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THE BOEING 737 MAX: EXAMINING THE FEDERAL AVIATION ADMINISTRATION'S OVERSIGHT OF THE AIRCRAFT'S CERTIFICATION

(116–46)

HEARING

BEFORE THE

COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

DECEMBER 11, 2019

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THE BOEING 737 MAX: EXAMINING THE FEDERAL AVIATION ADMINISTRATION'S OVERSIGHT OF THE AIRCRAFT'S CERTIFICATION

WEDNESDAY, DECEMBER 11, 2019

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

The committee met, pursuant to notice, at 10:02 a.m., in room 2167, Rayburn House Office Building, Hon. Peter A. DeFazio (Chairman of the committee) presiding.

Mr. DEFAZIO. The committee will come to order.

I ask unanimous consent the chair be authorized to declare recesses during today's hearing. Without objection, so ordered.

I ask unanimous consent the chair and ranking member of the full committee be recognized for 10 minutes each during the question rounds. Without objection, so ordered.

Before I begin, and similar to the previous hearing on the 737 MAX with the CEO of Boeing testifying in October, I want to explain an administrative matter regarding some documents we may use at today's hearing. I will be making two unanimous consent requests in reference to two document lists, List A, List B.

First, the documents contained on List B are marked "Export Controlled"; apparently, FAA stamps everything Export Controlled. We have been advised by House general counsel that the Constitution provides ample authority for us to release these documents. However, to prevent confusion with regards to documents with Export Controlled markings on them, I will be making unanimous consent requests 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 Controlled documents on List B as well as additional documents. We have made the ranking member's staff aware of the documents from both lists. The documents have been available to them.

And with that, I would ask unanimous consent that the documents on List B be disclosed pursuant to 50 U.S.C. section 4820(h)(2)(B)(ii) because withholding such information is contrary to the national interest. Hearing no 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.

[Lists A and B are on pages 154–239.]

I now recognize myself for opening remarks.

I want to thank our witnesses for being here today. This is the committee's fifth hearing on the design, development and certification of the Boeing 737 MAX in response to two catastrophic crashes that claimed 346 lives in the span of 5 months.

Once again, I would like to recognize the family members of those killed, some of whom are here today, and our thoughts are with you, as always. And we are here to ensure that the lives of your family members were not lost in vain and without response.

You can be sure this committee will continue to be aggressive in our oversight efforts to determine what went so horribly wrong and why, and we will not rest until we have enacted legislation to prevent future unairworthy airplanes from slipping through regulatory cracks and into airline service.

In November 2018, a few days after a powerful system running in the background of the 737 MAX called MCAS pushed Lion Air flight 610 into an unrecoverable dive, the FAA issued an emergency airworthiness directive that purported to inform pilots on how to respond to an erroneous activation of MCAS, while it actually never mentioned that system by name. In fact, during the certification of the 737 MAX, Boeing actively pushed the FAA to remove references to MCAS from the flight crew operating manual, as revealed in the emails and instant messages from Boeing executive Mark Forkner, which Boeing initially failed to provide to the committee. The FAA accepted Boeing's push, and Forkner went on to boast that he was "Jedi mind-tricking" other civil aviation regulators around the world to adopt the FAA's faulty decision.

But perhaps most chillingly, we have learned that shortly after the issuance of the airworthiness directive, the FAA performed an analysis that concluded that if left uncorrected, the MCAS design flaw in the 737 MAX could result in as many as 15 future fatal crashes over the life of the fleet, with the assumption, which is questionable, that 99 out of 100 flight crews could comply with the airworthiness directive and successfully react to the cacophony of alarms and alerts recounted in the National Transportation Safety Board's report on the Lion Air tragedy within 10 seconds. Such an assumption, we know now, was tragically wrong, and it certainly did not meet FAA's criteria of 10 to the minus 9.

Despite its own calculations, the FAA rolled the dice on the safety of the traveling public and let the MAX continue to fly until Boeing could overhaul its MCAS software. Tragically, the FAA's analysis—which never saw the light of day beyond the closed doors of the FAA and Boeing—was correct. And the next crash, taking more lives, was 5 months later, Ethiopian Airlines flight 302, March 2019.

The committee's investigation into the two 737 MAX crashes was launched just days after the second accident in March. We have received more than half a million pages of documents from Boeing, the FAA, and other parties that staff continues to analyze. And that does not even include numerous emails from the FAA that we have requested. We just received a large batch on Monday night in response to our April request. And others have yet to be provided.

We have interviewed and spoken with FAA employees and Boeing whistleblowers, among others. These documents, emails, and interviews are crucial to our investigation, which has uncovered a

broken safety culture within Boeing and an FAA that was unknowing, unable, or unwilling to step up, regulate, and provide appropriate oversight of Boeing. The FAA failed to ask the right questions and failed to adequately question the answers that agency staff received from Boeing.

Our investigation has revealed that many of the FAA's own technical experts and safety inspectors believe FAA's management often sides with Boeing rather than standing up for the safety of the public. Mr. Dickson, I have read your testimony. I appreciate the tenor and the substance of your remarks. I commend your commitment to cultivating a just culture among FAA employees, and ensuring that they have the analysis and tools necessary to make the right decisions in the name of safety.

But our investigation to date has established that FAA employees did not have the analysis and tools necessary to make the right decisions in the case of the 737 MAX. These safety specialists need your support. There is no imaginable situation in which they should be jammed or subjected to end runs by Boeing to their managers. I expect you and your subordinates to back them up, to defend their reasonable decisions based on technical evidence and mandated compliance with FAA regulations on safety.

Boeing made egregious errors, including the furtive implementation of MCAS while knowing it could present a catastrophic risk. The FAA also failed to do its job. It didn't provide the regulatory oversight necessary to ensure the safety of the flying public. The FAA trusted, but did not appropriately verify, key information and assumptions Boeing presented to the agency about the MAX. And this was at a time when Boeing's own employees, as we learned at our last hearing, reported they perceived undue pressure from management.

We are trying to figure out what went wrong here, fix it legislatively, and not ever allow something like this to happen again. In that spirit, on this panel we will hear from Administrator Steve Dickson and a member of the review panel that is assessing remedial changes to the MAX design.

Mr. Dickson, as I said, I appreciate what I read in your testimony about your approach for improved safety. But I will still have some tough questions for you, and I hope to hear from you about what the FAA has identified as faults and failures in the certification of the MAX, the FAA process generally, and what concrete steps you have taken to date to correct them. I also appreciate your commitment that the 737 MAX will not take flight again until you and your employees responsible for overseeing Boeing and certifying its MCAS overhaul are 100 percent confident in its safety.

On our second panel we will hear from two former FAA and Boeing employees as well as two well-respected experts in the fields of aviation safety and human factors for their perspectives on the faulty design. And we will hear from a Boeing whistleblower, FAA whistleblower, and a former employee of Boeing.

So therefore, I want to be certain, Mr. Dickson, that—I worked for a number of years, and it was only after people died in the ValuJet crash that I stripped FAA of its promotional responsibility, which was an artifact from the dawn of the commercial aviation era. And I want to be certain that that has not crept back in.

If the industry needs promotion, the Commerce Department can do it or they can do it themselves. You and your people are there for one reason and one reason only, to assure the safety of the flying public. And I look forward to your testimony today.

[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 to our witnesses for being here today. This is the Committee's fifth hearing on the design, development and certification of the Boeing 737 MAX in response to two catastrophic crashes that claimed 346 lives in the span of five months.

Once again, I'd like to recognize the family members of those killed in these preventable crashes, some of whom are here today. Our thoughts are with you all. We are here to ensure that the lives of your family members were not lost in vain.

You can be sure this Committee will continue to be aggressive in our oversight efforts to determine what went so horribly wrong and why, and we will not rest until we have enacted legislation to prevent future unairworthy airplanes from slipping through the regulatory cracks and into airline service.

In November 2018, a few days after a powerful system running in the background of the 737 MAX called MCAS pushed Lion Air flight 610 into an unrecoverable dive, the FAA issued an emergency airworthiness directive that purported to inform pilots on how to respond to an erroneous activation of MCAS, while never actually mentioning that system by name. In fact, during the certification of the 737 MAX, Boeing actively pushed the FAA to remove references to MCAS from the flight crew operating manual, as revealed in the e-mails and instant messages from Boeing executive Mark Forkner, which Boeing initially failed to provide to the Committee. The FAA accepted Boeing's push, and Forkner went on to boast that he was "Jedi mind-tricking" other civil aviation regulators to adopt the FAA's faulty decision.

But perhaps most chillingly, we have learned that shortly after the issuance of the airworthiness directive, the FAA performed an analysis that concluded that, if left uncorrected, the MCAS design flaw in the 737 MAX could result in as many as 15 future fatal crashes over the life of the fleet—and that was assuming that 99 out of 100 flight crews could comply with the airworthiness directive and successfully react to the cacophony of alarms and alerts recounted in the National Transportation Safety Board's report on the Lion Air tragedy within 10 seconds. Such an assumption, we know now, was tragically wrong.

Despite its own calculations, the FAA rolled the dice on the safety of the traveling public and let the 737 MAX continue to fly until Boeing could overhaul its MCAS software. Tragically, the FAA's analysis—which never saw the light of day beyond the closed doors of the FAA and Boeing—was correct. The next crash would occur just five months later, when Ethiopian Airlines flight 302 plummeted to earth in March 2019.

UPDATE ON INVESTIGATION

The Committee's investigation into the two 737 MAX crashes was launched just days after the second accident in March, and we have received more than half a million pages of documents from Boeing, the FAA and other parties that my staff continues to analyze. And that doesn't even include numerous emails from the FAA that we have requested; we just received a large batch on Monday night in response to our April request. And others are yet to be provided.

We have interviewed or spoken with FAA employees and Boeing whistleblowers, among others. These documents, email and interviews are crucial to our investigation, which has uncovered a broken safety culture within Boeing and an FAA that was unknowing, unable or unwilling to step up, regulate, and provide appropriate oversight of Boeing. The FAA failed to ask the right questions and failed to adequately question the answers that agency staff received from Boeing.

Our investigation has revealed that many of the FAA's own technical experts and safety inspectors believe FAA's management often sides with Boeing rather than standing up for the safety of the public. Mr. Dickson, I have read your testimony and appreciate the tenor and substance of your remarks. I commend your commitment to cultivating a just culture among FAA employees—and ensuring that they have the analysis and tools necessary to make the right decisions in the name of safety. But our investigation to date has established that FAA employees did not

have the analysis and tools necessary to make the right decisions in the case of the 737 MAX. These safety specialists need your support. There is no imaginable situation in which they should be jammed or subjected to end-runs by Boeing to their managers. I expect you and your subordinates to back them up: to defend their reasonable decisions based on technical evidence and mandated compliance with FAA regulations in the interest of safety.

Boeing made egregious errors, including the furtive implementation of MCAS while knowing it could present a "catastrophic" risk. The FAA also failed to do its job. It failed to provide the regulatory oversight necessary to ensure the safety of the flying public. The FAA trusted, but did not appropriately verify, key information and assumptions Boeing presented to the agency about the 737 MAX. And this was at a time when Boeing's own employees, as we learned at our last hearing, reported they perceived "undue pressure" from management.

PURPOSE OF HEARING

We are striving to understand what went wrong here and what we need to fix legislatively. Our goal is to prevent a future unsafe airplane design from slipping through the cracks and exposing millions of airline passengers to an unacceptable risk.

In that spirit, on our first panel, we will hear from FAA Administrator Steve Dickson and a member of the review panel that is assessing remedial changes to the 737 MAX design.

Mr. Dickson, I appreciate what I read in your testimony about your approach to improving safety. But, I will have some tough questions for you, and I hope to hear from you about what the FAA has identified as faults and failures in the certification of the 737 MAX and FAA processes generally—and what concrete steps you have taken to date to correct them. I also appreciate your commitment that the 737 MAX will not take flight again until you—and your employees responsible for overseeing Boeing and certifying its MCAS overhaul—are 100 percent confident in its safety.

On our second panel, we will hear from two former FAA and Boeing employees as well as two well-respected experts in the fields of aviation safety and human factors for their perspectives on the faulty design of this airplane.

UNDUE PRESSURE

On our second panel we'll hear from an FAA whistleblower that Boeing applied undue pressure on FAA managers to overrule those managers' own safety engineers and experts on safety-critical matters. According to information provided to the Committee, FAA safety engineers determined that an uncontained engine failure on a 737 MAX could send shrapnel through the rudder control cables. And in a high-thrust, low-energy situation such as initial climb off the runway—or even during the takeoff roll—the pilots would likely lose control of the airplane. But the FAA dismissed this concern. We need to know why.

Chair Larsen and I wrote Administrator Dickson about this issue early last month, and on Friday afternoon we finally received a response. However, your response still doesn't explain how the unanimous judgment of more than a dozen FAA safety experts was overruled by a single manager. On what data was that manager relying? I am glad that one of our witnesses on the second panel was directly involved in the rudder cable issue while he was at FAA so we can get his straightforward perspective on this issue based on his nearly three decades of experience at the agency.

PROMOTION OF INDUSTRY

In 1996, I pushed to remove the FAA's statutory mandate to "promote" the civil aviation industry following the ValuJet flight 592 accident. That's why I'm particularly concerned this investigation has produced rumors that some people within the FAA either feel it's their role to facilitate the U.S. aviation industry's agenda, or feel pressure from outside or from above to do so.

I want Administrator Dickson's absolute assurance today that he and Deputy Administrator Dan Elwell will clearly and frequently communicate to the FAA workforce—and to the industry—that the work of every single FAA employee must be in the service of one and only one objective: preserving aviation safety.

Let the industry promote itself. If it needs help in that effort, I'm sure the Commerce Department is happy to oblige. Your job, Administrator Dickson, is to regulate. The only thing you should be promoting is the highest possible level of safety.

Millions of lives are at stake. We have to get this right. We will be changing the certification laws to ensure the 346 lives lost in Ethiopia and in the Java Sea were not lost in vain.

I look forward to hearing from our witnesses about how we can accomplish that goal. Thank you.

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

Mr. GRAVES OF MISSOURI. Thank you, Mr. Chairman. I want to add my comments and recognize the families and the friends of the accident victims. We have not forgotten your losses. And I am sure that we all share the same goal, and that is ensuring that our system remains the number one system in the world and the safest system in the world.

This is the fifth hearing on Boeing and the tragic accidents that the committee has held in 8 months. In addition, there are at least a dozen other reviews and investigations that are ongoing. Some of them, I will say, have been completed recently, and we are fortunate to have one of the representatives from the Technical Advisory Board, or the TAB, that is going to be with us today. And I am pleased that the committee is going to hear from him on the TAB's ongoing work to independently evaluate the Boeing software fix.

Collectively, I am confident that these expert reviews are going to provide us with the insights that we need to keep our aviation system the safest in the world. Today the majority has invited the current FAA leaders to testify, and while they can address the FAA's efforts since the two accidents, they were not in charge for that 5 years between 2012 and 2017 when the MAX certification process and approvals took place.

And until we hear from the officials that were in charge at the time, then the investigation remains incomplete at best, and at worst it looks like we are willing to overlook the past administration's culpability in this matter. Now, having said that, as I have said many, many times, should the investigations reveal problems within the certification process, then I think Congress can and they should act, or we should act, accordingly.

We have to ensure that we have the benefit of all expert reviews and investigations that are still underway, and focus on the facts and the data from those reviews. And when it comes to aviation safety, I do believe we have to leave out the partisanship and the "gotcha" moments. And I know Administrator Dickson and his team and the thousands of FAA professionals are all dedicated to aviation safety and improving any process that needs improvement.

And I look forward to hearing what the Administrator is doing with the recommendations that have already been received and his own observations since, within the last year, taking leadership of the FAA. And I, along with the Republicans on this committee, am committed to addressing any problems discovered in the process and working with the chairman in a very bipartisan effort.

And I have said this before, too, and it bears repeating. As a professional pilot myself, I still believe that the FAA remains the gold standard in the world for safety. Air travel is the safest mode of transportation in history. And when the FAA clears the 737 MAX to fly again, it is going to be safe to fly. There is no doubt in my mind.

Working to ensure our aviation safety system improves is always the right goal, and we have a responsibility to do that together. And with that, I look forward to today's hearing, and would yield back the balance.

[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 recognize the families and friends of the accident victims. We have not forgotten your losses, and I assure you we all share the same goal—ensuring our system remains the safest in the world.

This is the fifth hearing on Boeing and the tragic accidents that the Committee has held in eight months. In addition, there are at least a dozen other reviews and investigations—some that have been completed recently. We are fortunate to have a representative from the Technical Advisory Board (TAB) with us today. I am pleased that the Committee will hear from him on the TAB's ongoing work to independently evaluate Boeing's software fix. Collectively, I am confident that these expert reviews will provide us with the insights we need to keep our aviation system the safest in the world.

Today the Majority has invited current FAA leaders to testify. While they can address FAA's efforts since the two accidents, they were not in charge between 2012 and 2017 when the MAX certification processes and approvals took place. Until we hear from the officials in charge at the time, the Majority's investigation remains incomplete at best and at worst looks as if they are willing to overlook the past Administration's culpability in the matter.

As I have said many times, should the investigations reveal problems with the certification process, Congress can and should act accordingly. However, we must ensure that we have the benefit of all the expert reviews and investigations still underway and focus on the facts and data from those reviews. When it comes to aviation safety, we must leave out partisanship and avoid "gotcha" moments.

I know that Administrator Dickson, his team, and the thousands of FAA professionals are all dedicated to aviation safety and improving any processes that need improvement. And I look forward to hearing what the Administrator is doing with the recommendations he has already received and his own observations since taking over leadership of the FAA.

I, along with all Republicans on the Committee, am committed to addressing any problems discovered in the process and working with the Chairman in a bipartisan fashion. I have said it before, and it bears repeating, as a professional pilot I still believe that the FAA remains the gold standard for safety. Air travel is the safest mode of transportation in history, and when the FAA clears the 737 MAX to fly again, it will be safe to fly. Working to ensure that our aviation safety system improves is always the right goal. We have a responsibility to do that together.

Mr. DEFAZIO. I thank the gentleman.

The subcommittee chair, Representative Larsen.

Mr. LARSEN. Thank you, Chair DeFazio. My comments will be relatively brief because I released a video statement yesterday, and I commend folks to that video statement for my full comments. But I do want to summarize it.

With today's hearing, the committee does reach another milestone in its investigation. It is increasingly clear the process by which the FAA evaluates and certifies aircraft is itself in need of repair. Congress must reevaluate and improve the current certification process to ensure the safety of the flying public.

As this critical oversight work continues, the 346 lives tragically lost in the Lion Air and Ethiopian Airlines crashes will remain at the forefront of these efforts. Several of the family members of the victims are here today, and I extend my deepest condolences to you and your loved ones. Your advocacy makes a difference.

The FAA must fix its credibility problem. Just like I asked Boeing CEO Dennis Muilenburg at the committee's last hearing, today I expect to hear from the FAA the three main mistakes the FAA itself made regarding the 737 MAX, and the specific steps the agency is taking to restore public confidence. I also look forward to hearing about the TAB's progress as it looks over the FAA's shoulder as the agency works on a return to service decision.

From today's second panel, the two former Boeing and FAA employees are providing an important perspective on questionable management decisionmaking that seemed to prioritize economic interests over public safety. Further, I am interested in learning more from the safety experts on the panel about the integration of human factors as aviation technology becomes increasingly automated. Airplanes are changing, but the Federal Government and certification is not changing with those airplanes.

Though 2019 is coming to an end, the committee's investigation is far from over. The committee will continue to maintain safety as the guiding principle and use all available tools to ensure the safety of the traveling public. With that, thank you, and 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.

With today's hearing, the Committee reaches another milestone in its investigation.

It is increasingly clear the process by which the FAA evaluates and certifies aircraft is itself in need of repair.

Congress must reevaluate and improve the current certification process to ensure the safety of the flying public.

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Though 2019 is coming to an end, the Committee's investigation is far from over.

The Committee will continue to maintain safety as the guiding principle and use all available tools to ensure the safety of the traveling public.

Thank you, I yield back.

Mr. DEFAZIO. I thank the gentleman.

With that, I recognize the ranking member of the subcommittee, Mr. Graves from Louisiana.

Mr. GRAVES OF LOUISIANA. Thank you, Mr. Chairman.

First I want to thank the families for being at the hearing today, our fifth hearing on the MAX. As I have said at every previous hearing and I am going to say again today, your efforts remind us

that this is about people. It is not about Government bureaucracy process. It is about people and safety. And I want to thank you all for your advocacy efforts throughout this process.

Mr. Chairman, we are on our fifth hearing today, and there are extraordinary efforts underway to ensure that we are able to extract every single lesson that we can from the 737 MAX disasters. As some have noted, the ongoing investigations are investigations that have completed:

The Special Committee of the Safety Oversight and Certification Advisory Committee; the Joint Authorities Technical Review, or the JATR; the Technical Advisory Board, or the TAB; the Flight Standardization Board; Boeing board of directors Committee on Airplane Policies and Processes; the National Transportation Safety Board, the NTSB; this very committee—the majority has an investigation underway. We have the Department of Transportation's inspector general. We have the Department of Justice criminal investigation. We have the Securities and Exchange Commission investigation, and others, and the Indonesian and the Ethiopian authorities as well. So multiple investigations. A lot going on.

Today at this hearing we have the Administrator of the FAA, and Mr. Dickson, thanks for being here. As I recall, you have been on the job for 4 months. And so you are here to talk right now about, I guess, path forward—where we are, what we have learned, and path forward.

In the second panel we have a number of folks, including quasi-whistleblowers. And I want to be clear: I am not being derogatory. As I understand, they have not sought official whistleblower status, but folks that sort of played that role of whistleblowers. And so we have folks that were there, intimately involved in the process, perhaps, and they are able to shed some light on what was going on on the ground.

So we have someone, the Administrator, who is the current Administrator and he has been there for 4 months. We have folks that were involved in the process on the ground that are, again, somewhat whistleblower status. What we do not have, and what we have not had in any of these hearings, are the people that actually made the decisions back when—this process when the aircraft was being certified. There is a gap in this hearing, and Ranking Member Graves and I have requested over and over again that we fill that void.

Look. I can go through, and I can say all these acronyms, and I can talk about all these investigations. But if we don't have the full slate of understanding of what is going on here, then we are at risk of making decisions that don't have the full view. And I have no desire whatsoever to sit here and rub somebody's face in the ground. I don't.

But I do, and I made a commitment to those folks and I am going to fulfill it—I do want to make sure that we understand everything that happened and we don't allow mistakes to be made again. We need to learn from the mistakes, and we need to learn from the successes, and we need to build upon both of those.

And so I do hope, as we continue this process, as we move forward in this investigation, that we fill that void and we understand what has happened every step of the way, and that we are able to

make decisions that truly yield the safest, the absolute safest, aviation system possible, and that we are able to ensure that passengers on airlines, domestic and foreign, that they will continue to be flying on the safest means of transportation available.

So I want to thank you again for being here. I want to thank you and many folks behind you and under you for all of the work that you all have done to get us to where we are. I think everyone knows what our end zone is, what our end goal is, and that is to ensure that we prevent and we work to prevent, absolute perfection. And I look forward to hearing your testimony as well as that of the second panel. 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, for calling today's hearing. I also want to thank the families and loved ones of the victims of Lion Air Flight 610 and Ethiopian Airlines Flight 302 for being here. Your efforts continue to remind us that this isn't about government and bureaucracy, it's about people and safety.

This is our fifth Boeing 737 MAX-related hearing of the year, and there are extraordinary efforts underway to ensure we extract every lesson we can from the accidents. Those efforts include the investigations of the Special Committee of the Safety Oversight and Certification Advisory Committee, the Joint Authorities Technical Review, the Technical Advisory Board, the Flight Standardization Board, the Boeing board of directors committee on airplane policies and processes, the National Transportation Safety Board, this committee's majority's investigation, the Department of Transportation Inspector General, the Department of Justice criminal investigation, the Securities and Exchange Commission investigation, and the Indonesian and Ethiopian authorities' investigations.

Today, we will hear from Administrator Dickson, who's been on the job for four months, and a member of the Technical Advisory Board to talk about what we've learned and the path forward. We will also hear from some witnesses who have worked inside the certification system on the ground.

No matter what angle you look at these issues from, safety is everyone's end goal. I'm worried that the Majority's investigation seems to be taking a turn in a direction I don't believe is helpful and could be harmful to the shared goal of safety. It seems more and more that the investigation is about trying to paint our aviation system as corrupt or broken. I believe strongly that nothing can be further from the truth. There's a difference between learning hard truths about where we have fallen short or needing to improve and undermining a system that has kept billions of people safe over the years. Let's make sure we keep our system the safest in the world.

What we don't have today, and haven't had in any of these hearings yet, are the FAA officials who made any of the decisions back when the aircraft was being certified. That creates a gap in the hearing record, and Ranking Member Graves and I have requested repeatedly that we fill that void.

I am committed to doing everything we can to make sure we learn from any mistakes, but if we don't have a full understanding of what happened, then we're at risk of making uninformed decisions about how to ensure we have the absolute safest system possible.

Mr. DEFAZIO. I thank the gentleman.

Before I begin my questions, I would observe we have been asking since we received our first tranche of emails from FAA and Boeing to interview career staff who are the people who made the decisions at the FAA. And until recently, with the new Administrator, we were being stonewalled and being told, no, you can't talk to the line employees who raised concerns. You can only talk to managers.

And that has changed with this Administrator, and we have interviews scheduled with the people who actually made the decisions. If we find that it went higher than that, we will call those people. But we just spent 7 hours jointly, Republican and Democratic staff, questioning the current head of safety, who was there when this document was issued about the probability of another crash, and says he wasn't aware of that and he wasn't aware of anything that went on.

So I don't know how high up this went, and I think that is one of the problems and that is one of the things we have got to look at. I think most of these decisions were made by captive regulator managers in the Seattle offices, and no one in the national offices knew a damned thing about it. So we are going to get to the bottom of this. And if it goes any higher than that, we will have those people.

So with that, I will recognize myself for questions.

Mr. GRAVES OF MISSOURI. Statements.

Mr. DEFAZIO. Oh, I forgot. Thank you. Thank you. Thank you. Thank you. I got carried away there.

[Laughter.]

Mr. DEFAZIO. Mr. Administrator.

TESTIMONY OF HON. STEPHEN M. DICKSON, ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION, ACCOMPANIED BY EARL LAWRENCE, EXECUTIVE DIRECTOR, AIRCRAFT CERTIFICATION SERVICE, FEDERAL AVIATION ADMINISTRATION; AND MATTHEW KIEFER, MEMBER, TECHNICAL ADVISORY BOARD

Mr. DICKSON. Thank you, Mr. Chairman. Good morning, Chairman DeFazio, Ranking Member Graves, and members of the committee. Thank you for inviting me here today to speak with you about the Federal Aviation Administration's approach to safety oversight, and to provide you with an update concerning the Boeing 737 MAX.

With me today is Mr. Earl Lawrence, the Executive Director of the FAA's Aircraft Certification Service since December of 2018.

When we fly anywhere in the world, we enjoy a certainty of safety that is unrivaled in the modern transportation era. That is because the FAA and the world's aviation regulators understand that the success of the global aviation system rests squarely on our shared commitment to safety and our common understanding of what it takes to achieve it.

Together we have built a safety record that is the envy of other transportation modes, the healthcare field, and others. But we are humbled when our best efforts fail. On behalf of the United States Department of Transportation and the FAA, I would like to once again extend our deepest sympathy and condolences to the families of the victims of the Ethiopian Airlines and Lion Air accidents, and thank you for being here today.

Deputy Administrator Dan Elwell and I have met with the family members and friends of those on board. We have seen their pain, their loss, and it reaffirms the seriousness with which we must approach safety every single day. That is why we are working tirelessly to ensure that the lessons learned from these terrible

losses will result in a higher margin of safety for the aviation industry globally.

For the 737 MAX return to service, the FAA fully controls the approvals process and is not delegating anything to Boeing. We will retain authority to issue airworthiness certificates and export certificates of airworthiness for all new 737 MAX airplanes manufactured since the grounding.

When the 737 MAX is returned to service, it will be because the safety issues have been addressed and pilots have received all the training they need to safely operate the aircraft. This process is not guided by a calendar or schedule.

Actions that must still take place include a certification flight test and completion of work by the Joint Operations Evaluation Board, which will include pilot training needs. Additionally, the FAA and the Technical Advisory Board, or TAB, will review the final design documentation. Finally, I am not going to sign off on this airplane until I fly it myself.

Today's unprecedented safety record was built on the willingness of aviation professionals to embrace hard lessons and to proactively seek continuous improvement. In addition to this committee's investigation and other congressional efforts, we welcome the scrutiny and recommendations from several independent reviews.

Included in these are:

A Joint Authorities Technical Review, or JATR, that the FAA launched to conduct a comprehensive assessment of the MAX automated flight control system certification;

The TAB we initiated to conduct an independent review of the proposed integrated system, training, and continued operational safety determination for the aircraft—and as an aside I would like to recognize and thank Mr. Matt Kiefer, to my left here, also testifying here this morning, for his work as a member of this board;

Recommendations from the NTSB and the Indonesian accident report on Lion Air flight 610;

The DOT's inspector general audit of the 737 MAX certification; and finally,

A report from the Secretary's Special Committee on Aircraft Certification.

We believe that transparency, open and honest communication, and our willingness to improve our systems and processes are the keys to restoring public trust in the FAA and the safety of the 737 MAX.

Now, beyond the 737 MAX, the FAA is committed to addressing issues regarding aircraft certification processes not only in the United States but around the world. These issues include:

Moving toward a more holistic versus transactional, item-by-item approach to aircraft certification;

Integrating human factors considerations more effectively throughout the design process; and

Ensuring coordinated and flexible information flow during the FAA's oversight process.

We and our international partners must also foster improvements in how aircraft are designed and produced, but also on how they are maintained and operated. We at the FAA are prepared to take the lead in this new phase of system safety.

Aviation's hard lessons and the hard work in response to those lessons have paved the way to creating a global aviation system with an enviable safety record. But we recognize that safety is a journey, not a destination, and we must build on the lessons learned, and we must never allow ourselves to become complacent.

Thank you, and this concludes my statement, and I am happy to take your questions.

[The prepared statement of Mr. Dickson follows:]

Prepared Statement of Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration

Chairman DeFazio, Ranking Member Graves, and Members of the Committee:

Thank you for inviting me here today to speak with you about the Federal Aviation Administration's (FAA) approach to safety oversight and to provide you with an update concerning the Boeing 737 MAX. On behalf of the United States Department of Transportation and everyone at the FAA, I would like to, once again, extend our deepest sympathy and condolences to the families of the victims of the Ethiopian Airlines and Lion Air accidents. Deputy Administrator Dan Elwell and I have met with the family members and friends of those onboard. In these meetings, we have seen their pain, their loss, and it reaffirms the seriousness with which we must approach safety every single day. That is why we are working tirelessly to ensure that the lessons learned from these terrible losses will result in a higher margin of safety for the aviation industry globally.

Accompanying me here today is Earl Lawrence. Mr. Lawrence is the Executive Director of the FAA's Aircraft Certification Service, where he is responsible for type certification, production approval, airworthiness certification, and continued airworthiness of the U.S. civil aircraft fleet including commercial and general aviation activities.

STATUS OF THE 737 MAX RETURN-TO-SERVICE

Safety is the core of the FAA's mission and is our first priority. We are working diligently to ensure that the type of accidents that occurred in Indonesia and Ethiopia—resulting in the tragic loss of 346 lives—do not occur again. The FAA is following a thorough process for returning the 737 MAX to service. This process is not guided by a calendar or schedule. Safety is the driving consideration. I unequivocally support the dedicated professionals of the FAA in continuing to adhere to a data-driven, methodical analysis, review, and validation of the modified flight control systems and pilot training required to safely return the 737 MAX to commercial service. I have directed FAA employees to take whatever time is needed to do that work.

With respect to our international partners, the FAA clearly understands its responsibilities as the State of Design for the 737 MAX. In September, we met with more than 50 invited foreign civil aviation officials, all of whom have provided input to the FAA and will play a role in clearing the 737 MAX for flight in their respective nations. We are also conducting and planning a number of outreach activities, including providing assistance to support foreign authorities on return-to-service issues; maintaining transparency through communication and information sharing; and scheduling meetings for technical discussions.

As I have stated before, the FAA's return-to-service decision on the 737 MAX will rest solely on the FAA's analysis of the data to determine whether Boeing's proposed software updates and pilot training address the known issues for grounding the aircraft. The FAA fully controls the approvals process for the flight control systems and is not delegating anything to Boeing. The FAA will retain authority to issue airworthiness certificates and export certificates of airworthiness for all new 737 MAX airplanes manufactured since the grounding. When the 737 MAX is returned to service, it will be because the safety issues have been addressed and pilots have received all of the training they need to safely operate the aircraft.

Actions that must still take place before the aircraft will return to service include a certification flight test and completion of work by the Joint Operations Evaluation Board (JOEB), which is comprised of the FAA Flight Standardization Board (FSB) and our international partners from Canada, Europe, and Brazil. The JOEB will evaluate pilot training needs. The FSB will issue a report addressing the findings of the JOEB and the report will be made available for public review and comment.

Additionally, the FAA will review all final design documentation, which also will be reviewed by the multi-agency Technical Advisory Board (TAB). The FAA will issue a Continued Airworthiness Notification to the International Community providing notice of pending significant safety actions and will publish an Airworthiness Directive advising operators of required corrective actions. Finally, I am not going to sign off on this aircraft until all FAA technical reviews are complete, I fly it myself using my experience as an Air Force and commercial pilot, and I am satisfied that I would put my own family on it without a second thought.

OVERSIGHT OF AIRCRAFT CERTIFICATION

Safety is a journey, not a destination—a journey we undertake each and every day with humility. Today's unprecedented U.S. safety record was built on the willingness of aviation professionals to embrace hard lessons and to proactively seek continuous improvement. The FAA both welcomes and invites scrutiny of our processes and procedures. In addition to this Committee's investigation, several independent reviews have been initiated to look at different aspects of the 737 MAX certification and the FAA's certification and delegation processes generally.

The first review to be completed was one that the FAA commissioned—asking nine other civil aviation authorities to join the FAA in a Joint Authorities Technical Review (JATR) to conduct a comprehensive assessment of the certification of the automated flight control system on the 737 MAX. The JATR was chaired by former National Transportation Safety Board (NTSB) Chairman Christopher Hart and was comprised of a team of experts from the FAA, National Aeronautics and Space Administration (NASA), and the aviation authorities of Australia, Brazil, Canada, China, the European Union, Indonesia, Japan, Singapore, and the United Arab Emirates. Never before have 10 authorities come together to conduct this type of review. I thank the JATR members for their unvarnished and independent review and we welcome their recommendations.

The FAA also initiated a TAB made up of FAA Chief Scientists and experts from the U.S. Air Force, NASA, and Volpe National Transportation Systems Center. The TAB's task is to conduct an independent review of the proposed integrated system, training, and continued operational safety determination for the 737 MAX. The TAB recently briefed me, and previously briefed this Committee, on their progress and the status of Boeing's and the FAA's responses to the return-to-service action items.

Last month, the FAA received recommendations from the NTSB and the Indonesian National Transportation Safety Committee's accident report on Lion Air Flight 610. We are carefully evaluating the recommendations in both of these reports as we continue our review of the proposed changes to the 737 MAX. Work also continues on the Department of Transportation's Inspector General audit of the 737 MAX certification, as well as this Committee's investigation and other congressional reviews. Finally, we are also awaiting a report from the Secretary of Transportation's Special Committee on aircraft certification. This blue-ribbon panel was established earlier this year to advise and provide recommendations to the Department on policy-level topics related to certification across the manufacturer spectrum.

We believe that transparency, open and honest communication, and our willingness to improve our systems and processes are the keys to restoring public trust in the FAA and in the safety of the 737 MAX when it is returned to service. The FAA is fully committed to addressing the recommendations from all of the various groups reviewing our certification processes. We will implement any changes that would improve our certification activities and increase safety. It would be premature, however, to discuss any changes concerning the FAA's certification processes or FAA's personnel at any level before this Committee's investigation and other ongoing reviews have concluded, and we have a chance to carefully analyze their results and recommendations.

MOVING FORWARD

Beyond the 737 MAX, the FAA is committed to addressing issues regarding aircraft certification processes not only in the United States, but around the world. These issues include:

- moving toward a more holistic versus transactional, item-by-item approach to aircraft certification—taking into account the interactions between all aircraft systems and the crew;
- integrating human factors considerations more effectively throughout the design process, as aircraft become more automated and systems more complex; and
- ensuring coordinated and flexible information flow during the oversight process.

Yet, if we are to continue to raise the bar for safety across the globe, it will be important for the FAA and our international partners to foster improvements in

standards and approaches not just for how aircraft are designed and produced, but also how they are maintained and operated. We at the FAA are prepared to take the lead in this new phase of system safety. I see our strategy coalescing around four themes: Big Data; Just Culture; Global Leadership; and People.

Big Data

The FAA must continue leaning into our role as a data-driven, risk-based decision-making oversight organization that prioritizes safety above all else. We do that by breaking down silos between organizations and implementing Safety Management Systems supported by compliance programs and informed by data. We look at the aviation ecosystem as a whole, including how all the parts interact: aircraft, pilots, engineers, flight attendants, technicians, mechanics, dispatchers, air traffic controllers—everyone and everything in the operating environment. The FAA is examining the data we have, identifying data we may need, and looking for new methods for analyzing and integrating data to increase safety.

Just Culture

In addition to the technical work required for truly integrated data, a key enabler of a data-driven safety organization is a healthy and robust reporting culture. A good safety culture produces the data you need to figure out what's really happening. If we know about safety concerns and we know where threats are coming from and how errors are occurring, we can mitigate the risks and fix the processes that led to those errors. A good safety culture demands that we infuse that safety data into all of our processes from top to bottom—in a continuous loop.

To be successful, a safety organization relies on a Just Culture that places great value on front-line employees and those involved in the operation raising and reporting safety concerns in a timely, systematic way, without fearing retaliation. A Just Culture starts at the top. It's something leadership has to nurture and support everywhere in the organization. Employees have to see the results, see what the data is showing, and see how the organization is using analysis tools to identify concerns and errors and put actions in place to mitigate them.

Global Leadership

Today, the U.S. aviation system is the safest, most dynamic and innovative in the world, and we have the numbers to prove it. This is largely due to these collaborative approaches to safety. An example of the kind of collaboration and safety innovation we can use to lead the global aviation safety system to even higher levels of performance is Aviation Safety Information Analysis and Sharing (ASIAS). ASIAS is one of the crown jewels of the aviation safety system in the United States. It is unique in the world. Its purpose is to proactively discover and mitigate emerging safety issues before they result in an incident or accident.

ASIAS de-identifies airline and company proprietary data submitted by a growing number of stakeholders in accordance with information sharing agreements and governance protocols. This ensures a level of protection for participants and protects against disclosure of a specific flight crew or entity, which has helped to foster a culture of trust within the ASIAS program and across stakeholder organizations. As trust has developed, data access has increased and enabled advancements in data analysis methodologies through more automated capabilities and the fusing together of data streams that provide a 360-degree perspective on safety issues. This "fusion" bypasses the limits associated with analyzing data in separate silos of information, provides insight from multiple integrated data sources, and enables analysts to better understand the full context of safety events. ASIAS works in partnership with the Commercial Aviation Safety Team (CAST) that proactively mitigates risks thorough the voluntary adoption of Safety Enhancements.

Over the years, the FAA has exercised a leadership role in the promotion and development of global aviation safety. We have helped raise the bar on safety standards and practices around the world working with ICAO and other civil aviation authorities. We have an opportunity to do even more. We are committed to expanding our efforts with other authorities around the world and to fostering safety standards and policies at ICAO to help meet the public's expectations of the highest possible levels of safety globally, even in areas the FAA does not regulate directly. Without safety as a foundation, we cannot have a vibrant aviation industry in any country, much less between countries. Our international air transportation network is a tightly woven fabric that is dependent on all of us making safety our core value.

People

We live in an incredibly dynamic time in aviation, with new emerging technologies and capabilities transforming the NAS. But at its core, a huge technical, operational, and regulatory agency like the FAA is made of people—people who are

driven to serve, people with families, hopes and dreams, and most importantly, people who are dedicated safety professionals. I have the utmost respect for the jobs that they do every day, making sure our skies are safe and that the operation of the system is efficient—and serves the public—as well as it possibly can. It's now time to show the next generation of aviation leaders what incredible opportunities lie ahead for them in our field, both personally and professionally. It is the people who will innovate and collaborate to take us to the next level of safety, operational excellence, and opportunity.

CONCLUSION

Aviation's hard lessons and the hard work in response to those lessons—from both government and industry—have paved the way to creating a global aviation system with an enviable safety record. But as I mentioned earlier, safety is a journey, not a destination. We have achieved unprecedented levels of safety in the United States. Yet what we have done in the past and what we are doing now will not be good enough in the future in an increasingly interconnected world. We must build on the lessons learned, and we must never allow ourselves to become complacent.

Those lessons teach us that in order to prevent the next accident from happening, we have to look at the overall aviation system and how all the pieces interact. Time and again, it has been shown that accidents happened due to a complex interaction of multiple issues. Focus on a single factor will lead us to miss opportunities to improve safety that come from regulators and industry raising the bar not just in certification, but in maintenance and training procedures. That will require truly integrated data and collaboration, enterprise-wide. When our data—and our organizations—are kept in silos, we may miss information that could provide an opportunity to make important safety decisions that will improve processes or even prevent accidents entirely. We have to be constantly learning from each other—regulator and those we regulate—to help each other improve.

The United States has been, and will continue to be, the global leader in aviation safety. We are confident that continuing to approach this task with a spirit of humility, openness, and transparency will bolster aviation safety worldwide.

This concludes my statement. I will be glad to answer your questions.

Mr. DEFAZIO. Thank you, Mr. Administrator.

With that, Mr. Kiefer, your testimony.

Mr. KIEFER. Good morning, Chairman DeFazio, Ranking Member Graves, and distinguished members of the committee. Thank you for having me here today. It is an honor to be on the panel.

I would like to first start by expressing my condolences to the families and the friends of those who lost their lives in the Lion Air and Ethiopian Airlines accidents. Their memories were with us on our team as we did our work.

My name is Matt Kiefer, and I currently work for the U.S. Air Force Airworthiness Office. I have worked in the aviation industry for over 25 years in the military and in the private sector. This has included work in flight test, system design and integration, systems engineering management, and systems safety.

As an aerospace engineering officer in the Navy Reserve, I am responsible for the Navy's part of a joint team that performs combat forensics analysis on aircraft battle damage. I am also an instrument-rated private pilot with over 600 hours of flight experience.

I was asked by the FAA to participate on a team known as the Boeing 737 MAX Technical Advisory Board, also known as a TAB. This is an independent team of industry experts with no past involvement in the 737 MAX development or certification.

Our team is made up of experts from various specialties, including test pilots, aerospace engineers, and chief scientists, with backgrounds in flight controls, flight operations, simulators, human factors, computer systems and software, flight standards, and systems

safety. We were chosen for our ability to take a look at the 737 MAX changes objectively, with fresh eyes, because we are independent from Boeing and the FAA certification effort of the aircraft.

Our team was tasked to examine and review the changes Boeing is making to the 737 MAX flight control system, and make recommendations back to the FAA as to the suitability of those changes before the aircraft is returned to service.

Our team had our first face-to-face meeting with Boeing at their facilities in Seattle in May, where we spent time working with the Boeing engineering department. This meeting started off with encouragement from the FAA and Boeing management to dig deep into the systems and scrutinize the work that has been done to develop the solutions to the problems that led to the accidents, and give our unbiased opinion as to the suitability of those fixes.

At this meeting, we started by learning about how the speed trim and MCAS function, as well as having discussions on the various failure modes of the system. We were then given indepth debriefings on what happened with the two mishap aircraft, including information on the Lion Air flight that occurred the day before the first accident. After that, we were given detailed briefings with good discussion on the changes that had been developed for MCAS.

Our team was also given the opportunity to fly the 737 MAX simulator at the Boeing engineering facility. Many of our team members, both pilots and engineers alike, got the opportunity to fly the simulator with the old software and with the new. We were able to experience the accident scenarios and were able to observe the aircraft behavior with MCAS operating properly as well as how the aircraft handles with MCAS disabled.

During these meetings, which included multiple online conferences and two face-to-face meetings at Boeing, our team had the full cooperation of Boeing engineering and flight test staff, as well as good participation from the avionics subcontractor.

At the first face-to-face meeting, the team started to develop action items that had been determined are necessary before returning the aircraft to service. These action items are being actively tracked by the TAB and with Boeing and the FAA. All action items that the team made for return to service have either been addressed and closed or are presently in work.

The TAB is still working with Boeing to accept products to close the remaining action items. Once all this work is complete, the TAB will present the final report to the FAA. The TAB still has work to do to complete our assessment of the changes to the Boeing 737 MAX systems, and are awaiting more information on the development assurance, testing of the software, final safety assessments, and final training for the aircrew.

Pending the team's determination that the remaining review results meet our expectations, our team feels that the changes made to the flight control system of the 737 MAX should vastly improve the safety of the aircraft, in keeping with the highly successful safety record of the previous models of the Boeing 737.

Thank you, and I will be happy to answer any questions you have for me.

[The prepared statement of Mr. Kiefer follows:]

Prepared Statement of Matthew Kiefer, Member, Technical Advisory Board

Good morning Chairman DeFazio, Ranking Member Graves and Members of the Committee. Thank you for having me here, it is my honor to participate on this panel today.

First I'd like to introduce myself. My name is Matt Kiefer and I have been working in the aviation industry for over 25 years. In that time I have worked in aircraft maintenance on fighter jet aircraft as well as general aviation aircraft. I have worked as a flight test engineer and been responsible for all flight test data acquisition at an aircraft modification company as well as system design and integration for aircraft modification programs. I have worked for the U.S. Department of Defense as a lead systems engineer for a Navy aircraft program and been responsible for system safety engineers working across several different Air Force programs. I have also been an Aerospace Engineering Officer for the Navy Reserve for over ten years where I specialize in combat forensics analysis of aircraft battle damage. Currently I am working in the Air Force airworthiness office where I am responsible for some aspects of policy and manage the division's computer systems to include the one that processes airworthiness reviews. I am also a Lieutenant Commander in the Navy reserve attached to an engineering unit that supports NAVAIR. Additionally I am an instrument rated private pilot with over 600 flight hours in general aviation aircraft.

I was asked by the FAA to participate on a team known as the B737 MAX Technical Advisory Board otherwise known as a TAB. This is an independent team of aviation industry experts with no past involvement with the B737 MAX development or certification. Our team is made up of experts from various specialties including test pilots, aerospace engineers and chief scientists with backgrounds in flight controls, flight operations, simulators, human factors, computer systems and software, flight standards and safety. These experts come from the FAA, NASA, the Air Force and the Volpe Center. We were chosen for our ability to take a look at the B737 MAX changes objectively with fresh eyes because we are independent from Boeing or the FAA certification effort of the aircraft. Our team was chartered to examine and review the changes Boeing is making to the B737 MAX flight control system and make recommendations back to the FAA as to the suitability of those changes before the aircraft is returned to service.

Our team started our work with some teleconferences where we became acquainted with the Boeing team and the 737 MAX airplane and its systems. We then had our first face-to-face meeting at the Boeing facilities in Seattle in May where we spent time working with the Boeing engineering department. This meeting started off with encouragement from FAA and Boeing management to dig into the systems and scrutinize the work that has been done to develop the solutions to the problems that led to the two accidents and give our unbiased opinion as to the suitability of those fixes.

At this meeting we started by learning more about how the speed trim system and MCAS function as well as having discussions on various failure modes with the system. We were then given in-depth debriefings on what happened with the two mishap aircraft including information on the Lion Air flight that occurred the day before the first accident. After that we were given detailed briefings with discussion on the changes that had been developed for MCAS.

Our team was given an opportunity to fly in the B737 MAX eCAB which is the engineering development simulator at the Boeing engineering facility. Many of our team members, both pilots and engineers alike got an opportunity to fly the simulator with the old software and the new software. We were able to experience the accident scenarios and were able to observe aircraft behavior with MCAS operating properly as well as how the aircraft handles with MCAS disabled.

Boeing engineers sat down with several of the engineers on our team to go over the software development and certification for the flight control system. These sessions consisted of deep dives on how MCAS was developed as well as a look at how the changes are being implemented. Time was also spent by some of the team members reviewing aspects of the flight manual and training given to pilots of the B737 MAX.

During these meetings, which included multiple online conferences and two face-to-face meetings at Boeing, our team had the full cooperation of the Boeing engineering and flight test staff as well as good participation from the avionics sub-contractor. After these meetings, briefings and demonstrations the team gathered to assemble our findings and recommendations. Some of these we have determined are necessary before returning the aircraft to service. These recommendations/action

items are being actively tracked internally to the TAB and with Boeing and the FAA. All recommendations that the team made for return to service have either been addressed and closed or are presently in work. The TAB is still working with Boeing to accept products to close the remaining action items. Once all of this work is complete the TAB will present a final report to the FAA.

There are four main changes to the B737 MAX flight control system software that have been developed to prevent future accidents like the ones that happened with the Lion Air and Ethiopian Air flights. They include the following:

1. Angle of Attack (AoA) comparison—an addition to MCAS that will now compare readings from both angle of attack sensors on the aircraft. If there is a difference of more than 5.5 degrees the speed trim system will be disabled. Also included in this change is something known as a "mid- value select" which uses data from both sensors together to create a third input that will help to filter out any AOA signal oscillatory failures or spurious sensor failures. This modification will prevent MCAS from commanding nose down trim when a single AoA sensor reports a false AoA as it happened in the two accident flights.
2. MCAS resynchronization—this change will account for manual electric trim inputs made by the pilot while MCAS is activating. It will track whatever input the pilot makes and return the pitch trim to that setting when MCAS retrims back to normal.
3. Stab trim command limit—is an addition that will limit the maximum nose down trim that the automatic flight control system can command to prevent the pitch trim from reaching an uncontrollable situation.
4. FCC monitors—software monitors have been added to the flight control computers that will cross check pitch trim commands against each other. If a difference is detected by these monitors the automatic trim functions are disabled. This protection helps prevent erroneous trim commands from a myriad of causes that could occur in the automatic flight control system.

These design changes in the software that controls the automatic pitch trim features including MCAS should prevent angle of attack sensor failures from causing the pitch trim to operate when it should not. Further, they should prevent the trim from activating erroneously for other reasons as well.

I would like to note that all along through our team's progress we have gotten nothing but assistance and courtesy from Boeing. At no time have any of our members been pressured to reach any predetermined conclusions nor were we encouraged to operate according to a timetable or schedule. Conversely we have been told by the FAA and Boeing leadership to emphasize safety and diligence in our research.

The TAB still has work to do to complete our assessment of the changes to the B737 MAX systems as we are awaiting more information on the development assurance, testing of the software, final safety assessments and final training for aircrew. Pending the team's determination that the remaining review results meet our expectations, our team feels that the changes made to the flight control software in the B737 MAX should vastly improve the safety of the aircraft, in keeping with the highly successful safety record of the previous models of the Boeing 737.

Mr. DEFAZIO. Thank you for your work and for your testimony, and I expect there will be questions later.

Mr. KIEFER. Yes, sir.

Mr. DEFAZIO. With that, then, I would recognize myself for the first round of questions.

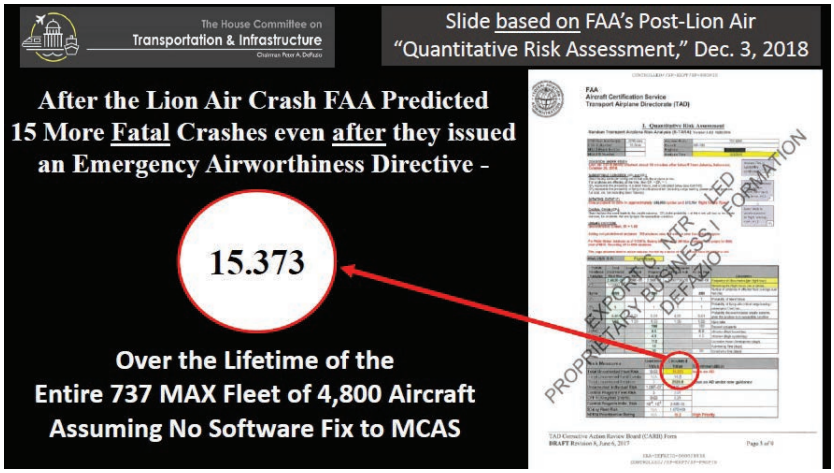
Administrator Dickson, we know you weren't there. But obviously, I expect that you and your staff have put a substantial amount of energy into trying to determine what happened and how it happened, as you are charged with making it work right in the future.

So I have got to ask about this TARAM analysis, which was done on December 3, 2018. Again, you weren't there. Mr. Bahrami was there. He was head of safety. And he met with me and Mr. Larsen and I can't remember who else might have been there, and told us this was a one-off accident in February.

Yet this analysis, which I thought the staff was going to put up, was—thank you—was available at that time. He apparently says

he was unaware of it. He knew there was such a process, but he didn't know they had evaluated this plane and this system. But this analysis says that—this is post-Lion Air—that in the lifetime of these aircraft, in operation, they predicted there would be a potential of 15 fatal crashes.

[Slide]



Mr. DEFAZIO [continuing]. I am not aware of any other certified transport aircraft that has such an analysis. I mean, the normal analysis is 10 to the minus 9. This far exceeds that. And I question why, given this TARAM—and I don't know where it went since it didn't go to the head of safety—why the aircraft wasn't grounded once this analysis was done, as opposed to allowing the plane to fly while Boeing worked on a fix.

We have talked a lot about being a data-driven organization with you and former Administrator Elwell when we had the second incident, when the plane stayed up yet for another couple of days, and the assumptions that were made here is only 1 out of 100 pilots wouldn't react properly and effectively in that 10-second period. Yet in the two instances extant—well, there were actually three. There was a triggering, which was recovered, in Indonesia. Then there was a triggering which wasn't recovered, and then Ethiopia. So we have essentially a 33-percent success rate. But even after the first, we had a 50-percent success rate.

I am just wondering, I mean, in retrospect do you think it should have been grounded after Lion Air, given this TARAM analysis?

Mr. DICKSON. Well, thank you for your question, Mr. Chairman. And I will say at the outset, as you noted, I was not at the FAA when this analysis was done. However, I want to advocate for my people. And they need—we are a data-driven organization, as you said, and I know this—with all due respect, any indication that any level of accidents is acceptable in any analysis is not reflective of the 45,000 dedicated professionals at the FAA, whether they are involved in air traffic or aviation safety. So I want to make that abundantly clear. That is absolutely our highest priority.

Having said that, the reason that we have the safest airspace in the U.S. in the world has been through decades of developing data systems and decisionmaking tools that will allow us to make the best decisions, and prioritize in the interests of safety.

So remember, the information that was available at the time was we really didn't know what the root cause of the accident——

Mr. DEFAZIO. If I could, Mr. Administrator, I understand. But I have only got 10 minutes, and I have at least a couple other questions.

So OK, you are not going to say anything definitive. I would hope you would look into the distribution——

Mr. DICKSON. Of course.

Mr. DEFAZIO [continuing]. Of this TARAM. It didn't come to the attention of the head of safety, he tells us, so I don't know where it went or who had access to it and what they may have advocated. I think it is a pretty critical thing. And again, I am not aware of any other aircraft where this sort of analysis has found something that is going to cause crashes inevitably and been allowed to fly. I mean, it just doesn't meet your standards. So I appreciate the fact that you are going to look into that and refuse that.

Now, I want to ask, again, I am concerned about Boeing's influence over—particularly, it seems like this all stops in the regional offices. We will find out with further interviews with FAA employees. But again, with 7 hours with Mr. Bahrami, he is not aware of any of the issues we raised outside that were—where decisions were made up in Washington State.

And there are two issues regarding lightning protection on the 787, where the plane was certified for production with the lightning protection. Boeing decided to strip the lightning protection off, and after they produced 40 airplanes, they came to the FAA and said, "Oh, by the way, you certified it with lightning protection. We have taken it off. We would like you to change your decision that it is necessary." And again, safety analysts objected, and they were overruled by a local manager.

And then the rudder: The rudder issue was actually seven safety analysts said, "No, you need to relocate the rudder controls," and we do have photos of what happens when you lose rudder controls on an airplane, particularly on climb-out or at a critical time. I wish the staff would put that slide up, please, if they are listening. And that is a critical thing.

[Slides]

Mr. DEFAZIO [continuing]. And they were upheld at two levels of review. So in total, we had 14 people at the FAA say, they should relocate or better protect the rudder controls in the wing, given this large new engine and the potential for uncontained failure and fragmentation. And they were overruled by a single manager, apparently again at the local level.

This causes concern on my part, that there doesn't seem to be—and we haven't found yet—that there are levels of review beyond the local office. Are you going to be looking at that issue or problem as part of a solution?

Mr. DICKSON. Yes. Well, thank you for the question, Mr. Chairman. And I think that it is important to understand that as we work through these processes and when you have technical people involved in discussions, these processes by design encourage debate. And there are differences of opinion as we work through the processes.

And ultimately, remember that the managers who were involved in these decisions are themselves, are themselves experts, and there are times when they may have been overruled. And it is not

a matter, in my view, of what the applicant, or the manufacturer in this case, wants.

It is really a matter of letting the process work. And ultimately, the decision needs to be made on behalf of the agency, and on occasion, that maybe the manager that has a broader view that may be able to make that decision. I do think that there are some improvements that we can put in place. Aviation safety is working, as I mentioned, on just——

Mr. DEFAZIO. Thank you, Mr. Administrator. And one last question—I am running out of time and do not want to abuse my privileges here—Boeing self-certified and installed defective slats on 137 applications, and you just announced a $4 million civil fine for this deliberate abuse. And we have heard a lot of other things about production pressures, and we will hear more about that from the second panel.

I am concerned that will you look at these issues. And also we will hear from the second panel about concerns about whether or not sensors were installed, the AOA sensors installed properly because of production pressures, calibrated properly because of production pressures. Again, I have concern.

Again, and I do not get the sense thus far that you are ready to go there, that we may have a captive regulatory problem in the field offices. Because there are an awful lot of decisions that have gone in Boeing's favor, overruling a whole lot. The 787 had a safety specialist say, "Hey, you can't put a lithium battery in that plane without putting it in a steel box and venting it over the side." Overruled. Guess what? The plane gets grounded for 2 months because, hey, you have got to put it in a steel box and vent it over the side.

There have been an awful lot of people who seem to have been pressing it and right, and the question is, maybe this needs to go beyond the local office when we are talking about safety-critical systems.

And with that, I have run out of time. But I hope you will look at that issue. Thank you. Thank you, Mr. Administrator.

Ranking Member Graves.

Mr. GRAVES OF MISSOURI. Thank you, Mr. Chairman.

Something I worry about just a little bit is the direction we are taking—and this isn't about Democrats and Republicans because I hear it from both sides—and questioning the safety of our system. And that does worry me because I want people to feel safe getting in the air.

And I have heard people say, on both sides, that we have a system that is absolutely fundamentally broken. And my question to you, Administrator, is—and I don't think there is any system that can't use improvement, particularly when it comes to Government. But do you believe our system is fundamentally broken? We have worked a long time to get our certification process to where it is today. And so I ask you that question. Are we broken?

Mr. DICKSON. No. It is a great question. The system is not broken. However, with any process, and I have said many times, even in these last 4 months, that all processes need to be improved really each and every day, and to the extent there are gaps in the processes or, in the case of the MAX, fragmented, inadequate commu-

nication; data that didn't have the fidelity that we needed; the lack of a safety management system at manufacturers—those kinds of things are all improvements that can be put into place.

And I believe that the construct that we have, whether it is at an air carrier or manufacturer or an airport, of the agency being in a position to exercise effective oversight and not be captive, but also have fluid information flow and data flow from the regulated entity, is extremely important because that is the foundation of what has led to the margin of safety that we enjoy in the United States today.

Mr. GRAVES OF MISSOURI. I am going to change directions just a little bit so members of the committee can hear from a pilot's perspective. And I know you are typed in several different aircraft. In fact, name the aircraft you are typed in right now, commercial aircraft.

Mr. DICKSON. Commercial aircraft, the 727, 737, 757, 767, and the Airbus A319, 320, and 321.

Mr. GRAVES OF MISSOURI. So when you—and I have talked about this, that it is—a crash should never focus on one thing. We have got pilot issues. We have got maintenance issues. We have got Boeing. We have got—and everybody has a part of this that bears some of the blame.

But I have talked a lot about runaway trim and how MCAS, or any autopilot, for that matter, how it manifests itself. And it manifests itself as a runaway trim issue, which something here in the United States, we learned as pilots, whether that is private pilot training, commercial training, ATP training, is memory items, muscle memory.

And you go through those mental items. And can you explain—sometimes I get up here and harp on this stuff and don't explain it very well. But can you explain what it feels like? And I know you have run through the scenarios, too, in the simulator of these accidents. Can you explain runaway trim? Can you explain for the committee's benefit muscle memory and what you have taken away from your perspective?

Mr. DICKSON. Sure. Well, thank you for the question. This actually gets to the chairman's question on looking at what information was known right after the Lion Air accident. We had flight recorder data that indicated some issues with crew performance. We also had information with how the airplane was maintained. And if any of those had gone a different way, that accident would not have occurred, and events would have manifested themselves differently.

The pilot is part of the system, and so when we are designing flight control systems, any time you have a flight control problem, if the airplane is not doing what you wanted to do, the first thing you do is fly the airplane. And that means disconnecting the automation; in this case, if the autopilot is on, disconnect it. The autothrottles, disconnect them. Let's get the airplane under control and find out what is going on.

And then you execute whatever emergency procedure you have. In this case, with runaway stab trim, if the airplane has got control pressures that are undesirable, trim the airplane up. And then in most airplanes you disable the electric trim system and then can trim the airplane manually. Slow down. The airplane is not on fire.

You have not lost an engine. There is plenty of time. There is not any urgency in addressing the issue. So that is how we want to manage the workload in the cockpit in these events.

But runaway stabilizer trim, I have had it during my career. It is not a regular occurrence on modern aircraft, but it is something that every pilot learns during their initial qualification, whether in light aircraft or matriculating through commercial aviation aircraft as well.

Mr. GRAVES OF MISSOURI. So again—and I know when you read the report, too, that the copilot—the pilot asks, "Can you trim the aircraft?" Which at one point I think the aircraft accelerated through 500 miles per hour; at least, that is what some of the initial telemetry—you might explain that, too. Because I have tried to explain it before.

When you are trying to trim an aircraft that is going way too fast, the pressures that are against those control surfaces—you might do a better job of explaining that, too. I have used the analogy of trying to push a car door open when you are going down the road at 100 miles an hour, and it is very hard to get that.

It is the same thing you get on control surfaces when you are trying to trim something manually. You might go into a little bit further with that.

Mr. DICKSON. Sure. At high speed, I mean, this is why with any flight control problem it is important to maintain control of the aircraft. And that usually means, for a large commercial airplane, staying below 250 knots. And then if you have something like a flat base symmetry or an undesirable control force, a lot of times you will go back and reestablish what the previous configuration was.

In this particular case dealing with a trim issue, those forces are going to be much greater, which I believe is your point, at a higher speed because the controls are much more effective at high speed than they are at a slower speed.

Mr. GRAVES OF MISSOURI. So I am going to—and there has been a lot of talk directed at people blaming the pilots, which I do not believe the pilots are to blame in this. I think they were fighting for their life. And that is essentially what they were doing, and the passengers.

I think they were overwhelmed. I think they were trying to figure out what was going on. We know they reengaged the system. But I place a lot of that blame—and there is plenty of blame to go around in this whole thing again, whether that is manufacturer or pilot response or maintenance, whatever it is.

But I still go back to, and I have said this before, the Ethiopian Government that owns Ethiopian Airlines in that particular crash, that is who I place a lot of focus on because they put those two individuals in that cockpit. And it is unfortunate that that is the case. And that is the thing that worries me more than anything else. Because we do have different training standards throughout the world, very different training standards.

