difference between an AOA indicator and an AOA sensor. And the AOA sensors in disagreement, obviously, had an impact on the MCAS system. But the AOA indicator in the cockpit—an AOA indicator isn't a primary flight system. It is not even a secondary flight system. In fact, in all my thousands of hours of flying, I don't think I have ever been in an airplane that has an AOA indicator in it.

And there is a—there has been a lot of emphasis placed on these AOA indicators in the cockpit. And it is a little frustrating, because, to be quite honest with you, it—those are more for a maintenance reference than they are for—they are not a flight instrument, by any stretch.

But with that, Chairman, I appreciate this hearing.

Mr. DEFAZIO. I thank the gentleman. I am told that Ms. Davids has a brief question.

Ms. Davids?

Ms. DAVIDS. Thank you, Chairman.

So the certification process is my primary concern here, as a legislator, as a Member of Congress who sits on the T&I Committee. Our job is to create the framework under which regulations will be promulgated, that are going to be the things that keep the flying public safe.

And I think that—the first thing I want to say is that this might be the first time in Boeing's history that we are facing a situation where the culture of the company's top management was controlled

more by a profit motive because of short-term concerns than by the long-term business model that you keep bringing up of safety.

Based on all of the things that we have seen here today, I am interested in figuring out how we make sure that, as we come up with that framework that might need to be reevaluated, whether it is the type certification, amended type certification, or, when we drill down into it, what gets into a manual or not, and how much pilot training is required.

I have heard you say a number of times the system can be improved. And I am wondering if you have some specific areas that we, as legislators, need to be looking at.

Mr. MUILENBURG. Congresswoman, I appreciate that question. And while we have had some challenging questions today, I think we have a shared objective around safety of the aviation system.

We believe there are several areas where we can work together. Some are on the regulatory front.

We have discussed earlier things around design guidelines. Some of the longstanding industry standards, I think, need to be revisited.

There are some regulations on the books that could be updated to take advantage of new technology.

We believe pilot——

Ms. DAVIDS. What are those longstanding industry standards?

Mr. MUILENBURG. Pardon?

Ms. DAVIDS. What are the—what is a longstanding industry standard that you—

Mr. MUILENBURG. A good example are——

Ms. DAVIDS [continuing]. Specifically think that we need to look at——

Mr. MUILENBURG [continuing]. Are assumptions around pilot reaction times in various failure modes and scenarios.

So, again, it gets to what we assumed on pilot reaction times, for example, in an MCAS failure scenario. We think it is time for us to—just to revisit those, from an industry standpoint, especially for digitally enhanced airplanes, going forward.

We think there are opportunities for us to work together on talent development, the pipeline for future pilots and maintenance technicians——

Ms. DAVIDS. Do any of the longstanding industry standards that you think need to be looked at include things that, as a manufacturer, you would be in charge of?

Mr. MUILENBURG. Well, the——

Ms. DAVIDS. Because the two things that you mentioned have to do with pilot training.

Mr. MUILENBURG. The first one has to do with—actually, with design criteria.

John, you wanted to——

Mr. HAMILTON. Yes, I think it is both. I think there is advisory circulars released by the FAA that should be updated.

But then there is also our own internal guidelines and design guides that need to be updated to reflect what we are learning from these two accidents.

Mr. MUILENBURG. We have also updated our design requirements organization internally to do better cross-sharing across defense

and military sectors. I think that is an area where the Government can help.

I think investing in future simulation technology, taking advantage of virtual reality and augmented reality technologies to enhance pilot training opportunities is another area.

The science of human factors, and how we——

Ms. DAVIDS. Do you——

Mr. MUILENBURG [continuing]. How we design for the future, another example.

Ms. DAVIDS. Do you think that—what about when it comes to type certification, and the improvements or advancements, technologically, that have been made?

We have spent this whole time talking about the family of 737s that got the original certification in 1967. Where is that—what do you think we need to be doing about making sure that, as lots of new technology and an entirely new system is being integrated into a aircraft, that we are doing our jobs to make sure that this doesn't happen again. Because you are talking about a lot of improvements that you are already making, but it sounds like we need to be making sure that the FAA, as regulators, know about those things before we run into a situation like this.

Mr. HAMILTON. Yes, I would recommend—and this is one of the JATR recommendations, is that the FAA work with industry on part 21, on the change product rule, and look—see if there is any enhancements that are required in that area.

Ms. DAVIDS. I yield back.

Mr. DEFAZIO. And I believe this will be the last questions. Ms. Craig has not yet had an opportunity to ask questions, and I would recognize her.

Ms. CRAIG. Thank you, Mr. Chairman. I know it has been a long day for the families of the victims here, and I just want to say my condolences to each of you, and thank you so much for being here.

I have been in and out of this hearing almost all day today, and during a previous iteration of life, when I worked in business, you know, my job was in medical technology. And in that sector there is something called the MAUDE database. And if there is an early warning of an issue, we were required to report those things publicly. Our customers were required to report those things publicly. And many of the questions I have asked, as we have had a number of hearings with the FAA and with others, is how do we create, moving forward, a more robust, post-market reporting system for issues that occur.

My first question, really, Mr. Muilenburg, is, in hindsight, when should you have grounded this plane?

Mr. MUILENBURG. Congresswoman, we have asked ourselves that question many, many times. And if we knew back then what we know now, we would have grounded it right after the first accident.

If we could have saved one life, we would have done it. That is what we would have done.

Ms. CRAIG. Mr. Muilenburg, I spent the last 4 years of my business career as the head of global HR for a Fortune 500 company, and I have seen tough decisions firsthand from the inside.

There has been a lot of conversation today about your compensation. And earlier this afternoon you indicated that, well, that is up

to the board of directors. I pulled up the proxy statement from 2019, and did a little back-of-the-envelope calculation.

What I want to make sure is that the people who loved those who died, sitting in this room today, are assured by you that Boeing executives who now regret not acting and making decisions understand the pain that they are going through.

My back-of-the-envelope calculation, just on the number of underlying stock options that you still have that are or are not vested, is that just in stock options—and I understand Boeing moved from stock options to performance-based RSUs and restricted stock. Many companies have done that.

What I want to understand is that you are not going to personally benefit and profit over the swings in the stock price over this last year. Because if I look at Morgan Stanley's report, they expect, once these planes are ungrounded, your stock potentially to reach $500 a share. And I know that is a long way from there today.

But you said earlier today that your board of directors makes compensation decisions. Back of the envelope, just in stock options, up to $500, you would have another $30 million. That is based on the price at $75.97 that those options were issued at. I understand how this works.

If your board in February, when they meet to issue your performance grants and your restricted stock options, awards you stock options for the 2019 time period, will you commit to this committee and these family members sitting here today to decline those awards?

Mr. MUILENBURG. Congresswoman, we don't issue stock options. Just trying to—I want to answer your question.

But our board will do a comprehensive review. They will make their decisions. It is not about the money for me, and it is—that is just not why I came to Boeing. And——

Ms. CRAIG. That is why I said I understand you don't get stock options any more. The ones issued in 2013, you have got some that haven't vested. You are still going to get, like, millions of dollars from those. But when your board meets they could decide to give you performance-based RSUs this cycle, this time around. Or they could give you restricted stock units.

Will you commit today to decline those awards if your board chooses to give them to you?

Mr. MUILENBURG. Congresswoman, I am anticipating that this year's annual bonus cycle is zero. That is not where I am focused.

I didn't come to this company for money. That is not why I am here. And I—my board will do their work. But as I believe we already announced last week, we expect our annual bonus cycle to be a zero payout for our executives this year, and that starts with me.

Ms. CRAIG. Thank you for being here, and thank you.

Mr. Chairman, I yield my time.

Mr. DEFAZIO. I thank the gentlelady.

I ask unanimous consent that the record of today's hearing remain open until such time as our witnesses have provided answers to any questions that may be submitted to them in writing.

And some were submitted here today by various Members, and we got a commitment that we would get answers on that. For in-

stance, the displacement of any litigation to Indonesia, which I asked; questions that Mr. Graves asked; and others.

I also ask unanimous consent that the record remain open for 15 days for any additional comments and information submitted by Members or witnesses to be included in the record of today's hearing.

Without objection, so ordered.

Again, I want to extend my condolences to the families, thank the witnesses for their testimony.

And the committee stands adjourned.

[Whereupon, at 3:27 p.m., the committee was adjourned.]

SUBMISSIONS FOR THE RECORD

List A, Submitted for the Record by Hon. DeFazio

MCAS Preliminary Design Memo—TBC-T&I 010920 (p.1), 010926 (p.7)

[redacted]

Boeing Proprietary

PDDM Number: 737-8-PDDM-[redacted]

Preliminary Design Decision Memo

To: <PDDM DL> November 8, 2012
Title: High Speed Pitch-Up Rev A
Reference: D523A300 Rev E (737 MAX-8)
D523A301 Rev E (737 MAX-7)
D523A302 Rev E (737 MAX-9)

Originator: [redacted]	Phone: [redacted]	M/S: 61-49	Org: C&EA	Org# B-L214	
Supervisor: [redacted]	Phone: [redacted]	M/S: 61-49	Org: C&EA	Org# B-L214	

☐ Pre-Implement (Immediately approved followed up by standard routing process)

PDDM APPROVAL

[redacted] Date
737MAX Chief Project Engineer

[redacted] Date
737 Product Development Chief Engineer

[redacted] Date
737 PD Chief Technical Deputy

This PDDM authorizes 737 Engineering to revise all designs, analysis, and documentation to incorporate the change described in this PDDM.

The above signers agree with the recommended changes with respect to Rev E, and to reflect this PDDM in their respective sections of the Configuration Control Document.

☒ 737-8 ☒ 737-9 ☒ 737-7

TSDB Study #[redacted]

Benefit/Objective:
Refining the changes of implementing MCAS and [redacted].

Summary:
The larger diameter MAX engines degrades an already marginal pitch-up handling characteristics of the MAX wing at high Mach numbers. Maneuvering Characteristics Augmentation System (MCAS) assists with the stick force per g handling characteristic during the maneuver [redacted] The new configuration implements both solutions in order to make the maneuver predictable and readily controllable for certification.

Page 1
737-8- PDDM-[redacted]

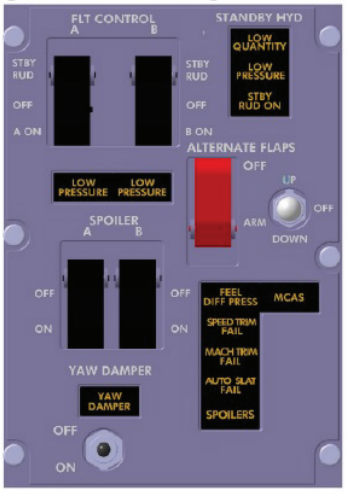
Boeing Proprietary

BOEING PROPRIETARY TBC-T&I 010920

[redacted]

[redacted]

Figure 2.14 Revised P5-3 Flight Controls Panel



[redacted]

AOA Sensor email string—TBC-T&I 10584–10586

[redacted]

From: Boeing Employee
Sent: 12/17/2015 10:44:54 AM
To: Boeing Employee
CC: Boeing Employees [redacted]
Subject: RE: MCAS Stab Rapid Reversal on PSIM model
Attachments: image001.jpg; image002.jpg

I went back and looked at my notes from a blade out evaluation [redacted] They were conservatively estimating [redacted] Conclusion for the FCC was that the first order lag filter to AOA would reduce the amplitude of the oscillation at these frequencies to a negligible impact. [redacted]
Pilot modes are typically around [redacted] They could only sustain [redacted] behavior for short intervals.
Are we vulnerable to single AOA sensor failures with the MCAS implementation or is there some checking that occurs?

Thus I don't see a [redacted] AOA oscillatory mode as a concern with what I know now. That being said, I would not get in the way if there was a way to improve this while not adversely impacting other aspects of the system/system response. And we will have to see if/how the results change after the stab motor deceleration characteristics are made more realistic.

[redacted]
Aero-Stability&Control, 737MAX & AR Advisor
[redacted]

From: Boeing [redacted]
Sent: Tuesday, December 15, 2015 1:26 PM
To: Boeing Employee
Cc: Boeing Employees [redacted]
Subject: RE: MCAS Stab Rapid Reversal on PSIM model

[redacted]

Attached is the fsbias frequency sweep and it was hard to find a trim condition that generates a large enough AOA to create MCAS command. I had to put [redacted] of column force and the case I can generate MCAS command was [redacted] and bellow. And the produced stab command has returned to the original position within the requirements.

Freq tested (Hz): [redacted]

And, yes, the previously shown plots are AOA directly driven and I believe it is it is not likely happen above [redacted] MCAS oscillations considering the aircraft inertia / dynamics.

[redacted]

From: Boeing Employee
Sent: Tuesday, December 15, 2015 8:45 AM
To: Boeing [redacted]
Cc: Boeing Employees [redacted]
Subject: RE: MCAS Stab Rapid Reversal on PSIM model

[redacted]

I don't like the end result, but am still struggling to see this as a realistic result. Is the AOA directly driven? I would like to see column or vertical gust as the driver to see if the physics allow everything to track. [redacted] is fast for the airplane to respond to but might be too slow for a notch filter? It did take a long time for the stab to run away.

[redacted]
Aero-Stability&Control, 737MAX & AR Advisor
[redacted]

From: [redacted]
Sent: Monday, December 14, 2015 12:35 PM
To: [redacted]
Cc: [redacted]
Subject: RE: MCAS Stab Rapid Reversal on PSIM model

Yes, I put a large input because I wanted to trigger MCAS function from the level flight condition. MCAS's threshold Alpha is between 4.5 and 5 deg depending on the Mach, and to get the full deflection, we need to have 7 to 7.5 deg of AOA. I don't think this large amplitude gust is not likely especially at Mach 0.7 – 0.8 ranges.

The g's produced due to this AOA change is about [redacted] from the trim. I have turned off the Nz restriction [redacted] when I run this serious of run for the stability analysis. Since I have inserted an additional AOA to excite the signal, no column was used to excite the system.

Yes, I am waiting for the stab model update to do MCAS function's stab position estimate if necessary.

If we have a 1 wave of MCAS condition (Wind up turn case) then we expect a stab return position error of [redacted] above the frequency quick stab reversal is commanded [redacted] that pilot needs to re-trim with a pickle switch. But I assume, with that kind of an event, pilot probably needs to re-trim the airplane anyways during the manual flight. If this magnitude of vertical gust continues then we would encounter runaway stab that needs to be corrected by the pickle switch or engaging autopilot. I have attached a frequency sweep of lesser magnitude [redacted] and the runaway stab happens at around [redacted] and above this time. I have also disengaged Nz engagement criteria for this run.

I am not declaring we have issues as long as we are accepting the continuous gust case for the first flight and I need your feedback.

[redacted]

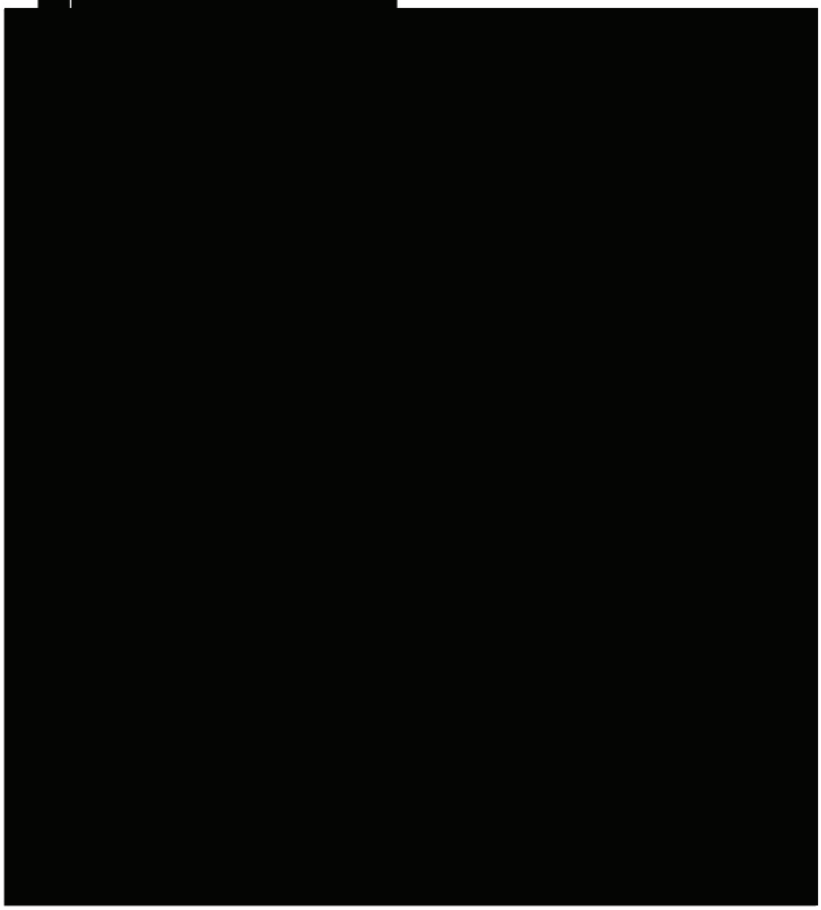
From: [redacted]
Sent: Monday, December 14, 2015 11:16 AM
To: [redacted]
Cc: [redacted]
Subject: RE: MCAS Stab Rapid Reversal on PSIM model

OK
Looks like a pretty big input for your time history plots. How many g's are you generating? How much column to generate that AOA response? The rate limits of the stab were always going to introduce issues for higher rate inputs.

Are you waiting for the PSIM model enhancement before you take next steps? Or are you declaring we have a problem now? Is there a specific case that you would declare a problem where we might investigate with a pilot in the cab?

[redacted]

[redacted]
Aero-Stability&Control, 737MAX & AR Advisor
[redacted]



Slide presentation to Ethiopian Air—TBC-T&I 001999–002000; 002018

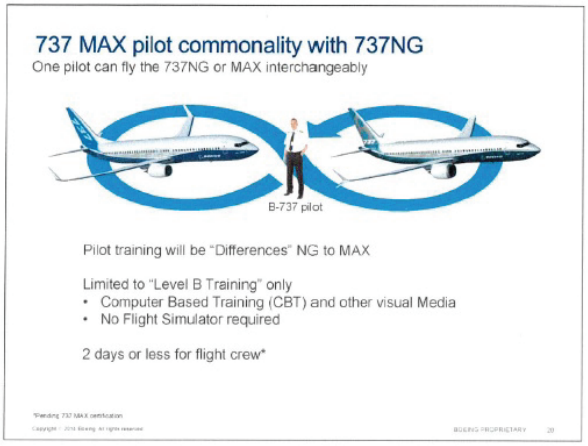
737 MAX, 777X & 787-9 Executive Review

March 4, 2014

BOEING PROPRIETARY


Ethiopian
The 737 MAX advantage
MAX efficiency | MAX reliability | MAX passenger appeal

[redacted]



Examples of system changes covered by differences training: LEAP engine and indications, environmental control system, fly-by-wire spoilers, electric landing gear control

Email string on Level B Training Intent—TBC-T&I 048705, 048706, 048707, 048708

[redacted]

From: Boeing Employee
To: Boeing Employees
Sent: 5/6/2013 12:07:28 PM
Subject: RE: 737MAX Firm Configuration Status/Help Needed

There is a still a risk with EASA as to whether they will accept the rotorburst approach.

[redacted]

-----Original Message-----
From: Boeing Employee
Sent: Sunday, May 05, 2013 7:29 PM
To: Boeing Employees
Subject: RE: 737MAX Firm Configuration Status/Help Needed

Thanks [redacted],

I thought we were good on decompression now that we have stepped up to 820 every for Airframe. Am I missing something?

[redacted]

-----Original Message-----
From: Boeing Employee
Sent: Saturday, May 04, 2013 12:15 PM
To: Boeing Employees
[redacted]
Subject: Re: 737MAX Firm Configuration Status/Help Needed

Thanks, [redacted] I look forward to the discussion. If there is time, we may also want to look at any EASA watch items... such as their acceptance of our decompression approach.

[redacted]

[redacted]
BCA Chief Structures Engineer - Technical Support
[redacted] M/S 03-JC -----Original Message-----
Boeing Employees
[redacted]

[redacted]

Boeing Employees
[redacted]

Subject: 737MAX Firm Configuration Status/Help Needed
Sent: May 4, 2013 11:35 AM

BCA Senior Chiefs and Functional Leaders,

[redacted]

For reference, here is current list of the remaining 14 open significant trade studies/risk issues. [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

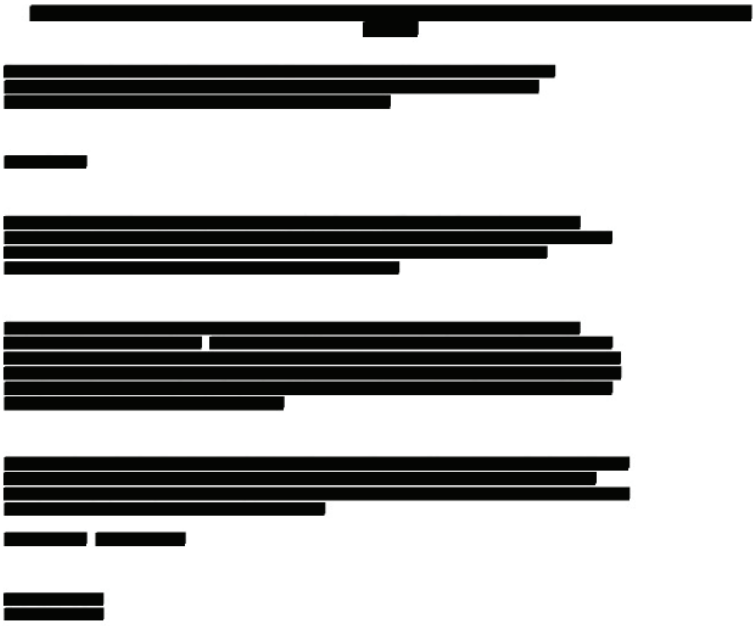
[redacted]

Differences Pilot Training: Ensuring that the level of change on the MAX keeps the Differences training to 16 hours or less of Level B training. Concerns include the impact of the resolution of 25.1322 trade and the Autopilot roll saturation change driven by the addition of MCAS to the flight controls system.

[redacted]

Flight Deck Alerting FAR 25.1322. The FAA has informally told us they are struggling to approve our applicant position regarding flight deck alerting.

[redacted]



PowerPoint on Training Marketing—TBC-T&I 000588 (p.1), 000597 (p. 10)

[redacted]

Four 9x12-inch displays (common to 787) with higher graphics capability replace six 8x8-inch displays
All 737NG flight deck functionality retained
Supports future functionality
Emphasis on commonality
Potential future navigation and communication functionality – runway excursion mitigation features, ADS-B In (Automatic Dependence Surveillance-Broadband In), future Airport Moving Map, Synthetic Vision System

FAA Letter of Dec. 13, 2018—TBC-T&I 297016

[redacted]

U.S. Department of Transportation
Federal Aviation Administration

Northwest Mountain Region
Colorado, Idaho, Montana, Oregon, Utah Washington, Wyoming

Seattle Aircraft Evaluation Group
Flight Standards Regional Office
2200 So. 216th Street
Des Moines, Washington 98198

December 13, 2018

Subject: Boeing 737 MAX Meeting Overview

Dear [redacted]:

Boeing and the Transport Aircraft Evaluation Group (Transport AEG) group met on December 13, 2018 to discuss a plan to review, evaluate, and validate B-737 MAX system enhancements to the Maneuver Characteristics Augmentation System (MCAS). This letter follows up that conversation in an effort to document the meeting and establish an open line of communication.

The B-737 MAX Amended Type Certificate (ATC) fleet of aircraft meets all aircraft certification standards. Boeing is proposing an enhancement to the MCAS flight control law. In accordance with AC 120-53B, Change 1, the Transport AEG will evaluate the enhanced system for flight training considerations, and regulatory compliance. The Transport AEG requires Boeing to propose training in accordance with AC 120-53B, Change 1. The result of the evaluation will be documented in the Flight Standardization Board (FSB) Report.

Please submit a plan of evaluation and validation at your earliest convenience.

If you have any questions or comments, please contact me at [redacted]

Best Regards,

[redacted]

[redacted]
B-737 FSB Chair
Transport AEG

CC: [redacted]

Boeing Letter of Jan. 30, 2019—TBC-T&I 29017–297018

[redacted]

BOEING

[redacted]
ODA Lead Administrator

The Boeing Company
P.O. Box 3707 MC 081-53
Seattle, WA 98124-2207

JAN 3 0 2019

RA-19-00269

[redacted]
SEA AEG
Department of Transportation
Federal Aviation Administration
2200 S. 216th Street
Des Moines, WA 98198-6547

[redacted]

Subject:	Boeing Response to Transport AEG letter
RA Project No.:	N/A
Response Due:	02/28/2019
Expedited Response:	No
References:	(a) Letter from SEA AEG dated December 13, 2018

As you will recall, the Maneuver Characteristics Augmentation System (MCAS) flight control law was not originally included in the 737 NG to 737 MAX differences tables nor was a specific reference included in the FCOM/QRH. Boeing believes that the rationale supporting that decision remains valid. However, Boeing recognizes that operators have expressed a strong interest for information regarding the MCAS flight control law.

Based on customer requests for information and training material, and the FAA Transport AEG's request to evaluate FCC P12.1 design enhancements to the MCAS flight control law, Boeing proposes that level A training and checking be added to the 737-800 to 737-8 differences tables.

As background to support this recommendation, Boeing believes that difference between the 737 NG and 737 MAX relating to the MCAS flight control law do not affect pilot knowledge, skills, abilities, or flight safety. AC 120-53B states that in this case, difference levels are not assigned; nor are they applicable to pilot training and qualification. Nonetheless, as noted above, based on customers' continued interest in the MCAS flight control law, we propose that the training/checking noted above should be adopted.

[redacted]

BOEING

[redacted]
RA-19-00269
Page 2

In order to substantiate Boeing's proposal, we recommend that the Base Aircraft for the evaluation be a 737-800 (representing the NG series) and the Candidate Aircraft be a 737-8 (representing the MAX series). No tail number need to be assigned as these differences are not affected by individual aircraft configuration. Boeing proposes to demonstrate similar flight and handling characteristics between the base aircraft and candidate aircraft by using flight simulators.

Boeing requests a meeting with the FAA Transport AEG to discuss a plan to evaluate and validate this training proposal and that this evaluation be completed with involvement of EASA and TCCA under the Joint Operational Evaluation Board (JOEB).

Please contact [redacted] or by email at [redacted] if you require further information.

The information being forwarded to the FAA by or with this correspondence is considered proprietary to The Boeing Company and/or its suppliers, and is provided on a confidential basis.

The data provided should be returned to Boeing immediately following use by the FAA, including any copies thereof which the FAA may be required to make in the course of its review. Boeing does not authorize the FAA to retain any portion of the materials being supplied.

Sincerely,

[redacted]
Date: 2019.01.30
07:19:42 -08'00'

[redacted]
The Boeing Company ODA Deputy Lead Administrator
[redacted]

[PR]

cc:

FAA Letter of March 1, 2019—TBC-T&I 297019–297020

[redacted]

U.S. Department of Transportation
Federal Aviation Administration

Northwest Mountain Region
Colorado, Idaho, Montana, Oregon, Utah Washington, Wyoming

Seattle Aircraft Evaluation Group
Flight Standards Regional Office
2200 S 216th St.
Des Moines, Washington 98198

March 1, 2019

[redacted]
737 Chief Technical Pilot
The Boeing Company
P.O. Box 3707, MC-081-53
Seattle, WA 98124-2207

Subject: Boeing 737-8 Maneuver Characteristic Augmentation System (MCAS) Evaluation
Letter of Proposal RA-19-0029 FAA Response Letter

Dear [redacted]:

The Transport Aircraft Evaluation Group (AEG), Seattle Branch, received The Boeing Company's B-737-8 MCAS Evaluation Letter of Proposal RA-19-0029 FAA Response Letter on January 30, 2019.

AC 120-53B, Change 1 outlines the process for evaluating and determining aircraft handling qualities via a T2 test, and evaluating and determining any training differences between a base aircraft and candidate aircraft via a T3 test. Boeing's unique proposal includes aspects of both a T2 and a T3 for the evaluation of updated FCC 12.1 Software, which includes design changes to the flight control law of MCAS. The evaluation proposal addresses both a handling quality evaluation and a training differences evaluation between the B-737NG and B-737-8 (MAX) series aircraft.

The FAA has accepted The Boeing Company's proposal including evaluation test conditions in the B-737-800 and B-737-8 Full Flight Simulators (FFS) in Miami, FL on March 13. The FAA would like to caution Boeing that the acceptance of the proposal does not constitute a passing acceptance that the results of the evaluation will be determined to be Level A differences. AC 120-53B, Change 1 identifies that requirements to meet Level A training differences is that training between related aircraft that can adequately be addressed through self-instruction. Level A training represents knowledge requirement that, once appropriate information is provided, understanding and compliance can be assumed. Level A compliance is achieved by such methods as issuance of operating manual page revisions, dissemination of operating bulletins, or differences handouts to describe minor differences in aircraft. Level A training is limited to the following situations:

(a) A change that introduces a different version of a system/component for which the pilot has already shown the ability to understand and use,

b) A change that results in minor or no procedural changes and does not adversely affect safety if the information is not reviewed or forgotten,

(c) Information that highlights a difference, which is evident to the pilot, inherently obvious, and easily accommodated (e.g., different location of a communication radio panel, a different exhaust gas temperature limit that is placarded, or changes to non-normal "read and do" procedures).

[redacted]

When the FAA evaluated the original B-737-8, MCAS was removed from the Differenced Table proposal for the T2 and T3 evaluation due to the system design which was presented as autonomous to the pilot, operation was "way" outside the normal operating envelope, and no flight crew procedures or checklists were affected by the addition of the flight control law. The original level of training difference that was proposed in 2016 was Level B differences.

The FAA is concerned that software change, FCC 12.1, may not meet the definition of Level A differences. Specifically, Level A states that the change does not adversely affect safety of flight if the information regarding MCAS operation is not reviewed or forgotten. The FAA is willing to evaluate Boeing's proposal for Level A training; however, we are advising the Boeing Company that the evaluation is proceeding at risk. The FAA understands that the changed SPEED TRIM FAIL light QRH checklist is a read and do non-normal checklist which falls under the definition of Level A differences item (c). The newly proposed note in the checklist identifying "pitch stability may be affected during manual flight with flaps up when approaching minimum maneuver speeds or during high maneuver loads" will require validation that those handling qualities and/or the checklist do not require a higher level of pilot knowledge, skills, and abilities as defined by AC 120-53 B, Change 1.

The FAA is conducting the FSB evaluation as a joint evaluation with EASA and TCCA. The pass/fail testing criteria will be presented to Boeing and a mutually agreeable plan will be established between Boeing, FAA, EASA, and TCCA prior to the scheduled March 13, 2019 evaluation.

Sincerely,

[redacted]

B-737MAX FSB Chair
Seattle Aircraft Evaluation Group

Email on Level B Training—TBC-T&I 010892–010894

[redacted]

From: Boeing Employee
on behalf of Boeing Employee
Sent: 9/23/2016 9:12:55 AM
To: Boeing Employee
Subject: FW: MAX Differences Training approved at Level B!!!!!
Attachments: B737 MAX PQP Gate 4 Letter of Acceptance - SIGNED.pdf; MAX MDR listing -8 .pdf; ODR 737-800 to MAX-8.pdf

Here is the correspondence from FAA regarding same type rating on MAX as well as training level differences.

[redacted]

Lead Engineer
Flight Controls And Systems
Flight Crew Operations Integration
Flight Deck Engineering

The Boeing Company

[redacted]

[redacted]

From: Boeing Employee
Sent: Tuesday, September 13, 2016 2:39 PM
To: Boeing Employees
Subject: RE: MAX Differences Training approved at Level B!!!!!

From: Boeing Employee
Sent: Tuesday, September 13, 2016 12:07 PM
To: Boeing Employees
Subject: RE: MAX Differences Training approved at Level B!!!!!

Thanks [redacted] One more question – did we get the FAA provisional approval letter yet? If so can I get a copy of that as well?

[redacted]

Lead Engineer
Flight Controls And Systems
Flight Crew Operations Integration
Flight Deck Engineering

The Boeing Company

[redacted]

[redacted]

[redacted]

From: Boeing Employee
Sent: Tuesday, September 13, 2016 12:05 PM
To: Boeing Employees
Subject: RE: MAX Differences Training approved at Level B!!!!!

They are provisionally approved pending final type cert.
[redacted]can you send them to [redacted]please?

Sent from my BlackBerry 10 smartphone.

From: Boeing Employee
Sent: Tuesday, September 13, 2016 12:03 PM
To: Boeing Employee
Subject: RE: MAX Differences Training approved at Level B!!!!!

[redacted]

Are the MDR and ODR tables approved by the FAA yet? I ask because I need approved tables to verify the airplane level training requirements.

[redacted]

Lead Engineer
Flight Controls And Systems
Flight Crew Operations Integration
Flight Deck Engineering

The Boeing Company

[redacted]

From: Boeing Employee
Sent: Tuesday, August 16, 2016 2:48 PM
To: Boeing Employees
Boeing Employees

[redacted]

[redacted]

Boeing Employees
[redacted]

Subject: MAX Differences Training approved at Level B!!!!!
Importance: High

All,

I'm happy to inform you that we successfully passed the T-3 Differences Training Validation Flight today, establishing the 737MAX as the same type rating as the 737NG, and requiring no greater than Level B (Computer Based Training, CBT) differences training between the two!

This is provisional approval, pending final Part 25 Type Certification, and assuming no significant systems changes to the airplane. The FAA will be sending us a Provisional Approval letter within the next 2 weeks, documenting the Joint Flight Operations Evaluation Board acceptance of this finding. FAA, Transport Canada, and EASA are now considered to have accepted this Level B determination.

This culminates more than 3 years of tireless and collaborative efforts across many business units. Flight Technical, Flight Technical Data, Training Development, Flight Deck Crew Ops, All MAX engineering teams, Flight Test Engineering and of course [redacted] Engineering Test Pilot team all should be commended for their efforts in getting us to the finish line.

CAS Communications and 737 Program Communications are jointly crafting a BNN article to be released upon receipt of the FAA's provisional approval letter.

Thank you again for all your collective support.

[redacted]
737 Chief Technical Pilot
[redacted]
BOEING

FAA Memo of June 30, 2017, from Transport Airplane Directorate to Aircraft Certification Service (AIR) Voluntary Safety Oversight Board

Federal Aviation Administration

Memorandum

Date: JUN 30 2017

To: Aircraft Certification Service (AIR) Voluntary Safety Oversight Board

From: [redacted] Transport Airplane Directorate, [redacted]

Prepared by: [redacted] Transport Standards Staff, [redacted]

Subject: Recommendations Regarding Safety Review Process (SRP) Item 10, 737 MAX Flight Control System Rotorburst Exposure

The Transport Airplane Directorate (TAD) reviewed the subject safety item and related report, dated January 13, 2017, from the AIR Voluntary Safety Oversight Board (the Board). In its report, the Board recommended the TAD take specific actions associated with Federal Aviation Administration (FAA) type certification and exemption procedures for the current Boeing 737-8 (737 MAX) amended type certification program. The Board also recommended the TAD develop specific guidelines to assist in interpreting the term "practical" as used in Title 14, Code of Federal Regulations (14 CFR) part 25 and related guidance documents.

The Board's recommendation 1 suggests the FAA retain the finding of compliance for 14 CFR 25.903(d)(1) on the 737 MAX program. The TAD determined to delegate the finding of compliance in accordance with 14 CFR part 183, "Representatives of the Administrator," and the processes and criteria established in FAA Order 8100.15B, "Organization Designation Authorization Procedures."