And when you have an airline that is growing as fast as they were growing, and you are throwing people in the cockpit, they may know how to fly the computer, but it goes back to what you said: You still have to come back—and I have said this before,

too—the most important safety factor you can have in any aircraft is a pilot that can handle whatever that situation is.

And I don't care if the pilot has 200 hours or 20,000 hours. There are airplanes that—or pilots that I will get in an airplane with that have 200 hours that I believe in their ability. And there are pilots out there that have 20,000 hours that I will never get in an aircraft with. It is all about how they handle whatever situation it is.

And so I still come back to training standards. And I think we are going to hear a little bit about that. And if we have more questions, I have got some questions for the folks that have been reviewing this because I know there is some talk about pilot training standards.

But I do appreciate your perspective on this. And again, I think there is a lot of blame to go around. But I do feel bad for those two pilots because I think they were absolutely overwhelmed with the task at hand.

Mr. DICKSON. Well, Congressman, I would just say I appreciate your comments. But I would just caution everyone, and I think you would agree with this, I am not about casting blame on anyone or anything. I am about identifying problems, issues, and developing solutions, and improving the process.

And there is a lot to be done in all of these areas, both with the technical processes, the human factors issues, and international pilot training standards as well.

Mr. GRAVES OF MISSOURI. I completely agree with you. And that is exactly why we are here, which I appreciate the chairman's point of view and what the committee is trying to do. It is unfortunate that we had to have people killed to get to this point, which has happened before in Government.

But I do think we need to be cautious as we move forward, too. We have to fix the system, whatever needs to be upgraded. But I do think we have to be very cautious moving forward and not have knee-jerk reactions because we do want to keep—and this comes back to my initial statement. I want to make sure that we have a safe system.

I do believe we have the safest system in the world, and it is the gold standard. And I want to make sure it stays that way. But I don't want to tear it apart by the same token.

Thank you, Mr. Chairman.

Mr. DEFAZIO. I thank the gentleman for his questions. And we are going to proceed in order of seniority. And first would be Representative Norton. Seniority and arrival; if you weren't here at the beginning, then——

Ms. NORTON. Thank you, Mr. Chairman. This is a very important hearing. I appreciate this hearing today.

And Administrator Dickson, I appreciate your being here. Let me say I also appreciate the answers you have provided so far to the Quiet Skies Caucus, of which I am a cochair. We are concerned, obviously, about allegations that FAA was a captive of the industry. So I want to ask you a series of questions that go to Boeing's delays in providing safety information. It looks like repetitive delays. We are trying to see whether or not we can break with that.

In 2015, did the FAA enter into a settlement agreement with Boeing—that is 4 years ago—to resolve multiple enforcement cases

against Boeing that were either pending or under investigation at the time?

Mr. DICKSON. Yes, we did.

Ms. NORTON. Is it also true that under the agreement, Boeing had to immediately pay $12 million into the U.S. Treasury?

Mr. DICKSON. Yes, ma'am.

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

Mr. DICKSON. That is correct.

Ms. NORTON. Do these genesis of settlements show a pattern of systemic issues on the part of Boeing, including failure to identify problems, failure to put corrective actions in place, inadequate resources, and inadequate training?

Mr. DICKSON. Well, I have to say I have yet to conclude that with respect to the settlement agreement. But it is something that is under consideration, and it could be the subject of future litigation. But I certainly reserve the right to take further action with respect to that agreement.

Ms. NORTON. We are talking about in the past, now, failure to identify problems, failure to put corrective actions in place. You are saying that is under litigation?

Mr. DICKSON. No, it is not under litigation. But it is a consideration about what actions may occur in the future with respect to the remaining actions before the 2020 timeframe that you talked about.

Ms. NORTON. Well, I think those failures are pretty clear, Administrator Dickson.

In designing and developing and manufacturing the 737 MAX, Boeing has run into issues in meeting the obligations in most of these categories. Isn't that true?

Mr. DICKSON. I am sorry. Can you restate—I am not sure I understood the question.

Ms. NORTON. Yes. In designing and in developing and manufacturing the 737 MAX, isn't it true Boeing has run into issues in meeting the obligations in most of the categories I just previously named?

Mr. DICKSON. I am not aware. Perhaps Mr. Lawrence may be aware. I am not aware of any specific issues.

Ms. NORTON. Has Boeing met all the obligations under the agreement?

Mr. LAWRENCE. That is still under evaluation right now.

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

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

Mr. DICKSON. Not at this time. But as I mentioned earlier, that is under consideration, and I reserve the right to go ahead and proceed appropriately.

Ms. NORTON. Thank you, Mr. Dickson. Thank you, Mr. Chairman.

Mr. DEFAZIO. I thank the gentlelady.

Representative Gibbs.

Mr. GIBBS. Thank you, Mr. Chairman. And I too want to extend my condolences to the families of the victims. This tragedy—it is just unbelievable that you have to suffer through this. I am glad you are here today.

Mr. Dickson, just to kind of start this out a little bit, you mentioned about identifying problems. And to me, it seems like, when I have tried to learn on this, that a software glitch, maybe a sensor issue, pilot awareness and training, and then also some of the problems trying to identify.

But then my overall question, talking about since you are the new Administrator, when you came in, were you concerned about what the relationship was with the FAA inspectors and the Boeing technical people, inspectors, and the relationship, and the culture between the two?

Mr. DICKSON. I knew there were questions about that. Of course, my experience is from the commercial airline industry, 27 years, and 12 years as a senior leader of flight operations. And I have seen the power and the benefit of safety management systems, and that how it has led to the incredible margin of safety that we have now.

But manufacturing is a new environment for me, and what the regulatory process is. I think one of the challenges that you have in an aircraft certification project is that it takes place over many years. And so I have become aware of, throughout this committee's investigation, the result or what we have seen so far, the Joint Authorities Technical Review, my own observations and conversations with the team out in Seattle about when we are bringing in various parts of the team and how engaged everyone is from beginning to end of the process.

So there is the relationship between the FAA and the manufacturer. But there is also how the pieces within the FAA are fitting together and working together and communicating with each other.

Mr. GIBBS. And it has expanded a little bit, the relationship to FAA, relationship with the European Union Aviation Safety Agency, and the relationship to Airbus and other manufacturers, foreign manufacturers, for compliance, for inspection and certification.

Mr. DICKSON. It is a different model, similar. But I think the issues are very similar. Over in Europe they have, again, a different legal construct, and EASA would actually have to take certificate action. Our system is a little more flexible in some respects. Delegation is something that has to be earned. It is a privilege. And it is really reliant on our trust with the applicant. And to the extent that that needs to be addressed, that will affect the decisions going forward.

Mr. GIBBS. Mr. Kiefer, as you are a TAB member, the Technical Advisory Board, conducting the review of the 737 MAX changes in pilot training, recommendations to ensure independence, and an unbiased review of the 737 MAX changes, how has that review—what is the progress and what do you think we—the conclusions related to the safety changes to date?

Mr. KIEFER. As far as conclusions go, our team is still—we still have work ongoing with Boeing. We have action items to Boeing for

further safety assessments. We are also waiting to see the final training modules and so forth. But the items that we have reviewed to date are looking good.

Mr. GIBBS. So the software changes, you are——

Mr. KIEFER. Yes. The software changes that have been put in place are addressing the failures that led to the two accidents. And——

Mr. GIBBS. Was there also a sensor issue, or lack of duplication or additional sensors?

Mr. KIEFER. OK. So I will address that by saying one of the new changes that Boeing has made to the software will have the MCAS as a system looking at both angle-of-attack sensors on the aircraft so that if one should fail like they did in the two mishap aircraft, the system will detect that and disable MCAS.

Mr. GIBBS. On pilot training and awareness, do you have any concerns that additional training and awareness when it fails—what does the manufacturer do to make sure that pilots are more aware of training? Do you have any comments on that?

Mr. KIEFER. So far as I have seen, the training that they have developed for the—and our team, the training that we have seen is adequate.

Mr. GIBBS. OK. Thank you. I yield back.

Mr. DEFAZIO. I thank the gentleman.

Representative Johnson.

Ms. JOHNSON OF TEXAS. Thank you, Mr. Chairman. I ask unanimous consent to put my opening statement in the record.

Mr. DEFAZIO. Without objection, so ordered.

Ms. JOHNSON OF TEXAS. Thank you.

[The prepared statement of Ms. Johnson of Texas is on page 153.]

Ms. JOHNSON OF TEXAS. Administrator Dickson, the faces of the people being shown over here—I don't know whether you can see them—are indelibly in our mind. And the only thing we are trying to get at is how we avoid this again. And so the last two airlines developed by Boeing, the 787 and the 737 MAX, have been the subjects of worldwide groundings. Before the 787 grounding, the last airline type to be grounded was the DC–10 in 1979.

What do these groundings tell us about Boeing's ability to deliver quality, airworthy airplanes? And what do these groundings tell us about FAA's ability to conduct effective oversight of the aircraft certification process?

Mr. DICKSON. Well, thank you. It is an appropriate question. I want to ensure that you and everyone here in the committee, the families, and the American public know that my highest priority is to make sure that nothing like this happens again; but not only that, that we continue to raise the margin of safety in the U.S. aviation system, and use our influence to do so around the world.

These groundings, again, I think they illustrate that what we have done historically we cannot be satisfied with. We have got to continue to put process improvements in place. We have got to support our people. We have got to make sure we have got the right skill sets in our workforce, and that we are making decisions the right way, with safety as our absolute highest priority.

So again, that involves just culture, both within the manufacturer and the regulator; the separation of safety issues from business issues—there can't be undue pressure on one side or the other; and we have got to make sure that system is absolutely clean.

I think we also need to remember that in hindsight, there are other accidents that have happened over history where airplanes were not grounded because we didn't have data at the time. And TWA 800 is an example. We have Air France 447, where there were some similar human factors and issues involved there.

And I think that, again, this is where pointing the finger of blame prematurely ends up being counterproductive because we just move on to the next thing. So I think that my interest is in the whole system and how all the parts interact. And as flight decks and airplanes continue to become more and more modernized, we need to understand that humans are a part of the system.

They are a part of the design process. They are a part of maintaining the aircraft. They are a part of operating the aircraft. And human frailty and our ability to be able to engage with systems and be part of the system, all that needs to be taken into account in the design moving forward.

Ms. JOHNSON OF TEXAS. Thank you very much. Do you believe that the recent failures of the Boeing 737 MAX or Boeing's ability to deliver safe, reliable airplanes says anything about the organization designation authorization structure?

Mr. DICKSON. It is a good question. And I think that, again, as I said before, the ability to delegate to the private sector has existed for decades. And actually, in one form or another, it goes back to the 1920s.

And if you look at the commercial airlines, which again is what I am most familiar with, the certificate management offices that oversee the major airlines have typically 30 or 40 operations inspectors who are supervising a pilot force at that airline of maybe more than 10,000.

But they rely on those who are flying the airline every day—the line check airman, the instructor designees, who are really there and take their obligations as FAA designees very seriously. I think there is an analogy to being able to do the same thing at the manufacturer. But that does not mean that there aren't improvements that need to be put into place.

I think that the ability to have higher fidelity data around the globe—we have airplanes that can stream data almost immediately off the airplane now. And we need to be able to put protocols. We need to work with labor. We need to work with the manufacturers. And we need to work within the FAA to make sure we can take that data, and it will allow us to make better decisions under an appropriate safety management system.

Mr. DEFAZIO. Thank you.

Mr. Massie.

Mr. MASSIE. Thank you, Mr. Chairman.

Mr. Kiefer, can you get into a little more detail about the changes to the flight control system that you have observed that have been made?

Mr. KIEFER. Yes, sir. Soo there are four main changes that have been made to the speed trim system in MCAS in the flight control system of the 737 MAX. The first is, as I said, there is now going to be an angle-of-attack sensor comparison between the two angle-of-attack sensors. If they vary more than 5½ degrees from each other, the speed trim system in MCAS will be disabled.

The next one is maximum stab trim command limit. So this is a limit put into the software that will prevent the stabilizer from trimming to a point where the pilot will no longer have control authority by pulling on the control wheel alone using elevator controls.

The other one is the MCAS resynchronization change that has been made. This change will account for any manual trim inputs that the pilot makes with the electric manual trim while MCAS is activating, and then return the trim back to that new setting once MCAS is done or once angle of attacks come back out of the MCAS range. This also will prevent more than one MCAS firing during an angle-of-attack event.

The last change is a change that has the two flight control computers in the aircraft monitoring each other's performance. And if there is an errant or spurious trim command that comes from one that is not also commanded by the other, it will shut that trim system off.

Mr. MASSIE. It seems like after the first crash, and definitely after the second crash, there was sort of a rush to the flight simulators, and let's recreate the problem and see how pilots respond to that. And in hindsight, we know the failures were a combination of human factors, user interface design, and an individual component failure.

In the certification process before even the plane is certified, is there enough testing in the flight simulator of individual component failure? Because it seems like with the 737 MAX, when there were changes to the user interface, the flight control system, it would have been wise to go into the flight simulator then and simulate failures like the angle-of-attack sensor instead of after the fact.

Can you tell us, Mr. Lawrence, to what degree those things are tested for in the certification process?

Mr. LAWRENCE. Thank you very much for the question. Human factors testing and flight testing is a current requirement of any aircraft certification project. And in fact, just to warrant that, that is one of the reasons why we have had a delay in the reintroduction of the 737.

It was that very testing earlier this year that our test pilots identified some issues and required some additional changes to the system. And that is when we added the additional comparators and change in the flight control system so that the two computers would be talking to each other.

So it is a factor in the system, and it is flight tested as well. So obviously, some things can't—you don't want to go up and flight test some things that are very dangerous; that is why the simulators are used. But we try to accommodate every possible failure that we can think of in the testing and certification of the aircraft upfront.

Mr. MASSIE. Both crashes were tragic, and if we knew all the factors in hindsight, they probably could have been avoided. But the second one seems more tragic, given that it was a similar set of factors as the first.

In hindsight, or looking forward, better yet, what could we do between after a crash like the Lion Air crash—what could you do at the FAA to prevent the second crash? I am not saying what should people have done before. But what are we going to do going forward to stop the second crash from ever happening? Mr. Dickson.

Mr. DICKSON. Well, I think it is a great question. And I think I would just go back to the availability of data earlier, and to be able to look at root causes. Because ultimately, we are looking at a process by which a fix is being put in place. And how urgent and what kind of timeframe are we looking at? Or is it a high enough risk—remember, this is all about managing risk—and is it a high enough risk that the airplane would actually need to be grounded?

Mr. MASSIE. Thank you. My time is expired.

Mr. DEFAZIO. I thank the gentleman.

And with that, Representative Larsen, the chair of the subcommittee.

Mr. LARSEN. Thank you. Mr. Dickson, you were a pilot, active pilot for Delta for how long?

Mr. DICKSON. For 27 years.

Mr. LARSEN. For 27 years. And then after you were a pilot for Delta, you worked for Delta in operations. Is that right?

Mr. DICKSON. Well, I was—so during my career, I flew as a line pilot for about 9 years, and then was the senior vice president of flight operations for the last 12 years of my career.

Mr. LARSEN. OK. And in that role you were pretty active inside of Delta as well as with outreach to the Federal Government in a capacity to the FAA?

Mr. DICKSON. Yes, sir.

Mr. LARSEN. So I know you have been on the job for 4 months. But you were not just air-dropped into this job at FAA. You actually know what you are doing coming to the job. Is that right?

Mr. DICKSON. Yes.

Mr. LARSEN. Mr. Lawrence, you have been at the FAA for about 9 years, even though in your new job you just started last year, 2018. But before that, you were active in the Experimental Aircraft Association and other things. You just weren't air-dropped into your job last year. You actually know what you are doing in this new job. Right?

Mr. LAWRENCE. Correct.

Mr. LARSEN. All right. So I think you should be proud of your credentials and not underplay them and the role that you play, both looking forward and in looking back. I wasn't in Congress when a lot of things passed in Congress, but I am in my job and I am responsible for those things.

You are responsible for the things that happened before you got there, just as other people were. But you are responsible now for those things that happened before you got there.

Mr. DICKSON. Absolutely.

Mr. LARSEN. As well as you being responsible going forward.

Mr. DICKSON. Absolutely. The buck stops—I mean, I am responsible.

Mr. LARSEN. I am glad we can agree on that. Also, I would note that the existing ODA program didn't exist in the 1920s, although ODA in some form did exist back in the 1920s. The existing one started in 2005, passed under an FAA law. So that is what we are dealing with now as well, not what it was in the 1920s, but what it is now.

Mr. DICKSON. Right.

Mr. LARSEN. It is very different than what it was. So I just want to establish some baseline here about what we are talking about, not the 1920s, not the fact that you are new to the job, because you are actually not all that new to the job. And given that, I want to ask you about some of the decisions that have been made at the FAA. And you may not be able to answer them today, but you need to answer them.

For instance, the Boeing CEO, Mr. Muilenburg, stated to us the FAA fully vetted the company's 2016 revised system safety assessment. But the Indonesian accident authorities found that the FAA's response was simply to accept that submission—so fully vetted versus simply accept—with a note indicating that that approval was delegated to Boeing. So that is what the Indonesian air authorities noted in their report.

So is that the process? Is fully vetting, is all that means is that Boeing gave it to FAA and the FAA accepted that, and that is what "fully vetting" means?

Mr. DICKSON. Fully vetting, in my definition, doesn't mean that. I would defer to Mr. Lawrence on the technical details. But I would say that from my understanding, it is not unusual for design applicants to come in and ask for certain things to be delegated.

Mr. LARSEN. Mr. Lawrence?

Mr. LAWRENCE. So fully vetted would not just be a cursory review, and that is not what is done in the system. As we have talked about in the past, delegation is really used primarily in routine and well-understood areas. But it also relies on the data that were provided. And that is, as has been mentioned earlier, an area that we are focusing on. If we don't have the right information, it won't result in the correct answers.

Mr. LARSEN. So the JATR report also found that MCAS certification deliverables were not adequately updated by Boeing to reflect the changes to the flight control system. We sorted that out in the last hearing. At any time during the process, did the FAA notify Boeing that these documents were in fact insufficient? And if not, why not? I am trying to get at gaps in the process we use to certify. That is what I am getting at. So if not, why not?

Mr. DICKSON. My understanding is the design change for MCAS, which is what I believe you are referring to, was not made evident to the aircraft evaluation group, which would be responsible, really, for looking at the operational implications of how the system was working.

There may have been some conversations within either the flight test or technical areas of the FAA. So I think what it indicates is this issue of fragmented communication and the fact that there was information out there. But it was difficult to put the whole pic-

ture together to make a sound decision. That is absolutely something that we need to address going forward.

Mr. LARSEN. OK. I have run out of time. Sorry about the questions, but I had to spend so much time bucking up your credentials to show that you are qualified to answer these questions for us today. And they don't all have to take—we need to get to the folks who made these decisions as well.

But I have confidence that you have the credentials to answer these questions and help us. And I also have confidence to find out where the gaps are and hold folks responsible for that as well. And I will hold you responsible for that.

Mr. DICKSON. Thank you.

Mr. DEFAZIO. I thank the gentleman.

Now Representative Perry.

Mr. PERRY. Thank you, Mr. Chairman. I also want to acknowledge the representatives of those and their families who were lost in the tragedy, and offer my condolences as well. We appreciate your attendance and advocacy here today.

Mr. Dickson, Administrator, we want to make sure that we have all the information so that we can trust the fidelity of the outcome of this when it finally is complete. In that vein, on October 7th of this year, the AP broke a story entitled, "Airline Went into Records after MAX Crash, Engineer Says," which detailed the contents of a whistleblower complaint submitted to the FAA and other international air safety regulators by Ethiopian Airlines former chief engineer Yonas Yeshanew.

Can I ask unanimous consent to have this entered into the record?

Mr. DEFAZIO. Without objection, so ordered.

Mr. PERRY. Thank you, Mr. Chairman.

[The AP news story follows:]

Article of October 7, 2019, "Airline Went Into Records After MAX Crash, Engineer Says," by Bernard Condon, Submitted by Hon. Perry

[The article is retained in committee files and is available online at https://apnews.com/5ff095b8b9954b03925410680e8c907d.]

Mr. PERRY. The allegations outlined in the complaint are shocking and speak to a culture of corruption permeating the state-owned airline, Ethiopian safety regulators, and the Ethiopian Government at large. If true, the allegations of fabricating documents, signing off on shoddy repairs, and even beating those who got out of line appear to be directly relevant to investigations into the cause of the crash in question.

Do you have an update on the status of the investigation into this complaint? And do you expect that completion of this investigation prior to the publication of the crash investigation report? And in light of these allegations against Ethiopian Airlines, a state-owned enterprise and that nation's safety regulators, does the FAA still have confidence in the integrity and validity of the current crash investigation being led by the Ethiopian Government?

Mr. DICKSON. Well, thank you for the question. I do not have an update today. But I will just say that, again, in this process of im-

proving, we need to make sure as we made decisions and as the agency works with the committee to improve the margin of safety globally that we take all of the factors into account.

And of course, the FAA, I think, has a responsibility to influence globally, even those that we don't directly regulate. We do punt some of that through ICAO, but we also do it with bilateral and regional relationships as well. So as various facts come to light, we certainly need to take those into account as we make decisions.

Mr. PERRY. I appreciate your answer. And I would just caution you, I suppose, even though you don't have an update. It seems like we would want to make sure that we had all the relevant information prior to the report, the crash investigation report. And this might be relevant. It may not, but we should know that.

I would like to switch gears here a little bit. The FAA has identified December 20th, just in a few days, of this year as the new projected date to release the NPRM on remote ID and tracking of UAS. Is FAA still on track to release the NPRM, which is essentially in 8 or 9 days? And if this date does pass without release of the rulemaking, what are your plans to hold people accountable for the continued delays?

Mr. DICKSON. Thank you for the question on the remote ID. The process is it is actually out of the FAA at this point. It has proceeded out of the Department of Transportation and is under review through OMB channels. And so I expect any time now that we would have it out there. I don't have an exact date for you. I am certainly hopeful that it will be by December 20th.

Mr. PERRY. Could you restate that last part about December 20th

Mr. DICKSON. I am hopeful that it will be out by December 20th. I am certainly planning on——

Mr. PERRY. But you will confirm it is out of FAA's hands now?

Mr. DICKSON. Well, it is already out of FAA's hands, yes.

Mr. PERRY. All right. Thank you, Mr. Director. I yield.

Mr. DEFAZIO. I thank the gentleman. And OMB is a perpetual problem as we try and move forward on safety issues, and let's hope that they can get this one done promptly.

With that, I would turn to Representative Napolitano.

Mrs. NAPOLITANO. Thank you, Mr. Chairman.

Mr. Dickson, the U.S. aviation industry has to be commended, and the FAA, for a stellar safety record over the past decade, up until the Lion accident. And our deepest condolences to the families, and thank you for being here.

However, checks have uncovered a system both at Boeing and FAA about complacency in their commitment to safety because it has such a stellar record for so long. And complacency can be a dangerous thing, particularly in industries that are truly safety-critical.

Despite this, we are not aware of any key efforts or initiatives in FAA to emphasize and re-energize the safety culture that once existed. We do understand, and you have talked to your staff about not rushing the process of ungrounding the MAX, for instance, and emphasizing safety first.

But has FAA hired safety experts from outside the aviation industry to take a fresh look at your processes? And has it begun to hire more human factors experts, as some reviews have suggested

you should? Have you personally sat down with the FAA managers and FAA technical staff in their Seattle office to hear the recommendations for improving FAA, and their concerns about oversight of Boeing? I would like to know what you have done to address safety and oversight issues at FAA.

Mr. DICKSON. Well, thank you. It is a great question, and I actually welcome the opportunity to respond.

On my first day at the agency, in my first town hall, I talked about the importance of just culture, which means that we need to have a systematic way for employees to bring their concerns forward, and we will have better-thought-through solutions. We can't have groupthink. We have got to have honest debate as we make these decisions. And my experience in the airline industry is that that kind of construct is extremely powerful in raising the safety bar.

Along with that, in my first 3 weeks I made a visit out to Seattle to see for myself and to talk to the team out there. And I actually had a conversation with one of our human factors test pilots, a Ph.D. in human factors, and asked her whether we had adequate human factors expertise and whether it was embedded in our processes as effectively as it needs to be. And I learned a lot from that conversation. I think there is an opportunity for us to continue to update and improve those skills in our workforce, and that is a big area of focus for me.

Mrs. NAPOLITANO. Sir, we are particularly interested in the testimony of Dr. Endsley on the second panel, dealing with the human factors involved with aircraft design, certification, and operation, a topic that I have discussed with a certain friend of mine, a professor of engineering at USC, Dr. Meshkati.

What do you think FAA and Boeing can do better to incorporate human factors into the design and certification process of airplanes to prevent future accidents?

Mr. DICKSON. That is a great question. I am also interested in hearing the comments, human factors comments, in the second panel. And I have had a chance to read the testimony, and couldn't agree more with the principles that are articulated there.

I think as cockpits become more and more automated over the decades, the job of flying an airplane does not get easier. But what it does is it changes the nature of where the threat is that needs to be mitigated. And there is an issue sometimes with manual flying skills if we are operating in an automated fashion too often. There is also an issue with losing situational awareness. And this is—it is impossible to engineer out human error.

So as we build modern airplanes, it is very important to do so in a way that keeps the pilot engaged with the flight path of the aircraft because ultimately, management of flight path of the aircraft, putting it where it needs to be at any point in time, whether it is on the ground, taxiing the airplane, or flying it in the air, it amounts to three things, and that is understanding where your airplane is supposed to be, understanding your clearance, putting the airplane there to comport with the clearance, and then making sure it stays there.

And humans are not very good passive monitors. And so this is where the issues about how engaging and the forms of tactile feed-

back that are presented to the pilot as he or she is flying the aircraft are extremely important, even as flight decks become more automated in the future.

Mrs. NAPOLITANO. Thank you. Mr. Chair, thank you.

Mr. DEFAZIO. I thank the gentlelady for her questions and the answers.

Representative Davis.

Mr. DAVIS. Thank you, Mr. Chair, and thank you to all of our witnesses for being here.

There are 794 Boeing employees living in my congressional district who work at their facilities in St. Louis, Missouri, or Mascoutah, Illinois. And back in October, we had the Boeing CEO before this committee, sitting right where you are, Administrator Dickson. And I explained to him that any time we have tragedies like those that are being discussed today, it really breaks my constituents.

They are workers that are there. It breaks their hearts because they want to make sure that the planes that they are manufacturing are going to be able to fly safely, and we don't have tragic accidents that affected so many families that are here in this room today. And again, I echo my colleague from Pennsylvania, Mr. Perry's, comments. Our hearts go out to you. Our condolences. But thank you for your presence.

Administrator Dickson, in your testimony you mentioned you are working tirelessly to ensure the FAA learns from mistakes surrounding these tragedies. And I know you mentioned in your testimony—I know you have answered some of my colleagues' questions—but what specifically have you not addressed yet—is the FAA doing to ensure that oversight programs work to protect passengers flying by plane, and also to preserve the dignity of the workers, my constituents, who build the planes?

Mr. DICKSON. Well, thank you for the question. I certainly—we are all in this together. And the situation with the 737 MAX is unprecedented in many respects, and so for the time being we have pulled that work inside the FAA. We are not delegating anything to Boeing because the expectation is that the FAA is going to use its resources and the resources of others—we talked about the TAB here—to make sure that we dot every I and cross every T.

And that is not to be bureaucratic or slow about it. But we need to make sure that the public has confidence in the airplane, and I am confident that I would put my own family, and those Boeing employees would put their own families on the airplane, once we are finished with this process.

So again, we have a number of milestones yet to complete. We have gone through the workload management engineering simulator modules most recently. That data is being analyzed. And we are currently looking at how the software has been developed, along with our international partners, and running all the audit trees that need to be run when you are talking about software. After that there will be a certification flight and then, as you know, I am going to be flying the airplane myself before I sign off on it.

Separately, we are involving not only U.S.-trained pilots but pilots from around the world in ensuring that the training require-

ments that we require for getting the airplane flying again are where they need to be.

Mr. Lawrence, I don't know if you had anything else you wanted to add.

Mr. DAVIS. Any other witnesses want to add?

[No response.]

Mr. DAVIS. OK. Well, Administrator, thank you. And I am going to relay the same thing that I relayed to the Boeing CEO. Look, we expect results. No family should go through the tragedy that these families have gone through. We know there are things that we could all do better. We want to be here to assist you and the FAA to make that happen. But results matter.

And I certainly appreciate your presence here today. I certainly appreciate your leadership, and look forward to working with you. And Mr. Chairman, I yield back.

Mr. DEFAZIO. I thank the gentleman.

And with that, Representative Lipinski.

Mr. LIPINSKI. Thank you, Mr. Chairman.

I want to start off by—so that no one out there faints, I do not believe we should get rid of ODA. I am not suggesting that. But I wanted to preface what I was going to say with that because, Administrator, you had said that the system is not broken. But improvements can be made.

We have seen 346 people die. And there was a second crash, and we knew more after the first crash, before that second crash. And so I would say the system is broken. Something went wrong.

The first thing I want to raise is something Chairman DeFazio raised at the beginning, the MCAS risk assessment document. After the first crash, do you know—are you aware—of where this—well, who saw this document in the FAA?

Mr. DICKSON. I was not involved in that. I am not sure exactly. I cannot speak for who saw it. I know that it was—again, it is a decision tool that the——

Mr. LIPINSKI. Who makes the decision, then?

Mr. DICKSON. Well, the board that comes together on continuous airworthiness, essentially uses it to make its decisions. Earl can walk you through how that process works.

Mr. LAWRENCE. So whenever we get reports, and we get reports on a regular basis, we are constantly plugging those reports into tools and evaluating what action needs to be taken. And obviously, this was a very large action. We did not need the forms to tell us this was a tragedy and that we needed to act quickly.

But the forms do educate us on how to respond. And what the form——

Mr. LIPINSKI. Was this an acceptable risk, though?

Mr. LAWRENCE. It is not an acceptable risk, and that is why we issued an emergency AD before we even completed the first set of evaluations, and then followed up with several other evaluations on what additional——

Mr. LIPINSKI. Let me——

Mr. LAWRENCE [continuing]. Actions needed to be taken.

Mr. LIPINSKI [continuing]. Ask a question on that. You mentioned the emergency AD. Because I wanted to ask: Why was there no mention of MCAS in that emergency AD?

Mr. LAWRENCE. So the Continuing Airworthiness Review Board is made up of pilots from our aircraft evaluation group. It is made up of maintenance people. Made up of engineers. They evaluated all the information, and they made a determination not to use those words because those words were not included in the Boeing manuals to start with.

And we—there was a discussion: Would that create too much confusion? Because the system that needed to be addressed was the trim system. And so they did not use those words at that time because the action that needed to be taken by the pilots was the——

Mr. LIPINSKI. It all started with the——

Mr. LAWRENCE [continuing]. Trim runaway checklist.

Mr. LIPINSKI [continuing]. MCAS not being named in the manual to begin with. I don't have much time, so one other thing that I wanted to mention, follow up a little bit on what Mr. Larsen, Chairman Larsen, had been talking about.

I have a degree as a mechanical engineer. I know a little bit about airplanes, not certainly as much as the pilots here do. But I also have a degree in systems engineering. I don't understand how it is possible that part of the procedure is not to look at the entire system. It makes no sense to me that you would just look at each piece of the system and not how the entire system works together.

And to me, that says to me that the process is broken. The ODA process is broken. I just want to be very clear that I think that that needs to be changed.

Administrator Dickson, I wanted to get your response on that.

Mr. DICKSON. I think the use of integrated systems safety assessments is absolutely an area that we have incorporated, actually, in the MAX process up to this point. And putting gates into the process at which this occurs more frequently is definitely something that we need to be looking at.

And remember, those systems safety assessments are—that is actually one of the process improvements I am talking about putting in place in the very short term, even with ongoing certification activity.

Mr. LIPINSKI. Thank you. I yield back.

Mr. DEFAZIO. I thank the gentleman. And in my first questions, I did ask that you would look at the distribution of this TARAM report. And I would like given what Mr. Lawrence just said, to know specifically if the continued airworthiness panel received this document and considered it at that time. Thank you.

With that, I would recognize Representative Babin.

Dr. BABIN. Thank you, Mr. Chairman.

I want to thank you, expert witnesses from the FAA, as well for your testimony. I also want to thank the families and friends of those who were lost in the tragedies.

Before I get to my questions, I want to make just a quick comment. I think it is lamentable that we are once again discussing the Boeing 737 MAX crashes, and not one FAA official in charge from the time when the decisions related to the certifications in question were made has been asked to testify.

I know that Ranking Member Sam Graves and Ranking Member Garret Graves have requested the chairman hold a hearing with these individuals. And I look forward to that in the future.

Administrator Dickson, could you briefly discuss how other countries certify their planes? And maybe Mr. Lawrence can chime in here as well. Do they have something similar to the process that we use here? It is my opinion, and that of several others, that we shouldn't throw the baby out with the bathwater because our system and processes are not broken. But what improvements could be made to our current framework to ensure proper certification oversight?

Mr. DICKSON. That is a great question, and I will let Mr. Lawrence elaborate on my 35,000-foot answer.

Dr. BABIN. OK.

Mr. DICKSON. The processes around the world, and we are really talking about the four primary states of design that we are working with—although there are other entities that build and design airplanes—it is really EASA, the Europeans; the Canadians; and the Brazilians. And processes are similar.

Because of different legal formulations and the fact that EASA is a multinational regulator that sits on top of the national regulatory authorities, there are some differences in how far their process goes and how it is managed.

I think that the concepts are the same in terms of delegation, but rather than delegating individual items, for example, if you contrast our system with the Europeans, we have a lot of flexibility in delegating, and it is basically a privilege to be able to delegate certain items.

Usually, as Mr. Lawrence said earlier, they are pretty routine items. And the FAA can modify those decisions once it starts, whereas in Europe they actually have a design certificate, essentially, for the manufacturing entity. So really the whole process is delegated in many respects, but there is not the ability to delegate individual items. They have an oversight system set up to look at——

Dr. BABIN. Yes. As briefly as you can, Mr. Lawrence. I have another question or two. Thank you.

Mr. LAWRENCE. I think that is a very good description. The key difference is, on the legal system that EASA and the European Union is working under, it is a certificate that a manufacturer, a design organization, achieves. And so they have an approval.

So it is really a different system. There is not a constant review of things. And in our system, we can pick and choose what we want to review, what we feel we need to review, where there is more upfront work, though, in the European system. I would say there is a lot more review and understanding ahead of time. And those are some of the things that we are looking to do as well.

Dr. BABIN. OK. Thank you. We have heard a lot about how assumptions may have been made about pilot capabilities that we are learning may not have been accurate. Can you shed some light on how those assumptions were made, as quickly as possible, Mr. Dickson?

Mr. DICKSON. The assumptions are really of some longstanding in terms of the technical requirements. They were developed over

a period of years with test pilots and engineers. And I don't know if there are any other details on that that you would like to share. But these are some of the things that, as a result of the reviews that we are doing now and other external reviews, that are being revisited.

Dr. BABIN. OK. Thank you. And then adding to it, in your opinion, is there anything that we in the United States can do to standardize the qualifications of pilots globally? We have done that well here domestically, I think very well. But what about internationally, and what role could the FAA play in encouraging that?

Mr. DICKSON. Thank you for the question. I think that the FAA can play a very influential role there. As a matter of fact, we introduced a paper at the recent ICAO assembly, and I was part of the team that went up there, the International Civil Aviation Organization, about lifting global pilot training standards. And so that is something that we have taken on as an agency already.

But then we will also have similar discussions with regional regulatory entities and associations as well as some of the bilateral relationships that we have around the world.

Dr. BABIN. OK. Thank you. My time is expired. I yield back, Mr. Chairman.

Mr. DEFAZIO. I thank the gentleman.

With that, Representative Cohen.

Mr. COHEN. Thank you, Chairman and Ranking Member Graves, for holding this important hearing. And thanks to the witnesses for being here today, and to the families. Again, my condolences.

Today's hearing is another significant step in our oversight of the two fatal Boeing 737 MAX accidents. These tragedies, which claimed the lives of 346 individuals, have unearthed a slew of problems regarding the FAA's ability to effectively oversee those it regulates.

For instance, one issue that has raised serious concerns relates to the angle-of-attack, AOA, disagree alerts. An AOA disagree alert warns pilots when the aircraft's AOAs, angle of alert sensors, do not match. In August 2017, Boeing learned that the AOA disagree alerts were only functional on the planes where customers also purchased an optional AOA indicator. To put that into context, 20 percent of Boeing 737 MAX customers purchased those optional AOA indicators.

AOA disagree alerts were not functioning, then, on about 80 percent of the 737 MAX aircraft sold to airlines around the world. Southwest Airlines, which does operate in my hometown, even said in a statement that it only learned that this system was optional after the Lion Air tragedy.

We learned in our previous hearings in October that Boeing initially decided to wait to fix the defect for 3 years after discovering this flaw. Boeing also confirmed that it kept producing planes with this known defect, and did not inform the FAA or its customers about it until after the Lion Air crash in October 2018. This was over 1 year after Boeing learned about the defect.

More alarmingly, the Indonesian Civil Aviation Authority's final report on the Lion Air crash found that the inoperative AOA disagree alert on the airplane "contributed to the crew being denied valid information about abnormal conditions." This is completely

unacceptable. Someone needs to be truly held accountable. Someone needs to be held accountable at Boeing.

Administrator Stephen Dickson and the FAA shares in this. Why has the FAA not taken any actions against Boeing, including a civil penalty for knowingly delivering aircraft with defective, nonfunctioning parts that pilots believed were functioning?

Mr. DICKSON. Well, thank you for the question, Congressman. And I have not made a decision on this and a number of other matters, as I mentioned earlier. I have expressed my disappointment to the Boeing leadership about that they need now and previously to be transparent in the sharing of information with my team here at the agency. And so I reserve the right to take further action, and we very well may do that.

I am not going to say today exactly what that may consist of, but the facts that you just presented will certainly go into that decision.

Mr. COHEN. Thank you, sir. Do you think that it almost borders on criminal? They have knowledge of a defect, and they don't give notice, and they invite the flying public onto those planes?

Mr. DICKSON. I don't have an opinion on that. I will say that, again, if you look, as I said in my remarks or in answer to a question earlier, I am not at this point interested in casting blame because I want to run all of these issues to ground and I want to fix the problem. There will be time for the rest as we move forward.

Boeing has—grounding the airplane, not delegating anything during the MAX return-to-service process, not delegating the airworthiness certificates on each individual undelivered aircraft. We talked earlier about the slat tracks enforcement action, and I haven't ruled out other actions as necessary and as you point out. And I will take those actions——

Mr. COHEN. Thank you. I appreciate you doing that. There are serious concerns about Boeing's transparency about the alert system that have been raised.

Today I introduced the Safety Is Not for Sale Act. I introduced it with Senators Markey and Feinstein, and we introduced it earlier in the Senate. This bill would require all air carriers to adopt additional safety features and ensure all nonrequired safety enhancing equipment is offered or provided to all carriers without an additional charge.

Aviation safety should not be treated as a luxury, bought or sold for an extra fee. Mr. Nader would say you shouldn't charge for seatbelts, and you shouldn't. The flying public expects and deserves more. I look forward to continuing to work with my fellow committee members and relevant stakeholders to ensure the safety and airworthiness, hopefully, of the Boeing 737 MAX. And with that, I yield back the balance of my time.

Mr. DEFAZIO. I thank the gentleman.

Now I will turn to the ranking member of the subcommittee, Garret Graves of Louisiana.

Mr. GRAVES OF LOUISIANA. Thank you, Mr. Chairman.

Mr. Chairman, I want to cite the comments that my friend from California, Mrs. Napolitano, made earlier about the safety of the domestic aviation industry, the FAA. I was reading a Wall Street Journal article this morning, and it cited how, prior to the 737

MAX disasters, I believe it was the Boeing planes had an accident 1 out of every 10 million flights.

Comparatively, if you look at the European, Brazilian, Canadian, and other manufacturers that are largely governed by their civil aviation authorities, it was an accident once for every 3 million flights. So again, 1 in every 10 million flights, 1 in every 3 million flights. And we certainly do need to get back to that level of safety, or, as I said before, even better.

In the aftermath of the Indonesian crash, so there was an emergency airworthiness directive that was put in place, which is rare. But also, there was—the CARB was established, a Corrective Action Review Board. Did the Corrective Action Review Board, did they—were there any recommendations they made that FAA did not follow?

Mr. DICKSON. No. The FAA followed the recommendations from the experts on the CARB.

Mr. GRAVES OF LOUISIANA. And these are——

Mr. DICKSON. And that was to develop the MCAS software check.

Mr. GRAVES OF LOUISIANA. And these are technical experts?

Mr. DICKSON. Yes, sir.

Mr. GRAVES OF LOUISIANA. And did they recommend a grounding?

Mr. DICKSON. They did not.

Mr. GRAVES OF LOUISIANA. They did not recommend a grounding? When the plane was ultimately grounded in the aftermath of Ethiopia, which actually, by the way, in the Ethiopian Air disaster, did they comply with the EAD? Did the crew comply with the EAD in that case?

Mr. DICKSON. Well, again, the accident report is not out yet, so it remains to be seen. On my first day at the agency I did have a chance to see the flight data recorder information from both accidents and compare the two. And in my estimation, for whatever reason, the AD procedures that the FAA expected to be followed were not followed.

Mr. GRAVES OF LOUISIANA. And so I just want to make sure we highlight this because in the future, if something happens and an AD is issued, an emergency airworthiness directive is issued, we need to ensure that there is a better process, that those lessons learned are actually applied and complied with. And so I think that is one of the many lessons learned.

And you are exactly right, and I want to express caution with my own statements. We do need to make sure we wait for the Ethiopian report to be completed to see what their takeaways are.

A question was asked of you earlier, and I want to give you an opportunity to perhaps clarify. You were asked if you were responsible for decisions of your predecessors. Now, look. I ultimately ran for the Congress because I was frustrated by what was here and I wasn't happy with the performance. That motivated my decision to run.

We are where we are as a Nation today, as a Congress. We are where we are as an FAA. Are you responsible for each of the decisions that were made that got us to where we are? Or are you responsible with where we are now and where we go?

Mr. DICKSON. Well, I appreciate your comments, Congressman Graves. I feel responsible, regardless. And that is just who I am. And I think it is important that—Chairman DeFazio mentioned the career professionals at the FAA. I need to advocate for them and I need to support them.

I need to make sure that they have got the tools and the direction and the support, whether it is Earl Lawrence and his team or Ali Bahrami in the Aviation Safety Organization. Flight standards, the Air Traffic Organization, whatever the case may be, my job as a servant leader is to make sure that they have what they need to be effective in their jobs.

So I feel responsible for that. And I want to take those lessons that are learned, and apply them to put improvements in place so that we continue to raise the bar on safety.

Mr. GRAVES OF LOUISIANA. Well, and I certainly share the objective of raising the bar and ensuring that we have maximum safety.

So let me get to the last point here. So the CARB did not recommend a grounding, but the plane was ultimately grounded. Was that a decision by the technical folks or was that decision by someone else, to ultimately ground the plane?

Mr. DICKSON. That was a decision, I believe, that was made by Mr. Bahrami, I think, or at least was driven by the availability of additional data.

Mr. GRAVES OF LOUISIANA. That was my understanding, that——

Mr. DICKSON. Yes. Then-Acting Administrator Elwell.

Mr. GRAVES OF LOUISIANA [continuing]. It came from Mr. Bahrami as well.

And I just want to make note, Mr. Chairman, that this was not a decision of the technical folks. This was the decision of the leadership, to ultimately ground the plane. Yield back.

Mr. DEFAZIO. I thank the gentleman.

Representative Sires.

Mr. SIRES. Thank you, Chairman, for holding this hearing. Administrator Dickson, thank you for being here. And my heart goes out to the family members that are here.

Later on, we are going to be hearing from Ed Pierson, who oversaw a portion of the 737 MAX final assembly at the Renton plant in Washington State. Mr. Pierson wrote to and met with general managers of the Boeing 737 fleet months prior to the Lion Air tragedy to express his concern that the safety and quality were being compromised due to Boeing's production pressures.

According to Mr. Pierson, in early 2018 Boeing's job behind the schedule spiked to 10 times the normal amount, and the rollout on-time percentage dropped to below 10 percent. Also, a part backlogged caused Boeing to begin experiencing substantial out-of-sequence work.

This means work was performed outside its planned location or time, which increases the risk of mistakes. Boeing's tracking system saw quality issues increase by over 30 percent. I understand that Mr. Pierson's attorney has written to you three times?

Mr. DICKSON. He has written to me—I received a letter from him in September, I believe.

Mr. SIRES. Well, according to him, it is three times in September to alert you to Mr. Pierson's concerns of chaotic, rapidly deterio-

rating factory conditions that he witnessed at the Boeing production facility. He also wrote that he believed the flying public would remain at risk unless this unstable production environment is rigorously investigated and remedied.

Administrator Dickson, the FAA grants production certificates to Boeing. Right? They grant the——

Mr. DICKSON. Yes, sir.

Mr. SIRES. OK. Has the FAA investigated any other production concerns of Boeing's that Mr. Pierson has raised?

Mr. DICKSON. We have engaged Mr. Pierson, and we are looking into these issues. Mr. Lawrence may have more details on this. But we take concerns wherever they come from seriously, and we have a process for dealing with that, for interviewing and investigating concerns that are raised by individuals and things that we observe during our own oversight.

Mr. SIRES. I don't mean to be difficult. But I just think, to look into it, it doesn't seem enough. I want a commitment from you that we are going to investigate these concerns for the——

Mr. DICKSON. And we are doing that. You have my commitment. We are doing that.

Mr. SIRES. Thank you. I don't have any further comments.

Mr. DEFAZIO. OK. I thank the gentleman.

Representative Spano.

Mr. SPANO. Thank you, Mr. Chair. And I too want to express my condolences to the members of the families that are here today. My prayers are with you, and I just ask God's peace and comfort as you deal with this difficult tragedy in your lives.

I had an opportunity several months ago to have a meeting with a colleague of mine, a friend who is also a pilot and had flown the 737 MAX. At the time, he and I—I am not a pilot; I just ride in airplanes. That is as much as I know about them.

But what he expressed to me is there was a periodic briefing that pilots are provided, which potentially provides—essentially, it is a binder that includes memos, directives, information that pilots should be aware of as it relates to safety issues on the planes that they are piloting.

He told me that this particular issue with the MCAS system was in fact, to his recollection, included within that binder of things to be aware of. All right? But that it was kind of buried at the bottom of a stack of such memos. OK? So I guess my question—and so from his perspective, and it certainly seems from my perspective as a lay person, that if you are going to have a memo relating to an issue of such importance buried in a stack this big, are you really providing any meaningful direction to pilots?

And so, given that scenario, is that in fact the case? Can you comment on that? Appreciate that. Thank you.

Mr. DICKSON. Well, I believe—thank you for the question—as Deputy Administrator Elwell had said in his previous testimony, it is my belief, and he shares it, that pilots should have known about the system on the airplane. It should have been part of the initial training, particularly as the design was changed so that it would operate more in the heart of the flight envelope.

With respect to information about unscheduled stabilizer trim and the emergency airworthiness directive, as Mr. Lawrence said

earlier, that is an extraordinary action. I think the last one that the FAA had done was about 2 years earlier, in 2016. It is something that should be stamped on top of everybody's forehead out there.

So if that is not reaching the level of prominence that it needs to in the operator community, that is definitely something that we need to look at.

Mr. SPANO. Yes. Thank you. And I would encourage you to do that because the takeaway that I got from my conversation from him is that he was certainly aware of the issue, but the fact that you would have such an important memo with regard to an issue of safety that is essentially buried, that can't happen. It seems to me that those should be issues that should be number one in terms of prominence.

Another question I had for you is that there—and if there was a question earlier, I apologize—but are you aware of allegations by a former FAA safety engineer that the FAA's management safety culture is broken and demoralizing to dedicated safety professionals? And if you are, how do you respond to that allegation?

Mr. DICKSON. Well, I want to make sure—again, on my first day at the agency, I emphasized that. And this has to come from the top, that we need to have a healthy safety reporting culture. It is what we demand of those that we regulate. I come from the airline business, and the ability to be able to systematically intake or uptake safety concerns is extremely important to the safe operation of an airline. And I think it is equally important, if not more so, within the agency.

So we need to—as people raise issues, either through their chain of command, through their boss, or as whistleblowers, there also needs to be this middle ground where we are able to take in systematically safety concerns.

One of the things that we need to do a better job of is going back after decisions are made and communicating to the workforce what all the considerations were, and why decisions are being made because sometimes there may be a perception that, oh, you sided with this person or that person, or this company or—you know, chose to retain someone in the agency. That is not the right lens that we need to be looking through these things.

Also, we want to have a system where we encourage healthy debate as we make decisions. You are going to have, whether there are pilots or engineers, subject matter experts, you want to have that healthy debate, but ultimately somebody has to make the decision. And in these cases that you are referring to, the decision-makers themselves are actually experienced technical experts as well.

Mr. SPANO. Thank you, sir. I yield back.

Mr. DEFAZIO. OK. I thank the gentleman.

Now Representative Johnson.

Mr. JOHNSON OF GEORGIA. Thank you, Mr. Chairman. I would ask that the TARAM report that you displayed during your questioning be placed back on the screen.

And Mr. Dickson, I would like to direct your attention to it. In December of 2018, about 1 month after the Lion Air flight 610 crashed, the FAA performed this risk assessment that calculated

the likelihood of future 737 MAX crashes caused by the erroneous MCAS activation. Is that correct?

Mr. DICKSON. Yes, sir. It is correct.

Mr. JOHNSON OF GEORGIA. And this is the report that issued from that analysis. Correct?

Mr. DICKSON. Yes. And actually, my previous answer—I should elaborate—this is looking at all the factors that went into the accident, so not only MCAS but the other——

Mr. JOHNSON OF GEORGIA. Not just the MCAS?

Mr. DICKSON. The other factors, yes.

Mr. JOHNSON OF GEORGIA. But you would admit that the results show an unacceptable risk?

Mr. DICKSON. Yes. And that is why the actions were taken, to reduce that risk.

Mr. JOHNSON OF GEORGIA. In fact, it is a drastic unacceptable risk, is it not?

Mr. DICKSON. Yes. So what it is indicating to us is essentially, over the life, about a 45-year period, that we would have an unacceptable level of risk, and so we need to take action to be able to reduce that risk to the level that we want.

Mr. JOHNSON OF GEORGIA. So this is definitely an important document that exists within the bowels of the FAA. Correct?

Mr. DICKSON. It is a decision support tool. Remember that before, data like this was——

Mr. JOHNSON OF GEORGIA. My question is that this document exists in the bowels of the FAA. Correct?

Mr. DICKSON. It exists—I wouldn't necessarily say—I think we are pretty aware of it at the highest levels of the FAA now.

Mr. JOHNSON OF GEORGIA. But when did the highest levels of the FAA—well, let me put it like this: Who was it that took action on this report? And when was the first action taken?

Mr. DICKSON. Well, the first action was taken just about immediately, I think.

Is that correct, Earl?

Mr. JOHNSON OF GEORGIA. And so what was the date? And what was the action taken?

Mr. DICKSON [to Mr. Lawrence]. How would you describe that?

Mr. LAWRENCE. So the first action that was taken, sir, was the emergency AD, even before these forms were completed, and——

Mr. JOHNSON OF GEORGIA. Well, I want to know: After this form was completed, what was done? Because you have said that it was a drastically unacceptable risk. And it was—this study was performed prior to the Ethiopian Airlines crash.

Mr. DICKSON. Yes, sir.

Mr. JOHNSON OF GEORGIA. Which my friends on the other side, by the way, want to try to impugn that it was the Ethiopian Airlines, an African airline, and their personnel who were somehow responsible for both of these crashes, when this hearing is about the FAA certification process. And I resent that.

But getting back to my point here, what was done about this report when it was first received by the FAA?

Mr. LAWRENCE. So again, this is a tool used by our——

Mr. JOHNSON OF GEORGIA. What was the date?

Mr. LAWRENCE [continuing]. By a board that meets on a regular basis, and——

Mr. JOHNSON OF GEORGIA. What was the date on this? What is the date?

Mr. LAWRENCE. Yes. Before this report was even completed, it was recognized that we needed to do additional work, that even the——

Mr. JOHNSON OF GEORGIA. OK. Well, what I am getting to is what was done after this report was generated?

Mr. LAWRENCE. Before this report was generated, the action was——

Mr. JOHNSON OF GEORGIA. After the report was generated. After the report was generated, is what I was getting at.

Mr. LAWRENCE. There wasn't an additional action after this because the action prior to this even being completed was to redesign the system. What this report guided the board to look at was how much time would we allow Boeing to redesign the system?

Mr. JOHNSON OF GEORGIA. Well, let me ask this question. Can either one of you admit to yourselves that the FAA made a mistake in not taking action on this TARAM report when it was first issued?

Mr. DICKSON. I would say that this is something that we need to look at very closely, and——

Mr. JOHNSON OF GEORGIA. Well, I mean, was a mistake made?

Mr. DICKSON. Obviously, the result is not satisfactory.

Mr. JOHNSON OF GEORGIA. Well, you just can't bring yourself to say that we made a mistake? And you weren't even there at the time.

Mr. DICKSON. Absolutely. This is a part of the process that we need to look at. Whether it was the data that goes into the decision, the decision did not achieve the result that it needed to achieve.

Mr. JOHNSON OF GEORGIA. Now, is the fact that the FAA, overseeing Boeing with 45 personnel to 1,500 to Boeing—does that indicate that perhaps there is a problem with staffing in the FAA certification process so that we do not allow the fox to guard the henhouse to the extent that it happened with the 737 MAX?

Mr. DEFAZIO. If you could briefly answer his question because we are over time.

Mr. DICKSON. I think that that is something that we need to look at. It is not numbers as much as it is the skill set within the workforce because that group that is overseeing the Boeing ODA has the ability to draw resources from without the agency, very similar to the way that a certificate management office oversees an airline.

Mr. JOHNSON OF GEORGIA. OK. Thank you.

Mr. DEFAZIO. I thank the gentleman.

Representative Miller.

Mrs. MILLER. Thank you, Chairman DeFazio.

And to all of you who lost loved ones, my heart goes out to you. I hope you have been able to be surrounded by family and friends and your faith in love and the light that it will bring you. It was a horror for you, and my heart does go out to you.

I think that this discussion and the questions that we have had today from both sides of the aisle indicate how we want to not ever

have this happen again. It is definitely a bipartisan issue because we are all human beings, and we all want to be safe, and we all—I assume we all take airplanes somewhere at some time in our life. And there are moments when you fly, if you are not a pilot, you kind of go, ooh, what was that?

And so moving forward, it appears to me that we need more transparency and communication when it comes to creating an international aviation safety standard that does work for everyone. It also appears that there are many areas that we need to work on. The only way for us to come together to tackle safety is to understand that we need to take a multifaceted approach to the issue. And I believe that is what you all are trying to do.

Mr. Dickson, can you elaborate on the Joint Authorities Technical Review and what exactly is included?

Mr. DICKSON. Well, thank you, and I appreciate the question and the opportunity to comment. I agree with you 100 percent that these issues need to be looked at from an aviation system perspective. And we are seeing a lot of growth in the system internationally, and the U.S. is a stable—it is a growing, healthy system, but it is a pretty mature, stable system. And what we do here, we are selling airplanes around the world. It needs to be able to work everywhere. And so the issues that we need to look at may vary somewhat.

But in terms of the JATR report, I think it is very important to understand that the FAA commissioned that group itself. But it is sort of like one piece of the pie. And it does not offer the complete perspective. The perspective from the TAB is another perspective that will inform our future efforts. We also have the Secretary's Special Committee. We have the investigative activities of this committee, as well as the Senate Commerce Committee, and then also, the DOT IG report.

So all of these things, and including our own internal analysis, will help us get to the right answer. And that is what we look forward to working with you on.

The JATR report really comes down to—if you take all of the 12 recommendations, it really comes down to 3 things. And that is, A, a holistic approach rather than, OK, I have followed this rule and worked down the checklist. More transactional is the word that I use in aircraft design.

A more effective integration of human factors considerations throughout the design of the aircraft, and not just building the machine and then figuring out how to operate it on the end. Now, that is simplistic. That is not how the process works today. But that is an end of the spectrum that maybe we need to move a little more closely to what I have described with a more integrated human factors approach.

And then there are some shortcomings that have been identified that I have seen in how various offices within the manufacturer communicate with each other, and then the entities within the FAA. I think we need to bolster our systems engineering expertise. We don't build the airplane. We just need to oversee the process by which the manufacturer builds the airplane.

And to do that system engineering expertise is very important to understand how all these systems interact; and then also, project

management discipline, because these certification projects take place over multiple years. And if you look at the continuing operational safety of a fleet, you are talking about a product that is going to be out there for maybe 35 to 50 years, from——

Mrs. MILLER. OK. I want to interrupt you also. I want to ask you: Knowing that our products will be used across the world, often in places that we are not able to regulate, how can we continue to improve safety standards across aviation as a whole?

Mr. DICKSON. Well, that is a great question. It is something that is of great interest to me. Again, there are ways that we can work through ICAO, and there are ways that we can work bilaterally and regionally. But we also need to take a look at, what are the responsibilities when you are developing and selling a product around the world, not just for a U.S. manufacturer, but for all the certification authorities that we talked about. And how do you take those issues into account? And does the manufacturer need to be looking at who the customer is in terms of what the support is in terms of operation?

Mr. DEFAZIO. I thank the gentleman for his answer.

Just back for a minute to the TARAM, and I hate to keep belaboring, but I still think this is an incredibly critical issue. And in response to Representative Johnson, you said the result wasn't satisfactory. And again, I want to really track how that was utilized in the decisionmaking process because yes, you issued an airworthiness directive, but that was the month before.

Then you got the TARAM, which says, wait a minute. We are going to lose 15 of these planes, and you just said 35 to 50 years. But when within 35 to 50 years? And unfortunately, it was within 5 months. So I think it was way less than satisfactory. It was catastrophic.

So with that, we would turn to Sean Patrick Maloney.

Mr. MALONEY. Thank you, Mr. Chairman.

Mr. Dickson, do you know who Ed Pierson is?

Mr. DICKSON. I have not met him personally, but I know of him.

Mr. MALONEY. And you understand he was the senior manager at the Boeing 737 Renton, Washington, plant. Right?

Mr. DICKSON. Yes, I do.

Mr. MALONEY. And you understand he oversaw production for the 737 final assembly?

Mr. DICKSON. Yes.

Mr. MALONEY. And a moment ago when you were responding to my colleague's questions, you could not bring yourself to say that the FAA made any mistakes here. I know you used different language. I think some of us would feel better if you showed a little more passion for this, sir.

So I want to give you another opportunity at this. I know you knew that he wrote to you—that Mr. Pierson wrote to you once in September. But in fact, he wrote to you three times, sir. He wrote to you in September, he wrote to you in October, and he wrote to you in November. And I know you just got on the job.

But he didn't just write you letters. He sent you extensive information, didn't he, sir?

Mr. DICKSON. Yes.

Mr. MALONEY. On production problems that he identified at the Renton facility?

Mr. DICKSON. Yes.

Mr. MALONEY. So my question to you is: Have you interviewed Mr. Pierson?

Mr. DICKSON. We have reached out to Mr. Pierson to schedule——

Mr. MALONEY. That is not my question. Have you interviewed him?

Mr. DICKSON. I know that we have contacted him, yes. I don't know if—I am not——

Mr. MALONEY. Excuse me. He is sitting right over there. Will you commit, as we sit here today, that you will interview Mr. Pierson?

Mr. DICKSON. Absolutely.

Mr. MALONEY. Will you investigate the production problems at the Renton facility?

Mr. DICKSON. Yes.

Mr. MALONEY. Have you done so to date?

Mr. DICKSON. I know that there is ongoing activity through our oversight.

Mr. MALONEY. Sir, I am sorry. That is not good enough. You have got a bunch of people over here who lost loved ones. Come on. Have you to date investigated production problems at the Renton facility?

Mr. DICKSON. I believe we have. I am not aware of the details.

Mr. MALONEY. Well, let's talk about that. Have you got any information on that, Mr. Lawrence? Have you interviewed production line workers at Renton?

Mr. LAWRENCE. Yes, we have.

Mr. MALONEY. How many?

Mr. LAWRENCE. I cannot give you a specific number. We do have open investigations on the production of the——

Mr. MALONEY. Is it more than five?

Mr. LAWRENCE. I would not quote a number without going back to my investigators to give you the exact number.

Mr. MALONEY. So it is fair to say that neither of you have any specific information about whether you have actually interviewed production workers at Renton. I mean, I know you say you think you have. I know you say you are going to look into it.

Sir, we are sitting here at a hearing in the United States Congress. You have been on the job for a while now. I take it this is the most important thing on your plate, fair to say. Right?

Mr. DICKSON. Absolutely.

Mr. MALONEY. So are we going to interview the production workers at the Renton facility? Is it going to be a real thing? Can you come to us and give us some answers to what you are actually going to dig into? Because we know this was not just a software problem. Right? We know it was a hardware problem.

And you got a guy who wrote you detailed information who served at the plant as the senior manager, who served 30 years in the Navy before that. Naval Academy grad. Knows what he is talking about. Couldn't get an answer to three detailed letters he sent you. Never interviewed him as we sit here.

And honestly, it would be great if you had some specifics on what you have done to look at the production problems at that facility. Can you shed any light on that for us?

Mr. DICKSON. You have my commitment that we are looking into those problems, and we will continue to do so.

Mr. MALONEY. But you don't know whether you—you don't know how many workers you have interviewed?

Mr. DICKSON. Not sitting here today, no.

Mr. MALONEY. Mr. Lawrence?

Mr. LAWRENCE. We have interviewed workers, and we can provide those for questions for the record afterwards.

Mr. MALONEY. I would appreciate that. Have you reviewed quality and production records from the facility?

Mr. LAWRENCE. Yes, we have.

Mr. MALONEY. Would you tell us about that?

Mr. LAWRENCE. There are ongoing investigations, and again, we can look at providing additional investigative reports at the appropriate time.

Mr. MALONEY. So you can't tell us anything about whether you have learned anything as we sit here about whether production problems, detailed in great detail by Mr. Pierson in the letters he sent to you now months ago—I mean, are you aware that 4 months before the first crash, he brought these problems to Boeing's attention? Are you aware of that, gentlemen? Four months before the first crash.

Mr. DICKSON. I know that there were—yes, that concerns were raised, yes.

Mr. MALONEY. That is right. And do you understand that after the Lion Air crash, he went up and down the chain at Boeing. He went to the CEO. He went to the general counsel. He went to the board. Are you aware of that? He sent them letters, too.

Mr. DICKSON. Yes.

Mr. MALONEY. Saying all the same things. And you know what they did? They sat on it until a second plane crash. That is what happened. A bunch more people lost their lives.

Some of those pictures are right over there. And so we are sitting here now, a year later, and neither of you can tell me whether you got anything specific on the production problems that he identified 4 months before the first crash?

So I am going to give you another chance, Mr. Dickson. Has the FAA made any mistakes here?

Mr. DICKSON. I think that is evident, that we have got issues that I need to address and that our team needs to address, and that we have processes that need to be improved. So I would agree with you.

Mr. MALONEY. You can't say that word "mistake," huh? That one is just sticking on your lips there.

Mr. DICKSON. I don't want to blame other—again——

Mr. MALONEY. It is not about blame, sir. It is about accountability. We are not trying——

Mr. DICKSON. Accountability—OK. again, I am accountable. So I hold myself accountable.

Mr. MALONEY. Can you say that the FAA made a mistake in not taking seriously Mr. Pierson's concerns in a timely way?

Mr. DICKSON. We are taking the—we are taking all concerns, any concerns that are raised, we are going to take seriously and run them to ground in a systematic way so that we can make the right decisions.

Mr. MALONEY. Yield back.

Mr. DEFAZIO. I thank the gentleman for his questioning.

And I would just ask, very quickly, given the investigation, which you tell us is ongoing, of the production issues, will that be completed and instruct you in terms of whether or not the plane is allowed to fly, and under what conditions it is allowed to fly, and what conditions of inspection will be mandated on these planes before it is allowed to fly?

Mr. DICKSON. We will——

Mr. LAWRENCE. One thing that I can add is we have retained the issuing of the airworthiness certificates. And so the FAA will be doing that this time. It is not going to be part of the Boeing system. So we will be doing that ourselves to assure that they earn airworthy condition before any are returned to service.

Mr. DEFAZIO. All right. Thank you.

Mr. Meadows.

Mr. MEADOWS. Thank you, Mr. Chairman.

Mr. Lawrence, I am going to follow up on something that Mr. Maloney just shared because I think it is important that we get to the bottom of this.

Is it reasonable to expect that in the next 60 days, that you can interview an additional 10 line workers at the facility?

Mr. LAWRENCE. Whatever—wherever the investigation——

Mr. MEADOWS. All right. Well, I will make it harder, then. That was a softball.

Mr. LAWRENCE. Yes. Yes.

Mr. MEADOWS. And so I am going to throw an inside pitch. By gosh, interview at least 10 people and report back to this committee. Do I have your commitment to do that?

Mr. LAWRENCE. Yes, you do.

Mr. MEADOWS. All right. Mr. Dickson, I am going to come to you because you have obviously been advised by counsel or somebody to not admit that the FAA made a mistake. And I am just giving you—your counsel is giving you bad advice.

Did the FAA at some point in this process make a mistake?

Mr. DICKSON. Yes.

Mr. MEADOWS. Thank you.

Mr. DICKSON. Yes. My only—again, my only—I just don't want to leave it at that. That is my point——

Mr. MEADOWS. No. I get that. And listen. There is enough——

Mr. DICKSON [continuing]. Is that I want to—I want to take——

Mr. MEADOWS [continuing]. There is enough pictures over here and enough blame to go around. I get that. But what I am saying is, it is very frustrating, when it is obvious that mistakes were made, that you just don't say, "Mistakes were made." And I understand lawyers always say, "Don't admit anything because of this."

But I am just telling you, in the real world we have to look at it that a mistake was made, and obviously, not one but multiple mistakes. And we have got to get to the bottom of it. So here is my question for you.

There is the suggestion—the committee has had the suggestion—that indeed, that there is a perverted incentive on the certification process, where you have FAA employees that, whether it be bonuses or anything else, that they don't actually engage in the proper way of putting safety first.

Would you agree with that? Not agee with that? Comment on that?

Mr. DICKSON. I do not agree with that. And I have made it very clear to my workforce and my team that I support them in keeping safety as their highest priority.

Mr. MEADOWS. All right. So what do we have to do to make sure that when things come in—and let me just tell you, you have got two people behind you that are part of your staff that I have the highest regard for. One worked on committee staff with me. The other worked in my personal staff, Mr. Newman. And there is no one who will work harder on this issue and get involved in it.

And so I know you have got some people that are very capable working with you. I guess my question to you is: How do we put in the process of making sure that what we have is that it doesn't go into—I am not going to use a black hole narrative. But how does it not get swept up in the bureaucracy where there is a concern. There is a legitimate concern. And it just doesn't reach the right person until we have a fatality. How do we change that process?

Mr. DICKSON. Well, there are several different ways. So you can't get into analysis paralysis, or bureaucracy in these things. You have got to have real-time data upon which to make decisions that is visible across the whole organization.

Mr. MEADOWS. I am glad you said that because here is one of the things. This is not the chairman's first rodeo nor mine. And when we talk about certification, I want to streamline certification. What I am concerned about is the FAA looks at the certification process—and we are recertifying screws and things that, quite frankly, are taking a whole lot of time. And then on the critical areas, they get the same bandwidth in terms of the certification process, whether we are working with Boeing or anyone else.

Is there a way for us to highlight those new areas that are coming to the market as part of an aviation product, and perhaps deemphasize some of the other things in this certification process to speed it up, whether it be on private individuals, or in this case, a commercial? Is there a way for us to do that?

Mr. DICKSON. I certainly think there is a way to make the process less bureaucratic and more fluid. That is part of what the JATR worked for.

Mr. MEADOWS. Will you come up with four recommendations to report back to this committee on how you can do that?

Mr. DICKSON. Yes.

Mr. MEADOWS. All right. And then the last thing, in the 20 seconds I have left. Obviously, we have got a system that has not been repaired and it still has flaws in it. Will you commit to the American people right now that you will set up a hotline for our pilots to call in, that if they are seeing an issue—so the users, the very people that actually have to use equipment, where they can get something to you right now where that comes to your attention, will you be willing to set that up in the next 60 days?

Mr. DICKSON. We have a hotline now.

Mr. MEADOWS. That comes to you. I know you have a hotline. We have got hotlines all over the Federal Government and they are worthless because they take about 2 years to get a return phone call.

Mr. DICKSON. Understand.

Mr. MEADOWS. I am talking about coming to you.

Mr. DICKSON. We will set that up, absolutely.

Mr. MEADOWS. Thank you, sir. I yield back.

Mr. DEFAZIO. Representative Brownley.

Ms. BROWNLEY. Thank you, Mr. Chairman. And I too wanted to add my condolences to the families who are here today. As the holiday season surrounds us, where families gather together, our hearts and my heart breaks for all of you.

But I also want to thank you very, very much for your presence here today because your presence is helping us to get to the truth, and it is only the truth that is going to save future lives. So I want to thank all of you for being here today.

And I wanted to ask one more time, with regards to this risk assessment predicting 15 more accidents. And I wanted to ask the question, maybe, in a different way.

Mr. Dickson, you have said several times that the buck stops with you, and you are the man ultimately accountable for the FAA. And so we have talked a lot about the past, and we understand that the past has to be fixed.

So I want to look to the future and say that if an employee had brought this risk assessment to you and put it on your desk—you are the FAA Administrator—you were given that information. Would you have made a decision, a risk assessment—and I understand it is over 45 years—but that 15 more accidents could occur, would you have grounded the airplane?

Mr. DICKSON. It is hard to Monday morning quarterback these things, as you know. And I believe that the individuals who were involved in making the decision were acting on the best information they had at the time.

Ms. BROWNLEY. But I am talking about you in the——

Mr. DICKSON. They were taking action to drive that level of risk.

Ms. BROWNLEY. I am talking about you in the future now.

Mr. DICKSON. With what I know now, yes. Yes.

Ms. BROWNLEY. If that came to you——

Mr. DICKSON. With what I know now.

Ms. BROWNLEY. If that came to you and you saw that report, you would ground the airplane today?

Mr. DICKSON. I would have——

Ms. BROWNLEY. Not second-guessing what happened in the past, but today.

Mr. DICKSON. With what I know today, yes, with what I know today. But again, it is hard for me to go back and determine in those days what information goes into——

Ms. BROWNLEY. Yes. I am just trying to set a similar story, but something that would happen in the future where you're——

Mr. DICKSON. And remember, this document that we have been looking at is only a decision support tool. It is not the decision. The CARB comes together with subject matter experts, and certainly I

would want to confer with them and make sure that we ran all the issues to ground on making a decision.

Ms. BROWNLEY. You would be on high alert, though, if that document was before you?

Mr. DICKSON. Yes.

Ms. BROWNLEY. And you would ultimately ground the airplane, if I understood you correctly?

Mr. DICKSON. Well, again, knowing what I know now, it is impossible for me to go back. I know a lot more now than they knew back then.

Ms. BROWNLEY. Thank you. The other thing, Mr. Dickson, I wanted to ask is that there was a Washington Post story last night that revealed that the FAA plans to establish the aircraft certification safety program management branch. And apparently this is a new safety branch to address gaps in FAA's oversight following the accidents and will "help improve understanding of systemic areas of risks, and facilitate identification of emerging safety issues."

I have to say I am disappointed to read about it in the media instead of hearing directly from the FAA. Can you tell us why the committee was not made aware of it? And secondarily, how will this new office help ensure that the same mistakes are not made in the future?

Mr. DICKSON. So this actually is misreported. The purpose of this office—it is actually a reorganization that Mr. Lawrence had been looking at for—I think the organization had been looking at it for about 2 years. And he can give you the details.

Mr. LAWRENCE. Thank you for the opportunity to clarify that one. It was a misrepresentation of an email that had gone out by my staff. There is no new office. There is an Office of Accident Investigation; that still exists and will continue, and there is not a change there.

It was how I was organizing my folks, has been repeated several times here. There are always opportunities to improve our system, to do a better job on communication and the flow of information within any organization. And that was an email announcing that we were assigning somebody to look at how best to set up the flow of communication and safety information within the organization.

So yes, we are taking action. But it has not been—it is not a new office, and certainly was not an approved organization of any kind. It was——

Ms. BROWNLEY. So you are evaluating a reorganization to be more effective?

Mr. LAWRENCE. It is part of our reorganization that was started 2 years ago, and making the tweaks and fixes as we go through that to make sure that we are covering all the issues that we should be in an appropriate way.

Ms. BROWNLEY. Thank you. Mr. Chairman, I yield.

Mr. DEFAZIO. I thank the gentlelady.

Representative Carbajal.

Mr. CARBAJAL. Thank you, Mr. Chair. I am a little under the weather so I am going to try to get through these questions.

But first, I want to offer my condolences to the families that are here today. I can't even imagine your pain and your loss.

Administrator Dickson, from the emails released to the committee in October, it is clear that Boeing did not want to disclose the MCAS in the flight crew operations manual, FCOM, an aircraft training manual for pilots. Boeing minimized or hid the true power of the MCAS system, convincing the FAA to delete mention of it in the FCOM, and therefore hiding its existence from the Flight Standardization Board.

What do you plan to do within the FAA to ensure and change this dynamic? And two, how will you ensure that the FAA and not Boeing or some other manufacturer is determining what is and is not appropriate for pilots to know about what is on their airplanes?

Mr. DICKSON. Thank you for the question. This gets back to the issue that was identified both through the interviews and emails that you spoke about, and by the Joint Authorities Technical Review, that this design change was not communicated to the FAA, the folks who needed to make the decision on the aircraft evaluation group.

I believe that there were some communications, perhaps, to our flight test group or within the engineering circles, but they didn't make it so that we had issues both within the agency and——

Mr. CARBAJAL. Mr. Dickson, we could spend all day talking about what transpired. But the question is: What do you plan to do to change this dynamic so it doesn't continue to happen again?

Mr. DICKSON. So improve our project management to make sure that the team is staying together as a cohesive team so they are all hearing things at the same time, no matter what phase of the project that we are in, and everybody understands what the implications of design changes may be.

Also putting gates into the process to make sure that we have checkpoints going because you have got a bunch of parallel processes going on at the same time. From time to time we need to loop back and make sure that these systems interact correctly.

Increased use of system safety assessments, as we talked about earlier.

And then finally, I would like to work with the Congress on implementing safety management systems for manufacturers, which will again facilitate even better information flow between the applicant and the agency.

Mr. CARBAJAL. And does that address the issue of having the FAA be in the driver's seat and making the determinations, not the manufacturers?

Mr. DEFAZIO. Yes. We make those determinations now, and we will continue to do so.

Mr. CARBAJAL. Thank you. Administrator Dickson, I would also like to get your thoughts on the recent testimony from the National Transportation Safety Board Chairman, Robert Sumwalt, where he highlights the positive benefits of safety management systems.

Given your experience in the aviation sector, do you agree with the Chairman's perspective that safety management systems improve safety?

Mr. DICKSON. I have spoken with Chairman Sumwalt about this, and we have had dialogue on their recommendations and on SMS, and I am a huge proponent of SMS. I believe it has been very bene-

ficial in the airline industry and the commercial aviation industry. And it should be applied in this environment as well.

Mr. CARBAJAL. Do you have personal experience with the SMS system during your time at Delta?

Mr. DICKSON. Yes, sir, I do.

Mr. CARBAJAL. Do you think adoption of the SMS system for manufacturers with FAA oversight would provide similar benefits?

Mr. DICKSON. Yes. In multiple ways. It provides the ability for, again, a systematic way for the regulator to get higher fidelity data, more in realtime, from the manufacturing process. It also creates more fluid communication both within the agency, for folks to raise concerns and for them to be processed, and for us to go back to the workforce. But it requires the participation of labor, and also the agency, and also the manufacturer to be able to make it work effectively.

Mr. CARBAJAL. Thank you. You know, I have heard a lot of issues and suggestions raised by my colleagues today—the hotline that was suggested, a number of other things. As a second-term Member of Congress, I always wonder: When do we find out if all those items were implemented? When will you report back to us after this hearing to go over that list of issues that were discussed today, to share with us when they have been implemented or will be implemented in terms of a timeframe?

Mr. DICKSON. I will work with the chairman and the ranking member to put a timeline on those things. Some of what we have talked about, we are already doing, and we have incorporated some of the lessons learned from the MAX return-to-service process. We will apply those immediately going forward.

We are looking, as an example, at some of the lessons that we learned from the TAB process, and bringing them into our certification activities going forward. So it sort of depends on the topic that you are talking about, but I am happy to work with——

Mr. CARBAJAL. Thank you. I am out of time. I would appreciate getting that information. Mr. Chair, I yield back.

Mr. MEADOWS. Yes. To my second-term colleague, because after two terms you start to understand this is the land of promise but not necessarily delivery, so that is why I put a 60-day timeframe on those requests. And so either we will get that back in 60 days or we will get an explanation of why. And I will be glad to work with you in a bipartisan manner to make sure that we get it done.

Mr. CARBAJAL. Thank you.

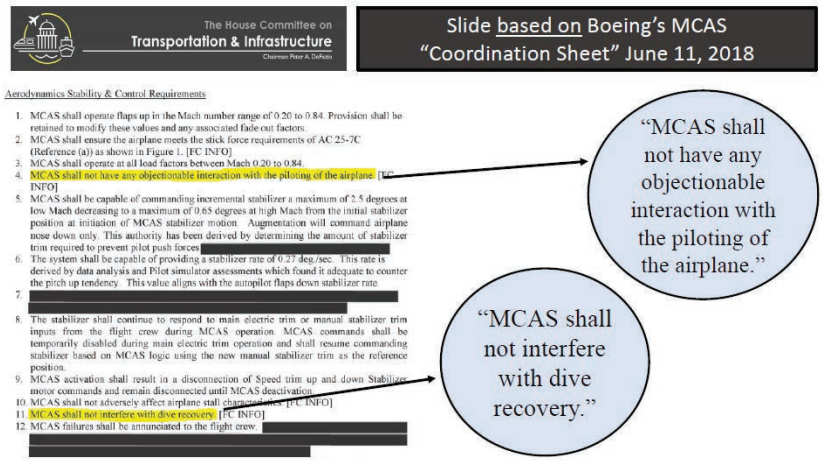
Mr. DEFAZIO. I thank the gentleman for his clarification.

Representative Stanton.

Mr. STANTON. Thank you very much, Mr. Chairman.

Administrator Dickson, at our last MAX hearing in this committee last October, Boeing admitted that MCAS did not meet its own design requirements. I think we have a slide that is going to come up now.

[Slide]



Mr. STANTON [continuing]. This is taken from Boeing's coordination sheet, which outlined the company's requirements for MCAS. As you can see, Boeing's criteria stated: "MCAS shall not interfere with dive recovery." It also stated: "MCAS shall not have any objectionable interaction with the piloting of the airplane."

When I showed this to Boeing at our last hearing, Boeing's chief engineer admitted the obvious, that MCAS interfered with dive recovery on both Lion Air flight 610 and Ethiopian Air flight number 302.

Administrator Dickson, do you agree with that assessment?

Mr. DICKSON. Based on what I know about how the system was initially designed and how the design was changed, I think that is correct.

Mr. STANTON. Unfortunately, when I asked another obvious question on whether MCAS had an objectionable interaction with the piloting of the accident flights, Boeing did not give a straight answer. In plain and simple terms, Boeing failed to admit that the MCAS impacted the ability of the pilots to control the plane. That is shameful.

How can anyone look at what happened in the cockpit of those flights and think the pilots had any chance to counter a system that they knew nothing about? This coordination sheet that you have on the screen today is dated June 11, 2018, which is after the MAX was certified. But we have seen earlier versions of the same document from March 2016, before the MAX was certified, and it contains the exact same MCAS design requirements.

Administrator Dickson, did the FAA receive a copy of this coordination sheet before the MAX was certified?

Mr. DICKSON. I am not aware that we would have. And I believe that is around the time when the design was modified. But I would have to check.

Mr. STANTON. Should the FAA have received this document?

Mr. DICKSON. I would say so.

Earl, have you got any opinion on that?

Mr. LAWRENCE. Well, this document is outlining what our requirements are on Boeing. And so these are the regulatory requirements, and this outlines what the requirements would be to obtain certification.

Mr. STANTON. Thank you.

Mr. Dickson, did MCAS interfere with dive recovery on Lion Air flight 610 or Ethiopian Air flight 302?

Mr. DICKSON. Yes, it did. I would just point out again that there is—the pilot, again, is part of that system. And the design was relying on the pilot to be the mitigating factor, and that proved to be incorrect.

Mr. STANTON. Boeing failed to meet its own design requirements for a system that was certified by the FAA. Despite this shocking reality, has the FAA issued any fines or penalized Boeing for that failure at this time?

Mr. DICKSON. Not at this time. But I reserve the right, as I said earlier, to take action in the future.

Mr. STANTON. Beyond the design requirements, has the FAA issued any fines to Boeing for its failures on the 737 MAX?

Mr. DICKSON. Not at this point.

Mr. STANTON. And my final question: Since these tragic accidents, has the FAA made any changes to how it certifies software design requirements, certifies other manufacturer aircraft components, or to any part of the certification process?

Mr. DICKSON. Yes. As I mentioned, we have not delegated anything throughout this process. We are relying on resources throughout the agency. We have brought in the Technical Advisory Board to run in parallel with us, with experts from NASA and Volpe and the Air Force and others. And we are also working very closely with the international authorities as well.

Mr. STANTON. So you are working on them, but as of yet, no specific changes?

Mr. DICKSON. Well, yes, those changes are being implemented for the MAX project. Absolutely.

Mr. STANTON. Mr. Dickson, for me and for so many Americans, these accidents, these tragic accidents, have shaken our confidence in the FAA. And we owe it to the families who lost loved ones to do better, and we must get this right. Anything else would be a disservice to them and to all those who put their faith in the safety of our air system.

I yield back.

Mr. DEFAZIO. I thank the gentleman.

Representative Davids, vice chair of the subcommittee.

Ms. DAVIDS. Thank you, Chairman. And thank you all again for continuing to be here.

Administrator Dickson, I want to follow up about the rudder cable on the 737 MAX. As you know, at least half a dozen of the FAA's own technical specialists, as well as an expert panel established by the FAA's safety review process, raised serious concerns that the rudder cable on the 737 MAX could be severed if the engine failed, causing pilots to lose control of the aircraft. This concern is not just a theoretical concern. The FAA guidance is rooted in the tragic 1989 DC–10 crash in Sioux City, Iowa. And 112 people died in that crash.

In your response to Chairman DeFazio and the Aviation Subcommittee Chair Larsen's letter on this issue, you said, "We followed the FAA procedures." Except that doesn't seem to be the case, which we will get to in a second.

There is a kind of cornerstone of the FAA procedures, which is that the components will become safer over time. It seems like a good rule of thumb to follow. So when the FAA reviewed and approved the 737 NG model, the FAA found that the 737 NG had a lower risk of a severed cable than the 737 classic model. And the reason that the risk was lower is because the engine on the 737 classic was more powerful.

So based on the determination that there was a lower risk in the 737 NG, it was approved. So there is a 1997 issue paper for the 737 NG that warned that engines in the future on 737 models, if they got bigger, it would increase the risk of severing that cable, and that additional steps to protect the cable would be needed.

Which brings us to the 737 MAX, which has a bigger engine and potentially greater risks of severing the cable. The FAA, though, did not require any design changes. Instead, it ignored that 1997 warning.

So my question is: Why didn't the FAA follow the guidance from the 1997 issue paper and require additional protections for the rudder cable?

Mr. DICKSON. Well, thank you for the opportunity to respond. And this is—I think it is important to understand that these debates and discussions among subject matter experts are part of what gets us to a safer system. And there are a couple of different approaches that can be taken in these instances.

Ms. DAVIDS. Do those approaches include ignoring an issue paper?

Mr. DICKSON. Well, no. I am just saying that there are approaches on—there are prescriptive rules that can be followed, and there is also sometimes data that can be applied based on the performance of a proven system.

And in this case, the team looked at—eventually, when the decision was made, looked at the mitigations that had been put in place in terms of floor structure and also the casing around the CFM LEAP engines, and the reliability of those engines, and the fact that they are already certified, essentially, from their initial manufacture as capable of extended twin engine operations, which is an extremely high level of reliability.

And so taking all of that into account, there is actually a risk in adding complexity to an improved system that was put in place in the 1990s to deal with the hardover rudder issues from the accidents that we talked about earlier. And when you introduce a fleet that has got additional complexity into an operation that has already got thousands of airplanes out there that have different maintenance practices, that itself creates a risk. And so that is how that decision was made.

And remember that the manager who is making that decision is actually a technical expert——

Ms. DAVIDS. At FAA?

Mr. DICKSON [continuing]. Himself. Yes. FAA, yes.

Ms. DAVIDS. Or with Boeing?

Mr. DICKSON. No. At FAA.

Ms. DAVIDS. OK. So the concern here is that, first of all, you are talking about increased complexity and not following the guidance that had previously been stated, and not doing a new type certificate.

So I think there are a lot of inconsistencies in the way that you are describing this process. And the overarching concern is that the process for safety reviews is becoming either inconsistent or more lax, and that control is being increasingly delegated to the manufacturers.

So I think that—I obviously have run out of time. But I do think that there needs to be some serious consideration around the—you have said yourself, this is a whole system. And across the system, we have been hearing inconsistencies and places where it seems as though the FAA has been more lax. And I think that that is something that we can address and need to address.

I yield back.

Mr. DICKSON. I can assure you we will not be lax. And actually, I believe that the decisions that we are making are going to be more rigorous because of the reliance on data and performance.

Mr. DEFAZIO. I thank the gentlelady and the gentleman.

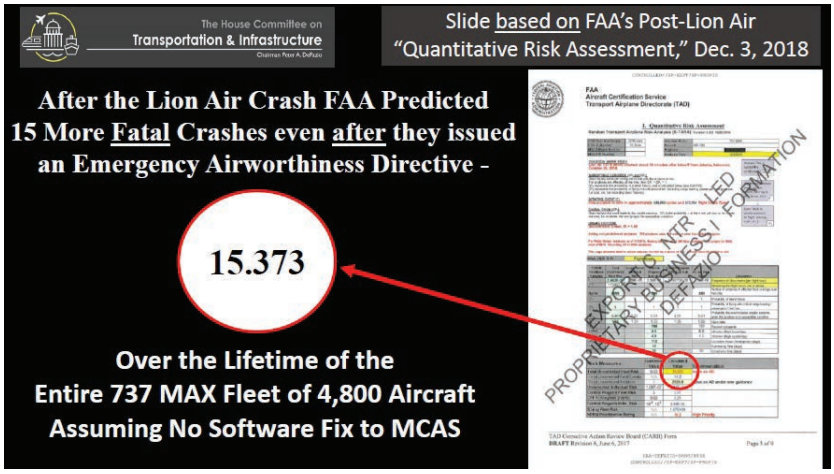
Representative Lamb.

Mr. LAMB. Thank you. And Mr. Chairman, could you put the slide back up with the 15 number on it that we were looking at earlier?

Mr. DEFAZIO. TARAM report?

Mr. LAMB. Yes. Thanks.

[Slide]



Mr. LAMB [continuing]. Now, Mr. Administrator, based on everything that you know now, and I understand you weren't in office at this time—but based on everything that you know now, if you saw a report like this with the 15.373 number on it, that day or the next day would you have been comfortable with a member of your own family flying on a 737 MAX?

Mr. DICKSON. Yes, I would have. But that is because I understand how the airplane operates, and I understand how to deal with flight control issues. But on the other hand, there is a—immediate aggressive action was being taken. And again, this is just one aspect of trying to put some rigor around what otherwise would be a very subjective decision.

Mr. LAMB. Do you think it is reasonable to expect that I, who am not a pilot, or one of my constituents, who don't know the inner workings of aircraft and how pilots are trained and how they receive warning messages like this—do you think it would have been reasonable for them to feel safe flying on a 737 MAX the day after this information was known to the FAA?

Mr. DICKSON. Again, at this point dealing with what were the driving factors in the accident, in the Lion Air accident; and again, based on the information that was available at the time, the emphasis was on the procedural aspect of accomplishing the runaway stabilizer trim.

And so, again, that was the mitigation that was put in place immediately. And then a very aggressive timeframe in terms of the software modification.

Mr. LAMB. Yes. But what I am saying is people are relying on you to protect them.

Mr. DICKSON. Yes.

Mr. LAMB. In an area that they do not know a whole lot about, and a lot of trust is required for them to participate and feel safe about our airline industry. And nothing you just said provides a reason why a person should have felt safe stepping onto a 737 MAX when the FAA was in possession of the information.

Let me ask you a slightly different way. There are echoes in this incident of a situation that happened in western Pennsylvania, where I represent, in 1994 when there was a plane crash in Beaver County. And we have a witness coming in in the panel after you, Captain Cox, who is going to say that that incident, which was USAir flight 427, "was a recurrence of a fault that had brought down United Airlines flight 585 3 years earlier. We did not learn all we could from it, as a result, 132 perished near Pittsburgh."

He goes on to say, "We did not learn all we could from Lion Air 610 before the Ethiopian 302 accident." And as a result, we lost not only all the people in the Lion Air crash whose family and friends are with us here today, but the second wave of people in Ethiopia.

And so what I don't understand is all these years later, all these years after the Pittsburgh crash in 1994, what is being done to make sure that we learn the first time and it does not take two crashes for us to fix the problem? What is changing?

Mr. DICKSON. It doesn't. It doesn't. I mean, that is why we need to make the processes more rigorous and have better analytical tools so that we can drive that risk down and know that the actions that we are taking will have that effect.

Mr. LAMB. Who is being held accountable for the fact that pilots were not told about MCAS and that, in fact, the references to MCAS were removed from the manual? Who is being held accountable for that?

Mr. DICKSON. Well, I think that is part of the process that we are all going through.

Mr. LAMB. So you don't know?

Mr. DICKSON. I think we are all being held accountable for it. And we all need to make sure that that doesn't happen again.

Mr. LAMB. I think we have different definitions of being held accountable. Mr. Chairman, I yield back.

Mr. DEFAZIO. I thank the gentleman.

Now Representative Malinowski.

Mr. MALINOWSKI. Thank you, Mr. Chairman.

Mr. Dickson, earlier in the hearing you said that one of your priorities is to make sure that there is appropriate separation at the FAA between business issues and safety issues. I was struck by that; it is a very important point.

And given that you said that, I take it you believe that there has not always been sufficient separation between business and safety considerations. Is that a fair——

Mr. DICKSON. Well, I was actually referring to the manufacturer. I was referring to Boeing and the indications of pressure on the workforce to accomplish certain things, and being able to make sure that that didn't impact safety decisions. And it is something that I want to make sure doesn't bleed over into our workforce.

Mr. MALINOWSKI. Well, exactly. I mean, I am concerned also about pressure on the FAA because here is something that those of us here who have looked at this feel seems to be happening, that a manufacturer like Boeing will begin production of an aircraft. They will complete all the steps up to the finalizing production, including ordering materials, before getting FAA permissions.

Then they will say, "Oh, my gosh." If the FAA raises a concern, they will say, "Oh, my gosh. We have to get—we are almost there. We will lose a tremendous amount of money if we don't get this plane into the marketplace." And then the FAA sometimes seems to take that into account.

I mean, isn't that potentially what happened, for example, when the FAA initially said that flight simulator training would be required for the 737 MAX, and then Boeing said, "We have this agreement with Southwest Airlines. We were promised a million-dollar rebate per plane if it didn't require flight simulator training." And then the FAA says, "OK. You don't have that requirement."

Do you think those business concerns may have bled into the FAA's decision there?

Mr. DICKSON. I know, having spoken with our AEG pilots in Seattle, and having read some of what their concerns have been that have been expressed to the committee investigative staff, that this was an item of concern that they had from very early on in the project.

And so they were very engaged from the very early days, and went through a process of—over a year—of making sure that pilots from airlines were brought in, actual those who were flying the 737 NG on a regular basis. We are able to have proficiency even without additional simulator training on the 737 MAX.

So that was something that was of concern and that was resolved through the process. But it is something that we need to watch for, absolutely.

Mr. MALINOWSKI. And what about the decision to exempt Boeing from the requirement that new commercial airlines be equipped with the EICAS system that would allow the aircrew to prioritize all the different cautions and alerts that they received? That system was required on the 747–400, the 757, the 767, the 777, the 787. The 737 MAX is the only aircraft that was not required, that was exempted from that rule, I think, since 1982.

Weren't there cost considerations that factored into that decision?

Mr. DICKSON. That is a great question. In my view, it wasn't so much of a cost consideration, but how do you integrate an airplane like that into an existing fleet. And I will let Mr. Lawrence tell you how that process works.

Mr. LAWRENCE. So the question on that particular one is we have a very large fleet and operators of that existing aircraft. And if you change the procedures and the positioning and the switches and the information, do you introduce another safety hazard?

And so that was the debate on that particular system. It wasn't as much of a cost, per se. It was looking at—you have Southwest Airlines as an example, with a whole existing 737 fleet. You have all their pilots trained, all their maintenance folks trained, the whole system built on that. And what are the risks of introducing a new system that dramatically changes that?

So it is a debate. We are not saying it is—that there aren't good arguments on both sides of that discussion. I am just saying that it is a discussion, and making those determinations of whether you are going to allow an aircraft to continue in that fleet in its existing configuration. Those are all part of the discussions. And safety is the driver in all of those discussions.

Mr. MALINOWSKI. Thank you. I yield back.

Mr. DEFAZIO. I thank the gentleman.

Representative Allred.

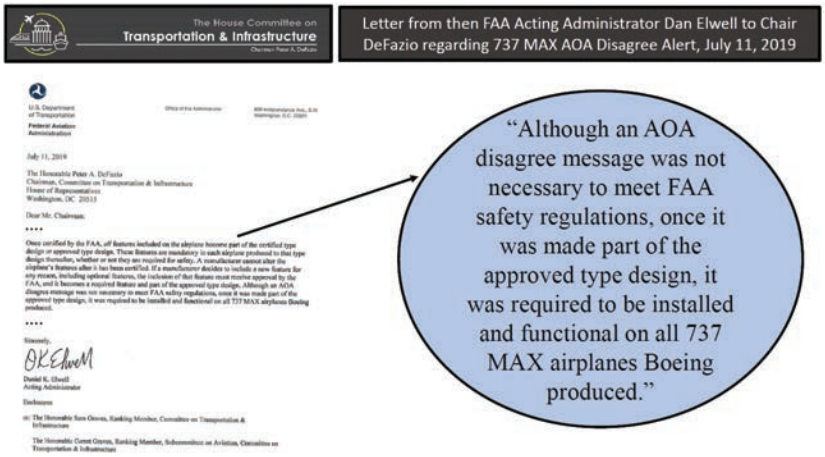
Mr. ALLRED. Thank you, Mr. Chairman.

I want to pick up on the line of questioning of Representative Lamb's around accountability, Mr. Administrator. As you know, the 737 MAX was certified with the AOA disagree alert being a standard feature on the aircraft.

However, in August 2017, Boeing learned that the AOA disagree alert was not functioning on an estimated 80 percent of the entire 737 MAX fleet. Boeing concealed this flaw from the FAA and operators for more than a year, during which it continued to build and deliver planes with this nonfunctioning alert. More troubling, pilots expected the AOA disagree alert to be operational and it wasn't.

In July of this year your predecessor, then-Acting Administrator Dan Elwell, explained how Boeing's actions violated FAA regulations in a letter to this committee, which I think we have a slide of.

[Slide]



Mr. ALLRED [continuing]. This is what he wrote: "Once certified by the FAA, all features included on the airplane become part of the certified type design or approved type design. These features are mandatory in each airplane produced to that type design thereafter, whether or not they are required for safety. . . . Although an AOA disagree message was not necessary to meet FAA safety regulations, once it was made part of the approved type design, it was required to be installed and functional on all 737 MAX airplanes Boeing produced."

I will repeat that the disagree alert was "required to be installed and functional on all 737 MAX airplanes Boeing produced." You may not believe that the absence of an AOA disagree alert is a safety issue, but I strongly believe that Boeing's open defiance of FAA requirements in knowingly delivering airplanes without it is both a legal and an ethical issue.

It is my understanding that the FAA has not penalized Boeing in any way for this conduct, or even taken any other actions to reprimand the company for its behavior. I know you have been here 4 months, but the word "accountability" has been used a few times. When I had the CEO of Boeing sitting here, I told him I thought we might have a different definition of that word. I hope that you and I don't share a difference in that word's definition as well.

Why hasn't the FAA done anything to hold Boeing accountable? It is your agency, and most important to the public, for this sort of egregious behavior.

Mr. DICKSON. Thank you for the question. And we have already taken actions, as you know. Obviously, the airplane is grounded. We are not delegating anything to Boeing during the MAX return to service. We are not even delegating the individual airworthiness certificates for each aircraft.

We have taken action, recent enforcement action, and we have additional actions under consideration, both with the existing settlement agreement that we discussed earlier here, and there may be additional actions, as required. And I reserve the right to take them, and I will take them, as appropriate. And you point out a good example here.

Mr. ALLRED. Well, thank you. I think that where we have regulations in place and where we have a purposeful evasion of them, if there is no consequence for that evasion, then the regulation doesn't matter.

And so I hope that we will see enforcement of this. And a lot of my colleagues, we are trying to determine the balance that we should strike here. Is the process fatally flawed? What changes need to be made? But this, in my opinion, is an example of something that is just a decision that needs to be made by the FAA on how they are going to enforce their own regulations, knowing that a violation occurred.

Mr. DICKSON. Congressman, I couldn't agree with you more. Safety is our highest priority, most important core value. And what supports that is accountability.

Mr. ALLRED. Absolutely. Thank you, Mr. Chairman. I yield back, if you want to take any time.

Mr. DEFAZIO. I thank the gentleman.

Representative García.

Mr. GARCÍA. Thank you, Mr. Chairman.

Mr. Dickson, I would like to ask you some questions about the FAA's Associate Administrator for Aviation Safety. As you know, our committee staff had the opportunity to interview him last week, and you have been provided with a copy of the transcript.

I have to say I am shocked at some of the things he didn't know. One, he hadn't seen Boeing's flight crew operations manual bulletin following the Lion Air crash. When he was shown a copy of the flight crew operations bulletin that Boeing issued following the Lion Air crash, he said this was the first time he had seen it.

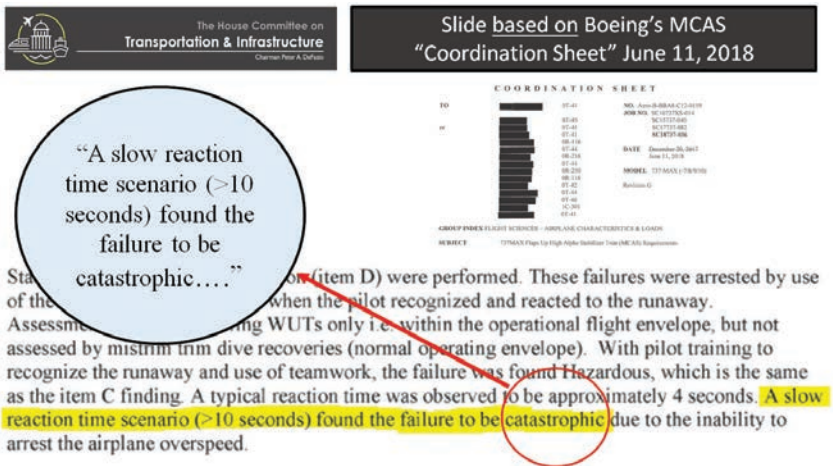
He was asked, "Have you seen this document before?", and he replied, "No, I have not. But it is an FCOM—flight crew operations manual."

He was then asked, "You don't recall seeing this prior to today?"

He answered, "No."

And two, he was unaware that Boeing knew if a pilot didn't react to the unanticipated MCAS activation within 10 seconds, the result could be catastrophic. The slide that has come up on the screen shows Boeing's coordination sheet. When we asked him about this key document that was released at our last hearing—showing that Boeing knew that if pilots did not respond to unanticipated MCAS activation within 10 seconds, the result could be catastrophic—he said he was not aware of the document.

[Slide]



Mr. GARCÍA [continuing]. FAA's chief safety officer was asked, "So let's take it out of the hypothetical. You are aware that this committee held a hearing on October 30 at which Boeing testified. Is that correct?"

"I watched some of it," he replied.

He was then asked, "OK. At the hearing, a document was made public, a coordination sheet from Boeing on which contained a functional hazard assessment, a portion of which said if a pilot didn't react within 10 seconds, the result would be catastrophic. That was information made public at the hearing. Were you——"

He interrupted, "No. I was not aware of that."

The Member then asked, "You didn't watch it? Weren't aware of it? So you are not aware?"

And Mr. Bahrami replied, "No, I didn't. You know, like I said, I was in Montreal at the assembly, and I just watched portions of the hearing. And I do not know about this document."

Administrator Dickson, this was the response of the FAA's chief officer. He seemed completely unaware of the fact that Boeing believed if pilots reacted to unanticipated MCAS activation in 10 seconds or more, it could lead to the complete loss of the aircraft. The result? Catastrophic accident, like we saw in the Lion Air crash and the Ethiopian Airlines crash.

This seems like a pretty important piece of information for the head of safety of FAA to be aware of and understand. This release of this document was widely reported in the press, including by the New York Times, Washington Post, Seattle Times, Forbes, Reuters, and NPR.

Mr. Dickson, do you believe the Associate Administrator for Aviation Safety, FAA's chief safety officer, should have seen at some point over the past 13 months, a copy of Boeing's flight crew operations manual bulletin, and that it used after the Lion Air crash?

Mr. DICKSON. You know, I can't substitute my judgment for his. I believe this is a technical certification requirement or an assumption.

Mr. GARCÍA. Should he have known, Mr. Dickson? Yes or no?

Mr. DICKSON. You know, I think that—you know, I would hope that he would have been aware as to what was made public in the hearing.

Mr. GARCÍA. So is that a yes?

Mr. DICKSON. Again, I will have to talk to him about it.

Mr. GARCÍA. Thank you. Do you believe the Associate Administrator for Aviation Safety should be aware that if a pilot failed to react to unanticipated MCAS activation within 10 seconds, the result could be catastrophic?

Mr. DEFAZIO. You are on the clock here, at about 7 minutes here.

Mr. DICKSON. Sorry, can you restate real quick? I——

Mr. GARCÍA. Do you believe that the Associate Administrator for Aviation Safety should be aware that if a pilot failed to react to unanticipated MCAS activations within 10 seconds, the result could be catastrophic?

Mr. DICKSON. I think that he was aware of the—of the criteria. I do not know that he had seen this exact document.

Mr. DEFAZIO. OK, I thank the gentleman. The gentleman's time has expired.

Mr. GARCÍA. Thank you. I yield back.

Mr. DEFAZIO. Representative Payne.

Mr. PAYNE. Thank you, Mr. Chairman.

Administrator Dickson, in its report, the Joint Authorities Technical Review found that the FAA had inadequate awareness of the MCAS function. Which, coupled with limited involvement, resulted in an inability of the FAA to provide an independent assessment of the adequacy of the Boeing proposed certification activities associated with the MCAS. It appears that the trust Congress gave FAA with delegation authority has been broken.

What steps is the FAA, and you personally, taking to ensure that a lapse such as this does not happen again.

Mr. DICKSON. Thank you, Congressman, a great question. I appreciate the opportunity to respond.

Our whole construct here is based on trust. And it is important that, as the regulator, we can trust the manufacturer that we are delegating certain things to. And it is a privilege. It is not a right; it is not a certificate that they have. It is a privilege to have those items delegated.

That is why we have pulled back on this particular project, on the 737 MAX. And as we do certification activity——

Mr. PAYNE. So Boeing does not have that privilege anymore, correct?

Mr. DICKSON. At this point, that is correct.

Mr. PAYNE. All right. I would suggest that might be something that is looked at across the board, so there are not issues with other airlines. But we are talking about Boeing right now, and so we are trying to make sure that this does not happen again.

Also, the JATR report also recommended that the FAA conduct a workforce review of Boeing's Aviation Safety Oversight Office engineers at FAA to ensure that there is a sufficient number of experienced specialists to adequately perform certification and oversight duties. Has there been a workforce review conducted?

Mr. DICKSON. Yes, it is in process. There is actually a 10-year workforce plan for the Aviation Safety Organization. This group is

part of that. And as we get the JATR report and the other reviews of the process, we are looking specifically at human factors, such as——

Mr. PAYNE. So there are no results yet? It is still in the process?

Mr. DICKSON. Yes, and we are putting those into action now.

Mr. PAYNE. Administrator Dickson, I am the 23d Member on this side of the aisle to ask questions. And I have sat here for a lengthy period of time and I have heard you respond numerous times that we are in the process. Is there anything that has been completed and done with respect to this issue?

Mr. DICKSON. Yes. As I said, we have brought in experts from outside the agency, the Technical Advisory Board. Mr. Kiefer is a member of that. We have opened ourselves up to review as no regulator ever has in this process with the Joint Authorities Technical Review. We have the Secretary's Special Committee on Aircraft Certification, which is coming forward with additional recommendations. And with respect to the 737 MAX, as I have said, we have not delegated any activity, including the issuing of individual airworthiness certificates, tail by tail, on those aircraft. So those are some very significant actions and there are more to come.

Mr. PAYNE. Well, sir, I would implore you as someone that is sitting here, as opposed to where you are, and as Mr. Meadows, the gentleman from North Carolina, asked you and you were able to answer him specifically that you would have certain things done in a time period, that you try as diligently as possible to get these things done.

Sitting here, looking at these pictures is difficult. I have loved ones of my own. And as I look through those pictures, I have young children and cousins and brothers that run the myriad of those pictures. We are fortunate that we are not sitting there.

So it is our obligation where we sit, to make sure that no other family has to sit in that corner again.

And with that——

Mr. DICKSON. Congressman, I would just say I agree with you 100 percent. That is why we are working diligently each and every day, really around the clock. And that is why I support my people in these efforts. And that is frankly why I am going to personally fly the airplane myself and go through the proposed training and do everything I can, so that I would put my own family on the airplane without a second thought. And that is my absolute——

Mr. PAYNE. My time has expired. Thank you.

Mr. DEFAZIO. I thank both gentlemen.

Representative Balderson. I believe these will be the last questions.

Mr. BALDERSON. Thank you very much, Mr. Chairman. Thank you, panel, for being here. Also, I extend my condolences to the families and thank you all for being here.

Administrator Dickson, on September 25, 2019, Boeing's Committee on Airplane Policies and Processes announced a new product and services safety organization. This organization is responsible for reviewing all aspects of product safety, including investigating cases of undue pressure and anonymous safety concerns raised by employees.

Is the FAA satisfied with this new review process and do you believe Boeing will take anonymous safety concerns reported by its employees more seriously?

Mr. DICKSON. Well, thank you for the question. I think that it remains to be seen. It is easy to move around boxes on the org chart and to appear to be doing something. We will have to see how it is implemented and how it is incorporated into their safety culture. And we are going to be doing the same thing or similar things within the agency as well.

But I do think that the ability for employees to systematically bring forward safety concerns is absolutely foundational to the safety system that we have.

Mr. BALDERSON. Thank you. I would agree with that.

My next question for you, Mr. Administrator, is while the ongoing investigations continue to get to the bottom of these two crashes, are you aware of any legislation this committee and Congress can pass now to improve aviation safety?

Mr. DICKSON. I would be happy to work with the committee. I do believe that the support for moving to implementing safety management systems for manufacturers would be very beneficial. I also believe that support for data analysis and data consolidation, making our data systems more modern, that is one of my most important strategic pillars at the agency and that is something, another area where I think we can definitely improve.

Mr. BALDERSON. Thank you very much. Mr. Chairman, I yield back my remaining time.

Mr. DEFAZIO. I thank the gentleman. And I do want to thank the panel for devoting so much time, I think, answering questions for the most part responsibly, and for your further commitments to continue this work and respond to some particular suggestions that were raised here.

With that, the committee will recess for 5 minutes while we assemble the next panel.

[Recess.]

Mr. DEFAZIO. OK, votes are pending so we are going to move along right now, even though it has not been quite 5 minutes.

Panel 2, I would like to welcome the next panel, Mr. Edward Pierson, Boeing retiree, appearing in his individual capacity, with many years of experience in the industry; Mr. G. Michael Collins, FAA retiree, appearing in his individual capacity, again with many years' experience in a regulatory role at FAA; Dr. Mica R. Endsley, president of SA Technologies, former Chief Scientist, U.S. Air Force, former president, Human Factors and Ergonomics Society; and Captain John Cox, president and CEO of Safety Operating Systems.

Thank you all for being here today. We look forward to your testimony. Without objection, your full statements will be included in the record.

So we will now proceed with your testimony. Five minutes, as best you want to summarize.

Mr. Pierson. I don't think it's on.

TESTIMONY OF EDWARD F. PIERSON, FORMER SENIOR MANAGER, BOEING, APPEARING IN HIS INDIVIDUAL CAPACITY; G. MICHAEL COLLINS, FORMER AEROSPACE ENGINEER, FEDERAL AVIATION ADMINISTRATION, APPEARING IN HIS INDIVIDUAL CAPACITY; MICA R. ENDSLEY, Ph.D., APPEARING ON BEHALF OF THE HUMAN FACTORS AND ERGONOMICS SOCIETY; AND JOHN M. COX, CHIEF EXECUTIVE OFFICER, SAFETY OPERATING SYSTEMS

Mr. PIERSON. Forgot to push the button. Sorry.

Chair DeFazio, Ranking Member Graves, members of the committee, good afternoon. Thank you for inviting me to testify today. My name is Ed Pierson.

I would first like to provide my heartfelt condolences for all the families and friends who lost loved ones on Lion Air flight 610, Ethiopian Airlines flight 302. Your loss and grief are truly unimaginable.

Please allow me to provide a little information about myself. I retired from the Boeing Company in August of 2018 as a senior manager at the 737 factory in Renton, Washington. I graduated from the Naval Academy, served in the military as a naval flight officer and held several leadership positions, including squadron commanding officer. I have over 30 years of aviation experience.

I believe production problems at the Renton factory may have contributed to these two tragic crashes. But I do not believe our regulators are paying enough attention to that factory, and I am calling for further investigation. I formally warned Boeing leadership in writing on multiple occasions, specifically once before the Lion Air crash and again before the Ethiopian Airlines crash, about potential airplane risk due to the unstable operating environment within the factory. Those warnings were ignored.

June 9, 2018, while the Lion Air airplane was being produced, 4 months before it crashed, I wrote an email to the 737 general manager, advising him to shut down the production line to allow our team time to regroup so we could safely produce planes. Following that email, I requested a one-on-one meeting with the general manager on July 18 and repeated my recommendation to shut down the factory for a brief period of time.

When I mentioned that I have seen operations in the military shut down for lesser safety concerns, I will never forget his response, which was, "The military isn't a profit-making organization."

During this timeframe, the 737 factory was in chaos. Every single factory health metric was getting record low marks and each one was trending in the wrong direction. Those metrics are detailed in my written testimony and include overtime, quality reports and out-of-sequence work. Keep in mind that, on October 29, 2018, when the Lion Air plane crashed killing 189 people, it was only 2 months old.

After the crash, I wrote a letter directly to Boeing's chairman, president and CEO, Dennis Muilenburg. Mr. Muilenburg asked the general counsel to communicate with me and we spoke on three occasions, where I renewed my warnings. I stressed that investigating the factory, talking with frontline employees was urgent, as I was very concerned that this might not be an isolated incident.

On February 14, 2019, Boeing's assistant general counsel assured me that Boeing had seen nothing that would suggest the existence of embedded quality or safety issues. I wrote a followup letter with supporting documentation to Boeing's board of directors, requesting that they take urgent action, but received no response.

Less than 1 month later, on March 10, 2019, Ethiopian Airlines flight 302 crashed, killing 157 people. That airplane was only 4 months old.

The U.S. regulator's investigation of these crashes has been as disappointing as Boeing's insistence that it had no systemic quality or safety issues. Over the last 8 months, I have delivered detailed information about the factory to those regulators and investigators. I specifically requested that this information be shared with the international investigators in Indonesia and Ethiopia. I also shared production quality concerns about other 737 airplanes built during that timeframe at the same factory with the National Transportation Safety Board, the FAA and the Department of Transportation. The disturbing responses of the leaders of these agencies are detailed in my written testimony.

Despite my information, regulators have continued to direct their primary, perhaps exclusive, focus on their certification process, pilot training and the design failure of the flight control system, specifically the MCAS software. But the component that first failed leading to both crashes is the angle-of-attack sensor part, which is an historically reliable part.

Both Boeing and the FAA knew in December of 2018 that the original angle-of-attack sensor on the Lion Air airplane had failed, which is clearly a production issue since the airplane was brand new. Although the defective Boeing-installed sensor was replaced with a Lion Air-installed part before the crash, that does not explain why the Boeing part failed in the first place. It appears the same sensor failed on the Ethiopian Airlines flight.

Let me be clear. I am not saying that I know factory conditions caused these two crashes. I am saying that a combination of three circumstances justify an investigation of those factory conditions.

First, there have been two fatal crashes.

For the record, I would like to make a note that there was actually a total of 347 people that were killed as a result of these crashes. There was an Indonesian diver doing recovery operations that also passed.

My second reason is I saw firsthand the factory was stressed beyond anything in my experience.

And third, there have been 13 other safety incidents involving faulty hardware or other systems, many of which were serious. Any one of these circumstances alone should justify an investigation of production. Together, they amount to an open-and-shut case for such an investigation.

The bottom line is the 737 factory needs to be thoroughly investigated and closely monitored by regulatory authorities, specifically the FAA, on a continuous basis into the future. I have included recommendations for the committee's consideration in my written statement.

Thank you again for providing me this opportunity. I am ready to answer your questions.

[Mr. Pierson's prepared statement follows:]

Prepared Statement of Edward F. Pierson, Former Senior Manager, Boeing, appearing in his individual capacity

Chairman DeFazio, Ranking Member Graves, Members of the Committee, good afternoon. Thank you for holding this hearing and inviting me to testify today. My name is Ed Pierson and I am a former Senior Manager at Boeing's 737 Factory in Renton, Washington. Before I provide my substantive testimony, I need to provide my heartfelt condolences to the families and friends who lost loved ones on Lion Air Flight 610 and Ethiopian Airlines Flight 302. Your loss and grief are truly unimaginable.

I am here to discuss the alarming state of Boeing's 737 Renton, Washington factory in 2018. During this period, the factory produced hundreds of aircraft, including the two 737 MAX planes that crashed in October 2018 and March 2019. I witnessed a factory in chaos and reported serious concerns about production quality to senior Boeing leadership months before the first crash. I formally reported again before the second crash. No action was taken in response to either of my reports.

MY BACKGROUND

I worked for Boeing from 2008 until my retirement in August 2018. In my last assignment I served as a Senior Manager in Boeing's 737 Renton, Washington Factory. In this role, I worked within the Production System Support organization and oversaw production support for 737 Final Assembly, P-8 and Wings manufacturing operations. Before assuming this position, I served as a Senior Manager in the Boeing Test & Evaluation organization, which is responsible for flight testing newly manufactured planes. In addition to my work at Boeing, I served honorably in the U.S. Navy for 30 years, including as a Squadron Commanding Officer, earning the rank of Captain. I am a graduate of the U.S. Naval Academy, Navy Flight School and George Mason University. My resume and military biography are attached as Exhibits 1 and 2.

THE STATE OF THE RENTON, WASHINGTON FACTORY IN 2018

The 737 is the flagship of Boeing's Commercial Airplanes division. Boeing currently manufactures all of its 737 planes in Renton: the 737 MAX, the 737 Next Generation, and the P-8 Poseidon, a military variation of the 737.

By June 2018, I had grown gravely concerned that Boeing was prioritizing production speed over quality and safety. In early 2018, Boeing experienced a substantial backlog in its production of 737 aircraft. Initially driven by the delayed delivery of critical parts, the logjam quickly cascaded into numerous other problems within the Renton factory, with key metrics growing continuously worse. "Jobs Behind Schedule" (JBS) spiked to greater than ten times the normal amount, and the "Roll Out on Time" percentage routinely dropped below 10%. In turn, the "B1 Flights on Time" rate [1] also dropped substantially.

Despite the delays, Boeing continued its much-publicized push to increase production at Renton from 47 to 52 planes per month in June 2018 and made clear its intent to increase the production rate again to 57 planes per month in 2019. Boeing said nothing about the chaos that such goals created on the production floor. To meet its heightened production target, Boeing initiated "major recovery operations" at Renton. I realized these recovery operations were prioritizing production speed over quality, placing both manufacturing employees and the flying public at risk. The fallout from these operations was widespread and largely concealed from public view. In Boeing's 2nd quarter 2018 earnings report there was zero mention of the state of the factory.

The factory did not have enough skilled employees, specifically mechanics, electricians and technicians to keep up with the backlog of work. As a result, the planned factory overtime rate more than doubled. From my military and private-sector experience, I knew that employee fatigue from excessive overtime inevitably produces process breakdowns—e.g., workmanship mistakes, missed inspection items, incomplete paperwork, or failure to follow established functional test procedures—all of which add considerable risk to the safety of airplanes. Moreover, the parts backlog was leading to substantial "out of sequence" work, meaning the work

[1] "B1" is a flight-test term for the first test flight of a manufactured airplane.

was performed in an area or at a time other than its planned location or time. This too increases the risk of process breakdowns and quality mistakes.

At the same time, actions and decisions by new factory leadership and a major supply chain reorganization led to further dysfunction. Boeing canceled daily "tiered" meetings, which were crucial to information sharing between shifts, replacing them with a once-a-shift large daily status meeting held in the Town Hall conference room. Following that transition, I witnessed numerous instances where manufacturing employees failed to communicate effectively between shifts, often leaving crews to wonder what work was properly completed. At the new Town Hall meetings, 737 program leadership increased schedule pressure by publicly grilling lower-level managers about delays in front of a hundred or more of their peers, even when the cause of a delay was completely beyond the individual employee's control. I grew increasingly worried that this dogmatic focus on schedule, coupled with employee fatigue, would inevitably lead to rushed work and circumvention of established manufacturing processes. Many employees expressed similar concerns and frustration publicly and in private.

Unsurprisingly, the confluence of parts delays, employee fatigue, out-of-sequence work, communications breakdowns, and schedule pressure led to a decline in quality. Boeing rigorously tracks identified process breakdowns and quality defects during production using a computerized database. Each database entry represents a quality defect during production, such as incomplete or incorrect build instructions, missing or malfunctioning equipment, missing inspections, or missing, damaged, or incorrect parts. More significant defects are elevated to a "Nonconformance Report" (NCR), which requires engineering and quality personnel to sign off on a corrective action. During the relevant period, the factory saw quality issues increase by over 30%, and NCRs grew rapidly as well. There were many quality issues related to Electrical Wiring Interconnect System (EWIS) compliance, such as problems with functional testing of wiring or chaffed, cut, or pinched wires. I knew that improperly manufactured, installed, or tested wires can cause intermittent electrical or electronic data errors on critical plane systems.

Boeing Refused to Address Its Deteriorating Factory Conditions

Alarmed by the Renton factory's rapid and unprecedented decline, I emailed the 737 Program's Vice President and General Manager, Scott Campbell, on June 9, 2018. *See* Exhibit 3 (emails to 737 General Manager). Given the serious and time-sensitive nature of my concerns, I bypassed multiple levels of my supervisory chain and executive management to communicate directly with Mr. Campbell, the senior 737 executive who could address the factory conditions. I sent that email nearly four months before the first 737 MAX crash, expressing the gravity of my concerns as follows:

> I fully appreciate the importance of doing our best to meet RO, paint windows, B1s & delivery schedules. But there is a much, much higher risk that we cannot lose sight of. I'm talking about inadvertently imbedding safety hazard(s) into our airplanes. As a retired Naval Officer and former Squadron Commanding Officer, I know how dangerous even the smallest of defects can be to the safety of an airplane. Frankly right now all my internal warning bells are going off. And for the first time in my life, I'm sorry to say that I'm hesitant about putting my family on a Boeing airplane.

To address the worsening factory conditions, I recommended that Boeing "[s]hut down the production line to allow our team time to regroup so we can safely finish the planes." In response, Mr. Campbell assured me that "safety and quality is number one and schedule come [sic] after that," but he did not acknowledge, let alone act on, my recommendation that Boeing shut down the line to allow workers time to safely address the production backlog.

Over the following weeks, factory conditions worsened. In early July, I requested an in-person meeting with Mr. Campbell to further discuss my concerns. When we met on July 18, I gave multiple examples of process breakdowns, explained the numerous metrics indicating a decline in quality, and reiterated my recommendation that Boeing shut down the line to address product and worker-safety risks. In response, Mr. Campbell told me, "We can't do that. I can't do that." I pushed back, explaining that I had seen operations in the military shut down over less substantial safety issues, and those organizations had national security responsibilities. Mr. Campbell responded tersely, "The military isn't a profit-making organization."

In addition to shutting down the line, I also recommended a thorough engineering and quality analysis to determine if the production environment had caused safety risks that needed to be disclosed to Boeing customers. Mr. Campbell also bristled

at this recommendation, but ultimately promised to have human resources pull overtime statistics and to task the engineering and quality organizations with conducting this analysis.

I left Mr. Campbell's office somewhat shocked by his dismissiveness and general unawareness towards the factory turmoil. At the recommendation of another senior manager, I documented the conversation in an email to Mr. Campbell the next day, noting Mr. Campbell's promise to address the cultural issues and worker fatigue and to conduct a quality and engineering analysis to determine if there were "any potential quality risks that might require us to alert our customers." *See* Exhibit 3. Before my voluntary retirement from Boeing on August 1, 2018, I shared this email exchange with several colleagues, who I hoped would monitor the resolution of these problems. To my knowledge, Boeing never acted on my recommendations.

BOEING FAILED TO INVESTIGATE ITS CHAOTIC PRODUCTION ENVIRONMENT EVEN AFTER TWO DEADLY CRASHES

Several months later, on October 29, 2018, Lion Air Flight 610 crashed, killing all 189 people on board. Because Boeing manufactured the Lion Air airplane at Renton in the summer of 2018, I immediately feared the chaotic factory conditions had contributed to this tragic loss of life. When the Preliminary Aircraft Accident Investigation Report failed to address that possibility, I started a months-long effort to force Boeing and the accident investigators to focus on the Renton factory. My efforts did not bear fruit.

I first made several calls to Boeing's Communications Office, asking to speak with the Boeing employees supporting the accident investigation. After weeks of fruitless efforts with the Communications Office, Norwegian Air Flight 1933—a 737 MAX aircraft also manufactured in the summer of 2018—conducted an emergency landing in Iran on December 14, 2018 due to an engine issue. Feeling increased urgency, I decided to appeal directly to Boeing's Chairman, President and CEO, Dennis Muilenburg. In a December 19, 2018 letter, I requested Mr. Muilenburg's assistance in contacting the Boeing employees supporting the Lion Air accident investigation. Exhibit 4 (Dec. 19, 2018 letter to Muilenburg). On January 7, 2019, I received a call from Boeing's General Counsel, retired Judge Michael Luttig. Mr. Luttig stated that Mr. Muilenburg had reviewed my letter and instructed him to follow up with me. After discussing my background and concerns regarding the Renton factory, I again reiterated my request to speak directly with the Boeing employees supporting the investigative team for the Lion Air crash. Mr. Luttig acknowledged this request and said he would share my information with Mr. Muilenburg and CFO Greg Smith.

On January 21, I again spoke with Mr. Luttig about my concerns. Mr. Luttig said that all the 737s in service had received thorough post-manufacturing inspections and that Boeing had not seen any issues with the other planes in the 737 fleet. Mr. Luttig then asked what I would do to investigate my concerns. I recommended that Boeing establish a cross-functional team of subject matter experts who could review data for potential quality and engineering risks and interview employees on the ground about the health of the Renton factory. In response to this proposal, Mr. Luttig recommended that they add Assistant General Counsel Padraic Fennelly to the conversation.

The following day, I spoke with Mr. Luttig and Mr. Fennelly over the phone and once again reiterated my concerns and recommendations. Shortly after the call began, however, I came to believe Mr. Luttig and Mr. Fennelly were more interested in placating me than seriously investigating the factory conditions. Disappointed with the call, I promptly documented my core recommendation by email: "Forming a cross functional [Non-Advocate Review] team to conduct an objective, comprehensive assessment of what occurred last year and the current state of the program . . . This assessment would need to include the analysis of production related data (e.g., quality data) and talking with employees." *See* Exhibit 5 (emails exchanged with general counsel). I stressed that investigating the Renton factory conditions was "obviously an ongoing urgent matter—it was urgent last summer [and] made even more urgent this fall." *Id*.

Two weeks later, having heard nothing further, I sent another email to Mr. Luttig and Mr. Fennelly, setting out in painstaking detail the concerns I had been raising since June 2018: employee fatigue and schedule pressure, aggressive leadership communication, mounting quality defects (including numerous functional test and Electrical Wiring Interconnect System problems), staffing constraints, process deviations, communications breakdowns, and others. I emphasized that "the sheer volume of these issues highlights the considerable & unnecessary risk the company was (is still?) taking to meet ever increasing airplane production rates and delivery schedules" and that "production mistakes may have been made with this airplane

and potentially others." *Id*. I also felt Boeing had misled the public about the state of 737 production: "Record numbers of airplanes delivered makes for good headlines, but they can belie the reality of production health." *Id*.

On February 14, Mr. Fennelly responded that Boeing had considered my information but had "seen nothing from any of [its data] sources that would suggest the existence of embedded quality or safety issues." *Id*. Unsatisfied, I escalated my concerns to the Board of Directors in a February 19 letter that detailed my internal reporting efforts and requested urgent action from the Board. *See* Exhibit 6 (Feb 19 letter to Board).

Before I received any response, tragedy struck again: On March 10, 2019, Ethiopian Airlines Flight 302 crashed, killing 157 people. Another 737 aircraft manufactured in Renton in 2018 had experienced a serious—and in this instance, deadly—safety issue within its first months in service, despite Mr. Fennelly's assurance less than one month earlier that there was no cause for concern.

I concluded that Boeing would not take appropriate action on its own accord. Two days after the crash, I again wrote Boeing's Board, this time to explain that I would be contacting the National Transportation Safety Board (NTSB) and Federal Aviation Administration (FAA) directly due to Boeing's disappointing response. *See* Exhibit 7 (Mar. 12, 2019 letter to Board).

MY EFFORTS TO ENGAGE FEDERAL REGULATORS

Following my March 12, 2019 letter to Boeing's Board, I immediately attempted to contact the NTSB and other regulators. After months of bureaucratic inaction, unexplainable delays, and communications from my attorneys, an NTSB investigator assigned to the Ethiopian Airlines crash finally contacted me to arrange a telephone interview. I provided him with detailed information, yet he estimated that the interview would require only 15 minutes. That interview occurred on June 26, 2019. *See* Exhibit 8 (Key points provided to NTSB investigator on June 26, 2019). The NTSB investigator had no responsibility for any matters other than the Ethiopian Airlines crash. My information, however, was not limited to that airplane. Instead, it concerned hundreds of aircraft manufactured over many months, including not only the Lion Air airplane but also numerous other planes that have experienced significant safety incidents. The NTSB's reluctance to interview me, and the limited scope of the interview it conducted, raised alarms that the agency shares Boeing's aversion to exploring systemic causes for the crashes.

As a result, I sent a letter through my counsel directly to NTSB Chairman Robert L. Sumwalt on June 28, 2019, setting forth my concerns about the condition of the Renton factory in 2018 and the lackluster response I had received from the NTSB. I requested Mr. Sumwalt ensure my information be shared with the Indonesian and Ethiopian accident investigators in accordance with ICAO Annex 13 procedures. *See* Exhibit 9 (June 28, 2019 letter to NTSB). I provided documentation of my communications with Boeing leadership; proposed that the NTSB analyze the engineering, quality data, and manufacturing history of the Lion Air and Ethiopian airlines planes; and offered to assist the investigation in any way possible, including by identifying witnesses who could corroborate my information regarding the Renton factory environment.