The Board's recommendations 2-6 suggest FAA actions to ensure Boeing shows compliance to 14 CFR 25.903(d)(1) for the 737 MAX airplane, and proposes the use of an exemption if the design is not found compliant. The TAD oversaw Boeing compliance activity in accordance with 14 CFR part 21, "Certification Procedures for Products and Parts," and Order 8110.4C, "Type Certification," as well as 14 CFR part 183 and Order 8100.15B. The TAD would have considered any petition for exemption in accordance with 14 CFR part 11 requirements if Boeing had determined it necessary to submit such a petition; however, Boeing did not submit a petition for exemption.

The Board's recommendation 7 is general in nature, and is not specific to the 737 MAX program or 14 CFR 25.903(d). It suggests the FAA develop methodology or guidelines to ensure that deciding what constitutes "practical design solutions" is more objective and less opinion-based.

Because the terms "practical," "practicable," and "minimize" are open to interpretation, the FAA uses these terms sparingly in rulemaking and guidance. We recognize that some direction is needed in meeting standards or guidance containing these terms. Advisory Circular (AC) 20-128A, "Design Considerations For Minimizing Hazards Caused By Uncontained Turbine Engine And Auxiliary Power Unit Rotor Failure," does provide guidance for these terms that is most useful for a new airplane design and new type certificate. However, the guidance is not as practical for changes to previously approved, compliant designs such as the Model 737 that has fifty years of design history. The TAD will determine if clarified guidance can be provided for 14 CFR 25.903(d) to address design changes or airplane derivatives where practical design solutions may differ from what may be considered practical for a new airplane design. If we develop additional guidance, we will include it in an update to AC 20-128A.

The Board's report also indicates that AC 20-128A levies certain requirements for complying with 14 CFR 25.903(d) and that Boeing did not follow FAA policy and guidance for incorporating practical design precautions to minimize the risk of damage from uncontained engine failure as identified in AC 20-128A.

In considering a deviation from the guidance in AC 20-128A, the TAD carefully considered the exemplary safety record of the most recent 737 flight controls system as compared to earlier 737 flight control system designs that were linked or suspected to have contributed to accidents and incidents including United Airlines Flight 585 near Colorado Springs, Colorado in March 1991, USAir Flight 427 near Aliquippa, Pennsylvania in September 1994, and Eastwind Airlines Flight 517 near Richmond, Virginia in June 1996. In order to avoid unintended consequences, the TAD was reluctant to dictate that a design change must be made to a proven system in order to meet the criteria identified in AC 20-128A that could reduce the risk in one area only to unexpectedly increase the risk in another area.

Although Boeing did not follow AC 20-128A, the AC does not serve as a requirement and is one means, but not the only means, to comply with 14 CFR 25.903(d). Applicants typically identify deviations from established FAA policy and guidance at the time of application or early during the initial design phases of the project. The FAA must consider applicant proposals for alternative compliance methods. For the 737 MAX, the TAD established a method of compliance (MOC) issue paper to document Boeing's proposal for complying with 14 CFR 25.903(d) after Boeing identified a deviation from established guidance and policy. The issue paper, which was signed in March 2016, also documents the FAA's acceptance of the proposed method of compliance.

The MOC established in the issue paper called for Boeing to:

> "List all possible design solutions based on current technology and show that you have taken all practical means to minimize the hazards to the airplane. As part of this assessment, show that any design considerations or accepted design precautions identified in AC 20-128A that you have not incorporated are not practical or would negatively affect the level of safety for this 737 derivative aircraft;" and
>
> "Complete an assessment of the new engines and show that there is a negligible difference in the threat posed by uncontained engine failure as compared to the threat from all previously approved 737 engines."

The accepted method of compliance for the 737 MAX relative to 14 CFR 25.903(d) permits the use of probability to establish that hazards from a rotorburst event have been minimized. The Board suggests that probability should not be used in complying with 14 CFR 25.903(d), even though 14 CFR 25.903(d) specifically introduces the standard to "minimize the hazards." However, the Board also determined that the probability of a catastrophic rotorburst event was 2.93×10^{-10} per flight (note: The Board used different assumptions regarding the critical window of exposure than Boeing in its probability analysis). That number indicates the condition is not likely to occur over the life of the 737 MAX fleet.

For compliance with 14 CFR 25.981(a)(3), specific to preventing fuel tank ignition from a lightning strike, the TAD granted relief from full compliance to applicants when they showed that incorporating certain design precautions was not practical and that a catastrophic event resulting from such a lightning strike was extremely improbable. Since 14 CFR 25.981(a)(3) explicitly requires the fuel tank ignition prevention rather than minimization, an exemption, rather than a MOC issue paper, was necessary to allow this compliance method. In the case of 14 CFR 25.903(d), the rule requires design precautions to "minimize the hazard," and does not specify what those precautions must be. Therefore, an assessment of probability can be considered in complying with the requirement.

Boeing was required to show compliance to 14 CFR 25.903(d) in accordance with the compliance method documented in the MOC issue paper. As discussed above, that compliance method involved Boeing identifying all possible design solutions and incorporating practical design precautions to minimize the risk of damage from uncontained engine failure. The TAD is currently evaluating Boeing's showing of compliance for the 737 MAX relative to 14 CFR 25.903(d) as part of the TAD's oversight of the Boeing Company per Organization Designation Authorization procedures and Order 8100.15B.

In summary, the TAD has considered the Board's recommendations and believes that the TAD met the Board's intent by following existing FAA rules, orders and procedures related to certification and delegation activities. The TAD will evaluate the possibility of developing additional guidance for the application of 14 CFR 25.903(d) to airplane design changes or derivatives.

Boeing presentation of Nov. 2016, "Undue Pressure: Key Learnings and Next Steps"

BOEING

Undue Pressure: Key Learnings and Next Steps

[redacted]

AR and PA Administration
Boeing Commercial Airplanes

[redacted]

Acronyms

- The following list of acronyms are used in this presentation:

- AR – Authorized Representative
- ARit – Authorized Representative in Training
- BG&O – Business Goals and Objectives
- BPI – Boeing Process Instructions
- CAS – Commercial Airplane Services
- CPO – Certification Plan Owner
- CRI – Certification Review Item
- DAE – Design Approval Engineer
- DCCS – Design Change Classification System
- DOIP – Delegated Organization Inspection Program
- FAA – Federal Aviation Administration
- MOC – Method of Compliance
- M-Unit – Manufacturing Unit Member
- NPRM – Notice of Proposed Rule Making
- ODA – Organization Designation Authorization
- OMT – Organization Management Team
- PA – Project Administrator
- SAW – Safety and Airworthiness
- SME – Subject Matter Expert

Expected Outcome

At the conclusion of this presentation, you will understand:

- The results of the undue pressure survey, as well as results from the FAA supervision activity
- Key learnings from recent undue pressure concerns
- Changes being made to address feedback and key learnings
  - Engagement of key stakeholders to address concerns early
  - Utilize internal audit system to monitor concerns
  - Revise Undue Pressure BPI and training course to simplify process and add more clarity
  - Implement new tool that will eliminate paper form and allow better tracking of status and actions

Undue Pressure is a priority

Undue Pressure Survey

November 2016

- 523 responded as of 11/28/16
- In addition to the question results, the comments provided were plentiful and insightful
- Themes from comments:
  - High Workload causes pressure
  - Schedule Pressure
  - Providing for a "neutral" question response would have been preferred
  - Concerns often stem from more senior management. Direct management tends to understand undue pressure
  - 787 and CAS highlighted as areas of concern
  - Suggestions sharing information on undue pressure cases with others might help with learning and understanding
  - Dual role (AR vs SME) can cause confusion leading to potential undue pressure
  - ARs handle potential undue pressure situations themselves without need to elevate

Question	% respondents Strongly Agree/Agree
I understand the process for reporting undue pressure	97
I understand what is and what is not undue pressure	93
I encounter situations where I perceive potential undue pressure	39
If yes, how frequently?	20% - once 65% - few times 11% - several times 4% - frequently
In performing my role, I have experienced undue pressure beyond my direct reporting structure	24
I am comfortable raising potential undue pressure to:	
My Management	90
SAW	92
ODA Administrators	90
I am confident the process will effectively address the issue raised	82
I am concerned about consequences if I report potential undue pressure	29
In my interactions with the FAA, I am treated fairly and professionally by the FAA	98

Thank you for participating in our very important survey!

FAA Supervision Activity

Fall/Winter 2016

- FAA interviewed approximately 50 ARs from Aug 2016 – Jan 2017
- Undue pressure was one of the main elements of the interviews
- FAA feedback provided:
  - No findings necessary
  - No instances of undue pressure that were not addressed
  - Process for reporting undue pressure well understood

13. Oversight Program

FAA oversight of Boeing's ODA consists of supervision activities conducted by the OMT, and scheduled inspections conducted by teams of FAA engineers and inspectors under the DOIP. At any time and for any reason upon request, BCA will allow the FAA to inspect the facilities, products, articles, and records related to the projects and functions performed under this authorization to support OMT supervision. The lead administrator or compliance administrator is responsible for the coordination and facilitation of OMT supervision activities.

As the result of supervision and inspections, the FAA provides feedback to Boeing about OCA performance, and may require corrective actions. See Section 17 for requirements associated with responding to FAA requests for corrective action.

Recent FAA Supervision Focused on Undue Pressure

Key Learnings

AR vs SME

Recent concerns have highlighted the need for more clarity between the AR and SME role.

Finding vs. Showing Responsibilities

AR Finding ... Showing SME

AR Responsibilities	Transitional Responsibilities	Lead Engineer Responsibilities
Comply with BCA ODA Procedures Manual and FAA regulations, policy and accepted means of compliance	Lead resolution of design and certification issues. Provide guidance to address inadequate showings of compliance	Assign work, oversee work planning and set priorities
Provide concurrence (TSR) to Certification Plans	Provide certification plan inputs and certification requirements guidance	Responsible for preparation of the showing of compliance and knowledge of regulations applicable to design
Approve Data for Compliance to FAA Regulations	Mentoring/Consulting: DAEs, CPO, Design Engineers	Support/review design decisions
Submit Requests for Conformity	Demonstrate integrity, sound judgment, and a cooperative attitude *	Provide/monitor status on all deliverables
Witness Tests Required for Compliance	Support resolution of in-service difficulties	Provide DAE inputs into DCCS.
Support AR Appointment Process and Annual Performance Evaluations. Mentor ARIT's	Coordinate common certification approach across models/systems/ARs	Conduct analyses and assessments used for showing compliance.
Maintain independence when performing delegated functions	Review/negotiate proposed regulatory policy – issue papers, special conditions, exemptions, NPRMs, CRIs, etc.	

Many ARs are tasked with developing showings of compliance

Key Learnings

AR vs SME, Continued

- Higher level engineers who are SMEs in their area are typically utilized to develop less costly new methods of compliance.
- Development programs are aggressive about challenging the status quo and look to high level engineer SMEs to lead efforts.
- When these engineers are also ARs, lines are frequently blurred between when the engineer is acting in an applicant SME role and when they are in an AR role.
- Conflict can occur when ARs are asked to develop and then approve applicant's proposals.

Conflict is most likely to occur when developing new MOCs

Key Learnings

AR vs SME, Continued

How to Mitigate - Management

- ✓ Assign others to develop showings of compliance
- ✓ Consider an independent reporting structure from the program
- ✓ If same person performing both roles, ensure BG&Os are clear on SME vs. AR responsibilities and avoid inappropriate measures for AR responsibilities

  Example of a business goal that may lead to problems: "Ensure compliance to all applicable FARs and advise and mentor team members on developing cert basis."
- ✓ Foster an environment that respects the AR role
- ✓ Understand and embrace applicant's ownership of showings of compliance

Both management and ARs have a role in mitigating undue pressure

Key Learnings

AR vs SME, Continued

How to Mitigate – AR

- ✓ Communicate early about possible conflict. Include SAW and AR Administration.
- ✓ Consult with other ARs and AR Advisor
- ✓ Be able to explain and justify why a proposal is not viable
- ✓ Understand applicant has option to present proposal to the FAA

Both management and ARs have a role in mitigating undue pressure

Key Learnings

Definition of Undue Pressure

What is the definition of "undue pressure"?

Different perspectives of what is and what is not undue pressure.

Management Intent **VS** AR Perception

Perceptions are Important

Key Learnings

Definition of Undue Pressure, Continued

Unwarranted, excessive, or unjustifiable force, coercion, or bullying of Unit Members (ARs, PAs, and M-unit members) while performing or attempting to perform their roles and authorized functions/delegated authority.

This may include but is not limited to:

- Creating, supporting, or ignoring conflicting restraints upon an ODA unit member while he/she is performing authorized functions, including decisions about workmanship, quality, conformity, deviations, safety, and approving data;
- Giving an ODA unit member responsibilities that conflict with those of the ODA unit;
- Not providing sufficient resources, including time, for the ODA unit member to perform his/her role and authorized functions;
- Directing, threatening or intimidating ODA unit members to approve data that is noncompliant or to force a particular result;
- Shopping for an ODA unit member who will agree with management to find a particular result;
- Using salary planning to threaten or bully ODA unit members;
- Fostering an environment that promotes intimidation.

These Types of Issues Should be Raised

Changes Being Made

Reg Amin Actions

- Increasing awareness among engineering and program leadership
  - Briefed development program leadership on recent issues and provided information on key learnings
- Partnering with SAW to help identify and mitigate potential issues
- Incorporating interviews of ARs in high risk areas during internal audit activity
- Revising "Undue Pressure" training course:
  - Adding more information and clarity of the SME vs. AR role
  - Provide a better definition of undue pressure
  - Revise certain scenarios to reflect actual issues
- Emphasizing applicant's role in developing showings of compliance by providing better guidance on required content and responsibilities

Learn From the Past to Improve the Future

Changes Being Made

Reg Amin Actions, Continued

- Revising BPI 3876 to:
  - Provide better definition of undue pressure
  - Allow any person to submit a concern
  - Eliminate "watch item" category
  - Results of an investigation will determine if action is required or not
  - Provide more robust escalation process
- Implementation of New Tool
  - "Smart" form technology
  - Allows workflow
  - Assign and track actions
  - Provides better visibility and management of issues

BPI revision and tool implementation expected 2nd qtr 2017

Better Process and Tool will Enable Better Mitigation

Key Take-Aways

- Survey, FAA interviews and recent issues have provided better insight into where focus is needed regarding undue pressure
- Engaging early with SAW, management and/or AR Administration is key in helping to mitigate potential issues
- Key learnings are being incorporated into training, tools and processes in order to better mitigate and manage undue pressure concerns.

We Take Undue Pressure Seriously

Letter of Feb. 22, 2019, from FAA Aircraft Certification Service to Boeing

U.S. Department of Transportation
Federal Aviation Administration

Aviation Safety

2200 South 216th Street
Des Moines, WA 98198-6547

February 22, 2019

In Reply
Refer To: 860-19-0120

File Number: CMP2019NM520011

[redacted]
Regulatory Administration
The Boeing Company
P.O. Box 3707, M/C 081-53
Seattle, WA 98124-2207

Dear [redacted]

Subject: The Boeing Company (TBC) Regulatory Administration (RA) Project Number PS16-0765, "Recommend Approval of 787 Fuel Tank Structural Lightning Protection System Safety Assessment," Deliverable Number 4 and Deliverable Number 5 for Certification Plan (CP) Number 20595

References: 1) Boeing Letter RA-19-00480, dated February 13, 2019
2) Boeing Letter RA-19-00481, dated February 13, 2019

The Federal Aviation Administration (FAA) BASOO Branch Organization Management Team (OMT) completed its review of the reference letters and their enclosures.

Disposition:

☐	Responsibility for review and FAA approval of the subject document is hereby delegated to the cognizant Engineering Unit Member(s). The OMT has not reviewed the document.
☐	No compliance action. The FAA finds the subject document to be in compliance with the applicable regulatory requirements and, thereby, approves it.
☐	Opportunity For Improvement (OFI). See Comments section.
☒	Informal Compliance Action (iFCA) The required file number is provided above. The OMT is rejecting the subject document because it does not meet the requirement(s) defined in the referenced Boeing Procedures Manual (BPM) section. We have identified the following regulatory noncompliance and have determined it is eligible for informal compliance action. Rationale is provided in Comments section, if needed. See Required and Encountered Conditions sections.

Required Condition:

1. Title 14 Code of Federal Regulations (14 CFR) Section 21.20, Compliance with applicable requirements, states, "The applicant for a type certificate, including an amended or supplemental type certificate, must- (a) show compliance with all applicable requirements and must provide the FAA the means by which such compliance has been shown..."

2. 14 CFR Section 183.57, Responsibilities of an ODA Holder, states, "The ODA Holder must- (a) comply with procedures contained in its approved procedures manual."

3. Boeing Commercial Airplanes ODA-300064-NM-ODA Procedures Manual (BPM) Section 15.1.7, BCA Compliance Showing, states, "BCA, as the Applicant, is responsible for a complete and accurate showing of compliance."

4. Certification Plan (CP) 20595, Revision C, Section 10.0, identifies FAA Special Condition (SC) 25-414-SC as an applicable regulation. SC 25-414-SC section 2.(b)(2) states:

   > "2.(b) The Boeing Company must show that the design includes at least two independent, effective, and reliable lightning protection features (or sets of features) such that fault tolerance to prevent lightning-related ignition sources is provided for each area of the structural design proposed to be shown compliant with these special conditions in lieu of compliance with the requirements of § 25.981(a)(3). Fault tolerance is not required for any specific design feature if:
   >
   > > (2) fuel tank vapor ignition due to that feature and all other non-fault-tolerant features, when their fuel tank vapor ignition event probabilities are summed, is shown to be extremely improbable."

5. Certification Plan (CP) 20595, Revision C, Section 9.0 MOC Discussion, states that for the Fuels System Safety Assessment, Deliverables 4, 5, and 6, "EME [electromagnetic effects] test data (gathered per FAA AC 20-53B and 787 EASA CRI D-02) will be assessed to show the applicability of the results for compliance to the applicable regulations using the guidance provided in 787-8/-9/-10 FAA Issue Papers P-6, 'Fuel Tank Ignition Protection – Wing Structural Lightning Protection Requirements,' and P-29, 'Fuel Tank Structural Lightning Protection Means of Compliance for Special Conditions.'"

   Issue Paper (IP) P-29 states: "Risk Assessment Requirement of Paragraph 2.(b)(2) of Proposed Special Condition: The intent of this paragraph is to require a structured risk assessment based numerical probability analysis to show that a fuel vapor ignition event is extremely improbable when the risk due to **all** non-fault-tolerant structural lightning protection design features is summed."

Encountered Condition:

In review of the submitted compliance documents by the reference (1) and (2) letters, we have determined that an assessment has not been included to show that fuel tank vapor ignition due to all non-fault-tolerant features, when their fuel tank vapor ignition event probabilities are summed, is shown to be extremely improbable as required to comply with the Special Condition 25-414-SC in accordance with the methods of compliance documented in IP P-29.

Please submit the corrective action taken to obtain compliance and the causal analysis for the regulatory noncompliance within 30 calendar days. [Note: As this is an informal compliance action, provide a simple analysis, not a Boeing Problem Solving Model (BPSM).]

Re-submittal Information:

☒	Re-submittal is not required. The Organization Designation Authorization (ODA) may approve the subject document once it has been determined that all OMT comments have been addressed.
☐	*Re-submittal is required. The OMT requires that the subject document be re-submitted to the OMT for approval once all OMT comments have been incorporated. *If selected, a comment is required. See Comments section.

The OMT has the following comments:

1. The reference letters submitted Deliverables 4 and 5, Fuel Tank Structural Lightning Protection System Safety Assessment (SSA), Boeing Documents D602Z830-999, Appendix II, Revision AH, and D602Z830-999-9 Appendix V, Revision H, to demonstrate compliance with 14 CFR Sections 25.981(a)(3) and Special Condition 25-414-SC. Following our review of the document and coordination with the Boeing Company, we have determined that Boeing has not included some non-fault tolerant features located in lightning Zone 3 in the assessment to show that all non-fault-tolerant features, when their fuel tank vapor ignition event probabilities are summed, is shown to be extremely improbable. We understand that Boeing interpreted the methods of compliance accepted in IP P-29 to provide relief to the fault tolerance requirements due to a Zone 3 direct attachment and, therefore, were not required to consider the non-fault tolerant features in the showing of an extremely improbable ignition event. This interpretation is incorrect and inconsistent with the requirement of the SC. The compliance documentation must be updated to make the showing of compliance required by 25-414-SC item 2.(b)(2).

   Consistent with the SC, the relief to the fault-tolerant requirements for Zone 3 direct attachment described on page 6 of IP P-29 do not also provide relief that would allow not including the Zone 3 non-fault tolerant features in the roll-up in showing an ignition event to be extremely improbable. The two requirements are independent and compliance is required to be shown for each.

2. For the demonstration of compliance with 25-414-SC item 2.(b)(2) that needs to be added to the referenced deliverables in consideration of this design change, Boeing must follow the guidance described in IP P-29 beginning on page 9: "Risk Assessment Requirement of Paragraph 2.(b)(2) of Proposed Special Condition." It should be emphasized that the probability of the lightning strike is the probability for a strike in all of Zone 3 and the assessment may not consider the probability of lightning attachment to a specific location within Zone 3. If a critical lightning strike is used to further reduce the overall probability of a Zone 3 strike, the definition of the critical lightning strike and the probability of that strike must be properly substantiated. In addition, the summation of the non-fault tolerant features needs to include all direct and conducted current ignition sources in the summation, including those resulting from a direct attachment in Zone 3.

3. In showing compliance with the SC, the top level summation in showing a fuel tank ignition event to be extremely improbable must include all non-fault tolerant features for the airplane (the summation should not be limited to a given lightning strike zone or fuel tank, but should be conducted at the airplane level). While it is assumed that all previous type design changes have previously been rolled into the top-level event during previous certification projects, this should be verified (i.e., the proposed final type design established by this project considering all type design changes introduced since the original type certification must be shown to be compliant). For example, it was not apparent during the course of the recent discussions between Boeing and the FAA whether items such as CFRP edge-glow resulting from the single failure of the edge-seal in Zone 2 had been previously identified in these SSAs as a non-fault tolerant feature and included in the showing that fuel tank ignition event to be extremely improbable.

4. As a result of the removal of the Copper Foil from the areas identified in the CP and compliance deliverable, the compliance deliverable states the edge-seal was required to be added to certain locations to meet the EME requirements in the area. However, the conclusion in Section H.3 (ref 1) and Section V.3 (ref 2), Critical Design Configuration Control Limitations (CDCCL) and Airworthiness Limitation Instructions (ALI), stated that there was no impact to the Airworthiness Limitations (AWL). Because the SC in its entirety was included in the CP, it is requested that the compliance document Sections H.3 and V.3 be updated to discuss how the existing ICA are adequate for meeting the requirements of SC Item 3, which states:

   > "The applicant must perform an analysis to show that the design, manufacturing processes, and airworthiness limitations section of the instructions for continued airworthiness include all practical measures to prevent, and detect and correct, failures of structural lightning protection features due to manufacturing variability, aging, wear, corrosion, and likely damage."

Although the compliance document refers to AWL 28-AWL-88, it appears this is a CDCCL requirement applicable to repairs or alterations only. We have noted that CDCCL 28-AWL-83 may also be applicable and may need to be reconsidered.

5. In addition to Item 4 above, we understand that the non-fault tolerant features in Zone 3 may not have previously been identified in the Boeing SSAs. For any non-fault tolerant feature that is identified as a result of the update to the SSA document, a corresponding ALI would be expected to comply with the requirements of SC Item 3 noted above. We recognize that this would result in the addition of at least one deliverable to CP 20595. Therefore, if it is determined that an AWL document revision is required, we delegate the acceptance of that related CP revision to the responsible PA, and we also delegate the approval of the Special Compliance Items (SCI) AWL document to the responsible Engineering Unit Members (E-UM)s.

6. In addition to the SCI AWL document (if needed), the OMT also delegates the revision to Deliverable 4 and Deliverable 5 to the responsible E-UM. Please submit an informational copy of the revised documents along with signed FAA 8100-9 forms following E-UM approval.

If you have any further questions regarding this issue, please contact [redacted] by telephone at [redacted] or by email at [redacted]

Sincerely,

[redacted]

Aircraft Certification Service

Letter of March 1, 2019, from FAA Aircraft Certification Service to Boeing

U.S. Department of Transportation
Federal Aviation Administration

Aviation Safety

2200 South 216th Street
Des Moines, WA 98198-6547

March 1, 2019

In Reply
Refer To: 860-19-0149

[redacted]
Regulatory Administration
Boeing Commercial Airplanes
P.O. Box 3707, M/C 081-53
Seattle, WA 98124-2207

Dear [redacted]:

Subject: BASOO and Organization Management Team (OMT) Response to Boeing Appeal related to Boeing Commercial Airplanes (BCA) Regulatory Administration (RA) Project Number PS16-0765, and 787 Lightning Zone 3 Compliance to Special Condition 25-414-SC

References:
1) Boeing Letter RA-19-00647, dated February 25, 2019
2) The Boeing Company Organization Designation Authorization (ODA) Procedures Manual, ODA-300064-NM, Revision E.2
3) OMT Letter 860-19-0120, dated February 22, 2019
4) Boeing Letter RA-19-00367, dated February 6, 2019

The Federal Aviation Administration (FAA) BASOO Branch has received the reference (1) letter that submitted a request for an FAA OMT/ODA Unit Appeal Resolution Meeting in accordance with Section 1.1.6, Regulatory Issue Resolution, of the reference (2) procedures manual. The appeal was submitted in response to the reference (3) letter and related informal compliance action (iFCA) that rejected two compliance deliverables related to Project Number PS16-0765 for not showing compliance with the requirements of Special Condition (SC) 25-414-SC item 2.(b)(2). In response to the reference (1) letter, a meeting was held between the OMT and Boeing, on February 27, 2019, to review the nature of the appeal and discuss both the Boeing and the OMT positions.

Following our review of the reference (1) letter and in further consideration of the discussions held during the appeals meeting held, on February 27, 2019, the FAA BASOO accepts the position that was provided by the applicant with the following comments.

1. Considering the applicable policy in method of compliance (MOC) Issue Paper P-29 applicable to the Boeing Model 787 (ref. project TC6918SE-T), we do not disagree that the conclusions associated with the applicants approach can be reasonably made as a result of the language therein. Furthermore, we recognize that the MOC in the issue paper has been applied consistently since originally applied in support of 787 type certificate issuance, and from the are consistent with the discussions at the time of the initial development of the issue paper. For clarity, we understand that the applicant shows and the unit has found compliance with SC 25-414-SC item 2.(b)(2) for all non-fault tolerant features that result from the threats outlined earlier in the SC. This aspect was made clear during our discussion, on February 27, 2019.

2. In addition, the BASOO notes that the issue raised is not a result of the change associated with the reference project, however changes were made to ensure the continued compliance to the subject aspect of the SC consistent with previously approved design changes.

We are providing this written disposition of the Boeing appeal in accordance with Section 1.1.6 of the reference (2) procedures manual. In addition, based upon information provided and further review, the BASOO is closing informal compliance action CMP2019NM520011, FAA Letter 860-19-0120, with no further action required at this time. All other aspects of the reference (3) letter (i.e., delegation of the finding of compliance) are unaffected.

If you have any questions regarding this issue, please contact [redacted] BASOO Branch, by telephone at [redacted] or by email at [redacted]

Sincerely,

[redacted]

Aircraft Certification Service

List B, Submitted for the Record by Hon. DeFazio

Coordination Sheet—Revision D—TBC-T&I 029160–029166

[redacted]

BOEING PROPRIETARY

C O O R D I N A T I O N S H E E T

TO [redacted] 0T-41, 0T-44

NO. Aero-B-BBA8-C12-0159
JOB NO. SC10737XS-014
SC15737-040
DATE March 30, 2016

cc [redacted] 0T-46, 0T-45, 9C-03, 0T-41, 0T-41, 0R-116, 0R-120, 0R-116, 0T-44, 0T-42, 0T-44, 0R-120, 0T-46, 14-HA

MODEL 737-MAX (-7/8/9)

Revision D

GROUP INDEX FLIGHT SCIENCES – 787 & PRODUCT DEVELOPMENT

SUBJECT 737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements

REFERENCES See Page 2

Summary

This document provides the Aerodynamics Stability & Control requirements for the Flaps Up High Alpha Stabilizer Trim operation for the 737-MAX. The system is now being referred to as the Maneuvering Characteristics Augmentation System (MCAS).

The addition of the larger engine nacelle and fan diameter on the 737MAX have been shown via review of BTWT 2337 wind tunnel data to produce a nose-up pitching moment during operation at high alphas and mid Mach numbers. MCAS contributes to countering any pitch up tendency in flight. The requirements for the MCAS function are provided in this document.

Flight test results have shown that two changes to MCAS are required. The first involves expanding the use of MCAS to improve Flaps Up, low Mach stall characteristics and identification. The second is an update to the high Mach data tables to improve maneuvering characteristics.

Prepared by (Signature on file)
[redacted]
B-BCA7, 0R-120
[redacted]

Prepared by (Signature on file)
[redacted]
B-BBA8, 0R-120
[redacted]

Reviewed by (Signature on file)
[redacted]
B-BBA8, 0R-120
[redacted]

Approved by (Signature on file)
[redacted]
B-BBA8, 0R-120
[redacted]

[redacted]

Revision D: This coordination sheet has been revised to include updated requirements and revised MCAS Alpha Trigger and Stabilizer command schedules to improve Flaps Up stall characteristics and identification spanning the Mach 0.20-0.60 range. These changes are required based on flight test results. This revised MCAS schedule is based on the new external configuration based on flight test consisting of a [redacted] In addition, the high Mach MCAS command schedule has been revised based on flight test results.

Revision C: This coordination sheet has been revised to include updated requirements based on MCAS design and predicted flight characteristics. In addition, the preflight MCAS schedules have been included for documentation.

Revision B: This coordination sheet has been revised to include updated requirements and functional hazard assessments based on MCAS design and predicted flight characteristics. Specific MCAS incremental stabilizer authority and activation/deactivation parameters of Mach number, body angle-of-attack, and normal load factor are updated.

Revision A: This coordination sheet has been revised to include updated requirements based on MCAS development Pilot assessments and changes to the airplane's pitching moment characteristics due to a [redacted]

REFERENCES
(a) AC 25-7C: Flight Test Guide for Certification of Transport Category Airplanes
(b) MCAB Simulator Test Plan and Session Summaries 10.31.12 & 11.6.12
(c) Preliminary Design Decision Memo D523A300, Revision E

Discussion

FAA Requirements and Guidance

FAR 25.143(g) Controllability and Maneuverability – General, requires that changes of gradient that occur with changes of load factor must not cause undue difficulty in maintaining control of the airplane, and local gradients must not be so low as to result in a danger of over-controlling. Reference is made to CFR amendment 25-129 for the described FAR25.143(g) requirement.

FAR 25.201, Stall Demonstration, states that the handling qualities must be adequate to allow a safe recovery from the highest angle of attack attainable in normal flight. In addition, the behavior of the airplane must give the pilot a clear and distinctive indication of being in a stalled condition (stall ID).

FAR 25.203(a), Stall Characteristics, states that no abnormal nose-up pitching may occur. The longitudinal control force must be positive up to and throughout the stall. In addition, it must be possible to promptly prevent stalling and to recover from a stall by normal use of the controls.

[redacted]

FAR 25.251(e), Vibration and Buffeting, requires determination of the onset of perceptible buffeting. The buffet onset envelope is published in the AFM. The regulation further requires that inadvertent excursions beyond this boundary not result in unsafe conditions.

FAR 25.255, Out-of-Trim Characteristics, requires that the stick force vs. g curve have a positive slope up to and including, V_{FC}/M_{FC}. At speeds between V_{FC}/M_{FC} and V_{DF}/M_{DF}, the stick force may not reverse. These characteristics need not be demonstrated beyond maneuvering load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelope.

AC 25-7C, Flight Test Guide, considers a minimum value of 50 lb. to reach limit load to be acceptable per 25.143(g). The AC also provides guidance for the demonstration of buffet onset and the determination of what constitutes unsafe conditions, per 25.251(e), framed by the characteristics of maneuvering stability, the relationship of pilot force and load factor. It states that any pitch-up tendency should be mild and readily controllable, and that the airplane's pitch response to primary longitudinal control should be predictable to the pilot.

MCAS Performance and [redacted]

MCAS was implemented to improve the stick force gradient sufficiently to try and meet the requirements as shown in Figure 1. Piloted simulation assessments in the motion cab found the stick force gradient to be desirably increased, but a pitch-up tendency in the region of initial buffet was found to be unacceptable [redacted] The stabilizer rate was chosen to attain the required stick force gradient up to initial buffet, knowing that there was a shortfall in its ability to improve the post stall pitch up tendency. To improve the post stall pitch-up, a wind tunnel test [redacted] which would alter the pitching moment characteristics. This new [redacted] proved to reduce the pitch-up tendency and the consequent g overshoot compared to the baseline [redacted] Simulation assessment with the [redacted] showed the pitch characteristics to be improved enough with MCAS active to provide a desirable increase in stick force gradient and a reduced pitch up tendency.

Aerodynamics Stability & Control Requirements

1. MCAS shall operate flaps up in the Mach number range of **0.20 to 0.84** ~~0.68 to 0.82~~. Provision shall be retained to modify these values and any associated fade out factors.
2. MCAS shall ensure the airplane meets the stick force requirements of AC 25-7C (Reference (a)) as shown in Figure 1. [FC INFO]
3. ~~**MCAS shall operate at all load factors between Mach 0.20 to 0.84. MCAS shall not activate until load factors exceed 1.3g. Once activated, MCAS hysteresis design shall deactivate MCAS at load factors of not less than 1.1g.**~~
4. MCAS shall not have any objectionable interaction with the piloting of the airplane. [FC INFO]
5. MCAS shall be capable of commanding incremental stabilizer a maximum of **2.5 degrees at low Mach decreasing to a maximum of 0.65 degrees at high Mach** ~~0.55 deg~~ from the initial stabilizer position at initiation of MCAS stabilizer motion. Augmentation will command airplane nose down only. This authority has been derived by determining the

[redacted]

amount of stabilizer trim required to prevent pilot push forces [redacted]

6. The system shall be capable of providing a stabilizer rate of 0.27 deg./sec. This rate is derived by data analysis and Pilot simulator assessments which found it adequate to counter the pitch up tendency. This value aligns with the autopilot flaps down stabilizer rate.
7. [redacted]
8. The stabilizer shall continue to respond to main electric trim or manual stabilizer trim inputs from the flight crew during MCAS operation. MCAS commands shall be temporarily disabled during main electric trim operation and shall resume commanding stabilizer based on MCAS logic using the new manual stabilizer trim as the reference position.
9. MCAS activation shall result in a disconnection of Speed trim up and down Stabilizer motor commands and remain disconnected until MCAS deactivation.
10. MCAS shall not adversely affect airplane stall characteristics. [FC INFO]
11. MCAS shall not interfere with dive recovery. [FC INFO]
12. MCAS failures shall be annunciated to the flight crew. [redacted]
13. The system should be designed to minimize the likelihood of system activation during normal operation to avoid unnecessary rotation of the trim wheels.
14. The probability of a system hard over, oscillatory failure, and loss of function shall be commensurate with the hazard levels shown in the FHA table. These were determined by Pilot simulator assessments of MCAS failure modes.
15. [redacted]
16. MCAS shall be inactive while the autopilot is engaged. Autopilot engagement shall disable MCAS.
17. **Transition from Autopilot to manual flight above the MCAS trigger angle of attack shall result in MCAS becoming active. This requirement is based on piloted cab evaluations and results in improved recovery capability to the normal flight envelope.**
18. MCAS shall be capable of commanding incremental stabilizer as a function of body angle-of-attack and Mach number. MCAS activation shall occur when the body angle-of-attack exceeds the threshold angle where adverse pitch and/or stick force gradients occur for each Mach number. [redacted] Provision shall be retained to modify these values and any associated fade out factors.

MCAS Schedules

The following two tables define the ~~prefight~~ **flight-updated** schedules used in the MCAS control law logic **to support both Flaps Up stalls at low-to-mid Mach and maneuvering characteristics at high Mach .** [redacted] ~~The lowest and highest Mach numbers have sufficiently high angles to ensure MCAS will not trigger below or above the table end Mach break points.~~ The MCAS control law calculates a body angle-of-attack using alpha vane, pitch rate, and airspeed. Table 2 defines the amount of incremental stabilizer MCAS will command

[redacted]

for a given change in angle-of-attack as a function of Mach. ~~The maximum change in stabilizer due to MCAS is 0.55 deg SFRL.~~

[redacted]

~~Preliminary~~ Functional Hazard Assessment

Item	Hazard Description	Phase	Failure Condition	Effect Class
A	Loss of Flaps Up High Alpha Stabilizer function (MCAS)	**Flaps Up flight** ~~Cruise~~	Decrease in stability with load factor **and angle of attack**	IV(Minor) Normal flight envelope III (Major) Operational flight envelope
B	Uncommanded High Alpha Stabilizer function operation (MCAS) to maximum authority ~~(0.55 deg)~~	ALL	Stabilizer runaway due to MCAS control law stabilizer deflection limit. Pitch trim functionality is retained.	III (Major) Normal flight envelope II(~~H~~Hazardous) Operational flight envelope
C	Uncommanded MCAS function operation equivalent to 3 second mistrim (0.81 deg)	ALL	Stabilizer runaway equivalent to 3 seconds of mistrim (FAR25.255). Pitch trim functionality is retained.	III (Major) Normal flight envelope II (Hazardous) Operational flight envelope
D	Uncommanded MCAS function operation to pilot reaction	ALL	Stabilizer runaway until pilot recognition and reaction	II (Hazardous) Operational flight envelope

The **original** hazard assessments were obtained by pilot assessment in the motion simulator. Critical combinations of weight and CG were tested. The session summaries which provide the

[redacted]

results can be found in the job file: [redacted] **The hazard assessments were revisited and determined to have not changed in hazard classification based on the most recent MCAS update. The uncommanded MCAS command to the maximum nose down authority at low Mach numbers (3 degrees) was evaluated in the 737 MAX cab and rated as Minor. The high Mach recovery is the critical factor in establishing the hazard rating for this item.**

The loss in stabilizer function (item A) without annunciation is based on the handling qualities of the airplane with MCAS inactive. The reduction in stick force versus 'g' gradient and the presence of a pitch up tendency not meeting the mild and readily controllable requirement were found unacceptable. The hazard category was deemed Major in the operational envelope. Upon further review, the pilots found that no special procedures were required in part due to the system not operating in the normal envelope. **For the low Mach stalls, the pilots rated loss of MCAS as Major based on flight test results with the existing configuration.**

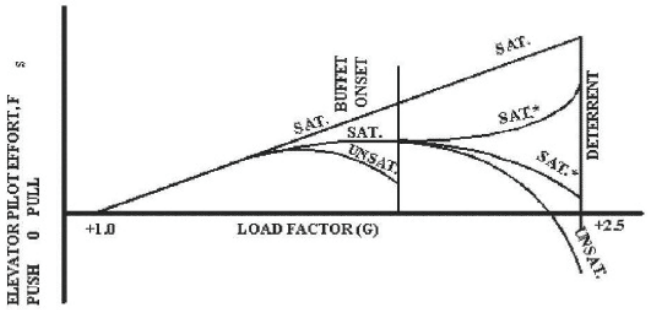
Two scenarios were used to assess the stabilizer runaways (items B & C). One was a runaway at MCAS activation during a wind up turn maneuver, the other a wings level recovery from a level flight stabilizer runaway based on FAR25.255, "Out of Trim Characteristics". Mistrim amounts were tested to the MCAS CLAW maximum stabilizer limit (0.65 deg.) and 3 seconds of mistrim as per the FAR and input from the flight test community. The MCAS stabilizer deflection rates were used.

For the stabilizer runaways in the WUT maneuver (i.e. in the operational envelope) to the CLAW limit, the runaways were found Major, and the 3 second runaways found Hazardous. The Hazardous category was applied mainly due to the tendency to overspeed during the recovery rollout for those cases where the WUT was performed near the maximum operating speeds.

For the wings level mistrim recoveries, the runaway occurs at Vmo/Mmo and a recovery made at Vdf/Mdf. The runways with the stabilizer mistrimmed to the CLAW limit were found Major. For the wings level 3 second mistrim stabilizer cases, some were found Major and some Hazardous. The Hazardous assessment was reduced to Major for a recovery initiated at 3 seconds past overspeed warning. The recovery at Vd/Md is appropriate to the intent of FAR25.255, but is a more severe condition than would be expected during the failure mode. Reduction of this speed would have reduced the workload and hazard category. This is to be verified in future cab sessions.

Stabilizer runaways to pilot reaction (item D) were performed. These failures were arrested by use of the aisle stand cutout switch when the pilot recognized and reacted to the runaway. Assessments were done during WUTs only i.e. within the operational flight envelope, but not assessed by mistrim trim dive recoveries (normal operating envelope). With pilot training to recognize the runaway and use of teamwork, the failure was found Hazardous, which is the same as the item C finding. A typical reaction time was observed to be approximately 4 seconds. A slow reaction time scenario (>10 seconds) found the failure to be catastrophic due to the inability to arrest the airplane overspeed.

Figure 1. (AC 25-7C Figure 31-1)



Coordination Sheet—Revision G—TBC-T&I 030584–030592

[redacted]

COORDINATION SHEET

TO	[redacted]	0T-41	**NO.** Aero-B-BBA8-C12-0159
			JOB NO. SC10737XS-014
		0T-45	SC15737-040
cc		0T-41	SC17737-082
		0T-41	**SC18737-036**
		0R-116	
		0T-44	**DATE** ~~December 20, 2017~~
		0R-216	June 11, 2018
		0T-44	
		0R-250	**MODEL** 737-MAX (-7/8/9/10)
		0R-116	
		0T-42	Revision G
		0T-44	
		0T-46	
		1C-301	
		0T-41	

GROUP INDEX FLIGHT SCIENCES – AIRPLANE CHARACTERISTICS & LOADS

SUBJECT 737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements

REFERENCES See Page 3

Summary
This document provides the Aerodynamics Stability & Control requirements for the Flaps Up High Alpha Stabilizer Trim operation for the 737-MAX. The system is now being referred to as the Maneuvering Characteristics Augmentation System (MCAS).

The addition of the larger engine nacelle and fan diameter on the 737MAX have been shown via review of BTWT 2337 wind tunnel data to produce a nose-up pitching moment during operation at high alphas and mid Mach numbers. MCAS contributes to countering any pitch up tendency in flight. The requirements for the MCAS function are provided in this document.

Requirements and functionality for MCAS have been modified to improve upon characteristics observed during 737-7, 8, & 9 flight testing.

Prepared by [redacted]
B-BCA8, 0R-250

Reviewed by [redacted]
B-BBA8, 0R-250

Reviewed by [redacted]
B-BBA8, 0R-250

Approved by [redacted]
B-BBA8, 0R-250

[redacted]

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Revision G: This coordination sheet has been revised to include the updated MCAS stabilizer command schedule to improve low speed (1.3Vsr) Flaps Up windup turns. Improvements to high altitude stall characteristics have been observed with the updated MCAS stabilizer command schedule. Additionally, changes were made to improve windup turns spanning the Mach 0.82 – 0.84 range. These changes are required based on 737-7 flight test results.

Table 2 for the incremental stabilizer schedule is now applicable to only the 737-8/9. A new table for the 737-7/10 has been defined that includes the updated MCAS stabilizer command schedule for Mach values 0.50, 0.60, and 0.82.

The updated MCAS stabilizer command schedule in the lower speed range has been validated in a piloted CAB session with James Hanley on May 25, 2018.

Revision F: This revision summarizes updates to the MCAS requirements for the 737-7 and 737-10, based on 737-9 flight test results which indicated marginal characteristics for the minimum column force windup turns at aft CG. Though the 737-9 was ultimately deemed certifiable, it was recognized that changes for the 737-7 & 10 should be made to ensure characteristics on those models are more clearly certifiable.

[redacted]

[redacted]

Table 1 for the angle of attack trigger schedule is now applicable to only the 737-8/9. A new table for the 737-7/10 has been defined that adds angle of attack triggers as a function of body pitch rate, as seen in Table 3. For body pitch rates below [redacted] the 737-8/9 and 737-7/10 schedules are the same. [redacted]

MCAS angle of attack triggers scheduled with body pitch rate have been validated via desktop analysis and in a piloted cab session with [redacted] on December 20th, 2017.

Revision E: This revision summarizes the updates to MCAS requirements based on flight test results to support the Black Label FCC functionality. Table 1 (Angle-of-Attack Trigger Schedule) was updated to provide more margin prior to MCAS activation between [redacted] This

[redacted]

was necessary to allow trim to zero column force for the purpose of demonstrating static lateral-directional stability characteristics as [redacted]

[redacted]

[redacted]

All of these changes were validated via desktop analysis and in a piloted cab session with [redacted] on June 30, 2016.

Revision D: This coordination sheet has been revised to include updated requirements and revised MCAS Alpha Trigger and Stabilizer command schedules to improve Flaps Up stall characteristics and identification spanning the Mach 0.20-0.60 range. These changes are required based on flight test results. This revised MCAS schedule is based on the new external configuration based on flight test consisting of a [redacted]. In addition, the high Mach MCAS command schedule has been revised based on flight test results.

Revision C: This coordination sheet has been revised to include updated requirements based on MCAS design and predicted flight characteristics. In addition, the preflight MCAS schedules have been included for documentation.

Revision B: This coordination sheet has been revised to include updated requirements and functional hazard assessments based on MCAS design and predicted flight characteristics. Specific MCAS incremental stabilizer authority and activation/deactivation parameters of Mach number, body angle-of-attack, and normal load factor are updated.

Revision A: This coordination sheet has been revised to include updated requirements based on MCAS development Pilot assessments and changes to the airplane's pitching moment characteristics due to a [redacted]

REFERENCES
(a) AC 25-7C: Flight Test Guide for Certification of Transport Category Airplanes
(b) MCAB Simulator Test Plan and Session Summaries 10.31.12 & 11.6.12
(c) Preliminary Design Decision Memo D523A300, Revision E

Discussion

FAA Requirements and Guidance

FAR 25.143(g) Controllability and Maneuverability – General, requires that changes of gradient that occur with changes of load factor must not cause undue difficulty in maintaining control of the airplane, and local gradients must not be so low as to result in a danger of over-controlling. Reference is made to CFR amendment 25-129 for the described FAR25.143(g) requirement.

FAR 25.201, Stall Demonstration, states that the handling qualities must be adequate to allow a safe recovery from the highest angle of attack attainable in normal flight. In addition, the behavior of the airplane must give the pilot a clear and distinctive indication of being in a stalled condition (stall ID).

FAR 25.203(a), Stall Characteristics, states that no abnormal nose-up pitching may occur. The longitudinal control force must be positive up to and throughout the stall. In addition, it must be possible to promptly prevent stalling and to recover from a stall by normal use of the controls.

FAR 25.251(e), Vibration and Buffeting, requires determination of the onset of perceptible buffeting. The buffet onset envelope is published in the AFM. The regulation further requires that inadvertent excursions beyond this boundary not result in unsafe conditions.

FAR 25.255, Out-of-Trim Characteristics, requires that the stick force vs. g curve have a positive slope up to and including, V_{FC}/M_{FC}. At speeds between V_{FC}/M_{FC} and V_{DF}/M_{DF}, the stick force may not reverse. These characteristics need not be demonstrated beyond maneuvering load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelope.

AC 25-7C, Flight Test Guide, considers a minimum value of 50 lb. to reach limit load to be acceptable per 25.143(g). The AC also provides guidance for the demonstration of buffet onset and the determination of what constitutes unsafe conditions, per 25.251(e), framed by the characteristics of maneuvering stability, the relationship of pilot force and load factor. It states that any pitch-up tendency should be mild and readily controllable, and that the airplane's pitch response to primary longitudinal control should be predictable to the pilot.

MCAS Performance and [redacted]

MCAS was implemented to improve the stick force gradient sufficiently to try and meet the requirements as shown in Figure 1. Piloted simulation assessments in the motion cab found the stick force gradient to be desirably increased, but a pitch-up tendency in the region of initial buffet was found to be unacceptable due to [redacted]. The stabilizer rate was chosen to attain the required stick force gradient up to initial buffet, knowing that there was a shortfall in its ability to improve the post stall pitch up tendency. To improve the post stall pitch-up, a wind tunnel test [redacted] which would alter the pitching moment characteristics. This new [redacted] proved to reduce the pitch-up tendency and the consequent g overshoot compared to the baseline [redacted]. Simulation assessment with the [redacted] showed the pitch

[redacted]

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characteristics to be improved enough with MCAS active to provide a desirable increase in stick force gradient and a reduced pitch up tendency.

Aerodynamics Stability & Control Requirements

1. MCAS shall operate flaps up in the Mach number range of 0.20 to 0.84. Provision shall be retained to modify these values and any associated fade out factors.
2. MCAS shall ensure the airplane meets the stick force requirements of AC 25-7C (Reference (a)) as shown in Figure 1. [FC INFO]
3. MCAS shall operate at all load factors between Mach 0.20 to 0.84.
4. MCAS shall not have any objectionable interaction with the piloting of the airplane. [FC INFO]
5. MCAS shall be capable of commanding incremental stabilizer a maximum of 2.5 degrees at low Mach decreasing to a maximum of 0.65 degrees at high Mach from the initial stabilizer position at initiation of MCAS stabilizer motion. Augmentation will command airplane nose down only. This authority has been derived by determining the amount of stabilizer trim required to prevent pilot push forces [redacted]
6. The system shall be capable of providing a stabilizer rate of 0.27 deg./sec. This rate is derived by data analysis and Pilot simulator assessments which found it adequate to counter the pitch up tendency. This value aligns with the autopilot flaps down stabilizer rate.
7. [redacted]
8. The stabilizer shall continue to respond to main electric trim or manual stabilizer trim inputs from the flight crew during MCAS operation. MCAS commands shall be temporarily disabled during main electric trim operation and shall resume commanding stabilizer based on MCAS logic using the new manual stabilizer trim as the reference position.
9. MCAS activation shall result in a disconnection of Speed trim up and down Stabilizer motor commands and remain disconnected until MCAS deactivation.
10. MCAS shall not adversely affect airplane stall characteristics. [FC INFO]
11. MCAS shall not interfere with dive recovery. [FC INFO]
12. MCAS failures shall be annunciated to the flight crew. [redacted]
13. The system should be designed to minimize the likelihood of system activation during normal operation to avoid unnecessary rotation of the trim wheels.
14. The probability of a system hard over, oscillatory failure, and loss of function shall be commensurate with the hazard levels shown in the FHA table. These were determined by Pilot simulator assessments of MCAS failure modes.
15. [redacted]
16. MCAS shall be inactive while the autopilot is engaged. Autopilot engagement shall disable MCAS.
17. Transition from Autopilot to manual flight above the MCAS trigger angle of attack shall result in MCAS becoming active. This requirement is based on piloted cab evaluations and results in improved recovery capability to the normal flight envelope.

[redacted]

18.

a. [redacted]

b. [redacted]

19.

a. For the 737-8/9: MCAS shall calculate a body angle-of-attack for reference to the MCAS Angle of Attack Trigger Schedule and Incremental Stabilizer Schedule using pitch rate, vane angle of attack, and true airspeed.
b. For the 737-7/10: MCAS shall calculate a body angle-of-attack for reference to the MCAS Angle of Attack Trigger Schedule and Incremental Stabilizer Schedule using body pitch rate, vane angle of attack, and true airspeed.

MCAS Schedules

The following ~~three~~ **four** tables define the flight-updated schedules used in the MCAS control law logic to support both Flaps Up stalls at low-to-mid Mach and maneuvering characteristics at high Mach. [redacted] The MCAS control law calculates a body angle-of-attack using alpha vane, pitch rate, and airspeed. Table 2 defines the amount of incremental stabilizer MCAS will command for a given change in angle-of-attack as a function of Mach **for the 737-8/9. Table 4 defines the amount of incremental stabilizer MCAS will command for a given change in angle-of-attack as a function of Mach for the 737-7/10.**

[redacted]

[redacted]

[redacted]

[redacted]

Functional Hazard Assessment

Item	Hazard	Phase	Failure Condition	Effect Class
A	Loss of Flaps Up High Alpha Stabilizer function (MCAS)	Flaps Up flight	Decrease in stability with load factor and angle of attack	IV(Minor) Normal flight envelope III (Major) Operational flight envelope
B	Uncommanded High Alpha Stabilizer function operation (MCAS) to maximum authority	ALL	Stabilizer runaway due to MCAS control law stabilizer deflection limit. Pitch trim functionality is retained.	III (Major) Normal flight envelope II(Hazardous) Operational flight envelope
C	Uncommanded MCAS function operation equivalent to 3 second mistrim (0.81 deg)	ALL	Stabilizer runaway equivalent to 3 seconds of mistrim (FAR25.255). Pitch trim functionality is retained.	III (Major) Normal flight envelope II (Hazardous) Operational flight envelope
D	Uncommanded MCAS function operation to pilot reaction	ALL	Stabilizer runaway until pilot recognition and reaction	II (Hazardous) Operational flight envelope

The original hazard assessments were obtained by pilot assessment in the motion simulator. Critical combinations of weight and CG were tested. The session summaries which provide the results can be found in the job file: [redacted] The hazard assessments were revisited and determined to have not changed in hazard classification based on the most recent MCAS update. The uncommanded MCAS command to the maximum nose down authority at low Mach numbers (3 degrees) was evaluated in the 737 MAX cab and rated as Minor. The high Mach recovery is the critical factor in establishing the hazard rating for this item.

The loss in stabilizer function (item A) without annunciation is based on the handling qualities of the airplane with MCAS inactive. The reduction in stick force versus 'g' gradient and the presence of a pitch up tendency not meeting the mild and readily controllable requirement were found unacceptable. The hazard category was deemed Major in the operational envelope. Upon further review, the pilots found that no special procedures were required in part due to the system not operating in the normal envelope. For the low Mach stalls, the pilots rated loss of MCAS as Major based on flight test results with the existing configuration.

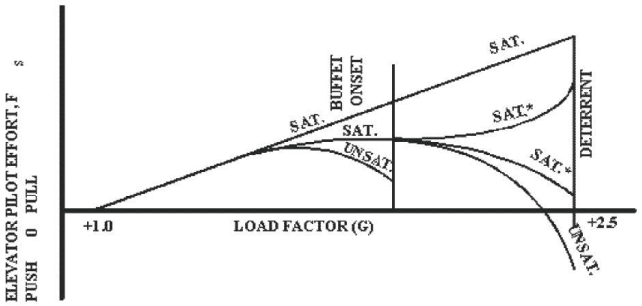
Two scenarios were used to assess the stabilizer runaways (items B & C). One was a runaway at MCAS activation during a wind up turn maneuver, the other a wings level recovery from a level flight stabilizer runaway based on FAR25.255, "Out of Trim Characteristics". Mistrim amounts were tested to the MCAS CLAW maximum stabilizer limit (0.65 deg.) and 3 seconds of mistrim as per the FAR and input from the flight test community. The MCAS stabilizer deflection rates were used.

For the stabilizer runaways in the WUT maneuver (i.e. in the operational envelope) to the CLAW limit, the runaways were found Major, and the 3 second runaways found Hazardous. The Hazardous category was applied mainly due to the tendency to overspeed during the recovery rollout for those cases where the WUT was performed near the maximum operating speeds.

For the wings level mistrim recoveries, the runaway occurs at Vmo/Mmo and a recovery made at Vdf/Mdf. The runways with the stabilizer mistrimmed to the CLAW limit were found Major. For the wings level 3 second mistrim stabilizer cases, some were found Major and some Hazardous. The Hazardous assessment was reduced to Major for a recovery initiated at 3 seconds past overspeed warning. The recovery at Vd/Md is appropriate to the intent of FAR25.255, but is a more severe condition than would be expected during the failure mode. Reduction of this speed would have reduced the workload and hazard category. This is to be verified in future cab sessions.

Stabilizer runaways to pilot reaction (item D) were performed. These failures were arrested by use of the aisle stand cutout switch when the pilot recognized and reacted to the runaway. Assessments were done during WUTs only i.e. within the operational flight envelope, but not assessed by mistrim trim dive recoveries (normal operating envelope). With pilot training to recognize the runaway and use of teamwork, the failure was found Hazardous, which is the same as the item C finding. A typical reaction time was observed to be approximately 4 seconds. A slow reaction time scenario (>10 seconds) found the failure to be catastrophic due to the inability to arrest the airplane overspeed.

Figure 1. (AC 25-7C Figure 31-1)



[redacted]

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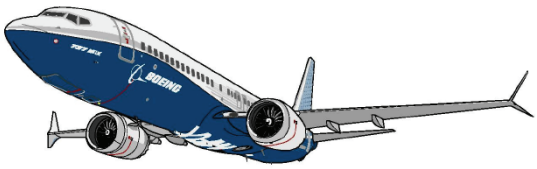


737-8

Flight Crew Operations Manual

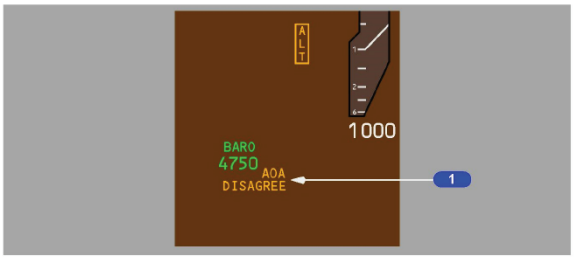
P. T. Lion Mentari

Document Number D6-27370-MAX-MLI
Revision Number: 4
Revision Date: August 16, 2018

F/O	First Officer
FPA	Flight Path Angle
FPV	Flight Path Vector
FSEU	Flap Slat Electronic Unit
G	
GA	Go–Around
GEN	Generator
GP	Glide Path
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
G/S	Glide Slope
H	
HDG	Heading
HDG REF	Heading Reference
HDG SEL	Heading Select
HPA	Hectopascals
HUD	Head-Up Display
HYD	Hydraulic
I	
IAS	Indicated Airspeed
IASC	Integrated Air Supply Controller
IDENT	Identification
IN	Inches
IND LTS	Indicator Lights
ILS	Instrument Landing System
INBD	Inboard
INOP	Inoperative

INTC CRS	Intercept Course
ISFD	Integrated Standby Flight Display
ISLN	Isolation
K	
K	Knots
KGS	Kilograms
L	
L	Left
LAM	Landing Attitude Modifier
LAT	Latitude
LBS	Pounds
LDG ALT	Landing Altitude
LE	Leading Edge
LVL CHG	Level Change
LIM	Limit
LNAV	Lateral Navigation
LOM	Locator Outer Marker
LONG	Longitude
M	
MAG	Magnetic
MAN	Manual
MCAS	Maneuver Characteristics Augmentation System
MCP	Mode Control Panel
MDA	Minimum Descent Altitude
MDS	MAX Display System
MFD	Multi-Function Display
MEL	Minimum Equipment List

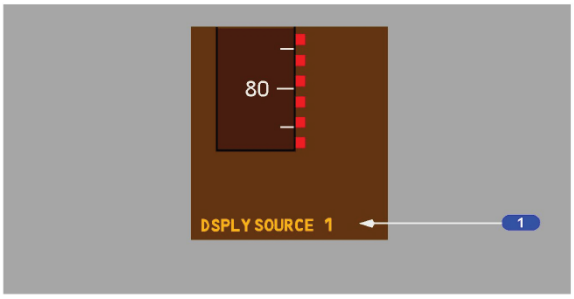
PFD Annunciations and Alerts
Angle of Attack (AOA) Disagree Alert



1 AOA Disagree Alert (amber)

Indicates the Captain's (left) and First Officer's (right) angle of attack values disagree by more than 10 degrees for more than 10 continuous seconds.

Display System Annunciations



1 Display System Annunciations

When there is a problem with the DPC display system, one of the following indications will appear in the lower left corner of the primary flight display:

DSPLY SOURCE 1 or 2 (amber) – DPC 1 has failed or DPC 2 has failed.

MCAS Development and Certification Overview—TBC-T&I 130073–130074; 130075–130117

[redacted]

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The Boeing Company
P.O. Box 3707
Seattle, WA 98124-2207

MAR 0 1 2019

RA-19-00256

[redacted]
Manager, AIR-860
BASOO Branch
Department of Transportation
Federal Aviation Administration
2200 S. 216 Street
Des Moines, WA 98198-6547

[redacted]

Subject:	Submittal of MCAS Development and Certification Overview
Model:	737MAX
FAA Project No.:	N/A
RA Project No.:	N/A
EASA Project No.:	N/A
EASA Level:	N/A
Response Requested:	None – Informational Only
Expedited Flow:	No
Reference:	FAA/Boeing meeting on December 17, 2018, MCAS Development and Certification Overview
Special Instructions:	Please forward to [redacted]

This letter is to submit:

Updated presentation material from the Reference meeting

This letter is being sent for:

Information only

[redacted]

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[redacted]
RA-19-00256
Page 2

Please contact this office or the following individuals if you have further questions:

Certification Engineer: [redacted]
Program Manager: [redacted]

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Sincerely,

[redacted]
Director, BCA Engineering
[redacted]

GWO

Enclosure: MCAS Development and Certification Overview

cc

Name	SP	Encl	MC	Title
[redacted]			X	FAA Program Mgr., 0600-1222
			X	FAA
			X	FAA
			X	FAA
			X	FAA

[redacted]

Enclosure to RA-19-00256
Page 1 of 43

MCAS Development and Certification Overview

[redacted]

[redacted]

Enclosure to RA-19-00256
Page 2 of 43

Compliance Review Summary

737 MAX MCAS Control Law

- All certification deliverables (Cert Plans, ICA Documents, etc…) in support of MCAS control law certification are compliant.
- Review of all Boeing internal analysis in support of MAX development and certification deliverables were completed per process and are compliant.
- Assessment of Compliance Identified Several Areas for Improvement
  - Opportunities to Enhance Records of Decisions
  - Inconsistencies in Documentation
- Aerodynamics Stability & Control completed further evaluation of the Functional Hazard Assessment for loss of MCAS control law function in a corner condition of the normal flight envelope.
  - Confirmation via Flight Test that loss of MCAS rated as minor

Agenda

- Development and Certification Timeline
- MCAS Control Law Design Overview
- System Level Hazard and Safety Assessments
- Flight Controls Certification Deliverables
- Airplane Level Hazard, Safety, and Single & Multiple Fault Assessments
- Instructions for Continued Airworthiness (ICA)
- Flight Crew Training and Documents
- Maintenance Training and Documents
- MCAS Compliance Assessment Summary
- AoA Disagree Flight Deck Indication

Agenda

- Development and Certification Timeline
- System Design Overview
- System Level Hazard and Safety Assessments
- Flight Controls Certification Deliverables
- Airplane Level Hazard, Safety, and Single & Multiple Fault Assessments
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[redacted]
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[redacted]

System Design Overview
Summary

Maneuvering Characteristics Augmentation System (MCAS) Description:

- MCAS is a pitch augmentation flight control law implemented on the 737 MAX that commands nose down stabilizer to enhance pitch characteristics with flaps up during elevated angles of attack.
- MCAS is activated without pilot input and only operates when the autopilot is disengaged.
- MCAS control law becomes active and applies automatic nose down stabilizer in increments based on a table schedule as a function of AOA and Mach
  - The maximum command amount at any point in the table schedule is limited to 2.5 degrees
  - Stabilizer is commanded at a rate of 0.27 degrees per second (same rate as flaps down speed trim)
  - Maximum magnitude of stabilizer command is lower at high Mach number and greater at low Mach number (for the same AOA above the activation threshold)
- After AOA falls below the hysteresis threshold (0.5 degrees below the activation angle), MCAS commands nose up stabilizer to return the airplane to the trim state that existed before it entered the MCAS activation region
- MCAS stabilizer operation can be stopped and reversed by a pilot using the electric thumb switches and commanding stabilizer trim in the nose up direction
- If elevated AOA conditions persist and increase, MCAS commands additional incremental stabilizer in accordance with the table schedule referenced above

[redacted]

System Design Overview
MCAS vs. Speed Trim: Pilot Inputs and Effect on MCAS and Speed Trim

Effect of Column Cutout
- Does not inhibit MCAS commands
- Inhibits Speed Trim commands

Effect of Electric Stabilizer Trim (i.e. thumb switch input)
- Overrides both MCAS and Speed Trim commands

Effect of Stabilizer Cutout switches
- Inhibit both MCAS and Speed Trim commands

Effect of Manual Trim (i.e. trim wheel)
- Overrides both MCAS and Speed Trim commands

Effect of Trim Override switches
- Overrides column cutout switches only

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MCAS System Level FHA

Summary

- Development of FHAs for MCAS control law was consistent with process and assumptions used on all Boeing models.
- Loss of MCAS control law function assessed as Minor in the Normal Flight Envelope and Major in the Operational Flight Envelope.
- All FHAs involving unintended MCAS activation were assessed as Major in the Normal Flight Envelope and Hazardous in the Operational Flight Envelope.
- Consistent with FAA regulations and Boeing process MCAS FHA events were not evaluated in the SSA as they were assessed as Major.

[redacted]

Fundamental Assumptions Utilized in Functional Hazard Assessments

- Fundamental assumptions used in flight control FHAs across all Boeing models. Consistent with 25.671, 25.672 and AC 25-7C for compliance evaluation for 25.143.
  - Uncommanded system inputs that are readily recognizable and can be counteracted by overriding the failure by movement of the flight controls in the normal sense by the flight crew do not require specific procedures.
  - Action to counter the failure shall not require exceptional piloting skill or strength
  - The pilot will take immediate action to reduce or eliminate increase control forces by re-trimming or changing configuration or flight conditions
  - Trained flight crew memory procedures shall be followed to address and eliminate or mitigate the failure
- FHA evaluation for MCAS and Stab Trim was consistent with the above fundamental assumptions and resulted in the following.
  - Unintended stabilizer trim inputs are readily recognized by movement of the stab trim wheel, flight path change or increased column forces.
  - Aircraft can be returned to steady level flight using available column (elevator) or stabilizer trim.
  - Continuous unintended nose down stabilizer trim inputs would be recognized as a Stab Trim or Stab Runaway failure and procedure for Stab Runaway would be followed.

[redacted]

System Level Functional Hazard Assessment (FHA)

MCAS Certification Approach

- Determination of functional hazard categories (*e.g.*, Major, Hazardous, Catastrophic) was by Boeing pilot assessment performed in the simulator and aligned with Advisory Circular AC 25-7C.
- Single MCAS unintended activations were inserted via the Stabilizer Trim System in the Simulator to asses impact to handle qualities and associated flight crew actions.
- Accumulation or combination of failures leading to unintended MCAS activation were not simulated nor their combined flight deck effects.
- Upon each design iteration of MCAS, the functional hazard categories were re-assessed. The assessments were validated following each iteration.
- When assessing unintended MCAS activation, the function was allowed to perform to its authority and beyond before pilot action was taken to recover
  - Failures were able to be countered by using elevator alone.
  - Stabilizer trim available to offload column forces.
  - Stabilizer cutouts were available but not required to counter failures.
- Based on this evaluation, unintended MCAS activation was assessed as Major in the Normal flight envelope.

[redacted]

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System Level Functional Hazard Assessment (FHA)

MCAS FHAs

- Four failure conditions were evaluated per our FHA process in the Normal flight envelope and in Operational flight envelope and then assessed the effect for each failure condition in both of those envelopes.
- Conditions assessed:
  - Loss of MCAS function
  - Unintended MCAS activation to the control law table limit (accounted for erroneous AoA)

[redacted]

- All four conditions determined to meet hazard assessment / probability requirements.
- Erroneous Angle of Attack (AoA) was accounted for within unintended MCAS activation to control law table limit.

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System Level Functional Hazard Assessment (FHA)

Erroneous Inputs to MCAS Control Law

- Erroneous inputs to MCAS control law could result in loss of MCAS function or unintended MCAS activation.
- Unintended MCAS activation due to erroneous input would still be subject to the control law table limits encoded in the MCAS software (2.5 deg maximum incremental stabilizer movement)
- Unintended MCAS activation has previously been shown to be:
  - Major in normal flight envelope.
    - Failure can be countered by using elevator alone.
    - Stabilizer trim available to offload column forces.
    - Stabilizer cutouts available but not required to counter failure.
  - Hazardous in the operational flight envelope.
    - The probability of being outside the normal flight envelope is 10^{-3} (ref AC 25-7C). Therefore, a condition that meets the integrity requirements for a Major within the normal flight envelope also meets the Hazardous integrity requirements for the operational flight envelope.

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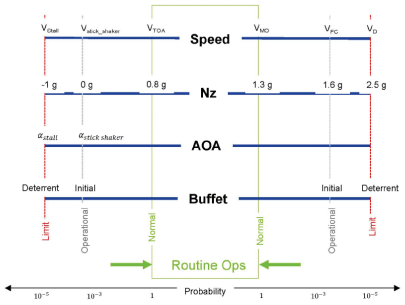
Flight Envelope Definitions



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[redacted]

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MCAS Flight Controls Certification

Summary

- "737 NG/MAX Enhanced Digital Flight Control System, Autothrottle, and Yaw Damper Safety Analysis" showed compliance for [redacted]
- "737 Stabilizer Trim Control System Safety Analysis" showed compliance for [redacted]
- Flight test conducted concurrent with Aero S&C flight testing to demonstrate MCAS control law function and effects of loss of function during Control System Malfunctions Testing.
- During MAX development FCC and MCAS Control Law identified as Development Assurance compliant system following ARP 4754.

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[redacted]

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MCAS Certification

CP 13474 "737-8 Amended Type Certificate – Flight Controls – Autoflight (EDFCS/FCC)"

- Deliverable 8: D241A018-12, "737 NG/MAX Enhanced Digital Flight Control System, Autothrottle, and Yaw Damper Safety Analysis" for [redacted]
  - Existing catastrophic fault trees modified to account for the MCAS failure contributions to the top event
  - No warning required as a failure of the function did not pose an unsafe condition. In addition, counteraction of failures of the function did not require exceptional pilot skill or strength and is accomplished by movement of the flight controls in the normal sense.
  - Detected failures in MCAS are annunciated by the illumination of the existing SPEED TRIM (caution) light – repurposes existing speed trim structure

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[redacted]

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MCAS Certification

CP 13471 "737-8 Amended Type Certificate – Flight Controls – Primary, Elevator and Stabilizer Control"

- Deliverable 9: D251A018-6, "737 Stabilizer Trim Control System Safety Analysis" for [redacted]
  AR Recommend Approval
  - Existing catastrophic fault trees modified to account for the MCAS engage discrete failures contributing to loss of the control column cutout function
  - Identification of the established functional hazards in normal and operational flight envelope

G-4.2 FHA Results

Functional Hazard Assessment findings for the 737 MAX Stabilizer Trim Control System are presented in Table G4-1 below. Probabilites are given for both a 1.9 hour standard flight length case as well as for a 9.0 hour maximum duration ETOPS mission. Note the two different flight phases designated for MCAS related hazards – "Normal Flight Envelope" and "Operating Flight Envelope". Operating flight envelope for the MCAS function refers to a wind-up turn.