On August 6, 2019, NTSB Managing Director Sharon W. Bryson sent a one-page response to my June 28, 2019 letter, informing me that my "concerns fall outside the scope of the NTSB's role in the 737 MAX accident investigations." *See* Exhibit 10 (Aug. 6, 2019 letter from NTSB). I was stunned by this response. Accident investigators routinely review maintenance and training records going back years. And yet, when two new airplanes crashed just months after they were built, the NTSB unilaterally deemed the chaotic and unstable production environment in which they were made to be outside the scope of the accident investigations.

On September 17, 2019, counsel wrote on my behalf to both FAA Administrator Steve Dickson and Secretary of Transportation Elaine Chao, again laying out my concerns about the chaotic state of production at the Renton factory and imploring the agencies to share my information with accident investigators. *See* Exhibit 11 (Sept. 17, 2019 letter to DOT) and Exhibit 12 (Sept. 17, 2019 letter to FAA). The FAA's response was to treat my letter as a "Safety Hotline" report. *See* Exhibit 13 (Oct. 14, 2019 letter to FAA). I received no response from the DOT. I followed up with an additional letter to the FAA on Nov. 5, 2019, expressing renewed safety concerns in light of the Indonesian government's release of its Final Aircraft Accident Investigation Report for Lion Air Flight 610, discussed in greater detail below. *See* Exhibit 14 (Nov. 5, 2019 letter to FAA). Although the FAA suggested in October that it might wish to interview me, I have heard nothing from the agency since then.

To date, I have submitted to numerous interviews involving the Department of Justice, the DOT's Office of the Inspector General, and the NTSB. But I have received no confirmation that any of my information concerning the state of the Renton factory has been shared with accident investigators.

MORE RECENT DEVELOPMENTS AND ONGOING CONCERNS

I remain gravely concerned that the dysfunctional production conditions may have contributed to the tragic 737 MAX crashes and that the flying public will remain at risk unless this unstable production environment is rigorously investigated and closely monitored by regulators on an ongoing basis. My concerns are heightened by the regulators' apparent exclusive focus on the design failure of the flight control system, specifically the failure of the Maneuvering Characteristics Augmentation System (MCAS) software. But MCAS is a system designed to correct flight anomalies when they occur. It was not the first failure event that led to these crashes.

Instead, according to publicly available information, the likely cause of both crashes was the transmission of incorrect information to the planes' MCAS by faulty Angle of Attack (AOA) sensors, which in turn caused the planes to execute a series of abrupt maneuvers contributing to the pilots' loss of control. Despite this, there has been limited discussion by Boeing and American regulators of the faulty AOA sensors, let alone a determination of the root cause(s) of their failures in the two crashes. In September 2019, however, the European Union Aviation Safety Agency (EASA) informed the European Parliament that Boeing had not provided an "appropriate response to Angle of Attack integrity issues" and indicated that it would not unground the 737 MAX until such a response was provided.

My concerns about the AOA sensors multiplied when the Indonesian government released its Final Aircraft Accident Investigation Report for Lion Air Flight 610 on October 28, 2019. The Final Accident Report explains that on October 27, 2018, the day before the Lion Air crash, the plane's AOA sensor was deemed defective and removed from the plane. Boeing subsequently tested that AOA sensor on December 10, 2018 and confirmed it was faulty. It is possible that a similarly faulty AOA sensor was installed on the Ethiopian Airlines plane that crashed on March 10, 2019.

AOA sensors have a long history of reliability. No one has asked why two brand-new AOA sensors on two brand-new planes inspected, installed, and tested by Boeing at the Renton plant during the summer of 2018 failed. And no one has investigated whether the hundreds of other planes manufactured during the summer of 2018 at Renton—including the currently flying 737 Next Gen airplanes and P-8 military airplanes—have faulty AOA sensors or other production quality issues.

I raised these concerns in a third letter to the FAA on November 5, 2019, urging Administrator Dickson to issue an Emergency Airworthiness Directive to airlines and Boeing requiring them to inspect, test, and, if necessary, replace similar model AOA sensors. *See* Exhibit 14 (Nov. 5, 2019 letter to FAA). I received no response.

The number of safety-related events involving this relatively new aircraft is another alarming indicator that Renton production was seriously deficient. Using publicly available information, I have identified thirteen occasions where safety incidents occurred on 737 MAX aircraft just weeks or months into their service life. *See* Exhibit 15 (providing my analysis of recent 737 incidents). Combined with the two crashes, this means that 15 aircraft, or 4% of the 737 MAX airplanes delivered to customers had already experienced a safety incident. While I am unable to perform a statistical comparison with other aircraft, it is unacceptable to me that passengers on one of every 25 airplanes can expect to experience a safety incident.

Although it is imperative to correct Boeing's flawed MCAS software and pilot training, it is no less imperative to thoroughly evaluate why the AOA sensors provided faulty data in the first place, and whether those reasons implicate Renton production more broadly. It is alarming that these sensors failed on multiple flights mere months after the airplanes were manufactured in a factory experiencing frequent wiring problems and functional test issues. Regulators simply must ask questions about the conditions of the Renton factory and Boeing must answer them candidly. The safety of the flying public depends on it.

CONCLUSION

Although delivering record numbers of airplanes does in fact make for good headlines, the numbers can mask the reality of production health and airplane quality. I witnessed that on-the-ground reality and I watched with grief and horror as 346 individuals lost their lives in the Lion Air and Ethiopian Airlines crashes. We would be remiss if we failed to remember that another individual that wasn't on one of these airplanes also died as a result of these crashes. He was an Indonesian rescue diver named Syachrul Anto.

I am not a disgruntled employee and I never imagined that I would find myself in this position. I am here today for one reason: to prevent future tragedies by ensuring that regulators and Boeing take every step necessary to prevent the loss of additional lives. Those steps must include a thorough investigation into the production of 737 aircraft at the Renton Factory and close monitoring by regulators from this point forward.

I have attached a list of recommendations for the committee's consideration.

RECOMMENDATIONS FOR THE HOUSE TRANSPORTATION & INFRASTRUCTURE COMMITTEE

1. Direct the FAA to conduct a comprehensive investigation of the 737 Renton, Washington Factory (Final Assembly, P-8 & Wings) to determine if reported problems still exist. If the international accident investigators want to be a part of this investigation they should be afforded the opportunity. The FAA should take appropriate actions as necessary depending on the results of the investigation.
2. Direct the FAA to issue an Emergency Airworthiness Directive for Boeing and airlines to inspect, test and if necessary replace faulty AOA Sensors (per Eric Havian's Nov 5, 2019 letter to the FAA)
3. Direct the FAA to deploy enough qualified employees into Boeing's factories to closely monitor production operations and be available to respond to production concerns from Boeing employees. These FAA employees need to be accessible to Boeing employees working on all shifts and be easily visible (FAA jackets, FAA shirts, FAA posters, etc.).
4. Direct the FAA to analyze reports of safety incidents involving 737 airplanes (MAX, NG & P-8) built since 2017 and to provide a comprehensive risk assessment to this committee NLT Jan 1, 2020. The analysis needs to include the 13 other MAX incidents brought to the attention of the committee.
5. Direct the FAA to develop rules to limit work hours for employees involved in airplane manufacturing.
6. Direct the FAA to require Boeing to get FAA approval prior to increasing production rates and to closely monitor production rate increases to ensure production stability.
7. Direct the NTSB to develop a streamlined witness interviewing process to ensure future witnesses are interviewed in a timely manner. Publish this process on the NTSB website.

EXHIBITS

EXHIBIT 1—RESUME

Available at http://docs.house.gov/meetings/PW/PW00/20191211/110296/HHRG-116-PW00-Bio-PiersonE-20191211.pdf

EXHIBIT 2—MILITARY BIOGRAPHY

United States Navy
Biography

Captain Edward F. Pierson

Captain Ed Pierson was born in Washington, DC. He graduated from the U.S. Naval Academy in 1985 with a Bachelor of Science degree. He attended flight school and was designated a Naval Flight Officer in 1986.

Following initial flight training, he reported to Patrol Squadron 11 (VP-11). There he served as a Navigator and Tactical Coordinator flying maritime patrol missions. During this tour he qualified as a P3C Mission Commander, Mine Warfare Officer, and Instructor Tactical Coordinator.

After completing his first tour, Captain Pierson was chosen to serve as a Joint Staff Action Officer at the Pentagon. He gained joint/combined operations experience as a Crisis Action Team member while supporting Operation Desert Storm within the National Military Command Center.

Following his Joint Staff assignment, Captain Pierson was selected to serve as Special Assistant, Bureau of Politico-Military Affairs, U.S. State Department. He later assumed the duties of Crisis Management Officer supporting the State Department's Operations Center where he gained national security affairs, foreign policy development, and defense trade controls experience working inside the interagency process. During this period, Captain Pierson earned a Master of Public Administration degree from George Mason University.

Captain Pierson joined the Navy Reserves at VP-69, NAS Whidbey Island, WA in 1993 where he flew ASW, ASUW, CN, ISR and SAR missions inside the PACOM and SOUTHCOM AORs. As a Department Head and later while serving as VP-69's Executive Officer, Captain Pierson led numerous joint warfare initiatives including the teaching of joint operations and national security affairs at the tactical level. Captain Pierson assumed command of VP-69 in 2003. During his CO tenure, VP-69 was awarded the coveted "Battle E" and "Golden Wrench" awards. Following his CO tour Captain Pierson became an Instructor for the Center for Naval Leadership.

Captain Pierson reported to U.S. Third Fleet in 2007. Captain Pierson held a variety of senior leadership roles at Third Fleet including Air Operations Officer, Battle Watch Captain and Current Operations Director. He assumed command of U.S. Pacific Command's Det 322 in 2010, which transitioned to Det 301, providing direct support to PACOM's J-3 Directorate. At PACOM Captain Pierson qualified as Joint Operations Center (JOC) Director where he was responsible for monitoring the coordinated employment of all naval, ground and air forces in the Pacific theater.

From 2011-2013, CAPT Pierson commanded U.S. Pacific Fleet's Joint Contingency Unit. He provided strategic planning and operations analysis support while successfully integrating ASW, BMD & CYBER operations into a highly effective joint planner training program. During this assignment he was handpicked by USPACOM to represent the U.S. military as JOC Director & lead U.S. Maritime Observer for several highly visible Seventh Fleet international exercises.

Captain Pierson served as Chief Staff Officer for Training, Readiness & Strategic Communication for the Reserve Management Analysis Unit from 2013-2015 within the Office of the Chief of Naval Operations (OPNAV), Pentagon where he led several improvement initiatives including transforming administrative process improvements for 80,000 reservists. Captain Pierson retired in 2015 after 30 years of honorable service.

Captain Pierson's decorations include the Defense Meritorious Service Medal (two awards), Meritorious Service Medal (two awards), Joint Service Commendation Medal, Navy and Marine Corps Commendation Medal, Navy and Marine Corps Achievement Medal, and various unit awards.

EXHIBIT 3—EMAILS TO 737 GENERAL MANAGER JUNE AND JULY 2018

Ed Pierson

From: Pierson (US), Ed <[redacted]@boeing.com>
Sent: Wednesday, July 25, 2018 6:57 AM
To: Pierson (US), Ed
Subject: RE: Recovery Operations & Safety Concerns

Follow Up Flag: Follow up
Due By: Tuesday, July 24, 2018 7:00 PM
Flag Status: Flagged

From: Campbell (US), Scott A
Sent: Friday, July 20, 2018 6:49 AM
To: Pierson (US), Ed <[redacted]@boeing.com>
Subject: RE: Recovery Operations & Safety Concerns

Great insight and appreciate you coming to talk with me…already started to make sure our teams are more focused on the boeing behaviors so we don't have those peppered questions any more.

Thanks again
Scott

From: Pierson (US), Ed
Sent: Thursday, July 19, 2018 2:47 PM
To: Campbell (US), Scott A <[redacted]@boeing.com>
Subject: FW: Recovery Operations & Safety Concerns

Scott,

Thanks for meeting with me yesterday to discuss employee & product safety. As we discussed "how" people are talked to has a direct impact on our culture.

If an employee routinely gets peppered with schedule related questions like:

- Why haven't you met your schedule commitment?
- When are you going to be done?
- How come your jobs didn't get completed?
- When are you going to be off the airplane?
- Why didn't your team get the work done?
- Etc.

Combined with fatigue is a potentially dangerous recipe for rushed work & the short circuiting of established processes...as we have seen.

I'm all for personal accountability, however many times the answers to these questions are completely out of the control of that individual employee--parts not available, bottlenecks in our processes, dependency on another employee or team to get their work done & equipment issues just to name a few variables.

If an employee is not performing, there is a proven best practice leadership technique of talking with the employee in private, asking how we can help him/her, provide them additional training, etc. Putting employees on the spot publicly to defend why they are not on schedule is not good for morale or retention. As we

discussed if we are going to ask questions in public they should be questions like how can I help you stay on schedule?, how is your quality?, are you following the process?, does the process need to be changed?, do we need to provide better training?, do you need additional resources? etc.

For several months now we got away from our production standards by not conducting BPS Tier meetings. I'm happy to see we are returning to the tier meetings so this should help with communications.

I appreciate your willingness to look for ways to implement additional OT controls to minimize risks associated with employee fatigue. Pulling the OT data for our union employees to ID the folks that are working way too much is a good idea. Unfortunately this data will not include the huge amount of OT hours managers are routinely putting in, so additional controls are needed.

Finally I appreciate your commitment to ask Quality & Engineering to conduct additional analysis on the defects that were reported in the last quarter to see if there are any potential quality risks that might require us to alert our customers. I recommend this analysis include traveler data because as you know, working out of position makes identifying defects that much more difficult.

Thanks, Ed

Ed Pierson
Line Side Control Senior Manager
Final Assembly & P-8 Program
737 Operations Center Team Member
Click here to provide feedback to Operations Center Team
Bldg 4-81, Renton, WA, MS 9W-08
[redacted]

Notice: This communication may contain sensitive information. If you are not the intended recipient, or believe that you have received this communication in error, do not print, copy, retransmit, disseminate, or otherwise use the information. Respond to the sender that you have received this e-mail in error, and delete the copy you received.

From: Pierson (US), Ed
Sent: Monday, July 09, 2018 12:47 PM
To: Andrus (US), Marla A <[redacted]@boeing.com>
Subject: FW: Recovery Operations & Safety Concerns

Marla,

I would like to request a 30 min meeting with Scott on the topic of safety. I know he is super busy and my schedule isn't much better. So I'll give you a call tomorrow (Tue) to help find a day/time that might work.

Thanks, Ed

Ed Pierson
Line Side Control Senior Manager
Final Assembly & P-8 Program
737 Operations Center Team Member
Click here to provide feedback to Operations Center Team
Bldg 4-81, Renton, WA, MS 9W-08
[redacted]

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From: Pierson (US), Ed
Sent: Sunday, June 10, 2018 10:12 AM
To: Campbell (US), Scott A <[redacted]@boeing.com>
Subject: RE: Recovery Operations & Safety Concerns

Thanks Scott

Ed Pierson
Line Side Control Senior Manager
Final Assembly & P-8 Program
737 Operations Center Team Member
Click here to provide feedback to Operations Center Team
Bldg 4-81, Renton, WA, MS 9W-08
[redacted]

Notice: This communication may contain sensitive information. If you are not the intended recipient, or believe that you have received this communication in error, do not print, copy, retransmit, disseminate, or otherwise use the information. Respond to the sender that you have received this e-mail in error, and delete the copy you received.

From: Campbell (US), Scott A
Sent: Sunday, June 10, 2018 6:48 AM
To: Pierson (US), Ed [redacted]@boeing.com>
Subject: Re: Recovery Operations & Safety Concerns

Ed some great insight and things we are talking about constantly. We need and will remind everyone constantly that safety and quality is number one and schedule come after that. We are trying to make sure people take the time off so the can recharge...because your right we don't want people coming to work tired. My leadership team and I run daily mtgs on this and I will bring it up today to remind themselves and their teams that safety and quality is the first on our list!

Thanks again
Scott

From: Pierson (US), Ed
Sent: Saturday, June 9, 2018 1:32 PM
To: Campbell (US), Scott A
Subject: Recovery Operations & Safety Concerns

Scott,

I have some safety concerns that I need to share with you as the leader of the 737 Program. I know you care deeply for the safety of our employees and the safety of our products & I trust you will take appropriate action. As you are aware the program is struggling through major recovery operations. Today we have 38 unfinished airplanes located outside the factory. The following concerns are based on my own observations and 30 years of aviation safety experience. I'm including some recommendations because it is important not to just pass along problems.

My first concern is that our workforce is exhausted. Employees are fatigued from having to work at a very high pace for an extended period of time. This obviously causes stress on our employees and their families. Fatigued employees make mistakes. This is especially true when combined with the hazards of unfamiliar environments like working out of position (slips, trips, falls, LOTTO, etc.). As a manager representative on the IAM Joint Programs Site Safety Committee, I know fatigue is frequently listed as a causal factor in serious occupational accidents. It has also become the #1 contributing factor to vehicle accidents.

My second concern is schedule pressure (combined with fatigue) 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. For example, making a workmanship mistake, missing an inspection item, not properly completing paperwork or failing to recognize a functional test failure. I fully appreciate the importance of doing our best to meet RO, paint windows, B1s & delivery schedules. But there is a much, much higher risk that we cannot lose sight of. I'm talking about inadvertently imbedding safety hazard(s) into our airplanes. As a retired Naval Officer and former Squadron Commanding Officer, I know how dangerous even the smallest of defects can be to the safety of an airplane. Frankly right now all my internal

warning bells are going off. And for the first time in my life, I'm sorry to say that I'm hesitant about putting my family on a Boeing airplane.

I see that you have scheduled another discussion on Boeing Behaviors on Monday. As you've stated previously, talking about & cheerleading around this topic is not the same as modeling it. I fear serious process breakdowns will continue to occur if we continue pushing our employees to the limit. With this in mind, I'm making the following recommendations:

#1 – Remind everyone that meeting RO, paint windows, B1s & Deliveries is important, but not nearly as important as building the highest quality product and working safely.

#2 – Shut down the production line to allow our team time to regroup so we can safely finish the planes outside and then shift our attention to the planes inside. I don't make this recommendation lightly. 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. Thank you for considering my feedback. Ed

Ed Pierson
Line Side Control Senior Manager
Final Assembly & P-8 Program
737 Operations Center Team Member
Click here to provide feedback to Operations Center Team
Bldg 4-81, Renton, WA, MS 9W-08
[redacted]

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EXHIBIT 4—LETTER TO BOEING CEO, DECEMBER 19, 2018

Dec 19, 2018

Ed Pierson
[redacted]

Mr. Dennis Muilenburg
Chief Executive Officer
The Boeing Company
100 North Riverside
Chicago, Illinois 60606

Mr. Muilenburg:

I am writing this letter to ask for your assistance. Although we have never personally met, I feel like I know you after watching years of ethics training videos. You strike me as an honorable man, someone that would do the right thing even it is painful.

I am a recently retired Boeing employee and have information that may be helpful to the Lion Air Flight 610 accident investigation. I have made repeated efforts to identify and speak with the individual who is the Boeing primary lead. I have provided my name and personal phone number and asked for a return call. Unfortunately, as of this date, I have not received any return phone calls.

I am not trying to disrupt this critically important investigation. As background I worked within the 737 Program at the Renton plant the last 3 years as a Senior Manager. I'm very proud to have worked at Boeing with so many hard-working professionals—many of whom I consider close friends.

I understand Indonesia's National Transportation Safety Committee is leading the investigation into this tragedy and our NTSB, the FAA and Boeing are in support roles. Admittedly the information I need to share isn't favorable to Boeing, but I believe it is very important nonetheless. Most importantly, I believe Boeing is in the best position to address my concerns in the most expedient manner, more so than the FAA, NTSB or NTSC.

Like everyone else I feel horrible for the families of the 189 people that lost their lives. My sole objective is helping to ensure this never happens again. I am specifically asking your assistance to help me get in touch with the Boeing lead. If I am unable to speak with this individual before Jan 7th, then I feel I would have no other choice but to engage the FAA, NTSB or the NTSC. The urgency of this matter is highlighted with the recent emergency landing of the Norwegian 737 MAX in Iran.

Thank you in advance for your assistance. Of course, I am open to talking with you directly if you desire.

Sincerely,

Ed Pierson

Ed Pierson
[redacted]

EXHIBIT 5—EMAILS WITH BOEING'S GENERAL COUNSELS, JANUARY AND FEBRUARY 2019

Ed Pierson

From: Ed Pierson [redacted]
Sent: Friday, February 15, 2019 10:15 AM
To: 'Fennelly (US), Padraic B'
Subject: RE: 737 Program Safety Concerns

Padraic,

Thank you for responding. Unfortunately I don't think this is a sufficient response. Sincerely, Ed

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From: Fennelly (US), Padraic B [redacted] @boeing.com>
Sent: Thursday, February 14, 2019 11:26 AM
To: Ed Pierson [redacted]; Luttig (US), Michael < [redacted] @boeing.com>
Subject: RE: 737 Program Safety Concerns

Ed --

I wanted to thank you again for reaching out to us and for raising your concerns about the production challenges on the 737 program last year. And thank you also for taking the time to speak with us about the nature of those concerns. As I know you understand, the safety of our airplanes is of paramount importance to every single person here at Boeing.

As we told you we would, after our last call we shared your concerns with the senior leaders who have direct oversight and responsibility for 737 production and quality. We walked through the issues you raised, in detail, and I can assure you your concerns were taken very seriously. I don't think it will surprise you to learn that ensuring the safety and quality of the 737, including during the recent production challenges, has been the subject of intense focus by BCA.

As I'm sure you know, Boeing closely monitors production quality data, as well as other data related to the overall health of the production system, including, and especially, during periods of disruption like the one experienced last year on the 737 program. Moreover, all of our aircraft are subject to rigorous inspection before they are certified, delivered, and enter into service. Boeing also has access to data concerning the in-service performance and reliability of the 737 fleet. We have seen nothing from any of these sources that would suggest the existence of embedded quality or safety issues, whether or not as a result of the production disruption experienced last year. And I can give you Boeing's assurance that it will continue to closely monitor the production and performance of the 737, as it does for all of its airplanes.

Finally, as to the investigation into the Lion Air incident, rest assured that Boeing is fully supporting the investigation, cooperating with, and under the direction of, the relevant government authorities, including the NTSB, FAA, and NTSC. While that investigation continues, Boeing is strictly prohibited from commenting publicly. I would, however, refer you to the statements and the preliminary report from the investigating authorities for additional information on the incident.

All of us at Boeing share your concern for safety, and, again, we very much appreciate not only your willingness to bring these concerns forward, but also to discuss these concerns with us in detail.

Best regards,

Padraic

From: Ed Pierson [redacted]
Sent: Thursday, February 7, 2019 9:06 AM
To: Luttig (US), Michael <[redacted]@boeing.com>; Fennelly (US), Padraic B <[redacted]@boeing.com>
Subject: RE: 737 Program Safety Concerns

Resending due to transmission error

Judge,

It has been 2 weeks since we last spoke. You encouraged me to call or email you & Padraic if I had any additional questions or thoughts. I appreciate the 2 long conversations we had as a result of my Dec 19th letter to CEO Dennis Muilenburg ref: Lion Air Flight 610 Accident Investigation. I was under the impression you would be getting back to me soon. Please excuse my frustration and the length of this email. From my vantage point the lack of a timely response by the company to serious safety concerns involving the 737 Program, specifically the production of NG, MAX & P-8 airplanes has been disturbing.

I know how swiftly Boeing moves when senior executives, especially the CEO, want to get something done. Resources are made immediately available. Therefore by now, I assume at a minimum you have shared the essence of our phone conversations with the CEO & the 2 technical leads supporting the Lion Air accident investigation (Mike Sinnett & John Hamilton). I also assume a decision has been made whether or not to form a cross functional team to develop a comprehensive, objective assessment of these safety concerns to eliminate the possibility that production problems could have been a root cause to the accident per my recommendation. Additionally and equally important, to ensure other airplanes are not affected as well by these same safety concerns.

If such a team has been formed, they should be well on their way to understanding what was going on within the 737 Program when the Lion Air airplane was being built. Again this is also the same timeframe as the building of the Norwegian 737 airplane that was forced to conduct an emergency landing in Iran. As previously mentioned, I'm willing to share my observations with such a team and to help in any way I can to ensure future tragedies don't occur.

In a good faith effort to be as forthcoming as possible and not knowing if such a team will ever be formed, I want to share my personal observations of the operating environment at the time these airplanes were being built in the Renton factory last year. I'm confident other employees will corroborate these observations. I expressed these concerns to the 737 General Manager in June and July 2018. They include:

Employee Fatigue & Schedule Pressure – Employees worked an excessive amount of extended OT over the course of many months. It is well known that fatigued employees are far more likely to make quality mistakes and to be involved in occupational accidents & near misses. I heard many employees including managers express frustration about how physically tired they were and the impact OT was having on their personal lives. Some employees welcomed the extra money whereas others appeared to wear this as a badge of honor, while still others believed this was an ill-advised effort to produce airplanes. "When are you going to be done, done" was a repeatedly asked question. It was one of many questions used to apply schedule pressure on employees under the guise of holding people personally accountable. In other words this meant how come your crew hasn't finished their jobs and when the heck are you going to be off the plane so others can proceed with their work. This question was oftentimes followed up by "you gave me your word your crew would be off this airplane and they weren't, why not"? Very difficult questions to answer when one factors in all the other variables going on during this timeframe as described below. This relentless schedule pressure was being put on frontline union employees, team leaders and managers by senior management. Understaffed MRB Engineers were also frequently being pressured to process Tags more expeditiously.

Leadership Actions & Inactions – 1st and 2nd line manufacturing managers were peppered with schedule related questions and publicly criticized (berated) during daily status meetings held over the course of many months in the

Town Hall conference room in front of 100+ colleagues. Executives routinely disregarded, bypassed and/or ignored the technical advice of experienced senior managers regarding recovery planning. Efforts to review "Boeing Behaviors" on a daily basis felt shallow and insincere in light of this aggressive communication style. Understandably there were concerns that less experienced managers might model this type of leadership and communication style with their respective teams. In July I specifically asked the GM if he had attended any of these meetings and he said he hadn't.

President McCallister also made what many people felt was a rash decision to immediately implement LSCCs in the 4-81 & 4-82 buildings in 1 week. Reassigning such a large number of employees to the factory floor over such a short period of time without having a clear, agreed upon workflow process added considerable disruption to an already unstable and stressful environment. He made this decision after a weekend site visit & despite the fact there was a cross functional management team working to develop a more seamless implementation plan. There appeared to be absolutely no interest at the executive level in slowing or stopping the production line to give employees and our suppliers the chance to catch up. As I mentioned in our 1st conversation, last June and July I recommended to the 737 GM to stop the production line. In a dismissive manner he told me "we can't do that, I can't do that." I responded by asking "why not, I've seen larger operations shut down for far less safety issues. He challenged me asking "like where?" I responded "in the military and those organizations have national security responsibilities." His response, "well the military isn't a profit making organization."

Quality Issues – QA Inspectors were overloaded with a backlog of inspection requests. There was a shortage of QA inspectors particularly on weekends. Thousands of SATs & hundreds of Tags were piling up. Much higher than normal numbers.

Each SAT represents a quality defect in one of our processes (something is preventing the airplane from being built…damaged parts, missing parts, wrong parts, incomplete build instructions, wrong engineering drawings, equipment missing, equipment not properly working, inspection missing, tool missing, tool needed, etc.). There were plenty of concerns about EWIS compliance. Common problems included wire length issues, connector issues, cannon plug issues, component testing issues, functional test issues, wires chaffed, wires cut, wires pinched, etc. If improperly manufactured, installed or tested wires (electrical & data carrying) can cause intermittent electrical or data errors. We also had plenty of adhesive & electrical bonding/grounding issues going on.

Supply Chain Disruptions – In addition to the widely publicized reports of late deliveries of Spirit fuselages and CFM engines, we had hundreds of other parts that regularly failed to meet load dates from dozens of suppliers. This even included vital parts from internal Boeing suppliers like ESRC & TDRC (e.g., power panels and tubing).

Staffing Constraints – Reports of inadequate number of manufacturing employees and not enough qualified specialists (e.g., electricians, CSMS technicians, QA inspectors). Electrical and CSMS 1st line managers that were consistently pressed to commit to finishing their functional tests were simultaneously pleading for additional qualified resources. In some situations staffing relief was provided whereas in other cases it didn't come or didn't come fast enough. Besides pulling P-8 employees from the P-8 line, hundreds of new employees were added from Everett in the midst of these major recovery operations requiring onboarding assistance and job training. This placed additional burdens on overworked team leaders, crews and managers. Throwing more bodies at the problem didn't seem to help during this timeframe.

Process Deviations – We moved away from standard LMS processes outlined in the 737 Production System Handbook. This was readily apparent with the sudden cancellation of all daily LMS tiered meetings (crew, TL and 1st line manager meetings). These daily tiered meetings served as an important communication backbone allowing crews to review work completed or not completed on the last shift, work needed to be completed, resource requirements, SATs/Tags, etc. Business review meetings were also routinely cancelled which limited the transfer of time-sensitive feedback from compliance audits.

Communication breakdowns – Stripped of these recurring LMS tiered meetings, crews and managers struggled to effectively communicate especially across shifts. There were numerous failures in the use of existing shift to shift

technology to document important turnover information. Instead the new daily status meetings held in the Town Hall Conference Room relied on the use of hundreds of different colored hand written sticky notes, different colored ink, and individual airplane schedules plastered all over the walls. This proved to be very confusing to many people and it was hardly indicative of a world class manufacturing facility.

Safety Incidents – There were a large number of high hazard safety incidents. Having so many employees working away from their normal work location introduced many new hazards (e.g., fall, electrical, hydraulic, etc.). Of course since employees were working such long hours to get the job done, there also seemed to be a reluctance in submitting near miss reports—it was just going to add more work on the part of the person submitting the report.

Functional Test Delays & Failures – All the out of position work largely driven by supply chain problems led to large numbers of Oil On, Power On, EWIS, HIRF & CSMS test delays/failures exacerbating the workload of functional test employees.

Facility Limitations – Because we had so many unfinished airplanes we ran out of available airplane parking spaces. Handicap, manager and executive parking spaces were rapidly converted to airplane parking spots. Some of the sites didn't have adequate airplane grounding adding additional hazards. We were also severely space constrained and didn't have enough space for the storage of wings that were being produced while we waited for fuselages to arrive. So wings were squeezed into different areas in the factory creating additional head and eye hazards.

Equipment Shortcomings – Not enough hydraulic mules, CSMS carts, Power carts, etc. inside and outside the factory and on the flight line. Sensitive test equipment was subjected to damage due to all the transportation movements. Some electrical equipment was also left out in the rain.

Recovery Planning Efforts – IEs were repeatedly tasked to produce and reproduce an inordinate amount of recovery plans, burn down plans, data reports, etc. There seemed to be an unquenchable desire to produce a wide variety of complex reports on the personal whim of a single executive, usually on very short notice. This put a significant drain on IE resources that were also trying to help their respective shops.

Deteriorating Factory Health Metrics – Every single metric used to ascertain factory health was getting record low marks. This included Factory Jobs Behind Schedule (>10 x normal), Average Jobs Behind Schedule per airplane, Travelers, SATs, Tags and Call Board requests. Not surprisingly the higher OT drove higher build costs. We had a lot more airplanes waiting to be finished outside the factory then we had inside the factory being built. Large amounts of incomplete jobs were also dropped on our Preflight crews.

Most of these production problems are not unusual. Employees are usually able to overcome these challenges following standardized processes with leadership support. Taken as a whole, the sheer volume of these issues highlights the considerable & unnecessary risk the company was (is still?) taking to meet ever increasing airplane production rates and delivery schedules. Employees with 20+ years 737 experience stated they had never seen the production system in such bad shape. As you stated, leaders based in Chicago were aware of these recovery issues. Nonetheless being aware of these problems and fixing them are two completely different matters. Just because an airplane flies safely one day doesn't mean it will fly safely the next. This is the insidious nature of imbedded defects. Although I can't speak from firsthand experience now, based on investor reports I believe there is a high probability many of these problems & associated risks are still occurring. Record numbers of airplanes delivered makes for good headlines, but they can belie the reality of production health.

Again to be very clear, I'm not saying anyone did anything deliberate to jeopardize the Lion Air airplane. What I am saying is production mistakes may have been made with this airplane and potentially others, due to the reasons outlined above. I believe Boeing has a duty to proactively support the accident investigation. I can't help but wonder what Boeing's response would be if this had been a U.S. airline accident. I know there are billions of dollars at stake in the contract between Boeing & Lion Air. I'm confident Boeing has the resources to fix these problems. The question is whether or not there is the ethical leadership and will to set aside pride and potential liabilities to get to the truth.

Sincerely, Ed Pierson

From: Ed Pierson <[redacted]
Sent: Tuesday, January 22, 2019 3:50 PM
To: '[redacted]@boeing.com'[redacted]@boeing.com>; [redacted]@boeing.com'
<[redacted]@boeing.com>
Subject: RE: 737 Program Safety Concerns

Judge & Padraic,

Thank you for the teleconference today. I understand you will be talking with some of your colleagues and will get back in touch with me. This is obviously an ongoing urgent matter—it was urgent last summer made even more urgent this fall. I would like to make a recommendation and a request:

Recommendation: As we discussed, looking at program level metrics provides an important, but limited view of what was (is?) going on inside the 737 Program. Forming a cross functional NAR team to conduct an objective, comprehensive assessment of what occurred last year and the current state of the program, would provide an even more important view. This assessment would need to include the analysis of production related data (e.g., quality data) and talking with employees. If such a course of action were to be taken, it would be crucial to talk with frontline employees, union leaders and 1st level managers—not just senior management. This in turn should provide clarity on follow-up actions that need to be taken. Of course such a team would also need to be properly resourced and operate with the full support of the CEO. I have great faith in Boeing employees.

Request: Please provide an estimate of when you will be able to get back in touch with me. Thanks, Ed

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From: Ed Pierson <[redacted]
Sent: Monday, January 21, 2019 8:03 PM
To: '[redacted]boeing.com>; [redacted]'
<[redacted]@boeing.com>
Subject: 737 Program Safety Concerns

Judge & Padraic,

FYI. Ref: Tuesday's teleconference. Ed

EXHIBIT 6—FIRST LETTER TO BOEING BOARD OF DIRECTORS, FEBRUARY 2019

Feb 19, 2019

Boeing Board of Directors
Office of the Corporate Secretary
Boeing Corporate Offices
100 N. Riverside Plaza MC5003-1001
Chicago, IL 60606-1596

Corporate Secretary:

Please distribute the attached letters to the Board of Directors. I have made copies for each Board member. Thank you.

Sincerely,

Ed Pierson

cc: Robert A. Bradway
David L. Calhoun
Arthur D. Collins Jr.
Kenneth M. Duberstein
Admiral Edmund P. Giambastiani Jr.
Lynn J. Good
Lawrence W. Kellner
Caroline B. Kennedy
Edward M. Liddy
Susan C. Schwab
Ronald A. Williams
Mike S. Zafirovski

Feb 19, 2019

Boeing Board of Directors
Office of the Corporate Secretary
Boeing Corporate Offices
100 N. Riverside Plaza MC5003-1001
Chicago, IL 60606-1596

Board of Directors:

My name is Ed Pierson. I am a recently retired Boeing employee. In my last assignment I served as a Senior Manager, Production System Support within the 737 Program in Renton, Washington. I'm writing to ask for your assistance on what I believe is an urgent matter.

Last year in June and July 2018, I tried unsuccessfully to stop the production of 737 NG, MAX & P-8 airplanes due to product and worker safety concerns (Encl. #1).

On Aug 13, 2018 Lion Air took delivery of a 737-8 MAX airplane. On Oct 29, 2018 this new airplane crashed off the coast of Indonesia killing 189 people. The accident is still under investigation. The investigation is being led by Indonesia's National Transportation Safety Committee (NTSC). Boeing is supporting this investigation along with the NTSB and FAA.

The NTSC published a Preliminary Aircraft Accident Investigation Report on Nov 28, 2018. The preliminary investigation and associated news reports make no mention of the possibility a production problem could have been a contributing factor. I pray this was not the case, but given the state of the 737 Program at the time this airplane and others were built, it needs to be thoroughly investigated. For this reason, I attempted unsuccessfully on multiple occasions to contact the Boeing employee(s) supporting the NTSC's investigation in early December to share information that I believe might be helpful to the investigation.

On Dec 14, 2018 a Norwegian 737-8 MAX airplane made an emergency landing in Iran reportedly due to engine problems. On Dec 19, 2018 I sent a letter to Boeing's CEO (Encl. #2).

On Jan 7, 2019 Boeing's General Counsel contacted me on behalf of the CEO in response to my letter. We had a follow-up conversation on Jan 22, 2019 with BCA's Assistant General Counsel. At the conclusion of this last conversation, the General Counsels promised to follow-up and to get back in touch with me.

I made the same recommendation to the attorneys that I would have made to the Boeing technical employees supporting the investigation had I been afforded the opportunity to talk with them directly. I recommended the forming of a cross functional team of subject matter experts to conduct a comprehensive, objective assessment of

these safety concerns to eliminate the possibility that production problems could have been a contributing factor in the accident. I also requested an estimate of when they would be able to get back in touch with me, but did not get a response. On Feb 7, 2019 I wrote a detailed email outlining my observations of the production environment at the time the Lion Air, Norwegian and other NG, MAX & P-8 airplanes were being built last year. On Feb 14, 2019 the Assistant General Counsel responded (Encl. 3) to my email stating:

> "…we shared your concerns with the senior leaders who have direct oversight and responsibility for 737 production and quality. We walked through the issues you raised, in detail, and I can assure you your concerns were taken very seriously. I don't think it will surprise you to learn that ensuring the safety and quality of the 737, including during the recent production challenges, has been the subject of intense focus by BCA."

The Assistant General Counsel goes on to say:

> "…Boeing closely monitors production quality data, as well as other data related to the overall health of the production system, including, and especially, during periods of disruption like the one experienced last year on the 737 program. Moreover, all of our aircraft are subject to rigorous inspection before they are certified, delivered, and enter into service. Boeing also has access to data concerning the in-service performance and reliability of the 737 fleet. We have seen nothing from any of these sources that would suggest the existence of embedded quality or safety issues, whether or not as a result of the production disruption experienced last year."

Regrettably, despite program oversight, monitoring of production quality data, post production procedures, and the monitoring of in-service performance, something obviously went seriously wrong with both the Lion Air and Norwegian airplanes. The seriousness of these issues combined with a possible connection to the tragic loss of 189 lives warrants more than just a walk through with executives. The senior leaders who were responsible for 737 oversight were the same individuals that oversaw the production system deteriorate to the point described in my Feb 7, 2019 email and presumably are the same individuals that are still dealing with production system health issues, recovery operations and supply chain challenges mentioned in investor reports. It is worth noting the current 737 General Manager was not in the 737 Program at the time these airplanes were being built, so he cannot speak with firsthand knowledge.

Was this a comprehensive, objective assessment by the General Counsels on behalf of the CEO? What about talking with frontline employees like IAM members, shop stewards, Team Leaders, 1st & 2nd line managers per the recommendation? Certainly, their perspectives would provide a more well-rounded picture. I counted approximately 35 assertions in my Feb 7, 2019 email. How many of them were checked out and corroborated to have occurred during the building of the Lion Air and Norwegian Air airplanes? Are they still occurring? Did this walk-through effort by the attorneys (which

lasted no more than 5 business days) include an analysis of production health and quality related data? Or, was the walk through conducted over the course of a single meeting or a couple meetings? Did anyone talk to our commercial and defense customers to see if they are having any maintenance or spare parts acquisition issues with these airplanes that might be indicative of production problems? At what point does chronic, abnormal production operations become normal operations?

Candidly, there remains many serious unanswered questions. For these reasons, I ask the Board of Directors' assistance in your corporate governance and oversight role to ensure:

a). the details of these safety concerns as outlined in my Feb 7, 2019 email are discussed with the Board of Directors and does not stop at the CEO or General Counsel levels;

b). an independent assessment of the 737 Program is conducted per the recommendation outlined in my Jan 22, 2019 email, to include taking appropriate follow-up actions as required—such as asking customers to conduct inspections of in-service airplanes and developing agreed upon criteria for stopping the production system in the future to mitigate risk;

c). the results of items a & b are shared with the appropriate Lion Air accident investigation authorities at Boeing, FAA, NTSB & NTSC;

d). Boeing confirms with me these actions have been taken NLT Apr 15, 2019. I fully realize Boeing is not obligated to take these actions or get back in touch with me. However, absent such a confirmation, I will be left to assume these actions were not taken and will be forced to pursue another course of action.

I believe these are reasonable expectations with a reasonable deadline. I have no interest in scaring the public or wasting anyone's time. I also don't want to wake up one morning and hear about another tragedy and have personal regrets. Of course, this is something no one wants to happen. For what it is worth, if requested I would make myself available to the Board to answer any questions or provide additional information.

I'm trying to give Boeing every opportunity to do the right thing because only Boeing can fix these internal problems. We owe it to the families devastated by the Lion Air accident, our employees, stockholders and the people that continue to trust their lives with Boeing airplanes around the world.

Sincerely,

Ed Pierson

Ed Pierson
[redacted]

Enclosures:
#1 Emails to Boeing 737 Vice President & General Manager
#2 Letter to Boeing Chairman, President & CEO
#3 Emails to Boeing General Counsel & Assistant General Counsel

cc: Robert A. Bradway
David L. Calhoun
Arthur D. Collins Jr.
Kenneth M. Duberstein
Admiral Edmund P. Giambastiani Jr.
Lynn J. Good
Lawrence W. Kellner
Caroline B. Kennedy
Edward M. Liddy
Susan C. Schwab
Ronald A. Williams
Mike S. Zafirovski

EXHIBIT 7—SECOND LETTER TO BOEING BOARD OF DIRECTORS, MARCH 2019

Mar 12, 2019

Boeing Board of Directors
Office of the Corporate Secretary
Boeing Corporate Offices
100 N. Riverside Plaza MC5003-1001
Chicago, IL 60606-1596

Board of Directors:

On February 19, 2019 I wrote the Board requesting urgent actions be taken to address safety concerns potentially relating to the Lion Air accident and to rule out risks to other 737 airplanes manufactured during the same timeframe. This communication followed what I believe to be an insufficient response to the Dec 19, 2018 letter I sent the CEO and follow-up conversations with the General Counsels. Due to ongoing public health & safety concerns, I gave Boeing a deadline to confirm these actions had been taken. In my opinion these safety concerns came about as a result of senior leadership actions/inactions, schedule pressure, overworked employees, understaffing, process deviations, supplier and quality issues. These issues are outlined in the enclosures in my Feb 19th letter.

Sadly, the urgency is now even greater as a result of this week's horrible Ethiopian Airlines crash. Although the MAX airplane is rightfully the subject of intense focus right now due to these accidents, it is critically important to note other 737 airplanes were built at the same Renton, WA site during the same timeframe. This includes 737 Next Gen (NG) and P-8 airplanes. Most people are unaware these different versions of the 737 are built at the same site.

I'm very proud to have worked at Boeing and truly believe these issues are all fixable. However, I'm not proud of the way Boeing has handled this matter. I have offered to help the company identify and address these issues both as an employee and as a retiree. This offer still stands. As a courtesy and in an effort to be as transparent as possible, I want the company to know that I intend to engage the NTSB and FAA directly. At this point I now believe this is a faster course of action to improve aviation safety.

In the meantime, I strongly recommend expanding whatever internal investigation is going on to include the production of all 737 airplanes manufactured at the Renton, WA site during the timeframe these airplanes were built, including the 737 Next Gen (NG) and P-8 airplanes.

Sincerely,

Ed Pierson

Ed Pierson
[redacted]

cc: Robert A. Bradway
David L. Calhoun
Arthur D. Collins Jr.
Kenneth M. Duberstein
Admiral Edmund P. Giambastiani Jr.
Lynn J. Good
Lawrence W. Kellner
Caroline B. Kennedy
Edward M. Liddy
Susan C. Schwab
Ronald A. Williams
Mike S. Zafirovski
J. Michael Luttig
Dennis A. Muilenburg

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EXHIBIT 8—KEY POINTS PROVIDED TO THE NATIONAL TRANSPORTATION SAFETY BOARD, JUNE 2019

Jun 26, 2019

Mr. Lovell,

Below are 12 key points I want to leave you with from today's interview (6/26/19). These points augment our discussion today and the information previously provided in the documents sent to you on my behalf by my attorneys. Thank you, Ed Pierson

Key Points

1. The 737 manufacturing facility (737 Plant) in Renton, Washington was in horrible shape when the Lion Air 737-8 MAX airplane was manufactured there last summer (2018).
2. In June and July 2018 (prior to the Lion Air accident), I expressed serious concerns about the quality and safety of the airplanes being built in the factory to the 737 General Manager and recommended the shutting down of the manufacturing line. He refused to do this.
3. I made additional recommendations including reducing the amount of overtime (OT) on IAM employees and analyzing engineering and quality data to determine if there were any potential quality risks that might require us to alert our customers. I don't know if the 737 GM carried out these recommendations.
4. The Ethiopian airplane was built just a few months after the Indonesian airplane at the same Renton, Washington factory. (Prior to the Ethiopian Accident I had written Boeing's CEO & Board of Directors).
5. There is plenty of evidence in the form of media reports, factory metrics, industrial engineering reports, supply chain reports, process monitoring reports, and manufacturing quality data that show just how chaotic the manufacturing environment was in 2018 (still is?). This information and data should be made immediately available to both the Indonesian and Ethiopian accident investigation teams.
    a. Data sources include factory metrics like Jobs Behind Schedule, SATs, Tags, Squawks, Shift to Shift Turnover Notes, Daily Missing Parts Reports, Compliance Audits, OT, etc. Many factory processes were clearly unstable. A complete list of data sources can be provided upon request.
6. During this same period in 2018, 737 executives placed extreme and unreasonable schedule pressure on understaffed factory workers to expedite work in order to produce more airplanes (still going on?).
7. A tremendous amount of OT was performed by hundreds of employees over many months.
8. There was evidence of fatigue from the mechanics, electricians, technicians, QA inspectors, managers and other employees from all the OT and what had now become chronic schedule recovery operations.
9. There is ample data (SAT reports, Tags, shift turnover notes, etc.) confirming the large amount of "out of sequence" work and process breakdowns that resulted in rushed & sloppy workmanship. This quality management is inconsistent with Boeing's Production Certificate and FAA Order 8120.2G.
10. Manufacturing issues that were occurring while these 2 airplanes were being built could be contributing factors to the accidents. The past and current state of the factory needs to be thoroughly investigated by both investigation teams. These teams should be afforded the opportunity to talk with employees to get a well-rounded picture of the operating environment at the time these airplanes were built.
    a. Examples: late work; electrical wiring EWIS issues; key electrical parts that regularly missed planned installation dates like engines, power panels & wire bundles; functional test issues with electrical, HIRF & CSMS testing; inadequate staffing; not enough qualified employees like electricians, technicians and engine mechanics, & test equipment availability problems.
    b. IAM mechanics, electricians, quality inspectors and first line managers that built these airplanes who were placed under this misguided schedule pressure by executives should be interviewed.
11. Important flight control questions (that may be related to manufacturing issues) have yet to be answered, at least in public. For example, why did the AOA Sensors fail in the first place? Were the sensors improperly designed? Manufactured incorrectly? Installed incorrectly? Tested incorrectly? A potential bird strike on the Ethiopian airline does not explain the other flights. Since the AOA Sensors did fail as evidenced by the faulty data output, how come Boeing and the FAA have not directed airlines to inspect and if necessary, replace/fix the sensors on 737 airplanes currently in-service around the world?
12. Chronic manufacturing problems that occurred in 2018 at the 737 plant (ref: the documents you acknowledged receipt on 6/4/19) could potentially lead to future 737 MAX, NG or P-8 accidents. If any of these problems are still occurring within the factory, they must be fixed immediately.

EXHIBIT 9—LETTER TO THE NATIONAL TRANSPORTATION SAFETY BOARD, JUNE 2019

CONSTANTINE CANNON LLP

Eric Havian
Partner
[redacted]

SAN FRANCISCO | NEW YORK | WASHINGTON | LONDON

June 28, 2019

BY FEDEX

Honorable Robert L. Sumwalt
Chairman, National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594

Re: Whistleblower Information Regarding Boeing 737 Production Concerns and 737 MAX Crashes

Dear Chairman Sumwalt:

We represent Ed Pierson, a recently retired Boeing Senior Manager who possesses significant information regarding the alarming state of Boeing's 737 Renton, Washington factory in 2018. Mr. Pierson worked within the Production System Support organization and was responsible for overseeing production support for 737 Final Assembly and P-8 manufacturing operations. In 2018 Boeing manufactured hundreds of aircraft at the Renton factory, including both 737 MAX planes that crashed within the last year. Mr. Pierson is gravely concerned the chaotic and rapidly deteriorating factory conditions may have contributed to these tragic crashes and the flying public will remain at risk unless this unstable production environment is rigorously investigated and ruled out as a contributing factor.

Mr. Pierson's concerns are underscored by the fact, according to publicly available information, that no firm determination has yet been made about the root cause(s) of the faulty Angle of Attack (AOA) sensors that contributed to both accidents. These devices have a long history of reliability, and it is alarming these sensors failed on multiple flights with two failures resulting in fatal crashes—just a few months after both airplanes were manufactured. Accordingly, the accident investigation teams should aggressively investigate the 737 factory to determine if manufacturing errors could be probable causes contributing to the faulty AOA performance on both aircraft.

The enclosed binder provides documentary evidence that details and substantiates Mr. Pierson's concerns about 737 MAX production. These documents include Mr. Pierson's recommendation in June 2018—four months before the first crash—to "[s]hut down the production line to allow our team time to regroup so we can safely finish the planes." Alarmed by numerous metrics showing a dramatic decline in the factory's performance and an unprecedented number of production errors, Mr. Pierson also recommended a thorough engineering and quality analysis to determine if potential risks might need to be communicated to Boeing customers. Mr. Pierson

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150 California Street, Suite 1600, San Francisco, CA 94111 Telephone: 415-639-4001 Facsimile: 415-639-4002 http://www.constantinecannon.com
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reported his concerns directly to the senior leadership of Boeing's 737 Airplane Program, but Boeing rejected his recommendations.

After Mr. Pierson left Boeing in August, the Lion Air crash confirmed his worst fears. Despite his retirement, Mr. Pierson wrote to Boeing's CEO and later to Boeing's Board of Directors reiterating and amplifying his manufacturing concerns, requesting their assistance in contacting the Boeing employees supporting the Lion Air accident investigation, and proposing urgent action to determine if manufacturing problems contributed to the accident. Boeing's General Counsel spoke with Mr. Pierson on several occasions, eventually asking for Mr. Pierson's recommendations. Mr. Pierson insisted again that the production line be stopped and the operating environment within the factory be investigated. Once again, Boeing took no action and declined to shut down production. The tragic Ethiopian Airlines accident followed.

Mr. Pierson next brought his concerns to numerous Federal agencies including the NTSB. Initially, the NTSB ignored Mr. Pierson's communications. After months of effort, Mr. Pierson finally spoke with an NTSB investigator assigned to the Ethiopian Airlines crash on June 26, 2019. However, Mr. Pierson's information is not limited to the Ethiopian Airlines crash. To the contrary, it concerns hundreds of aircraft manufactured over many months, including not only the Lion Air plane but also numerous other planes that have experienced significant safety incidents.

Mr. Pierson's experience with the NTSB suggests its investigators may be ill-positioned to communicate his information about Boeing's manufacturing conditions to persons with the appropriate level of authority to thoroughly investigate the extent to which those conditions may have contributed to the two accidents and may also risk future 737 accidents. Having repeatedly raised the alarm at Boeing and been ignored each time, Mr. Pierson is justifiably worried the NTSB's reluctance to interview him may signal the agency shares Boeing's aversion to exploring systemic causes for the crashes.

As the Chairman of the NTSB's Board, you are best-positioned to ensure the Indonesian and Ethiopian Investigators-in-Charge and their respective investigative teams have an appropriate opportunity to thoroughly investigate the manufacturing conditions and records at the Renton, Washington factory. As a data-driven and fact-based organization, the NTSB, in concert with the international investigative teams, should be very interested in analyzing the engineering and quality data and manufacturing history of these airplanes. To facilitate such an investigation, Mr. Pierson has provided a list of manufacturing data sources and records, as well as a list of serious incidents involving other 737 MAX planes. Upon request, Mr. Pierson can also identify numerous witnesses that would corroborate his information regarding the factory environment. All of this information should also be shared with the investigative teams.

Finally, we wish to emphasize that Mr. Pierson is not an alarmist. He has held numerous leadership positions in both the public and private sectors. He honorably served in the military for 30 years

to include serving as a Squadron Commanding Officer. But even to Mr. Pierson, the state of the Renton factory was undeniably alarming. He believes that any investigation into the 737 MAX crashes and the long-term safety of aircraft manufactured at the Renton site must include a rigorous examination of the dangerously unstable production environment he witnessed first-hand as a senior manager.

We appreciate your attention to these exceedingly serious issues and trust you will give Mr. Pierson's concerns the due consideration they deserve. We request you share all the information he has voluntarily provided to the NTSB with the Indonesian and Ethiopian Investigators-In-Charge, as well as with appropriate U.S. agencies. Please confirm whether you have reviewed Mr. Pierson's information and shared it with the appropriate stakeholders by July 12.

We look forward to hearing from you soon. Mr. Pierson is eager to assist your investigation in any way possible.

Sincerely,

Eric Havian

cc: Bruce Landsberg, Jennifer Homendy, and Earl F. Weener

EXHIBIT 10—LETTER FROM THE NATIONAL TRANSPORTATION SAFETY BOARD, AUGUST 2019

National Transportation Safety Board

Washington, DC 20594

Office of the Managing Director

August 6, 2019

Mr. Eric Havian
Constantine Cannon LLP
150 California St., Ste. 1600
San Francisco, CA 94111

Dear Mr. Havian:

This is in response to your June 28, 2019, letter regarding the "whistleblower" information provided by your client, related to the production of the Boeing 737 aircraft; specifically, the potential impact of poor factory conditions on the production of the 737 MAX.

To provide you some background, the NTSB is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant accidents in the other modes of transportation—railroad, highway, marine, and pipeline. We determine the probable cause of the accidents and issue safety recommendations aimed at preventing future accidents. In addition, we carry out special studies concerning transportation safety and coordinate the resources of the federal government and other organizations to provide assistance to victims and their family members affected by major transportation disasters. The NTSB derives this authority from Title 49 *United States Code* Chapter 11.

Your client's concerns fall outside the scope of the NTSB's role in the 737 MAX accident investigations. We are serving solely as an accredited representative to the Indonesian and Ethiopian investigations under Annex 13 of the International Civil Aviation Convention and are not independently investigating either accident.

One of the NTSB's accredited representatives received your information by phone a few weeks ago, which is consistent with the written materials you sent with your letter. He has reviewed the information in the context of the ongoing investigations and will contact you if he has any questions.

We suggest that you contact the Office of the Inspector General at the US Department of Transportation, if you have not already done so.

Sincerely,

Sharon W. Bryson

Sharon W. Bryson
Managing Director

43528

EXHIBIT 11—LETTER TO THE SECRETARY OF TRANSPORTATION, SEPTEMBER 2019

CONSTANTINE CANNON LLP

Eric Havian
Partner
[redacted]

SAN FRANCISCO | NEW YORK | WASHINGTON | LONDON

September 17, 2019

BY FEDEX

Honorable Elaine L. Chao
Secretary of Transportation
U.S. Department of Transportation
1200 New Jersey Ave, SE
Washington, DC 20590

Re: Whistleblower Information Regarding Boeing 737 Production Concerns and 737 MAX Crashes

Dear Secretary Chao:

We represent Ed Pierson, a recently retired Boeing Senior Manager who possesses significant information regarding the alarming state of Boeing's 737 Renton, Washington factory in 2018. Enclosed please find a letter to FAA Administrator Steve Dickson regarding Mr. Pierson's concerns over the chaotic and rapidly deteriorating conditions at the Renton factory, as well as a binder providing evidence that details and substantiates Mr. Pierson's concerns

We appreciate your attention to these exceedingly serious issues and hope that you will give Mr. Pierson's concerns the consideration they deserve.

Sincerely,

Eric Havian

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150 California Street, Suite 1600, San Francisco, CA 94111 Telephone: 415-639-4001 Facsimile: 415-639-4002 http://www.constantinecannon.com
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EXHIBIT 12—LETTER TO THE ADMINISTRATOR OF THE FEDERAL AVIATION ADMINISTRATION, SEPTEMBER 2019

CONSTANTINE CANNON LLP

Eric Havian
Partner
[redacted]

SAN FRANCISCO | NEW YORK | WASHINGTON | LONDON

September 17, 2019

BY FEDEX

Honorable Steve Dickson
Administrator, Federal Aviation Administration
800 Independence Ave., SW
Washington, DC 20591

Re: Whistleblower Information Regarding Boeing 737 Production Concerns and 737 MAX Crashes

Dear Mr. Dickson:

We represent Ed Pierson, a recently retired Boeing Senior Manager who possesses significant information regarding the alarming state of Boeing's 737 Renton, Washington factory in 2018. Mr. Pierson worked within the Production System Support organization and was responsible for overseeing production support for 737 Final Assembly and P-8 manufacturing operations. In 2018 Boeing manufactured hundreds of aircraft at the Renton factory, including both 737 MAX planes that crashed within the last year. Mr. Pierson is gravely concerned that chaotic and rapidly deteriorating factory conditions may have contributed to these tragic crashes and the flying public will remain at risk unless this unstable production environment is rigorously investigated and remedied. As you know, FAA production certification is an integral part of the airplane certification program.

Mr. Pierson's concerns are underscored by the fact, according to publicly available information, that no firm determination has yet been made about the root cause(s) of the faulty Angle of Attack (AOA) Sensors that contributed to both accidents. These devices have a long history of reliability, and it is alarming these sensors failed on multiple flights with two failures resulting in fatal crashes—just a few months after both airplanes were manufactured. The AOA Sensors failed for a reason. Did they fail because they were designed, manufactured, installed, or tested incorrectly? Each of these areas fall under Boeing's manufacturing responsibilities. Simply stating the AOA Sensors sent faulty information to MCAS is a woefully inadequate and evasive conclusion. We suspect this may partially explain why EASA and other international regulators are still understandably concerned about AOA Sensor integrity.

Mr. Pierson's concerns, however, are not limited to the AOA sensors or these tragic crashes. To the contrary, they extend to hundreds of aircraft manufactured over many months, including numerous other planes that have experienced significant safety incidents. For example, there

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have been at least thirteen other incidents involving new MAX airplanes all produced from the same factory during a fourteen-month timeframe. In fact, one of these airplanes was only one month old. The flying public is completely unaware of these other incidents.

The enclosed binder provides documentary evidence that details and substantiates Mr. Pierson's concerns about the 737 MAX production environment and depicts a disturbing sequence of events currently unknown to the public. These documents include Mr. Pierson's recommendation in June 2018—four months before the first crash—to "[s]hut down the production line to allow our team time to regroup so we can safely finish the planes." Alarmed by numerous metrics showing a dramatic decline in the factory's performance and an unprecedented number of production issues, Mr. Pierson also recommended a thorough engineering and quality analysis to determine if potential risks might need to be communicated to Boeing customers. Mr. Pierson reported his concerns directly to the senior leadership of Boeing's 737 Airplane Program, but Boeing rejected his recommendations.

After Mr. Pierson left Boeing in August, the Lion Air crash confirmed his worst fears. Despite his retirement, Mr. Pierson wrote to Boeing's CEO and later to Boeing's Board of Directors reiterating and amplifying his manufacturing concerns, requesting their assistance in contacting the Boeing employees supporting the Lion Air accident investigation, and proposing urgent action be taken to determine if manufacturing problems contributed to the accident. Boeing's General Counsel spoke with Mr. Pierson on several occasions, eventually asking for Mr. Pierson's recommendations. Mr. Pierson insisted again the production line be stopped and the operating environment within the factory be investigated. Once again, Boeing took no action and declined to shut down production. The tragic Ethiopian Airlines accident followed.

Mr. Pierson next worked tirelessly to bring his concerns to the attention of the accident investigation teams and numerous Federal agencies, including the National Transportation Safety Board (NTSB), the Department of Transportation's Office of Inspector General, and the Department of Justice. After months of effort and unexplainable delays, Mr. Pierson was finally interviewed by an NTSB investigator assigned to the Ethiopian Airlines crash on June 26, 2019. Following that conversation, I wrote directly to NTSB Chairman Robert Sumwalt on June 28, 2019 on behalf of Mr. Pierson and requested the NTSB share all the information he voluntarily provided to the NTSB with the Indonesian and Ethiopian Investigators-In-Charge, as well as with appropriate U.S. agencies.

On August 19, 2019 I received a written response from the NTSB's Managing Director to my June 28 letter stating that "Your client's concerns fall outside the scope of the NTSB's role in the 737 MAX accident investigations." The NTSB's determination that Mr. Pierson's production concerns are "outside the scope" of the international accident investigations is truly bewildering. Accident investigators routinely review maintenance and training records going

back years. And yet, two new airplanes crash just months after they were built, and the NTSB unilaterally deems the chaotic and unstable production environment in which they were made to be outside the scope of the accident investigations? We doubt the Indonesian and Ethiopian investigators and international regulators would agree with this determination.

We believe as the new leader of the FAA you may be completely unaware of the facts enclosed in the attached documents. Because the NTSB has not confirmed this information has been shared, we are now sharing these documents with you directly. We ask that you review them carefully, paying particular attention to the timeline and chronology of events. We request you share all this information with the FAA representatives on the two accident investigation teams and the Indonesian and Ethiopian Investigators-in-Charge.

As a data-driven and fact-based organization, the FAA, in concert with the other investigative teams, should be very interested in analyzing the engineering and quality data and manufacturing history of these airplanes. To facilitate such an investigation, Mr. Pierson has provided a list of manufacturing data sources and records, as well as the list of serious incidents involving other 737 MAX planes. Upon request, Mr. Pierson can also identify numerous witnesses that would be able to corroborate his information regarding the factory environment.

Finally, we wish to emphasize that Mr. Pierson is not an alarmist. He has held numerous leadership positions in both the public and private sectors. He honorably served in the military for 30 years to include serving as a Squadron Commanding Officer. But even to Mr. Pierson, the state of the Renton factory was undeniably alarming. He believes that any investigation into the 737 MAX crashes and the long-term safety of aircraft manufactured at the Renton site must include a rigorous examination of the dangerously unstable production environment he witnessed first-hand as a senior manager.

We appreciate your attention to these exceedingly serious issues. Mr. Pierson was heartened by your commitment during your swearing-in remarks to follow the facts, and we trust you will give Mr. Pierson's concerns the due consideration they deserve. Please confirm whether you have reviewed Mr. Pierson's information and shared it with the appropriate stakeholders by September 30th. Mr. Pierson is eager to assist the investigation in any way possible.