Effect Category Event Source	Hazard Event	Flight Phase	Contributing Interfacing Systems	Calculated Probability		FTA Reference
				Standard Flight (1.9 FH)	ETOPS Flight (9.0 FH)	
Hazardous	Loss of main electric nose down trim prior to piloted go around, but after stabilizer float sprung on dual channel autoland	Go around	None	[redacted]	[redacted]	G6-1, p. 1, STABGA
Hazardous	Stabilizer trim system uncommanded motion with override, but requires very high flight crew workload for safe landing	Landing	None	[redacted]	[redacted]	G6-2, p. 3, G615
Hazardous	Uncommanded MCAS function operation	All (Operating Flight Envelope)	None	[redacted]	[redacted]	G6-2, p. 8, G647

[redacted]

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Flight Test

CP 13471 "737-8 Amended Type Certificate – Flight Controls – Primary, Elevator and Stabilizer Control"

- Deliverable 15: CFTP C1.39.AAC "737-8 Primary Flight Control System" – AR Recommend Approval for 1st Rev
  - [redacted]
  - Test Report Deliverable 17 – AR Approval
  - Test report points to conditions flown concurrently with C1.21.AAL "737-8 Maneuvering Characteristics" (reference CP 13669)

[redacted]

Flight Test

CP 13669 "737-8 Amended Type Certificate –Aerodynamics – Performance, Stability and Control"

- Deliverable 40: CFTP C1.14.ADD "737-8 Stall Characteristics" – AR Recommend Approval
  - [redacted] Demonstrate compliant stall characteristics.
  - Test Report Deliverable 42 – AR Approval
- Deliverable 34: CFTP C1.21.AAL "737-8 Maneuvering Characteristics" – AR Recommend Approval for 1st Rev
  - [redacted] Demonstrate compliant maneuvering characteristics and associated column force characteristics during wind up turns.
  - Test Report Deliverable 36 – AR Approval
- Deliverable 7: CFTP C1.33.AAD "737-8 Control System Malfunctions" - AR Recommend Approval for 1st Rev
  - [redacted] Demonstration of loss of MCAS function
  - Test Report Deliverable 9 – AR Approval

[redacted]

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[redacted]

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Airplane Level Hazard, Safety, and Single & Multiple Failure Assessments

Summary

- For the MAX development Single and Multiple Failure analysis was completed and followed BPI-[redacted]
- Per BPI-[redacted], MCAS was not evaluated individually as a new/novel on the MAX as the control law had been previously implemented on 767 GTTA.
- "Erroneous AOA, one source" was identified and not analyzed as part of S&MF assessment per Engineering judgment.
- During case selection per Engineering judgment the worst case multiple failure of "Erroneous L & R Air Data" and "Erroneous L or R Air Data" replaced "Erroneous AOA, one source" failure scenario.
- S&MF analysis completed prior to the design change to MCAS control law during flight test. Reevaluation of design change not required per BPI-[redacted].
- While the version of MCAS included in the S&MF analysis was not reflective of the certified configuration; current assessment is that the S&MF final report would have included the same crew action that is already considered in the S&MF analysis.

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[redacted]

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Airplane Level Safety Assessments (ASA)

Single and Multiple Failure Accomplishment Summary – D910A010

- Completed by Systems Engineering with input from Safety and Functional Areas
- Developed per BPI-[redacted], "Conducting Single and Multiple Failure Analyses"
  - Step 1 – Team identifies cases based on prior models, changes in airplane/architecture. Cases accepted/rejected in this step. Rationale for rejection reviewed.
  - Step 2 – Analysis performed. Data includes failure effects and cascading effects.
  - Step 3 – Teams determine if failure hazard classification is appropriate for case.
  - Step 4 – Resolve actions in AI database.
  - Step 5 – E-CAB testing.
  - Step 6 – Document results.

[redacted]

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[redacted]

Airplane Level Safety Assessments (ASA)

Single and Multiple Failure Accomplishment Summary – D910A010

- AVN-16: Loss of one AOA followed by an erroneous AOA
  - Deemed potentially catastrophic before crew recognition of issue
  - Catastrophic rating consistent with Displays and Air Data system safety assessments and AC 25-11A
  - Acceptability Rationale based on crew training, appropriate flight crew action and the probability of failure being extremely remote.

4.19.2 Analysis Summary

Baseline Configuration: 737-7, -8, and -9 MAX
Significant Flight Phase and Conditions:
- Flight phase of failure occurrence: All flight phases
- Environmental conditions: IMC, Night, wet runway
- Operational conditions: IFR
- Significant flight phase and conditions for follow-on effects: No

Airplane-Level Effects:
- MMEL: No
- Diversion by Procedure: No
- Diversion Expected by Pilot: Not called out by procedure, but flight crew likely would divert

Failure Case Probability	Failure Case Cumulative Hazard Category	Required Probability On the Order Of (Based on Hazard Categorization)
[redacted]	Catastrophic	1E-9 or less

Acceptability Rationale:
- Results in a misleading single source air data situation for primary displays. Potentially catastrophic before flight crew recognition of issue. Crew training supports recognition and appropriate flight crew action.
- Failure event probability is beyond extremely improbable

[redacted]

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[redacted]

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Instructions for Continued Airworthiness (ICA)

ICA Documents

- For the MAX development program all ICA documents required for certification were produced to comply with [redacted] and followed Boeing release process BPI-[redacted] "Showing Compliance for Instructions for Continued Airworthiness (ICA)"
- Aircraft Maintenance Manual & Integrated Fault Isolation Manual did not require inclusion of information specific to MCAS as they include all pertinent information required to diagnose MCAS control law input failures in the material that addresses Stab Trim control law input failures.
- MCAS not included in Systems Description Section of AMM.
- Wiring Diagram Manual properly captures the airplane wiring changes for the Stabilizer Column Cutout due to incorporation of the MCAS control law.
- Relay implemented in Stabilizer Column Cutout system to incorporate MCAS is monitored by the FCC and no periodic maintenance is required.

[redacted]

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Instructions for Continued Airworthiness (ICA)

ICA Documents

- Airworthiness Limitations Certification Maintenance Requirements (ALCMR)
- Enhanced Zonal Analysis Procedure (EZAP)
- Aircraft Maintenance Manual (AMM) ★
- Configuration, Maintenance and Procedures (CMP)
- Fault Isolation Manual (FIM) ★
- Damage Tolerance Rating (DTR)
- Maintenance Review Board (MRB)
- Non Destructive Testing (NDTG)
- Structural Repair Manual (SRM)
- Standard Wiring Practices Manual (SWPM)
- Task Cards (TC) – data not in AMM
- Weight and Balance Manual (WBM)
- Wiring Diagram Manual (WDM) ★

★Denotes item reviewed for inclusion of MCAS

[redacted]

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[redacted]

Flight Crew Training & Manuals
Summary

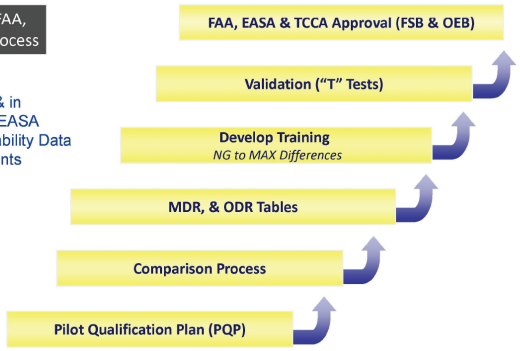
- Pilot Qualification process for the MAX followed AC 120-53B and Issue Paper O-1.
- Final approved FSB Report and Other Differences Requirements (ODR) Tables for the MAX did not include MCAS control law.
- Flight Crew Operations Manual (FCOM) does not include a specific systems description of MCAS control law.
- Boeing and FAA AEG specifically discussed inclusion of MCAS in ODR table and system description in FCOM. FAA concurred with Boeing recommendation that inclusion of MCAS in the ODR table and FCOM was not necessary.

Training and FCOM

Pilot Qualification Plan Process

A Joint Boeing, FAA, EASA and TCCA process

- Gated process
- Per AC120-53B & in compliance with EASA Operational Suitability Data (OSD) requirements



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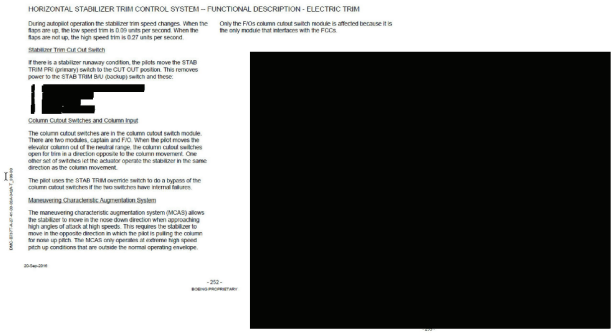
Maintenance Training and Documents
Summary

- As part of ATA Chapter system description the MCAS control law is referenced including the control law schematic.



HORIZONTAL STABILIZER TRIM CONTROL SYSTEM – FUNCTIONAL DESCRIPTION - ELECTRIC TRIM

During autopilot operation the stabilizer trim speed changes. When the flaps are up, the low speed trim is 0.99 units per second. When the flaps are not up, the high speed trim is 0.27 units per second.

Stabilizer Trim Cut Out Switch

If there is a stabilizer runaway condition, the pilots move the STAB TRIM PRI (primary) switch to the CUT OUT position. This removes power to the STAB TRIM B/U (backup) switch and these:

[redacted]

Column Cutout Switches and Column Input

The column cutout switches are in the column cutout switch module. There are two modules, captain and F/O. When the pilot moves the elevator column out of the neutral range, the column cutout switches open for trim in a direction opposite to the column movement. One either set of switches or the actuator operate the stabilizer in the same direction as the column movement.

The pilot uses the STAB TRIM override switch to do a bypass of the column cutout switches if the two switches have internal failures.

Maneuvering Characteristic Augmentation System

The maneuvering characteristic augmentation system (MCAS) allows the stabilizer to move in the nose down direction when approaching high angles of attack at high speeds. This requires the stabilizer to move in the opposite direction in which the pilot is pulling the column for nose up pitch. The MCAS only operates at extreme high speed pitch up conditions that are outside the normal operating envelope.

Only the F/Os column cutout switch module is affected because it is the only module that interfaces with the FCCs.

[redacted]

[redacted]

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[redacted]

Assessment Summary

• Opportunities to Enhance Records of Decisions

- MCAS Control Law Removal from Differences Training Table (ODR) and FCOM
  - Boeing and FAA AEG discussed and agreed on removal of MCAS control law during MAX development and certification.
  - Supporting rationale discussed between Boeing and FAA and accepted by FAA, but not formally documented in meeting minutes.
  - Reviewed FCOM and released MAX FSB Report do not reference MCAS.
  - No process violation or non-compliance

- Engineering & Pilot Assessment of Repeated Unintended MCAS Control Law Activation
  - Engineering and Test pilots discussed scenario of repeated unintended MCAS activation during MAX development and deemed no worse than single unintended MCAS activation.
  - Discussion and supporting rationale documented in pilot meeting summary email on June 22, 2016 and not documented in formal certification artifacts
  - No process violation or non-compliance

[redacted]

Assessment Summary

• Inconsistencies

- MCAS Systems Descriptions in Maintenance Training Material and Not Included in ICA Documents
  - Maintenance Training material developed and released prior to ICA documents provide description of pre-flight test MCAS control law.
  - No process violation or non-compliance

- FCOM Acronyms Section Referencing MCAS
  - Artifact left behind from earlier drafts of the FCOM prior to removal of MCAS from FCOM and FAA acceptance.
  - No process violation or non-compliance

- EDFCS SSA Data Document D241A018-13
  - Data Document is a repository for SSA supporting data and is not a certification deliverable nor referenced in SSA Compliance Documents D241A018-12 for the MAX or NG.
  - Supplemental non-certification data documentation updates not yet formally published to include the MAX.
  - EDFCS SSA D241A018-12 document used appropriate data in support of compliance for the MAX.
  - No process violation or non-compliance

[redacted]

Assessment Summary

• Inconsistencies

- D251A018-6, "737 Stabilizer Trim Control System Safety Analysis" Compliance Document
  - Description of functional failure in the Fault Hazard Assessment table referenced preliminary MCAS control law authority limits and was not updated to reflect certified design.
  - Identification of the probability for the Hazardous condition of unintended MCAS activation referenced the incorrect gate within the Fault Tree Analysis for Stabilizer Runway.
  - Compliant probabilistic assessment in Fault Tree Analysis maintained with revision.

- D910A010, "Single and Multiple Failure Accomplishment Summary"
  - "Erroneous AOA, one source" was identified and not analyzed as part of S&MF assessment. Similar to previous derivative development programs like 747-8
  - Supporting rationale provided was, "Covered by Erroneous L&R Air Data, Erroneous L or R Air Data covers single probe loss case".
  - Rationale should have pointed to "Loss of one AOA followed by Erroneous AOA" which was a part of the S&MF assessment during MAX development. Condition was not evaluated in the simulator but deemed acceptable as failure was found to be extremely improbable.
  - S&MF analysis completed prior to the design change to MCAS control law during flight test and not reevaluated. Current reassessment is consistent with previous S&MF analysis which is supported by crew action in acceptability rationale.
  - No process violation or non-compliance

[redacted]

Compliance Review Summary

737 MAX MCAS Control Law

- Review of all certification deliverables (Cert Plans, ICA Documents, etc…) in support of MCAS control law certification are compliant.
- Review of all Boeing internal analysis in support of MAX development and certification deliverables were completed per process and are compliant.
- Assessment of Compliance Identified Several Areas for Improvement
  - Opportunities to Enhance Records of Decisions
  - Inconsistencies in Documentation
- Aerodynamics Stability & Control completed further evaluation of the Functional Hazard Assessment for loss of MCAS control law function in a corner condition of the normal flight envelope.
  - Confirmation via Flight Test that loss of MCAS rated as minor

[redacted]

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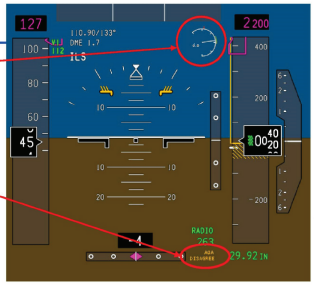
[redacted]

'AOA DISAGREE' and Optional Angle of Attack Flight Deck Indication

Design Overview

- **Optional Angle of Attack Indication**
  - Implemented in BP99 for 737NG - first delivered December 1999.
  - Requirements carried over for 737 MAX.
- **'AOA DISAGREE' disagree**
  - Implemented in BP06 for 737NG - first delivered July 2006.
  - Annunciation was a customer request to assist maintenance troubleshooting.
  - Displayed on PFDs when the left and right AOA disagree 10+ degrees for 10 continuous seconds.
  - [redacted]
  - AOA data received from the ADIRUs via A429.
  - If the data from the ADIRUs are unavailable or invalid, the annunciation will not be displayed.
  - Requirements carried over for 737 MAX.



- AOA DISAGREE alert does not require any pilot action.
- There are other flight deck effects that pilots should understand that may indicate the presence of erroneous AOA data, including the ALT DISAGREE and IAS DISAGREE alerts.

[redacted]

737 MAX 'AOA DISAGREE' Flight Deck Indication

COSP 2018-2116

- MDS PR693 "AOA DISAGREE Annunciation" discovered in October 2017
- AOA DISAGREE is not displayed unless the optional AOA indicator is displayed.
- Determined to be requirements not implemented correctly by supplier in display system software.
- Testing of previous black label software on versions did not discover this issue.
- PR Review Process concluded to resolve the PR with MDS BP2 which is part of MAX-10 ATC (EIS 3Q 2020).

[redacted]

737 MAX 'AOA DISAGREE' Flight Deck Indication

COSP 2018-2116 Summary Rationale

Determined to be Not a Safety Issue (Dec 6, 2018)

- IAS DISAGREE and ALT DISAGREE may be displayed with an AOA DISAGREE. AOA DISAGREE is supplementary information with no additional crew action.
- All appropriate crew action is contained in the IAS DISAGREE and ALT DISAGREE QRH procedures.
- The IAS DISAGREE and ALT DISAGREE annunciations are displayed independent of the AOA DISAGREE annunciation.
- AOA DISAGREE, IAS DISAGREE, and ALT DISAGREE are observed faults and have corresponding IFIM Tasks.
  - Task 34-10-00-810-801 SPEED DISAGREE Shows on PFD – (Captains's) – Fault Isolation
  - Task 34-10-00-810-802 SPEED DISAGREE Shows on PFD – (First Officer's) – Fault Isolation
  - Task 34-20-00-810-801 ALT DISAGREE Shows on PFD – (Captains's) – Fault Isolation
  - Task 34-20-00-810-802 ALT DISAGREE Shows on PFD – (First Officer's) – Fault Isolation
  - Task 34-20-00-810-803 AOA DISAGREE Shows on PFD (Captains's) – Fault Isolation
  - Task 34-20-00-810-804 AOA DISAGREE Shows on PFD (First Officer's) – Fault Isolation
  - The first step in all tasks is to look in OMF Existing Faults, 34 Air Data Inertial Reference System for related maintenance messages.

[redacted]

Presentation on Stall Characteristics—TBC-T&I 033941–033942, 033944–033945, and 033947

[redacted]

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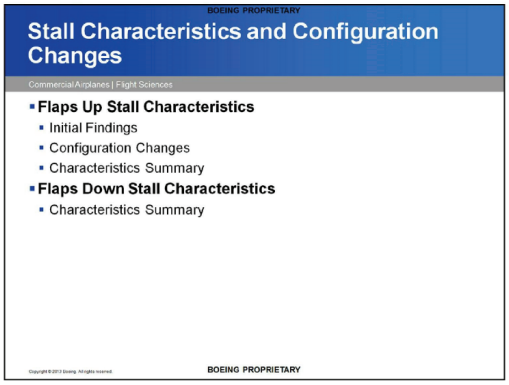
BCA Airplane Programs

737MAX –Brief on Stall Characteristics and Configuration Changes

Presenter: [redacted]

Briefing date: July 2016

[redacted]


BOEING PROPRIETARY
Stall Characteristics and Configuration Changes
Commercial Airplanes | Flight Sciences
Flaps Up Stall Characteristics
Initial Findings
Configuration Changes
Characteristics Summary
Flaps Down Stall Characteristics
Characteristics Summary
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[redacted]

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Flaps Up Stall Characteristics

Commercial Airplanes | Flight Sciences

- **Configuration Changes**
  - [redacted]
  - EFS tuning & MCAS addition for low speed will be validated soon

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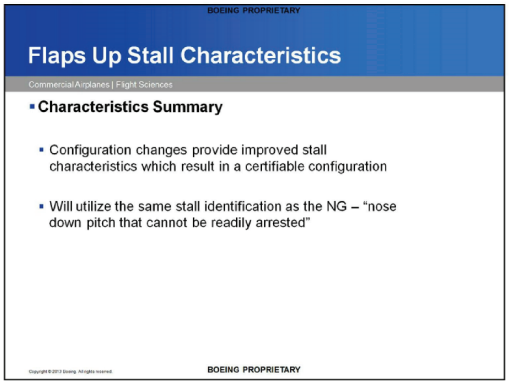
BOEING PROPRIETARY
Flaps Up Stall Characteristics
Commercial Airplanes | Flight Sciences
Characteristics Summary
Configuration changes provide improved stall characteristics which result in a certifiable configuration
Will utilize the same stall identification as the NG – "nose down pitch that cannot be readily arrested"
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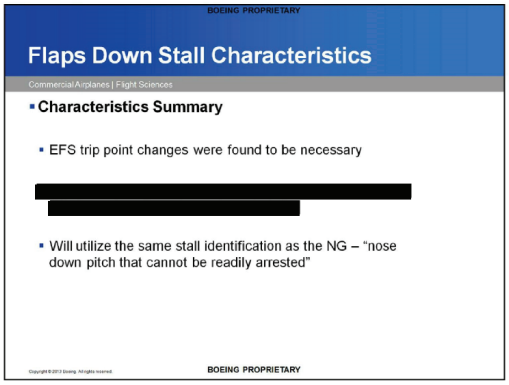
5

[redacted]


BOEING PROPRIETARY
Flaps Down Stall Characteristics
Commercial Airplanes | Flight Sciences
Characteristics Summary
EFS trip point changes were found to be necessary
[redacted]
Will utilize the same stall identification as the NG – "nose down pitch that cannot be readily arrested"
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7

Transmittal Letter and Revision O of Certification Plan—TBC-T&I 371200–371201, TBC-T&I 371202 (p.1), 321228 (p. 27), 371503 (p. 302)

[redacted]

BOEING [redacted]

The Boeing Company
P.O. Box 3707 MC 03-37
Seattle, WA 98124-2207

OCT 18 2016

RA-16-03821

[redacted]
737 Project Certification Manager
European Aviation Safety Agency
Ottoplatz, 1
D-50679 Cologne,
Germany

Dear [redacted]

Subject:	Submittal of 737 MAX Deliverable 9, "737NG/MAX Enhanced Digital Flight Control System, System Description" at Revision O, for Certification Plan 13474
Model:	737-8
RA Project No.:	PS12-0038
EASA Project No.:	0010018697
EASA Level:	N/A
Response Due:	No
In Reply To:	N/A
References:	(a) Boeing Document D241A018-11, "737NG/MAX Enhanced Digital Flight Control System, System Description"," Revision O , dated August 25, 2016 (b) Certification Plan 13474, "737-8 Amended Type Certificate - Flight Controls - Autoflight (EDFCS/FCC) & Autothrottle," Revision L (c) LOI CAI 07-01, Issue 11, "Definition of Panel 7 Level of Involvement in Compliance Demonstration," dated September 21, 2016
Special Instructions:	Please forward this letter and enclosure to Panel 07.

This letter is to submit:

(x) Compliance Data Deliverable 9 for Certification Plan 13474

Please find enclosed with this letter the submittal of reference (a) document for Deliverable 9 in the reference (b) certification plan for familiarization only. This letter is in response to reference (c) letter and associated Level of Involvement (LOI) Certification Action Item (CAI).

[redacted]

BOEING

This letter is being sent for:

(x) Familiarization Only for Panel 07.

Please contact this office or the following individuals if you have further questions:

[redacted]

The information being forwarded to the EASA by or with this correspondence is for the exclusive purpose of support of applications for or amendments to Type Certificates, is considered proprietary to The Boeing Company and/or its suppliers, and is provided on a confidential basis.

Sincerely,

[redacted]

ODA Deputy Lead Administrator
(425) 237-1383, MC 03-56
FAX: (425) 294-9340

ra

Enclosure:

- Boeing Document D241A018-11, "737NG/MAX Enhanced Digital Flight Control System, System Description"," Revision O

Cc:

Name	Enclosure	Share Point	Message Courier	Comments
Mr. [redacted]	Yes	Yes	No	FAA 737 Program Manager, 6Y-01
Mr. [redacted]	Yes	No	Yes	07, Powerplant & Fuel Systems, EASA

[redacted]

RA-16-03821 Enclosure

BOEING

CAGE Code 81205

737NG/MAX ENHANCED DIGITAL FLIGHT CONTROL SYSTEM, SYSTEM DESCRIPTION

DOCUMENT NUMBER:	RELEASE/REVISION:	RELEASE/REVISION DATE:
D241A018-11	**O**	August 25, 2016

CONTENT OWNER: [redacted]
Autoflight (BE325)
All revisions to this document must be approved by the content owner before release.

[redacted]

2. SYSTEM OVERVIEW

2.1 Historical Overview

Rockwell Collins supplies the major EDFCS components. The EDFCS is designed as a compatible replacement for the DFCS system (supplied by Honeywell) and includes the functionality previously provided by the autothrottle computer (supplied by Smiths Industries). In addition, EDFCS provides expanded capabilities supporting CAT IIIb Lower Weather Minimum (LWM) autoland. Subject to the limitation that FCCs must be installed as matched pairs, the Rockwell Collins EDFCS FCCs and MCP can directly replace the Honeywell DFCS FCCs and MCP (see Table 2.5.1-1). In these situations, the Rockwell Collins MCP/FCCs operate "transparent" to previous DFCS operation and do not support the advanced operational modes supplied by the EDFCS. A major goal for the EDFCS was preservation of autopilot and autothrottle operational transparency with the DFCS and autothrottle computer. When operating in similarly configured airplanes under similar operating conditions, a user will be presented with a common look and feel whether using the DFCS with an autothrottle computer or the EDFCS. The EDFCS offers increased functionality not present in the DFCS, however, so the DFCS FCC cannot be used on EDFCS configured airplanes.

2.2 Operational Overview

The EDFCS provides integrated operation of the following major flight control functions:

- Altitude Alert
- Autopilot (including Autoland)
- Flight Director
- Speed Trim
- Mach Trim
- Maneuvering Characteristics Augmentation System (MCAS) – 737 MAX
- FMC Interface & Mode Control
- Autothrottle Interface, N1 Limits, & Mode Control (for those airplanes equipped with a separate external autothrottle computer).

OR

- Integrated Autothrottle function (for those airplanes using the EDFCS internal autothrottle function with no separate autothrottle computer installed)

The integrated system control function provides control of the:

- Command control display function with respect to the selected parameter values to be displayed and the MCP pushbuttons to be lighted.
- Altitude alert function with respect to altitude selection and alerting.
- Autopilot function with respect to engagement and mode control.
- Flight director function with respect to activation and mode control.

[redacted]

6.6.2 Maneuver Characteristics Augmentation System (MCAS) (737MAX)

Flight Control Computer (FCC) Operational Program Software (OPS) update will add the MCAS function. The MCAS function drives the stabilizer during flaps up high angle of attack maneuver in the Mach range of 0.2 to 0.84 to provide a desirable increase in stick force gradient and a reduced pitch up tendency. FCC software revisions include the following:

- Prioritize and command stab trim motor for MCAS operations using the existing Speed trim channel
- FCC in command will output an MCAS engage discrete to set high stab trim motor rate and inhibit the aft column cut-out function in the Column Switching Module within the MCAS operating envelope.
- MCAS will command a stabilizer at 0.27 degrees per second (equivalent to the flaps down autopilot deflection rate)
- The stabilizer deflection will not exceed the Autopilot flaps up airplane nose down limit (stated for clarity only)
- Revise BITE software to account for new I/O

[redacted]

Presentation to EASA—TBC-T&I 371753, 371755, 371758, 371767, and 371768

RA-17-00444 Enclosure E

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737-8 EASA Validation – Phase 1 Familiarization

Aero Performance & Handling Qualities Systems Description
November 2016

RA-17-00444 Enclosure E

System Description – Aero Performance and Stability & Control

737-8 Principal Aero Impacted Change Areas

Changes from 737-800 with Winglets, 2011 PIP, Carbon Brakes and Short Field Performance Enhancement

Systems Revisions
- Fly-by-wire spoilers
  - Maneuver Load Alleviation (MLA) replaces speed brake load alleviation system
  - Landing Attitude Modifier (LAM) for nose gear contact margin
  - Landing Attitude Modifier (LAM) for glideslope capability
  - Direct Lift Control (DLC) for elevator Jams
  - Emergency Descent Spoilers (EDS) for rapid decompressions
- Maneuver Characteristics Augmentation System (MCAS)
- Revised Rudder Pressure Limiter

Design Weights	Delta Weights
Max Taxi Weight	+7,000 lb
Max Takeoff Weight	+7,000 lb
Max Landing Weight	+6,500 lb
Max Zero Fuel Weight	+7,100 lb

Fuselage Revisions
- Remove aft body vortex generators (VGs)
- Section 48 revised

APU Revisions
- New inlet with retractable door

Nose Landing Gear
- Gear lengthened 8"
- Longer doors

New CFM LEAP-1B Engine
- New core & new larger fan
- Higher bypass ratio (BPR)
- Increased Thrust (BET +1000lbs)

Empennage Revisions
- New longer tailcone loft
- Revised elevator
- Stabilizer strakelet
- Revised stabilizer trim limits
- Revised rudder stops

Wing Revisions
- New natural laminar flow advanced technology (NLF AT) winglet with out board divergent trailing edge
- Revised VG pattern, stall strip, and vortilon pattern
- Removal of retractable landing lights
- Krueger flap changed for nacelle and TR clearance

New Propulsion Installation
- New struts and fairings
- New nacelle with laminar flow lip
- Fan chevrons
- New thrust reversers (TR) – increased thrust and revised efflux pattern
- Revised chine size and position

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RA-17-00444 Enclosure E

Aero Overview

Flight Control Systems Pertinent to Aerodynamics

New Systems for the 737 MAX:

- Fly-by-wire spoilers (Spoiler Control Electronics – SCE)
  - Maneuver Load Alleviation (MLA)
  - Landing Attitude Modifier (LAM)
  - Direct Lift Control (DLC)
  - Emergency Descent Spoilers (EDS)
- Maneuver Characteristics Augmentation Systems (MCAS)

RA-17-00444 Enclosure E

MCAS Overview

Maneuver Characteristics Augmentation System

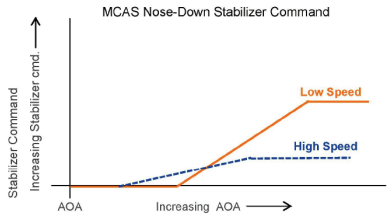
- New system on the 737 MAX
- Drives stabilizer input in the Airplane Nose Down direction to enhance stability at high angles-of-attack
- Improves stick force gradients for both high speed and low speed conditions
- Based on angle-of-attack as a function of Mach number
- Maximum authority at high speed is 0.65 degrees stabilizer; maximum authority at low speed is 2.5 degrees stabilizer

RA-17-00444 Enclosure E

MCAS Details

Maneuver Characteristics Augmentation System

- Operational outside of normal operating envelope (high angles-of-attack)
- Only operational for flaps up
- Commands are removed after angle-of-attack is reduced below the activation angle



Flight Test Certification Report—TBC-T&I 055903–055914

[redacted]

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Controlled by ECCN: 9E991

Document: [redacted]
Section: C1.14.AAD
Release Date: NOV 0 6 2017

BOEING TEST & EVALUATION
SEATTLE, WASHINGTON

FLIGHT TEST CERTIFICATION REPORT

AIRPLANE MODEL: 737-8

TITLE: 737-8 STALL CHARACTERISTICS

FTP ID: C1.14.AAD PROJECT NO: PS12-0038

PREPARED BY: [redacted] 5/31/17
APPROVED BY: 6/5/17
[redacted]
COORDINATED BY: 5/31/17
APPROVED BY: 6/7/2017
ACCEPTED BY: 10/30/17 DATE

☒ Checkmark indicates 8100-9 form(s) attached.

REVISION	DATE	ADDITIONS	DATE
		ORIGINAL RELEASE PAGES Cover Page, Pages 1 through 83 (4) 8100-9 Forms	NOV 0 6 2017

BOEING PROPRIETARY - EXPORT CONTROLLED: ECCN 9E991

[redacted]

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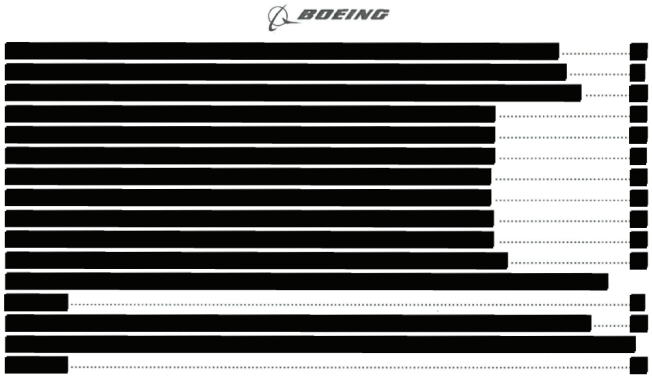

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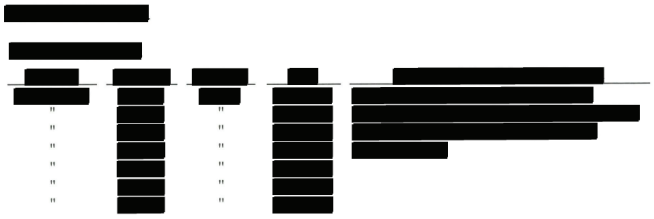
[redacted]



REFERENCES

(a) Certification Flight Test Plan C1.14.AAD, "737-8 STALL CHARACTERISTICS", Rev B.

(b) Project Number PS12-0038.

(c) Certification Plan 13669, rev N, Deliverable Reference Number #42.

(d) "Code of Federal Regulations, Title 14: Aeronautics and Space, Part 25 – Airworthiness Standards: Transport Category Airplanes," Sections 25.23(b)(3)[25-0]; 25.201[25-108]; 25.203[25-84]; 25.207(e)[25-108]. This project is showing compliance to FAA, EASA, and TCCA requirements.

(e) CSs 25.23(b)(3), 25.201, 25.203, 25.207(e).

(f) CAR 525.207

(g) Boeing Document D541A008-5602P, "Flight Test Plans, Logs, and Data, Model 737-8, Airplane 1A001," Tests 013-05, 013-06, 013-09, 013-12, 013-14, 013-26, and 013-34.

(h) Boeing Document D541A008-5602C, "Flight Test Airplane Configuration and Status, Model 737-8, Airplane 1A001," Tests 013-05, 013-06, 013-09, 013-12, 013-14, 013-26, and 013-34.

(i) Advisory Circular AC 25-7C, "Flight Test Guide for Certification of Transport Category Airplanes," dated October 16, 2012.

[redacted]

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SUMMARY

Testing was conducted on a Boeing Model 737-8 equipped with CFM LEAP-1B engines to demonstrate compliance with applicable regulations concerning stall characteristics.

[redacted] All conditions were completed successfully as proposed in the Certification Flight Test Plan (CFTP), Reference (a), and as authorized by the Type Inspection Authorization for the Reference (b) Project Number. The test data show compliance with the applicable certification regulations, References (d), (e), and (f). This report satisfies the requirement of Reference (c) Certification Plan deliverable.

INTRODUCTION

The following regulations were identified as applicable to this testing, per Reference (a). All regulations are to Amendment 25-137 plus 25-141 of Code of Federal Regulations, Title 14 (14 CFR) Part 25 unless otherwise specified.

14 CFR 25.201[25-108] – Stall Demonstration

(a) Stalls must be shown in straight flight and in 30-degree banked turns with—
  (1) Power off; and
  (2) The power necessary to maintain level flight at 1.5 V_{SR}, where V_{SR} corresponds to the reference stall at maximum landing weight with flaps in the approach position and the landing gear retracted.

(b) It must be possible to meet the applicable requirements of Section 25.203 with—
  (1) Flaps, landing gear, and deceleration devices in any likely combination of positions approved for operation;
  (2) Representative weights within the range for which certification is requested;
  (3) The most adverse center of gravity for recovery; and

(c) The following procedures must be used to show compliance with Section 25.203;
  (1) Starting at a speed sufficiently above the stalling speed to ensure that a steady rate of speed reduction can be established, apply the longitudinal control so that the speed reduction does not exceed one knot per second until the airplane is stalled.
  (2) In addition, for turning slight stalls, apply the longitudinal control to achieve airspeed deceleration rates up to 3 knots per second.
  (3) As soon as the airplane is stalled, recover by normal recovery techniques.

(d) The airplane is considered stalled when the behavior of the airplane gives the pilot a clear and distinctive indication of an acceptable nature that the airplane is stalled. Acceptable indications of a stall, occurring either individually or in combination, are—
  (1) A nose-down pitch that cannot be readily arrested;
  (2) Buffeting, of a magnitude and severity that is a strong and effective deterrent to further speed reduction; or
  (3) The pitch control reaches the aft stop and no further increase in pitch attitude occurs when the control is held full aft for a short time before recovery is initiated.

[redacted]

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INTRODUCTION, (CONT'D)

14 CFR 25.203[25-84] – Stall Characteristics

(a) It must be possible to produce and to correct roll and yaw by unreversed use of the aileron and rudder controls, up to the time the airplane is stalled. No abnormal nose-up pitching may occur. The longitudinal control force must be positive up to and throughout the stall. In addition, it must be possible to promptly prevent stalling and to recover from a stall by normal use of the controls.

(b) For level wing stalls, the roll occurring between the stall and the completion of the recovery may not exceed approximately 20 degrees.

(c) For turning flight stalls, the action of the airplane after the stall may not be so violent or extreme as to make it difficult, with normal piloting skill, to effect a prompt recovery and to regain control of the airplane. The maximum bank angle that occurs during the recovery may not exceed:

(1) Approximately 60 degrees in the original direction of the turn, or 30 degrees in the opposite direction, for deceleration rates up to 1 knot per second; and

(2) Approximately 90 degrees in the original direction of the turn, or 60 degrees in the opposite direction, for deceleration rates in excess of 1 knot per second.

14 CFR 25.207(e) [25-108] – Stall Warning

(e) The stall warning margin must be sufficient to allow the pilot to prevent stalling when recovery is initiated not less than one second after the onset of stall warning in slow-down turns with at least 1.5g load factor normal to the flight path and airspeed deceleration of at least 2 knots per second, with the flaps and landing gear in any normal position, with the airplane trimmed for straight flight at a speed of $1.3V_{SR_0}$ and with the power or thrust necessary to maintain level flight at 1.3 V_{SR}.

[redacted]

BOEING

INTRODUCTION, (CONT'D)

The test participants included:

Test No.	Date	Engineer(s)	Pilot(s)
013-05	08-22-16	[redacted] (Boeing – TD)	[redacted] FAA)
		[redacted] (FAA – Flt. Test)	[redacted] Boeing)
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – Engr.)	
		[redacted] (Boeing – Engr.)	
013-06	08-23-16	[redacted] (Boeing – TD)	[redacted] (FAA)
		[redacted] (FAA – Flt. Test)	[redacted] (Boeing)
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – Engr.)	
		[redacted] (Boeing – Engr.)	
013-09	08-26-16	[redacted] (Boeing – TD)	[redacted] (FAA)
		[redacted] (FAA – Flt. Test)	[redacted] (Boeing)
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – Engr.)	
		[redacted] (Boeing – Engr.)	
013-12	08-29-16	[redacted] (Boeing – TD)	[redacted] (FAA)
		[redacted] (Boeing – FTEA)	[redacted] (Boeing)
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – Engr.)	
		[redacted] (Boeing – Engr.)	
013-14	08-31-16	[redacted] (Boeing – TD)	[redacted])
		[redacted] (FAA – Flt. Test)	[redacted] (Boeing)
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – Engr.)	
		[redacted] (Boeing – Engr.)	
013-26*	09-16-16	[redacted] (Boeing – TD)	[redacted] (Boeing, AR)
		[redacted] (Boeing, AR)	[redacted] (Boeing)
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – Engr.)	
		[redacted] (Boeing – Engr.)	
		[redacted] (Boeing – Engr.)	

[redacted]

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013-34*	09-24-16	[redacted] (Boeing – TD)	[redacted] (Boeing, AR)
		[redacted] (Boeing, AR)	[redacted] (Boeing)
		[redacted] (Boeing – FTEA)	
		[redacted] (Boeing – Engr.)	
		[redacted] (Boeing – Engr.)	

* 8100-9 forms for these tests are included in this report

[redacted]

INSTRUMENTATION AND DATA REDUCTION

The airplane was equipped with an Airborne Data Analysis and Monitor System (ADAMS) and a Data Acquisition and Recording (DAR) system for in-flight monitoring and post-flight data processing. Manual notes recorded during testing are contained in Reference (g).

Recorded data was reduced using the following Flight Test Computing System (FTCS) programs: Basic Airplane (BA), Sideslip Angle Calibration (BETA), and Filter (FLTR). Time history plots presented in this report were produced from digital data sampled at [redacted] (sps). Table 1 presents a list of parameters that have been plotted at [redacted] in Figure 1 through Figure 68. Table 2 contains the list of parameters shown in the configuration tables of Figure 1 through Figure 68. These scalar values are taken at the beginning of the plotted conditions.

[redacted]

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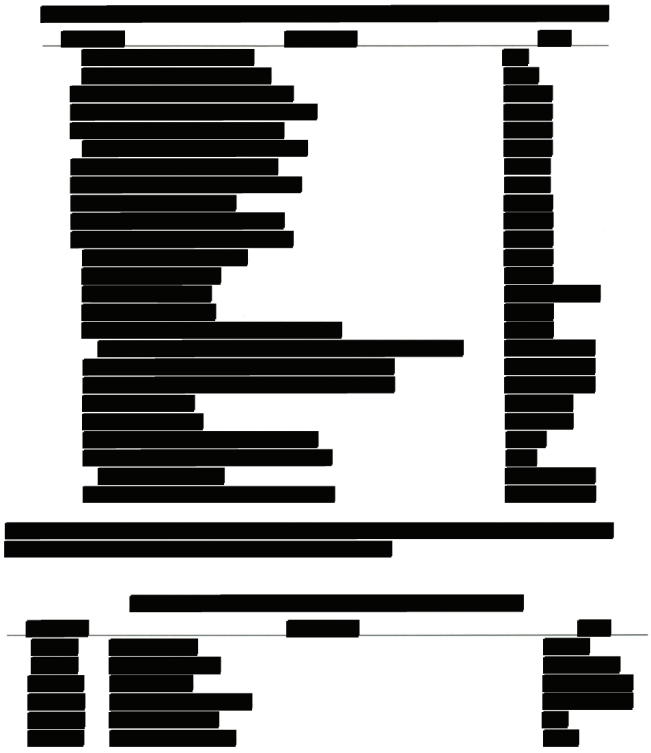
INSTRUMENTATION AND DATA REDUCTION, (CONT'D)



[redacted]

[redacted]

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RESULTS AND DISCUSSION

All conditions were performed successfully and demonstrated that stall characteristics of the 737-8 are compliant with applicable regulations. Handling characteristics were satisfactory and column forces exhibited a positive gradient from the trim speed through stall identification. Sufficient roll control was also demonstrated for all stalls, including wings level and turning maneuvers. Pilots used normal piloting techniques to recover from all conditions.

[redacted]

[redacted]

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RESULTS AND DISCUSSION, (CONT'D)

[redacted]

Email chain and memo on promise of No Simulator training—FAA-DeFazio 32883–32890

CONTROLLED//SP-PROPIN

FW: 737MAX training question

From: [redacted](FAA)" <[redacted]@faa.gov>
To: [redacted](FAA)" <[redacted]@faa.gov>
Cc: [redacted](FAA)" <[redacted]@faa.gov>, "[redacted](FAA)" <[redacted]@faa.gov>
Date: Mon, 11 May 2015 18:34:21 -0400
Attachments: B737MAX Briefing Memo signed 05102015.pdf (137.41 kB)

[redacted]

I wanted to bring you up to speed as to the questions that have been asked of us directly from [redacted] through [redacted]. A lawyer at Rockwell Collins emailed [redacted] explaining that Boeing was stating that a pilot will not need a simulator to train on the MAX. [redacted] ultimately asked [redacted] "is this true"? That email started a fire storm of digging from HQ looking for answers. In response to [redacted] request, I wrote a briefing paper. The briefing paper is attached, and it is really rough. I'm sure there are mistakes, but the important stuff about training level determinations are in there. Below you will see the email that [redacted] wrote to [redacted] briefed [redacted] today on the AEG FSB process. When I hear more, I will let you know.

In case there are more questions that might filter to the BASOO or TAD, I felt you should be aware. Let me know if you have any questions. I will be attending an AC re-write telecom the next three days, so I'll be working from home, but I'll be available via text or IM.

Thanks,

[redacted]

Seattle Aircraft Evaluation Group

[redacted]

We value your feedback and seek to improve the services we provide. Please take a few moments to visit the website shown below to let us know how we did. Select **Seattle Washington AEG** [redacted] from the pull down menu before writing your comments. Thank you. Click this link to send feedback.

From: [redacted](FAA)
Sent: Sunday, May 10, 2015 8:58 PM
To: [redacted](FAA)
Cc: [redacted](FAA)
Subject: FW: 737MAX training question

[redacted]

T is is the email that ultimately went out. [redacted] made some changes to the briefing paper. You will probably want this copy for your records. I will also get you the Word version.

Have a good week,

[redacted]

Seattle Aircraft Evaluation Group

[redacted]

We value your feedback and seek to improve the services we provide. Please take a few moments to visit

the website shown below to let us know how we did.
Select **Seattle Washington AEG** [redacted] from the pull-down menu before writing your comments.
Thank you. Click this link to send feedback.

From: [redacted] (FAA)
Sent: Sunday, May 10, 2015 1:44 PM
To: [redacted] (FAA)
Cc: [redacted] (FAA); [redacted] (FAA); [redacted] (FAA); [redacted] (FAA)
Subject: RE: 737MAX training question

[redacted]

This email presents the short answer in the body and a briefing memo (attached) to present the details. The B737MAX presents some very contentious issues between Boeing and the FAA that will likely heat up as we approach rollout and evaluation of the aircraft. The Seattle AEG will remain true to the process in every step along the way to make sure the final training (safety) determinations are correct. The final AEG evaluation will not occur until fall 2016.

Boeing is advertising and communicating to their customers what they "desire" on issues that have not yet been evaluated. The 737MAX is not a simple derivative of its previous models. It is a very complex modification incorporating many new and novel features and the new aircraft must incorporate many new certification rules into the design. Boeing is doing everything they can to be exempt from the new certification rules and keep the aircraft the same type rating with minimal training differences. They are advertising and directly telling t eir customers that it will require no more than B level differences (Computer Based Training) to train between the aircraft (B737NG and B737MAX). As you know, we don't control what Boeing communicates.

However, the Boeing customers intimately familiar with the B737MAX development recognize there is a gap between what they are being told by Boeing and what they know about the major differences the aircraft will present. One of their concerns is, if they need a simulator to train the differences, they need to know with enough lead time (about 2 years) to have the simulator on line and ready to train their crews.

The evaluation of training requirements for a new aircraft can't happen until after the aircraft is built and flight test completed. The first B 737MAX aircraft is currently under construction with a completion date around November/December of 2015. Flight testing will then go on for about 9 months before it will be ready for the AEG to evaluate. The Seattle AEG will evaluate the handling quality differences between the NG and the MAX and ultimately determine the difference training required to transition from the NG to the MAX. This Flight Standardization Board (FSB) activity will be conducted in accordance with our FSB guidance, AC 120 53B.

Boeing and the Seattle AEG are in continual communication and negotiations for FSB evaluation criteria. The FSB evaluation is scheduled to commence in September 2016. We have reason to be ieve that Boeing's assessment of B Level training differences (Computer Based Training) between the MAX and NG will be insufficient. This has been communicated to Boeing over the past two years thro gh a series of formal letters and Issue Papers. A final determination will not be completed until November 2016.

The attached briefing memo outlines the evaluation process and the major concerns with the B 737MAX. I anticipate these issues to be an ongoing conversation as things continue to heat up. I will be prepared to articulate the details as needed.

Regards

[redacted]

[redacted]
Seattle Aircraft Evaluation Group
[redacted]

CONTROLLED//SP-PROPIN

We value your feedback and seek to improve the services we provide. Please take a few moments to visit the website shown below to let us know how we did.
Select **Seattle Washington AEG** from the pull-down menu before writing your comments.
Thank you. Click this link to send feedback.

From: (FAA)
Sent: Saturday, May 09, 2015 5:50 AM
To: (FAA)
Cc: (FAA); (FAA)
Subject: Re: 737MAX training question

Thanks

Flight Standards Service

On May 8, 2015, at 17:15, (FAA) < @faa.gov> wrote:

I'm working on a complete brief to fill in many of the blanks left open by these questions. It's not as simple as seems to understand. You will definitely have it by Monday.

Regards,

Seattle Aircraft Evaluation Group

We value your feedback and seek to improve the services we provide. Please take a few moments to visit the website shown below to let us know how we did.
Select **Seattle Washington AEG** from the pull-down menu before writing your comments. Thank you. Click this link to send feedback.

From: (FAA)
Sent: Friday, May 08, 2015 1:49 PM
To: (FAA)
Subject: Fwd: 737MAX training question

Can you get me some info on the training question below. By Monday if possible. Thanks

Sent from my iPad

Begin forwarded message:

From: "(FAA)" < @faa.gov>
Date: May 8, 2015 at 4:24:07 PM EDT
To: "(FAA)" < @faa.gov>
Cc: "(FAA)" < @faa.gov>, "(FAA)" < @faa.gov>, "(FAA)" < @faa.gov>
Subject: FW: 737MAX training question

we added this to the 1 on 1 list but didn't talk about it yesterday. Can you update me on it on Monday, please?

[redacted]

-----Original Message-----
From: [redacted] FAA)
Sent: Monday, May 04, 2015 12:22 PM
To: [redacted] @rockwellcollins.com'
Cc: [redacted] (FAA); [redacted] (FAA); [redacted] (FAA)
Subject: FW: 737MAX training question

[redacted] -- sorry, I missed this message last week.. And I don't know the answers -- but will check.
[redacted] -- please put this on the AFS 1-on-1 list.
[redacted] could you get someone looking into this, please?
[redacted]

-----Original Message-----
From: [redacted] [mailto:[redacted] @rockwellcollins.com]
Sent: Wednesday, April 29, 2015 7:12 AM
To: [redacted] (FAA); [redacted] (FAA)
Subject: 737MAX training question

[redacted]

Can one of you answer the following question or point me in the right direction to pose the question?

Has the FAA established a position for Training Requirements for 737NG qualified pilots that wish to transition to the 737MAX?

We have heard that Southwest believes a 737NG Full Flight Sim + only difference training on a simple 737MAX DeskTop training device may be sufficient Vs. Training on a 737Max Full FI.

I have not been able to find anything definitive on the FAA web site but I did find the following in a July 2014 Boeing Media Room release regarding their selection of TRU (Textron) to supply full flight simulators and flight training devices for the 737 M.

"Current Next-Generation 737 customers who will begin operating the MAX can continue training new pilots on one of 14 Next-Generation 737 full-flight simulators within the Boeing Flight Services training network followed by a short differences training course for the 737 MAX. Pilots already certified on the Next-Generation 737 will not require a simulator course to transition to the 737 MAX."

I imagine Boeing has to have some level of agreement from the FAA to make the statement in the second sentence.

Thanks in advance for your assistance.

[redacted]
Rockwell Collins
[redacted]
[redacted] @rockwellcollins.com

Federal Aviation Administration

Memorandum

Date: May 10, 2015

To: [redacted] Flight Standards

From: [redacted] Seattle Aircraft Evaluation Group (SEA-AEG), [redacted]

Prepared by: [redacted], SEA AEG,

Subject: Boeing 737 MAX Type Rating Determination and Pilot Training Requirements

The Boeing 737 Flight Standards Board (FSB) is responsible for evaluating new, amended and supplemental type certificated aircraft and systems for pilot type rating determination as well as pilot training between related 737 aircraft. In this case, Boeing is presenting an amended aircraft type, the B-737 MAX airplane. Boeing would like this airplane to hold the same pilot type rating as the other family of 737 aircraft. Boeing has also stated that it's their intention to have minimal training associated with the new airplane as it relates to other 737 aircraft. The process in which we determine the type rating and any training differences is accomplished through the FSB process and conducted in accordance with AC 120-53B with the Seattle Aircraft Evaluation Group (SEA AEG).

The Boeing 737 MAX aircraft is a derivative airplane from the family of 737 aircraft. There are three distinct 737 families operated in the NAS, the 737-100 /-200, the -300/-400/-500 and the -600/-700/-800/-900(ER). The last group is the current production known as the Next-Generation (NG). The Boeing 737 MAX airplane will be the 4th generation of 737 airplanes and will have the designation B-737-7/-8/-9.

Boeing made application with the FAA for the amended type certificate in May 2012. The application includes the three new 737 model aircraft. Boeing and the FAA have been working on certifying the aircraft since the initial certification application. The Boeing Aviation Safety Oversight Office (BASOO) is responsible for the oversight of the certification process and lives with AVS-AIR. The SEA AEG is responsible for evaluating the aircraft for pilot type rating and training level differences, while these are two separate processes, the BASOO and the SEA AEG have been working congruently with Boeing to streamline the process. This collaboration has proven to be very important and effective. For the past 3 years, Boeing has continually argued

with the BASOO that they cannot meet the latest amendments of aircraft certification regulations due to the impact on flight crew training. The SEA AEG FSB Chair and a subsequent team of inspectors have been present in all certification meetings in order to inform Boeing certification teams that these training level determinations are not determined by AVS-AIR and will be evaluated in accordance with AC 120-53B during the FSB process.

Boeing has been conducting bi-weekly meetings with the AEG to establish a means of compliance with how to apply AC 120-53B to the amended type certificate. Boeing's position is that computer based training is sufficient to train pilots currently qualified on the NG to the MAX differences. Because Boeing is seeking the "same" 737 type rating for the MAX, a comparison between the NG and the MAX must be established in order to determine that it is indeed the "same" type rating. Boeing is choosing to only evaluate the MAX against the NG aircraft. The training level determination between that pair of aircraft will allow an air carrier to fly both aircraft with the same pilot group using a reduced training program footprint. Boeing is not comparing the older family of 737 aircraft against the MAX; therefore an air carrier cannot have reduced training between those families of 737 aircraft. If an air carrier operates the 737-200 through 500 as part of their fleet, they would be forced to split their pilot group in two separate the fleets of 737 aircraft. Currently, there are two large air carriers in the U.S. operating both the older models and the NG aircraft that will also be adding the MAX to their fleet: Alaska Airlines, and Southwest Airlines. These operators will not be able to have a pilot operate any of the older non-NG and the MAX aircraft in mixed fleet flying. Boeing is aware of this short coming.

As the project has evolved, Boeing has been forced to make several substantial systems changes due to new certification requirements that will likely increase pilot training requirements. Boeing maintains that the difference training required to fly both the NG and the MAX is not affected by these changes. It is Boeing's intention not to have a task trainer or simulator to train pilots between the NG and the MAX; The SEA AEG disagrees with this assessment. The SEA AEG has identified system differences that may require a pilot to be trained in a simulator or hands on task trainer. The following systems could affect flight handling characteristics of the aircraft and system differences requiring additional pilot training:

- Fly-by-wire (FBW) Spoilers – secondary flight control system that will augment the primary flight control systems. The addition of FBW spoilers could potentially affect the handling characteristics of the aircraft. Essentially, how the aircraft feels to the pilot. In addition to handling characteristic changes, the fly-by-wire spoilers will provide system support for other certification requirements, i.e. emergency descent profile requirements, jammed elevator mitigation through the direct lift control system, landing attitude modifier, and the maneuver load alleviation system.
- Direct Lift Control – new system introduced to help the pilot flare the aircraft in case of a jammed elevator. This system utilizes the fly-by-wire spoilers and must be manually activated by the pilot. The system will change the flight handling characteristics of the aircraft during a jammed elevator control event. It is the opinion of the AEG that this system will need to have a full flight simulator to train the pilots. Boeing was required by aircraft certification to add this system in order to meet today's certification regulations.

- Landing Attitude Modifier (LAM) – The nose landing gear on the MAX will be extended 8 inches for ground clearance due to larger engines on the MAX. Because the landing gear is longer, the LAM is in place to protect the nose gear during landing and is only active <200'. This system is designed to be invisible to the pilot however, due to the extended nose wheel landing gear, it is anticipated that the pilot sight picture for taxi, takeoff and landing will be different. Only a full flight simulator can be used for takeoff and landing credit.
- Roll Command Alerting System (RCAS) – This system incorporates several new systems to the pilot:
    1. Enhanced Bank Angle Warning (EBAW) – provides roll arrow alert and aural alert telling the pilot which way to roll when the airplane is banked greater than 45 degrees or when the aircraft is greater than 25 degrees nose up or 10 degrees nose down. This is highly integrated system that may require simulator training.
    2. Autopilot Roll Saturation Alerts (ARSA) – required by CFR Part 25 regulations. This tool alerts the pilot when the autopilot is 75% saturated and when the autopilot is 100% saturated and when the aircraft is departing its intended flight path. These alerts are not intuitive to the flight crew and additional QRH procedures may be necessary.
- Max Display System – 3 new large flat panel display units will replace the 6 display units currently in the NG. Due to the size, the landing gear handle will change, current alerts will be displaced to the large flat panel display and 12 new alerts are added, the flap position indicator will now be digital and moved to a different location, the clock will now be digital requiring different pilot interaction. Due to some of the changes, muscle memory pilot interaction will be affected. These changes may require a training device for training.
- Environmental Control System (ECS) – The pneumatic system on the MAX is changing to an electronic system. The 737 has had many pilot error issues associated with the ECS (pressurization and bleed system) due to a lack of crew alerting. The MAX will add crew alerts for this system to mitigate the risk of pressurization issues. These changes will affect pilot training.

In addition to the new systems going on the MAX, Boeing is certifying some of the same new aircraft systems from the MAX on the NG. Boeing would like to do this with hopes that it will reduce the level of training between the NG and the MAX. However, the new systems on the NG are only offered as optional equipment. This proposed NG modified aircraft is the base model Boeing is using as the certification basis aircraft. This presents an additional crew training issue by having a hybrid NG that does not represent the majority of the existing world fleet.

Historically, during a new aircraft certification, the manufacturer will propose the minimum level of pilot training needed for the new aircraft. It is common practice for the manufacturer to request minimal pilot training due to the cost impact for their customers. AC 120-53 B lays out a systematic way of conducting evaluations to determine not only pilot type rating but also the level of training required to fly both the new aircraft and the family of aircraft it is related. The evaluation of the MAX will be broken into three different activities. First it is required to evaluate the flight handlings qualities of the aircraft. (T2 test) This highlights if there are any

flight characteristic differences associated between the original aircraft already certified, in this case the NG, and the new aircraft candidate, the MAX. If the new MAX feels different to the pilots when flying, that would automatically require a full flight simulator to train the MAX pilots. This test is conducted by putting 6 FAA certified 737 NG pilots in a full flight simulator and conducting a checkride for each pilot. This allows the FSB Chairman and Boeing to assess each pilot individually and their performance in the NG. Each pilot is then put in the B-737 MAX aircraft to perform the same checkride without any training in that aircraft. The pilot is evaluated individually on performance differences. The pilots are then asked to fill out a survey to identify the pilot perspective differences of the MAX and the NG. The results are compiled and a determination is made whether or not the MAX has similar enough flight handling characteristics as to not require additional simulator training.

The next evaluation is conducted with 6 different FAA current and qualified 737 NG pilots. (T3 test) Its purpose is to assess whether or not the Boeing MAX training material is sufficient for the pilot candidates to fly the MAX aircraft. The 6 pilot candidates go through a refresher course on the NG to evaluate their performance. Then the 6 pilots go through Boeing's developed training course on the MAX. Once complete with the differences training, the 6 pilot candidates fly the new MAX aircraft and perform a full type rating checkride. The checkride is conducted in accordance with Pilot Proficiency Check requirements of the Pilot Training Standards (PTS). Should the majority of the candidates pass the course, the presented course can be validated and a level of training differences required to fly that pair of aircraft is determined. The level of training differences associated between the NG and the MAX set a standard for the minimum training required to fly both aircraft for an air carrier at the same time (mixed fleet flying).

Finally, an initial pilot type rating course for the 737 MAX will be conducted. This course will be conducted after the MAX has been certified and a full flight simulator has been granted interim level C certification by FAA simulator team. The current projected date for this is May 2017. Boeing will present a new pilot type rating course to 4 FAA pilots who have never been trained on a B-737 aircraft. The pilot type rating course will be concluded with a checkride in accordance with PTS standards in a B-737 MAX simulator. Upon completion of the checkride, the 4 candidates will then fly a normal flight in the actual aircraft to validate that the training received. Boeing's initial type rating course will be available to 14 CFR Part 142 training centers for approval and any carrier solely operating the B-737 MAX a B-737 MAX for development of company specific course.

Currently, Boeing proposes that the minimum level of training required to fly the MAX compared to the NG is level B as defined by AC 120-53B. Level B training is applicable to related aircraft with system or procedure differences that can adequately be addressed through aided instruction. At level B, aided instruction is appropriate to ensure pilot understanding, emphasize issues, provide a standardized method of presenting material, or aid retention of material following training. Level B aided instruction can utilize slide/tape presentations; computer based tutorial instruction, stand-up lectures, or video tapes.

FAA memo of March 10, 2014, on rudder cable—FAA-T&I 30223–30228

CONTROLLED//SP-EXPT/SP-PROPIN

Federal Aviation Administration

Memorandum

Date: March 10, 2014 UPDATED 22 Sep 2014

To: [redacted] Aircraft Certification Service, [redacted]

From: [redacted] Transport Airplane Directorate, [redacted]

Prepared by: [redacted]

Subject: Rudder Cable Protection from Uncontained Engine Failure for the Boeing 737 MAX and Airbus A320neo

Summary: Neither Boeing or Airbus has incorporated adequate rudder cable protection from uncontained engine failure (UEF) in the proposed design of the respective 737 MAX and Airbus A320neo airplanes as required by Title 14 Code of Federal Regulations (14 CFR) part 25 and applicable policy and guidance.

Issue: According to the hazard assessment required as part of the type certification safety analysis, single failures resulting from UEF on takeoff are classified as "catastrophic" for both the 737 MAX and A320neo. UEF debris impacting the rudder cable during takeoff is classified as "catastrophic" due to uncontrolled departure from the flight path. Per 14 CFR 25.903, catastrophic single failures must be minimized. For flight controls including the rudder cable, Advisory Circular (AC) 20-128A calls for redundancy, separation, or shielding as means for minimizing the threat.

Neither Boeing nor Airbus has made an effort to minimize this catastrophic single failure per AC 20-128A. Both manufacturers have argued that the changes that would be necessary to comply per applicable guidance are impractical and provide only a small incremental benefit in safety. The FAA Transport Airplane Directorate (TAD) and European Aviation Safety Agency (EASA) do not concur with the Boeing or Airbus position. EASA has released a certification review item (CRI) to Airbus and Boeing on this subject calling for compliance in accordance with EASA/FAA harmonized policy and guidance. The TAD plans to release a similar issue paper to both manufacturers.

Background: Boeing and Airbus are installing new engines on the 737 MAX and A320neo, respectively. These engine changes are categorized as "significant" per the Changed Product Rule of § 21.101. UEF is considered an "affected area" per CPR on both programs due to significant engine changes.

Both the 737 MAX and the A320neo have similar proposed mechanical rudder control systems. Boeing and Airbus agree that the hazard assessment for UEF that disables the rudder cables on takeoff is potentially catastrophic. Both manufacturers concur that incorporation of the new engines on their respective airplanes constitute affected areas and that a new showing of

compliance to § 25.903(d)(1) is required. Both manufacturers previously agreed that they would show compliance in accordance with the latest advisory material in Advisory Circular (AC) 20-128A. However, it appears both manufacturers overlooked the impact the new engines would have on the unchanged rudder cables. Neither design meets the standards per the regulatory guidance.

In August 2013, we asked Boeing how they were addressing the threat. We also asked EASA how Airbus was addressing it. Both manufacturers told us that they believe their designs are compliant, that design changes such as including automation or redundancy are impractical, and that these design changes would result in a minimal improvement in safety. Both manufacturers are concerned with potential impact on their resources and program schedules.

The guidance on minimizing the threat from UEF in AC 20-128A resulted from lessons learned through accidents. The 1989 McDonnell Douglas DC-10 accident near Sioux City, Iowa resulted from UEF debris impacting flight control components. Following that accident, the FAA-chartered Aviation Rulemaking Advisory Committee (ARAC), co-chaired by Boeing, developed the harmonized guidance in AC 20-128A which was subsequently adopted by the FAA and EASA's predecessor, the Joint Airworthiness Authority, in 1997. For flight controls in particular, AC 20-128A cites redundant cables within the rotor burst zone and automatic compensation through fly-by-wire controls systems as practical means to minimize the hazard. The November 2010 UEF on the Airbus A380 near Singapore highlights the hazard of UEF on airplane safety and the fact that UEF events continue to occur even on new engines.

The TAD and EASA do not find the Boeing or Airbus proposed position to be acceptable as they do not minimize the risk of this single catastrophic failure condition. To comply it is likely that a design change consistent with the guidance in AC 20-128A will be required.

It should be noted that the FAA raised this issue in 1994 during the Boeing 737 Next Generation (NG) type certification program before publishing AC 20-128A. At that time we told Boeing in an issue paper that they would have to address this issue in the future if they made significant changes in the 737 NG engines.

Numerous type certificated airplanes address this concern with redundant cables or through automation. These airplanes include the Boeing 777 and 787 and the Airbus A380 and A350.

Airbus has completed its intended firm configuration of the A320neo. Type certification (TC) is scheduled for September 2015.

According to Boeing, they achieved firm configuration in July 2013. First flight is scheduled in 2016 with TC scheduled for 2017.

Intended Actions: The TAD intends to release an issue paper to Boeing requiring they protect the rudder cable from UEF per AC 20-128A. The TAD also intends to concur with the EASA CRI issued to Airbus requiring the same protection. To comply, both manufacturers will likely have to make design changes. Because the A320neo is nearing TC, we will consider granting a time-limited exemption, if necessary, to allow entry into service as planned while a design fix is developed and implemented. A similar time-limited exemption may also be warranted for the 737 MAX.

Briefing Paper Update 22 September 2014

Activity since last update:
November 20, 2013: The FAA requested a meeting with Boeing to discuss compliance to 25.903(d) (1) using the
March 26, 2014: FAA Position on Issue paper SF-1 was approved and sent to Boeing.
September 09, 2014: In response to Issue paper SF-1, Boeing presented their position relative to IP SF-1.

Summary of 9 September 2014 Boeing Presentation:
Boeing believes that their current rudder control system is compliant 14 CFR 25.903(d)(1). This rule requires minimization. Boeing investigated 8 different design options and believes none significantly increases overall airplane safety. Boeing also believes that none are appropriate or required for compliance. Boeing stated that even though AC 20-128A states

> *"Flight Controls Elements of the flight control system should be adequately separated or protected so that the release of a single one-third disc fragment will not cause loss of control of the airplane in any axis. Where primary flight controls have duplicated (or multiplicated) elements, these elements should be located to prevent all elements in any axis being lost as a result of the single one-third disc fragment. "*

that the rule itself requires only minimization, and they believe they have minimized this condition.

Boeing presented to the FAA 8 different design concepts they investigated to address the 14 CFR 25.903(d)(1), AC 20-128A and the IP SF-1. Boeing evaluated the practicality of each design concept against the following 3 criteria:

1. Eliminate or effectively minimizes the catastrophic hazard of the UEF that severs rudder cables during takeoff without adversely affecting airplane or system performance
2. Improve or maintain the overall safety of the airplane (Does not add catastrophic failure modes of higher probability than the UEF/rudder cable event).
3. Does not excessively impact the 737-MAX program or the airlines

Table 1 contains a summary of these design concepts with Boeing and FAA assessments. Of the eight design concepts presented, Boeing concluded that none were practical as the considered that none met all the criteria identified. However, the FAA found that several of the designs are practical in that they will effectively address compliance with 14CFR 25.903(d)(1), AC 20-128A, and IP SF-1. We also found that there are several designs that address the: 1) UEF/rudder cable event, 2) they maintain airplane performance, and 3) they do not add unacceptable failure modes. Therefore, we conclude that Boeing has not minimized this particular risk per the 25.903(d)(1) and the accompanying guidance.

Recommendation:
We recommend that Boeing further develop their most promising designs concepts and incorporate the best design to show compliance to 14 CFR 25.903(d)(1), IP SF-1, and the guidance in AC 20-128A. The impact of design changes on the " same type rating" may be Boeing chief concern when considering some of these design changes. Boeing needs to provide information on how the practical design concepts might affect the airplane "same type rating" and perhaps commonality of maintenance operations too.* Again, type certification for the 737MAX is well over two years away. We believe this gives them adequate to develop and implement appropriate design changes prior to type certification.

4

Summary FAA-EASA Meeting Regarding the Airbus A320NEO:
In August FAA specialists participated in a telecom with EASA specialists to discuss the Airbus response to the EASA CRI. The Airbus response to CRI is very similar to that of Boeing. Airbus believes they have minimized the risk, and that additional design changes will not increase the safety commensurate with the cost. Also in Airbus's response to the CRI E-56,

"Airbus orientation to proceed in the future with the development of electrical rudder is subject to further technical and Single Aisle program validation."

To our knowledge Airbus does not plan to pursue the "electric rudder" on the NEO program. We believe that EASA is waiting on the FAA to determine their ruling on the NEO and MAX programs. Again, the NEO is scheduled for delivery in less than one year. This means the FAA requires design change, we may need to consider mechanisms such as time-limited-exemptions to prevent an undue burden on Airbus this close to type certification.

* The SEA AEG has stated to Boeing that the type rating determination and training differences are determined through the Flight Standardization Board (FSB) process in accordance with AC 120-53B. Boeing has made a concerted effort to minimize the aircraft system differences as to not affect pilot training. Boeing has presented a Pilot Qualification Plan (PQP) to the SEA AEG. This PQP is Boeing's proposal for type rating determination and pilot training differences. Currently, the SEA AEG and Boeing have not come to agreement on the PQP proposal. However, we are meeting bi-weekly with the intent of having an agreement on a basic PQP by October, 2014.

Boeing Design Concepts Investigation and Evaluation Summary

#	Description	Effect	Boeing Assessment	FAA Assessment	Other Potential Issues
1	Dual rudder cables	By separation of dual cables provide rudder control after UEF/rudder cable event	Not appropriate: - does not provide 100% protection - HQ affected by Increased friction - Cost weight and schedule issues	Concur	None
2	Low pressure hydraulic back-up system	Provide rudder pedal command through low pressure passive hydraulic system.	Not appropriate - Does not provide 100% protection - HQ affected by new system	Concur	None
3	Increased rate rudder trim	Provide a dual rate rudder trim actuator by adding a high rate mode to act as thrust asymmetry compensation (TAC). Through computer control high speed trim is moves rudder after engine failure	Not appropriate: - Introduces new catastrophic failure mode - Pilot would need to retrim with speed changes	Do not concur - This is practical - Does not add catastrophic failure mode - We do not consider retrim an issue as retrim is required for speed change for any engine failure	Possible differences training issue.
4	Increased authority yaw damper (YD)	Increases current YD authority and adds one new high authority YD. Through computer control high authority YD moves rudder after engine failure	Not appropriate - Adds catastrophic failure modes - Extensive rework not commensurate with safety increase	Do not concur - Failure modes may not be cat & will be addressed in SSA - Does required extensive rework	Possible differences training issue.
5	Spudder control law concept	Utilize the fly-by-wire spoilers to provide TAC	Not appropriate - Spoilers provide inadequate	Concur	

			authority to neutralize the UEF yawing moment		
6	Fly-by-wire rudder	Utilize various means through autopilot components, actuator changes and avionics to provide TAC	Not appropriate - May add catastrophic failure modes - Extensive integration issues	Do not concur - SSA will address new failure modes - Using CATIII A/P contains necessary hardware	Possible differences training issue.
7	Wheel to rudder crosstie	Provides rudder displacement with control wheel rotation. Requires use of CATIIIB A/P servos	Not appropriate - Reduces but does not eliminate exposure time to catastrophic event due pilots will not use wheel until after liftoff. - Degrades overall safety of airplane	Concur	Possible differences training issue.
8	Thrust asymmetry compensation	Provide a pyrotechnic actuator attached to aft torque tube to provide TAC	Not appropriate - Adds a catastrophic single failure	Do not concur - If implemented through the feel and centering such failure modes might be alleviated. Similar in content to dual speed rudder trim concept	

Issue Paper of March 21, 2016, on rudder cable—FAA-DeFazio 28872–28888

CONTROLLED//SP-EXPT/SP-PROPIN

ISSUE PAPER

PROJECT: Boeing Model 737-7/-8/-9
Project No. PS12-0037, PS12-0038, PS12-0039

ITEM: SF-1
STAGE: 4

REG. REF.: § 25.903(d)(1)

DATE: July 24, 2015

NATIONAL POLICY REF.: AC 20-128A

ISSUE STATUS: Open

SUBJECT: Engine Rotor Burst and Rudder Mechanical Flight Control Cables

BRANCH ACTION: ANM-100B, ANM-100B, ANM-112, ANM-113, SEA-AEG

COMPLIANCE TARGET: Pre-ATC

Means of Compliance

STATEMENT OF ISSUE

Boeing has applied for an amended type certificate (ATC) to certify Models 737-7/-8/-9 (737 MAX) as a derivative of Model 737-700/-800/-900 (737NG) airplanes. The 737 MAX CFM LEAP-1B engine is 20 inches longer than the CFM56-7B engine used on the 737NG airplanes. The LEAP-1B engine includes a larger fan diameter and the addition of 3 new engine stages that include an additional high pressure turbine (HPT) disk. The HPT and fan sections of turbine engines are the most energetic and most hazardous sections. Title 14, Code of Federal Regulations (14 CFR) 25.903(d)(1) requires design precautions be taken to minimize the hazards from an engine rotor failure. The 737 MAX rudder control system design does not include design precautions considered to be practical, per Advisory Circular (AC) 20-128A, to minimize the hazards of uncontained engine failure. Boeing's hazard assessment has classified an uncontained engine failure that disables the rudder cables on takeoff as catastrophic. AC 20-128A provides appropriate guidance on addressing this hazard and showing compliance to § 25.903(d)(1).