Sincerely,

Eric Havian

cc: Elaine L. Chao, U.S. Secretary of Transportation
Arjun Garg, FAA General Counsel
H. Clayton Foushee, Director, FAA Office of Audit and Evaluation

EXHIBIT 13—SECOND LETTER TO THE ADMINISTRATOR OF THE FEDERAL AVIATION ADMINISTRATION, OCTOBER 2019

CONSTANTINE CANNON LLP

Eric Havian
Partner
[redacted]

SAN FRANCISCO | NEW YORK | WASHINGTON | LONDON

October 14, 2019

BY FEDEX

Honorable Steve Dickson
Administrator, Federal Aviation Administration
800 Independence Ave., SW
Washington, DC 20591

Re: Whistleblower Information Regarding Boeing 737 Production Concerns and 737 MAX Crashes

Dear Mr. Dickson:

On September 17, 2019, we sent you a letter requesting your assistance in connection with the alarming state of Boeing's 737 Renton, Washington factory in 2018, and the possible connection between the chaotic factory conditions and the tragic 737 MAX crashes that killed hundreds of people. In response to the letter, we have received the following communications from the FAA:

1. A voicemail message from Clay Foushee, FAA Director of Audit & Evaluation (since the voicemail, Mr. Foushee has not returned our calls)
2. An automated email from the FAA Hotline on October 1, 2019 with subject line "S20190930021 Safety Hotline - Acknowledgement Ltr"
3. An email from Michael Millage on October 8, 2019 with subject line "FAA Review of Eric Havian Aviation Safety Hotline Report"

Although we appreciate these communications, we believe they are missing the mark. We did not submit a message on the FAA Safety hotline but rather sent you extensive documentary evidence detailing our client's warnings to Boeing leadership about the chaotic and unstable state of the 737 Factory in Renton, Washington and the potential for tragic consequences. Notably, Mr. Pierson warned Boeing leadership *before* the Lion Air accident that it should shut down the production line and then again prior to the Ethiopian Airlines accident. Nevertheless, Boeing leadership—including its General Counsel, CEO, 737 General Manager, and Board of Directors—never acted on Mr. Pierson's warnings and recommendations.

Mr. Pierson is not seeking a limited investigation into one-off process deviations or product defects. Rather, Mr. Pierson's concerns relate to a culture of profit-over-safety that pushed factory workers to the breaking point, led to unprecedented numbers of observed process breakdowns, and produced an inherently unsafe work environment that might have contributed

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to the loss of hundreds of lives. That is why we asked you to share the information we provided with the FAA representatives on the 737 MAX accident investigation teams and the Ethiopian and Indonesian Investigators-in-Charge. The accident investigators are supposed to have access to all relevant information and are responsible for conducting the investigation in accordance with ICAO Annex 13. Please confirm that you have shared this information with these individuals.

Of course, Mr. Pierson is also willing to assist any FAA investigation into the Renton factory. We will respond separately to Mr. Millage's questions, although we do not believe the nature of Mr. Pierson's information can effectively or efficiently be conveyed in writing. Mr. Pierson would welcome the opportunity to speak with Mr. Millage in person or by phone to elaborate on his concerns and address any additional questions. We stress, however, that Mr. Pierson's concerns extend beyond isolated incidents of nonconformance. For months, backlogs, delays, and schedule pressure overwhelmed the workforce at Renton, and virtually every measure of factory health deteriorated to unprecedented lows. These factory conditions posed an unreasonable risk to production quality, and as a result, public safety.

Mr. Pierson is gravely concerned that, despite the loss of hundreds of lives, these issues remain unaddressed and could be exacerbated once the 737 MAX is ungrounded and Boeing rushes to ramp up production and push out completed planes. In addition to sharing Mr. Pierson's information with the relevant investigators, we hope that the FAA will undertake a rigorous examination of the Renton factory to ensure that it does not return to the inherently unsafe conditions Mr. Pierson witnessed first-hand.

We appreciate your attention to this matter. Please contact us with any questions.

Sincerely,

Eric Havian

cc: Elaine L. Chao, U.S. Secretary of Transportation
H. Clayton Foushee, Director, FAA Office of Audit and Evaluation
Michael Millage, Management Specialist, FAA Aviation Safety Technical Program

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EXHIBIT 14—THIRD LETTER TO THE ADMINISTRATOR OF THE FEDERAL AVIATION ADMINISTRATION, NOVEMBER 2019

CONSTANTINE CANNON LLP

Eric Havian
Partner
[redacted]

SAN FRANCISCO | NEW YORK | WASHINGTON | LONDON

November 5, 2019

BY FEDEX

Honorable Steve Dickson
Administrator, Federal Aviation Administration
800 Independence Ave., SW
Washington, DC 20591

Re: Unsafe Condition on 737 Airplanes Requires Emergency Airworthiness Directive

Dear Mr. Dickson:

We write to call your attention to an urgent matter of public safety in connection with the ongoing investigation of the 737 MAX.[1] Last week on October 28, 2019, the Indonesian government released the Final Aircraft Accident Investigation Report for Lion Air Flight 610 ("Final Accident Report"). Information in the report suggests that there may be hundreds of potentially defective Angle of Attack ("AOA") sensors installed not only on the grounded 737 MAX, but also on **currently flying 737 NG airplanes and P-8 military airplanes**. An Emergency Airworthiness Directive should be issued immediately to airlines and Boeing requiring them to inspect, test and, if necessary, replace similar model AOA Sensors.

The Final Accident Report states that the AOA Sensor (part number 0861FL1, serial number 21401) made by Rosemount Aerospace (currently Collins Aerospace) that was removed the day before the crash on October 28, 2018 was found to be faulty during testing on December 10, 2018 at a Collins Aerospace facility. It is possible that a similarly faulty AOA sensor was installed on the Ethiopian Airlines Flight 302 airplane that crashed on March 10, 2019.

[1] On September 17 and October 14, 2019, we sent you letters requesting your assistance in connection with the alarming state of Boeing's 737 Renton, Washington factory in 2018, and the possible connection between the chaotic factory conditions and the tragic 737 MAX crashes that killed hundreds of people. On October 22, 2019, FAA employee Michael Millage contacted us to coordinate a time to speak with our client, Ed Pierson. We are awaiting Mr. Millage's availability; Mr. Pierson remains ready and willing to meet with the FAA.

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This part was inspected, installed, and tested by the Boeing Company at its 737 manufacturing plant in Renton, Washington during the summer of 2018.

The Final Accident Report states in pertinent part:

> Examination of the AOA sensor revealed an intermittent open circuit in the resolver #2 coil wiring. At temperatures above approximately 60°C, the resolver functioned normally, but did not function below that temperature. (Final Accident Report, p. 37)
>
> The examination concluded that the field failure of the 08-NCW-24YQ resolver was due to a loose loop in the rotor coil magnet wire that had been exposed and encapsulated in the epoxy used to hold the end cap insulator on the rotor. The epoxy caused the magnet wire to adhere to both the end cap insulator and the rotor shaft insulator. Because the CTE of the two insulators differ over 3 times from each other, thermal cycling from normal operation in the field caused the magnet wire to fail in fatigue as expansion and contraction rates and possibly directions differed from each side of the magnet wire. The failure manifested as a temperature dependent intermittent open. Physical examination of the resolver, including continuity tests, CT scans, and SEM imaging, concluded that this was the only magnet wire break in the unit and visual evidence of cracking, arcing, and metal "working" support the CTE theory of fatigue of the magnet wire. (Final Accident Report, p. 287)

This malfunctioning part represents an unsafe condition for other 737 airplanes manufactured during the same timeframe as the Lion Air Flight 610 airplane. This production defect needs to be corrected immediately.

A malfunctioning AOA sensor could result in pilot overload, potentially causing the loss of an airplane. Boeing's Flight Crew Operations Manual Bulletin No. TBC-19, dated November 6, 2018, describes those effects as follows:

> 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.

To protect the public, the FAA should immediately issue an Emergency Airworthiness Directive requiring airlines and Boeing to inspect, test, and potentially replace model AOA Sensors similar to the one originally installed on the Lion Air Flight 610 airplane. At a minimum, the airplanes that should be inspected include all 737 MAX, 737 NG and P-8 airplanes that were manufactured in the timeframe between the production of the Lion Air Flight 610 airplane during the summer of 2018 and the crash of Ethiopian Airlines Flight 302 on March 10, 2019.

To be clear, immediately issuing an Emergency Airworthiness Directive is only the first step the FAA must take—and it will not solve the underlying problem. A brand-new AOA sensor, inspected and installed by Boeing, should not fail. That it did only underscores the need for a comprehensive investigation into the chaotic and alarming state of Boeing's 737 Renton, Washington factory in 2018. Our client Mr. Pierson is ready and willing to assist the FAA in any way possible.

Sincerely,

Eric Havian

cc: Elaine L. Chao, U.S. Secretary of Transportation
Arjun Garg, FAA General Counsel
H. Clayton Foushee, Director, FAA Office of Audit and Evaluation

Exhibit 15—Recent 737 Max Safety Incidents

Date	Type	Airline	Registration	Line #	B1-Flight	Reason
5/12/18	737-9	Thai Lion Air	HS-LSI	6816	4/14/18	two loud bangs prompted crew to shut down the right engine.
10/29/18	737-8	Lion Air	PK-LQP	7058	7/30/18	crash under investigation.
12/1/18	737-8	WestJet	C-GZSG	7005	7/7/18	STAB OUT OF TRIM light occurred just after flaps up on departure.
11/14/18	737-8	Sunwing	C-GMXB	6956	5/13/18	Multiple systems failures. Replaced left ADIRU.
12/14/18	737-8	Norwegian Air Shuttle	LN-BKE	7110	10/14/18	Low oil pressure indication on the left engine.
12/14/18	737-8	Aerolineas Argentinas	LV-HKU	6753	1/7/18	zone of adverse weather caused the failure of the left hand engine.
12/24/18	737-8	Air Canada	C-FSCY	6695	11/27/17	returned to origin after noticing decreasing hydraulic quantity.
12/29/18	737-8	Air Canada	C-FSIP	6841	3/13/18	lost wing anti-ice system due to an intermittent fault.
1/6/19	737-8	SpiceJet	VT-MAX	7103	9/12/18	left engine shutdown due to a restriction in fuel flow.
1/13/19	737-8	Air Canada	C-FSCY	6695	11/27/17	rejected takeoff due to a Master Caution light for forward door.
1/28/19	737-8	Air Canada	C-FSEQ	6814	2/12/18	right engine shutdown due to a low oil quantity and a low oil pressure.
1/29/19	737-8	TUI Airways	G-TUMA	7211	11/4/18	due to an abnormal engine (LEAP) indication.
2/12/19	737-8	American	N308RD	6652	12/13/17	crew declared an emergency due to hydraulic failure indication light.
3/10/19	737-8	Ethiopian Airlines	ET-AVJ	7243	10/30/18	crash under investigation.
3/26/19	737-8	Southwest	N8712L	6290	9/18/17	lost right engine on initial climbout.

Summary: 15 emergencies involving airplanes built during a 13 month timeframe; 2 crashes & 13 incidents

Mr. DEFAZIO. Thank you.

Mr. Collins, you are recognized.

Mr. COLLINS. I want to thank Chairman DeFazio, Ranking Member Graves and the members of the committee for this opportunity to testify. I also want to offer my condolences to the family members and friends of those who died in the two tragic 737 MAX accidents.

I am a retired aerospace engineer from the FAA with over 29 years of experience. Before that, I worked at Boeing for 5 years. I was the lead FAA engineer on the NTSB's TWA 800 accident investigation. That accident was caused by an explosion of a fuel tank on a 747 airplane. Therefore, I have seen firsthand the devastation caused by a catastrophic airplane accident.

I became the FAA fuel tank safety program manager as FAA began addressing the lessons learned from the TWA 800 accident. During this time, we issued two major fuel tank safety rules, one focused on preventing fuel tank ignition sources and a second focused on reducing fuel tank flammability.

I have heard FAA executives state that safety is our highest priority. I agree that safety was their highest priority when I started working at the FAA in 1989. However, over the last 15 years or so, FAA management culture has shifted to where the wants of applicants now often take precedent over the safety of the traveling public. A clear example of this is the issue of the rudder control on the 737 MAX.

Over the objections of FAA technical specialists, the airplane was approved with a rudder control design that is unchanged from the original 1960s design. It has a single-string control system consisting of cables running from the cockpit to the rudder. This means that, in the event of an uncontained engine failure during takeoff, a catastrophic loss of control of the airplane could occur if an engine fragment cuts one of the cables.

In 1989, a DC–10 crashed during an attempted landing at Sioux City after an engine had an uncontained failure. Engine debris damaged the airplane's three independent hydraulic systems that powered the flight controls. This disabled all the flight controls. The flight crew attempted to land but crashed while landing. The result was 111 fatalities and 47 serious injuries.

Because of the DC–10 accident and based on industry committee recommendations, in 1997 the FAA updated the compliance policy in a revised AC 20–128A. The AC specifically requires protecting the rudder controls from one-third disk fragment projectile in the event of an uncontained engine failure.

During the 737 MAX project, FAA management initially agreed with technical specialists that the existing design did not comply with the FARs, considering the new engine on the airplane. As the certification date neared and Boeing had not made a design change, FAA management decided not to require that Boeing modify the 50-year-old rudder control design. An FAA employee submitted the issue to the FAA's internal safety reporting process as a safety concern report.

I was one of four members of the FAA's safety oversight board when the safety concern was submitted. The board includes two aerospace engineers and two managers. The submittal included the

issue paper used to document agreement with the applicant and the method of compliance. The issue paper was signed by four managers, and all seven aerospace engineers and the project pilot disagreed with the method of compliance. The board identified a subject matter expert panel to review the SRP report and make recommendations to the board. The panel included four aerospace engineers and two managers, all from various FAA offices.

The consensus-based recommendation of the panel included a statement that the method of compliance in the issue paper does not comply with the associated FAA regulations, the FARs. The board agreed with the panel report and forwarded it to the responsible FAA manager as the board's recommendation.

The manager did not accept the board's recommendations, therefore overruling the board and the panel. That manager was the same manager that had overruled the technical specialists on the issue paper process.

In considering the nonconcurrences on the issue paper, the SME panel report and the oversight board recommendations, a total of at least 13 FAA aerospace engineers, 1 pilot and at least 4 FAA managers disagreed with the method of compliance the other managers allowed to be used.

By comparison, although the Airbus A320Neo was approved with a similar rudder design, EASA worked with Airbus to reach agreement that Airbus will revise the design using the guidance in the 1997 AC and incorporate the new design during production on all A320 series airplanes.

Thank you for this opportunity. I hope my testimony will help improve the FAA management safety culture and the aircraft certification service.

[Mr. Collins's prepared statement follows:]

Prepared Statement of G. Michael Collins, Former Aerospace Engineer, Federal Aviation Administration, appearing in his individual capacity

I want to thank Chairman DeFazio, Chairman Larsen, Ranking Member Graves, and the other members of the committee for this opportunity today. I also want to offer my condolences to the family members and friends of those who died in the two tragic 737MAX accidents.

I am a retired FAA Aerospace Engineer with 29 and a half years' experience in the FAA as a propulsion specialist; 5 years' experience in Boeing Commercial Airplane Company; and several years' experience in other safety critical industries including nuclear and non-nuclear power plant design. Although I am not representing anyone else, I know I have the support of many of my past coworkers at the FAA.

As the committee reviews the FAA oversight of the 737MAX certification, it is an opportunity to review the overall issue of FAA oversight and the safety culture of management in the FAA's Aircraft Certification Service. When I first started working at the FAA in 1989, the management I worked for had a much different safety culture than today. In my early years at the FAA, I found management very supportive of engineers in the evaluation of proposed airplane design changes. Management supported engineers when they identified features that did not comply with the Federal Aviation Regulations (FARs). I was taught the FARs defined the minimum level of safety for airplane designs. If we discovered a design that did not comply, we identified the issue to our managers and the applicant's Designated Engineering Representative (DER). We then all worked with the applicant to help them develop design changes that resulted in a design all the FAA specialists agreed met the minimum safety standard defined in the FARs. It was a much more a collaborative environment than what exists today.

There were some controversial issues then too, but typically the final FAA position was something everyone on the FAA team, engineers and managers alike, could agree was an acceptable method of compliance to the FARs.

After the investigation of the TWA 800 accident and shortly after the 2001 Fuel Tank Safety rule was issued, I saw a significant shift in management. It was an erosion of the safety philosophy. FAA management shifted away from supporting FAA technical specialists (FAA aerospace engineers) in favor of industry positions. This shift continued until I retired in July 2018. The most recent and clear example of this erosion in safety culture was regarding the minimum level of safety debates on how to protect the rudder controls on the 737MAX from catastrophic damage from an uncontained failure of the new engines.

737MAX RUDDER CONTROL—PROTECTION FROM CATASTROPHIC FAILURE DUE TO UNCONTAINED ENGINE FAILURE

I was not working on the 737MAX at the time, so I was not involved in the original discussions of the rudder control design. I became involved as one of four members on the Safety Oversight Board when a safety concern (report) was submitted to the AIR Safety Review Process. The safety reports were submitted to the Board with the submitter's identifying information removed (de-identified).

The Board reviewed the submittal which included the Issue Paper used to document the agreement with the applicant on the means of compliance the applicant would use to the relevant FARs. In this case, the Issue paper was signed by two managers, but all 7 FAA technical specialists (aerospace engineers) and the project pilot disagreed with the method of compliance described in the issue paper and therefore did not concur. Three FAA aerospace engineers did sign the issue paper, but their function was administrative. It was to ensure the issue paper was coordinated with the appropriate technical specialists.

The SRP Oversight Board determined the issue was complex enough that we would identify a Subject Matter Expert (SME) Panel to review the SRP report and make recommendations on the safety concern to the Board. The SME Panel members were selected based on their expertise in the subject and were chosen from various FAA offices so many were not involved in the original discussions. All recommendations from the SME Panel, as well as from the Board, are required by the SRP process to be consensus-based decisions. That is, the final report and recommendations from the SME Panel, and the Board, must be something all members of the respective panel or Board "can live with." It is not based on majority rule.

The SME Panel included four FAA aerospace engineers and two FAA managers. The consensus-based recommendations of the SME Panel include a statement that the method of compliance directed by FAA Management and included in the issue paper does not comply with the associated Federal Aviation Regulations (FARs). The method of compliance did not meet the required minimum level of safety. Note that the report also included recommendations on design changes that would result in an acceptable means of compliance to the associated FARs.

The SRP Oversight Board, which was comprised of two aerospace engineers and two managers, agreed with the SME Panel report and forwarded it to the responsible FAA Aircraft Certification Service Division/Directorate manager. The FAA Division/Directorate manager responded later to the Board that the Transport Airplane Directorate (TAD) "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 SRP Oversight Board determined the Division/Directorate manager did not implement the Board's recommendations and therefore, in accordance with the SRP Process, the Board forward the Board/SME Panel's recommendations and the Division/Directorate manager's response to the Deputy Director, Aircraft Certification Service, AIR–2, for his/her information.

Therefore, when considering the non-concurrences on the issue paper, the SME Panel report and the SRP Oversight Board members recommendation; a total of at least thirteen FAA aerospace engineers, one pilot and at least four FAA managers disagreed with the method of compliance other FAA managers allowed Boeing to use.

Note the SRP report said the Airbus A320neo rudder control had a similar design to the 737MAX. The submitter said the FAA certification team for the A320neo had reached agreement with EASA and Airbus that Airbus would change the design to a compliant "fly by wire" rudder control design and implement the new design into production after certification. Although FAA did not require such a design change through a time-limited partial grant of exemption, information on the internet about

a contract for rudder control servos indicates Airbus is proceeding with the design change.

737MAX FUEL TANK SURFACE TEMPERATURE

Another issue submitted to the Safety Review Process on the 737MAX project was where an agreement was made with the applicant using an issue paper to allow fuel tank temperatures above the maximum temperature allowed by the FARs. In this case, the technical specialist (aerospace engineers) working the issue did all sign the issue paper, indicating their concurrence. The issue paper document agreement on a finding that the applicant's method of compliance was an "Equivalent Level of Safety" to the normally accepted means of compliance. However, an employee submitted a safety concern about the decision in the issue paper to the SRP. The SRP Oversight Board designated a new, unique, SME Panel to review the safety report and make recommendations to the Board. The SME Panel agreed with the SRP submitter that the issue paper agreement was not an equivalent means of compliance with the associated FAR and made several recommendations. The SRP Oversight Board accepted the SME Panel report and forwarded it the responsible Division/Directorate manager. I do not know how the Division/Directorate manager responded as there had not been a response when I left the SRP Oversight Board prior to my retirement.

737MAX FUEL PUMP CIRCUIT PROTECTION

An issue that was not raised in the SRP is related to the 737MAX fuel pump electrical circuit protection. FAA fuel pump ignition source prevention requirements essentially require ground fault interrupter (GFI) or similar fast acting circuit protection with active faulty detection and annunciation of failures on fuel pump power circuits. This requirement is to prevent electrical arcs in fuel tanks from failures of the high-power fuel pump wires. An FAA manager provided guidance to Boeing without going through the issue paper process for certification of a GFI installation that was contrary to FAA published policy in Advisory Circular 25.981–1C and in a "generic" fuel pump issue paper on the Transport Airplane Issues List. The manager told the applicant they could consider fuel in the area between the fuel pump and the housing the fuel pump is installed in as a flame or spark barrier. This guidance was given by the manager despite FAA technical specialists reminding the manager that there were known failures on a similar fuel pump installation (L–1011) that experienced a wiring failure inside the pump and burned a hole through both the fuel pump and the housing. (Fortunately, that L–1011 event did not result in a fuel tank explosion because the pump housing was under liquid fuel.) The FAA manager told the applicant that taking credit for fuel in the space between the motor and housing, which is typical for Transport Category fuel pump installations including the L–1011 installation, 'was not prohibited by the AC.'

At the same time, the FAA required Airbus to modify their fuel pump GFI installation before certification of the A320Neo. Before the FAA required modification, the proposed A320Neo GFI installation was like what the FAA manager allowed to be certificated on the 737MAX.

787 LITHIUM-ION BATTERY CONTAINMENT

Before the AIR Safety Review Process was implemented in mid-2015, there were other examples of FAA management accepting applicant's positions over the concerns of FAA technical specialists, the FAA's aerospace safety engineers. For example, during initial certification review of the new technology 787 lithium battery system design the certification of the 787, an FAA technical specialist determined the lack of a fireproof enclosure could result in catastrophic failure due to uncontrolled fire from the battery. He proposed to FAA management that the special conditions design of for the airplane system lithium-ion battery should include a requirement for a steel containment structure that would be vented overboard. FAA management overruled the specialist. The specialist worked to modify a new special condition that was applied to the battery installation so a containment system would be required. Unfortunately, FAA managers pushed to delegate 95 percent of the certification to the applicant, including the high risk, new technology, battery installation. Without FAA safety engineer oversight, the ODA found the design without an enclosure to be compliant. Sadly, after certification, the airplane system lithium-ion battery experienced two extremely dangerous fire events and the FAA mandated the 787 fleet to be grounded. The design changes the FAA mandated to allow the 787 to fly again included a steel battery containment box that was vented overboard; as originally proposed by the FAA aerospace engineer.

ISSUING EXEMPTIONS THAT ARE NOT IN THE (TRAVELING) PUBLIC INTEREST

FAA management often issues exemptions with more consideration to the financial interest of the applicant compared with the safety interest of the Traveling Public.

An example of this is a four-year time-limited exemption that allowed production of 737NG airplanes with a non-compliant Fuel Quantity Indicating System. Non-compliant means it does not meet the minimum engineering safety level. The non-compliance was with the safety regulation that was issued in 2001. This regulation was created to prevent future accidents and address engineering design problems learned from the TWA Flight 800 accident, which was caused by a fuel tank explosion. On December 18, 2013, the FAA issued a "Time-Limited Partial Grant of Exemption," Exemption No. 10905 (DMS docket FAA–2012–17). The justification stated by the applicant was the additional time needed to develop a compliant design. However, the applicant and all transport category manufacturers were aware of this design shortfall since the TWA 800 accident investigation. This allowed continued production of a non-compliant design. It required incorporation of a few design changes but did not bring the design into compliance with the minimum level of safety required by the associated FARs. It granted the manufacturer 48 months to continue production of the 737NG, at the end of which the exemption required "the FQIS on all newly-produced airplanes must be shown to comply with §§ 25.901(c), Amendment 25-46, and 25.981(a)(3), Amendment 25-102, or later amendments." Note that an applicant for *new type* design has only 60 months to complete the FAA type certification project.

Near the end of the 48-month period, the manufacturer petitioned for an extension of the exemption (docket item FAA–2012–1137–0010). I was assigned the task to evaluate the petition for extension. I was also instructed to check with the FAA Counsel who had worked on the 2015 Boeing Settlement Agreement (https://www.faa.gov/news/press_releases/news_story.cfm?newsId=19875). I asked the FAA Counsel if the extension was related to the Settlement Agreement. He responded that yes, it is related to the Settlement Agreement. He recommended we not grant the extension and instead require the applicant comply with the requirements of the original time-limited partial grant of exemption. I drafted a denial letter and provided it to the manager. The manager then held the letter for several months until Boeing withdrew the petition for extension (FAA–2012–1137–0012). However, Boeing then submitted a new petition for extension and FAA granted them a permanent exemption (FAA–2012–1137–0019). This permanent exemption required some additional modifications to improve the safety of the 737NG FQIS, but it allowed Boeing to continue to produce 737NG airplanes with FQIS systems that did not meet the fuel tank ignition prevention requirements in the FARs. This was more in the financial interest of the petitioner than the safety interest of the traveling public.

In contrast, the FAA issued an airworthiness directive in 1999 (AD 99–03–04) that required modification of the 737 Classic (737–100, -200, -300, -400, and -500 series) FQIS to meet the same fuel tank ignition prevention requirements that they granted a permanent exemption for the 737NG. The FAA also issued an airworthiness directive in 1998 (AD 98–20–40) that required modification of the 747 Classic (747–100, -200, -300, SP, and SR series) FQIS that met the same fuel tank ignition prevention requirements. These airworthiness directives were issued because the FQIS failure mode that would have been eliminated by full compliance to the FARs for which the above exemption was granted was identified by the NTSB as the most likely ignition source that caused the TWA Flight 800 accident [1].

FARS VS. INDUSTRY CONSENSUS STANDARDS

There is a move to replace the Federal Aviation Regulations for Transport Category Airplanes (14 CFR part 25) with industry developed "consensus standards." I caution against such a change. The FARs have been developed over time and new regulations typically were adopted to incorporate lessons learned from fatal accidents. Therefore, many of the FARs were issued to prevent future accidents based on those lessons learned. Replacing with industry standards may lose those lessons.

[1] "The National Transportation Safety Board determines that the probable cause of the TWA flight 800 accident was an explosion of the center wing fuel tank (CWT), resulting from ignition of the flammable fuel/air mixture in the tank. The source of ignition energy for the explosion could not be determined with certainty, but, of the sources evaluated by the investigation, the most likely was a short circuit outside of the CWT that allowed excessive voltage to enter it through electrical wiring associated with the fuel quantity indication system." (Executive Summary, NTSB Report on TWA Flight 800 Accident (NTSB/AAR–00/03)

Also, using industry standards, as was done with the FARs for Small Airplanes (14 CFR part 23) makes it difficult for the public to comment onchanges or understand the regulations. FARs are public. Industry standards must be purchased from the industry organization.

NON-COMPLIANT DESIGN FEATURES DISCOVERED DURING ODA AUDITS

When a design is type certificated using the ODA process, the ODA certifies to the FAA that the design compliant and the FAA then grants the type certification. Later, if the design is found not to be compliant during an audit, the issue is usually closed by a statement from the ODA that they will correct the non-compliance the next time they make a design change in that area; which could be never. I recommend that in cases where an ODA has said a design complies and it is later determined it does not comply, the ODA be required to bring the design into compliance during production. The production could continue under a time limited exemption until the compliant design is incorporated into production. The FAA could also evaluate the need to mandate retrofit of the airplanes delivered with the non-compliant design. Otherwise, the ODA company can produce the non-compliant design in potentially thousands of airplanes; each of which has a life of 20 to 30 years. This should be considered an unacceptable risk to the public, since the FARs do define the minimum acceptable level of safety for the type design.

CONCLUSION

I hope these examples demonstrate that even with the perceived limited resources of the FAA, their technical specialists did have the ability and resources to identify safety issues. Prior to the ODA system being implemented, FAA certificated the highly successful 757,767, 777, and 747–400 with fewer FAA engineers who conducted direct oversight of company designees. However, more recently the FAA management safety culture often seems more interested in allowing applicants to produce designs that do not comply with the minimum safety standards defined by the FARs. This flawed FAA management safety culture has resulted in approval of airplanes with flaws resulting in grounding of the 787, two horrific 737 MAX accidents with the tragic loss of 346 lives and grounding the 737MAX for the last 9 months. Families have been destroyed. Airlines and the flying public have also been severely impacted by the groundings.

Balanced regulatory oversight supported by a strong FAA safety culture is not costly to the industry, it's the foundation on which the previous unprecedented safety record was built. Most of the aerospace engineers I worked with are dedicated public servants who want to do what is best for the traveling public. Not just what is best for applicant's short-term bottom line. The existing FAA management safety culture is broken and demoralizing to dedicated safety professionals.

I hope this committee considers this information when drafting future legislation.

Mr. DEFAZIO. Thank you.

Dr. Endsley?

Ms. ENDSLEY. Chairman DeFazio, Representative Meadows and members of the committee, thank you for the opportunity to testify today on behalf of the Human Factors and Ergonomics Society. I express my heartfelt sympathies to the families of the victims of both the Lion Air and Ethiopian Airline crashes. It's heartbreaking.

The way in which technology is designed significantly affects the performance of its human operator. Optimizing the relationship between humans and technological systems is the essence of human factors engineering. When the system is easy to use, it guards against typical human limitations and errors and helps people to rapidly understand key information about what is happening, high levels of human performance can be achieved. When poor system design encourages accidents, good system design can prevent them.

A key foundation to safe air travel is the design and development of the controls, displays and automated systems that pilots rely upon to operate their aircraft. Our 70-year history shows that aviation safety is significantly enhanced when human factors engineer-

ing is prioritized in the design and development of aircraft. History has also shown us the catastrophic consequences when human factors design is secondary to other considerations or is outright ignored.

In the case of the Boeing 737 MAX 8, the failure to incorporate known human factors design principles and human factors engineering processes, its analysis, design, testing and certification, paved the way for both the Lion Air and the Ethiopian Airline crashes. These accidents resulted from inaccurate data provided by the aircraft's angle-of-attack sensor and its cascading effects on MCAS. The addition of the MCAS automation and its inherent unreliability, however, create significant new challenges for pilot performance that were not addressed.

While automation can be beneficial, it also leads to new types of human error. Slow or incorrect pilot actions in operating and intervening in automation control are common problems and have been found in over 26 automation-related accidents among air carriers.

Human factors research on these challenges sheds light on several automation deficiencies that impacted the pilots of the 737 MAX 8. First, automation often leads to workload spikes in abnormal situations. In both accidents, the pilots were significantly overloaded, both mentally and physically. They were forced to manage multiple, competing alerts that led them away from the MCAS problem, and they needed to exert considerable physical force on the control column in order to counteract MCAS actions and maintain flight control.

Secondly, automation also often results in low situational awareness. In these accidents, the pilots struggled, as they were not provided with the needed displays for understanding the functioning of MCAS, nor with the AOA sensor disagreement displays that were needed to oversee it. The various alerts that were provided were nondiagnostic and confusing. In addition to these challenges, under the high workload and distractions that were present, it appears the Ethiopian Airline crew lost situational awareness of their airspeed.

Third, automation confusion is a frequent challenge in aviation accidents, and it was a central problem on the MAX 8. Automation confusion stems from both poor transparency of the behavior of the automation due to inadequate displays, as well as an inadequate understanding of how MCAS automation works due to the inadequate training on the system. In addition to failing to include MCAS in the flight manuals, training that provided actual experience in detecting, diagnosing and responding to failure conditions was not provided.

Finally, the pilots needed to be able to take over and fly the aircraft manually. Without clear, unambiguous failure indications and training, the air crew could not successfully carry out the needed remediation procedures in the timeframe that was expected. And the manual forces required for pitch control could not be maintained.

Like most avoidable accidents, the Ethiopian Airline and Lion Air crashes provide important human factors lessons that should be leveraged to improve the safety of our aviation system and to guard against similar problems in other safety-critical systems.

These automation problems could have been easily prevented by following established human factors design principles and standards for human-automation interaction and alarm presentation. Emphasis on human factors engineering and aircraft systems analysis, design, testing and certification is critical for building in aviation safety.

We applaud recent statements by the FAA Administrator and Boeing senior management to reinforce their commitment to safety as the highest priority. And we hope they continue to support this message through their actions.

My submitted testimony provides greater detail on the automation and design deficiencies of the aircraft and both near-term remedies and longer term prevention recommendations.

Thank you for the opportunity to share these insights today and I look forward to answering your questions.

[Ms. Endsley's prepared statement follows:]

Prepared Statement of Mica R. Endsley, Ph.D., Human Factors and Ergonomics Society, appearing on behalf of the Human Factors and Ergonomics Society

Chairman DeFazio, Ranking Member Graves, Members of the Committee, thank you for the opportunity to testify today on behalf of the Human Factors and Ergonomics Society (HFES). With over 4,600 members, HFES is the world's largest nonprofit association for Human Factors and Ergonomics professionals. HFES members include researchers, practitioners, and federal agency officials, all of whom have a common interest in working to develop safe, effective, and practical human use of technology, particularly in challenging settings. HFES has a particularly strong record of expertise in aviation over its 70-year history.

There is a long history of blaming the pilots when aviation accidents occur. However, this does nothing towards fixing the systemic problems that underlie aviation accidents that must be addressed to enhance the safety of air travel. Often accidents are caused by design flaws that do not take the human operator's capabilities and limitations into account. Bad design encourages accidents; good design prevents accidents. Solving these systematic design challenges is the primary calling of the field of Human Factors Engineering, which *applies scientific research on human abilities, characteristics, and limitations to the design of equipment, jobs, systems and operational environments in order to promote safe and effective human performance*. Its goal is to support the ability of people to perform their jobs safely and efficiently, thereby improving the overall performance of the combined human-technology system.

Recent investigations of the Lion Air and Ethiopian Airlines crashes of the Boeing 737-Max8 aircraft have highlighted the importance of Human Factors in the design, testing and certification of aircraft.[1, 2] Neglect of attention to Human Factors was also cited by both the National Transportation Safety Board (NTSB) and the FAA Joint Authorities Technical Review (JATR) in their reviews of the contributors to these accidents.[3, 4] I will discuss the field of Human Factors Engineering and its role in supporting high levels of human performance and reducing accidents in safety critical systems such as aviation, particularly as it relates to the use of automation and these tragic aircraft accidents. This includes (1) a discussion of key Human Factors research on the ways that automation directly affects human performance, (2) Human Factors design problems associated with the 737-Max8 flight deck pilot interface, (3) Human Factors design process shortcomings, and (4) organizational and safety culture issues that are implicated in these accidents.

HUMAN FACTORS ENGINEERING

The practice of Human Factors Engineering is based on scientifically derived data on how people perceive, think, move, and act, particularly when interacting with technology. The way in which any technology is designed significantly affects the performance of the people who interact with it. The user interface of the technology can make human performance much more efficient and human error significantly less likely when it is designed to be compatible with basic human capabilities. When

the system is easy to use, guards against typical human frailties and errors (i.e. error tolerance and error resistance), and helps people to rapidly understand key information about what is happening, high levels of human performance in operating the system can be achieved. Conversely, if the technology design is complex, its displays are difficult to perceive or understand, it is easy to make errors, and significant effort is required to piece together needed information in order to stay abreast of a complicated and dynamic situation, the likelihood of human error increases greatly.

Human Factors supplants a misplaced emphasis on blaming the pilot or over-reliance on training, and instead creates systematic improvements in human performance through improved system design. While training is important, it cannot overcome poor system designs in the long run.[5] People are still likely to make the same types of errors if the system design is not consistent with human capabilities and limitations. For example, when researchers recreated one automation-related aviation accident, they found that 10 out of 12 pilots made the same error as the pilots in the accident when confronted with the same conditions.[6] Further, a well-designed system that is consistent with user's needs and is easier to operate is also easier to train; thus, potentially reducing training requirements as well as improving human performance.

The Human Factors profession can be traced back to early work in aviation when it was discovered that a large number of crashes occurred due to human errors that resulted from aircraft cockpits that were inconsistent with basic human capabilities and limitations. This spurred research on the perception, movement, and reaction time of aviators that was used to significantly reduce the frequency of aviation accidents over the following decades by redesigning the controls and displays of the aircraft to be more consistent with pilot characteristics.[7]

Since this beginning, Human Factors Engineering has expanded considerably to address human performance challenges across a wide range of industries including aviation, transportation, manufacturing, military operations, power systems, space, healthcare, consumer products, and many more. Today, Human Factors and Ergonomics Society members are involved in conducting research on how people interact with new technologies, and are actively engaged in applying Human Factors design processes and knowledge across government and industry organizations. The Human Factors field is multi-disciplinary; it includes primarily engineers and psychologists, as well as physiologists and other professionals. Over 50% of the Society's members have PhD's and 32% have masters degrees. This blend of backgrounds lends itself well to addressing the wide range of considerations needed to optimize human performance in any system.

AUTOMATION AND HUMAN PERFORMANCE

Automation has increasingly become a part of modern systems in a wide variety of domains, including aviation systems, power systems and automobiles. Across the past 50 years, considerable evidence has mounted demonstrating many benefits from automation, but also many challenges involving human interaction with automation that can contribute to catastrophic failures.[8–10] Just as no man is an island, so too, no automation is an island. Automation must be able to work successfully with human users or, ultimately, it will fail.

While automation has many benefits, it also creates new types of errors that must be addressed through careful system design to prevent these new and often catastrophic errors.[8, 11] A long list of automation-related aviation accidents precedes the recent accidents involving the Boeing 737-Max8 that provide significant lessons learned. A recent study listed 26 automation-related accidents among major air carriers between 1972 and 2013, where the pilots were significantly challenged in understanding what the automation was doing and interacting with it correctly to avoid the resulting accident.[12] Several key challenges for human performance can be identified with automation use in aircraft flight decks.

Insufficient Pilot Training and the Loss of Manual Skills

Human operators have an important role in complex technological systems because of their ability to be flexible, learn, and adapt to unexpected situations.[13] To do this, however, pilots must be highly trained and experienced in managing the aircraft and its systems across a wide variety of flight conditions.[14, 15] Today's airline training environments have been criticized as providing insufficient attention to practice and exposure to the wide variety of alerts and non-normal situations that may be encountered in flight.[16] Inadequate training on automation has been found to be a critical problem in many automation accidents.[17]

Pilots are often encouraged to use automation and use it frequently.[18] As pilots use automation more often, however, they become reliant on it,[19] and skills needed for manual performance and decision-making can deteriorate.[9, 20] This includes both fine-motor skills associated with aircraft flight control and cognitive skills associated with cross-check and carrying out flight operations.[21, 22] Further, newer pilots, trained primarily to operate via automation, may never create well-learned skills for manual aircraft operations. Poor manual flight skills were implicated in the fatal crash of Colgan Air in 2009, for example.[23]

Automation Creates High Workload Spikes and Long Periods of Boredom

While automation has frequently been implemented with the goal of reducing manual workload, it can actually increase pilot workload during already high workload periods, such as when a route change is needed or when a problem occurs. This renders it difficult to use, and often pilots must quickly take over manual control in such circumstances which can be quite challenging.[24] It also can make already low workload periods even less engaging, creating new problems associated with lack of vigilance and poor monitoring.[25, 26] This has been called the *irony of automation*.[8]

Automation Confusion is Common

Poor operator understanding of system functioning is a common problem with automation, leading to inaccurate expectations of system behavior and inappropriate interactions with the automation.[27, 28] This is largely due to the fact that automation is inherently complex, and its operations are often not fully understood, even by pilots with extensive experience using it.[29, 30] A study of the factors underlying automation accidents and incidents found that two of the biggest problems were inadequate understanding of automation and poor transparency of the behavior of the automation.[17]

Pilots report being highly challenged in determining what the plane is doing and why, and predicting what it will do next, creating a problem of automation surprise.[31] Very often the misalignment between pilots' understanding of how the aircraft will behave and its actual behavior is only discovered when the aircraft acts unexpectedly. At that point there may be too little time available to discover the problem, properly understand it, and take appropriate action before an accident occurs.[32]

Automation confusion is most likely to occur when three main factors are present[33]:

- The automation acts on its own without immediately preceding directions from the pilot;
- The pilot has gaps in knowledge of how the automation will work in different situations; and
- Weak feedback is provided to the pilot on the activities of the automation and its future activities relative to the state of the world.

Low Situation Awareness to Support Automation Oversight and Intervention

Automation is often *brittle*[34], unable to operate outside of the situations that it is programmed for, and subject to inappropriate performance due to faulty sensors or limited knowledge about the current situation. Therefore, the ability of the pilot to supervise the automation and correct for its deficiencies is critical. While some engineers assume that pilots need less information about what is happening when automation is involved, the reverse is actually true. Situation awareness of both the state of the automation and of the systems the automation is controlling is critical to the ability of the pilot to effectively oversee it and make appropriate interventions and control inputs as needed.[35] Pilots need to keep track of the state of the aircraft and its operation in the flight environment, the state of the automation that is controlling some portion of the job, and information that will allow them to check the reliability and performance of the automation.

Achieving a high level of situation awareness, however, has been found to be much more difficult when automation is involved. A key challenge associated with automated systems is that it tends to reduce the situation awareness of the human operator.[35] Pilots with low situation awareness are said to be "out-of-the loop." Low situation awareness when working with automated systems stems from three main sources:[35]

- *Displays*—Poor information presentation is a significant problem with many automated systems. The system developers may either accidentally or intentionally remove key cues that pilots rely on to determine that the system is operating successfully, as was the case with the implementation of fly-by-wire aircraft.[35] The difficulty of determining that automation is not working correctly is a key challenge with automation use. The inadequacy of the displays pro-

vided has been found to be a frequent cause of aircraft accidents and incidents involving automation.[17]

- *Vigilance*—Automation often puts people into the role of passive monitor, however, in general, people are poor monitors of automation.[36] Vigilance decrements can be significant, occurring both because of over-trust in automation,[17, 19, 37] and because people are in general poor at maintaining vigilance when passively monitoring.[38, 39]
- *Engagement*—A person's level of engagement decreases when they move from actively performing a task to passively watching another entity performing the task.[35, 40, 41] With low engagement, it has been found that people have a much lower understanding of what is happening than when they are performing tasks themselves. A review of automation research was summarized by a fundamental automation conundrum: "*The more automation is added to a system, and the more reliable and robust that automation is, the less likely that human operators overseeing the automation will be aware of critical information and able to take over manual control when needed*".[42]

As automation becomes more technologically capable, with increasing levels of reliability and robustness for performing an ever-widening range of tasks, people will become even more hampered by low situation awareness and fall short in the requirement to oversee the automation and interact with it effectively. Even when system designs are improved and people are vigilant, the degrading effects of reduced engagement are difficult to overcome.[42]

HUMAN FACTORS AUTOMATION ISSUES IN BOEING 737-MAX8 ACCIDENTS

The two recent crashes involving the Boeing 737-Max8 aircraft involved several of these known automation challenges. These accidents resulted from inaccurate data provided by the aircraft's angle-of-attack (AOA) sensor and its cascading effects on the Maneuvering Characteristics Augmentation System (MCAS) that was developed to automatically provide pitch stability following the addition of new, larger engines on this version of the aircraft. The following analysis of the Human Factors and Safety problems contributing to these accidents is based on the accident reports released by the relevant investigation boards,[1, 2] reviews by the NTSB[4] and the FAA JATR[3] in the United States, and other publicly available information on the accidents and events leading up to it.

Insufficient Reliability of MCAS Automation

Several critical design decisions created an automated system that was inherently brittle and not resilient to the inevitable problems that can happen in the real world. First, the MCAS system on the 737-Max8 was designed to operate from the inputs of only one AOA sensor, unlike a version of the MCAS developed for the United States Air Force KC-46 that measured and compared the inputs from two sensors.[43] When the single AOA sensor provided inaccurate inputs, it created an automated system that performed repeated, erroneous trim actions. The automation had an erratic effect on the stability of the vehicle that was at odds with pilot goals and actions. Redundancy is fundamental to the design of a safe and resilient system; in this case a redundant sensor could have provided the indications needed for alerting the automation and the pilot of an anomaly. Simple maintenance errors, as occurred in the Lion Air accident, can have catastrophic consequences and should be guarded against though the use of Human Factors design principles in the design of maintenance tasks, procedures, and training.

Further, the 737-Max8 MCAS was designed to engage and then reengage repeatedly, rather than only the single engagement allowed by the version designed for the United States Air Force.[43, 44] This created a situation in which the automation continued to perform inappropriate and unsafe actions (based on erroneous input data), that the pilots could not seem to override manually. The basic design of the MCAS automation contained built-in assumptions regarding automation reliability that proved to be unfounded, and that left the pilots highly challenged in managing the aircraft safely.

Automation Confusion, Lack of Training and Inadequate Automation Transparency

Automation confusion was high as the pilots struggled to understand what the aircraft was doing. The pilots had no previous knowledge of MCAS and the aircraft provided no displays to indicate that MCAS was acting on the aircraft trim, nor any displays to help them understand that it was getting erroneous data. They were in the dark regarding the functioning of MCAS in these accidents.

Further, the pilots were not aware of or trained on MCAS, and it was not included in their flight manuals, leaving them confused as to why the plane was behaving erratically. They could not develop a correct understanding of the situation they

were facing because they had no mental model to support this process. Effective training on how to overcome automation failures involves not only a written notice or description of the automation, but also actual experience in detecting, diagnosing, and responding to such events,[18] which was not provided on the Boeing 737-Max8.

High Pilot Workload

In both accidents the pilots were heavily overloaded in trying to manually control the airplane, needing to exert considerable physical pressure on the control column to compensate for the repeated out-of-limit trim problems. They were simultaneously faced with multiple competing alerts provided by the aircraft. Alerts associated with indicated airspeed (IAS) disagree and altitude disagree were inadequate to help them to understand the fundamental problem they were facing as a result of a faulty AOA sensor. The alerts further created extra workload as the Lion Air pilots attempted to run indicated checklists and work with Air Traffic Control to check their instrument readings.

The NTSB's preliminary report on these accidents highlights the significant mental workload caused by multiple alerts and their role in further distracting the pilots.[4] The alerts provided were insufficient to help the pilots properly understand and diagnose the situation they were in, or to direct them to the appropriate checklists for managing it. The NTSB recommends that "*the FAA develop design standards, with the input of industry and human factors experts, for aircraft system diagnostic tools that improve the prioritization and clarity of failure indications (direct and indirect) presented to pilots to improve the timeliness and effectiveness of their response.*"[4] The Human Factors and Ergonomics Society strongly agrees with this recommendation.

Lack of Support for Situation Awareness

In these accidents, the pilots were unable to gain the needed situation awareness for accurate decision making. They were faced with an aircraft that repeatedly made uncommanded pitch changes while they received multiple alerts on airspeed disagreements and altitude disagreements, which they attempted to address. However, these alerts primarily served to add workload and distractions. Displays of the MCAS operation actions (e.g. trim up or down), and displays that would have helped the pilots to understand the state of the aircraft as affected by the MCAS system were not provided.

For example, the inclusion of the AOA sensor display on the primary flight display (PFD) was sold as a system upgrade option. It was not included as a part of the addition of MCAS to the 737-Max8. However, neither the airline customers nor the pilots may have been aware of the need for AOA displays to support proper diagnosis of MCAS behaviors when making such a purchasing decision, due to the lack of information provided about MCAS and how it functioned. While Boeing had previously classified the AOA indicator display and AOA disagree lights as supplemental information and not necessary for the operation of the aircraft, the development of the MCAS system, and its reliance on the AOA sensors, should have created a re-evaluation of this decision. The pilots in these accidents were not provided with the needed displays for understanding the functioning of MCAS, nor of information needed to oversee its performance.

There is also some evidence that the pilots may have lost situation awareness of other automated systems whilst dealing with the problems generated by MCAS. While there is only a preliminary accident report available on the Ethiopian Airline accident, it indicates that the crew did correctly set the STAB TRIM to CUTOUT and turned off the autopilot. Subsequently, however, their high airspeed made it much more difficult to manually trim the aircraft and maintain the desired pitch. The aircraft throttle remained at 94% N1 throughout and the aircraft did not stop at the input speed of 238 knots but continued to around 340 knots (vmo). While it is possible the pilots did not understand the impact of the airspeed on the control problems they were facing, it is likely they simply lost situation awareness of their airspeed due to over-reliance on the auto-throttle system. The Boeing's flight crew manual recommends use of auto-throttles in take out, climb, and all other phases of flight. Problems with loss of situation awareness of the state of automation and the systems they control are known to be more frequent when people are under higher workload and when working on competing tasks.[45, 46] Task fixation is more likely to occur under high workload. In this accident, the captain was highly loaded with trying to fly the aircraft manually, needing to exert considerable manual force, and with only a very inexperienced first officer for help.

While alarms and alerts are a key method for helping pilots to detect and diagnose system failures, they were of little help in these accidents. Response to system alerts is not always automatic and immediate, contrary to the stated design as-

sumption of 3 seconds. Responses to alarms and alerts are affected by many factors including the salience of the alert for gaining attention, form of presentation, agreement/disagreement with other indicators, and prior experience with the alert.[47, 48] People must also interpret the meaning of alarms, which depends on context, their mental model of what is happening, and expectations.[49, 50] Often people seek to confirm alarms, and need additional time to properly diagnose the meaning of the alarms in order to select appropriate actions. For example, Boeing's own data on controlled flight into terrain accidents over a 17-year period show that 26% of these cases involved no response, a slow response, or an incorrect response by the pilot to the GPWS alarm.[51]

When multiple alerts across multiple systems are involved, as was the case in these accidents, considerable workload is added and much more time may be required to determine the root cause of the problems so as to select the appropriate response.[47] Multiple failures can cause contradictions between procedures or even prevent their complete execution. The time to respond to the alerts was further delayed due to the fact that the pilots had not been trained to recognize the events and alerts they were presented with, nor to understand MCAS, its reliance on the AOA sensor, and its impact on aircraft control and other flight systems.[18] A NASA Study found that the probability of responding correctly for non-trained aircraft emergencies was only 7%, as compared to highly trained "textbook" emergencies at 86%.[52]

In summary, information that would have informed pilots about the activation of the MCAS or the faulty data inputs to it were lacking on the 737-Max8. The absence of prior training on the MCAS led to a lack of understanding of what was happening to aircraft control. The various alerts that were provided were non-diagnostic and confusing, adding to workload and leading away from a correct understanding of the pitch trim problem, rather than contributing towards a correct resolution in the available time frame. Pilot responses to the alerts were significantly delayed and inadequate due to these deficiencies.

Inability to Successfully Assume Manual Control

Boeing has a widely publicized Cockpit Automation Philosophy that has guided its aircraft development over the past several decades.[53] Its key tenants are that the pilot can always override the automation, and that it should be an aid to the pilot but not replace the pilot. In keeping with this guiding principle, in most other Boeing aircraft the pilot can always easily resume control by shutting off the autopilot system. However, the MCAS operated outside of this autopilot system and operated at odds with commanded pilot inputs.

It is unclear why the design of the 737-Max8 MCAS departed from this consistent automation design philosophy and how the pilots were to know that the MCAS automation was continuing to operate, even after the autopilot was disengaged. Normally, pulling back on the control column will interrupt electronic stabilizer nose down commands in the 737. However, this was not effective in the 737-Max8 as it was set to repeat its actions if it continued to detect an out of trim problem.[1] Further, the first officer's side was modified to inhibit pilot column cut-out functions while the MCAS was functioning.[1] Thus, the simple, and normal responses that normally worked did not.

Proper decision making and performance in the aircraft is highly dependent on accurate situation awareness. While it has been noted that the STAB TRIM CUTOUT switch could have been used to resolve the MCAS problem, this procedure was not used by the crew of Lion Air due to the many factors discussed that lead to their lack of situation awareness. Procedures are only useful when the correct procedure can be selected and applied in a given situation. In the case of the Ethiopian Airlines accident, which occurred after the FAA issued an Emergency Airworthiness Directive on the MCAS[54], the pilots set the STAB TRIM to CUTOUT as directed, however, the flight crew continued to experience flight control problems and concluded that the trim was not working. It appears that their loss of situation awareness of the airspeed may have confounded their efforts to manually trim the aircraft, due to the high speeds generated.

Once the pilots became involved in trying to overcome the MCAS trim activations, they were required to exert considerable manual force (in excess of 100 pounds according to the Lion Air accident investigation) to combat the actions of the system. Concerns have arisen as to the levels of physical force required and the ability of pilots to combat the strong forces associated with MCAS and the 737-Max8's engines under the conditions involved in these accidents. Although the Ethiopian Airline crew was able to turn off MCAS via the STAB TRIM CUTOUT switch, they subsequently flew for some two and half minutes while needing to exert manual forces on the control column to compensate for the mis-trim. The FAA Code of Fed-

eral Regulations (CFR 25.143) requirement is to not exceed 75 pounds for one-handed or 50 pounds for two-handed short-term control of pitch, and 10 pounds of force for any long-term control of pitch (more than 3 seconds), due to the effects of manual fatigue. These pilots eventually stated "pitch up together" and "pitch is not enough" before turning the electric trim system back on, presumably because they could no longer perform this task manually. This led to the reactivation of MCAS and loss of aircraft control.

A determination is needed as to the ability of pilots (both male and female) to exert sufficient manual force to counteract the forces exerted by MCAS at the pitches and speeds in the operational envelope, and to operate manually in the case of a need to deactivate the system due to failures such as were experienced by these aircrew. A recent study by the FAA found that over 60% of females and between 15 and 65% of males (depending on age) were unable to meet current FAA code requirements for short term force application.[55] Further, 10 pounds of force for yoke pitch and stick pitch (the long term requirement) could be maintained for less than 5 minutes by between 42% and 60% of females and 12% of males.[55] These results should be extended to address international populations and used to update CFR 25.143 and to update aircraft cockpits to support actual pilot capabilities.

7 Human Factors Principles for Automation that Prevent Accidents

A number of good design principles for improving people's ability to successfully oversee and interact with automated systems have been developed that could have prevented these accidents had they been applied. [48, 56, 57]

1. *Provide automation reliability*. A key tenant of safety is the design of highly reliable systems. Automation needs to be resilient to bad data and avoid single point failures by cross checking across multiple inputs. Further, graceful degradation should be supported such that if the automation is not getting good data, it can provide automatic self-checking behaviors, with an accompanying message to the pilot. In this case, the MCAS should have been designed to read and compare inputs from both AOA sensors, with significant AOA sensor disagreements being used to disable MCAS and support pilot understanding of its operation.
2. *The user should be in command*. Automation should not interfere with manual operations and manual override should always be possible. Because people have the ultimate responsibility for system safety, because they are more able to adapt to novel, unforeseen situations, and because they may have information about the situation that an automated system does not, they should always be able to easily and simply override the automation and take control. Pilots should be able to easily override activation by the MCAS, rather than having the system fight the user for control. Overcoming the MCAS actions on the trim system should have been as easy as overcoming other electronic trim actions via the control column.
3. *Provide automation transparency*. The state of the autonomy and its intended actions must be made highly transparent to the pilots. The current goals and assumptions of the autonomy, its current and projected actions, and how much confidence should be placed in its data and algorithms should be clearly represented.[48] The system should provide sufficient information to (1) keep pilots informed of its operating mode, intent, function and output, (2) inform pilots of automation failure or degradation, and (3) inform pilots if potentially unsafe modes are manually selected.[56] It is critical that the automation mode and status be clearly and saliently displayed. In this case a display showing that the MCAS was on and each time it engaged, as well as its effect on aircraft trim, would have provided key input to the pilots as to what the system was doing. If the MCAS is overridden by the pilot and turned off, this should be displayed as well to provide clear feedback to the pilots on its state. Secondly, the state of the world that the automation is basing its actions on, such as the AOA sensors in this case, need to be clearly displayed so the pilot can cross check the reliability of the automation to decide whether to trust it or override it.
4. *Provide training to users on automation to ensure adequate understanding and appropriate levels of trust*. New automation should be introduced with training to allow pilots to develop accurate mental models of how it works, an understanding of its limitations and reliability in different situations, and information on how to detect and recover from abnormal events and failure conditions. As a significantly new piece of automation that had a direct effect on aircraft control, experiential training (e.g. via simulations) should have been provided that would allow pilots to experience MCAS operations, its failure conditions, and to perform the tasks needed to recover from and effectively overcome abnormal conditions.

5. *Avoid increasing cognitive demands, workload and distractions and make tasks easy to perform*. The need to sort through multiple competing alerts provided a significant distraction and added workload. Systems should be intelligent enough to filter out extraneous, incorrect, and misleading alerts in order to eliminate both nuisance alarms and reduce unnecessary workload and distraction.
6. *Make alarms unambiguous*. A failure of the MCAS system due to poor sensor data input should be displayed with a clear unambiguous message. Attempting to diagnose a problem with messages or displays that also have other meanings (e.g. the altitude disagree and airspeed disagree warnings), is an invitation to error and significant delays in responding appropriately to emergent events. Any abnormal behavior of MCAS (as affected by degraded sensors or other factors), should be displayed with an MCAS alert warning that is distinct from other alerts.
7. *Support the diagnosis, management, and assessment of multiple alarms*. System displays need to support pilots in determining the relationship between multiple alarms, so as to better understand the root cause of any warnings. If root causes are not independent, this needs to be understood, otherwise individually addressing them may not resolve a problem or make it worse. Pilots need support in responding to and handling multiple alerts, which can cause contradictions between procedures or even prevent their complete execution and degrade the utility of the alerts. Alarm management systems for aircraft need to be redesigned to support pilot understanding of how alarms across systems interact, which actions are a priority, and what actions should actually be taken to resolve the underlying problem.

The lessons learned from these devastating accidents are important for the design, development and testing of automated systems for not only aviation, but also many other industries where automation is being implemented including military systems, power systems and automobiles. Assumptions of perfect automation are unwarranted and unless great care is taken in supporting the needs of the human operators to have good situation awareness of both the automation and the systems they are controlling, the resulting effect will be repeated tragedies of this nature.

HUMAN FACTORS PROCESSES FOR DESIGN AND CERTIFICATION

A FAA Human Factors team conducted a detailed study of automation-related aviation accidents in 1996. They found that *"problems with automation were not limited to any one aircraft type, manufacturer, or air carrier, but were systemic, pointing to much larger problems with the design of the pilot interfaces to the automation, as well as the processes used for design, training, testing, and regulation that were inadequate for addressing the inherent challenges associated with automation."*[30] Consistent with their findings, a number of issues pertaining to the Human Factors processes used for the design and certification of aircraft are highly relevant to the 737-MAX8 accidents that will be discussed in more detail. Addressing them across the aviation industry is critical to preventing future accidents.

Compliance with Human Factors Design Standards

A number of detailed design standards exist relevant to Human Factors and automation that should be adhered to in order to promote good performance and accident prevention. This includes the FAA Human Factors Design Standard,[56] DOD MIL-STD 1472G Design Criteria Standard: Human Engineering,[58] and SAE 6909 Standard Practice for Human Systems Integration.[59] In the case of the 737-Max8, adherence to design principles for human-automation interaction and alarms would have significantly reduced the likelihood of these accidents, as has been discussed.

Incorporation of Human Factors Engineering in the Design Process

Early incorporation of Human Factors analysis, design, and testing during the design process must be emphasized in order to build in safe, efficient operability. The importance of designing in a consideration of human capabilities and limitations throughout the design process is well established.[60] The design of the operator interface cannot occur at the end of the design process; it is integral to the system design and must occur early during system design to ensure that the combined human-machine system will operate safely and effectively.

It is unknown whether Boeing included Human Factors Engineers in its analysis, design, and testing activities, and, if so, whether they were sufficiently empowered to affect the 737-Max8 design. Given the many Human Factors deficiencies reported on in the accident analyses, NTSB and JATR studies, it is highly unlikely that Human Factors considerations received sufficient attention or prioritization in the design and development of the 737-Max8 MCAS system.

Professionals trained in Human Factors Engineering should be included on the design team and engaged throughout the design process in: (1) conducting analyses of requirements to support human performance, (2) determining system functionality and information needs, (3) designing displays needed to support human performance in both normal and non-normal conditions, and (4) conducting tests of the ability of operators to perform in both normal and non-normal conditions.

Conduct and Validate Safety Analyses

The value of any safety analysis rests on its thoroughness and its assumptions. A number of poor assumptions regarding MCAS were made during its development: (1) that uncommanded system inputs would be readily recognizable and acted upon by the flight crew with no additional training, (2) action to counter the failure would not require exceptional skill or strength, (3) the pilot would take immediate action counter the problem, and (4) trained flight crew memory procedures would be followed to mitigate the failure. These assumptions proved to be unwarranted in the accidents. The JATR also found that "*the system safety assessment and the functional hazard assessment, were not consistently updated*."[3] This set the stage for a failure of the safety analyses conducted to adequately capture the real risks involved in the system design.

Any assumptions made during safety analyses should be thoroughly vetted and evaluated to ensure that overly optimistic assumptions do not invalidate the benefits of such efforts. When automated systems are involved it is important that safety analyses always consider the potential for invalid inputs to the system, encountering unexpected situations outside of system design limitations, the need for human oversight and intervention, and recovery from automation failures of any kind. Further, safety analyses need to ensure that accurate assumptions are made about human performance, based on human performance data collected in realistic operational conditions when using the system as designed.

Conduct Robust Human User Testing to Validate System Designs

The careful testing of any new safety critical system is imperative, particularly when automation is involved. In that various types of real-world events occur that may not have been anticipated during the design process, automation's behavior may often prove unexpected. The NTSB's recent Safety Recommendation Report[4] points out that specific failure modes that could lead to uncommanded MCAS activation were not simulated as a part of Boeing's function hazard assessment validation tests. Therefore, resultant flight deck problems, such as misleading warning messages and erroneous information displays, were not unearthed during the testing process or assessed for their safety implications. The NTSB recommends that "*the FAA develop robust tools and methods, with the input of industry and human factors experts, for use in validating assumptions about pilot recognition and response to safety-significant failure conditions as a part of the design certification process*".[4] The Human Factors and Ergonomics Society strongly agrees with this recommendation.

It is critical that testing of automation and operator interfaces include:

1) both normal and non-normal events, including automation failures and recovery;
2) a representative sample typical of operators who are external to the system design process; and
3) objective measures of human performance, including actions taken, errors, performance times, workload and situation awareness.

Support for Human Factors Assessments in Aircraft Certification

The FAA also has a significant role in the design and development process for aircraft technology due to its responsibility as the certifying body. In that it is always possible for design teams to make errors in their assumptions and processes, or for cost and schedule goals to subtly degrade safety decisions, there is great value in having an external certification body who can provide a second review and an independent assessment of the safety of the system.

The JATR report indicates that: (1) the FAA certification team did not fully understand the overall impact of the new MCAS system design, (2) the MCAS was not evaluated as a complete and integrated system on the new aircraft, and (3) Boeing failed to inform the FAA of significant design changes over the design process complicating their task.[3] It appears that the FAA was unable to perform its important safety role due to the use of delegated authority, or "self-certification," in which Boeing was able to provide many of its own tests and analyses without independent verification and validation. This process misses the point of the value provided by an independent certification process.

Critical to this situation is that the FAA may have inadequate numbers of Human Factors engineers involved in aircraft certification in addition to the pilots who are often serve in this role. Further, the JATR found that the FAA "*sometimes didn't follow their own rules, used out-of-date procedures and lacked the resources and expertise to fully vet the design changes implicated in two fatal crashes*."[3] The JATR recommends that:

> "*the FAA integrate and emphasize human systems integration throughout its certification process. Human factors relevant policies and guidance should be expanded and clarified and compliance with regulatory requirements as 14 CFR 25.1302 (Installed systems and equipment for use by aircrew), 25.1309 (Equipment, Systems, and Installations), and 25.1322 (Flight crew Alerting) should be thoroughly verified and documented. To enable the thorough analysis and verification of compliance, the FAA should expand its aircraft certification resources in human factors and in human systems integration*."[3]

The Human Factors and Ergonomics Society strongly agrees with this conclusion and recommendation.

ORGANIZATION AND SAFETY CULTURE

Development of Safety Culture

A strong safety culture is widely recognized as critical in high-consequence organizations such as aviation, power systems, and ground transportation. Studies have found that workplace-related disasters are often a result of a breakdown in an organization's policies and procedures that were established to deal with safety, and from inadequate attention being paid to safety issues.[61–66]

Many of the effects of a poor or broken safety culture may be subtle and subconscious. For example, a large body of research shows that decisions about what is a problem or not a problem can be easily influenced by reward structures, time pressures, or instructions.[67, 68] Actions and communications of senior management, or rewards for cost and schedule performance (which can be easily measured), can act to subtly shift people towards more risky decisions. While some organizations may tout "safety first" without backing it up, strong safety cultures are effective in promoting safety over short term profit objectives, overcoming fear of reporting that can keep problems hidden, countering non-compliance with standards, rules and procedures, and avoiding miscommunication on critical design and operational factors.

Boeing has historically had a strong commitment to safety and human factors in its flight deck programs, however, there are concerns about the possible degradation of the safety culture at Boeing. For example, it was reported in the media that a survey found that one in three Boeing employees reported they felt undue pressure from managers regarding safety-related approvals due to time and schedule concerns, and some 15% reported encountering such problems several times or frequently.[69] Further, over the past 15 years Boeing has reportedly lost many of its employees involved in Human Factors and it may not have involved them in the development of MCAS.

A renewed focus on developing and maintaining an effective safety culture sets the stage for avoiding the deterioration of design processes that led to these accidents, and should be encouraged in all safety critical organizations. This includes aircraft manufacturers, airlines operations and maintenance, and certifying bodies. The Human Factors and Ergonomics Society applauds recent statements by the FAA Administrator and Boeing Senior Management to reinforce their commitment to safety as the highest priority, and hopes they continue to support this message through their actions. For example, Boeing should examine the degree to which Human Factors and Safety experts are involved in their design and development programs across the enterprise and ensure that they are fully empowered to support safety.

Organizational Structure to Support Emphasis on Human Factors and Safety

In that program managers can consciously or subconsciously compromise safety due to organizational pressures to meet cost and schedule goals, it is imperative that safety-critical organizations put in place organizational structures to counter such tendencies and avoid safety breakdowns. For this reason, a best practice is to appoint a Vice-President level Manager of Human Factors and Safety, who oversees safety at the organization and who can raise safety concerns to the highest level of management. Qualified Human Factors and Safety professionals should be assigned to all technology development programs. They can identify potential prob-

lems to program managers and recommend design solutions to enhance human performance and avoid serious accidents. They should also have a direct line to the VP of Human Factors and Safety so that unaddressed problems do not remain hidden from top-level management.

Use of Qualified Human Factors Professionals

In many organizations, people assigned to address user interface design, user experience, human factors, training, and safety may have no formal training in these fields, or only cursory knowledge. This unfortunately seriously degrades the effectiveness of their efforts. Just like every other field of engineering, Human Factors Engineering is based on a significant body of formal education that is paramount to its successful practice. Because it is inherently interdisciplinary, however, its practitioners may have different degree titles (often Industrial Engineering or Cognitive/Experimental Psychology, as well as Human Factors). While there are a few bachelors level educational programs in Human Factors, most qualified practitioners will have master's or PhD degrees in the field. The Human Factors and Ergonomics Society maintains a directory of accredited academic programs in the field. The Board of Certification of Professional Ergonomists (BCPE) is the recognized body for certifying that individuals are qualified to practice Human Factors, ergonomics, and user experience through a combination of testing, experience, and academic qualifications. Currently there is no federal job code for Human Factors professionals, significantly complicating the ability of the FAA and other agencies from hiring personnel with the appropriate expertise.

RECOMMENDATIONS

The objective of Human Factors Engineering is not to assign blame after accidents occur, but rather to prevent accidents from occurring by improving the design of technologies and systems in advance. In this light, the Human Factors and Ergonomics Society recommends that the FAA:

1) Encourage Boeing, and other aviation manufacturers, to incorporate Human Factors processes and personnel into the analysis, design, development, testing, manufacturing, and maintenance of aircraft systems in order to comply with certification requirements. (Supports FAA JATR recommendation 4)
2) Promote a safety culture in aviation that drives a primary focus on the creation of safe products, which in turn comply with certification requirements. (Supports FAA JATR recommendation 6)
3) Expand its aircraft certification resources in human factors and in human system integration, and integrate and emphasize human factors and human system integration throughout its certification process. (Supports FAA JATR recommendation 7)
4) Review training programs for automated systems and recommend improvements to ensure flight crew are adequately trained in automation processes and dependencies.
5) Conduct a study to determine the adequacy of policy, guidance, and assumptions related to maintenance and ground handling training requirements, and needed human factors improvements to reduce maintenance errors. (Supports FAA JATR recommendation 11)
6) Conduct system safety assessments for all manufacturers of type rated aircraft to demonstrate the adequacy of assumptions regarding human performance, particularly as it relates to pilot understanding of and response to alerts, and ability to perform control functions manually when needed. (Supports NTSB recommendations)

In addition to these recommendations, Congress and the federal government can enact policies that will build up the FAA's and industry's capacity and expertise to better understand and address issues pertaining to alerting systems and human-automation interaction that are crucial to avoiding future catastrophic accidents in the nation's transportation and infrastructure. HFES recommends that Congress enact the following policies:

7) Direct the National Academies of Science Board on Human Systems Integration (NAS BOHSI) to conduct a study on human interaction with artificial intelligence, autonomy, and advanced automation technologies: enhancing safety and effectiveness. Such a study could bolster the knowledge and understanding of the many complex issues involved and provide important directions for the nation as it develops and implements these technologies across the coming decade.
8) Increase funding for Human Factors research at NASA and FAA on:

a. Understanding the effects of multiple alerts and the "design of aircraft system diagnostic tools that improve the prioritization and clarity of failure indications (direct and indirect) presented to pilots to improve the timeliness and effectiveness of their response." (supporting NTSB recommendations)
b. Developing "robust tools and methods for use in validating assumptions about pilot recognition and response to safety-significant failure conditions as part of the design certification process." (supporting NTSB recommendations)
c. The development of effective methods, displays, and training for supporting human oversight and interaction with automated systems. This could include support for the FAA's NextGen—Air Ground Integration Human Factors program's efforts around Human Error mitigation research, as well as the Flightdeck/Maintenance/System Integration Human Factors program, and NASA's Crew Systems and Aviation Operations program.
d. The development of tools to support human factors and safety assessments in the certification process. (supporting FAA JATR recommendations)

9) Direct the FAA to develop programs for educating management and engineers on Human Factors, the effects of automation on human performance in safety critical systems, and the incorporation of Human Factors Engineering processes, as well as the development of improved human-automation interaction approaches.
10) Direct the Office of Personnel Management to add job codes for Human Factors Engineer and Human Factors Psychologist to its list of occupational positions and establish appropriate qualifications in order to ensure that FAA and other federal agencies have access to and employ qualified Human Factors professionals.

SUMMARY

The science and practice of Human Factors Engineering is well established, with roots going back to the earliest days of aviation. Aviation is highly dependent on the design and development of safe, effective flight decks for pilot control. Achieving this goal is highly dependent on the early incorporation of Human Factors in the analysis, design, testing and certification processes. While this is true in general, it is even more important with automated systems and as use of artificial intelligence and system autonomy increases. The lessons learned from the tragic accidents of the 737-Max8 should be leveraged to improve the safety of our aviation system and to guard against similar problems in other safety critical systems.

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Mr. DEFAZIO. Thank you, Doctor.

Captain Cox?

Mr. COX. Good afternoon, Mr. Chairman. I thank you and the committee for asking me to share my views on the issues raised by these two tragic 737 MAX accidents. In my 50 years in aviation, and 33 as an aircraft accident investigator, I have not seen a more complex accident than Lion Air 610. Sadly, it was a forewarning of unanticipated conditions that existed which could lead to another accident. Ethiopian flight 302 was that accident.

For an investigator, the most difficult accident is when there is a reoccurrence of a previous accident. I saw this in the mid-1990s with the USAir flight 427 accident near Pittsburgh in September 1994. It was a reoccurrence of a fault that had brought down United Airlines flight 585 3 years earlier. We did not learn all we could. As a result, 132 perished near Pittsburgh.

We did not learn all we could from Lion Air 610 before the Ethiopian 302 accident. The investigation was not complete. But there was compelling evidence of a single failure that could cause mul-

tiple warnings and adversely affect the handling characteristics of the airplane. It is crucial that we learn all we can from these accidents so that there is no reoccurrence of the numerous factors that led to the catastrophic loss of these two flights.

There are immense complexities in these accidents. They are characterized as a loss of control–inflight accident. However, the contributing factors are numerous. Since the loss of these flights, there have been numerous attempts to blame one or two organizations or individuals. But this is inaccurate and misguided. Only with the consideration of all contributing factors can we learn all the lessons.

In the Lion Air accident, there are contributing factors from aircraft design, certification oversight, maintenance execution, pilot performance, pilot dependence on automation, human factors, culture and regulatory oversight of the operator. And within each of these contributors are numerous issues. This is why I make the statement this is the most complex accident I have seen in 33 years.

As the committee is aware, the National Transportation Safety Board and the Joint Authorities Technical Review have both recommended that future certification of aircraft include multiple warnings caused by a single failure. This was a critical factor in both of the accidents. The flight crews had multiple warnings occurring simultaneously, including one that is very distracting, the stick shaker.

During the ensuing pandemonium, the recognition of inappropriate stabilizer trim movement would have been difficult. This is one reason that the runaway trim stabilizer trim procedure was not immediately accomplished.

Aviation is the safest form of public transportation. We will fly 4½ billion passengers this year on 45 million flights safely. We have gotten progressively better since that first flight in 1903. And while the record is exceptional, it is not good enough for tomorrow or the day after. Aviation has to continue to be safer.

I am frequently asked the question, is the MAX going to be safe when it returns to service? My answer is, yes, for I have great confidence in the FAA and in Boeing. Additionally, I have confidence that the recommendations from the Indonesian Transportation Safety Committee and the U.S. National Transportation Safety Board and the Joint Authorities Technical Review, these recommendations for safety are not only for the MAX but for aviation overall.

We have a chance to take the lessons from these calamities and to make our skies safer. Let us not squander this opportunity. Let us carefully review each of the contributing factors of these accidents and improve the design certification processes to better address human factors, better failure analysis for multiple system failures, better pilot training with improved emphasis on manual handling skills, and improved organizational culture where the focus is on safety first.

This committee's recommendations and actions can improve aviation safety. We can enhance the FAA's ability to improve failure analysis, system safety analysis, which may prevent a future accident.

Let me conclude with an observation. I first soloed in 1970. Had we maintained the same accident rate from then to today, there would have been hundreds more accidents and thousands more fatalities. We were not satisfied with that safety record, nor should we be with today's much improved safety record. Let us learn all we can from the MAX accidents to improve aviation safety.

I look forward to your questions. Thank you, Mr. Chairman.

[Mr. Cox's prepared statement follows:]

Prepared Statement of John M. Cox, Chief Executive Officer, Safety Operating Systems

Good morning/afternoon Mr. Chairman. I thank you and the committee for asking me to share my views of the issues raised by the two tragic 737 MAX accidents.

In my 50 years in aviation, and 33 as an aircraft accident investigator, I have not seen a more complex accident than Lion Air flight 610. Sadly, it was a forewarning of unanticipated conditions that existed, which could lead to another accident. Ethiopian Airlines flight 302 was that flight.

For an investigator the most difficult accident is when there is a recurrence of a previous accident. I saw this in the mid 90s in the US Air flight 427 accident near Pittsburgh in September 1994. It was a recurrence of a fault that had brought down United Airlines flight 585 three years earlier. We did not learn all we could from it, as a result 132 perished near Pittsburgh.

We did not learn all we could from Lion Air 610 before the Ethiopian 302 accident. The investigation was not complete, but there was compelling evidence of a single failure that could cause multiple warning and adversely affect the handling characteristics of the airplane. It is crucial that we learn all we can from these accidents so that there are no recurrences of the numerous factors that led the catastrophic loss of these two flights.

There are immense complexities in these accidents. They are characterized as Loss of Control—Inflight accidents. However, the contributing factors are numerous. Since the loss of these flights there have been attempts to blame one or two organizations or individuals, but this is inaccurate and misguided. Only with the consideration of all contributing factors can we learn all the lessons.

In the Lion Air accident there are contributing factors from aircraft design, certification/oversight, maintenance execution, pilot performance, pilot dependence on automation, human factors, culture and regulatory oversight of the operator. Within each of the contributors are numerous issues. This why I make the statement it is the most complex accident I have seen in 33 years.

As the committee is aware, the National Transportation Safety Board and the Joint Authorities Technical Review have both recommended that future certification of aircraft include review of multiple warning caused by a single failure. This was a critical factor in both accidents. The flight crews had multiple warning occurring simultaneously, including one that is very distracting, the stick shaker. During the ensuing pandemonium, recognition of inappropriate stabilizer trim movement would be difficult. This is one reason that the runaway trim procedure was not immediately completed.

Aviation is the safest form of public transportation. We will fly nearly 4.5 billion passengers this year on 45 million flights safely. We have gotten progressively better since that first flight in 1903. While that record is exceptional, it is not good enough for tomorrow or the day after. Aviation has to continue to be safer.

I frequently am asked the question "Is the MAX going to be safe when it returns to service?" My answer is yes, for I have great confidence in the FAA and in Boeing. Additionally, I have confidence that the recommendations from the Indonesian National Transportation Safety Committee, the US National Transportation Safety Board, and the Joint Authorities Technical Review. These are recommendations for safety enhancements not only for the MAX, but for aviation overall.

We have a chance to take the lessons from these calamities, and make our skies safer. Let us not squander this opportunity. Let us carefully review each of the contributing factors of these accidents and improved design and certification processes to better address human factors, better failure analysis for multiple system failures, better pilot training with improved emphasis on manual flying skills and improved organizational culture where the focus is on safety first.

This committee's recommendation and actions can improve aviation safety. We can enhance the FAA's ability to improve failure analysis, and system safety analysis, which may prevent a future accident.

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I look forward to your questions.

Thank you Mr. Chairman.

Mr. DEFAZIO. Thank you for that testimony.

We have three votes coming up on the floor of the House right now, we're in process, so the committee will adjourn, and I will return immediately after the votes. Let's say, I mean, they drag out votes around here. Yes, OK, recess. Sorry, we are going to take a break. I would say 30 minutes. So we will give you 30 minutes, you can run down to the cafeteria. I hope you can all come back, please. Thank you.

[Recess.]

Mr. DEFAZIO. I apologize. I was almost all the way back here, and then the Republicans called a, "Doomed to Fail" procedural vote and I had to go all the way back to the floor again, so we waste a lot of time around here.

So, let's proceed to questions. Since I just got back and I want to gather myself for a minute, Rick, are you ready to question? OK.

Mr. LARSEN. I presume it will be 5 minutes.

Mr. DEFAZIO. Yes.

Mr. LARSEN. Five minutes on the clock?

Mr. DEFAZIO. Oh, yeah. Five minutes.

Mr. LARSEN. Yeah.

Mr. DEFAZIO. Yeah.

Mr. LARSEN. OK. I had to ask, thanks. So, thanks. I want to thank the folks for being here.

Dr. Endsley, in your discussion with regards to human factors, one of the issues we are looking at is, going forward, if we should change, and I think we should, but how we change the certification process and what changes ought to be made. How should we think about incorporating human factors analysis into the certification of airplanes?

Ms. ENDSLEY. The JATR report talks quite a bit about that, and we certainly concur with their recommendations to emphasize human factors more in the certification process.

The real value of certification is getting a second set of eyes on what is going on. It is way too easy for even very knowledgeable, well-intentioned engineers to make incorrect assumptions or errors in their analysis, and the ability to have that independent set of eyes looking at what is going on and the processes that are being used, and the outcomes of the results I think is extraordinarily valuable.

We need to make sure that those teams are equipped with well-qualified human factors engineers who understand a lot of the complexities of human behavior that are involved in these sorts of events, particularly with things like automation and alarm situations such as we saw here.

Mr. LARSEN. Yeah. In your opinion, and you may not have an opinion or knowledge. Maybe if someone else does have an answer to this, I would welcome that. Does the FAA currently have people in line to conduct human factors analysis of airplane designs and of system designs?

Ms. ENDSLEY. Yes. The FAA has some very well qualified human factors professionals. Dr. Kathy Abbott is in charge of certification on the human factors side and she is very knowledgeable about this. I think the issue is one of having enough people and having those people involved in that process such that they are getting the information they need and are involved all along the way.

That is really the most valuable way to incorporate human factors. You can't just put a stamp at the end. You have really got to be involved early on it and continuously.

Mr. LARSEN. Yeah. Anyone else want to answer that question on human factors about type, numbers of people, skills, capabilities within the FAA?

All right. OK. Nothing? OK.

Mr. Pierson, in your written testimony, you alleged that last year, the 737 program's vice president and general manager agreed to conduct a thorough engineering and quality analysis to determine if the production environment has caused safety risks. To your knowledge, was that analysis conducted? Are you at the microphone, please?

Mr. PIERSON. Not to my knowledge.

Mr. LARSEN. "Not to your knowledge"? Did you yourself do any follow up on that, or was that your role? Or whose role would have been to follow up on that in your organization?

Mr. PIERSON. That would have the general manager's responsibility with the appropriate leaders of the other organizations like engineering and quality.

Mr. LARSEN. Mm-hmm. In that circumstance, was Mr. Campbell within the ODA, and was your concern made into the ODA at Boeing for this question? Or was this outside of that?

Mr. PIERSON. This was a discussion that I had with him one-on-one. It wasn't involving anybody else in the ODA.

Mr. LARSEN. OK. All right. Is your argument, is the point that you are making in your testimony that this is a problem with production pressure because of economic factors, or a problem with the way Boeing is organized to build and to certify airplanes?

Mr. PIERSON. Could you rephrase that again, Congressman?

Mr. LARSEN. Yeah. Is your argument, or the point you are making with your testimony is a very good point. Is it because of economic pressures only, or is it a problem with how Boeing uses the ODA?

Mr. PIERSON. You know, I really don't have a comment about the ODA. As far as economic factors go, I am obviously not an economist. My issues were really what I saw in the factory and the environment, and the things that were happening at the time when those planes were being built, and then I wasn't there when the second plane was built. I had retired just prior to that, but——

Mr. LARSEN. Yeah——

Mr. PIERSON. That was my concern, and——

Mr. LARSEN. Right. All right.

Mr. PIERSON. I will say——

Mr. LARSEN. Yeah——

Mr. PIERSON. Just on the topic, if I may.

Mr. LARSEN. Sure.

Mr. PIERSON. There has been a lot of discussion about certification, and the certification process, and a lot of discussion on the left side, if you will, of the process which is the design and the flight training and things like that.

Mr. LARSEN. Right. Right.

Mr. PIERSON. The right is on the far right is what is called the production part, and Boeing is issued a production certificate that expects to have every plane built with the same level of repeatable quality. And so, that is a really important part of the airplane certification process that we shouldn't forget.

Mr. LARSEN. All right. Thank you.

Thank you, Mr. Chairman. I yield back.

Mr. DEFAZIO. I thank the gentleman. I will recognize myself now.

Captain Cox, we have heard from some through these hearings who have said, "Well, if this had happened with U.S. or European pilots, it would not have been a problem because they have superior training." Yet I believe you are aware of U.S. and European pilots who knew this problem was coming in a simulator and were unsuccessful in managing it. Is that correct?

Mr. COX. Yes, sir. I am aware of some anecdotal tests that were done with some European and North American pilots that also let the airplane get to a quite high speed, over speed condition. So, I don't believe there is evidence that can support a premise that it is exclusively due to their being developing world countries that these accidents were caused by this.

Mr. DEFAZIO. Right, and also, I think was it you used the word, "pandemonium"?

Mr. COX. Yes, sir.

Mr. DEFAZIO. Yeah. Now, what are you referring to there?

Mr. COX. The fact that when this situation occurs, that when the airplane breaks ground, you get somewhere around seven simultaneous failures, one of which is very, very distracting. The stick shaker. Literally the column in your hand is shaking and it is very loud. So, you as a pilot, the training comes in to, how do you sort through that? Where do you go back to the commonality and sort through that, and in what priority?

But with that much noise going on, and with these simultaneous failures, the word "pandemonium" is appropriate, sir.

Mr. DEFAZIO. OK. Yeah, I think NTSB said, "cacophony," I think is the word they used, but similar.

Mr. COX. I have had a stick shaker go off in an airplane with passengers, and it, by itself, is enough of a challenge, much less now compounded with six to seven other simultaneous warnings and failures. It would be a real handful.

Mr. DEFAZIO. Dr. Endsley, wouldn't that sort of fit into the human factors approach in terms of solving how quickly a pilot could solve that?

Ms. ENDSLEY. Yes. That was a big factor. The idea that pilots could respond in 3 seconds is based on a lot of things, but it would have to be a well-recognized cue for a well-trained procedure, and

that was not the case here. They had all kinds of multiple competing alerts which will really slow down decisionmaking time.

Mr. DEFAZIO. OK. Mr. Pierson, you mentioned it in your statement, but I would just like to revisit it. I think after your extraordinary persistence when you finally got in to see the general manager of the 737 program, would you just please give us a little color on that meeting? A little more than in your testimony? Yeah.

Mr. PIERSON. Congressman, you are referring to, I believe, our July 2018 meeting.

As far as just color, if you will, commentary is when the meeting started, it was a follow up to the email that I had written requesting a shutdown of the factory. I met with him, and I walked into the office and he asked me, "Why are you here?" And I said, "I am here to follow up to my earlier communication with you." And he asked me how it was going. And I explained that it was getting worse in my opinion, and that I echoed my recommendations.

I had a bit of a difference of opinion at that point, and then we talked, and at the end, he agreed that he would pull the overtime records and look at how much work we were asking of our union employees, and I emphasized that not only that is obviously really important, because they are the ones doing the lion's share of the work, but also the managers that are overseeing them. And then, the engineering quality analysis that I had requested be done to see if there was any possible issues that may have required us to alert our customers.

Mr. DEFAZIO. And nothing changed?

Mr. PIERSON. Not to my knowledge.

Mr. DEFAZIO. OK.

Mr. PIERSON. I retired in August.

Mr. DEFAZIO. Right, and we asked the CEO in the last hearing after he got that recommendation from you, and, "Did you close down the line?" "No." "Did you slow down the line?" "No." And apparently, none of the engineering reviews that you asked for or overtime reviews, if they were reviewed, they were disregarded. So, and when you posited that, from your experience in the Navy, this would say, "No. We have got to stop and revisit this and fix it," but he did say to you something about, "The Navy isn't a profit-making——"? What was that?

Mr. PIERSON. He said when I explained to him that, "In the military operations, if we have these kinds of indications of unstable safety type of things, we would stop." And he said that, "The military is not a profit-making organization." That's what he said.

Mr. DEFAZIO. Now, Mr. Collins, your involvement in the issue regarding the placement of, and/or lack of, additional protection for the rudder control cable, as I understand it, I mean, in the end, there were how many people involved in the—what do you call it? A nonconcur?

Mr. COLLINS. A nonconcurrence. Well, there was the issue paper nonconcurrence, and then there was the SRP panel, whose recommendation was rejected, and the board recommendation. So, I think it was a total of 13 engineers, 1 project pilot, and 4 managers documented that they did not agree with the decision.

Mr. DEFAZIO. And this was, to the best of your knowledge, overruled by a single manager who is in the office in Washington State?

Mr. COLLINS. Yeah. He is in the consolidated office. He was the transport airplane director manager at the time. He is the one that signed it and took responsibility.

Mr. DEFAZIO. Mm-hmm.

Mr. COLLINS. Others supported it. Other managers supported him.

Mr. DEFAZIO. And there were questions raised by the minority that they think, "Well, we should bring in former FAA Administrator Huerta or somebody else." To the best of your knowledge, did the decision on—because this is only one decision, and there have been others, and we are going to track these things down, but do you think that anyone higher up, like in the national office, was involved in the rudder cable issue or even aware of it?

Mr. COLLINS. Well, the safety SRP report of the board's recommendation, the manager had to come back and explain why he disagreed with that, and that went up to Air2, the deputy director of aircraft certification.

Mr. DEFAZIO. Oh.

Mr. COLLINS. In the earlier decision, it has been my experience in issues like this that they are discussed with the aircraft certification deputy or director.

Mr. DEFAZIO. And that is someone based in Washington?

Mr. COLLINS. Yes, in Washington, DC.

Mr. DEFAZIO. OK. Good. Then, that is a string to follow for us, and then, we will see where it goes from there. Thank you. That is helpful.

With that, I don't have any other questions at the moment, and I recognize Representative Norton.

Ms. NORTON. Thank you, Mr. Chairman. I appreciate your inviting these witnesses as well because they broaden our understanding. And I think I'd like to begin with Mr. Pierson because your testimony, as I understood it, focused primarily on the Renton, Washington, factory, but, in past hearings, I've raised concerns about the North Charleston, South Carolina, factory, which makes the Boeing 787 Dreamliner.

There we have reports of concerns from employees of defective manufacturing, even pressure not to report violations. Each time my office raised concerns with Boeing representatives they have assured me and my staff that the problems found in South Carolina were not systemic. Your testimony indicates some of the same issues were present in Renton, Washington. To your knowledge, how widespread were or are these issues, do you believe, Mr. Pierson?

Mr. PIERSON. Yes. Congresswoman, I have no experience at the South Carolina facility, but what you speak of I did witness at the Renton factory. There was certainly an inordinate amount of schedule pressure being placed on employees, and we had a lot of challenges with parts. I mean, normally, when the factory is running fine, everything is going well, but then we had kind of a cascading problem, and it just kind of got out of hand.

Ms. NORTON. I don't know why we'd want to trust Boeing without making sure that the FAA should go farther. In fact, would you favor that, the FAA going farther and doing an investigation of U.S. Boeing factories?

Mr. PIERSON. I fully support that. I'm encouraged to hear the FAA go in and do a thorough investigation. I really think that's necessary. And again, as I mentioned before, not only go and investigate, identify problems and fix them but maintain that presence that you need to have into the future.

Ms. NORTON. I'm going to suggest that following this hearing. Mr. Collins, you say that the culture at FAA shifted from supporting FAA technical specialists to favoring industry positions. This is something that concerned me in my questions this morning. I'd like to know what immediate steps you think FAA leadership can take to return the agency to a culture of safety you apparently experienced when you first began there.

Mr. COLLINS. I think that the culture has evolved, so it would take something to turn it around. I had experience working with Flight Standards for a bit, and they rewarded employees who raised safety issues. I think rewarding employees and managers who address safety issues might be a good help. I mean, I've heard—I don't have evidence, but I've heard in the past managers' bonuses and things were based on, in part, applicants' schedules.

Ms. NORTON. Applicants' what?

Mr. COLLINS. Schedules for projects to complete a project on time.

Ms. NORTON. Well, isn't that what leadership is all about? I mean, you can't change in any comprehensive way if you don't have somebody at the top for complicated organizations forcing change down. Do you think that the present leadership, for example, at FAA has the capacity to bring that kind of change or make sure that kind of change happens at Boeing?

Mr. COLLINS. And I can speak to the FAA. At the FAA, I think they have the ability to do it. It's going to take work to change the culture at all the different levels that has evolved over time.

Ms. NORTON. And apparently this is by now built into the culture at places like Boeing. That's why my question to Mr. Pierson was about not assuming that what you see at one Boeing factory won't be the case at another. It seems to me that given what we have learned, the recalcitrance of Boeing, it is going to be on us if we do not take the steps to systematically look at Boeing factories across the United States. Thank you, Mr. Chairman.

Mr. DEFAZIO. I thank the gentlelady. The gentlelady from West Virginia, Mrs. Miller, is recognized.

Mrs. MILLER. Thank you, Chairman DeFazio. Dr. Endsley, the FAA is looking into incorporating human factors into considerations throughout the design and certification process. Can you tell me about that?

Ms. ENDSLEY. Yes. That was one of the recommendations of the JATR, and we certainly concur with that. What needs to be done is to increase the staff that's available. We also need to increase some of the research that's needed to look at some of these issues that they're having challenges with such as multiple alerting situa-

tions and human automation interaction. There are a number of those kind of steps that can be done.

To enable the certification to really consider human factors, I think it's really important that they are there as part of that team and that they get the kind of data that's needed all through the process from the analysis to looking at the designs to reviewing test procedures and test results. That's a really important thing to be incorporated all the way through.

Mrs. MILLER. That was sort of my second question as well. So you're talking about multiple factors, multiple human factors in the beginning of your statement?

Ms. ENDSLEY. Yes. Human factors is really looking at every aspect of how humans perceive, think, how they move, the anthropometry, really all human characteristics and human capabilities and limitations and then designing the systems to be compatible with how we work and to guard against some of where our known failure points are.

So it's a systematic way of designing systems based on the research on how people work, and that's the way to really improve human performance. It works to not only improve the efficiency of your system but also guard against the kind of errors that lead to accidents.

Mrs. MILLER. Some people freeze. Other people the adrenalin starts to flow. So that will be difficult unless they are trained consistently how to react to specific problems, don't you think?

Ms. ENDSLEY. Training is extremely important, and it's a part of what we look at in human factors. So the first thing you want to do is design the system appropriately because it's very hard to train for bad designs. So you want to design it appropriately first, and then you want to train people, and training people on what to do in emergency situations is extremely important. It's very important for dealing with things like automation, automation failures and getting into these sorts of edges of the envelope where the automation doesn't behave properly.

And you have to really expose people to that so they know what cues look like, how to prioritize information, how to respond, how to communicate, and those well-learned behaviors then can be executed much more smoothly when the real thing happens.

Mrs. MILLER. How do we tackle that automation surprise?

Ms. ENDSLEY. We try to avoid it. So the way we have to address it is, one, training. So people actually get good training on the automation, which didn't occur in these accidents but we know is extremely important for automation because it's very complex. You can find even very experienced pilots don't actually know how the system is going to operate in a wide variety of circumstances. So training is important.

The other thing is really the displays we provide. Even well-trained pilots aren't going to do the right thing if they don't get the right information. For example, here they didn't have information or not what MCAS was really doing. They didn't have the information they needed to even understand that the angle-of-attack sensors disagreed or had a problem with it. So they didn't have the information they needed.

Mrs. MILLER. How to override it, so to speak?

Ms. ENDSLEY. So they could override it, right. So having all the procedures, having all the training won't work if you don't have the situational awareness you need to make the right decision.

Mrs. MILLER. OK. Thank you. I yield back my time.

Mr. DEFAZIO. I thank the gentlelady. Albio Sires.

Mr. SIRES. Thank you, Mr. Chairman. Mr. Pierson, thank you very much for being here today. It gives me a great deal of comfort to know that there are people like yourself out there that when you see something wrong you're willing to speak up and let people know what is going on and how you feel. I think as someone who travels on planes it's very comforting to know that you would try to do the right thing. You went through the management. They ignored you.

And this morning I just can't believe that after all we have gone through this morning we finally got a commitment from Mr. Dickson that they're going to investigate all your emails and the reasons that it happened. That's amazing to me after all this time. It took this hearing for them just to even look and investigate what your comments were. So I thank you.

Mr. PIERSON. You're welcome, Congressman. It's just the right thing to do.

Mr. SIRES. Was this pressure unique on employees at Boeing, or was it just this because of the 737 MAX, and they had to get them out, or was this something that was all the time at Boeing? Is this the culture, just keep pressuring the employees to push, push, push?

Mr. PIERSON. In my experience at Boeing, the other positions I was in at Boeing I didn't see that. In my vantage point, it was the factory. It was in the production facility. It's just the pressure and the schedule and scheduling. In 30 years in the military, I never saw that level of schedule pressure being put on people. When you put people in that kind of pressure and they're tired, mistakes are made, and I think the doctor would agree with that.

Mr. SIRES. Can you give me other examples of what was going on? Because I'm not well-versed on the factory or some of the issues that you talked about. What you saw, what you saw that was wrong.

Mr. PIERSON. Well, maybe it would be best to just very quickly give a—in the factory, everything is planned. Everything is planned and is supposed to be done in accordance with our FAA-approved production certificate. And when things are working fine, parts are getting delivered on time, the people are working in position, the plane moves down the line and then eventually is properly flight tested, et cetera.

End of 2017 and 2018 what I started observing—again, I wasn't alone, and this is why I've been adamant about talking to other employees at the site. We started having problems with our parts being delivered, and it wasn't just big parts like the engines, which was a chronic problem. We had other things that were really very important. Every part in a plane is important, but wiring, wire bundles, things like that, these are really important things.

This starts to lead to a lot of out-of-sequence work, and so resources are stretched. People that are used to working in one position or two are now being asked to kind of work all the way down

through the factory and maybe even outside, and of course that means their managers are also stretched, and the equipment is stretched. There's a lot of stuff going on, and it's very challenging, in my opinion, to maintain the level of quality that we really are expected to maintain.

Mr. SIRES. Do you stay in touch with some of your former workers, coworkers?

Mr. PIERSON. I'm sorry. Say again?

Mr. SIRES. Do you stay in touch with some of your coworkers?

Mr. PIERSON. I have a lot of friends at Boeing, and I for the most part with the exception of two employees I've been in contact with, I decided it wasn't really the right thing to do to talk to them about what I was trying to do and get the investigators to go look. So I haven't really talked to them.

Mr. SIRES. Because I was just wondering if that same practice continues today, what you observed while you were there. Has anything changed?

Mr. PIERSON. That's a great question. Again, I'm really encouraged the FAA is going to go in and do a thorough investigation, talk to employees and start with the employees that are actually building the plane, the people that are the mechanics and the electricians and the quality inspectors. Those are the people who are going to give the best perspective overall of how things are going. And looking at all the data in the production reports there's a lot to look at. I am encouraged by that, though, that they're committed to doing that.

Mr. SIRES. You're encouraged by what Mr. Dickson said this morning, that he's going to follow up on this?

Mr. PIERSON. I'm encouraged that they're going to do it. I'm a healthy skeptic right now, Congressman.

Mr. SIRES. Well, Mr. Chairman, I hope our committee follows up and makes sure that Mr. Dickson does what he committed to us this morning.

Mr. DEFAZIO. I can assure the gentleman we will be following that very closely. We want to see that commitment delivered on, and I appreciate Mr. Pierson's persistence in this matter.

Mr. SIRES. Thank you, Mr. Pierson.

Mr. DEFAZIO. With that I recognize Representative Brownley.

Ms. BROWNLEY. Thank you, Mr. Chairman. I just wanted to also note to the committee that's concerning to me is that Mr. Pierson also reached out to NTSB and to the Department of Transportation in his effort to get someone's attention, and in both cases with NTSB and Department of Transportation they did not take any action from your notifications. Is that correct?

Mr. PIERSON. It's correct, Congresswoman, that it was an effort to try to get the investigators. I was trying to get to them and share information, and it took over 3 months before they'd even agree to meet with me. They didn't want to receive the documents. Eventually, they did meet with me. They offered to give me 15 minutes. My attorneys and myself said that's not nearly enough time.

They only gave an hour and a half, and at the end of it all, they referred us to Department of Transportation IG and said that it was outside their scope. We had asked them again to pass the information to the Indonesian and Ethiopian investigators, and their

take on the matter was that it was beyond the scope of their responsibilities and those investigations.

Ms. BROWNLEY. Thank you. I heard a podcast on Boeing probably 6 or 8 months ago. I can't remember how long it was, but it was another Boeing whistleblower who was talking about production of the airplanes and the intensity that Boeing was putting on the employees to produce and produce in a timely way.

And in this podcast, they referenced the fact that they were directed at one particular time that there were engines that were not allegedly fully functioned engines. That they were marked and painted in a way that said there was some malfunction going on with the engine, and in this push to move the assembly line, that they actually were instructed to go use an engine off of that. I don't know if you ever observed anything like that.

The podcast went on to say, too, that there were tools and so forth left in the belly of the plane or in the tail of the plane. Just sort of sloppy work that wasn't being inspected, and I don't know if you witnessed anything like that?

Mr. PIERSON. Congresswoman, again, I didn't work in South Carolina. I will say that.

Ms. BROWNLEY. That was in South Carolina.

Mr. PIERSON. If you are asking about the Renton facility, I don't ever recall anybody ever saying, "Go get a part," that wasn't approved. I never saw that.

Ms. BROWNLEY. OK. OK, very good.

And Mr. Collins, in terms of talking about the FAA culture and how it really needs to change, was there a crash that occurred when you were employed by FAA?

Mr. COLLINS. Yes. I actually investigated two accidents. One was an Air France in Tahiti that ran off the runway and nobody was hurt, and the other was the TWA 800 accident where everybody died, and so, I was at the hangar. I was the lead FAA engineer on it when it became clear it was a fuel tank explosion.

Ms. BROWNLEY. And when you were at the FAA and those incidences occurred, did you see changes in the way FAA operated? Did you see changes in the culture of the organization?

Mr. COLLINS. I was kind of under the initial culture. We did a lot of work. We did two rulemakings to improve the safety. There were hundreds of airworthiness directives as we learned about different failures that could create ignition sources. It was really after implementation of the 2001 fuel tank safety rule a few years later where I saw industry resistance and management supporting it start to creep in.

Ms. BROWNLEY. Would you say that was the beginning of a cultural change starting to happen?

Mr. COLLINS. Yeah. That was when we first started seeing engineers nonconcurring on issue papers. I really don't remember it before then, so 2002, 2003ish.

Ms. BROWNLEY. And this culture is not just with the Boeing organization. It is with any manufacturer.

Mr. COLLINS. No. It is across the board with manufacturers. It is not just Boeing.

Ms. BROWNLEY. Thank you, sir.

I yield back, Mr. Chairman.

Mr. COLLINS. If I could add, the example of the rudder was the one that was the most dramatic because it was really unprecedented to have that many people document a disagreement like that.

Ms. BROWNLEY. Thank you.

Mr. DEFAZIO. I thank the gentlelady.

Yeah, Mr. Collins, just to follow up on that, you mentioned the name of one individual who we are going to seek to discuss this with. You mentioned there were others. Do you happen to recall their names?

Mr. COLLINS. On the——?

Mr. DEFAZIO. When they overruled everybody and said——

Mr. COLLINS. On the rudder control issue?

Mr. DEFAZIO. Yeah, yeah.

Mr. COLLINS. Yeah. One of the managers is Victor Wicklund. He was the transport standard staff manager.

Mr. DEFAZIO. Mm-hmm. OK. All right, because we are looking to pursue more interviews with FAA, and——

Mr. COLLINS. Right——

Mr. DEFAZIO [continuing]. I think we would want to discuss this with them, because——

Mr. COLLINS. Yeah, and the other one was the transport airplane directorate manager which was Jeff Duven.

Mr. DEFAZIO. All right. Yeah, because I mean, the rationale I saw was that the NG engine was slightly smaller than previous versions, and therefore, and had not had an uncontained failure, so therefore, even though the MAX engine was much larger, they thought it would be very dependable and never have an uncontained failure, which is like, "It's a new engine. How do you know that?"

Mr. COLLINS. I agree. I mean, as a propulsion engineer, I didn't see validity in that argument.

Mr. DEFAZIO. You didn't?

Mr. COLLINS. On a higher energy rudder.

Mr. DEFAZIO. Yeah.

Mr. COLLINS. And you have to, on the airplane side, assume you get the uncontained failure, and then protect against it. When the engine is being approved, their job is to show that it is not going to eject parts, but on the airplane side on the installation, you have to assume it is going to have those failures, and then protect the airplane from the failure.

Mr. DEFAZIO. Yeah. Thank you. So, you would say that during your lengthy tenure with FAA, and you just mentioned it in response to Representative Brownley, that you saw a change after you began. It was unusual to see nonconcurs before we went through the fuel tank issue.

Mr. COLLINS. Correct. Yes.

Mr. DEFAZIO. Yeah.

Mr. COLLINS. This just kind of creeped in after that.

Mr. DEFAZIO. Interesting, and you never saw, in your 30 years, one where this many people nonconcurred and got overruled?

Mr. COLLINS. No, and then, we had the additional part of the new voluntary safety reporting process. They brought in his specialists that weren't working on the project and reviewed it and

came to the same conclusion as those that didn't agree with the issue paper. And then, that was overruled. So, it was disappointing for it to go through that process and not see any change.

Mr. DEFAZIO. What do you think is—I mean, we have some will say, "Well, it would be impossible without ODA," and I agree. If you are going into minor aspects of the planes. My concern is anything that would take a plane down, FAA should be directly and fully informed of, and directly involved in, but I mean, what do you think about the current process, and how might we change it?

Mr. COLLINS. Well, and I agree. When I first started, I was taught that the Federal Aviation Regulations defined the minimum level of safety for the airplane, and this is where the means of compliance and lessons learned from accidents should be incorporated in showing compliance with that.

Mr. DEFAZIO. Mm-hmm.

Mr. COLLINS. And there are a lot of exceptions under 21–101 where new rules aren't incorporated in amended type of design, and then exemptions also where too often to me, it seemed the interest of the applicant was, again, over the interest of the traveling public.

Mr. DEFAZIO. Mm-hmm.

Mr. COLLINS. One example in my testimony is about an exemption that was granted for fuel quantity indicating wires, ignition prevention in the fuel tank where a 4-year time limited exemption was granted on the 737 NGs and, well, 5 years is all it takes for a new type design approval.

At the end of the 4 years, no change had been made, and then a permanent exemption was granted instead of making the manufacturer fix it.

Mr. DEFAZIO. OK.

Captain Cox, you have a lot of years in the air and I think you flew earlier versions of the '37. In one of the hearings, I showed an image of a flight deck from 100, and then an image of a flight deck from the MAX, and it just really didn't look like the same plane. I mean do you think we should consider how many times you can amend a certificate versus actually going through certification?

Mr. COX. It is an incremental step process so that pilots—and I flew the 200 and 300 and there was quite a bit of difference between those two, to the point that we finally split the fleet where only 200 pilots would fly the 73–200 and——

Mr. DEFAZIO. Really?

Mr. COX [continuing]. So we in essence treated it like a separate airplane. And some airlines have been willing to do that and others, for economic reasons have elected not to. There is a lot of difference between a MAX and the first-generation 737. I think it would be unreasonable to ask a pilot to fly a 100 or 200 on Monday, Wednesday, Friday and on Tuesday, Thursday go fly a MAX.

Mr. DEFAZIO. Right.

Mr. COX. But as the incremental steps that we are taking, I can understand how the FAA approved it, but I think the 737 is a bit unique because I don't think we have another airplane in the fleet that has as many derivative type certificates or that has been in service as long, and I don't think there will be another version of the 737. I think the MAX is the last one.

Mr. DEFAZIO. Right.

Mr. COX. So, I think the problem is, to some degree, going to cure itself.

Mr. DEFAZIO. Yeah, and I don't know if anybody could answer this, but they are trying to amend the type certificate for the 777 with folding wings and say that this doesn't require recertification. I am not aware of any commercial transport aircraft that have folding wings. It seems like a pretty radical departure.

Mr. COX. It is, but as an example, the Airbus, and I flew the 319, 20, and 21, there were subtle differences between the three airplanes but for the most part, they flew virtually identically.

Mr. DEFAZIO. Mm-hmm.

Mr. COX. The 737, 300, and 400 were very close.

Mr. DEFAZIO. Mm-hmm.

Mr. COX. 737, 700, and 800 are very close.

Mr. DEFAZIO. Mm-hmm.

Mr. COX. So, there are cases where the differences are minor, but there are some that the differences are significant.

Mr. DEFAZIO. OK. I guess at that point, I don't think I have further questions. Well, maybe staff has a further question, which is this? OK. Where? Which one? Where am I? OK.

OK. Captain Cox, as a former pilot and safety consultant, how important is it for a pilot to be knowledge and trained on new flight control systems, particularly something that is novel or unique, such as MCAS?

Mr. COX. I think the training is critical in the fact that the assumption was made that the pilots would instantly recognize inappropriate stabilizer trend movement.

Mr. DEFAZIO. Mm-hmm.

Mr. COX. With 737, starting with the 300 series, that trim system moves because of a system known as the speed trim system. So, you would have to recognize that movement in and of itself, uncommanded movement by the pilots in and of itself would not necessarily be a trim runaway, and when you have multiple failures that are going on, the recognition of an MCAS activation would be much more difficult. Hence, that needs to be trained as a possibility that if you see a stick shaker that comes on with multiple failures, recognize at the moment the flaps are retracted, you may get a significant nose-down input.

That was not done, and that training, I think that lack of or the failure of that training to be widely disseminated is a contributor here.

Mr. DEFAZIO. OK. Thank you.

And Dr. Endsley, again, human factors. MCAS, at least in the first flight, first accident, not in the manual. I mean, do you think in terms of a human factors approach that pilots should have been made aware if something is running in the background that can radically alter the behavior of the airplane?

Ms. ENDSLEY. Absolutely.

Mr. DEFAZIO. Yeah.

Ms. ENDSLEY. It is very hard to understand and diagnose what the plane is doing when it is a system you have never even heard of. They didn't have any information about why it was acting erratically, and as Captain Cox just pointed out, they didn't even

have good cues that would match up to running the procedure that Boeing assumed they would be able to run very rapidly.

Mr. DEFAZIO. Mm-hmm.

Ms. ENDSLEY. So, it was really this whole combination of factors of no information on the flight manual, no training, and no adequate displays that were just the worst possible combination.

Mr. DEFAZIO. Thank you. So then, and we have kept you a long time. This will be the last question, and I would ask anybody or everybody who wants to respond. What do you think is the biggest concern this committee should focus on regarding the FAA's capability of overseeing Boeing production and novel systems, given everything you have heard here today? I will start with Captain Cox.

Mr. COX. I think, based on the things that I have heard today and what I have learned over the months of watching this, I would encourage the committee: Don't get too focused. The JATR report was very good in taking a holistic view.

There is not a single cause to this accident, and you have a rare opportunity if the committee will view it in its entirety of the complexity, you can help really significantly promote aviation safety going forward, and I think that that was reinforced today here. There is an awful lot of focus on the FAA. There is an awful lot of focus on Boeing, and they are two of the major contributors to these tragedies, but they are not the only ones.

And so, I would encourage in the strongest possible term, sir, keep the focus broad.

Mr. DEFAZIO. Right. Well, and I would agree, and in terms of the AOA, we did have a company that hadn't repaired the AOA that was on—was that on Lion Air, I think, that they had even lost their license.

Mr. COX. Yes, sir, and if I might, the installation of the angle-of-attack sensor——

Mr. DEFAZIO. Mm-hmm——

Mr. COX [continuing]. On the Lion Air airplane. There is a calibration procedure that has to be followed, and the maintenance department signed off that they did it. It is not possible that they did.

Mr. DEFAZIO. Right, because it immediately was——

Mr. COX. Because that is very specifically what the procedure is for——

Mr. DEFAZIO. Mm-hmm——

Mr. COX [continuing]. Is to determine the accuracy of the sensor output.

Mr. DEFAZIO. Mm-hmm.

Mr. COX. So, this is, to come full circle——

Mr. DEFAZIO. Yeah——

Mr. COX [continuing]. This is the reason I say, "There is a lot of contributing factors."

Mr. DEFAZIO. Right. I get that.

Dr. Endsley, do you——?

Ms. ENDSLEY. Yes. There has been considerable discussion here today and also previously in the press about concerns about safety culture at both Boeing and the FAA that sort of underlie a lot of the failures we saw in good process and ended up being in good design.

The FAA Administrator and Boeing have made a number of announcements of things they are going to do to try to fix that, and we are glad to see that, but changing culture is really hard. You can't just give a one-shot and it is done. It is something you have to do every day.

It has a lot more to do with actions than with words, and so, the importance of really following up on those actions of taking safety issues very seriously, of reprioritizing safety with regard to production and cost in schedule, those changes are going to require a lot of continued interaction by management, and it is going to require bringing in a lot of people who are knowledgeable about these things to get those changes moved through the organization, and the NTSB has been talking about the importance of safety culture for the last 20 years. It is something we really need to emphasize as well as solving some of these basic process problems.

Mr. DEFAZIO. And I agree with you on that 100 percent. At my first meeting with Mr. Dickson when he was nominated, I talked to him on what I view as the principalities within FAA who seem resistant to Administrators and changes from that level, and he assured me that he was going to be reaching down in the organization and trying to change the culture.

So, Mr. Collins.

Mr. COLLINS. I agree with everything she said about changing the safety culture, and what Administrator Dickson talked about was all hands meetings and things. I think he needs to get down in the working level more, talk to groups of people. I was a union rep. The union reps usually feel a little more free and a little more protected in discussing issues than most employees but, you know, talk to them in the offices. The Seattle office for sure.

We always hear the conversation about resources and sure, you could use more aerospace engineers and maybe manage the resources better, but the lesson that I would like to leave is that when you have those resources and they identify safety issues, that really concerns me. The ones that are missed, you can do improvements and better oversight, but when managers are made aware of safety issues and compliance issues, I wish there would be a culture shift so that they would give more credibility and more thought to compliance versus production schedules and things.

Mr. DEFAZIO. OK. Thank you.

And finally, Mr. Pierson.

Mr. PIERSON. Congressman, I think just to try to keep it simple. First, an investigation. A detailed investigation of the production facility I think is definitely in order, and a very important thing is to maintain a presence in the factory. I should have mentioned earlier that I was there for 3 years and honestly, I had never saw, I never met an FAA employee in my 3 years in——

Mr. DEFAZIO. Really?

Mr. PIERSON. Yes, and I never actually remember any of my employees saying they talked to an FAA employee. Now, they may have been there, but they certainly weren't visible and present. My son said, "Shouldn't they be wearing a jacket or something?" Or maybe they should know that this is FAA people so if we are not getting the problem resolved by our normal chain, we need the regulators to do that.

And the last thing I would say is that you could have the most amazing design by the most brilliant engineers and flown by the most talented pilots, but if you have a tired mechanic or electrician that is overworked or a technician that is stressed because they haven't had a chance to take care of their family because they have been working so many hours, it could all be for naught.

So, don't lose sight of the fact that, again, we have to do the whole thing. Some from the design all the way out to ongoing production into the future.

Mr. DEFAZIO. Thanks, and yeah. Just on reflecting on your comment about not seeing an FAA employee on the floor, I mean, a number of years ago, I raised concerns when, as we moved more to an agency which, and this was more in terms of maintenance than production, but where they were spending much less time at maintenance facilities and more time reviewing paperwork they received from maintenance facilities, and I think it is vital for them to actually have a presence and they may not personally observe something while they are there, but it may be some employee who would want to come up to them and say, "Hey, I have got some concerns here. You are from the FAA. I want you to hear this."

Mr. PIERSON. Absolutely.

Mr. DEFAZIO. Yeah. OK. Well, thank you all. Thanks for your generous allowance of time. I appreciate your testimony, and we are going to continue with this investigation. I want to, again, give my condolences to the families, and thank you for your constructive—and I have to do some stuff, so just hang on for a second. My script.

OK. I assume this has got the right days here. We remain open until such a time as our witnesses have provided answers to any questions that may be submitted to them in writing.

So ordered.

I 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.

And again, I thank you, and I have nothing else to add, so the committee stands adjourned.

[Whereupon, at 3:35 p.m., the committee was adjourned.]

SUBMISSIONS FOR THE RECORD

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 issues related to the design, development, and certification of the 737 MAX. I am eager to hear from our panel of witnesses and receive testimony from Federal Aviation Administration (FAA) officials; a member of the Technical Advisory Board, which is an independent review panel established by the FAA to issue recommendations related to the certification of the 737 MAX; whistleblowers; and aviation safety experts.

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 simply, how we can prevent these accidents in the future.

As to safety, the Boeing 737 MAX was marketed as a safe, modern airplane; 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. The safety systems and backup systems on the Boeing 737 MAX failed to work properly and resulted in 356 deaths, including 8 Americans.

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. As I have noted before, 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. It is clear that the certification of this aircraft failed to detect technical problems from which even experienced pilots could not recover.

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. My heart truly goes out to the families who have lost loved ones in these tragedies.

Again, I look forward to the testimony of the witnesses 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 as we work to regain the trust of the American people in the airline industry.

Prepared Statement of Hon. Frederica S. Wilson, a Representative in Congress from the State of Florida

Thank you, Chairman DeFazio.

Thank you to our witnesses for being here.

I want to begin by extending my deepest condolences to the families and communities that lost loved ones in the Lion Air and Ethiopian Airlines crashes.

News reports and investigations have uncovered systematic failures that must be addressed at every level and I am committed to understanding each failure that led to the loss of 346 lives.

I am also committed to honoring the victims by using the full power of this committee to ensure the flying public's safety.

Based on the testimony set before me, I am concerned that actions and decisions were taken that ultimately abused legislation passed through this committee.

The FAA has routinely lauded its safety record with zero fatalities over the last decade.

These accidents must serve as a wake-up call to remind us that none of us can rest on our laurels.

In light of the information that has surfaced in the last few weeks, the decisions that we come to through this hearing must extend beyond fixing the MCAS system or a few lines of code to address the negligence that led us here.

We must address the Organization Designation Authorization program and the cozy relationship between Boeing and the FAA.

Our citizens deserve that.

The families who lost loved ones deserve that, too.

With that I will begin my questions.

Lists A and B, Submitted by Hon. DeFazio

Lists A and B:

- 9/11/2015 EASA letter to FAA
- 3/21/1997 Issue Paper
- 2/11/2015 FAA Letter to Boeing
- FAA-DeFazio—28834–28842 TAD Corrective Action Review Board (CARB) Presentation Form
- FAA-DeFazio—28843–28860 Safety Review Board information
- FAA-DeFazio—32891–32938 Presentation: BCA Airplane Programs, Organization Designation Authorization Technical Review Board

9/11/2015 EASA LETTER TO FAA

EASA
European Aviation Safety Agency

[redacted]
Project Certification Manager
Certification Directorate

2015(D)54135
CVU/aco/CT.1.1
Cologne, 11 Sept. 2015

Attn.: [redacted]
B737 MAX Program Manager

Federal Aviation Administration
International Branch, ANM-116
1601 Lind Avenue SW
Renton, Washington 98057-3356
U.S.A.

Attn.: [redacted]
737 MAX Regulatory Administration

THE BOEING COMPANY
P. O. Box 3707, MC 9U-EP
Seattle, WA 98124-2207
U.S.A.

Subject: **B737-7/-8/-9 (MAX): Uncontained Engine Rotor Failure event – Flight Control case**

Project: 0010018697

Attachment: EASA letter CVU/aspa/C(1.1) 2014(D)50520 dated 30/01/2014
CRI E-14/MAX Issue 1 dated 30/01/2014

Dear [redacted]

By this letter, and following the recent communications between EASA and FAA, we would like to share our concerns on the Uncontained Engine Rotor Failure (UERF) scenario that we have raised on the B737 MAX project.

In the frame of the B737-7/-8/-9 MAX project that introduces the new LEAP 1B engines, EASA raised a CRI addressing the issue in a general manner as well as in the focus of the flight controls.
This CRI E-14/MAX was released to Boeing on 30/01/2014, and since then, the EASA has not received any formal input, more than a year and half ago.

One year ago in October 2014, during the quarterly meeting in Seattle, a presentation was made by Boeing where panels 4 and 7, as well as the PCM participated. During this meeting, Boeing presented their arguments making a design change for the rudder impracticable. At that time FAA was convinced that 4 out the 8 design change trading-off were deemed potentially practical and requested further investigation from Boeing.

A year later, there is still no progress and communication from Boeing on this matter neither on the CRI nor during the subsequent EASA panel regular meetings (conference calls or face to face meetings).

Due to the fact that the CRI has never been answered by Boeing, there was no opportunities for EASA to better understand the design and the Agency is concerned to receive late information with no time to analyse properly and to exchange deeply with FAA, and with no possibilities to influence any decision that may be taken.

With this letter, EASA requests Boeing to make some progress on the overall problematic of CRI E-14/MAX and in particular the following points are expected to be addressed:

- Detail the design modifications to address the UERF/Rudder (MAX)
- Justify the design modifications to address the UERF/Rudder impracticalities (MAX)
- Contribution of the UERF / Rudder scenario to the overall 1/20 safety objective (MAX)
- Contribution of the UERF / Rudder scenario to the overall 1/20 safety objective (NG)
- Detail the design modifications to address the UERF/Elevator (MAX)
- Justify the design modifications to address the UERF/Elevator impracticalities (MAX)
- Contribution of the UERF / elevator scenario to the overall 1/20 safety objective (MAX)
- Contribution of the UERF / elevator scenario to the overall 1/20 safety objective (NG)

In addition to the expected formal Boeing 's position onto CRI E-14/MAX, EASA is willing to have a dedicated Panel 0/ Panel 4/Panel 7 discussion on Wednesday 30th – 08:30 CGN time to accommodate Panel 4 expert participation.

We thank you in advance for your understanding and active support.

Your sincerely,

[redacted]

[redacted]

Cc. (email): Boeing: [redacted] B737 MAX generic mailbox, Boeing generic email BDCO
EASA: [redacted]
FAA: [redacted]

ISSUE PAPER

PROJECT: Boeing Commercial Airplane Group
737-600/-700/-800
AT0328SE-T

REG.REF.: §§ 25.903

NATIONAL POLICY REF.: AC20-128

SUBJECT: Engine Rotor Non-Containment and Critical Flight Controls

ITEM: S-14
STAGE: 4, Revised

DATE: March 21, 1997

ISSUE STATUS: CLOSED

BRANCH ACTION: ANM-120S, 130S, 140S, 160S, ANM-AEG

COMPLIANCE TARGET: Pre-TC

STATEMENT OF ISSUE:

The Boeing Model 737-700 airplane directional flight control systems addressed in this issue paper consist of single loop cable systems controlling a flight control surface necessary for safe flight and landing. Primary flight control surfaces include the rudder, elevator, or aileron control systems. If critical portions of the flight control system passing through the engine rotor burst zone are damaged, control of the primary surface is lost. The current rudder control system design does not utilize design precautions considered to be practical to minimize the hazards following an uncontained engine failure.

BACKGROUND:

Following the Sioux City DC-10 accident, which was caused by an uncontained engine failure that damaged critical flight control systems, the FAA initiated a review of critical flight control system designs to determine what improvements would be needed to preclude loss of airplane control due to damage to critical flight control systems. This review confirmed that existing guidance for minimizing the hazards from uncontained engine failure defined by AC20-128, was adequate. This guidance includes separation, isolation, redundancy and shielding. During a recent certification review of the flight control systems on a transport category airplane it was determined that the applicant utilized a single loop cable driven flight control system. On this airplane the rudder control cable loop was routed through the engine rotor burst zone. During the takeoff exposure time, severing of either cable in the rudder control cable loop would result in a catastrophic event. Beyond this exposure time (20-40 seconds), rudder trim (separated from the

main cable loop) and other aerodynamic controls were available to provide for continued safe flight and landing.

Based on these findings, a survey of the rudder designs of the transport category airplane fleet was initiated. The findings of the survey indicated that the criticality of the rudder system varied depending upon the flight control effectiveness. For example the Boeing Model 727 remained controllable with a failed rudder system throughout the flight envelope, whereas, airplanes with wing mounted engines generally were not controllable during the takeoff phase of flight. All recent turbopropeller airplanes had rudder system design features that minimized the hazards from uncontained failure due to the requirements of §25.571 which required damage tolerance to be demonstrated for the likely structural damage resulting from an uncontained engine or propeller blade failure. It has not been practical for turbopropeller airplanes to comply with the damage tolerance requirement for propeller blades and therefore exemptions had been requested from this requirement. As part of the exemption process the FAA required that design features to minimize the effects of propeller damage be incorporated. Manufacturers typically incorporated dual redundant rudder systems or rudder bias systems as part of the compensating features of the exemption.

With regard to rudder control systems of recently certificated airplanes, the Transport Airplane Directorate sent out a survey to all local Aircraft Certification Offices in December 1994. Review of the survey results indicates that the FAA has required applicants for new type certificates to show that the rudder system is not critical or to provide redundant/separated rudder controls on recent projects. The following airplanes provide redundant separated rudder control systems as a means of compliance with §25.903(d): the Dornier 328; the Saab 2000; the Canadair Regional Jet; the Canadair Challenger; and the BAe 4100. The following airplanes have non-critical rudder systems: Falcon 2000; and Fokker-series airplanes. In addition, the following airplanes, for which applications for type certification have been received, have dual separated systems: Canadair Global Express; the Lear 45; the LET 610; IAI Galaxy; and the B777.

The success of these recently certificated airplanes demonstrates that designs with non-critical rudders, automatic rudder bias systems, or dual path rudder control systems within the uncontained engine debris zone are both technically feasible and economically a means to minimize the hazard to the aircraft from an uncontained engine failure.

There are a number of currently approved airplanes which have been found to meet the requirements of §25.903 with single-loop rudder cables passing through the rotor burst zone. These designs primarily utilize automatic rudder bias systems to provide rudder authority during the takeoff phase and have separated rudder trim systems that allow for the remainder of the flight envelope.

FAA POSITION:

The FAA has reviewed the design of the Boeing Model 737-700 airplane rudder control system, and hazard minimization features incorporated into the airplane design for protection from an engine rotor non-containment event. The proposed design concept of a single-loop flight control system, including rudder systems, which passes through the engine rotor burst zone does not meet the minimization requirements of §25.903(d)(1).

The standard of minimization as applied to control cables as discussed above should be applied to projects of a new, amended, or supplemental type certificate when either of the following modifications are made:

1) Installation of new or modified engines that increase the hazard to the flight controls because of the number or size of the rotor diameters.

2) Structural modifications (other than minor structural strengthening) in the area of the engine strike zone.

To ensure that the FAA's concern for the vulnerability of a single loop critical flight control system is addressed, this issue paper will inform Boeing that §25.903(d) and current related advisory material applies to all critical flight controls, including the rudder controls, within a rotor debris zone, and applies for all phases of flight, including takeoff. Further, it should be stressed that compliance with § 25.903 requires the use of separation, isolation, and redundancy as the principle means of showing compliance, not probability calculations. The proposed rudder control system for the Model 737-700 does not appear to comply with those requirements. The proposed system must be changed to comply with the current interpretation of §25.903(d).

APPLICANTS POSITION: (Reference Boeing letter B-T111-96-0238)

The FAA issue paper S-14 stated that the 737-700 rudder control system design does not satisfy a new FAA interpretation of the minimization requirements of FAR 25.903(d)(1). It also stated that the new interpretation of minimization, which would require redundant separated rudder controls, should be applied to all new airplane programs, and to any amended or supplemental type certificates when either of the following modifications are made:

1) Installation of new or modified engines that increase the hazard to the flight controls because of the number or size of the rotor diameters.

2) Structural modifications in the area of the engine strike zone.

It is Boeing's position that the risk for the 737-700 rudder control system has been minimized per FAR 25.903(d)(1) by separating the pedal and trim command paths. Furthermore, the new interpretation of minimization does not apply to the 737-700 because:

1) The 737-700 engine disk sizes are smaller than the 737-3/4/500 and therefore the overall risk for the rudder cable failure due to an engine burst is slightly less on the 737-700.

2) The structure has not been modified in the area of the engine strike zone where there is exposure to damaging the rudder cables.

CONCLUSION:

The criteria established, at Stage 2 of the issue paper, for requiring application of the standard of minimization of hazards for modifications made to current certificated airplanes were met by the Model 737-700 design.

Advisory Circular 20-128, "Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures," which was written to provide guidance and an acceptable method of compliance to 14 CFR 25.903(d)(1), states that "Modifications made to current certificated airplanes should not compromise the original airplane safety level relative to uncontained engine or APU rotor or fan blade failures." The Transport Airplane Directorate established the following criteria relative to flight controls:

> The standard of minimization as applied to control cables should be applied to projects of a new, amended, or supplemental type certificate when either of the following modifications are made: (1) Installation of new or modified engines that increase the hazard to the flight controls because of the number or size of the rotor diameters; or (2) Structural modifications (other than minor structural strengthening) in the area of the engine strike zone.

Boeing has stated that neither of the above modifications have been made to the Model 737-700. In addition, the Model 737-700 flight controls architecture and routing has not changed significantly from Model 737-300 within the burst zone. Therefore, solely because of the guidance provided above for modifications made to current certificated airplanes, compliance to § 25.903(d)(1) can be found for the critical flight controls.

Boeing should be aware that further increase in thrust, introduction of new engines, or changes to the structure or flight control system will necessitate a review of the FAA position and the requirements for redundancy and separation in the flight control systems. In anticipation of a long life for the new Model 737 derivative airplanes and the potential for changes, in particular growth in engine power or new engines, the FAA believes greater redundancy and separation in the design of the flight control systems in the vicinity of the rotor burst zone should be incorporated, although such improvements are not required at this time. In addition, it should be noted that for future certification programs, a greater level of minimization would be expected for a new type certificated aircraft.