BACKGROUND:

Following the Sioux City DC-10 accident, the FAA determined the compliance means to § 25.903(d)(1) were inadequate and tasked ARAC with developing a harmonized revision to AC 20-128. The revised AC was published in 1997. The regulatory language requires "minimizing the hazards" from uncontained engine and auxiliary power unit (APU) failures. The ARAC group, co-chaired by Boeing, reviewed the transport fleet accident records and airplane design practices used by manufacturers. Loss of airplane control due to damage to the flight control system, the cause of the Sioux City accidents, was determined to be a hazard that could be eliminated *through practical design considerations*. Review of airplane designs showed many older technology airplane designs used a single set of rudder cables in combination with a separate rudder trim system to maintain control following a rotor burst. During takeoff, when many uncontained failures occur, catastrophic loss of airplane control could occur due to the loss of engine thrust in combination with severing the rudder cables. For other phases of flight, the redundant rudder trim system in combination with other flight controls provided adequate control authority. The group determined incorporation of redundant cables or dual path rudder control systems within the rotor burst zone, automatic rudder bias systems (thrust asymmetry compensation), fly-by-wire control systems, shielding and other features could be employed to eliminate this hazard.

The guidance provided in AC 20-128A has been revised and includes paragraphs 7.a.5 and 8.c.1 which state:

> ***7.a.5 DESIGN CONSIDERATIONS.*** *Practical design precautions should be used to minimize the damage that can be caused by uncontained engine and APU rotor fragments. The most effective methods for minimizing the hazards from uncontained rotor fragments include location of critical components outside the fragment impact areas or separation, isolation, redundancy, and shielding of critical airplane components and/or systems. The following design considerations are recommended: a. Consider the location of the engine and APU rotors relative to critical components, systems or areas of the airplane such as: (5) Control systems, such as primary and secondary flight controls, electrical power cables, wiring, hydraulic systems, engine control systems, flammable fluid shut-off valves, and the associated actuation wiring or cables;*
>
> ***8.c.1 Flight Controls.*** *Elements of the flight control system should be adequately separated or protected so that the release of a single one-third disc fragment will not cause loss of control of the airplane in any axis. Where primary flight controls have duplicated (or multiplicated) elements, these elements should be located to prevent all elements in any axis being lost as a result of the single one-third disc fragment. Credit for maintaining control of the airplane by use of the trim controls or other means may be obtained, providing evidence shows that these means will enable the pilot to retain control.*

The currently proposed 737 MAX rudder is controlled by the pilot by two separate means. A single set of mechanical control cables transfer pilot inputs to the rudder and an electrically powered rudder trim actuator is controlled by the pilot through a rudder trim knob on the flight deck. The rudder is also controlled through an integrated yaw damper. The cables run near the centerline of the airplane through the floor beams, while the control wires for the rudder trim actuator are routed in the overhead raceway. This configuration provides for separation for engine rotor failure except during takeoff and initial climb. During takeoff and initial climb (V1 to V2 + 25 seconds), the rudder trim actuator does not have enough rate capacity to maintain continued safe flight and landing if an engine rotor failure disables the rudder mechanical control cables. Additionally, pilots are not trained to respond to sudden yawing motions using trim controls. It should be noted that while the exposure time is roughly 40 seconds, uncontained failures are more likely to occur during takeoff because the engine is highly stressed at this power setting.

FAA POSITION: (February 10, 2014)

Boeing's 737 MAX uncontained engine analysis should follow the guidance in AC 20-128A. The increased fan diameter and additional stages in the LEAP-1B engine are significant changes that increase the risk/hazards associated with an uncontained engine failure. The current 737 MAX single-load rudder control system design passes through the engine rotor burst zone and does not satisfy the minimization requirements of § 25.903(d)(1) for an uncontained engine failure during takeoff and initial climb.

In showing compliance, applicants should use the latest guidance, including published advisory material, in effect on the date of application. As such, Boeing should follow AC 20-128A for the 737 MAX. The FAA is aware of approved airplane type designs today that comply with this guidance, either through dual mechanical control cables or with other independent systems to protect the airplane from this threat. Therefore, Boeing can identify practical design changes that will eliminate this catastrophic single failure from a 1/3 engine rotor disc or other failures disabling the rudder cables during the critical exposure period. In accordance with AC 20-128A, Boeing should make *practical design changes* to address this catastrophic single failure to comply with § 25.903(d)(1).

Beyond the specific hazard regarding the loss of the rudder control due to rotorburst, the FAA expects that the guidance of AC 20-128A will be followed during the evaluation of the new engine installation for all of the changed and unchanged areas of the 737 MAX. Early communication of the preliminary results of the rotorburst hazards analysis is requested to ensure that Boeing and the FAA have agreement that the airplane hazards have been minimized as required by § 25.903(d)(1).

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Model 737-7/-8/-9
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APPLICANT POSITION: (June 19, 2015)

Boeing agrees that the new engines on the 737 MAX necessitate a re-evaluation of the hazard to the rudder cables and all flight control systems from an uncontained engine failure (rotorburst). Boeing has incorporated design precautions to eliminate or minimize the hazard for each control system axis. With the incorporation of fly-by-wire spoilers into the lateral control system architecture, the rotorburst threat has been eliminated for the roll axis. For the pitch axis, the FAA has indicated per FAA letter 100B-15-69, dated Feb 9, 2015, that they will accept that the design of the elevator control system has incorporated design precautions that eliminate specific risks and reduce the remaining risks to a minimum level per AC 20-128A. For the yaw and pitch axis, Boeing has incorporated new structural features within the floor structure forward of the wing box to further minimize the threat to the rudder and elevator cables from disc fragments smaller than a 1/3rd disc fragment. The new intercostals will be sized commensurate with the configuration and sizing of the existing floor structure to which they attach. The energy levels associated with 1/3rd disc fragments are sufficiently high such that practical structural design changes do not exist that will eliminate the threat to the rudder or elevator cables.

Boeing intends to follow the guidance of AC 20-128A to minimize the airplane hazards to changed and unchanged areas of the airplane. This proposed means of compliance to 25.903(d)(1) for the 737 MAX is consistent with recently certified airplane programs since the release of AC 20-128A guidance material including the previously accepted interpretation of Section 8.c.1. Boeing has presented to the FAA at meetings where the minimum acceptable control requirements cannot be satisfied due to loss or degradation of flight controls due to an uncontained engine failure. The threat to flight controls and its associated systems are eliminated or minimized within the constraints of the overall airplane architecture by employing best design practices and precautions. Those conditions that are not eliminated are included in the airplane level hazard assessment for uncontained engine failure and are included in the statistical ("1-in-20") analysis (as defined in AC-128A) for compliance to 25.903(d)(1).

CONCLUSION:

As quoted in the initial FAA position, AC 20-128A states that "The elements of the flight control system should be adequately separated or protected so that the release of a single one-third disc fragment will not cause loss of control of the airplane in any axis." As noted in Boeing's position, the 737 MAX proposed type design does not meet this criteria for protecting flight controls, specifically the rudder mechanical flight control cables, from a single one-third disk fragment.

However, the FAA cannot discount Boeing's position that the design changes required to meet the criteria established in AC 20-128A as "practical design precautions" may not all be "practical" solutions for this airplane. The FAA recognizes that the 737 MAX is a

derivative of a 47-year-old airplane design and that the areas in question in the rudder control cable design are unchanged areas of the airplane design, though they are affected areas with respect to a showing of compliance with § 25.903(d)(1).

The FAA also cannot discount Boeing's numerical probability analysis showing that, on average, a catastrophic event due to a rotorburst that strikes the rudder cables is extremely improbable. While such a calculation is not relevant to showing compliance for a rotorburst or other potentially catastrophic single failure, it does provide some information on the expected level of average risk due to such an event if no unusual design, manufacturing, or maintenance problems occur.

Although it is not part of the showing or finding of compliance, the FAA also recognizes that the service history of the Model 737 with CFM engines has been excellent with respect to uncontained engine failures. The CFM engines installed on the Model 737-300 through -900, which include several variants of the CFM56-3 and CFM 56-7 series engines, have never had a disk failure or other uncontained engine failure in which large, high energy fragments exited the engine case. (The CFM56-3 series engine on the Model 737-300/400/500 had one uncontained failure event that released a compressor seal segment. The CFM56-5 series engines on Airbus A320 and A340 series airplanes have had one compressor disk failure. The CFM56-7 series engine on the Model 737-600/700/800/900 has had no uncontained failure events.) While the goal of all turbine engine manufacturers is to design the engine to avoid uncontained engine failure events, the CFM56 engine's success in service with multiple design variants indicates that the CFM design approach, analysis processes, decision-making processes, and production processes can consistently result in a design that has a very low rate of uncontained rotor failures. Assuming the same approaches and methods are applied in designing, evaluating, and maintaining the LEAP-1B engine, the FAA expects that the LEAP-1B engine will have a very low rate of uncontained engine failures similar to that demonstrated in the extensive service history of the existing CFM56 series engines.

Because direct compliance with § 25.903(d)(1) requires that the hazard to the rudder mechanical flight control cables be minimized from uncontained engine failures, the FAA would accept the following analyses from Boeing as an acceptable method of compliance for the 737 MAX in lieu of the methods contained in the AC:

> List all possible design solutions based on current technology and show that you have taken all practical means to minimize the hazards to the airplane. As part of this assessment, show that any design considerations or accepted design precautions identified in AC 20-128A that you have not incorporated are not practical or would negatively affect the level of safety for this 737 derivative aircraft.

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- Complete an assessment of the new engines and show that there is a negligible difference in the threat posed by uncontained engine failure as compared to the threat from all previously approved 737 engines.

All of Boeing's assessments to these criteria must be included in official certification documentation.

The method of compliance established in this issue paper is unique to the Model 737 MAX and its derivatives that utilize the LEAP engine. For other derivative airplanes, Boeing should provide data showing minimization per AC 20-128A or by other equivalent means as agreed upon with the FAA.

This issue paper is closed.

[redacted]
Transport Airplane Directorate
Aircraft Certification Service

21 MARCH 2016
Date

Boeing Commercial Airplane Company
Model 737-7/-8/-9
Project Nos. PS12-0037, PS12-0038, PS12-0039

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Boeing Commercial Airplane Company
Model 737-7/-8/-9
Project Nos. PS12-0037, PS12-0038, PS12-0039

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Attachment 1

Terms
This table defines the use of key terms in the FAA Position of this issue paper.
The table describes the intended functional impact.

Definition of Key Terms

	Regulatory Requirements	Acceptable Methods of Compliance (MOC)	Recommendations
Language	Must	Should	Recommend
Meaning	Refers to a regulatory requirement that is mandatory for design approval	Refers to instructions for the MOC	Refers to a recommended practice that is optional
Functional Impact	No design approval if not met	Alternative MOC has to be approved by an update to this issue paper or via another issue paper	None, because it is optional

DO NOT REMOVE FROM ATTACHED ISSUE PAPER
ISSUE PAPER COORDINATION GRID

SPECIALISTS

	ACO	BASOO	BASOO	BASOO	BASOO	BASOO
Branch	ANM-120S	ANM-106B	ANM-106B	ANM-130S	ANM-106B	ANM-106B
Name	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
Initials	N/A	N/A	N/A	N/A	Non-concur	
Date					9/10/15	

SPECIALISTS

	ACO	ACO	BASOO	ACO	AEG-AAW	AEG-AVI	AEG-OPS
Branch	ANM-140S	ANM-150S	ANM-106B	ANM-160S	SEA-AEG	SEA-AEG	SEA-AEG
Name	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Initials	Non-concur 9/15/15	N/A	N/A	Non-concur 9/15/15	[redacted] (for)	N/A	[redacted]
Date					7/29/15		7/30/15

BASOO - Technical Project Managers

	Structures	Avionics/Soft	Cabin Safety	Flight Test	Propulsion	Electrical	Mechanical
Branch	ANM-100B	ANM-100B	ANM-100B	ANM-100B	ANM-100B	ANM-100B	ANM-100B
Name	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Initials				Non-concur	Non-concur		Non-concur
Date	N/A	N/A	N/A	9/10/15	9/11/15	N/A	9/10/15

SPECIALISTS

	PO	PO	CMO	BASOO	ACO	ACO
Branch	ANM-100B	ASW-113	CMU-42	ANM-100B	ANM-120S	ANM-140L
Name	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Initials	[redacted]	[redacted]	N/A	N/A	N/A	N/A
Date	3/17/16	3/16/16				

SPECIALISTS

	TAD	TAD	TAD	TAD	
Branch	ANM-112	ANM-112	ANM-115	ANM-117	ANM-111
Name	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Initials	See Project File	See Project File	N/A	N/A	N/A
Date	1/15/16	1/15/16			

ACO BRANCH MANAGEMENT

	BASOO	BASOO	SACO	AEG	CMO	
Branch	ANM-106B	ANM-100B	ANM-100S	SEA-AEG	ANM-108	
Name	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
Initials	[redacted]	[redacted]	NA	[redacted]	NA	
Date	9/24/15	12/17/15		9/1/15		

TAD STANDARDS STAFF MANAGEMENT

		PRIME				
Branch	ANM-111	ANM-112	ANM-113	ANM-115	ANM-117	
Name	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
Initials	N/A	[redacted]		N/A	N/A	
Date		3-24-16				

737 MAX Issue Paper SF-1 - Disposition of Non-Concurrence Statements

The following issues were raised as a basis for not concurring with the issue paper. The FAA response follows the statement of each issue.

Issue 1:

Comment Summary: The conclusion cites the excellent service history of the 737 with respect to rotorburst, but that service history is the result of engine behavior and is not the result of a particular level of risk reduction at the airplane level. The reliability of the LEAP-1B engine with respect to uncontained failures is not established.

FAA Response:

The FAA partially agrees. We agree that the airplane's excellent service record is primarily the result of the lack of uncontained engine failures. The issue paper has been revised to cite the service experience of the CFM56 engine and CFM's record of successfully introducing engine designs that have a very low rate of uncontained engine failures. While we agree that the uncontained engine failure rate of the LEAP-1B is not established, we have determined that it is reasonable to expect that CFM will have similar success in introducing the LEAP-1B engine.

Issue 2:

Comment Summary: Do not agree that rudder control system changes that could significantly reduce the hazard are impractical to implement.

FAA Response:

The regulatory requirement for minimization of the hazards associated with an uncontained rotor failure recognizes that practicality must be considered when determining the design precautions that should be included to reduce the hazards. What is practical for one design may not be practical for a different design. In addition, the point in a certification program at which a potentially insufficient hazard mitigation is identified and an FAA position is finally reached has a direct impact on the practicality of making a design change. In this case the FAA determined that further reduction in the exposure of the rudder and brake control systems appears to be impractical at this late point in the program where resolution of this disagreement with the applicant has occurred. As part of showing compliance, the FAA is assigning to Boeing via this issue paper the task of identifying all of the possible design changes that could be taken to reduce the risk to the rudder and brakes control systems, and showing that each possible change is impractical.

Issue 3:

Comment Summary: We appear to be accepting Boeing's statement that changes to reduce vulnerability of the flight control system are impractical without seeing or evaluating their study of the options.

FAA Response: This issue paper does not contain a determination that further changes are impractical, but it does acknowledge that Boeing may be able to show that is the case. The issue paper requires compliance to be shown. It specifically requires Boeing to show that any design considerations or accepted design precautions identified in AC 20-128A that they have not incorporated are not practical or would negatively affect the level of safety for this 737 derivative aircraft.

Issue 4:

Comment Summary: We appear to be setting up the MOC agreement to have Boeing evaluate and approve their own analysis even though there has been disagreement over the method of compliance. Normally we retain findings in such situations without the FAA reviewing the material

FAA Response: Delegation is outside the scope of an issue paper. Delegation is based on a number of factors, however, once we have requirements and policy established the ODA should have the material needed to make a finding based on a showing by the applicant. We may choose even if we do delegate the finding to review through oversight and oversight.

Issue 5:

Comment Summary: Do not agree with including the paragraph in the conclusion that discusses the Model 737 service experience. While the paragraph says it's not part of the showing or finding, the fact that it is included implies that it was considered in making the finding. Considering service experience or the expected probability of an uncontained failure engine reliability as not relevant to a compliance finding with § 25.903(d).

FAA Response:

We agree that consideration of service experience or the expected probability of an engine uncontained failure is not directly relevant to a compliance finding for § 25.903(d). We have noted in the issue paper the excellent record of CFM engines during a very large amount of service experience as part of the justification for relying on Boeing's showing of what constitutes practical reduction of hazards in this case. We determined it is important to document that consideration because the FAA does not plan to allow the application of this issue paper to derivative programs beyond the Model 737 with CFM LEAP engines.

Issue 6:

Comment Summary: AC 20-128A, which addresses rotor burst and compliance with § 25.903(d), specifically discusses the need to protect primary and secondary flight control capability in the event of a rotorburst. In issuing the AC, ARAC and the FAA considered protection of flight control functions from loss due to a single large disk fragment striking the airplane to be practical. The 737 MAX design fails to duplicate or adequately protect the rudder control system and the brake control system function such that rudder control or brake control can be lost due to a single disk fragment striking the critical part of the aircraft. Other products have been required to address this issue through design changes.

FAA Response:

While the AC provides excellent technical advice and represents current FAA policy regarding an acceptable method of compliance, it is not necessarily the only allowable method of compliance. The regulatory requirement for minimization of the hazards associated with an uncontained rotor failure recognizes that practicality must be considered when determining the design precautions that should be included to reduce the hazards. What is practical for one design may not be practical for a different design. Inaddition the point in a certification program at which a potentially insufficient hazard mitigation is identified and an FAA position is finally reached has a direct impact on the practicality of making a design change. In this case the FAA determined that further reduction in the exposure of the rudder and brake control systems appears to be impractical at this late point in the program where resolution of this disagreement with the applicant has occurred. As part of showing compliance the FAA is assigning to Boeing via this issue paper the task of identifying all of the possible design changes that could be taken to reduce the risk to the rudder and brakes control systems, and showing that each possible change is impractical.

Issue 7:

Comment Summary: In 1997 at the conclusion of the 737-700 program, both the FAA and the JAA documented their concerns that the airplane design did not meet the then-current standard of safety. Issue Paper I-24 from that program allowed the continued use of a single rudder control cable system based on the engine not increasing the geometric hazard to the airplane relative to previous 737s, but stated that Boeing would be required to further reduce the hazard if the airplane was re-engined. The LEAP-1B engine installation on the 737 MAX is a new engine installation, and it significantly increases the geometric hazard posed by the engine due to the addition of rotor stages, the larger fan, and the more forward location of the engine.

FAA Response:

The 1997 737NG issue paper made a statement about the expected FAA position on future programs involving an engine change, but the acceptable means of compliance for any program is determined through that program's applicable certification plan. Applicants are always free to

propose their preferred methods of compliance, and the FAA is obligated to consider their proposal.

Issue 8:

Comment Summary: The proposed design of the 737 MAX is non-compliant with § 25.903(d). The means of compliance developed only for this applicant is arbitrary and capricious. The rulemaking process for exemptions should be followed, and the public should be allowed to comment on the associated reduction in safety. Approval of the proposed design without an exemption is not within the authority of the FAA.

FAA Response:

The FAA is acting within the discretion that is allowed under the wording and intent of § 25.903(d). The requirement in that regulation for minimization of the hazards associated with an uncontained rotor failure recognizes that practicality must be considered when determining the design precautions that should be included to reduce the hazards. What is practical for one design may not be practical for a different design. In addition, the point in a certification program at which a potentially insufficient hazard mitigation is identified and an FAA position is finally reached has a direct impact on the practicality of making a design change. In this case the FAA determined that further reduction in the exposure of the rudder and brake control systems appears to be impractical at this late point in the program where resolution of this disagreement with the applicant has occurred. Ultimately, the FAA's determining appropriate criteria for a method of compliance with § 25.903(d) involves the application of judgment and the exercise of discretion that is within the authority of the FAA.

This determination on the Boeing 737 MAX is consistent with the recent determination made for the Airbus A320 New Engine Option (or "A320neo") that included similar design characteristics.

Issue 9:

Comment Summary: The issue paper conclusion bases the acceptability of the single cable flight control system on the fact that the 737 Max is a derivative program. This position should not be the basis for a decision on whether the design is compliant. When the FAA established the certification basis for the 737 MAX, we considered the fact that the airplane was a derivative. We determined a new finding of compliance was required. The cert basis for the airplane was established due to the installation of a completely new engine that has additional disks, a larger fan and poses more risk to the airplane from uncontained engine failures. Once the certification basis was established to require a new compliance finding to §25.903, there is no policy that would provide a basis for considering the fact that the airplane is a derivative in the compliance finding to §25.903. As discussed previously, it is clearly practical to improve the design of derivative airplanes and the argument that it is impractical on the 737 MAX is not supported by data and facts.

FAA Response:

We have noted in the issue paper the fact that this is a derivative program as part of the justification for relying on Boeing's showing of what constitutes practical reduction of hazards in this case. We determined it is important to document that consideration because the FAA does not plan to allow the application of this issue paper to new airplane programs or derivative programs beyond the Model 737 with CFM LEAP engines.

Issue 10:

Comment Summary: FAA met with Boeing engineers during numerous discussions regarding the issue paper in order to discuss a number of possible compliant design options. After the final meeting we sent a letter to Boeing stating a number of these options were practical. This provision makes it appear there is some question as to whether it is practical to incorporate design changes. The FAA indicated it is practical to provide mitigation for both new and derivative designs, and for the 737 MAX design in particular. Having the issue paper conclusion assign to Boeing the task of inventorying and evaluating the practicality of further risk reduction for the rudder control system ignores the fact that the FAA already indicated that further risk reduction is practical.

FAA Response:

The regulatory requirement for minimization of the hazards associated with an uncontained rotor failure recognizes that practicality must be considered when determining the design precautions that should be included to reduce the hazards. What is practical for one design may not be practical for a different design. In addition, the point in a certification program at which a potentially insufficient hazard mitigation is identified and an FAA position is finally reached has a direct impact on the practicality of making a design change. The FAA's preliminary assessment regarding the practicality of certain design changes was made some time before the FAA made a final determination of its position on this issue. In this case the FAA determined that further reduction in the exposure of the rudder and brake control systems appears to be impractical at this late point in the program where resolution of this disagreement with the applicant has occurred. At this point, the FAA has determined that it will consider Boeing's assessment of the practicality of the possible design changes that is required in the conclusion section of the issue paper.

Issue 11:

Comment Summary: The FAA has been made aware that the new LEAP engine being installed on the 737 MAX adds more rotating stages, a larger fan, an additional solid bore to rim high pressure turbine disk, and that these features increase the risk to the airplane.There is an increased threat posed by the new engine installation. In fact this was a consideration when we established the certification basis and required a reassessment of the uncontained engine failure due to installation of a completely new, larger engine. Including a requirement for Boeing to

show a negligible increase in risk posed by the engine misrepresents the facts and makes it appear there is some question as to the fact that there is increased risk. This is misleading and should be reworded to clearly state we have determined there is an increased threat to the airplane due to installation of new engines.

FAA Response:

The FAA recognizes the concerns raised but acknowledges Boeing's assertion that they can show that the increase in the threat posed by the engine is negligible. The requirements in the conclusion section of the issue paper include a requirement for Boeing to show that any increase in the threat posed by the engine is negligible.

Issue 12:

Comment Summary: The conclusion statement appears to attempt to require Boeing to utilize the existing policy in the AC or other equivalent policy on future derivative programs other than 737 MAX derivatives. Once the FAA has agreed the AC methods need not be applied to the 737 MAX, how can they possibly require application of the AC to future derivative programs? The compliance means provided in this issue paper does not provide equivalency to the AC. This statement highlights how unique criteria that is arbitrary and capricious is being applied to the 737 MAX program.

FAA Response:

As stated in some of the other responses above, in this case the FAA determined that further reduction in the exposure of the rudder and brake control systems appears to be impractical at this late point in the program where resolution of this disagreement with the applicant has occurred. The regulatory requirement for minimization of the hazards associated with an uncontained rotor failure recognizes that practicality must be considered when determining the design precautions that should be included to reduce the hazards. The point in a certification program at which a potentially insufficient hazard mitigation is identified and an FAA position is finally reached has a direct impact on the practicality of making a design change. At this point, the FAA has determined that it will consider Boeing's assessment of the practicality of the possible design changes that is required in the conclusion section of the issue paper.

This determination on the Boeing 737 MAX is consistent with the recent determination made for the Airbus A320 New Engine Option or "A320neo" that included similar design characteristics.

Issue 13:

Comment Summary: The design is not compliant because Boeing has not taken any design precautions to minimize the hazards to the airplane flight control and brake systems cable designs to minimize the hazard from an engine rotor failure. The Agency should encourage Boeing and Airbus to seek time limited exemptions in order for them to complete design

improvements to bring the airplane into compliance with §25.903. The decision to allow certification of the A320 NEO and the 737 MAX with single cable control systems will result in production of over 100 airplanes per month for decades that have exposure to catastrophic events due to severing a single cable by fragments, similar in size to those generated in the A380 accident. This decision introduces unnecessary risk and should be reconsidered.

FAA Response: We note that Boeing has stated that they added structural members to the floor structure of the 737 MAX that provide some increase to the shielding provided to the rudder cables for smaller rotor fragments. We agree that there is some risk exposure for the 737 MAX due to rotorburst which is an inherent risk in any airplane design acknowledged in the § 25.903. The issue paper requires Boeing to show that any further possible changes to the rudder and brake control systems to reduce the hazards from a rotorburst event are impractical. It also requires Boeing to show that any increase in risk to the airplane in the event of a rotorburst is negligible compared to the risk on a Model 737 NG airplane. These measures are intended to ensure that the risk of a catastrophic event due to rotorburst on a 737MAX airplane will be comparable to or lower than that on a Model 737NG airplane.

Issue 14:

Comment Summary: I believe an uncontained engine failure on takeoff is likely to occur during the fleet life of a 737 MAX airplane and there is a risk that fragments from the engine could cut the rudder control cables. This type of risk was recognized when the guidance in AC 20-128A, applicable to the 737 Max, was developed and practical design solutions were included in the AC to eliminate this specific threat to the airplane. The practical design solutions listed in paragraph 7 of the AC include location of critical components outside the fragment impact areas or separation, isolation, redundancy, and shielding of critical airplane components and/or systems. Paragraph 8 "Accepted Design Precautions" of the AC was added based upon advice by the Aviation Regulation Advisory Committee (ARAC) in 1997. The ARAC group was tasked by the FAA to provide recommendations to the FAA for revisions to the AC following the Sioux City DC-10 accident that resulted from loss of flight control following an uncontained engine failure that damaged the flight control system. As described in Paragraph 8 e, the ARAC committee determined loss of flight control in all three axis flight axis could be mitigated following an uncontained engine failure.

FAA Response:

We acknowledge it is possible that an uncontained engine failure on takeoff may occur during the fleet life of a 737 MAX airplane. The intent of the word "minimize" in the regulation and the associated assessment of practicality of risk reduction measures is discussed in several of the responses above. The issue paper requires Boeing to show that any further possible changes to the rudder and brake control systems to reduce the hazards from a rotorburst event are impractical. It also requires Boeing to show that any increase in risk to the airplane in the event of a rotorburst is negligible compared to the risk on a Model 737 NG airplane. These measures are intended to ensure that the risk of a catastrophic event due to rotorburst on a 737MAX airplane will be comparable to or lower than that on a Model 737NG airplane.

Safety Review Program Findings and Recommendations—FAA-DeFazio 28922–28937

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SRP Item 10 – Findings and Recommendations to the SRP Safety Oversight Board

by
SRP Item 10 SME Panel
January 13, 2017

Summary

The SRP Item 10 SME Panel (hereafter referred to as simply "the SME Panel") was convened on November 3, 2016, to review the rudder control system design on the 737MAX in response to an SRP submission. The SRP reporter expressed concern that the 737MAX design does not comply with 14 CFR § 25.903(d)(1) and that the means of compliance for the 737MAX documented in Issue Paper SF-1 were inconsistent with FAA guidance and policy going back to the late 1990s. The SME Panel reviewed the report and accompanying documents and provided findings and recommendations in its technical answers to eight questions posed by the Safety Oversight Board.

Discussion of the Reported Safety Issue

The 737MAX rudder control system consists of a single loop cable connecting the rudder pedals in the flight deck to the hydraulically actuated rudder power control unit (PCU) at the rudder surface. The single loop rudder cable passes through the uncontained engine failure (UEF) debris zone and is thus susceptible to damage or severing. Per Boeing's analysis, if this condition were to occur between reaching 60 knots during the takeoff roll and reaching 400 feet altitude after liftoff, yaw control from the rudder could be lost during an engine-out condition. This could potentially lead to loss-of-control inflight or a runway excursion and resulting fatalities. Yaw control in other phases of flight would be maintained after a UEF/severed rudder cable event through rudder trim, the command path for which is separated adequately from the rudder cables through the UEF debris zone.

Compliance with § 25.903(d)(1) requires the applicant to assume an engine rotor non-containment. Typical Part 25 regulations provide specific performance based or prescriptive requirements. Guidance for how this is accomplished is contained in paragraph 8 and 9 of AC 20-128A. The safety objective in paragraph 10(c) of the AC requires that practical design considerations and precautions be taken. In the early 1990s the FAA defined the performance standard for the flight controls in AC 20-128A that provided specific performance standards determined to be practical by both industry and regulators. Per the AC a 1/3rd disc fragment

should not cause loss of control in any axis (ref 8(c)(1)), which is a proven design practice the 737MAX is being evaluated against (ref intro of paragraph 8).

The issue was reported through the SRP system after a meeting in which FAA management agreed with Boeing's position that the 737MAX design had minimized the hazards related to UEF, and that further design changes were not necessary for compliance. An issue paper on the subject (IP SF-1 for the 737MAX program, closed after the SRP report was provided) documented in the Stage 4 conclusion a means of compliance that would consider the current design compliant with § 25.903(d)(1) if Boeing documented that the design practices listed in AC 20-128A to address the issue were analyzed and found to be impractical. The key concerns raised by the SRP reporter, and reflective of the reporter's point of view, are:

- Boeing has not provided sufficient evidence to show the impracticality of proposed design changes to the 737MAX that would meet the intent of the guidance in AC 20-128A for preventing loss of directional control after an uncontained engine failure during takeoff. As such, the SRP reporter concluded that the 737MAX rudder system design is not compliant with § 25.903(d)(1).
- Based on their review of the design, FAA specialists working the 737MAX project concluded it was technically practical to incorporate one of several potential design changes that would satisfy the means of compliance described in AC 20-128A.
- Per the SRP reporter's understanding, the FAA has told Boeing, since the closing of the 737NG IP in 1997 and in various venues, that the existing 737 rudder cable design would not be compliant for a new (amended) TC.

The issue was reported to the SRP in August 2015 and was accepted and referred for SME Panel review in August 2016.

SRP Item 10 SME Panel Process

The SME Panel was tasked by the Safety Oversight Board to provide technical answers to eight questions. These questions, and the Panel's answers, are as follows:

1. Is § 25.903 based upon the assumption that an uncontained engine failure will occur and the hazard to the airplane is to be minimized following the uncontained engine failure?

    a. Answer: Yes

    b. Rationale/Analysis:

        I. The regulation states that precautions must be taken; it does not allow for consideration that engine rotor failure might not occur.

[Type text]

(d) Turbine engine installations. For turbine engine installations--(1) Design precautions must be taken to minimize the hazards to the airplane in the event of an engine rotor failure or of a fire originating within the engine which burns through the engine case.

II. Amendment 23 of part 25 revised the wording of § 25.903(d)(1), which remains unchanged in the latest amendment of part 25. The preamble to amendment 25-23 states "The purpose of the proposed amendment to § 25.903 (d) is to ensure that, for turbine engine installations, design precautions are taken to minimize the hazards to the airplane in the event of an engine rotor failure or of a fire originating in the engine which burns through the engine case". In response to comment(s) that engine rotor containment should be managed under part 33, the following response was provided "Service experience has shown that additional safeguards in the installation of the engine is necessary over and above those provided by Part 33 to minimize hazards resulting from engine rotor failure or engine case burn through". This further demonstrates the intent that the engine installer must assume an engine rotor non-containment event occurs and minimize the resulting hazard.

III. Paragraph 5 of AC 20-128A states "Since it is unlikely that uncontained rotor failures can be completely eliminated, parts 23 and 25 require that airplane design precautions be taken to minimize the hazard from such events."

IV. Part 33 incudes measures taken during the engine certification effort to ensure uncontained failures don't occur (or certain failures are contained) but it's recognized they still occur and that the resulting hazards must be minimized.

2) Is consideration of the reliability of a previously approved engine type consistent with the intent of § 25.903 when demonstrating the hazards are minimized for the installation of a new engine type?

a. Answer: No

b. Rationale/Analysis:

I. The hazard being evaluated is a single catastrophic failure, for which neither § 25.903(d)(1) nor AC 20-128A provide for consideration of engine reliability.

[Type text]

II. Even if past engine reliability were to be considered relevant to showing compliance to § 25.903(d)(1), the new LEAP engine on the 737 MAX is sufficiently different from the previous CMF56 engine currently installed on the 737 that past performance of the CFM56 model would not be considered relevant in predicting the performance of the LEAP engine in service. The LEAP engine includes additional disks, a larger fan, different materials and different operating limits from the existing approved engine.

III. As noted in question 1, it is assumed an engine non-containment occurs resulting in the failure models defined in paragraph 9.of AC 20-128A. Engine reliability is not an acceptable approach for minimizing the hazard, regardless of whether using a previously approved or new type engine. Engine non-containment failures may result from numerous issues not all of which are directly related to the original type design or past performance such as later amendments to the engine design, change of suppliers, introduction of aftermarket (Parts Manufacturer Approval – PMA) parts, overhaul, and maintenance, or FOD ingestion. Assuming future performance of a particular engine based on an existing approved installation is not considered appropriate or acceptable.

3) Is the guidance in AC20-128A based upon a conclusion by ARAC that it is practical to maintain airplane control in all 3 flight axes following an uncontained engine failure?

a. Answer: Yes

b. Rationale/Analysis:

I. The Authority/Industry working group that developed AC 20-128A convened to address (among other things) issues observed in the 1989 Sioux City DC-10 UEF accident. During their deliberations the working group found that it was practical to develop control system designs that maintain pitch, roll, and yaw control after an uncontained engine rotor failure.