The CONCLUSION section of this issue paper has been revised since Stage 4, dated August 12, 1996.

[redacted]

Transport Airplane Directorate
Aircraft Certification Service

5/1/97

Date

CONTACTS:

TITLE	NAME	PHONE
Originator	[redacted]	[redacted]
Project Manager	[redacted]	[redacted]
Project Officer	[redacted]	[redacted]

[redacted]

2/11/2015 FAA LETTER TO BOEING

U.S. Department
of Transportation
Federal Aviation
Administration

Transport Airplane Directorate
Aircraft Certification Service
Boeing Aviation Safety Oversight Office
1601 Lind Avenue Southwest
Renton, Washington 98057-3356

FEB 11 2015

In Reply
Refer To: 100B-15-69

[redacted]
ODA Lead Administrator
Regulatory Administration
Boeing Commercial Airplanes
P.O. Box 3707, M/C 03-56
Seattle, WA 98124-2207

Dear [redacted]:

Subject: 737 MAX Uncontained Engine Rotor Failure

References:
(1) Issue Paper SF-1, "Engine Rotor Burst and Rudder Mechanical Flight Control Cables," Stage 2, dated February 10, 2014
(2) FAA letter 100B-14-623 dated October 28, 2014
(3) FAA letter 100B-14-769 dated December 19, 2014

As shared with you in the January 26 and 28, 2015 meetings held between Boeing and the Federal Aviation Administration (FAA), we are concerned about the lack of progress and would therefore like to reemphasize our expectation for a timely resolution of the subject issue. During these discussions, the Boeing 737 MAX program informed us that they are not proposing a solution that will separate or protect the rudder control system to prevent loss of control of the airplane in any axis due to an uncontained engine failure (UEF) as called for in Advisory Circular (AC) 20-128A. It's worth noting that other design solutions that Boeing had previously considered and the Organization Management Team (OMT) believes may be practical to implement are considered by Boeing to be impractical. The FAA has previously sent letter references (2) and (3) requesting additional information showing why these approaches, some of which involve technology incorporated into transport airplanes in the 1990's, are not practical for the 737 MAX. Based on information Boeing shared in the January 26 and 28 meetings, we also now have questions regarding Boeing's intended method for protecting airframe structure from UEF.

Title 14, Code of Federal Regulations 25.903(d)(1) requires that the applicant take design precautions "to minimize the hazards to the airplane in the event of an engine rotor failure." We established AC 20-128A with industry involvement to provide an accepted method of compliance (MOC) with the requirements of § 25.903(d)(1). The MOC in AC 20-128A involves incorporating design precautions to minimize the hazards by "effectively eliminating specific risks and reducing the remaining specific risks to a minimum level" as stated in paragraph 8 to reduce the overall risk to an airplane created by UEF. With regards to flight controls, AC 20-128A, paragraph 8.c.(1) further states that "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."

Note that § 25.903(d)(1) requires the applicant to assume that UEF will occur. Therefore, use of probability of UEF should not be considered as part of a proposed MOC as it does not meet the plain language of the regulation.

Following the 1989 Sioux City DC-10 accident, the FAA determined the compliance means to § 25.903(d)(1) for "minimizing the hazards" from UEF were inadequate and tasked the Aviation Rulemaking Advisory Committee (ARAC) with developing a harmonized revision to AC 20-128. The ARAC group, co-chaired by Boeing, reviewed the transport fleet accident records and airplane design practices used by manufacturers and developed criteria for "minimizing the hazards" from UEF in accordance with the regulatory language of § 25.903(d)(1). ARAC determined that loss of airplane control due to damage to the flight control system, the cause of the Sioux City accident, was a hazard that could be eliminated through "practical design precautions" for which the ARAC also proposed criteria. ARAC's 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. ARAC determined incorporation of redundant cables or dual path rudder control systems within the rotor burst zone, means for the flight crew to maintain control of the airplane by use of trim controls or other means, shielding, and other features could be employed as "practical design precautions" to "minimize the hazard." The FAA adopted these ARAC recommendations by incorporating them into AC 20-128A in 1997 and retained the ARAC language that "Airplane designs submitted for evaluation by the regulatory authorities will be evaluated against these proven design practices."

The FAA raised this issue at the time of the 737NG certification in the 1990's. In 1997, the FAA determined that the 737NG complied with § 25.903(d)(1) based on existing guidance in the original AC 20-128 that was in place during Boeing's showing of compliance phase of the 737NG. However, at that time the FAA set the expectation in issue paper S-14 that design changes including new engines or further increase in thrust would necessitate further review. Considering this coordination, the FAA expected Boeing to have sufficient time to define a solution and plan to address this issue for the 737 MAX program.

Based on the installation of new engines, increased number of rotors and the increase in thrust, the FAA raised the issue with Boeing at the beginning of the 737 MAX program. In developing the project specific certification plan, the FAA and delegated organizations are required by FAA Order 8110.4C, paragraph 2-4.i.(2) to ensure that certification plan commitments are consistent with FAA policy which in this case is reflected in AC 20-128A. Following discussion with Boeing on the subject, the FAA signed the reference (1) issue paper.

Boeing has stated in various meetings, including the June 13, 2013 presentation to the European Aviation Safety Agency, their intent to follow AC 20-128A as the means of compliance to § 25.903(d)(1) for the 737 MAX. However, Boeing has not shown that their

latest proposal separates or protects the rudder control system or uses any other means to prevent loss of control of the airplane in the yaw axis due to UEF. Therefore, Boeing has not shown that the design minimizes the hazards to the airplane in the event of UEF as required by § 25.903(d)(1) and as indicated in AC 20-128A.

During the January 26 meeting, we also learned that Boeing's interpretation of the "1:20" allowance for structural discrete source damage due to UEF may not be in line with the guidance of FAA Policy Statement PS-ANM100-1993-00041. This memo provides guidance on performing a risk assessment to show compliance to § 25.571(e) for designs that cannot guarantee continued safe flight and landing for every failure scenario. This approach was documented in the conclusion of the 737NG issue paper A-4, dated January 22, 1997. We have communicated our concerns to you and the Boeing 737 MAX program. A formal request for a Potential Airworthiness Standards Noncompliance to § 25.571(e) has been addressed to Boeing in letter 100B-15-86.

We recognize that certain aspects of designing for compliance merit a different approach for an amended type certificate project compared to a new type certificate project. Based on our discussions with Boeing, we believe Boeing can show they have designed the elevator control system in a manner that effectively eliminates specific risks and reduces the remaining specific risks to a minimum level per AC 20-128A. However, the FAA is still seeking significant improvement from Boeing in designing precautions for the 737 MAX rudder control system to minimize the hazards to the airplane in the event of UEF.

In the January 28 meeting, Boeing stated that it would respond to the issue paper on February 16, 2015. If Boeing is proposing to deviate from the guidance included in AC 20-128A and use a different MOC to protect the rudder control system, Boeing is requested by the FAA to incorporate that position into the reference (1) issue paper and expedite submittal to the FAA for our review and consideration. Prior to submitting the Boeing position, the Boeing ODA Regulatory Administration must ensure, in accordance with Order 8100.15B, paragraph 3-6.b, that the Boeing response meets FAA regulations and policy. Although the Boeing proposal may deviate, the Boeing ODA Regulatory Administration must still ensure it is consistent with the policy contained in AC 20-128A. Failure to proceed to resolution of this issue in a timely manner may create a risk to the certification schedule.

If you have any questions, please contact [redacted] by telephone at [redacted] or by e-mail directed to [redacted]

Sincerely,

[redacted]

[redacted] Boeing Aviation
Safety Oversight Office, [redacted]

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18-PAD-0048

TAD Corrective Action Review Board (CARB) Presentation Form

CARB 1 – Unsafe Condition Determination

OEM COSP (21.3 Report) #	2018-1922
SACO Safety Investigation (SI) #	78-SI-0093
Monitor Safety / Analyze Data (MSAD) Event #	11876439
MSAD Safety Investigation #	
Noncompliance Notification Number (NCN) *(if applicable, or N/A)*	

Title: Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high

Engineer: [redacted]	**Branch:** AIR-783	**Date:**	12/11/2018
Branch Safety Position:	**Safety:** X	**Non safety:**	
Branch Mgr. Approval: [redacted]		**COS PM Review:** [redacted]	12/15/2018

Model(s)/Appliance Affected:	737-8/9 (MAX)		
Number of Affected Airplanes in Current Fleet:	US: 45	**Total:**	246
Does this issue affect current production?	Yes	No	
Does this issue affect out-of-production models (e.g., 727, 737CL, 757) **?**		No	
Yes *(provide LAACO contact)*		No	☒

Description of Service Difficulty or Issue:

On October 29, 2018, a 737-8 (MAX) crashed shortly after takeoff. Flight Data Recorder (FDR) data from the accident investigation suggests there was valid erroneous AOA sensor data associated with the captain's AOA vane. The bias in the high angle of attack direction resulted in activation of the MCAS function when the Flaps were retracted. The combination of the airplane nose down MCAS activation commands and airplane nose up pilot stab trim commands via the manual thumb trim switches resulted in excessive airplane nose-down attitude. The accident is still being investigated.

AD 2018-23-51 (November 7, 2018) required revising the Airplane Flight Manual (AFM). That AD identifies appropriate crew actions to mitigate the effects of a single AOA sensor. That AD was identified as interim action.

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Unsafe Condition or Consequences of No Action:

Repeated MCAS airplane nose down stabilizer trim commands resulting from a single erroneous valid high AOA sensor input, can, without appropriate intervention, can cause the flight crew to have difficulty controlling the airplane and lead to excessive nose-down attitude, significant altitude loss, and possible impact with terrain.

Manufacturer's Position:

Boeing has determined this to be Safety.

- Boeing issued a Flight Crew Operations Manual Bulletin to support AD 2018-23-51
- Boeing is developing design changes to the MCAS system.

Date of Meeting / Telecon with Manufacturer:	11/6/2018, Boeing SRB
Name of Manufacturer's Focal for this Issue:	[redacted]

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1. Quantitative Risk Assessment

Random Transport Airplane Risk Analysis (R-TARA) Version 2.4.2 10/20/2016

COS Item Number(s)	2018-xxxx
COS SI Number	16-SI-xx
MSAD Event Number	
MSAD SI Number	

Airplane Model	737 MAX
Branch	AIR-760
Engineer	[redacted]
Analysis Date	12/3/2018

CONDITION UNDER STUDY
Lion Air 737-8 (MAX) crashed about 10 minutes after takeoff from Jakarta, Indonesia, October 29, 2018.

SUSCEPTIBLE CONDITION (CP_1 and CP_2)
Describe any particular configuration that puts the airplane at risk.
If all airplanes are affected, all the time, then $CP_1 = CP_2 = 1$.
CP_1 represents the probability of a latent failure, and is calculated below (see Cell F42).
CP_2 represents the probability of flying in a critical condition (including cargo loading, passenger configurations, fuel load, etc. but excluding latent failures).

INITIATING EVENT (F)
One accident to date in approximately 135,980 cycles and 372,754 flight hours flown.

CAUSAL CHAIN (CP_3)
Describe how the event leads to the unsafe outcome. CP_3 is the probability that the event will lead to the unsafe outcome, for airplanes that are flying in the susceptible condition.

UNSAFE OUTCOME
Uncontrolled Crash, IR = 1.05

Adding not-yet-delivered airplanes: 250 airplanes now, 400 average over the entire program.

Per Flight Global database as of 11/25/18, Boeing has delivered 204 Max airplanes and orders for 4554, total of 4618. Rounding off to 4600 airplanes.

This page assumes interim action reduces the risk by a factor of 100. We still need HIP, NPRM or IAR.

Airplane flies in susceptible condition [CP_1, CP_2]

Airplane experiences event (system failure, pilot input, disturbance, etc.) [F]

Event leads to unsafe outcome (in-flight breakup, crash, etc.) [CP_3]

ANALYSIS IS IN: Flight Hours

TARAM Handbook Variables	Total Uncorrected Fleet Risk	Uncorrected Individual Risk	Control Program Fleet Risk	Control Program Individual Risk	90-day Fleet Risk	Description
F	2.683E-06	2.68E-06	2.68E-06	2.68275E-06	2.68E-06	Frequency of Occurrence (per flight hour)
UPT	113997.8					Remaining life (flight hours, per airplane)
Sigma	4600		200		250	Number of airplanes in affected fleet (average over fleet life)
CP_1	1	1	1	1	1	Probability of latent failure
CP_2	1	1	1	1	1	Probability of flying with critical cargo loading / passengers / fuel / etc.
CP_3	0.01	0.01	0.01	0.01	0.01	Probability that event causes unsafe outcome, given that airplane is in susceptible condition
IR	1.05	1.05	1.05	1.05	1.05	Injury ratio
EO			190		190	Exposed occupants
U (FH)			8.9		8.9	Utilization (flight hours/day)
U (FC)			4.5		4.5	Utilization (flight cycles/day)
CAD			112			Corrective Action Development (days)
RT			14			Rulemaking Time (days)
CT			30		90	Compliance time (days)

Risk Measures	Guidance Value	Calculated Value	Recommendation
Total Uncorrected Fleet Risk	0.02	15.373	Issue an AD
Total Uncorrected Fatal Events	N/A	14.6	
Total Uncorrected Fatalities	3	2920.9	Issue an AD under new guidance
Uncorrected Individual Risk	1.00E-07	2.82E-08	
Control Program Fleet Risk	3	2.01	
CFFR (Weighted Events)	0.02	0.01	
Control Program Indiv. Risk	10^{-9}, 10^{-6}	2.82E-08	
90-day Fleet Risk	N/A	1.07E+00	
NPRM Prioritization Rating	N/A	19.2	High Priority

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2. Qualitative Unsafe Condition Assessment Summary

Respond "YES" or "no" to each line item:

1.	**Airplane Safety:**		YES/no
	a.	The condition was likely a significant contributing factor in a catastrophic event (including relevant events on other airplane models).	Yes
	b.	The condition is **an approved design configuration**, or an escape of the production system, that could result in a catastrophic event.	No
	c.	The condition is a foreseeable single failure, cascading failure sequence, or common cause failure scenario that could result in a catastrophic event.	Yes
	d.	The condition is known or anticipated to occur in the life of the affected fleet and could result in: 1) Inability of a Principal Structural Element to sustain limit load, or 2) Any other structural failure that could result in a catastrophic event	No
	e.	The condition is anticipated to occur in the life of the affected fleet, is not likely to be detected by flight/cabin/ground crew, and brings the airplane within one foreseeable failure of a catastrophic event.	Yes
	f.	For multiple failure scenarios, a catastrophic event due to the scenario cannot be shown to be extremely improbable. *("Extremely improbable" implies probability of the order 10^{-9} or less, per AC 25.1309-1A.)*	Yes
2.	**Compromise of Required Safety Features:** The condition is a design shortfall, manufacturing escape, or failure that excessively reduces the availability or performance of a prescriptively required safety-related system or function.		No
3.	**Personal Unsafe Condition Determination:** The condition could result in serious injury or death to person(s) (including person(s) other than crew or passengers), and cannot be shown to be extremely remote.		No
4.	**Other (specify and provide rationale):**		

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Are the parts rotable?	Yes ☒	No
Rationale for rotability decision: Flight Control Computer (FCC) software is resident in the FCC. If an FCC is moved to another airplane, the Software can be moved to another airplane with the FCC.		

Note:
ADs that involve rotable parts require special handling, to ensure that the unsafe condition does not get rotated onto an airplane outside the applicability of the AD.
Components / parts that have the same form, fit, and function and can be removed from one airplane and installed on another airplane are considered ROTABLE. Structural components installed with a permanent fastener are not considered rotable. Points to consider:

- *Is the part physically capable of being installed on an airplane outside of the affected airplanes?*
- *Is this a part that could be removed from the airplane, modified or repaired, and reinstalled on another airplane?*
- *Is it reasonable to expect that the operators may have a reason to move the part to another airplane?*

Is this related to an Airworthiness Noncompliance?	Yes	No ☒
Noncompliance Notification Number (NCN):		
Associated regulations (14 CFR):		

Note:
Airworthiness noncompliance means the type design does not meet the requirements of one or more applicable Airworthiness Regulations (e.g., 14 CFR 25.571 or 25.1309). Boeing reports each noncompliance as a COS item with a description beginning with "NCN."

Is this related to a Manufacturing Nonconformity?	Yes	No ☒
Comments:		

Note:
Manufacturing nonconformity means the as-produced airplane does not conform to its type design, i.e., there has been a quality escape from the production system. If the nonconformity is explained in the "Description of Service Difficulty or Issue" on page 1, then it is not necessary to repeat that information here.

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Proposed FAA Action:	☐ Emergency AD (Complete short term safety determination) ☒ Immediately Adopted Rule (IAR) (Complete short term safety determination) ☐ High Priority Notice of Proposed Rule Making (NPRM) ☐ No Notice Final Rule (NFR) ☐ NPRM ☐ Supplemental NPRM **(see below)** ☐ Supersedure (NPRM/IAR/NFR) **(see below)** ☐ Special Airworthiness Information Bulletin (SAIB) ☐ No action required

Supplemental NPRM / Supersedure:	**Identify rationale for appropriate action:** ☐ **Effectivity error** *(change in affected airplanes, line #s, etc., should have been determined during SB development)* ☐ **Engineering error** *(incorrect part numbers, dimensions, processes, procedures, materials, and figures/illustrations)* ☐ **Unavoidable expanded scope based on fleet findings – new discovery outside scope of SB** *(additional airplanes affected and or areas affected based on the increase in scope due to fleet findings)* ☐ **New/current info changes FAA approach** *(FAA concurred with corrective action approach ... later decided on different approach. i.e., inspection approach to now requiring mod i.e., suction feed)* ☐ **Other** *(Any other issue that doesn't fall into the above categories)*

Short term safety determination (complete this section for emergency or IAR AD):

Per the TARAM analysis, the Control Program fleet risk is sufficiently low to allow continued growth of the fleet and operations until the changes to the system are retrofitted via Service Bulletin

Comments:

AD equivalent MCAS design change will be basic on the 737-7 at the time of Amended Type Certificate (ATC) issuance.

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End-to-End Airworthiness Directive Schedule Agreement

For Boeing issues, insert or attach:

(1) Boeing's draft End-to-End form, if they have provided one.

(2) A draft End-to-End form for CARB approval, that states the Risk Outer Marker Times (ROM-T) and Joint Preliminary Agreed Times (JPAT), as determined from the final risk analysis that you have coordinated with Boeing.

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APPENDIX 1 – Boeing Problem Solving Method (BPSM)

Planned AD Number:	*(to be filled in after CARB 1)*
Title:	737-8 (MAX) Lion Air Accident
Affected Airplane Model(s):	737-8/-9 (MAX)
Boeing COSP (21.3 Report) Number(s):	**2018-1922**
Noncompliance Notice (NCN):	*(if applicable, or N/A)*

FAA point of contact:

Name/Branch:	[redacted]
Phone number:	[redacted]
E-mail address:	[redacted]@faa.gov

Is Boeing required to submit a BPSM analysis document for this issue?

[X] Yes [ ] No

The FAA requests a BPSM analysis document for most safety issues, but it is not always necessary. In general, the focus of the BPSM will be on the causes that led or contributed to the unsafe condition. However, BPSM for supersedures and follow-on ADs should focus on the cause of the supersedure, and not the direct, technical cause that led to the unsafe condition. In other cases, the focus of the BPSM may be procedural issues.

What should be the focus of the BPSM?

[X] **Underlying causes or factors related to the unsafe condition**
Example: Three independent aircraft components all go "off-line" simultaneously due to a software counter overflow error.
Focus Areas: Are the specifications insufficient in this, and possibly other systems? Do they protect future designs from being subject to a similar failure mode? Is a cross-model, cross-system review needed?
Comments: BPSM is required, however the BPSM associated with AD 2018-23-51 is for the same issue. Two BPSMs are not necessary – the two planned ADs can be combined into a single submittal.

[ ] **Effectivity error**
Example: Change in affected airplanes (line #s, etc.), should have been determined during original service bulletin (SB) development.
Focus Areas: How were these airplanes missed the first time around? What measures are in place to capture the correct effectivity for future issues?
Comments:

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☐ **Engineering error**

Examples: Incorrect part numbers, dimensions, processes, procedures, materials, and figures/illustrations.

Focus Areas: What led to the errors in the service information? Why weren't the errors identified and corrected during the review/approval process before the service information was released?

Comments:

☐ **Unavoidable expanded scope based on fleet findings – new discovery outside scope of SB**

Example: Additional airplanes affected and or areas affected based on the increase in scope due to fleet findings

Focus Areas: Additional airplanes: Were relevant changes to production and their implementation points (affected line numbers) correctly identified? Did the production fix cut-in point match the effectivity of the SB? Was the production fix ineffective in correcting the problem?
Additional areas: How was the original scope of the problem determined? Was the originally-determined root cause complete and correct?

Comments:

☐ **New/current information changes FAA approach**

Example: FAA concurred with corrective action approach … later decided on different approach, i.e., inspection approach to now requiring mod (i.e., suction feed)

Focus Areas: What caused the original approach to be ineffective? Was the originally-determined root cause complete and correct? Why didn't the original BPSM (or equivalent method in place at the time) identify an effective solution?

Comments:

Note: BPSM may not be required for terminating actions (e.g., when an AD that mandates inspections as an interim corrective action is superseded by an AD that mandates a terminating modification).

☐ **Process, procedure, or other issues**

Example: Any other issue that doesn't fall into the above categories

Focus Areas: *Describe in detail the areas of interest for this issue.*

Comments:

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PSI Criteria: *P-B-1A*
Eng. Functional Leader: [redacted]
Prime TRB: *Systems*

Presentation Date: *11/15/2018*
Issue Owner: [redacted]
Resp. Eng. / Presenter: [redacted]

Airplane Model(s) Affected: *737MAX*

Issue Title: Erroneous AoA (Angle of Attack) Data Results in High Crew Workload

SRB Decision 11/15/18:

- [X] **Safety Issue** [X] Airplane [ ] Personal *List Models:* 737MAX
- [ ] **Not a Safety Issue** *List Models:*
- [ ] **No Safety Determination**
  - [ ] 1. Addressed by Existing Safety Process Action
  - [ ] 2. Under Active Government Investigation [ ] ASI Concur?
  - [ ] 3. Security Issue
  - [ ] 4. No Apparent or Suspected Boeing Product Contribution
  - [ ] 5. Insufficient Informat on

- [ ] **Request for Additional Time** **ECD:**

Reason Additional Time is Needed:

- [ ] **Referral to Cross-Program SRB** **Target X-SRB Date:**
- [ ] **Other SRB Action:**

<see BPG 298-17 04658, "Boeing Commercial Airplanes In-Service Product Safety Process Guide" for definitions>

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COSP Title:	Erroneous AoA (Angle of Attack) Data Results in High Crew Workload		
Event Airplane Information:	*LN7058*	*~800 FH*	*~400 FC*

Background:

- *MCAS (Maneuvering Characteristics Augmentation System) implemented on 737MAX to address pitch up tendencies at high angles of attack near stall conditions*
- *Single undetected AOA failure (high) can result in MCAS application of stabilizer nose down trim to the MCAS commanded limit from initial stab position*
- *Wheel/column trim switch resets MCAS*
- *Five seconds after last manual trim MCAS reasserts nose down trim if high AoA still present*
- *Pilots are able to use column trim switch to override MCAS input; which also resets MCAS*
- *Crew response for perceived stabil zer runaway is to activate aisle stand Stab Cutout Switch per Runaway Stabilizer NNC*
- *Subsequent repeated cycles of MCAS trim that are not fully reset via manual trim can exceed column authority*
- *Potential airplane effects that may increase workload that can complicate crew response :*
  - *Stick shaker activation*
  - *Activation of Elevator Feel Shift (increased column feel forces)*
  - *IAS DISAGREE message may appear on the PFD Speed Tape*

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MCAS Overview

The larger diameter 737MAX engines degrade a marginal pitch-up handling characteristic of the 737MAX wing at high angle of attack.

Maneuvering Characteristics Augmentation System (MCAS) commands nose down stabilizer to augment the unsatisfactory pitch-up handling characteristics

MCAS was implemented to improve the stick force gradient sufficiently to meet the requirements as shown in Figure 1.

Originally implemented for wind up turns. MCAS was expanded during the 737-8 flight test program to improve stall characteristics and identification during level flight.

[redacted]

MCAS is activated without pilot input and only operates in manual, flaps up flight

Mach limits

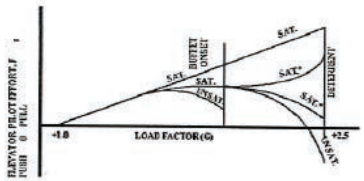
- **0.20<= Mach<=0.84**

AOA trigger is a function of Mach

Nose Down Stabilizer is a function of Mach & Delta AOA

- **Maximum authority set at up to 2.5 deg**
- **Stabilizer rate = 0.27 deg/sec**

Figure 1. (AC 25-7C Figure 31-1)



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System Description / Operation:

Implementation of MCAS

- MCAS function commands nose down incremental stabilizer deflection
  - Triggered by AoA exceeding identified threshold
  - Nose down stabilizer deflection limited to no greater than 2.5 degrees per MCAS activation
- MCAS is hosted in both FCCs.
  - Active Flight Control Computer (FCC) toggles for each flight.
  - Defaults to left FCC after power up, then alternates by flight.
  - Active FCC not affected by Flight Director switches or MCP master lights.
- MCAS uses AoA vane associated with the active FCC.
- MCAS bypasses column cutout function to allow ND stabilizer during NU column.
- Pilot manual trim or stabilizer aislestand cutout switches will override MCAS

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Root Cause:

- ***An erroneous AOA input that is undetected may cause MCAS operation and increase crew workload***
- ***Electrical failures might be another means of erroneous input.***

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Scope:

- ***737MAX airplanes in the fleet***
- ***737MAX deliveries and 737-7 ATC***

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Airplane Models Affected by the Potential Safety Issue:

Airplane Type/Model *	Model Affected by Issue?		Rationale (provide rationale for each airplane type/model)
	Yes	No	
707 / 727		X	
737-200/300/400/500		X	
737-600/700/800/900/BBJ		X	
737-7/8/9	X		
747-100/200/300/SP		X	
747-400		X	
747-8		X	
757		X	
767		X	[redacted]
777		X	
787		X	
717		X	
DC-8		X	
DC-9 / MD-80 / MD-90		X	
DC-10 / MD-10		X	
MD-11		X	
Other			

* *Applicability evaluation is intended to consider all relevant Boeing design approvals. This includes all Type Certificated models, TC'd military derivatives, minor models not listed, Boeing-held STCs, Boeing Service Bulletin modifications, etc. Applicability is NOT meant to include new designs prior to Type Certification, or non-TC'd military designs (ref. BPI-2748 and BPG 293-17-04658).*

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Safety Decision:

Airplane Level Safety Category 1D. Attention Level A, for 737MAX.

Summary Rationale:

The potential for loss of CSF&L due to inappropriate flight crew response to airplane effects resulting from AOA vane error is assessed to be more probable than 1E-9 per flight cycle. This decision supersedes the prior Category 3 "Other" safety decision from 11/6/18.

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Safety Decisions Guidelines

Meeting any one of the following guidelines shall be sufficient to identify a Safety Issue.
<see BPG 298-17-04658 for Guidance on PSI Evaluation using the Safety Decision Guidelines criteria>

	Yes	No
1. AIRPLANE SAFETY		
A. The condition was likely a significant contributing factor in a catastrophic event (including relevant events on other airplane models)	TBD	
B. The condition is a foreseeable single failure for which avoidance of a catastrophic event cannot be reasonably assured.		X
C. The condition is foreseeable, will result in inability of a Principal Structural Element to sustain limit load and avoidance of a catastrophic event cannot be reasonably assured.		X
D. A catastrophic event resulting from the condition is: **(1) More probable than 1E-09 *, unless the likelihood of a catastrophic event during the remaining life of the fleet is less than 10% **** **Or,** **(2) More probable than 1E-07 *, regardless of fleet risk.** * Average per-flight-hour or per-flight cycle probability as appropriate. See guidance. ** 10% fleet risk caveat is for issues affecting only out of-production models under LAACO jurisdiction.	X	
2. PERSONAL SAFETY **The condition could result in serious injury or death to person(s), including person(s) other than passengers or crew, and cannot be shown to be extremely remote.**		X
3. OTHER **An issue that any board member considers to be a safety concern, provided that supporting rationale is presented and accepted by the Board.**		

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COSP No.: 2018-1922

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FAA Transport Airplane Risk Assessment Methodology Worksheet:

ANALYSIS IS IN: Flight Cycles

TARAM Handbook Variables	Total Uncorrected Fleet Risk	Uncorrected Individual Risk	Control Program fleet risk	Control Program Individual Risk	90-day Fleet Risk	Description
F	3.80E-08	3.80E-08	3.8E-08	0.000000038	3.8E-08	Frequency of Occurrence (per flight cycle)
U*T	100,000					Remaining life (flight cycles per airplane)
Sigma	560		560		560	Number of airplanes in affected fleet (average over fleet life)
CP_1	1	1	1	1	1	Probability of latent failure
CP_2	1	1	1	1	1	Probability of flying with critical cargo loading / passengers / fuel / etc
CP_3	1	1	1	1	1	Probability that event causes unsafe outcome, given that airplane is in susceptible condition
IR	0.8969	0.8969	0.8969	0.8969	0.8969	Injury ratio
EO			198		198	Exposed occupants
U (FH)			9.34		9.34	Utilization (flight hours/day)
U (FC)			3.42		3.42	Utilization (flight cycles/day)
CAD			180			Corrective Action Development (days)
RT			290			Rulemaking Time (days)
CT			180		90	Compliance time (days)

Risk Measures	Guidance Value	Calculated Value	Recommendation
Total Uncorrected Fleet Risk	0.02	1.969	Issue an AD
Total Uncorrected Fatal Events	N/A	2.1	
Total Uncorrected Fatalities	N/A	377.9	
Uncorrected Individual Risk	1.00E-07	1.25E-08	
Control Program Fleet Risk	3	7.24	Take action at the earliest possible time.
Control Program Indiv. Risk	10^{-5}, 10^{-6}	1.25E-08	
90-day Fleet Risk	N/A	1.16E+00	
NPRM Prioritization Rating	N/A	19.3	High Priority

	IMT	CAD	RT	CT	
ROM-T	10.2	2.5	2.5	5.1	months
JPAT	21.4	5.9	9.5	5.9	months

Warning: JPAT IMT exceeds ROM-T IMT.

Consider a shorter control program.

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FAA Transport Airplane Risk Assessment Methodology Worksheet Notes:

Note 1: IR from Boeing calculation of IR for uncontrolled crash via FAA method. Value sent to FAA as enclosure to RA-18-01709.

Note 2: Sigma of 560 airplanes used in the TARAM calculation. Value corresponds to estimate of fleet size prior to corrective action.

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BCA Airplane Programs

Organization Designation Authorization (ODA) Technical Review Board (TRB)

737 MAX Impractical Exception Proposal – Flight Crew Alerting, 25.1322 (b)(2), (b)(3), (c)(2), (d)(1) and (d)(2)

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Presenter: [redacted]
•Manager, 737 Flight Crew Operations

Briefing date: June 7, 2013

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ODA TRB

737 MAX Impractical Exception Proposal
Flight Crew Alerting, 25.1322 (b)(2), (b)(3), (c)(2), (d)(1) and (d)(2)

- **Presented at ODA TRB on June 3, 2013**
  - Present for the presentation

Name	Name	Name
Board Members		
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
Key Attendees		
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

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Overview of Presentation

- **Situation**
  - The FAA has requested further justification for Boeing's 737 MAX 25.1322 exception proposal.
  - This presentation provides that justification and clarifies the exception proposal.
- **Goal**
  - FAA agreement with proposed impractical exception to14 CFR 25.1322 (b)(2), (b)(3), (c)(2), (d)(1) and (d)(2)
- **Agenda**
  - 14 CFR 25.1322 compliance
  - Current 737 Alerting Methodology
  - Change Impact to the 737 Fleet
  - Current compliance and exception request for subparagraph exceptions

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14 CFR 25.1322 Compliance

- **The current flight crew alerting system for the 737NG has shown compliance to 14 CFR 25.1322 at amendment 38.**
- **Boeing is seeking an impractical exception to the following subparagraphs of 14 CFR 25 1322 at amendment 131.**
  - Paragraph (b)(2) and (b)(3) and Paragraph (c)(2)
  - Paragraph (d)(1)
  - Paragraph (d)(2)

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25.1322 Flight Crew Alerting – Amendment 38

§ 25.1322 Flightcrew alerting

[Warning, caution, and advisory lights.]

[If warning, caution, or advisory lights are installed in the cockpit, they must, unless otherwise approved by the Administrator, be--
(a) Red, for warning lights (lights indicating a hazard which may require immediate corrective action);
(b) Amber, for caution lights (lights indicating the possible need for future corrective action);
(c) Green for safe operation lights; and
(d) Any other color, including white, for lights not described in paragraphs (a) through (c) of this section, provided the color differs sufficiently from the colors prescribed in paragraphs (a) through (c) of this section to avoid possible confusion.]
Amdt. 25-38, Eff. 2/1/77

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25.1322 Flight Crew Alerting – Amendment 131

§ 25.1322 Flightcrew alerting.

(a) Flightcrew alerts must:

(1) Provide the flightcrew with the information needed to:

(i) Identify non-normal operation or airplane system conditions, and

(ii) Determine the appropriate actions, if any.

(2) Be readily and easily detectable and intelligible by the flightcrew under all foreseeable operating conditions, including conditions where multiple alerts are provided.

(3) Be removed when the alerting condition no longer exists.

(b) Alerts must conform to the following pr oritization hierarchy based on the urgency of flightcrew awareness and response.

(1) Warning: For conditions that require immediate flightcrew awareness and immediate flightcrew response.

(2) Caution: For conditions that require immediate flightcrew awareness and subsequent flightcrew response.

(3) Advisory: For conditions that require flightcrew awareness and may require subsequent flightcrew response.

(c) Warning and caution alerts must:

(1) Be prioritized within each category, when necessary.

(2) Provide timely attention-getting cues through at least two different senses by a combination of aural, visual, or tactile indications.

(3) Permit each occurrence of the attention-getting cues required by paragraph (c)(2) of this section to be acknowledged and suppressed, unless they are required to be continuous.

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25.1322 Flight Crew Alerting – Amendment 131 (continued)

(d) The alert function must be designed to minimize the effects of false and nuisance alerts. In particular, it must be designed to:

(1) Prevent the presentation of an alert that is inappropriate or unnecessary.

(2) Provide a means to suppress an attention-getting component of an alert caused by a failure of the alerting function that interferes with the flightcrew's ability to safely operate the airplane. This means must not be readily available to the flightcrew so that it could be operated inadvertently or by habitual reflexive action. When an alert is suppressed, there must be a clear and unmistakable annunciation to the flightcrew that the alert has been suppressed.

(e) Visual alert indications must:

(1) Conform to the following color convention:

(i) Red for warning alert indications.

(ii) Amber or yellow for caution alert indications

(iii) Any color except red or green for advisory alert indications.

(2) Use visual coding techniques, together with other alerting function elements on the flight deck, to distinguish between warning caution, and advisory alert indications, if they are presented on monochromatic displays that are not capable of conforming to the color convention in paragraph (e)(1) of this section.

(f) Use of the colors red, amber, and yellow on the flight deck for functions other than flightcrew alerting must be limited and must not adversely affect flightcrew alerting.

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737 Crew Alerting Methodology

- **Overview of alerting methodology**
- **Crew Response to an alert:**
  - Trained to be habitual and reflexive
  - Follows protocols and is enforced throughout tra ning and a pilot's career
  - Takes in consideration operational decision making and priority setting by the flight crew

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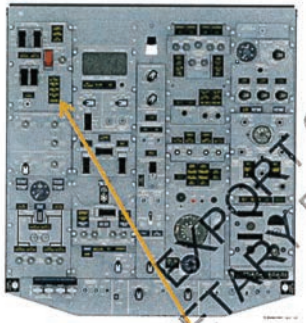
737NG Alerting Methodology

- How do flight crew alerts work today?



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737NG Alerting Methodology

- **The Master Warning/Master Caution concept is the same across the entire 737 fleet**

737-100/-200

737 Classic

737 NG

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Consistent Alerting Methodology is Important

- **Section 14 of AC 25.1322-1 recognizes the importance of maintaining a consistent crew alerting methodology within an existing airplane model fleet.**

- **From the AC:**
  - *"(a)(2) System upgrades to existing airplanes should be compatible with the original airplane's flightcrew-alerting phi osophy. The existing alerting system might not be able to facilitate the integration of additional systems and associated alerts due to limitations in the system inputs, incompatible technologies between the airplane and the system being added, or economic considerations."*
  - *"(a)(2)(b) Where possible, new alerts should be integrated into the existing flightcrew alerting system. If these alerts cannot be integrated, individual annunciators or an additional alerting display system may be added."*

- **Deviating from the established method of how the crew becomes aware of an alert will negatively impact flight crew performance.**

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Change Impact to the Fleet

- **737 flight crew alerting methodology has been effectively supporting 737 fleet operations for more than 45 years.**
  - The 737 fleet is the largest fleet in worldwide commercial operations.
  - Currently over 75,000 pilots are trained to use the 737 flight crew alerting methodology.
  - As these pilots will be operating both variants of the 737, they will carry over certain operational expectations.

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737 Fleet Statistics

- **The entire 737 fleet needs to be considered:**
  - Currently the 737 fleet consists of 6400 airplanes
  - 2000 more 737NGs will be built prior to 737 MAX
  - Current airplane retirement age = 30 years
  - 737NGs will remain in service until 2050
- **Current alerting system will be flown until 2050**
  - 737 MAX will be a minority in the fleet until 2030
  - Mixed fleet operation will continue until approximately 2050

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25.1322 (b)(2), (b)(3), (c)(2), (d)(1) and (d)(2) Impractical Exception

The Boeing Company is seeking an exception for 14 CFR 25.1322 at amendment 131 (5 paragraphs, but 3 issues):

- Paragraph (b)(2), (b)(3) and (c)(2) – distinguishing between cautions and advisories and providing timely attention getting cues through at least two different senses for caution alerts
- Paragraph (d)(1) – inhibit inappropriate or unnecessary alerts
- Paragraph (d)(2) – Suppressing the attention getting components of an alert caused by a failure of the alerting function

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Approach to each compliance exception

- What is the Regulation
- Associated hazard
- How don't we comply
- What are the implications of compliance

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14 CFR 25.1322 paragraphs (b)(2), (c)(2) and (b)(3)

- **14 CFR 25.1322 States:**

  - *(b) Alerts must conform to the following prioritization hierarchy based on the urgency of flight crew awareness and response.*
  - *(b) (2) Caution: For conditions that require immediate flight crew awareness and subsequent flight crew response.*
  - *(b) (3) Advisory: For conditions that require flight crew awareness and may require subsequent flight crew response.*

  - *(c)(2) Provide timely attention-getting cues through at least two different senses by a combination of aural, visual or tactile indications.*

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Hazard associated with (b)(2), (c)(2) and (b)(3)

- The possibility for a flight crew to not immediately identify a caution OR advisories might improperly interfere with a more urgent task.
  - By not distinguishing between cautions and advisories the flight crew is not assisted in prioritizing their response to a non normal condition.
  - Immediate awareness for a caution is not as dependable without the crew being stimulated through a second sense.

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14 CFR 25.1322 paragraphs (b)(2), (c)(2) and (b)(3) – What Does Not Comply In Current Design

- The 737 crew alerting methodology does not make a distinction between cautions and advisories.
- For some conditions requiring immediate awareness, timely attention-getting cues through two different senses are not provided.

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14 CFR 25.1322 paragraphs (b)(2), (c)(2) and (b)(3) – Implications of Compliance

737 MAX only: Minimal Hazard reduction

- For complex events, distinguishing between cautions and advisories might assist the flight crew in prioritization of actions
- Compliance would ensure dual sense stimulus for caution alerts, however:
  - For conditions that require urgent awareness, amber alerts are provided on the forward panel located in the pilots scan pattern.
  - Many of these amber alerts located on the forward panel have an associated aural or tactile attention-getting cue.
  - All alerts on the overhead panel FMC and aisle stand require a timely awareness of the alert.

The Boeing 737 fleet history does not indicate a need for a revision to the alerting methodology

- No documented accident or incident history due to the inability to distinguish between caution and advisories.
  - One accident (Helios) occurred due to a distinction difference between two warnings and led to a unique visual annunciation of the specific warning alert in each flight crew member's primary field of view.
- One accident (Turkish Airlines) led to an addition of an aural alert to the current 737 system.

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14 CFR 25.1322 paragraphs (b)(2), (c)(2) and (b)(3) – Implications of Compliance

Fleet Impact on the 737

- Negative impact to crew response
  - Direct compliance with these paragraphs results in a different flight crew alerting philosophy between the MAX and the current 737 fleet for cautions and advisories
    - Leading to crew confusion and delayed response when moving between the airplanes.
    - Human performance and response would be negatively impacted by requiring the crew to maintain two different mental models of how alerting systems work.
- Differences in interpretation of alert indications will cause crew confusion and delayed crew response.

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14 CFR 25.1322 paragraphs (b)(2), (c)(2) and (b)(3) – Compliance Requires

- Compliance with 14 CFR 25.1322 at amendment 131 requires the following:
  - Design change (see following slide for key change description)
  - Update all flight crew and maintenance documents, procedures and checklists

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Key Changes

- [redacted]

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Approach to each compliance exception

- What is the regulation
- What are the hazards
- How don't we comply
- What would compliance take

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14 CFR 25.1322 Paragraph (d)(1)

- **14 CFR 25.1322 States:**

> (d) The alert function must be designed to minimize the effects of false and nuisance alerts. In particular it must be designed to:
>
> (1) Prevent the presentation of an alert that is inappropriate or unnecessary.

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Hazard associated with (d)(1)

- The possibility for a flight crew to respond to an alert when no response is needed OR to respond in a way which could create an additional hazard to the airplane.

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14 CFR 25.1322 paragraphs (d)(1) – What Does Not Comply In Current Design

- The 737 crew alerting system does not have a central means to inhibit alerts when they are inappropriate or unnecessary.
  - Crew Alerting functions are distributed across multiple systems
  - There are no inhibits for master caution, 6 Pack annunciators, master fire warning lights or aurals
  - There is no phase-of-flight inhibit logic
  - No means for collector alerts and therefore no means to inhibit consequential alerts due to a common cause

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14 CFR 25.1322 paragraphs (d)(1) – Implications of Compliance

737 MAX only: Minimal Hazard reduction

- Compliance would reduce the hazard for false and nuisance alerts, however;
  - The 737 already has alert logic for some systems to prevent inappropriate or unnecessary alerts such as PSEU, EGPWS, RAAS, TCAS, WINDSHEAR, Engine Controls and the AUTOLAND system
  - Current Training incorporates the use of inhibits through non-normal checklists and appropriate responses during specific phases of flight
  - When an alert is presented during a phase of flight where action is inappropriate, the flight crew is trained to focus on the critical phase of flight task and defer response to the alert until later

The Boeing 737 fleet history does not indicate a need for a revision to the alerting methodology

- There have been no safety events attributed to the flight crew responding to an inappropriate or unnecessary alert.
- Boeing has reviewed the reported High Speed RTO's on the 737 airplanes in over 90 million flight cycles. There were slightly over 220 reported events, of which about 75 were identified as inappropriate aborts. These high speed aborts were due to illumination of Master Caution and 6-pack annunciators above 80 knots during takeoff, leading to an inappropriate crew response of aborting the takeoff.

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14 CFR 25.1322 paragraphs (d)(1) – Implications of Compliance

- Fleet Impact on the 737
  - Negative impact to crew response
    - Direct compliance with these paragraphs results in a different flight crew alerting methodology between the MAX and the cur ent 737 fleet, leading to crew confusion and delayed response when moving between the airplanes. Human performance and response would be negatively impacted by requiring the crew to maintain two different mental models of how alerting systems work.
    - Presentation of crew alerts to the flight crew on the 737 is essential to understanding the system state of the airplane. If consequential crew alerts are inhibited to prevent unnecessary alerts then the flight crew would lose awareness of the system state on the airplane.
    - A set of alerts for a specific condition would be different between the MAX and the current 737 fleet
    - Inhibited alerts on the 737 MAX will still be presented on the 737 NG, resulting in potential crew confusion about airplane state and actions required
    - A specific recurrent training requirement for the NG would be required to ensure the retention and understanding of airplane system state, and to accommodate the two different alerting methodologies between the 737 Classic/NG and the 737 MAX.

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14 CFR 25.1322 paragraphs (d)(1) – Compliance Requires

- Compliance with 14 CFR 25.1322 at amendment 131 requires the following:
  - Revise federated systems functionality to prevent inappropriate or unnecessary alerts OR create a central function to provide the same functionality.
  - Changes to Master Caution, Master Fire Warning, six pack annunciators and individual alert presentations.

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Approach to each compliance exception

- What is the regulation
- What are the hazards
- How don't we comply
- What would compliance take

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14 CFR 25.1322 paragraphs (d)(2)

- **14 CFR 25.1322 States:**

> **(d) The alert function must be designed to minimize the effects of false and nuisance alerts. In particular, it must be designed to:**
>
> **(2) Provide a means to suppress an attention-getting component of an alert caused by a failure of the alerting function that interferes with the flightcrew's ability to safely operate the airplane. This means must not be readily available to the flightcrew so that it could be operated inadvertently or by habitual reflexive action. When an alert is suppressed, there must be a clear and unmistakable annunciation to the flightcrew that the alert has been suppressed.**

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Hazards associated with (d)(2)

- The possibility for a flight crew to get distracted or fatigued from continual alerts
- The possibility for a flight crew to fail to respond to actual alerts masked by the failure of the alerting system.

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14 CFR 25.1322 paragraphs (d)(2) – What Does Not Comply In Current Design

- The 737 crew alerting system does not have a means to silence a nuisance Overspeed Clacker, Stick Shaker and Takeoff Configuration warning horn .
  - The means to silence a continuous failed aural of an Takeoff Configuration warning horn is by use of circuit breaker.

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14 CFR 25.1322 paragraphs (d)(2) – Implications of Compliance

737 MAX only: Minimal Hazard reduction

- All aural alerts on the 737 are currently cancellable, except Takeoff Configuration, Overspeed and Stick Shaker
  - Stick shaker tactile/aural alerts will not be cancellable. This is consistent with current Boeing practices
- Compliance would provide a means to cancel takeoff configuration warning horn and overspeed continuous aurals
  - The 737 has a non-normal checklist to cancel a false takeoff configuration warning horn following failure of the landing gear lever to retract through the use of a circuit breaker

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14 CFR 25.1322 paragraphs (d)(2) – Implications of Compliance

- Fleet Impact on the 737
  - A change in the method has a negligible impact
- Costs
  - Addition of a guarded aural cancel switch
  - Addition of discretes to the Aural Warning Module
  - Update flight crew and maintenance documents, procedures and checklists
  - Addition of an indication that an aural alert has been cancelled

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14 CFR 25.1322 not equal to EICAS

- The requirements in the rule discuss alerting and do not drive a specific system design
- Even though EICAS is used as the latest practice to comply with 14 CFR 25.1322, EICAS is not the only way to comply

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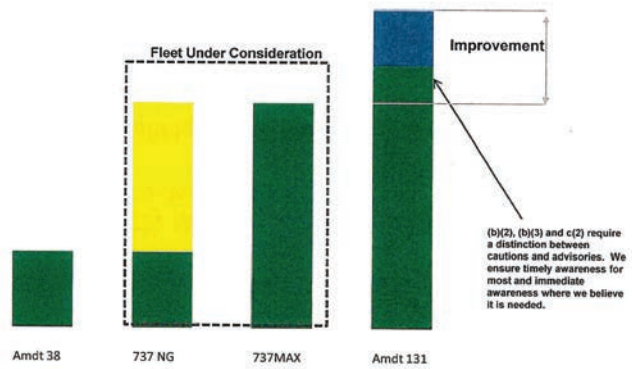
Incremental Compliance of Amendment 131 on 737NG/MAX Fleet



Assuming each paragraph improves safety by the same increment

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An Impractical Exception is appropriate because:

- Compliance would impact many elements of the system – Significant Cost
- Safety is improved for the 737 MAX but the required changes would have a negative impact on the combined fleet
- Safety is improved but benefit is not commensurate with cost.

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Conclusion

Boeing is seeking an Impractical Exception to 5 sub-paragraphs of 14 CFR 25.1322 at Amendment level 131

- This proposal minimizes the scope of the exception by showing compliance with as much of the latest amendment as practical.
- The proposed exception allows the 737 MAX crew alerting function to remain consistent within the 737 fleet, which is compatible with the guidelines of section 14 of AC 25.1322-1A, considering:
  - Fleet impact
  - Impact to affected systems when complying with subparagraphs
  - Schedule and risk impacts
  - Customer impacts
  - Same Type Rating impacts
  - Cost to Boeing and industry

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Backup Slides

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A fully compliant design, without EICAS

[redacted]

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Key Changes

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Key Changes

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Wiring Impact

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APPENDIX

QUESTIONS FROM HON. PETER A. DEFAZIO FOR HON. STEPHEN M. DICKSON, ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION

Question 1. According to a recent news report, in an email sent by an official at Transport Canada to the FAA, the European Union Aviation Safety Agency (EASA), and Brazil's civil aviation authority, the official stated that "[t]he only way I see moving forward at this point" with the 737 MAX was that MCAS "has to go."[1] Do you agree with this view? Do you believe the 737 MAX can be certified by the FAA if MCAS is removed altogether?

ANSWER. The FAA's first priority is safety. The agency will not approve the aircraft for return to service until it has completed rigorous testing and we are satisfied that it is safe.

The FAA understands that Transport Canada Civil Aviation put out a statement clarifying that the statement quoted in this question did not necessarily represent the views of their agency.

The FAA has a transparent and collaborative relationship with other civil aviation authorities as we all review and collaborate on the changes to software on the Boeing 737 MAX. The FAA and its international partners have engaged in robust discussions at various stages in this process as part of the thorough scrutiny of Boeing's work. We value and support constructive debate and candor in the exchange of information and perspective between our technical experts. The excerpted email is an example of those exchanges.

Stability augmentation systems are not new in aviation or aircraft design. MCAS is one part of the flight control system design. As specified by Boeing, MCAS is intended to help pilots in narrow regimes of the flight envelope and to meet part 25 airworthiness requirements.

The changes that are being made to MCAS software will prevent the system from making uncommanded pitch corrections based on errant inputs and causing the same type of problem that occurred during the two accident flights.

The FAA does not make design-level decisions for manufacturers. We certify submitted designs based on their conformity to FARs and safety evaluations. As stated above, the Agency will not approve the aircraft for return to service until the design changes have been rigorously tested and we are satisfied the aircraft is safe.

Question 2. An FAA Flight Standardization Board (FSB) develops pilot training criteria and requirements for pilots for a particular aircraft. At our May 15, 2019, Aviation Subcommittee hearing on the 737 MAX, then-Acting Administrator Elwell testified that the FAA had recently solicited public comment on a draft report prepared by the FSB for the Boeing 737 MAX. Deputy Administrator Elwell stated that "[t]he FAA will review this input before making a final assessment." Where is the FAA in the FSB process? Can the FAA make an assessment at this time regarding the pilot training that will be required after ungrounding the 737 MAX?

ANSWER. The FAA will carry out the FSB function after the completion of the Joint Operations Evaluation Board (JOEB). The JOEB is a multi-authority body, the outcomes of which will be documented in the FSB report. The FSB report was initially posted for public comment last April. The JOEB work will commence once critical certification milestones have been completed. Once the JOEB completes its evaluation of Boeing's proposed training requirements, the JOEB conclusions will be included in an updated FSB report. That report will be posted for public comment.

Question 3. According to the Joint Authorities Technical Review (JATR), the FAA "extensively delegated compliance findings . . . to [the] Boeing [Organization Des-

[1] Allison Lampert & David Shepardson, "Canadian official's email says 737 MAX software must go reflects 'working-level' view—regulator," Reuters (Nov. 22, 2019), available at: https://fr.reuters.com/article/industrialsSector/idUKL2N2821HI

ignation Authority] ODA. Safety critical areas, including system safety documents related to MCAS, were initially retained by the FAA and then delegated to the Boeing ODA."[2]

a. In your opinion, did the FAA over-delegate review of certain safety-critical functions, like MCAS, to Boeing?

ANSWER. A large, transport category aircraft such as the MAX consists of many thousands of parts and systems, all of which must be certified to meet FAA standards. The transport category aircraft certification process comprises four functions: 1) certification basis, 2) planning and standards, 3) analysis and testing, and 4) final decision and certification of design.

The certification work FAA typically delegates primarily relates to a single portion of the process-the third function outlined above-analysis and testing. About 94% of work in this area, for all aircraft, is delegated, and much of that work involves lower risk and routine items such as interior reconfigurations for seats, lavatories, galleys, etc. FAA also delegates analysis and testing of aircraft systems and airframe components when the applicant is using established and proven compliance methods and the organization or designee is authorized and has demonstrated the ability to perform the work to FAA's satisfaction.

The FAA determines the certification basis, identifies the standards, and makes all key and final decisions. The FAA is directly involved in the testing of new and novel features and technologies. The FAA does not delegate the other portions of the certification process.

For the software update efforts of the 737 MAX, FAA has retained all findings. No part of the review has been delegated to Boeing.

The FAA is reviewing how we structure our approach to delegation, while complying with the requirements mandated by Congress in the FAA Reauthorization Act of 2018. In addition, the FAA is in the process of reevaluating our delegation decisions for other current certification projects.

b. The JATR goes on to state that it is their belief that "FAA involvement in the certification of MCAS would likely have resulted in design changes that would have improved safety."[3] Do you agree with that assessment?

ANSWER. MCAS is not a stand-alone system, it is an element of the Speed Trim System. The Speed Trim System has been part of the flight control system on all prior 737 models. Thus, there was no certification of MCAS, but rather the flight control system.

The FAA is focused is on improving the certification system and considering the findings of the JATR and other independent reviews. As noted above, for software update efforts, the FAA has retained the approvals process for the flight control systems and is not delegating anything to Boeing. As part of the initial return to service effort, the FAA will retain authority to issue airworthiness certificates and export certificates of airworthiness for the grounded fleet and 737 MAX airplanes manufactured since the grounding. When the 737 MAX is returned to service, it will be because the safety issues have been addressed and pilots have received all of the training they need to safely operate the aircraft.

c. What steps is the FAA currently taking, if any, to review and make changes administratively to the current ODA program?

ANSWER. The Organization Designation Authorization (ODA) has long been a key part of the FAA's use of delegation. As the role ODA has played in FAA's safety programs has increased and the technical and compliance assurance capabilities of ODA holders have matured, it has become clear that FAA's approach to oversight must also evolve. ODA holders provide an effective compliment to FAA oversight and certification responsibilities during the certification process for a new or amended type certificate. Using ODAs during the certification process allows the FAA to focus on critical or new and novel technologies during the certification process.

In the FAA Reauthorization Act of 2018, Congress mandated that FAA establish an ODA Office within AVS. The intent of this mandate is to achieve standardization and consistency of oversight functions of the ODA program across AVS and facilitate risk based, system-level oversight for:

- Standardized application of policy;
- Proficiency of ODA Office and field staff in executing oversight processes;
- Monitoring of risk and performance issues; and
- Continuous improvement of AVS ODA program performance.

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[2] Joint Authorities Technical Review, October 11, 2019, p. 26, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[3] Joint Authorities Technical Review, October 11, 2019, p. 27, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

To this end, in March 2019, then Acting Administrator Dan Elwell approved the establishment of the AVS ODA Office in the Aircraft Certification Service's (AIR) System Oversight Division (AIR-800). We continue to operationalize the office with temporary staff. The Department of Transportation requested $7 million in the President's FY21 budget in order to permanently and effectively staff and resource this office.

Additionally, the FAA recently completed the charter for the ODA expert panel as required in the FAA Reauthorization Act of 2018. We have also completed the initial steps for the Panel to conduct an ODA Survey under the requirements of the Paperwork Reduction Act. Once the Panel has drafted the survey and conducted their review, the report will be developed and submitted to Congress as well as numerous FAA offices and advisory committees for consideration.

One area of focus is to improve the information flow and coordination between the operational and certification functions during the certification process. Thus, we are placing greater emphasis on operational involvement within the certification process and, more importantly, how design and operational assumptions are documented and communicated as part of type design. This is occurring for all certification projects currently under review by the agency.

The Aircraft Certification Service (AIR) and Flight Standards (AFX) are working cohesively and collaboratively to address structural organizational changes. Examples include appointing a single program manager for all certification projects; this program manager will have program oversight over both AIR and AFX. Our agency will also focus on strategic and tactical program management efforts, to include fostering better communication between all stakeholders. These efforts are among the most important process improvements we are implementing to our certification processes. They are of significant focus and are ongoing.

The FAA has much work to do to evaluate the many recommendations we have received to date from the various investigations, including recommendations related to the ODA program. Additional recommendations are expected from reviews still underway. The FAA is committed to reviewing all recommendations and improving its ODA program.

Question 4. On November 7, 2018, just days after the Lion Air crash, the FAA issued an Emergency Airworthiness Directive (AD) to provide critical information to pilots. This followed Boeing's issuance of a Flight Crew Operations Manual Bulletin the day before—which provided similar, critical information to pilots. Neither of these documents mentioned "MCAS" by name and apparently this omission was deliberate. According to the New York Times, at the last minute, an FAA manager told agency engineers to remove the only mention of MCAS in FAA's Emergency AD.[4]

a. Is this news reporting accurate?

b. If so, please explain why the FAA removed reference to MCAS from this Emergency AD?

c. If not, please explain why the FAA chose not to mention MCAS in the Emergency AD in the first place?

Boeing has told our Committee that it worked very closely with the FAA on the contents of both the Bulletin and FAA's Emergency AD.

d. Did Boeing ever ask, or in any way recommend or request, that the FAA NOT mention MCAS in the Emergency AD?

ANSWER (a.–d.). Airworthiness Directives (AD) are used to address unsafe conditions in aircraft and mandate fleet-wide corrective actions. An AD must address any unsafe conditions and avoid introducing new safety hazards. In this case, the FAA decided that an AD was necessary to address a runaway stabilizer event. Although in the time since, it has become clear that MCAS functionality was involved in two accidents, at the time of the Emergency AD decision, we were still in the early stages of an accident investigation. Furthermore, the FAA's opinion at the time was that introducing a new system name that did not exist in the aircraft documentation available to pilots had the potential to cause confusion in an emergency situation. MCAS is not a stand-alone system, but rather a name given to a section of code in the flight control computer, which is, in turn, part of the flight control system. The FAA therefore decided to remove the MCAS reference from the draft AD so that flight crews would focus on runaway stabilizer recognition instead of attempting to troubleshoot MCAS. In an emergency situation, it was more important for a crew

[4] Natalie Kitroeff, David Gelles and Jack Nicas, "The Roots of Boeing's 737 Max Crisis: A Regulator Relaxes Its Oversight," NEW YORK TIMES (July 27, 2019), accessed at: https://www.nytimes.com/2019/07/27/business/boeing-737-max-faa.html?searchResultPosition=2

to recognize and respond to a runaway stabilizer event than it was to troubleshoot MCAS.

We know from a Boeing "Coordination Sheet" released at our MAX hearing in October 2019 that Boeing had long known that if a pilot failed to respond to unintended MCAS activation within 10 seconds, the result could be catastrophic. Boeing apparently knew this at least by March 2016, and re-affirmed it in June 2018, more than one year after the 737 MAX had been certified by the FAA and just four months before the Lion Air accident.

e. When the FAA issued its Emergency AD, was the FAA aware that Boeing had determined that a failure to respond to unanticipated MCAS activation within 10 seconds could be catastrophic? If not, when did the FAA first become aware that if a pilot responded in 10 seconds or more to unanticipated MCAS activation it could be catastrophic?

ANSWER. At the time of original 737MAX certification, the FAA knew an MCAS failure could present itself as a runaway trim stab event, which is a well-known procedure in which pilots are trained. The FAA's analysis of the accidents and recommendations of several independent panels indicate that assumptions concerning MCAS used during certification need to be re-evaluated and adjusted to better reflect present-day cockpit conditions and pilot response expectations.

f. Do you believe it would have been helpful for 737 MAX pilots to know that if they failed to respond to unanticipated MCAS activation within 10 seconds the result could be catastrophic? If not, please explain why you believe that to be the case.

ANSWER. Pilots operating aircraft must be fully prepared and appropriately trained for known failure scenarios that may be encountered in service as documented in engineering hazard analysis and required by regulation.

g. In hindsight, do you believe Boeing provided adequate information to the FAA regarding MCAS when the FAA was preparing the Emergency AD?

ANSWER. After the Lion Air accident, the FAA knew there was a faulty AOA sensor which sent incorrect information to the aircraft flight control computer which then erroneously attempted to correct a nonexistent high angle of attack situation by trimming the aircraft nose down via the MCAS system. From the cockpit, the situation presented as a runaway stabilizer. The emergency AD was drafted to alert flight crews how to react when the aircraft attempted to trim nose down.

At the time of the emergency AD, the FAA was aware of MCAS. Boeing provided answers to questions related to the Lion Air accident and MCAS in general. We believed we had all the necessary information to issue an Emergency AD meant to immediately bring attention to a potentially unsafe condition and provide for interim corrective actions while the agency continued to investigate the accident.

The FAA requires manufacturers to provide any and all pertinent information to our safety specialists whenever a serious aircraft safety event or accident occurs.

Question 5. In the Flight Crew Operations Manual Bulletin that Boeing issued following the Lion Air crash, Boeing describes how erroneous angle of attack (AOA) can potentially cause many indications and effects in the cockpit, including: continuous or intermittent stick shaker; increasing nose down control forces; and as many as four different alerts or lights (IAS DISAGREE, ALT DISAGREE, AOA DISAGREE, and FEEL DIFF PRESS light).

a. It is my understanding that every newly type certificated aircraft since 1982 includes an "engine-indicating and crew-alerting system" (EICAS)—a system that can show pilots a list of messages, rather than lights indicating failure of a system, in order to help pilots prioritize responding to multiple simultaneous indications that may lead to pilot confusion. Why was this system not included in the 737 MAX during its original certification?

ANSWER. EICAS is not required to meet FAA regulations. 14 CFR § 25.1322, Flightcrew Alerting, describes what alerts must be included on a transport category airplane. It is a performance-based rule, meaning that the airplane must meet the required performance as stated in the rule and no specific means of meeting the requirements are stated. The decision to use EICAS as a way to show compliance with the requirements of § 25.1322 is a design choice made by the manufacturer.

b. Is the FAA evaluating whether an EICAS or similar system should be included in a re-certified 737 MAX before it is ungrounded?

ANSWER. The FAA is taking the external review recommendations into consideration in our evaluation of the changes to the 737 MAX. We will be conducting further reviews in this area for potential changes to our processes going forward.

Question 6. Please provide a detailed account of all communication between Boeing and FAA's Associate Administrator for Aviation Safety between the Lion Air

crash on October 29, 2018, and the Ethiopian Airlines crash on March 10, 2019, including:

a. the date, time, and mode (telephone, email, letter, in person meeting, etc.) of each communication;

b. the job title of the individual(s) at Boeing with whom the Associate Administrator communicated;

c. the subject of each communication;

d. copies of all communications to the extent they were in writing; and

e. a summary of all communications that were not in writing.

ANSWER (a.–e.). The Associate Administrator for Aviation Safety communicates regularly with Boeing representatives on a variety of aviation safety topics via different modes of communication, including during the time period referenced.

The Associate Administrator for Aviation Safety provided more detailed information about his communications with Boeing during his transcribed interview with Committee staff on December 5, 2019.