II. AC 20-128A provides a list of acceptable design practices that meet the objective of minimization (ref paragraphs 7(b) and 8(c) below). Included in the list is the requirement that release of a single 1/3 disc should not result in loss of control of the airplane in any axis. Since the release of this AC, numerous aircraft designs have met this requirement, so it is

technically practical to design a control system capable of maintaining control in all three axes after a UEF. Other Boeing models have met this requirement along with numerous other part 25 aircraft. Per paragraph 7(b) of AC 20-128A:

Critical airplane flight and engine control cables, wiring, flammable fluid carrying components and lines (including vent lines), hydraulic fluid lines and components, and pneumatic ducts should be located to minimize hazards caused by uncontained rotors and fan blade debris. The following design practices should be considered:
(1) locate, if possible, critical components or systems outside the likely debris impact areas.
(2) duplicate and separate critical components or systems, or provide suitable protection if located in debris impact areas.
(3) Protection of critical systems and components can be provided by using airframe structure or supplemental shielding.

These methods have been effective in mitigating the hazards from both single and multiple small fragments within the" 15 degree impact area. Separation of multiplicated critical systems and components by at least a distance equal to the 1/2 blade fragment dimension has been accepted for showing minimization from a single high energy small fragment when at least one of the related multiplicated critical components is shielded by significant structure such as aluminum lower wing skins, pylons, aluminum skin of the cabin pressure vessel, or equivalent structures.

Additionally, paragraph 8(c) of AC 20-128A states:

ACCEPTED DESIGN PRECAUTIONS. Design practices currently in use by the aviation industry that have been shown to reduce the overall risk, by effectively eliminating certain specific risks and reducing the remaining specific risks to a minimum level, are described within this paragraph of the AC. Airplane designs submitted for evaluation by the regulatory authorities will be evaluated against these proven design practices.

c. Loss of Airplane Control.
(1) Flight Controls. Elements of the flight control system should be adequately separated or protected so that the release of a single one-third disc fragment will not cause loss of control of the airplane in any axis. Where primary flight controls have duplicated (or multiplicated) elements, these elements should be located to prevent all elements in any axis being lost as a result of the single one-third disc fragment. Credit for maintaining control of the airplane by the use of trim controls

or other means may be obtained, providing evidence shows that these means will enable the pilot to retain control

Lastly, an FAA letter to GAMA dated March 23, 1995 specifically addresses loss of flight controls from UEF in paragraph (d), titled "Future Certification Criteria," which states:

"TAD will require redundant separated flight critical controls within the uncontained engine debris impact area on all future airplanes as described below...(2) For projects where application for a new, amended, or supplemental type certificate application (i.e. projects that have sufficient time for manufacturers to incorporate changes in the aircraft design without undue burden) that have the following characteristics: Installation of new or modified engines that substantially increase the hazard to the flight controls because of larger rotor diameters: or significant structural modifications in the area of the engine strike zone."

The SME Panel considers the information in this letter directly applicable to the 737MAX as the new LEAP engine will have a larger fan and additional rotor stages with respect to the existing CMF56 engine installation.

4) Would a design change for the 737MAX be practical to retain flight control capability in all three axes following an uncontained engine failure?

   a. Answer: Based upon the information reviewed by the SME Panel, two design solutions presented by Boeing appear practical.

   b. Rationale/Analysis:

      I. The term "practical" in this application involves a review from both the technical and cost perspective, including both direct costs of a design change and the cost of operational impacts introduced by the design change (e.g., additional flight crew training, maintenance, etc.).

      II. Boeing performed a trade study of various other design solutions in 2014 and the FAA identified 4 design options that appeared, at the time, to be practical. Boeing concluded none of the options studied were practical and presented high level information in 2015 to support that position. Boeing then concluded they had met the requirement of § 25.903(d)(1) to minimize exposure to the hazards of UEF through design changes to the degree practical. However the members of the SME Panel believe, based upon their own review, that at least two of

the options still appear practical and that Boeing's arguments to the contrary are not sufficient. The two potentially practical design changes are:

1. A rudder bias/thrust asymmetry compensation system, which automatically compensates for thrust loss with directional control inputs. Because the system would use different actuators, it would remain active even if the rudder cable were severed by a 1/3rd disc. This change would offer additional safety benefit during any single engine loss or thrust asymmetry by significantly reducing the risk of erroneous flight crew rudder inputs.
2. Dualized rudder cables through the UEF debris zone.

III. The rudder bias/thrust asymmetry compensation system would modify an existing autopilot actuation design for 737NG rudder control to provide automatic thrust asymmetry compensation, similar to such systems on the 777 and 787. Currently the actuation hardware is installed on about 10% of all NG airplanes and would continue to be offered as an option on the 737MAX to support Cat IIIC autoland capability. The modification would add thrust asymmetry logic similar to what is used on the 777 and 787. It could potentially require some additional wiring as well. Boeing stated that this system design is impractical because it would not provide complete protection from the hazard, and because it could introduce catastrophic failure scenarios that are more probable than the scenario it would address. Sufficient evidence of the first point has not been provided to the FAA, and the SME Panel does not accept the validity of the second point. Any system that is installed would need to meet the requirements of 14 CFR § 25.1309.

IV. For the dualized rudder cable design, the system would split the single loop cable into two independent paths through the UEF debris zone, then rejoin them aft of the zone. Boeing contends this solution is impractical because it raises friction forces in the rudder system. While this is not insignificant, the SME Panel does not believe this analytical prediction alone is sufficient to declare the system impractical. Per Boeing guidance the rudder is used only for taxi, take-off, crosswind control, and after loss of an engine. Boeing has not provided data (that the SME Panel is aware of) from analysis or simulator testing showing

the higher friction forces would prevent the effective use of rudder in these situations, and has not responded to the FAA's request to allow FAA flight test pilots to evaluate these pedal forces in the simulator. It also does not appear that Boeing developed mock ups to determine the actual friction increase or undertake efforts to reduce the friction. The SME Panel believes this trade study item was not adequately evaluated.

V. Based on these open questions, the ultimate determination of "practical" does not appear to have been completed to the extent necessary for the FAA specialists to agree with Boeing's conclusion. The SME Panel recommends that the Boeing Aviation Safety Oversight Office (BASOO) respond to Boeing with a request for additional details on what it would take to implement either of the two systems that were determined to be practical and meet the minimization criteria in § 25.903(d)(1), and to answer the questions raised by the SME Panel. The SME Panel reviewed Boeing's rotorburst report and does not think it provides sufficient analysis provided to the FAA to support Boeing's contention that design solutions are not practical from either a technical or cost perspective, especially when amortized over the number of airplanes expected to be built and Boeing's experience with this on similar airplanes.

VI. The FAA specialists working this project ultimately need Boeing's official position (response to the bullet items in the Conclusion section of the IP) to give a final opinion/assessment on the practical issue. If the Boeing official position is that it is impractical to eliminate the 1/3rd disc, single failure condition that would cause loss of control of the airplane because of the expense, then the FAA specialists need an opportunity to challenge this position, including support from FAA management, to ensure a realistic assessment is being put forth by Boeing.

5) Is a comparative risk assessment of the proposed 737MAX design to that of previously approved airplane designs consistent with the intent of § 25.903 when demonstrating the hazards are minimized?

   a. Answer: No

   b. Rationale/Analysis

I. Neither § 25.903(d)(1) nor AC 20-128A provide a path for comparative analysis. AC 20-128A generally addresses this issue in paragraph 5, which notes "although turbine engine and APU manufactures are making efforts to reduce the probability of uncontained rotor failures, service experience shows that uncontained compressor and turbine rotor failures continue to occur." The paragraph concludes with "since it is unlikely that uncontained rotor failures can be completely eliminated, parts 23 and 25 require that airplane design precautions be taken to minimize the hazards from such events". This clarifies the intent to minimize the hazards regardless of probability/reliability of any installed engine or APU, which would preclude use of previously approved designs in any § 25.903(d)(1) assessment of the 737MAX.

II. Additionally, engine rotor non-containment failures may result from numerous issues not directly related to the original type design or past performance of the engine such as changes in the engine design or suppliers, introduction of PMA parts, overhaul, maintenance, FOD ingestion, etc., so assuming an engine will continue to have the same engine rotor non-containment failure rate in the future based on past history is not considered valid.

6) Any other question the Panel determines is relevant to the subject SRP Report.

See Recommendations 4 and 5 and associated material in Appendices A and B.

7) Does the proposed 737MAX design meet the intent of the requirement of § 25.903 to minimize the hazard from uncontained engine failures?

a. Answer: As stated in our answer to question 4, based upon the information reviewed by the SME Panel, two design solutions presented by Boeing appear practical. If Boeing cannot provide a sufficient rationale to substantiate that these solutions are impractical, the design would not meet the intent of minimizing hazards from UEF as necessary to comply with § 25.903.

b. Rationale/Analysis:

I. The regulation (§ 25.903(d)(1)) states: Design precautions must be *taken to minimize the hazards to the airplane in the event of an engine rotor failure.* The acceptable means of compliance with the rule are described in AC 20-128A. The rudder control system employs none of the design features mentioned in the AC. The rudder cable runs through

the UEF debris zone and is exposed to all 1/3rd disk trajectories. The rudder cable is not duplicated, but the rudder control system does provide separation between the rudder control cable and the rudder trim system. The airplane has not been shown controllable by means of rudder trim control only after loss of one engine during the takeoff phase of flight

II. Given this information, the 737MAX rudder control system does not meet the guidance per AC 20-128A that states elements of the flight controls system should be "adequately separated or protected so that the release of a single one-third disc fragment will not cause loss of control of the airplane in any axis". However, paragraph 7 of AC 20-128A also states that design precautions should be practical. The SME Panel has not seen Boeing's response to the IP SF-1 that would support Boeing's position that design changes are impractical. The ultimate determination as to whether Boeing's analysis of the design change practicality is acceptable should be retained by the FAA.

8) If the Panel determines the 737MAX design does not comply with the intent of section § 25.903 when demonstrating the hazards are minimized, what action does the team recommend:

   a. Prior to type certification of the 737MAX?

   b. After the certification of the 737MAX?

The SME Panel recommends the FAA inform Boeing it needs to immediately move forward with coordination and discussion with the FAA on the practicality of implementing one of the two proposed rudder system solutions necessary to satisfy paragraph 8(c)(1) of the AC that the SME Panel still considers practical: the rudder bias system or dualized rudder cables through the UEF debris zone. The SME Panel sees the following possible outcomes of that coordination:

1. If Boeing can provide sufficient data and analysis to the FAA technical specialists to convince them that neither solution is practical, then the FAA will consider Boeing to have satisfied the conditions of IP SF-1 for compliance to § 25.903(d)(1).
2. If Boeing cannot provide data and analysis to support their position that these design changes are impractical, then Boeing will need to pursue one of the following courses:

[Type text]

a. Incorporate a design change that would establish direct compliance to § 25.903(d)(1) prior to approval of the 737MAX.
b. Request a time-limited partial exemption to § 25.903(d)(1) to enable them to develop and certify a design change, if Boeing can provide sufficient evidence that incorporation of a design change will significantly delay their planned approval and deliveries
c. Petition for a partial exemption to § 25.903(d)(1) that is not time limited, if Boeing can make the case that such an exemption is in the public's interest.

Summary of SRP Item 10 SME Panel Findings and Recommendations

In summary, the SME Panel made the following findings:

1. The SME Panel's review of the SRP report and associated documents revealed an underlying and fundamental difference of interpretation between technical specialists at the Boeing Organization Designation Authorization (ODA) and technical specialists at the FAA over the meaning of "practical" design options for minimizing airplane exposure to the hazards of a UEF. This difference appears to stem from several factors:
   a. The inherent subjectivity of the word "practical"
   b. A lack of clear guidance as to what factors should be considered in making a determination that a design change is "impractical", i.e. – cost of the change? Impact on operation? Additional weight/complexity?
   c. The difference in application of the AC guidance to a new type design vs. modification of an existing type design
   d. A potential misunderstanding about the use of probability analysis used in § 25.1309 compliance findings as a means to signify when risk has been minimized per § 25.903(d)(1)
2. The difference in interpretation between Boeing ODA and FAA specialists raises concern among the SME Panel as to the effectiveness and readiness of the Boeing ODA to find compliance on behalf of the FAA. A significant factor in the FAA's decision to delegate compliance findings to an ODA is the trust that the FAA places in the ODA to understand, interpret, and apply FAA regulatory and guidance material in the same manner that FAA specialists would apply it.
3. The difference of interpretations between Boeing ODA and FAA specialists placed FAA management in the position of having to make a decision as to which interpretation to follow. The SME Panel affirms that FAA management has the right to make such decisions on behalf of the Agency, even if those decisions do not reflect the consensus of FAA technical specialists. Nevertheless, such instances undermine the confidence of

the FAA technical staff and create an environment of mistrust that hampers the ability of the Agency to work effectively.

4. The means of compliance documented in the Stage 4 conclusion of IP SF-1 rely on Boeing's ability to successfully demonstrate they have made all practical design changes possible to minimize exposure to the hazards of UEF. While such analysis may still be forthcoming, to date the FAA specialists in the BASOO and Transport Standards Staff (TSS) have not seen a convincing rationale as to why at least two of the proposed solutions (dualized rudder cables and the rudder bias/thrust asymmetry compensation system) are not practical. As the schedule proceeds rapidly toward certification, the Panel is concerned about Boeing's ability to provide this rationale in time for the FAA to review and accept it, which is a necessary condition for finding compliance as documented in IP SF-1. The FAA specialists remain skeptical of Boeing's current rationale for these two systems and are concerned that, as schedule pressure increases, it will become more and more difficult for Boeing and the FAA to resolve this issue.
5. The IP process is intended to identify and resolve issues of concern between the FAA and its applicants. The closure of IP SF-1 with non-concurrences from FAA technical specialists indicates the issue raised in the IP was not resolved in a manner agreeable to both Boeing and the FAA. Generally, the specialists were unconvinced that Boeing could demonstrate that they had in fact minimized the exposure of the 737MAX rudder system to the hazards of UEF. The specialists were particularly concerned by the fact that the FAA expectations to include redundant control paths to comply with § 25.903 had been provided to Boeing for many years and in many forums. Furthermore, two particular elements of the proposed means of compliance are considered inconsistent with FAA policy and should not be propagated in future issue papers:
   a. The use of previous 737 service history as part of the compliance finding to § 25.903(d)(1) is not valid, as the catastrophic rudder control failure case exists regardless of the engine model installed. The rule and guidance requires evaluation of all catastrophic cases regardless of probability or previous service history.
   b. The reliability of CMF56 engine with respect to compliance with § 25.903(d)(1) is also not valid, given that the design change includes removal and replacement of the CMF56 with a LEAP-1B engine. The LEAP-1B engine is a new design operating at higher pressures and temperatures, which also includes a larger diameter fan and 3 additional stages thereby increasing the existing rudder cable control system catastrophic risk from an uncontained engine failure in the new 737 MAX design.

The SME Panel provides the following recommendations to the SRP Oversight Board:

[Type text]

1. Remind Boeing that the FAA will retain the finding to § 25.903(d)(1) for the 737MAX rudder control system, as the finding of "practical" is a determination to be made by the FAA based on existing industry practice, cost of implementation and safety benefit. Delegation of this decision to any company potentially places that company's interests above the FAA responsibility for safety and compliance, as the company has a vested interest in minimizing costs and schedule impact.
2. Inform Boeing there is currently insufficient data provided to the FAA to support a finding of compliance that all practical design considerations and precautions have been taken for the rudder control system on the 737MAX to support a compliance finding for § 25.903(d)(1).
3. Obtain sufficient information, data, and coordination between the FAA and Boeing such that a determination of compliance can be made by the FAA oversight office responsible for finding compliance. This may or may not result in incorporation of a design change, but a general consensus of compliance should be found as to the practicality of incorporation into the 737MAX design. If compliance is found, document this information in the final compliance finding.
4. If compliance cannot be found, the BASOO should inform Boeing they need to petition for an exemption, or consider re-opening IP SF-1 or developing a new IP to restart the process for resolving the issue.
5. If incorporation of a rudder control system change is determined practical, it should be implemented prior to approval of the 737MAX. If incorporation prior to approval would place significant burden on Boeing, the FAA should consider issuance of a time-limited partial exemption to § 25.903(d)(1) for the rudder control system only and work with Boeing to implement a reasonable schedule for approval of the rudder control system change and incorporation into both production and fielded 737MAX airplanes. The probability of the event could be taken into consideration in this regard when making a risk-based decision for granting the exemption; therefore the SME Panel has provided an estimate of the overall event probability in Appendix A, with supporting information in Appendix B.
6. Boeing is also entitled to petition for a partial exemption to § 25.903(d)(1) that is not time-limited, if they can make a case that such an exemption is in the public's interest. The probability of the event calculated in Appendix A would be applicable for this consideration as well.
7. Long term: the FAA TSS should explore the underlying issues of interpretation related to the term "practical" in guidance material for part 25 requirements. If possible, the TSS should develop some methodology, or at least guidelines, that can aid in making discussions about practical design solutions more objective and less opinion-based.

[Type text]

APPENDIX A. Probability Calculation

The SME Panel calculated the probability of a UEF event occurring during takeoff and severing the rudder cable during a critical time window in which loss-of-control or a runway excursion, with resulting potential for fatalities, would likely result. The probability is estimated to be on the order of 2.9×10^{-10} events per departure (equivalent to 0.29 events per 1 billion departures).

Although not relevant for the subject of finding compliance for § 25.903; this estimation of the probability of a catastrophic outcome for the issue of concern has merit as a supporting point to grant a potential petition for exemption. The following section and table provide details on the calculation of this value.

Assumptions

The SME Panel assumed the catastrophic "window of exposure" during takeoff to begin at the engine-out rejected takeoff (RTO) decision speed, V_1, and to end when the airplane has reached 400 feet of altitude. This critical window differs from the exposure window used by Boeing, in that Boeing assumed the exposure would begin when the airplane had reached 60 knots on the takeoff roll. The SME Panel considers this to be too conservative, as the expectation for crew response to an engine failure of any type up to V_1 would be to immediately cut power and initiate an RTO. During an RTO, asymmetric braking should be adequate to maintain control of the airplane in the yaw axis. The SME Panel agrees with Boeing that the event window ends after the airplane reaches 400 feet above ground level (AGL). The SME Panel also assumed the takeoff phase starts at brake release, and should end at initial flap retraction, usually around 1500 feet AGL. It was necessary to make these assumptions in order to correctly calculate the probability as a function of departures rather than flight hours.

The SME Panel used historical event data from the Aviation Safety Network (ASN) that was flagged as "uncontained engine failure" in the ASN database, starting in 1959 through present. All events were reviewed and subcategorized by the subset of events that occurred on western-built jet airplanes. The SME Panel also used the 2016 Boeing Statistical Summary as a source of information about historical fleet hours and departures for western-built jet airplanes from 1959-present 2015. Events were included from 2016 in the assessment and probability, although the number of total departures through 2016 is not yet available. This is acceptable because it is a conservative assumption (i.e., the number of actual departures if 2016 were included would be higher for the same number of events, resulting in a lower rate).

[Type text]

The following table presents the results of the calculation:

Item	Value
UEF events on all jets, 1959-present	45 events
UEF events on part 25 western-built jets ("25WBJs") 1959-present	39 events
Subset of "25WBJ" events during takeoff phase (start of TO roll to initial flap retraction at 1500' AGL)	19 events
Ratio of "25WBJ" UEF events during TO phase to all events	0.487 *(19 of 39)*
Total departures of "25WBJ fleet", 1959-present	713,000,000
Rate of "25WBJ" UEF during TO phase per dep	2.66×10^{-8} events/departure *(= 19 /713,000,000)*
Average duration of TO phase (see Appendix B)	60 secs
Average during between V_1 and 400 feet AGL (see Appendix B)	15 secs
Ratio of TO duration between V_1 and 400 feet AGL	0.25 *(15 out of 60 secs)*
Rate of "25WBJ" UEFs expected between V_1 and 400 feet AGL	6.66×10^{-9} events/departure *(= .25 * 2.66×10^{-8})*
Number of (UEF + control cable failure), based on reports from all worldwide jet operations	2 possible (1 known on Ily 62, one possible DC-10 Sioux City)
Ratio of control cable failure per UEF, based on reports from all worldwide jet operations	0.044 *(=2 out of 45)*
Rate of "25WBJ" (UEF + control cable failure) during TO phase between V_1 and 400 feet AGL	**2.93×10^{-10} events/departure** ***(= 0.044 * 6.66×10^{-9})***

[Type text]

APPENDIX B. Calculation of takeoff phase durations

The durations of the full takeoff phase from brake release (BR) to reaching 1500 feet AGL, as well as the duration of the window between V1 and 400 feet AGL, were calculated as follows:

Basic kinematic equation of motion during takeoff roll:

$$\Delta t = \frac{Vf - Vi}{a}$$

where V_f = the final velocity at the end of time period (ft/sec)

V_I = the initial velocity at the start of the time period (ft/sec)

a = the average acceleration over the time period (ft/sec2)

Basic kinematic equation during initial climbout:

$$\Delta t = \frac{Hf - Hi}{ROC}$$

where H_f = the final altitude at the end of time period (ft)

H_I = the initial altitude at the start of the time period (ft)

a = the average rate of climb over the time period (ft/sec)

The following table shows the calculated durations using these equations:

					Full TO	V1 to 400'
Takeoff Roll Phase	a (g's)	V_i (KCAS)	V_f (KCAS)	Δt (sec)	t tot (sec)	t tot (sec)
a (BR to V1)	0.35	0	135	20.2	20.2	-
a (V1 to VR)	0.25	135	150	3.1	23.3	3.1
Initial Climb Phase	ROC	H_i (ft)	H_f (ft)	-	t tot (sec)	t tot (sec)
Vr to 400' AGL	2000	0	400	12.0	35.3	15.1
400' to 1500' AGL	2500	400	1500	26.4	61.7	-

These are generalized approximations for the purpose of a general probability estimate. In actuality the values of acceleration, ROC, V1, VR, etc. vary considerably between models.

APPENDIX

QUESTIONS FROM HON. PETER A. DEFAZIO FOR MR. MUILENBURG

General Questions

Question 1. Mr. Muilenburg, the last two new airplanes developed by Boeing, the 787 Dreamliner and the 737 MAX, have been the subjects of worldwide groundings. Before the 787 grounding, the last airliner type to be grounded was the DC–10 in 1979. What efforts has the company taken in response to both groundings to ensure future airplane designs do not have similar fates?

ANSWER. After the 737 MAX grounding, Boeing initiated a review by a special board committee. That committee recommended several changes to our organization and processes designed to enhance safety culture of the company. These changes include:

(1) Creating a permanent Aerospace Safety Committee within our Board of Directors to oversee and ensure safe design, development, manufacture, maintenance, and delivery of our products and services;
(2) Creating a Product and Services Safety organization to review all aspects of product safety;
(3) Realigning the Engineering function within the company, so that engineers across Boeing will report directly to the Chief Engineer;
(4) Establishing a design requirements program to further facilitate the incorporation of historical design materials, data and information, best practices, lessons learned, and detailed after action reports to reinforce Boeing's commitment to continuous improvement;
(5) Enhancing our Continued Operational Safety Program to aid transparency and visibility of safety related issues; the Continued Operational Safety Program now will require the Chief Engineer's review of all safety and potential safety reports;
(6) To anticipate the needs of future pilot populations, re-examining assumptions about flight deck design and operation in partnership with our airline customers and industry members;
(7) Expanding our Safety Promotion Center for employees to learn and reflect on our safety culture and renew personal commitments to safety;
(8) Expanding our anonymous safety reporting system to strengthen safety management systems within Boeing and our supply chain;
(9) Investing in new capabilities, including enhanced flight simulation and computing, and advanced R&D for future flight decks, as well as pilot and maintenance technician training and STEM education.

Question 2. Mr. Muilenburg, the 737 fuselage is based on the 707 fuselage introduced in 1958. The original 737 itself was type-certified in 1967. The trim wheel in the 737 MAX—an important part of the story of the 737 MAX crashes—also dates to the 1967 737 version. For more than 50 years this aircraft's type certificate has been amended 13 times. Redesigns may save design and development costs, but they present challenges regarding upgrades to the safety of the aircraft. What sorts of challenges did re-designing the 737NG into the 737 MAX present and when will Boeing decide the 737 has had its day and that it's time to develop an entirely new single-aisle airplane?

ANSWER. The certification of a derivative model aircraft is not necessarily less expensive, or less time consuming, than obtaining a new type certificate. For instance, the certification for the MAX took more than five years, which is longer than the process for some new type certificates. Each aircraft presents its own challenges. However, building upon existing, safe designs with a proven track record has continuously improved the safety record of the aviation industry for decades. As to future new-airplane development decisions, we make such decisions deliberately and

methodically, after studying the market demand and the current state of technology, among many other factors.

FAA Emergency Airworthiness Directive

The day after Boeing issued its November 6, 2018, flight crew operations manual bulletin numbered TBC–19, the Federal Aviation Administration (FAA) issued its emergency airworthiness directive (AD) to owners and operators of 737 MAX airplanes. Like Boeing's bulletin, the emergency AD described how erroneously high angle of attack (AOA) inputs can cause "repeated nose-down trim commands," with nose down trim increments "lasting up to 10 seconds," which, if not addressed, could cause control difficulties and "possible impact with terrain." As with the bulletin, there was no mention of MCAS whatsoever in this document issued to operators across the globe after the Lion Air flight 610 accident.

Question 1. Did Boeing work with the FAA to develop the FAA's emergency AD issued on November 7, 2018?

Question 2. Did Boeing have any discussions with the FAA, written or oral, specifically about whether MCAS should be mentioned in this document?

Question 2.a. If yes, why was MCAS ultimately excluded?

Question 2.i. Did Boeing recommend or suggest that MCAS be excluded?

Question 2.ii. If so, why did Boeing suggest MCAS be excluded from the FAA's emergency AD?

Question 2.b. If no, why did you not discuss MCAS with the FAA in regard to the emergency AD?

ANSWER. Boeing and the FAA worked closely together in developing both Boeing's Flight Crew Operations Manual Bulletin ("OMB") issued on November 6, 2018, and the FAA's Emergency Airworthiness Directive ("AD") issued the next day, on November 7, and were in agreement about the content of both issuances. Boeing also issued a fleet-wide message on November 10 that provided details regarding the MCAS function.

Boeing issued the November 6 OMB to all owners and operators of 737 MAX planes. The OMB called attention to the airplane effects and flight deck indications that could result from erroneous AOA data, including nose down stabilizer trim movement, and directed flight crews to existing procedures to address the condition. The OMB reinforced that implementation of the Runaway Stabilizer Non-normal Checklist, one of only a handful of procedures that pilots must commit to memory, was the appropriate response to uncommanded nose down stabilizer trim movement. The OMB also reminded flight crews of the importance of trimming out the airplane before turning off the electric stabilizer trim system, noting that "[i]nitially, higher control forces may be needed to overcome any stabilizer nose down trim already applied," and that electric stabilizer trim can be used to neutralize control column pitch forces before moving the STAB TRIM CUTOUT switches to CUTOUT." The OMB advised operators to insert it into their Flight Crew Operations Manual, and provided that the OMB "remains in effect until Boeing provides additional information on system updates that may allow this Bulletin to be canceled."

The same day Boeing issued the OMB, the FAA issued a Continued Airworthiness Notification, which advised that the MAX involved in the Lion Air incident "appears to have experienced anomalies in the angle of attack, airspeed, and altitude indications." The Notification further explained that Boeing had issued the OMB to address the issue, and that the FAA was considering mandating the OMB.

The FAA followed through with this action the next day (November 7), issuing an Emergency Airworthiness Directive to mandate the guidance in Boeing's OMB. The AD required the information in the OMB to be added to all 737–8 and 737–9 Airplane Flight Manuals within three days. This information included the instruction, almost verbatim from the OMB, to follow the existing runaway stabilizer procedure if flight crews experience circumstances involving uncommanded downward trim commands. Like the OMB, the AD also referenced the possible need for flight crews to use electric stabilizer trim to overcome nose down trim already applied before activating the stab trim cutout switches. Boeing began complying with this AD by including a revised Airplane Flight Manual with delivered 737 MAX airplanes, and advised operators on November 8 that the revised Manual was available on the Boeing web portal.

On November 10, responding to operator requests for additional information about the subject matter of the OMB and AD, Boeing sent a fleet-wide message to all 737 NG and MAX customers that provided technical details and operational information regarding the MCAS function.

Boeing's interactions with the FAA in connection with the preparation and issuance of the OMB and AD reflected the Company's commitment to full trans-

parency with the FAA and to acting in close coordination with regulatory authorities, and subject to their ultimate authority, on safety issues.

Boeing's Response Post-Ethiopian Airlines Flight 302 Accident

Mr. Muilenburg, at an April 29 press conference, you said that the AOA Disagree alert, which we learned was inoperative on most 737 MAX aircraft, "is not something that drives pilot action."

Question 1. Are you saying that pilots would do nothing if their AOA Disagree alert illuminates?

Question 2. How do you reconcile your comments with the Indonesian authorities' report released last month on the Lion Air crash indicating that without the alert's enabling, pilots could not document the issue, which may have helped maintenance staff identify the mis-calibrated AOA sensor that triggered MCAS on Lion Air flight 610?

ANSWER. Mr. Muilenburg was speaking about the fact that, at the time of the accidents, there were no specific pilot actions described in the Flight Crew Operations Manual for the situation when the AOA DISAGREE alert illuminated. We do not believe that the Lion Air report contains any contradictory information.

At the time of the accidents, and of Mr. Muilenburg's statement, references to the AOA DISAGREE alert in flight crew manuals and procedures did not direct the crew to take any specific action in response to the alert activating, but instead directed the crew to other information present on the flight display. Thus, the Boeing flight crew manual at the time of the accident included a checklist for the AOA DISAGREE alert, which sets forth the procedures that flight crew should use in a situation in which the alert activates. That checklist did not specify any pilot action, but rather highlighted that if the alert is on, "airspeed errors" and the "IAS DISAGREE alert" (airspeed), as well as "altimeter errors" and the "ALT DISAGREE alert" (altitude), "may occur."

These airspeed and altitude alerts are triggered independently of the AOA DISAGREE alert, and have their own prominent displays on the flight deck. Moreover, they have their own dedicated checklists that, unlike the then operative AOA DISAGREE alert checklist, *do* specify responsive crew action.

When the MAX returns to service, all MAX airplanes will have an activated and operable AOA DISAGREE alert as a stand-alone, standard feature.

Question 3. Mr. Muilenburg, at an April 29 press conference, you said that MCAS is "not something that needs to be trained on separately. It's fundamentally imbedded in the handling qualities of the airplane. And so, when you train on the airplane, you're being trained on MCAS."

Knowing what you know now, do you stand by your comments?

ANSWER. MCAS is an extension of the pre-existing Speed Trim function, which helps stabilize airplane speed by commanding stabilizer in the direction to oppose a speed change, and which has been used safely on 737 series airplanes for decades. As such, MCAS is part of an integrated flight control system, and its effects are embedded in the handling qualities of the airplane. Going forward, however, as Mr. Muilenburg testified, Boeing will provide additional information regarding the MCAS system as part of training for the MAX.

Question 4. Given the two accidents involving unintended MCAS activation, do you now believe that pilots should have known about MCAS before flying a MAX? If so, why now and not then?

ANSWER. In accordance with FAA regulatory guidance, flight training for all Boeing airplanes, including the 737 MAX, is designed to give pilots the knowledge, skills, and abilities necessary to safely operate each model on which they are licensed (or "type-rated"). Boeing and the FAA coordinated closely over the course of several years in developing the necessary training requirements and flight manual content for the MAX. Since the accidents, the FAA and Boeing have worked together to develop additional MAX flight crew training, as well as flight manual content, that addresses the updates Boeing has made to MCAS. The inclusion of specific training and flight manual content on MCAS is consistent with the feedback Boeing has received from pilots and its customers, and reflects the additional knowledge and understanding that Boeing has gained as a result of these accidents.

Question 5. Mr. Muilenburg, at an April 29 press conference, you stated MCAS was "designed to provide handling qualities for the pilot that meet pilot preferences. We want the airplane to behave in the air similar to the previous generation 737's. That's the preferred pilot feel for the airplane, how it feels as they're flying it. And MCAS is designed to provide those kinds of handling qualities at high angles of attack."

If that was indeed the goal, would it have been advisable to inform pilots of potential MCAS malfunctions that would affect handling qualities or the feel for the airplane?

ANSWER. In accordance with FAA regulatory guidance, flight training for all Boeing airplanes, including the 737 MAX, is designed to give pilots the knowledge, skills, and abilities necessary to safely operate the airplanes which they are licensed to fly. Boeing and the FAA worked together over multiple years to establish the appropriate training materials for the MAX. Since the accidents, Boeing and the FAA have worked together to develop additional MAX flight crew training, as well as flight manual content, that addresses the updates Boeing has made to MCAS.

Question 6. Mr. Muilenburg, immediately after the Ethiopian Airlines crash, Boeing made clear it believed that the grounding of the 737 MAX was unnecessary. In fact, media reports widely circulated your disagreement with the idea in your conversation with President Trump, and Boeing further stated on March 12 that "based on the information currently available, we do not have any basis to issue new guidance to operators."

Do you agree with regulators' decisions to ultimately ground the 737 MAX?

ANSWER. Boeing supports the FAA's decision to ground the 737 MAX.

Question 7. Did Boeing leadership ever consider issuing a service bulletin or requesting voluntarily that FAA ground the 737 MAX prior to the FAA's official grounding?

Question 7.a. If Boeing did consider this, please provide specifics. When was this issue raised, under what circumstances, and by whom? Why was the ultimate decision made not to request that the FAA ground the 737 MAX and who at Boeing made that decision?

ANSWER. Boeing does not have the authority to ground airplanes. Boeing does, however, provide civil aviation authorities and our airline customers with any relevant information we may receive or develop, so that they can make informed decisions on how to regulate aircraft operations.

In its written response to Question #16 of the Committee's April 1, 2019 request to Boeing, Boeing provided a detailed timeline of the actions taken by the company after the Lion Air accident through the date of the 737 MAX grounding, and we refer you to that response.

Question 8. When did Boeing first learn about the FAA decision to ground the 737 MAX in U.S. airspace?

ANSWER. Boeing learned about the grounding order on March 13, 2019.

Question 9. If Boeing felt that the 737 MAX was safe enough to not warrant grounding, why was it then pursuing software changes to MCAS even before the Ethiopian Airlines crash?

ANSWER. On November 6, after a week of intensive efforts to understand and analyze the accident sequence, a Boeing Safety Review Board ("SRB")—Boeing's established process for evaluating in-service safety issues—determined that the crew workload effects of erroneous AOA input leading to activation of the MCAS function presented a safety issue, and also determined that appropriate pilot action could counteract the condition. That same day, Boeing issued an Operations Manual Bulletin ("OMB") to the fleet calling attention to the airplane effects and flight deck indications of the condition, and directing flight crews to existing procedures to address it. Boeing also moved forward expeditiously to develop an update to the MAX's flight control computer software to eliminate the risk of erroneous AOA data leading to repeated MCAS activation.

On November 7, 2018, a day after Boeing issued its OMB, the FAA issued an Emergency Airworthiness Directive ("AD") requiring airlines to amend their Airplane Flight Manuals to include the OMB guidance. The FAA also convened multiple Corrective Action Review Board ("CARB") meetings—the FAA's analog to Boeing's SRB process—starting in late November to evaluate issues relating to the airplane effects of erroneous AOA data and MCAS activation. Relying on the FAA's independent risk analysis, the CARB process largely concurred with Boeing's analysis of the safety issue and proposed risk mitigation approach—although the FAA did determine that that Boeing should implement the flight control computer software update more quickly than Boeing had originally proposed, an accelerated schedule the Company accepted. Referencing the FAA's independent risk analysis, an FAA CARB concluded in December 2018 that, as development of the software update proceeded, the MAX fleet could continue operating until the new software was implemented on the FAA-approved schedule.

Implementing the revisions to the MAX's flight control computer software is a complex task, and the Company has been and remains committed to proceeding

carefully and deliberately. Throughout this process, Boeing has closely coordinated with the FAA (and other regulators) to ensure that the software update and related issues are evaluated thoroughly and comprehensively.

What Boeing Knew Then

You testified repeatedly before our Committee that had Boeing known what it knows now, the company would have made different decisions with regard to the 737 MAX. Specifically:

> In response to my question about why Boeing didn't design MCAS from day one to use information from both AOA sensors, you said, "Mr. Chairman, we have asked ourselves that same question over and over. And if back then we knew everything that we know now, we would have made a different decision."
>
> In response to Rep. Craig's question about when Boeing should have grounded the plane, you said, "Congresswoman, we have asked ourselves that question many, many times. And if we knew back then what we know now, we would have grounded it right after the first accident."

Before the Lion Air accident, Boeing was already aware that MCAS relied on just one AOA sensor, and according to documentation made public at the hearing, a Boeing engineer as far back as 2015 had already asked, "Are we vulnerable to single AOA sensor failure with the MCAS implementation or is there some checking that occurs?"

In addition, other documentation made public at the hearing established that Boeing was also already well aware, before the Lion Air accident, that if a pilot did not react to unintended MCAS activation within 10 seconds, the result could be catastrophic.

Question 1. What new information did Boeing learn only after the October 2018 Lion Air accident, that it didn't already know previously, with regard to the potentially catastrophic risk that a malfunctioning AOA sensor could have on the MAX due to its interaction with MCAS?

Question 2. What new information did Boeing learn only after the March 2019 Ethiopian Airlines accident, that it didn't already know previously, with regard to the potentially catastrophic risk that a malfunctioning AOA sensor could have on the MAX due to its interaction with MCAS?

ANSWER. In designing MCAS, Boeing relied on well-accepted, industry-wide assumptions in evaluating how pilots would react to the uncommanded activation of MCAS for any reason, including erroneous AOA. Those assumptions proved not to be accurate in these accidents. Accordingly, we now know that there is a greater risk from unintended activation of MCAS due to erroneous AOA data than we originally thought. Our system redesign addresses this issue.

Boeing CEO Bonus Pay

On November 5, 2019, it was reported that you were declining to take your bonus in 2019 and opting out of consideration for equity grants until the 737 MAX is back in the air. Yet, as of October 26, 2019, Boeing had already announced that it would not be paying annual bonuses to its management, executives, or unionized engineers and white-collar workers.

Question 1. What 2019 bonus, if any, are you declining to accept that Boeing had not already determined that you would not be receiving?

ANSWER. Mr. Muilenburg has requested that he not receive any bonus, either short- or long-term, for 2019. He has also requested that the Board not provide him any equity grants until the MAX returns to service globally. Mr. Muilenburg has also committed to donating the entire value of any previous equity grants that vest in 2020 to charity.

Question 2. With regard to your opting out of consideration for equity grants, are you foregoing consideration for these equity grants until the 737 MAX is back in the air, or are you merely deferring consideration for these equity grants?

ANSWER. Please see the response to the previous question.

Question 3. How much was your bonus in 2018, the year of the Lion Air accident, and how much of it have you offered to return?

ANSWER. Mr. Muilenburg's 2018 compensation is publicly available in Boeing's annual proxy statement, which can be found at www.boeing.com.

Question 4. How much did you receive in equity grants in 2018, the year of the Lion Air accident, and how much of these grants have you offered to return?

ANSWER. Mr. Muilenburg's 2018 compensation is publicly available in Boeing's annual proxy statement, which can be found at www.boeing.com.

Moving Lawsuits to Indonesia

In May, it was reported that Boeing had indicated in court filings that it was likely to request that cases on behalf of the victims of the October 2018 Lion Air accident involving the 737 MAX be moved to Indonesia. At the hearing, in response to questions from both Rep. Hank Johnson and me about whether Boeing plans to seek to move litigation filed on behalf of victims of the Lion Air accident from Chicago to Indonesia, you stated that you did not know the answer and would get back to our Committee with an answer.

Question 1. Your answer also suggested this was an issue you had not been briefed on or involved in, in any way at Boeing. Now that you have had time to review records relevant to this question since the hearing, did you receive any briefings regarding Boeing's litigation strategy regarding the Lion Air accident in Indonesia?

Question 2. Is Boeing planning to seek to move litigation filed on behalf of the families of victims of the Lion Air accident from Chicago to Indonesia?

Question 3. Does Boeing have any reason to believe that if it loses this litigation, it will ultimately have to pay less to the plaintiffs if the litigation takes place in Indonesia as opposed to in the United States?

Question 4. Are you aware of differences between the Indonesian legal system and the one we have in the United States including but not limited to the lack of a Seventh Amendment right to a jury trial, a right to a cross-examination of witnesses, and a requirement of discovery in Indonesia?

ANSWER. In response to both MAX accidents, Boeing has offered to engage in mediations in the United States to resolve the families' claims without the need for any litigation. To facilitate this, Boeing arranged for a prominent Chicago mediator, a former Chief Judge of the Circuit Court of Cook County, to assist, and is paying the full costs of all mediations. Since the middle of July, Boeing has been working with the mediator and the families who lost loved ones in the Lion Air accident, to settle these cases. We are pleased to have resolved approximately one half of the claims filed in the United States on terms that we believe fairly compensate the victims' families. We remain committed to this mediation process. If, at some point and despite Boeing's best efforts, an impasse is reached in the mediation process, the litigation may resume. And at that point, well-settled U.S. law will give Boeing the option of requesting that the court determine whether another jurisdiction is the appropriate venue for such cases.

Boeing is aware that there are differences between the litigation procedures available in the U.S. and those available around the world. United States courts have routinely found such foreign forums appropriate to handle aviation accident litigation in certain circumstances. All decisions in this litigation about forum will be decided by U.S. courts applying well-settled U.S. law.

QUESTIONS FROM HON. RICK LARSEN FOR MR. MUILENBURG

Question 1. I understand that when Boeing's attorneys met with Committee staff regarding Mr. Forkner's Instant Messages, Boeing was in the midst of investigating whether his reference to problems with MCAS in the simulator were actually problems with MCAS or with the simulator itself. Now that Boeing has had time to further investigate these issues, please provide the Committee with any supporting records indicating the problems that Mr. Forkner referenced were really problems with the simulator or conversely issues with MCAS itself.

Please include a list of Boeing managers or employees and FAA managers and employees to whom Mr. Forkner reported these issues, whether MCAS- or simulator-related, and the actions taken to remedy the issues and provide supporting records to verify this correction.

ANSWER. As you note, Boeing provided Committee staff with an extensive briefing on this topic. This included providing Committee staff with supporting records, including a discrepancy report for the simulator that closely matches the conditions described in the instant message, and documentation regarding the investigation and resolution of that discrepancy report. Our review remains ongoing; we have no additional documentation to provide at this time.

QUESTIONS FROM HON. SALUD O. CARBAJAL FOR MR. MUILENBURG

Question 1. In simulator tests, I understand that Boeing didn't even simulate erroneous MCAS activation to the full 2.5 degrees of stabilizer motion. Is that correct and if so please explain why that sort of simulation did not take place?

ANSWER. This is not correct. Among other conditions considered during the MAX development process, Boeing simulated uncommanded MCAS operation to the maximum nose down stabilizer authority both before and after the expansion of MCAS to operate in low speed conditions. In early 2016, Boeing conducted simulator testing in an engineering simulator known as an eCab involving the uncommanded activation of MCAS to 3.0 degrees of nose down stabilizer motion, which at the time was the maximum authority at low speed.

QUESTIONS FROM HON. SHARICE DAVIDS FOR MR. MUILENBURG

Question 1. Mr. Muilenburg, when and how did you learn that the AOA Disagree Alert on the 737 MAX was only functioning on aircraft that purchased the optional AOA Indicator? Please also include who informed you of that information and what you did in response.

ANSWER. Mr. Muilenburg was not aware of the discrepancy between how the AOA DISAGREE alert was intended to function, and how it was delivered, until after the Lion Air accident. At that point, the Boeing Company took swift action to address this issue. Pursuant to the recommendations of a special board committee, the Boeing Company has revised its Board structure to ensure issues like this are brought more quickly to the attention of senior management.

Question 2. Has Boeing taken any disciplinary action against any of the individual Boeing employees who were aware the AOA Disagree Alert was not functioning prior to the Lion Air crash and did not take any steps to either inform the FAA or your customers? If so, please describe what action Boeing has taken.

ANSWER. As Mr. Muilenburg testified, our current focus as a Company is on doing everything possible to ensure the safe return of the MAX to service. We owe this to our customers and the flying public. That said, once the MAX is safely back in service, the time will come to consider further questions of accountability. And Boeing will not hesitate to hold people accountable, where appropriate.

Question 3. Boeing's marketing brochures published after the FAA certified the 737 MAX in 2017 suggest that Boeing had expected the FAA to require more significant pilot training than FAA ultimately required for the MAX. Did the FAA's acceptance of Level B non-simulator training for the 737 MAX come as a surprise to Boeing?

ANSWER. The determination of what training was appropriate for the MAX was a multi-year process between Boeing and the FAA. Boeing provides input into that process. However, commercial aviation is a highly regulated industry, and both manufacturers and customers know that the relevant civil aviation authorities ultimately decide what training is required.

QUESTIONS FROM HON. SAM GRAVES OF MISSOURI FOR MR. MUILENBURG

Question 1. How is Boeing working to develop procedures that are more tolerant of "human factors" or interactions between "human and machine"? Is human performance currently a major consideration during the safety evaluation process?

ANSWER. Boeing's design, analysis and evaluation approach is based on FAA guidance and published industry standards. Human performance is and will continue to be an important consideration in the evaluation of all Boeing airplanes. As part of the design and evaluation process, Boeing has Human Factors specialists, engineers, and pilots that consider the effects of cognition, perception, physical ergonomics, anthropometry, and human computer interface on Boeing's design. Boeing is in the process of re-evaluating our processes and assumptions regarding human factors as a result of information we have learned from the investigations into the MAX accidents. This review is not limited to the MAX.

Question 2. It is Boeing's position that the MCAS was not hidden from FAA, customers, and pilots. In what ways did Boeing ensure MCAS was known and understood by all those parties?

ANSWER. Boeing briefed the FAA and international regulators on numerous occasions about MCAS and its final design parameters. Although MCAS itself had been discussed in multiple briefings over many years, the meetings and information exchanges with regulators regarding MCAS's final design parameters began in mid-2016 and continued over subsequent months. The information provided to the FAA in these interactions included MCAS's maximum stabilizer authority of 2.5 degrees, as well as other aspects of the control law's functioning. For example, the use of MCAS at low speeds was included in briefing materials for meetings between Boeing and the FAA in July 2016, a revised certification deliverable submitted to the

FAA in October 2016, and materials from validation meetings between Boeing staff and regulators in the fall of 2016.

In addition to these briefings, FAA personnel also observed the operation of MCAS during certification flight testing. Boeing and the FAA began certification flight testing of the 737 MAX 8 in August 2016. Multiple conditions involving MCAS activation were flown through January 2017. The objectives for these tests included demonstrating that the 737 MAX 8 had compliant maneuvering and handling characteristics in stall and near-stall conditions. The tests also evaluated whether the airplane could safely fly and land with various control system malfunctions or simulated failures. The conditions tested included MCAS's performance during low speed stalls, and during these tests, MCAS was activated nearly to the limit of its maximum stabilizer authority of 2.5 degrees. FAA personnel—including engineers, pilots, and at times both—were on board many of these flight tests to observe the performance of the flight conditions, including those involving MCAS. In some cases, FAA test pilots were at the controls and flew the relevant conditions. Boeing also provided the FAA with data of MCAS activating in low speed conditions.

Descriptions of MCAS were included in presentations given to multiple customers at conferences for MAX customers, and Boeing received questions from customers about MCAS and its operation prior to delivery. Boeing did not hide information on the system, and provided information in response to those customer inquiries.

Question 3. When the MAX and MCAS were being tested, what were Boeing's assumptions related to flight crews' reactions to erroneous MCAS function?

ANSWER. As authorized by applicable FAA guidance, including FAA Advisory Circular 25–7C ("Flight Test Guide for Certification of Transport Category Airplanes"), in conducting their hazard assessments, Boeing's subject matter experts made a series of assumptions about how a flight crew would react if MCAS failed or did not function as intended. Consistent with established FAA guidance, this included the assumption that the crew would recognize and address uncommanded MCAS activation through normal use of the control column and the electric trim switches, and that the crew would also be able to use the stabilizer cutout switches and rely on manual trimming (as outlined in the Runaway Stabilizer Non-Normal Procedure) to stop any unintended stabilizer motion. Test pilots participated in the simulator testing of MCAS and had vital input into the hazard analysis.

Question 4. How is Boeing working with customers, airlines, pilots, and regulators to address their concerns with the 737 MAX going forward?

ANSWER. Boeing has taken extensive action to update the MAX flight control system, and to rebuild confidence with our customers, our regulators, and the pilots who fly our aircraft.

We have made three key changes to the MCAS flight control software that will prevent accidents like these from happening again:

- The flight control system will compare inputs from both angle-of-attack sensors, and MCAS will not activate if the sensors disagree by 5.5 degrees or more.
- MCAS will no longer activate repeatedly. It will provide one input for each elevated angle-of-attack event.
- Finally, MCAS will never be able to command more stabilizer input than can be counteracted by the flight crew pulling back on the control column.

Boeing has worked to update the MAX flight control software, we have been actively engaged with airlines and pilots throughout the process. As of November 26th, 2019, Boeing has conducted simulator sessions with 545 participants from 99 of our airline customers and 41 global regulators to give them an opportunity to fly the new software. We have spent over 150,000 engineering and test hours relating to the MAX, and have flown more than 992 test and production flights.

Boeing has been transparent with regulators in their review of the MAX, and, consistent with our culture, we have prioritized safety. The MAX will not return to service until the FAA and other global regulators have complete confidence that it is safe to do so.

QUESTIONS FROM HON. GARRET GRAVES OF LOUISIANA FOR MR. MUILENBURG

Question 1. It does seem that Boeing, the Boeing ODA, and FAA did not always communicate well and had both lax as well as informal recordkeeping processes. Do you believe these processes need to be improved? If so, how would you propose to improve Boeing's communication and recordkeeping processes?

ANSWER. As Mr. Muilenburg testified, Boeing believes these processes can and should be improved. The FAA requires extensive and detailed recordkeeping from ODA holders in order to enable the FAA to conduct compliance checks and audits of those ODA holders' performance. Boeing is consistently working to improve the

performance of our ODA, and that includes our recordkeeping and our transparency with regulators.

Boeing's ODA procedures manual, which is approved by the FAA, contains procedures to ensure certain communications between Boeing ODA unit members and the FAA are formally documented and managed. These procedures help ensure the ODA is properly following FAA guidance. Expanding this type of documentation requirement will help facilitate both safety and transparency.

Question 2. Additionally, during the hearing I asked Mr. Muilenburg to provide the Committee with responses to the following questions:

Question 2.a. After reviewing the recommendations of NTSB and others available as of the date of the hearing (October 30, 2019), please advise the Committee of any of those recommendations that Boeing does not concur with?

ANSWER. Boeing is deeply committed to the safety of its products and the safety of the aviation system and value the role of the NTSB in promoting aviation safety. We do not oppose the recommendations from the NTSB to the FAA on September 26, 2019. Boeing has already undertaken steps that align with at least one of the NTSB's recommendations.

The NTSB recommended that FAA require manufacturers to consider the way cockpit design can impact pilot reaction to alerts and alarms that may sound in non-normal situations.As a result of a recommendation from a special committee of Boeing's Board of Directors, the company is already planning to work with our airline customers to re-examine the way we design our cockpits, with the goal of helping pilots to prioritize their attention and their actions when faced with multiple alerts and alarms. Boeing is taking this step with the recognition that pilot training and experience can vary significantly in different regions of the world.

Question 2.b. Provide an explanation of the specific changes Boeing is making to the 737 MAX to help us better understand the proposed fixes Boeing will submit to the FAA for recertification?

ANSWER. Boeing has made 3 key changes to the MCAS flight control software:

- The flight control system will compare inputs from both angle-of-attack sensors, and MCAS will not activate if the sensors disagree by 5.5 degrees or more
- MCAS will no longer activate repeatedly. It will provide one input for each elevated angle-of-attack event.
- Finally, MCAS will never be able to command more stabilizer input than can be counteracted by the flight crew pulling back on the control column.

In addition, working under the guidance of the U.S. Federal Aviation Administration, Boeing also addressed certain highly improbable scenarios involving the flight control computers on the 737 MAX. The two flight control computers on each MAX airplane will now monitor one another continuously, known as "cross-checking." This will further enhance the safety of the airplane.

Question 2.c. Provide responses to the following recommendations made by the 737 MAX accident victims' families. Is Boeing willing to commit to——

i. Publicly disclosing the MCAS fix?
ii. Clearly defining the utility of MCAS?
iii. Addressing concerns that the culture within Boeing might have been prioritizing the wrong things?
iv. Ensuring that there were no efforts to conceal the MCAS and its role?
v. Ensuring that the entire airplane is viewed as an integrated system, as opposed to individual components where safety regulators may not be able to recognize their role in the larger system.

ANSWER. Yes, Boeing is committed to keeping the public informed about the status of the enhancements being made to the MCAS system. Boeing has created a public website with information regarding the MAX to facilitate dissemination of information regarding the MAX. That website is located at http://www.boeing.com/737-max-updates/. Boeing is also committed to demonstrating the safety of the 737 MAX to regulators as well as the flying public, including the safety of its design and the improvements that have been made since the accidents. As Boeing has publicly stated, when the MAX returns to service, MCAS will compare inputs from both angle-of-attack sensors on the MAX, it will only activate one time per high angle-of-attack event, and MCAS will never command more stabilizer input than can be counteracted by the flight crew pulling back on the control column.

In addition, Boeing is committed to safety as a core value of the company. Boeing has undertaken a number of structural changes to strengthen this commitment, including the creation of a permanent Aerospace Safety Committee within our Board of Directors, the creation of a new internal Product and Services Safety organization, and reorganization of the company's engineering function. These changes will

enhance and amplify our focus on safety, strengthen our culture, and help to ensure that the safety of all our products are evaluated holistically.

Boeing is also committed to ongoing transparency with FAA and international regulators, who were briefed on multiple occasions about the existence of MCAS, as well as MCAS's final configuration and operating parameters. During the certification process, MCAS was installed on the airplanes used for training-related flight testing that the FAA administered in August 2016. And FAA personnel observed the operation of MCAS in its final configuration during certification flight testing, beginning in August 2016 and continuing through January 2017. Boeing is working hand-in-hand with regulators to return the 737 MAX to service.

Question 3. The Chairman read from a December 2015 email where a Boeing engineer asked: "Are we vulnerable to a single AoA sensor failure . . . " In what context was this email sent and what exactly is your understanding of the concern raised in the email? How was the concern addressed?

ANSWER. The development of MCAS was an integrated effort involving numerous technical disciplines across Boeing. Multiple Boeing test pilots, as well as engineers across many different organizations, were involved in the development process and in the work of designing the function's operating parameters, developing test conditions, and evaluating the safety and efficacy of the design. Information was shared freely among the individuals and groups involved in these efforts, and the discussion of issues relating to the evolving design was robust.

The referenced communication occurred during this design process. The issue raised in the quoted sentence was one among innumerable technical issues discussed during the design and development of the 737 MAX. As Mr. Hamilton testified, he has discussed the general topic of MCAS's reliance on a single sensor with one of the engineers involved in this exchange. As Mr. Hamilton further testified, this communication reflects and demonstrates Boeing's open engineering culture, which encourages the robust discussion of technical issues and concerns as an integral part of the design process.

Boeing engaged in a multi-step process for evaluating the potential safety considerations involved in the implementation of MCAS. At each stage of the design, development, and testing of MCAS, Boeing subject matter experts reviewed and evaluated the design change and its potential safety implications. The MCAS safety evaluation was consistent with applicable FAA guidance, including in relying on well-accepted, industry-wide assumptions by Boeing's experts about how crew members would act or react to different scenarios involving uncommanded MCAS activation.

Question 4. During the hearing, Mr. Hamilton stated that a version MCAS is implemented on the KC–46 tanker. Can you provide more details on the KC–46 tanker version of MCAS and the 737 MAX MCAS? Please describe any differences and the reason for those differences?

ANSWER. A version of the MCAS control law was implemented on the KC–46 767 Tanker airplane. However, the architecture, implementation, and pilot interface of MCAS are different for the KC–46 tanker and the 737 MAX.

The 737 MAX MCAS function is an extension of the pre-existing Speed Trim System. This system resides in the Flight Control Computer (FCC), and helps stabilize the airplane speed by commanding stabilizer in the direction to oppose a speed change. This system has been used safely on 737 series airplanes for decades. In adding MCAS to the 737 MAX, Boeing determined to utilize the existing speed trim system architecture, including use of a single sensor for AOA inputs, consistent with the fundamental airplane design principle of minimizing unnecessary changes to a sound and safe existing airplane design. With this design, the 737 MAX was able to meet all design requirements, including those associated with the applicable functional hazard assessment hazard categories.

Question 5. Were there differences between the final MCAS design and its original design requirements? The witnesses indicated that Boeing's MCAS design met FAA regulatory standards and Boeing's own design requirements. What were those standards and design requirements? On what basis was it determined that Boeing's MCAS design met FAA regulatory standards and Boeing's own design requirements?

ANSWER. MCAS's design changed over time. Boeing developed and refined MCAS design requirements, including those requirements discussed by the witnesses, such as the requirements related to dive recovery and MCAS's interaction with the piloting of the airplane, that defined how MCAS would function in normal operation. MCAS, as originally certified, met those requirements for normal operations. Unless otherwise expressly noted in the requirements, the specific requirements were not intended to apply to abnormal operation or in failure conditions. To assess those sit-

uations, Boeing experts initially performed a thorough safety assessment for the initial MCAS design, which would activate only in high-speed conditions, with Boeing test pilots and engineers conducting a number of piloted simulator sessions in 2012 and 2013 to evaluate possible hazards. In March 2016, concurrently with developing the requirements for MCAS to operate at low speeds, Boeing subject matter experts—including both engineers and experienced pilots—conducted an additional targeted assessment of the potential hazards posed by MCAS's greater stabilizer authority at low speeds. In performing this assessment, Boeing's experts applied their engineering judgment and piloting experience to the existing safety analysis and data for the earlier MCAS design, and also considered new performance data generated through piloted simulator testing and computer analysis of MCAS's operation at low speeds.

Boeing's subject matter experts had already concluded that MCAS's earlier design met all applicable functional hazard assessment thresholds. Based on their updated hazard analysis, Boeing's subject matter experts concluded at the end of March 2016 that the expanded version of MCAS also met all applicable requirements, and did not create any heightened risks beyond the earlier design.

Among other conditions tested during the MAX development process, Boeing considered uncommanded MCAS operation resulting in unintended nose down trim to the maximum stabilizer authority for both the earlier and expanded MCAS designs. In March 2016, based on new simulator testing, Boeing experts assessed this condition as a "Minor" hazard when uncommanded operation of MCAS occurred at low speed in the normal flight envelope. This was a lower classification category than had been assessed for the uncommanded operation scenario for the earlier MCAS design, which had been active only in high speed, high G-force conditions. Based on this testing and analysis performed during the lengthy MCAS development process, Boeing's technical experts determined that the hazard classification categories for both the high-speed and expanded MCAS functionality satisfied all applicable regulatory and certification requirements.

As authorized by applicable FAA guidance, including FAA Advisory Circular 25–7C ("Flight Test Guide for Certification of Transport Category Airplanes"), in conducting their hazard assessments, Boeing's subject matter experts made a series of assumptions about how a flight crew would react if MCAS failed or did not function as intended. This was the case for their hazard assessments of both the earlier and expanded MCAS designs. Consistent with established FAA guidance, this included the assumption that the crew would recognize and address uncommanded activation through normal use of the control column and the electric trim switches, and that the crew would also be able to use the stabilizer cutout switches and rely on manual trimming (as outlined in the Runaway Stabilizer Non-Normal Procedure) to stop any unintended stabilizer motion. Test pilots participated in the simulator testing of expanded MCAS and had vital input into the hazard analysis.

Question 6. Boeing has stated that it assumed that pilots would react a specific way to repeated, unexpected nose down stabilizer trim inputs due to MCAS activation. Can you describe what assumption Boeing made in terms of how pilots would react and what actions they would take in response to repeated, unexpected nose down stabilizer trim inputs? What was the basis for this assumption?

ANSWER. As authorized by applicable FAA guidance including FAA Advisory Circular 25–7C, in conducting their hazard assessments, Boeing's subject matter experts made a series of assumptions about how a flight crew would react if MCAS failed or did not function as intended. Consistent with established FAA guidance, this included the assumption that the crew would recognize and address uncommanded activation through normal use of the control column and electric trim switches, and that the crew would also be able to use the stabilizer cutout switches (as outlined in the Runaway Stabilizer Non-Normal Procedure) to stop any unintended stabilizer motion.

Question 7. In January 2019, Boeing recommended Level A differences training (pilot training) accompany introduction of the MCAS updates. Please describe on what basis Boeing made this recommendation.

ANSWER. In the wake of the Lion Air accident, Boeing and the FAA have carefully scrutinized the level and content of appropriate training for MAX pilots. Prior to the grounding of the MAX fleet on March 13, 2019, following the Ethiopian Airlines flight 302 accident, the FAA did not impose any additional training requirements for flight crews operating the existing MAX fleet, which still had the original, certified version of MCAS installed. The FAA and Boeing each independently deemed the issuance of the OMB and AD, combined with the existing training curriculum, sufficient to enable the safe operation of the fleet pending the implementation of up-

dated flight control computer software, which Boeing began developing immediately after the Lion Air accident.

Simultaneous with the development of that software update, Boeing and the FAA assessed potential additional training requirements for pilots who would operate MAX airplanes with the updated software, as is typical for such a design change. Boeing began working closely with the FAA starting in December 2018 to develop this training plan and associated evaluation testing.

Responding to the FAA's request for a training proposal, Boeing in January 2019 initially recommended Level A differences training for the MCAS updates. Boeing noted in support of this recommendation that the "difference between the 737 NG and 737 MAX relating to the MCAS flight control law do[es] not affect pilot knowledge, skills, abilities, or flight safety." No specific differences training is required under the applicable regulatory guidance when this standard is met. Boeing nonetheless was proposing Level A training in response to "customers' continued interest in the MCAS flight control law." Boeing also proposed a plan to substantiate the training proposal for the FAA, including the use of flight simulators to demonstrate various flight scenarios involving the updated MCAS functionality.

Boeing worked expeditiously to complete its evaluation and approval plan, submitting the final plan to the FAA on February 11. The FAA accepted the plan, and agreed to Boeing's proposed date for simulator testing of March 13. The FAA expressed willingness "to evaluate Boeing's proposal for Level A training," but also advised that the evaluation "is proceeding at risk," meaning that the FAA could ultimately determine based on the evaluation results to require a higher level of training.

The simulator testing took place as planned on March 13, using a test procedure agreed upon with the FAA. Representatives from the FAA—as well as the European Union Aviation Safety Agency and Transport Canada—participated in the testing.

The next day, March 14, the FAA sent Boeing its pilot training evaluation for the updated MCAS. The FAA noted that the Flight Standardization Board ("FSB") for the MAX had determined that "no pilot handling differences exist between the B–737 NG series and B–737 MAX aircraft in normal and non-normal operation of MCAS." In the FAA's evaluation, "[t]he NG and MAX aircraft handled the same and no aircraft device training is necessary." Nonetheless, the FAA explained, "[t]he FSB determined that Level B training and checking is required to ensure pilot knowledge and retention of MCAS for initial, transition, upgrade, and recurrent [training]." After describing the exhaustive test scenarios performed during the evaluation process, the letter concluded that "level B training is provisionally approved" pending certification of the MCAS updates.

In accordance with the FSB's determination, Boeing provided the FAA a computer-based Level B training module for evaluation. The FAA FSB evaluated and tested this module on March 18, and the following day the FAA wrote to Boeing that the module "satisfies the Level B training and checking requirement." On March 25, the FAA sent Boeing further written confirmation that "[v]alidation of level B [computer-based] training met all knowledge, skills, and abilities required to fly the MAX." And on April 16, the FAA posted a draft FSB report for public comment, in which the FAA described the FSB's "evaluation of the modified [MCAS] for training and checking differences determination," and stated that "[t]he MCAS system was found to be operationally suitable." That draft report has not been finalized.

Boeing's discussions with the FAA about pilot training for the MCAS updates have continued since the FAA's posting of the FSB's draft report in April. Boeing is committed to continuing to work with the FAA to ensure that pilots receive appropriate training to accompany the MCAS updates in connection with the MAX's return to service.

Question 8. Earlier this year, it was discovered that in 2017 Boeing learned that the AOA DISAGREE alert on the 737 MAX was not operable on all airplanes. What steps did Boeing take upon making this discovery? Did Boeing immediately inform the FAA and its customers? If not, why not?

ANSWER. In 2017, within several months after beginning 737 MAX deliveries, engineers at Boeing identified that the 737 MAX display system software delivered by Boeing's supplier did not correctly meet the requirements relating to the AOA DISAGREE alert. Instead of activating the AOA DISAGREE alert on all MAX airplanes, as Boeing's requirements provided, the software activated the alert only if an airline selected the optional AOA indicator. When Boeing's engineers identified the discrepancy between the requirements and the software, Boeing followed its standard process for determining the appropriate resolution of such issues. That review, which involved multiple company subject matter experts, determined that the

absence of the AOA DISAGREE alert did not adversely impact the safety, operation, or certification of the airplane. Accordingly, the review concluded, the existing functionality was acceptable until the alert and the indicator could be delinked in the next planned display system software update, scheduled for 2020.

Shortly after the Lion Air Flight 610 accident on October 29, 2018, both Boeing and the FAA informed MAX operators that the AOA DISAGREE alert was available only if the AOA indicator option had been installed. In the discussions that followed, Boeing fulfilled several customer requests to implement the AOA indicator, and by extension the AOA DISAGREE alert, on their airplanes. Boeing also discussed the status of the AOA DISAGREE alert extensively with the FAA—including the software discrepancy identified in 2017 and Boeing's determination that the issue was not safety related. In close coordination with the FAA, Boeing convened a Safety Review Board in December 2018, which confirmed the prior determination that the absence of the AOA DISAGREE alert from certain 737 MAX flight displays did not present a safety issue. Boeing fully informed the FAA about this result and the underlying analysis. The FAA subsequently informed Boeing that it had convened a Corrective Action Review Board and reached the same conclusion that the AOA DISAGREE alert issue did not present an unsafe condition.

Boeing determined shortly after the Lion Air accident to accelerate the AOA DISAGREE alert software update, and began the required software development. MAX customers were informed of this plan beginning in November 2018. As a result of these software development efforts, when the MAX returns to service, all MAX airplanes will have an activated and operable AOA DISAGREE alert.

QUESTIONS FROM HON. BRIAN BABIN FOR MR. MUILENBURG

Question 1. Would it be fair to say that you didn't inform pilots about MCAS because when there is an emergency in the cockpit, you want them to respond to the problem versus diagnose the problem? For instance, like when I am driving my car, and it's veering off the side of the road, I don't sit there and think, what is causing this, my first thought is to steer the car back into the lane. Is that a fair comparison?

ANSWER. In accordance with FAA regulatory guidance, flight training for all Boeing airplanes, including the 737 MAX, is designed to give pilots the knowledge, skills, and abilities necessary to safely operate each model on which they are licensed (or "type-rated"). This is not necessarily the same information that would be needed to diagnose particular types of failures, as the accepted training philosophy is to equip pilots to address the particular non-normal condition at issue, not diagnose the underlying cause of the failure. The priority in developing the pilot training curriculum is always on giving pilots the knowledge they need to safely fly the airplane.

Question 2. How do other manufacturers from other countries certify their planes? Do they have something similar to delegation?

ANSWER. Delegation is common in aviation systems throughout the world, though each regulatory authority handles delegation differently. For instance, the European Aviation Safety Agency also uses a system of delegation.

Question 3. This committee clearly has a lot of concern about how Boeing prioritizes its safety versus its desire to make a profit and increase its stock price. Boeing has talked a lot recently about the recommendations that its board made, in what I see as an attempt to respond to that criticism and concern. On a day-to-day basis, how will those changes really lead to Boeing making safer airplanes?

ANSWER. First and foremost, the changes Boeing has made will reinforce Boeing's safety culture. The Product and Services Safety organization will review all aspects of product safety, across the enterprise, ensuring that an independent organization within the company is responsible for reviewing safety concerns and allegations of undue pressure. It also enhances the presence of dedicated, safety-related leadership and accountability within Boeing's corporate structure. Moreover, by realigning the engineering function so that each engineer reports to the Chief Engineer, we have ensured that all engineers report to technical staff. Finally, we are expanding our safety promotion center to disseminate safety-related information throughout Boeing's global workforce.

In addition, Boeing is also re-examining flight deck design and operation assumptions, in coordination with the regulators, our commercial and defense customers, and other stakeholders. Pilot training and experience can vary across operators in a rapidly growing global aviation industry that faces pilot shortages in many regions, and new technologies have also caused design assumptions to evolve. Boeing will work with its partners to anticipate the needs of future pilot populations. That

review will help us design flight deck interfaces that reflect the needs of the thousands of additional pilots needed in the coming decades.

QUESTIONS FROM HON. JENNIFFER GONZÁLEZ-COLÓN FOR MR. MUILENBURG

Question 1. Mr. Muilenburg, given your statements on the values of Boeing including safety, quality, and integrity, why did it take so long for Boeing to alert the Federal Aviation Administration about internal concerns regarding the 737 MAX?

ANSWER. Safety, quality, and integrity are at the core of Boeing's values. Boeing offers its employees a number of channels for raising concerns and complaints and has a rigorous process in place to ensure such complaints receive thorough consideration. If, after review, Boeing identifies a safety issue with a product or program, the issue is promptly reported to the FAA.

Question 2. What steps has Boeing taken to change its internal culture to ensure that safety, quality, and integrity are put again at the forefront of focus at the company?

ANSWER. After the 737 MAX grounding, Boeing initiated a review by a special board committee. That committee recommended several changes to our organization and processes, several of which will further enhance Boeing's strong safety culture. These changes include:

(1) Creating a permanent Aerospace Safety Committee within our Board of Directors to oversee and ensure safe design, development, manufacture, maintenance, and delivery of our products and services;
(2) Creating a Product and Services Safety organization to review all aspects of product safety;
(3) Realigning the Engineering function within the company, so that engineers across Boeing will report directly to the Chief Engineer;
(4) Establishing a design requirements program to further facilitate the incorporation of historical design materials, data and information, best practices, lessons learned, and detailed after action reports to reinforce Boeing's commitment to continuous improvement;
(5) Enhancing our Continued Operational Safety Program to aid transparency and visibility of safety related issues; the Continued Operational Safety Program now will require the Chief Engineer's review of all safety and potential safety reports;
(6) To anticipate the needs of future pilot populations, re-examining assumptions about flight deck design and operation in partnership with our airline customers and industry members;
(7) Expanding our Safety Promotion Center for employees to learn and reflect on our safety culture and renew personal commitments to safety;
(8) Expanding our anonymous safety reporting system to strengthen safety management systems within Boeing and our supply chain;
(9) Investing in new capabilities, including enhanced flight simulation and computing, and advanced R&D for future flight decks, as well as pilot and maintenance technician training and STEM education.

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