Question 7. Did FAA's Associate Administrator for Aviation Safety have any discussions with Boeing about the potential grounding of the 737 MAX prior to the Ethiopian Airlines crash? If so, please:

a. provide the date, time, and mode (telephone, email, letter, in person meeting, etc.) of each such discussion;

b. identify the job title of the individual(s) at FAA who conducted such discussions with Boeing;

c. provide copies of any such discussions to the extent they were in writing;

d. provide a summary of all such discussions to the extent they that were not in writing;

e. indicate, for each discussion, whether the economic and/or financial impact that grounding the 737 MAX would have had on Boeing was discussed.

ANSWER (a.–e.). The Associate Administrator previously provided information about his communications with Boeing during a transcribed interview your staff conducted on December 5, 2019.

Question 8. In December 2018, after the Lion Air crash, the FAA produced a Quantitative Risk Assessment Random Transport Airplane Risk Analysis (R–TARA), based on the Transport Airplane Risk Assessment Methodology (TARAM), that calculated the estimated risk of another catastrophic 737 MAX accident during the lifetime of the fleet without a technical fix to the MCAS software. Please provide a list of all staff within the FAA's Aviation Safety (AVS) branch and the Office of the Administrator (AOA) who received, prior to the Ethiopian Air crash on March 10, 2019, a copy of this R–TARA analysis, or any memoranda, summaries, e-mails, or presentations about this analysis, and the date upon which each individual received it.

ANSWER. The FAA senior staff who prepared the TARAM were interviewed by Committee Staff. They answered staff questions related to the TARAM.

A TARAM is a scientific risk-assessment tool. It weighs a number of factors and is used to help the FAA quantify risk. It is not the FAA's sole decision-making tool; rather, its purpose is to assist the Corrective Action Review Board (CARB)—comprised of experts in their field—in making decisions about how to reduce or eliminate risk. The FAA would never accept a risk of additional accidents without taking immediate action, and in fact, the agency acted immediately—with interim and permanent steps—to respond to the Lion Air accident. The FAA issued an emergency AD reminding pilots how to deal with runaway speed trim eight days after the Lion Air accident and before the TARAM analysis was complete. When the AD was issued, the FAA determined the permanent action was to require a design change to address MCAS. That effort also was underway before the TARAM was prepared in December 2018.

The TARAM analysis of the 737 MAX MCAS safety issue was presented to the Seattle ACO Corrective Action Review Board (CARB) on November 28, 2018, December 12, 2018, and February 6, 2019. After reviewing the available information, the Seattle ACO recommended an Emergency Airworthiness Directive, AD 2018-23-51. The Seattle ACO then followed FAA's standard coordination process prior to formalizing the decision.

Question 9. Following up on Mr. Earl Lawrence's response to Rep. Sean Patrick Maloney, please provide a list of all workers at Boeing's Renton, Washington, facility by title, who have been interviewed by the FAA regarding production, quality, safety, or related matters concerning the 737 MAX since the Lion Air crash on October 29, 2018, as well as the dates of such interviews.

ANSWER. Since the Lion Air accident on October 29, 2018, the FAA has increased its oversight activities and conducted more than 115 investigations at the Boeing production facility in Renton, Washington. A majority of these investigations were conducted as part of the FAA's certificate management activities that focused on Boeing products and processes. While conducting these certificate management-related investigations, the FAA questioned numerous Boeing employees, but as these interactions are not considered formal interviews, the titles of those questioned are not recorded.

In addition to the certificate management-related investigations, the FAA conducted nine Aviation Safety Hotline/Whistleblower investigations related to the Model 737 MAX following the Lion Air accident. In support of those nine Aviation Safety Hotline/Whistleblower investigations, the FAA interviewed the following Boeing employees, by title:

Boeing Employee Title	Date of Interview (A) = Approximately
Assembly Inspector	4/10/2019
Engineer	4/10/2019
Assembly Inspector	4/15/2019 (A)
Quality Manager	4/15/2019 (A)
Test Area Manager	4/15/2019 (A)
Quality Manager	4/15/2019 (A)
Aviation Technician	4/18/2019 (A)
Aviation Maintenance Technician Inspector Lead	4/18/2019 (A)
Preflight Manager	4/18/2019 (A)
Materials Processor	5/3/2019
Lead Technician	5/13/2019
Software Test Engineer (Contractor)	5/15/2019
Kitting Team Lead	5/16/2019
Local Receiving Area Manager	5/16/2019
Local Receiving Area Team Lead	5/16/2019
Warehouse Team Lead	5/16/2019
Operations Delivery Manager	5/23/2019
Preflight Quality Manager	5/23/2019
Preflight Quality Manager	5/23/2019
Quality Manager	5/23/2019
Seattle Delivery Center Liaison Engineer	5/23/2019
Seattle Delivery Center Liaison Engineer	5/23/2019
Seattle Delivery Center Quality Manager	5/23/2019
Mechanic	5/29/2019 (A)
Mechanic	5/29/2019 (A)
Mechanic	5/29/2019 (A)

Boeing Employee Title	Date of Interview (A) = Approximately
Quality Inspector	5/29/2019 (A)
Quality Inspector	5/29/2019 (A)
Quality Inspector	5/29/2019 (A)
Flight Management System Software Engineer	6/5/2019 (A)
Structural Engineer	9/3/2019
Propulsion Structures Engineer	9/19/2019

In addition to the Boeing employees listed above, during the course of these Aviation Safety Hotline/Whistleblower investigations, the FAA interviewed two additional complainants that had worked at Boeing, but the FAA was not provided with their titles. One complainant was interviewed on April 10, 2019, and the other on April 16, 2019.

During the December 11, 2019, Congressional hearing the FAA Administrator committed to conduct additional interviews with Boeing employees in the Renton, Washington, production facility related to matters concerning manufacturing of the Boeing Model 737 MAX airplane. The FAA conducted interviews of the following Boeing employees on January 28 and 29, 2020:

- 3 manufacturing technicians
- 2 manufacturing engineers
- 3 quality technicians
- 2 Boeing ODA unit members
- 1 ODA manager
- 2 manufacturing managers

Lastly, it should be noted that the FAA has an office co-located at the Renton, Washington facility and aviation safety inspectors are on the production floor daily conducting safety oversight.

Amended Type Certificates

Question 10. The 737 MAX is a vastly different airplane than the original 737, yet the MAX did not require a new type certificate. The 737 fuselage is based on the 707-fuselage introduced in 1958. And the original 737 itself was type-certified in 1967. The trim wheel in the 737 MAX—an important part of the story of these crashes—also dates to the 1967 version. The MAX is also significantly different from the 737NG. It has new fly by wire spoilers, new winglets, new engines and revisions to the Flight Deck. Boeing has designed 14 variations of the 737 aircraft since the original was certified in 1967.

I have serious concerns that the amended type certificate is a strategic tactic to shortcut the FAA certification process—allowing the manufacturer to shave-off time during the review of its new aircraft by relying on data, tests, or assumptions used for the previous model made years (or even decades) earlier. In the case of the 737 MAX it was based on the design of an aircraft certified by the FAA half-a-century earlier.

At what point should all substantial design and technological changes make the FAA regard an aircraft as a new plane, requiring a new type certificate?

ANSWER. Amended type certificates are not intended to shortcut the certification process. Rather, they allow manufacturers to build on successful and safe prior designs while incorporating new or novel design changes. Amended type certificates allow the FAA to focus our certification resources on the proposed changes between models. The certification of the MAX took five years which is typical for new and amended type certificates.

Additionally, whether a manufacturer applies for an amended TC or a new TC, the project receives a current certification basis. A certification basis is the formal determination of the standards in FAA regulations that will apply to the project.

The determination to classify the Model 737-8 airplane as an amended type certificate is consistent with current guidance, as well as determinations made on previous certification programs.

Boeing applied for an amended TC for the Model 737-8 airplane in January 2012. The FAA established the certification basis for the Model 737-8 airplane in February 2014. The FAA classified the Model 737-8 airplane as an amended TC based on a review of the airplane design changes in accordance with 14 CFR § 21.19. Ac-

cordingly, the FAA concluded that the design changes for the Model 737-8 airplane did not require a new TC.

Question 11. Boeing applied for amended type certificates for the 777X, which will include two variants: the 777-9 (a derivative model of the 777-300ER) and 777-8 (a derivative model of the 777-9). Most notably, these planes will be constructed with new carbon-fiber-reinforced plastic wings with folding wingtips.

The FAA determined that the folding wingtips are "novel or unusual design features" and the agency issued "special conditions" containing "additional safety standards" for Boeing to meet to prove these wingtips are safe to operate.[5] Boeing determined that a catastrophic event could occur if the wingtips are not properly positioned and secured for takeoff or during flight.

However, in addition to these new wingtips—not contemplated before on commercial aircraft—the 777X will have a stretched fuselage, new engines, modified landing gear, and a new fuel system compared to its predecessor 777 model. And yet, the FAA has permitted Boeing to proceed with an amended type certificate, rather than requiring Boeing receive a completely new type certificate, which would involve a more extensive, top-to-bottom review of the design.

a. What is the FAA's estimate of the overall portion of commonality between the 777-9 and the 777-300ER?

ANSWER. We do not evaluate an applicant's proposal in terms of degree or percentage of commonality. Rather, we initially focus on the changes to the aircraft proposed by the applicant, and we work to ensure those areas meet the current requirements as described in response to question 10. We are still evaluating the system in its entirety to ensure that the aircraft meet FAA requirements and is safe to operate in accordance with our regulations.

b. How can tests or data from the prior model be used to certify the 777X given that the new wings, engines, materials, and other features may affect the handling and performance of the aircraft?

ANSWER. Prior to installation, there is a series of engineering evaluations and research and development testing that new components undergo, to include a wide range of inspection and testing prior to installation.

According to FAA Order 8110.4, Type Certification, certification tests are used by the FAA to verify the flight test data reported by the applicant or to obtain compliance data for flight testing conducted concurrently with the applicant. Certification tests may include flight, ground, functional, and reliability testing, along with engineering testing.

The FAA uses the certification tests to evaluate the aircraft's performance, flight characteristics, operational qualities, and equipment operation. The tests also determine operational limitations, procedures, and pilot information.

FAA Order 8110.4, Type Certification, provides an allowance for use of prior aircraft data in new designs, provided that strict conditions are met by the applicant. Use of prior data is helpful to understand what aspects of the new design need further review, regardless of any credit given for prior data in a new design. In the case of the 777x and the substantial changes to the wing design, we anticipate that Boeing will be developing extensive new data and will be required to conduct a robust amount of flight testing.

Presumably there will be new checklists for pilots to ensure the wingtips are properly configured before takeoff, and potentially caution lights, warning lights, or other functions associated with wingtip configuration or misconfigurations, requiring pilots to take specific actions in response. As you know, the FAA only required Level B (non-simulator) pilot training for the 737 MAX, despite a completely new software system (MCAS) on the plane.

c. Does the FAA expect there to be simulator training required for pilots transitioning from the 777-300ER to the 777X?

ANSWER. The FAA is currently engaged with Boeing to determine the level of training required for pilots transitioning from the B777 300ER to the 777X. The final determination of minimum training is ongoing, in accordance with the FSB process in AC 120-53, which will conclude with FAA's final determination of the minimum level of training after a draft FSB report is published for public comment.

[5] FAA, *Final Special Conditions*, 83 Fed. Reg. 23209 (May 18, 2018).

Joint Authorities Technical Review

Question 12. The JATR found that FAA's Boeing Aviation Safety Oversight Office (BASOO) is severely outnumbered by Boeing's ODA office—45 to 1,500 people respectively,[6] and many BASOO employees are junior engineers.

a. Do you believe that the FAA can adequately oversee the Boeing ODA with this employee ratio?

ANSWER. The approximately 45 BASOO employees oversee the Boeing ODA, not the 1500 individual Boeing employees. The FAA oversees the Boeing system as outlined in Boeing's FAA-approved procedures manual. Boeing, as the ODA holder, oversees, trains, and manages its 1500 ODA unit members. The purpose of organizational delegation is to transfer the burden on individual oversight from the FAA to the ODA holder. This is why the criteria for ODA appointment are stringent.

Additionally, in order to sustain the workforce needed by the FAA, we are recruiting engineers and training them for specialized functions within the agency. The workforce in the BASOO has completed training specific to their positions and is led by multiple senior engineers that oversee and advise the entire workforce. All FAA engineers and inspectors also have access to FAA resources like our Chief Scientific and Technical Advisors who are renowned in their respective fields of specialization.

b. In the wake of the 737 MAX crashes is the FAA taking any action to review the technical skills, expertise, and capacity of the BASOO to adequately perform certification and oversight duties of Boeing? If so, please explain what actions the FAA has already taken, is currently taking, or plans to take.

ANSWER. We are reviewing the structure of the BASOO to ensure appropriate oversight of the Boeing ODA and to identify opportunities to strengthen cross organizational coordination on our oversight efforts. We have also increased involvement in key areas such as system safety, AEG evaluation of installed systems and equipment evaluations and software development processes.

Question 13. As you know, the FAA oversight of the certification process for the B737 MAX was performed by the FAA's BASOO. Based on the JATR team's observations and findings, JATR recommended that the FAA conduct a workforce review of the BASOO engineer staffing level to ensure there is a sufficient number of experienced specialists to adequately perform certification and oversight duties, commensurate with the extent of work being performed by Boeing.[7]

a. Has the FAA conducted this review? If yes, please provide a copy of this review to the Committee.

b. If not, does the FAA plan to accept this recommendation and conduct a review?

ANSWER. The aerospace industry is a competitive workspace as employers like the FAA and Boeing compete for talented employees with the requisite training, skills and experience. The FAA is conducting a workforce review of the engineering staffing levels at the BASOO. The FAA regularly conducts recurrent reviews of positions throughout all of the offices, to include the BASOO. Staffing and hiring plan reviews are held on a recurring schedule and include review of a number of positions for each office to ensure adequate workload and staff distribution, analysis of specific job analysis tools which outline specific job duties, and validation of appropriate pay levels for the specific positions. This effort will allow the FAA to recruit and retain the most qualified personnel with the right skillsets to evaluate complex automation technologies. The focus of our hiring in the future will include various dynamic and safety-critical positions (e.g. system safety engineers and human factors systems engineers). Skillsets like these are becoming more important, as the integration of aircraft systems and the interaction of aircraft with the National Airspace System (NAS) continues to increase. Personnel with these skillsets will further enable our ability to be a data driven organization.

Question 14. The JATR found that while issues in human-machine interaction are at the core of all recent aviation accidents and are implicated in the two B737 MAX accidents, the FAA has very few human factors and human system integration experts on its certification staff. As a result, the JATR recommended the FAA expand its aircraft certification resources in human factors and human system integration.[8]

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[6] Joint Authorities Technical Review, October 11, 2019, p. 27, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[7] Joint Authorities Technical Review, October 11, 2019, p. VIII, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[8] Joint Authorities Technical Review, October 11, 2019, p. IX, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

a. Does the FAA plan to adopt this recommendation?

i. If yes, has the FAA determined how many new human factors experts it requires? Please detail the number and types of human factors experts the FAA plans to hire and when.

ii. If no, please explain why not.

ANSWER. The FAA is planning to expand its aircraft certification resources in human factors and human system integration. We are still in the process of determining the number and types of experts that the FAA plans to hire, as well as a timeline to hire new personnel.

The President's FY21 Budget request $7.5 million to help boost the FAA's human factors research on flight deck, maintenance, and system integration and requests $5 million towards recruiting individuals with specialized skillsets.

Question 15. The JATR report states that MCAS "used the stabilizer 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."[9]

Boeing maintains that it complied with all FAA regulations, and the aircraft, including MCAS, was compliant with the FAA's regulations and the company followed the appropriate FAA certification process. This signals to me that the certification process is broken or at least severely flawed if a manufacturer can develop an unsafe airplane that still meets all of the FAA's regulatory criteria. Do you agree that the FAA certification process is flawed?

ANSWER. The FAA certification process is well established and has contributed to consistently improving the safety record of transport category aircraft over the past 50 years. The FAA acknowledges that our processes, policies, guidance, and regulations do need to be updated periodically, and we are committed to continually improving the aircraft certification process along with our other processes. We are reviewing the recommendations presented by the JATR and other independent reviews in an effort to increase safety.

Question 16. The JATR found that Boeing submitted to the FAA's Aircraft Evaluation Group (AEG) a list of features of the B-737-8 MAX cockpit which were changed from the base model B737-800. After the FAA initially raised concerns that the cumulative effects of system changes from the B-737 NG to the B737 MAX could require additional pilot training, Boeing responded by pointing out that current FAA rules (Advisory Circular 120-53B) did not require the cumulative effects on system changes to be considered, a response the FAA later accepted.[10]

a. Please explain why the FAA ignored these initial concerns and ultimately acquiesced to Boeing?

ANSWER. The FAA did not ignore any initial concerns. The FAA carefully reviewed all design changes submitted by Boeing. The FAA followed established advisory guidance, as described in AC 120-53, during the FSB process. The FAA AEG continued to analyze all information supplied by the applicant (Boeing) throughout the FSB process as required by AC 120-53 until the final JOEB evaluation—which validated that the proposed training was adequate.

b. Does the FAA plan to revise Advisory Circular 120-53B and FAA Order 8900.1, per JATR's recommendations, to include an assessment of the cumulative effects of changed products, such as differences in aircraft systems, displays, flight characteristics, and procedures?

ANSWER. The FAA intends to comprehensively review and revise AC 120-53B and associated FAA Order 8900.1 guidance to improve the process for conducting and using FSB evaluations. To build upon the JATR findings, the FAA tasked the Air Carrier Training Aviation Rulemaking Committee (ACT ARC) to recommend changes to the process outlined in AC 120-53B to ensure that the current guidance is clear and to recommend changes where needed. The ACT ARC's work is in progress.

Question 17. The JATR report identified that the design process for the B737 MAX's flight control system "was not sufficient to identify all the potential MCAS hazards."[11]

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[9] Joint Authorities Technical Review, October 11, 2019, p. 14, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[10] Joint Authorities Technical Review, October 11, 2019, p. 43, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[11] Joint Authorities Technical Review, October 11, 2019, p. 30, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

a. How did the FAA's current certification process—widely touted as the safest and most trusted in the world—fail to identify the full range of potential MCAS hazards for the B737 MAX?

b. What steps is the FAA taking to ensure that the design process for future flight control systems adequately identifies all potential hazards?

ANSWER (a.–b.). We are evaluating the assumptions Boeing used in the original integrated Systems Safety Assessment (iSSA). The purpose of the safety assessment process is to identify potential safety issues early in the aircraft design through hazard classification and probability of occurrence. The underlying assumptions used during the system safety assessment process were well established. However, the recommendations from the JATR report and other independent reviews suggest that the full range of pilot reactions across all global operators should be re-assessed. As a result, we intend to assess our policy with other authorities for both evaluating and validating the underlying assumptions used in the safety assessment process.

Question 18. The JATR found that the fragmented submission of certification documents by Boeing could lead to FAA's BASOO, which is responsible for overseeing the Boeing ODA process and certification of Boeing products, having trouble successfully transferring critical information regarding MCAS to the Seattle Aircraft Certification Office (SACO), which is responsible for overseeing continued operational safety management of Boeing products once they are certificated.[12]

The JATR also noted that test pilots working in the certification process may not always have complete knowledge of operational issues, while pilots working in the operational evaluation process may not have complete knowledge of certification issues. This gap may contribute to limited communication between the two processes, creating the potential for a lack of operational insight into the certification process.[13]

What steps, if any, is the FAA taking to evaluate and improve internal FAA communications problems regarding the FAA's certification processes that have been observed and documented by independent reviews?

ANSWER. We are placing greater emphasis on operational involvement within the certification process and, more importantly, how design and operational assumptions are documented and communicated as part of type design. This is occurring for all certification projects currently under review by the agency.

The Aircraft Certification Service (AIR) and Flight Standards (AFX) are working cohesively and collaboratively to address structural organizational changes. Examples include appointing a single program manager for all certification projects; this program manager will have program oversight over both AIR and AFX. Our agency will also focus on strategic and tactical program management efforts, to include fostering better communication between all stakeholders. These efforts are among the most important process improvements we are implementing to our certification processes. They are of significant focus and are ongoing.

Question 19. The JATR recommended that the FAA's Changed Product Rules (e.g., 14 CFR §§ 21.19 & 21.101) and associated guidance (e.g., Advisory Circular 21.101-1B and FAA Orders 8110.4C) should be revised to require a top-down approach whereby every change to an aircraft is evaluated from an integrated whole aircraft system perspective.[14]

a. Does the FAA believe that its certification of the B737 MAX lacked this integrated whole aircraft system evaluation?

b. Does the FAA plan to adopt these recommendations or take other steps to require a more holistic approach to evaluating changes to aircraft?

ANSWER (a.–b.). Multiple investigations and reviews of the Boeing 737 MAX, have been conducted, some of which are still underway. We will consider all reports and recommendations—including those that come from the open investigations and reviews—in formulating possible updates to our regulations, policy, and guidance. The FAA is always looking for ways to improve our processes. The Changed Product Rule is a top-down approach that we have harmonized with EASA, Transport Canada and ANAC (the Brazilian authority). Changes and suggested improvements to this process, along with updated policy and guidance, will need to be worked with our international partners to ensure common understanding and common application.

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[12] Joint Authorities Technical Review, October 11, 2019, pp. 50-51, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[13] Joint Authorities Technical Review, October 11, 2019, p. XI, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[14] Joint Authorities Technical Review, October 11, 2019, p. IV, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

Question 20. According to the JATR, the B737-8 MAX accident scenarios were not properly identified during the testing and certification process.[15]

a. Why weren't these scenarios properly identified?

b. Does the FAA plan to change the certification process to ensure the agency is identifying the full range of accident scenarios? If so, what kind of changes does the agency intend to make?

ANSWER (a.–b.). The FAA certification process is well established and has contributed to consistently improving the safety record of transport category aircraft over the last 50 years and longer. Still, we acknowledge the need to continually improve our certification process along with our other processes.

Uncommanded stabilizer movement was identified as a potential failure scenario during the testing and certification. Possible crew response times to failures and emergency situations were based on industry-wide assumptions, but failed to take into account the full range of pilot experience across the global operating fleet. The FAA is in the process of reevaluating assumptions related to crew response for current certification projects and is reviewing our guidance for changes that will consider the level of aircrew training and proficiency globally.

Question 21. The JATR recommended the FAA should review training programs to ensure flight crews are competent in the handling of mis-trim events.[16]

a. Does the FAA plan to conduct this review? If so, does the FAA have a timetable on conducting this review?

ANSWER. The FAA plans to evaluate pilot performance during runaway stabilizer events, and pilot competency using manual trim during normal and abnormal conditions. For the 737 MAX, this evaluation will occur during the Joint Operational Evaluation Board (JOEB) evaluation this year. The FAA will analyze the results of the evaluation and training recommendations will be documented in the 737 FSB report that will be published for public comment before being finalized. The FAA will then approve U.S. carrier training programs to ensure the minimum level of training is met prior to any return to service.

b. How does the FAA plan to ensure all 737 MAX flight crews are fully competent in handling potential mis-trim events?

ANSWER. The FAA is currently evaluating a proposal submitted by Boeing. Once the FAA validates that this training is appropriate, the training requirements will be documented in the 737 MAX FSB report recommendations that are published for public comment prior to being finalized. Any U.S. operator's training programs will then be reviewed and approved by the FAA. The FAA will oversee the training programs to ensure they are delivered in a manner that is acceptable.

National Transportation Safety Board

Question 22. The National Transportation Safety Board (NTSB) has issued several recommendations to the FAA responding to the crash of Lion Air flight 610.[17] Implementation of these recommendations will save lives.

a. The NTSB recommended that the FAA require Boeing to ensure its assumptions regarding pilot responses to uncommanded flight control inputs fully account for the effects of a cacophony of flight deck cautions, warnings, and other indications on pilot recognition and response. Has the FAA informed Boeing that this will now be required, and if so what is the timeline for Boeing's compliance? If not, why not?

b. The NTSB recommended that the FAA develop robust tools and methods to validate assumptions about pilot recognition and response to significant failures. Has the FAA taken steps to address this recommendation and if so what steps has the agency taken?

c. The NTSB recommended that the FAA develop design standards for aircraft diagnostic systems that improve how quickly and effectively pilots respond to failures. Does the FAA intend to develop these standards and what steps has the agency taken to do so?

ANSWER (a.–c.). The FAA is continuing to review and address this NTSB recommendation along with all recommendations received. We are fully committed to ensuring that the lessons learned from the 737 MAX accidents are incorporated into the software updates and included in all future certification projects as appropriate.

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[15] Joint Authorities Technical Review, October 11, 2019, p. 41, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[16] Joint Authorities Technical Review, October 11, 2019, p. XII, available at: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[17] National Transportation Safety Board Safety Recommendation Report, "Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," (Sept. 19, 2019), pp. 12-13, accessed at: https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf

The FAA has included this review as part of our testing for the 737 MAX software updates by conducting an evaluation of its Installed Systems and Equipment for Use by the Flight Crew (14 CFR § 25.1302) and Minimum Flight Crew evaluation (14 CFR § 25.1523). These evaluations are focused on minimizing the occurrence of design related errors, enabling the crew to detect and manage errors if they do occur, and crew requirements for safe operation considering crew workload and controls.

Currently, there is no timeline for Boeing's compliance. We are considering recommendations from all independent reviews in addition to the NTSB recommendations received. The 737 MAX will not be returned to service until it is in compliance.

The FAA is continuing to review and address this NTSB recommendation along with all recommendations received. We are fully committed to ensuring that the lessons learned from the 737 MAX accidents are incorporated into the software updates of the 737 MAX and included in all future certification projects as appropriate. We are committed to the evolution of FAA regulations, programs, and initiatives so they are in sync with emerging technologies, while addressing associated human factors and global impact. We are also increasing program coordination with Flight Standards, including its Aircraft Evaluation Group, to ensure that operation and training issues are fully addressed.

As always, the FAA intends to work closely with stakeholders and industry standards groups (including SAE, AIA, and GAMA) for their collective input to update existing, and develop new, aviation standards.

QUESTIONS FROM HON. FREDERICA S. WILSON FOR HON. STEPHEN M. DICKSON, ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION

Pilot Training

Question 1. Administrator Dickson, ensuring that our nation's transportation workforce is highly trained has been a priority for me both as a member of this committee and as chair of the Subcommittee on Health, Employment, Labor, and Pension of the Committee on Education and Labor.

It was very disturbing to read numerous reports on Boeing decisions such as designing MCAS to rely on input from a single angle-of-attack sensor, removing MCAS references from the flight crew operation manuals, and downplaying the system to regulators. These decisions and other efforts to minimize training requirements for the 737 Max left pilots in the dark and jeopardized the flying public's safety.

Given what we have learned from the two crashes, the NTSB finding that the pilots "lacked the tools to identify the most effective response" to the crises they faced, and the catastrophic implications of an MCAS failure, do you now support additional training for 737 Max pilots?

ANSWER. The FAA Aircraft Evaluation Group (AEG) is responsible for determining the minimum level of training necessary to safely operate an aircraft and oversee implementation of pilot training. The FAA plans to evaluate pilot performance during runaway stabilizer events, and pilot competency using manual trim during normal and abnormal conditions. This evaluation will occur during the Joint Operational Evaluation Board (JOEB) which includes the FAA, EASA and TCCA. The FAA will then analyze the results of the evaluation and training recommendations will be documented in the 737 Flight Standardization Board (FSB) report which will be published for public comment before being finalized. The FAA will then approve U.S. carrier training programs to ensure the minimum level of training is met prior to any return to service.

The FAA is also currently evaluating a proposal submitted by Boeing, which will include both Computer Based Training (CBT) and simulator training. Once the FAA validates that this training is appropriate, the training requirements will be documented in the 737 MAX FSB report recommendations that are published for public comment prior to being finalized. Any U.S. operator's training programs will then be reviewed and approved by the FAA. The FAA will oversee the training programs to ensure they are delivered in a manner that is acceptable.

Question 2. Administrator Dickson, the final report on the Lion Air flight 610 found that Boeing did not simulate, as part of its functional hazard assessment validation tests, an erroneously high angle-of-attack input leading to uncommanded MCAS activation.

When renowned airline Captain, Chelsey "Sully" Sullenberger, the Hudson River Hero, testified before this committee about the status of the 737 Max, he made the following assertion regarding pilot training, "We should all want pilots to experience these challenging situations for the first time in a simulator and not in flight with passengers and crew on board . . . reading about it on an iPad is not even close to

sufficient. They need to develop a muscle memory of their experiences so that it will be immediately accessible to them in the future, even years from now, when they face such a crisis."

Knowing what you know now, do you agree with Captain Sully that 737 Max pilots should be provided Level-D simulator training?

ANSWER. Pilots operating aircraft must be fully prepared and appropriately trained for all known failure scenarios that may be encountered in service, as documented in engineering hazard analysis and required by regulation. For the MCAS software updates of the MAX, the FAA is currently evaluating updated training proposals to determine appropriate training requirements.

Question 3. Administrator Dickson, the NTSB recommended that the FAA develop standards for improved aircraft system diagnostic tools that help pilots better identify and respond to failures.

Will you provide this committee with your absolute assurance that any future Boeing airplane will include such a system?

ANSWER. The FAA has received recommendations from several investigative teams, including the Secretary's Special Committee, the Joint Authorities Technical Review (JATR), and the KNKT accident report. We are reviewing all of these recommendations, along with those from the NTSB, to ensure that process changes, where needed, are made, lessons learned are institutionalized, training programs are reviewed, and adequate guidance is available to manufacturers and operators. The FAA is also reviewing assumptions related to present-day cockpit conditions and pilot response expectations.

Question 4. Administrator Dickson, the NTSB recommended that the FAA reexamine its assumption that pilots will always recognize a non-normal condition in 1 second and respond within 3 seconds.

Do you support that recommendation?

ANSWER. The FAA is addressing this NTSB recommendation, to include examining the human factors aspects of current type certificated aircraft, as well as addressing future human factor challenges to help mitigate associated risks and promote improved situational awareness and safety.

Assumptions regarding design and aircraft-pilot interaction are currently being reviewed and addressed for the 737 MAX and other certification projects. As an example, during review and testing of Boeing's proposed software design changes last year, it was determined a broader review of how MCAS functions within the Speed Trim System was warranted considering past assumptions. This led to more extensive design changes.

Advancements in aircraft automation have contributed to an unprecedented level of safety in our domestic aviation system, but technology advancements necessitate continuous review. By further considering human factors and the interface between aircraft pilots and systems during certification, we will be moving toward a holistic approach to aircraft certification.

Question 5. Administrator Dickson, Boeing and the FAA assumed that the pilots would recognize a non-normal condition within one second and respond to that non-normal condition within three seconds. But the National Transportation Safety Board concluded that Boeing's assumptions in its assessment "of uncommanded MCAS (em-cass) function for the 737 MAX did not adequately consider and account for the impact that multiple flight deck alerts and indications could have on pilots' responses to the hazard."

Do you accept that finding?

ANSWER. We have taken the comments into consideration, as we are evaluating the changes to the 737 MAX for return to service. We intend to conduct further reviews in this area for potential changes to our processes going forward.

As mentioned, assumptions regarding design and aircraft-pilot interaction are currently being reviewed and addressed for the 737 MAX and other certification projects. As an example, during review and testing of Boeing's proposed software design changes last year, it was determined a broader review of how MCAS functions within the Speed Trim System was warranted considering past assumptions. This led to more extensive design changes.

Advancements in aircraft automation have contributed to an unprecedented level of safety in our domestic aviation system, but technology advancements necessitate continuous review. By further considering human factors and the interface between aircraft pilots and systems during certification, we will be moving toward a holistic approach to aircraft certification.

What are you doing to ensure FAA adequately considers pilot response times in designing future airplanes?

ANSWER. Pilot recognition and response times are one part of the safe design of the system. Another important part is the quality and timeliness of the aircraft information that is provided to the flight crews. The FAA is working to ensure flight crews receive aircraft information in a manner which is useful and to which a flightcrew can quickly respond. At times, a flightcrew's response will be a memory item and at other times the flightcrew's response will require additional diagnosis and reaction before countermeasures can be started.

The FAA has received several recommendations on pilot response times and how system safety assessments are conducted. We are reviewing all of the recommendations to identify where process changes are needed and ensure that we have adequate guidance for our employees and for designers/manufacturers. Design assumptions related to pilot reaction times must be substantiated and take the cockpit environment into consideration. Empirical data collected during our Joint Operational Evaluation Board (JOEB) process for aircraft certification projects will also be considered in our review.

NTSB Recommendations

Question 6. Mr. Dickson, the NTSB recommended that the FAA require Boeing to incorporate design enhancements, pilot procedures, and/or training requirements, where needed, to minimize the potential that pilots would respond to multiple cautions and warnings in a manner different from the manner that Boeing has assumed.

When do you plan to implement this recommendation?

ANSWER. The FAA is taking these recommendations into consideration for the redesign of the MAX. The FAA has completed multiple reviews of system safety assessments (SSA) for the Boeing 737 MAX and is in the process of certifying the design changes to address causal factors associated with the Lion Air and Ethiopian Airlines accidents, as well as additional changes to improve functionality.

The evaluation of the final design change will include a workload assessment, using revised pilot procedures, to minimize the potential for manufacturer assumptions to be inconsistent with pilot actions. The FAA will further assess these pilot procedures as part of an operational evaluation, to ensure that appropriate procedures and training requirements are included in the project approval. These activities will occur prior to the return to service.

QUESTIONS FROM HON. ANDRÉ CARSON FOR HON. STEPHEN M. DICKSON, ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION

Question 1. Administrator Dickson, please let me know who at FAA met with Boeing to discuss the information underlying the TARAM (Transport Airplane Risk Assessment Methodology) report.

a. Where did any such briefing, discussion or presentation on the TARAM take place?

b. Who received this information?

ANSWER (a.–b.). A TARAM is a scientific risk-assessment tool. It weighs a number of factors and is used to help the FAA quantify risk. It is not the FAA's sole decision-making tool; rather, its purpose is to assist the Corrective Action Review Board (CARB)—comprised of experts in their field—in making decisions about how to reduce or eliminate risk. The FAA would never accept a risk of additional accidents without taking immediate action, and in fact, the agency acted immediately—with interim and permanent steps—to respond to the Lion Air accident. The FAA issued an emergency AD reminding pilots how to deal with runaway speed trim eight days after the Lion Air accident and before the TARAM analysis was complete. When the AD was issued, the FAA determined the permanent action was to require a design change to address MCAS. That effort was also underway before the TARAM was prepared in December 2018.

The TARAM analysis of the 737 MAX MCAS safety issue was presented to the Seattle ACO Corrective Action Review Board (CARB) on November 28, 2018, December 12, 2018, and February 6, 2019. Boeing's Airplane Safety Engineering Focal attended each of the CARB meetings as an observer. The meetings were held at the FAA Regional Office in Des Moines, Washington. On February 13, 2019, the Seattle ACO Office Manager met with the Boeing 737 MAX Chief Project Engineer to discuss and sign the TARAM-derived risk-based corrective action schedule.

c. Who made the decision to act on the Airworthiness Directive?

ANSWER. After reviewing the available information, the Seattle ACO recommended an Emergency Airworthiness Directive, AD 2018-23-51. The Seattle ACO then followed FAA's standard coordination process prior to formalizing the decision.

d. Who had the authority to ground the MAX based on the TARAM last December?

ANSWER. The decision to ground the 737MAX was not based solely on the December 2018 TARAM.

The Administrator of the Federal Aviation Administration carries out statutory duties and powers related to aviation safety, including the authority to ground aircraft.

e. Did Mr. Ali Bahrami have the TARAM information in December 2018? If not Mr. Bahrami, who did?

ANSWER. The Associate Administrator previously answered this question during a transcribed interview your staff conducted on December 5, 2019.

The FAA followed the recommendation of the technical experts in Seattle following the Lion Air accident and issued an emergency AD within days of the accident. When additional data and information became available after the Ethiopian Airlines accident, the Associate Administrator for Aviation Safety recommended grounding the 737 MAX fleet.

QUESTIONS FROM HON. BRIAN K. FITZPATRICK FOR HON. STEPHEN M. DICKSON, ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION

Question 1. Administrator Dickson, my top aviation priority has been safety—I know that you and the FAA share that priority, but so far, the FAA has shown little intention of implementing the secondary barriers provision that was included in the FAA Reauthorization Act of 2018.

Currently, the Aviation Rule Making Council (ARAC) has dragged their feet. Can you speak to a realistic timeline of when this critical safety barrier will be implemented on new aircraft?

ANSWER. The FAA takes cockpit security seriously and is committed to meeting the intent of section 336 of the FAA Reauthorization Act of 2018 regarding secondary cockpit barriers. On June 20, 2019, the FAA tasked our Aviation Rulemaking Advisory Committee (ARAC) to provide information and recommendations on this topic. The ARAC formed a Flight Deck Secondary Barrier Working Group to address the tasking. We expect the Flight Deck Secondary Barrier Working Group to provide the ARAC with a report in early 2020 and expect the ARAC to consider that report at their March 2020 meeting. The ARAC's recommendations will help the FAA develop an approach that provides manufacturers with necessary technical information to enable implementation, as well as other information on costs and benefits required by the rulemaking process.

Under the Administrative Procedure Act (APA), the FAA must engage in a rulemaking proceeding to issue an order requiring installation of a secondary cockpit barrier on each new aircraft that is manufactured for delivery to a passenger air carrier in the United States operating under the provisions of part 121 of title 14, Code of Federal Regulations.

QUESTIONS FROM HON. PAUL MITCHELL FOR HON. STEPHEN M. DICKSON, ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION

Question 2. The various investigations of the Boeing 737 MAX accidents—including those by Congress, the FAA, Boeing, and the press—have shown many assumptions were made during the design and certification of the 737 MAX. With hindsight, it is clear some of those assumptions were faulty. It also appears that not every potential input and variable was entered into these assumptions.

a. What can and will the FAA do to reassess the assumptions it uses during aircraft certification?

b. What new internal processes—either via new procedures or staffing changes—can and will the FAA pursue to ensure robust testing of and counterpoints to assumptions it utilizes?

ANSWER (a.–b.). Assumptions regarding design and aircraft-pilot interaction are currently being reviewed and addressed for the 737 MAX and other certification projects. As an example, during review and testing of Boeing's proposed software design changes last year, it was determined a broader review of how MCAS functions within the Speed Trim System was warranted considering past assumptions. This led to more extensive design changes.

Advancements in aircraft automation have contributed to an unprecedented level of safety in our domestic aviation system, but technology advancements necessitate continuous review. By further considering human factors and the interface between aircraft pilots and systems during certification, we will be moving toward a holistic approach to aircraft certification.

Additionally, the FAA is reviewing how we structure our approach to delegation. In the case of Boeing, we have reduced the amount of delegation, and we have pulled back some of the previously delegated items. Specifically regarding the 737 MAX, the FAA has retained all aspects of the review. No part of the review has been delegated to the manufacturer. In addition, the FAA is in the process of re-evaluating our delegation decisions for other current Boeing projects.

We are carefully reviewing the recommendations received to date and are identifying the FAA and external stakeholders who would be responsible for the development and implementation of proposals to address the recommendations. This includes items like Recommendation R9 of the Joint Authorities Technical Review (JATR) report, which discusses operational design assumption of crew response.

Question 3. In the submitted written testimony from Mr. Edward Pierson, he noted that during a 13-month timeframe from 5/12/18 to 3/26/19, the Boeing 737 line had 15 emergencies, leading to 2 crashes and 13 incidents.

a. Is this statistic consistent with the FAA statistics on the 737 line?

b. If so, how does this record compare with other aircraft types?

c. If this statistic is an outlier, what accounts for this inconsistency?

ANSWER (a.–c.). The FAA's understanding of Mr. Pierson's comments is that he is referring to the two accidents that led to the grounding and current redesign of the 737 MAX, and 13 Service Difficulty Reports (SDR) received on the MAX aircraft. It is not unusual for transport aircraft to have 13 SDRs in the stated reporting time period.

The FAA reviewed the SDRs raised by Mr. Pierson and determined that none of them required an Airworthiness Directive (AD) mandating corrective actions for the airplane.

QUESTIONS FROM HON. PETER A. DEFAZIO FOR G. MICHAEL COLLINS, FORMER AEROSPACE ENGINEER, FEDERAL AVIATION ADMINISTRATION, APPEARING IN HIS INDIVIDUAL CAPACITY

Question 1. Mr. Collins, delegating authority to entities such as Boeing has been a long-standing practice which can be beneficial to the Federal Aviation Administration (FAA) in leveraging the technical expertise of manufacturers to help make key determinations concerning the safety of aircraft. However, there is a risk of over-delegation that can lead to regulatory capture where the FAA favors industry's interests at the expense of its regulatory responsibilities.

a. Over your three-decade career at the FAA, what are your observations on how the FAA has managed its relationship with the entities it regulates?

ANSWER. Delegating authority to entities such as Boeing has changed dramatically over my three-decade career as an FAA aerospace engineer in the Aircraft Certification Service. Thirty years ago, the system provided for direct oversight of and open communications between FAA technical specialists and those in industry to whom FAA delegated authority to make compliance findings under the Designated Engineering Representative (DER) system. Now, under the "Organization Designation Authorization" (ODA) system there is no direct oversight of and very limited[1] communication between FAA specialists and those in the ODA who are authorized to make compliance findings for the FAA ("unit members"). Instead of using FAA oversight to identify and correct safety issues (non-compliances) before certification, the FAA has been moving toward identifying safety issues during audits after a design has been certificated and is in production The concept of auditing after the certification to determine if the compliance finding was appropriate and process used to make the finding needs improvement is an ineffective and inefficient. The process leads to the flying public being exposed to potentially unsafe designs until or if the deficiency is found during an audit or disclosure by the company. Direct involvement of the FAA safety engineers and collaboratively working with the DERs resulted in identifying and fixing non compliances before the airplanes entered service.

In addition to the changes in delegation, FAA management has changed their focus from one that prioritized compliance to regulations and policy thirty years ago to a management culture that gives priority to applicants' positions, their costs and schedules over compliance to FAA regulations and policy. There are several examples of this shift in management focus in my written testimony such as the 737 MAX rudder control, 737 MAX fuel tank surface temperature, 737 MAX fuel pump circuit protection, the 787 lithium-ion battery containment as well as the issue of

[1] Boeing implemented internal procedures that required their ARs to get permission before talking with FAA certification engineers. This practice stifled a collaborative oversight and compliance working relationship.

FAA issuing exemptions that are more in the economic interests of the applicant than in the interest of the Public.

Regarding exemptions, Title 14 Code of Federal Regulations (14 CFR) section §11.81 is titled "What information must I include in my petition for an exemption?": Paragraphs (d) and (e) state:

> (d) The reasons why granting your request would be in the public interest; that is, how it would benefit the public as a whole;
>
> (e) The reasons why granting the exemption would not adversely affect safety, or how the exemption would provide a level of safety at least equal to that provided by the rule from which you seek the exemption;

However, FAA management often grants exemptions to petitioners (type design applicants) that allow designs that do not provide a level of safety at least equal to that provided by the rule. Those exemptions allow the applicant to produce a design that has a level of safety below that required by the FARs. Further, those exemptions are only in the financial interest of the applicant; they do not benefit the public as a whole as stated in the regulation.

b. What is the "right" amount of authority for the FAA to delegate to industry?

ANSWER. There is no numerical answer that defines the right amount of authority to delegate to industry. The right amount depends on the scope and potential safety impact of the certification project and each applicant's technical expertise, knowledge of Federal Aviation Regulations (FARs), the regulation's intent and published FAA policy.

One factor should be the applicant's compliance culture which is demonstrated by their ability to follow FAA regulations and policy. If an applicant repeatedly presents designs that clearly do not comply with the regulations and policy, and often argues with the FAA over the intent of the FAA's regulations, that does not demonstrate a good compliance culture. A designee is supposed to demonstrate the knowledge and ability to follow FAA regulations and policy.

Another factor should be the safety culture of the applicant. The Federal Aviation Regulations (FARs) define the minimum level of safety for obtaining an FAA type certificate. They do not define a maximum level of safety that should be included in a design. Applicants should demonstrate a safety culture that values presenting designs that not only meet the FARs but exceed the safety level required by the FARs for those critical safety designs where an additional safety level is in the public interest; as well as in the interest of the applicant to produce a safe product and maintain a high safety reputation with the public.

c. Would you say that the FAA has yielded too much authority to Boeing? Why or why not?

ANSWER. Yes, it does seem the FAA has yielded too much authority to Boeing; especially since granting Boeing an Organizational Delegation Authority (ODA). This has been demonstrated by the grounding of two type design approvals Boeing obtained under their ODA in each model's first year of operations. The first Boeing model approved under their ODA, the 787, was grounded for several months because the design of the lithium-ion battery installation approved under the ODA process was unsafe. As presented in my written testimony, an FAA technical specialist had proposed the FAA require a steel containment structure be required but was overruled. A steel containment structure was part of the design change that allowed the lifting of the grounding of the 787.

The second model approved under Boeing's ODA, the 737 MAX, series has now been grounded for nearly one year following the second of two catastrophic crashes. Those failures of the ODA demonstrate a lack of a good compliance culture and safety culture necessary for the authority FAA has yielded to Boeing.

In both instances, delegation decisions were made based upon management pressure and their desire to support Boeing's schedule needs. For instance, on the 787, the delegation should have been limited due to the significant amount of new technology incorporated into the design and the new global supply network and business model used to develop and manufacture the airplane. Rather than limit the delegation authority, FAA managers made decisions to delegate over 95 percent of the findings. On the 737 MAX managers made similar delegation decisions based upon resources and program schedule needs. Even then, the 737 MAX received type certification ahead of Boeing's schedule.

In addition, these are examples of how FAA has yielded too much authority to Boeing and other ODAs:

i. The Boeing ODA manual restricts what FAA aerospace engineers can look at technically and restricts what can be challenged by the FAA aerospace engineers.

ii. FAA management directed (forced) FAA technical specialists to delegate 90% and more of engineering safety findings to the Boeing ODA.

d. What does the FAA need to do to ensure that it is able to adequately oversee the work it delegates?

ANSWER. Delegation works best when there is direct communication, trust, integrity, and professionalism on both sides. The FAA aerospace certification engineers should be able to work directly with the designee (in this case, the ODA unit members) to establish and maintain trust. The FAA aerospace certification engineer must be able to review and approve novel and safety critical test plans and witness novel and safety critical testing to conduct proper oversight the of designee's knowledge of FAA regulations and policy as well as designee's professionalism. The designee must be allowed to directly communicate with the FAA aerospace certification engineers (and vice versa) at any time and to freely discuss engineering safety concerns and tackle in-service problems in a professional and collaborative manner.

FAA should be required to establish a formalized delegation decision process that is based upon factors noted above regarding the ODA performance, and the technical risk of the particular design aspect. The technical risk should be established by a team of experts consisting of FAA technical experts and outside experts if additional expertise is needed to address new technology aspects of a product. The retention status of an item would be established at the beginning of the program and it could not be changed without a formal decision by the technical team. Managers should not be able to override the team decision due to pressures by applicants later in the program due to schedule related concerns. Delegation decisions could be reviewed by the technical team and delegation authorized in consideration of new information provided by the applicant justifying delegation. FAA management should not direct delegation of authority to an applicant based on any arbitrary numerical value.

Current FAA policy for ODAs, including Order FAA Order 8100.15B, "Organization Designation Authorization Procedures," allows for FAA to determine how much to delegate to an ODA and allow for evaluating proposed unit members. However, a change in the 2018 FAA Reauthorization removes that ability. The change essentially made delegation a right of the ODA holder instead of a privilege. Section 212(a) requires the FAA to "delegate fully" to an ODA holder the functions specified in the ODA holder's procedures manual. The FAA can limit any function only after the delegation if investigation shows that public interest and safety require such a limitation. This is in contrast with current policy, which requires the FAA to retain certain inherently governmental functions, such as interpretations of airworthiness standards, and specific compliance findings if the ODA either has no experience with the issue or has demonstrated previously that it can't be relied on, e.g., by not following FAA policy in making a compliance finding. (See FAA Order 8100.15B, paragraphs 8-4, Limitations, and 8-6, Type Certification Programs.) Section 212(a) also requires the FAA, at the "request" of an existing ODA holder, to approve revisions to its procedures manual and to delegate fully each function described in the manual, with the same restrictions on limiting functions.

In addition, the FAA should dedicate additional resources (aerospace engineers) to the oversight function during certification instead of dedicating new resources to audit type functions.

Question 2. Mr. Collins, you were a member of the Safety Oversight Board that was responsible for reviewing safety concerns raised by FAA employees. One of the issues the board considered was the design of the rudder cable on the 737 MAX. According to several FAA technical staff, the rudder cable is at risk of being damaged—meaning that the plane could no longer be steered—from debris in the event of an uncontained engine failure. However, Boeing felt that the design changes were impractical, and FAA managers ultimately sided with Boeing over the agency's technical experts.

a. In the case of the 737 MAX rudder cable issue, was it unusual for so many experts to express their concerns over the FAA's reticence to have Boeing change the design?

ANSWER. Yes; it was very unusual for so many FAA technical experts as well as several FAA managers to disagree with the decision of some FAA managers on a means of compliance to the Federal Aviation Regulations. Even more unusual that they would document their disagreement in writing.

FAA management was not only reticent toward the end of the 737 MAX certification project to have Boeing change the design of the rudder controls from the original 1960's design; FAA managers actively developed the FAA position in the issue paper and their response to the SRP Oversight Board/SME Panel's determination to try to present a reason the old rudder control design could be found as com-

pliant to the FARs in spite of the lessons learned from the 1989 DC-10 accident. The result is the rudder control of the 737 MAX, as documented by the SME Panel report, is subject to a single failure causing a catastrophic accident as happened in the DC-10 accident. FAA management's reasons were found unacceptable by all those who documented their disagreement, including the independent SRP Subject Matter Expert Panel and the SRP Oversight Board.

The FAA management position at the end of the certification project is in stark contrast to their position earlier in the certification project when those same FAA managers signed FAA letters and the FAA issue paper stating Boeing needed to change the rudder control design in order to be compliant with the Federal Aviation Regulations. In effect, at the FAA management position early in the 737 MAX certification process agreed with the later position of the FAA technical specialists, SRP SME Panel and the SRP Oversight Board.

b. How concerned are you that the voices of the FAA's technical experts are not being heard and how do you believe that can undermine aviation safety?

ANSWER. I am very concerned that these days FAA managers more often spend time looking for ways justify accepting industry proposals while overruling the FAA technical specialists who have determined the industry proposal does not demonstrate compliance to the Federal Aviation Regulations (FAR). The technical specialists I worked with consider themselves public servants who want to make sure designs approved by the FAA do comply with the minimum standards in the FARs or truly provide an equivalent level of safety to the relevant FARs. As public servants, they know their decisions affect the safety of the flying public as well as those on the ground if an aircraft crashes.

When designs are approved that do not meet the minimum safety standards, it clearly undermines aviation safety. As I stated in my written testimony, it is also demoralizing to FAA technical specialists when managers continually overrule their technical findings.

I believe that those FAA managers who often overrule technical specialists are in many cases violating the regulations and policies and putting the public safety at risk. In order to send a message that the FAA has a just safety culture and will not accept this behavior, these managers should be held accountable.

c. What are your recommendations for ensuring the Safety Review Process (SRP) strikes the right balance between safety concerns and the industry's business interests?

ANSWER. The SRP process was created to provide a voluntary safety reporting process that provides the opportunity for FAA employees to report safety issues and for those issues to be evaluated using a collaborative process, rather than a unilateral FAA management process. It isn't intended to strike a balance between a safety concern and industry's business interests. It is intended to evaluate a safety concern, for example a concern an FAA decision allows a design that does not comply with the FAA regulations, and determine if the safety concern is valid. If the safety concern is valid, then the SRP process is intended to make recommendations to correct the safety issue.

When the issue involves a decision made regarding an applicant's proposed method of compliance, such as the 737 MAX rudder control issue I discussed in my written testimony, the SRP process evaluates the applicant's position and the FAA's decision against the FAA safety regulations and policy. When the SRP collaborative process determines an FAA decision was contrary to FAA regulations and policy, FAA management should take the Oversight Board's decision seriously instead of being defensive about it and just restating their support for their prior decision. This was the same difficulty the current Administrator had during your December 11, 2019 hearing in admitting the FAA made a mistake regarding the approval of MCAS on the 737 MAX..

With regard to striking a balance between safety and industry's business (cost) interests, when the FAA proposes a change to the regulations (FARs) they are required to perform an extensive cost-benefit analysis. The rulemaking process evaluates the cost of implementing the change to future designs against the safety benefit to the public as a whole. This process includes a public comment period and review of the rulemaking by the Department of Transportation. In additions, significant rulemaking is reviewed by the Office of Management and Budget before it is issued. It is during the rulemaking process that the FAA strikes the balance between safety and industry's cost interests. Therefore, when a design is non-compliant with FARs the FAA has not achieved the right balance between industry and public interest that was previously determined during the rulemaking process.

In addition, FAA regulations already have methods to try to balance compliance to the regulations with the cost to the applicant for changed products (e.g., amended

type certificate projects like the 737 MAX). When evaluating the application of newer regulations to a changed product, the Changed Product rule allows FAA to consider the cost of applying a new regulation verses the safety benefit. Using that process the FAA may decide to allow the applicant to continue to use the older regulations that applied to the baseline model by granting an "exception" or the FAA may decide it is in the public interest to require the applicant apply the latest regulation.

Advisory Circular (AC) 21.101-1B, "Establishing the Certification Basis of Changed Aeronautical Products" describes the use of exceptions. In section 2.2.1 it states "Section 21.101(a) requires a change to a TC and the area affected by the change to comply with the latest requirements, unless the change meets the criteria for the exceptions identified in § 21.101(b) or (c). The intent of § 21.101 is to enhance safety by incorporating the latest requirements into the type certification basis for the changed product to the greatest extent practicable."

For example, the FAA can evaluate if the newer cockpit display rules should be applied to a changed product such as the 737 MAX, or should an exception be granted that allows the applicant to use the regulations in the previous (baseline) model's certification basis. This is not a public process like rulemaking or petitions for exemption. I believe FAA Management has too often placed their priority on industry cost concerns verses the safety of the public as a whole when granting exceptions under the Changed Product Rule. Therefore, I recommend the FAA change the process for granting an exception to include an opportunity for the public to comment on proposed exceptions. The notice to the public requesting comment on a proposed exception should include all justification used by the applicant in their request for the exception; similar to the public exemption process.

In the case of the 737 MAX rudder control, the regulations had not been updated since the 737 model being changed. In fact, the FAA policy had not changed since the certification of the baseline 737 NG models. Therefore, a better way for FAA management to respond to a decision and recommendation by the SRP Oversight Process when it determines the method of compliance was not appropriate would be to use an existing tool the FAA has in the regulations to evaluate a design that does not comply with the regulations; the Exemption process defined under 14 CFR Section 11. FAA management should have required the applicant submit a petition for exemption and then FAA should have evaluated the petition using the process defined in Section 11. This was one of the SRP Panel/Oversight Board recommendations.

When evaluating the exemption, FAA should use a collaborative process between the local manager and the FAA technical specialists. Any exemption granted should be in the interest of the public as a whole, as stated in the regulations, and clearly provide an equivalent level of protection to the regulations, as stated in the regulation. Exemptions should not be granted solely on the basis of the financial interests of the applicant. As discussed above, when each regulation was issued it went through an evaluation of the cost to industry verses the safety benefit of the regulation. Exemptions should not be used as a method to circumvent the public cost benefit evaluation used when regulations were adopted.

In using the exemption process for the 737 MAX rudder cable issue, FAA Management could have granted a time-limited partial exemption to give Boeing additional time to modify the rudder design so that it complies with the regulations. This seems similar to how EASA worked with Airbus on the similar A320neo rudder design. Alternatively, FAA management could have granted Boeing a full exemption so Boeing could continue to produce the 737 MAX with the 1960s rudder design for another 30 years or however long the 737 MAX remains in production, although in my opinion that would not have been in the interest of the public as a whole.

Prior to the SRP being developed, I was on a joint Union-Management collaborative team that recommended a different type of voluntary safety reporting process that was similar to the very successful Air Traffic Safety Action Program (ATSAP). The proposal from the team included a third independent party in addition to Union representatives and Aircraft Certification Managers in the group evaluating the SRP report and making recommendations. Later, I was in a meeting when FAA management in Washington, D.C. (AVS-1 at the time) expressed her concern with having a third party in the process and would not agree to this proposal. Unfortunately, the SRP system that is in place today has once again demonstrated that FAA managers refuse to admit any fault in a past decision and correct poor safety decisions.

The existing SRP process could be improved by requiring upper level management (e.g., AIR-1) document their decision to either accept the SRP Oversight Board's recommendation or accept the FAA Division manager's decision to reject the Oversight Board's recommendation.

A further improvement to the SRP could be to add an independent review process for those SRP reports where FAA Management rejects the SRP Oversight Board recommendation. The issue could be submitted to the NTSB using a process like the existing Airman Appeal process. FAA could be required to submit the FAA Management justification together with the SRP report and Oversight Board recommendations to the NTSB for review. Such an independent review step could help develop a just safety culture in FAA Aircraft Certification Service management from the highest levels of management to the line managers.

QUESTIONS FROM HON. PETER A. DEFAZIO FOR MICA R. ENDSLEY, PH.D., APPEARING ON BEHALF OF THE HUMAN FACTORS AND ERGONOMICS SOCIETY

Question 1. Dr. Endsley, in your testimony you note that pilots were not aware of or trained on the maneuvering characteristics augmentation system (MCAS), and that "[e]ffective training on how to overcome automation failures involves not only a written notice or description of automation, but also actual experience in detecting, diagnosing, and responding of such events."

a. Does this mean you believe 737 MAX pilots should have had simulator-based training before flying the aircraft?

ANSWER. Scientific research shows that training pilots on fight deck automation is critical for developing a robust understanding of how it works. This mental model is needed to support pilots in understanding automation modes and accurately predicting its behaviors under both normal and non-normal conditions. An accurate mental model of how automation works is critical to developing good situation awareness and performance in flight operations.

While there was an expectation by Boeing that pilots did not need simulator training because the MCAS automation would be acting in the background, this expectation did not consider the challenges of abnormal events such as was experienced in these accidents. Simulator-based training on MCAS should have been provided to all pilots prior to flying the aircraft to allow them to develop the needed understanding of the behavior of the MCAS automation under both normal and non-normal events, such as degraded or inoperative sensors.

b. When the 737 MAX is ungrounded, do you think pilots should have to go through some kind of simulator-based training before being allowed to fly the aircraft again?

ANSWER. Prior to flying the 737-MAX, pilots should be provided with training on the MCAS system regarding how the newly revised system works as well as its limitations and potential failure modes. They should also be provided with the opportunity to fly a 737-MAX configured flight simulator and to experience potential failure conditions. The simulator training should include identification of critical cues that indicate a failure mode, differentiation between MCAS failure and other failure conditions, and execution of the proper response to any MCAS failures.

While some pilot training can be provided via classroom or computer-based training programs, it is important that flight simulators are also employed to ensure that pilots can recognize automation behaviors and failure conditions in context, can accurately carry out the appropriate procedures, and can experience aircraft flight handling changes to gain proficiency. Training programs should be tested and validated to show that they are successful in providing the needed skills to line pilots.

Question 2. Dr. Endsley, it has now been more than one year since Boeing admitted that it concealed from both the Federal Aviation Administration (FAA) and 737 MAX operators the fact that the angle of attack (AOA) disagree alert wasn't functioning properly on the vast majority of the 737 MAX fleet in service. Yet, the FAA hasn't taken any kind of enforcement action against Boeing for its failure to divulge this to the FAA or its customers. The FAA has issued no fines or penalties—despite the fact that this was a clear violation of FAA regulation.

Do you think the FAA should propose some kind of penalty against Boeing for its handling of the AOA disagree alert, and if it doesn't, what kind of message do you believe that sends to Boeing and industry?

ANSWER. Companies are responsible for establishing a strong safety culture that promotes the application of safety and human factors practices, and the open reporting of any system problems and appropriate remedial safety actions that are needed. This includes design changes, training, and communications with regulatory authorities and customers. While the Human Factors and Ergonomics Society strongly endorses such activities based on scientifically supported best practices, it is not our role take a position with regard to punitive actions or penalties pertaining to regulatory compliance. It is the purview of the government to determine the appropriate

proactive and/or reactive measures that should be taken in regards to regulatory compliance.

Question 3. Dr. Endsley, do you believe the FAA's November 7, 2018, Emergency Airworthiness Directive was insufficient for preventing the second 737 MAX accident. If so, why?

ANSWER. The Emergency Airworthiness Directive (AD) was clearly insufficient for preventing the second accident in the 737 MAX. While the AD addressed the issue of blocked AOA sensors affecting aircraft performance, it did not address the MCAS by name, nor did it explain how the MCAS used the sensor inputs to control the aircraft's pitch, leaving pilots with an insufficient mental model of MCAS in normal and abnormal situations. More importantly, it failed to mandate training on the MCAS, on correctly identifying problems with improper MCAS operations, and on proper procedure execution.

The revisions to the flight manual in the AD provide only a long list of potential problems that were not sufficiently diagnostic of the MCAS failure condition. The cues received by the pilots due to degraded sensors affecting MCAS were significantly different than the cues received with a runaway stabilizer trim, the procedure that Boeing and the AD instructed pilots to use, slowing diagnosis of the problem.

While the Indonesian Airlines crew was able to correctly identify the need to use the runaway stabilizer trim procedure (in that the first officer had completed initial training on the aircraft after the AD was issued), they were not able to correctly perform the execution of the procedure. A mis-trim was still in place after the crew set the system to CUT-OUT. Additionally, they were unaware of the disconnect of the auto-throttle system, leading to loss of situation awareness on airspeed. The combined mis-trim and high airspeed created a pitch problem that was uncontrollable.

QUESTIONS FROM HON. FREDERICA S. WILSON TO JOHN M. COX, CHIEF EXECUTIVE OFFICER, SAFETY OPERATING SYSTEMS

Joint Authorities Technical Review (JATR)

Question 1. Mr. Cox, the JATR found that the MCAS system was not evaluated as a "complete and integrated" function in the certification documents that were submitted to the FAA, that the safety analysis was fragmented among several documents, and parts of the System Safety Analysis (SSA) from the B737 NG were reused in the B737 MAX without sufficient evaluation.

How important is it to evaluate new flight systems and technology as a "complete and integrated function" of the aircraft?

ANSWER. In today's modern, complex airliners it is vital that the entire system be evaluated, not just individual components. This is the purpose of the System Safety Analysis. It is my understanding that Boeing evaluated MCAS with a System Safety Analysis in the original state (.6 degrees of stabilizer movement per activation) but not when the authority was increased (2.4 degrees of stabilizer movement per activation). This was a significant oversight or error.

I agree with the JATR that is very important that a complete and integrated system should be evaluated. Furthermore, each component should be evaluated for failure and the effect on the overall system. As an example; if an Angle of Attack sensor fails the system will be affected with the activation of the stick shaker, IAS Disagree, ALT Disagree, FEEL DIFF PRES, warnings plus the disengagement of the autopilot and autothrottles. Pilot response to these numerous and simultaneous warnings should be carefully evaluated for risk severity.

Certification criteria can be improved to be more inclusive of component failures that affect systems.

Boeing-FAA, Boeing-Airlines, Boeing-Pilots Communications

Question 2. Captain Cox, the Committee's investigation has revealed that Boeing communicated important information about MCAS and related systems to the FAA and airlines either in a fragmented way or not at all. Does that raise alarm in your view?

The Joint Authorities Technical Review found, and I quote, that "Aircraft functions should be assessed, not in an incremental and fragmented manner, but holistically at the aircraft level." Do you agree?

ANSWER. Boeing viewed MCAS as a subsystem of the Speed Trim System, and not of importance to the operator or crew. I respectfully disagree with this assessment. Any system that can move a major flight control, such as the stabilizer trim, should be explained to the operator and flight crew. It does concern me that the Boeing

evaluation did not adequately take into account the simultaneous failures that could occur which, could slow crew response and complicate diagnosing the problem.

I fully agree with the JATR that aircraft functions should be assessed in a holistic manner. With increasing complexity and increasing interrelation between systems (computers exchanging information with other computers) it is very important that system performance be evaluated carefully when a failure occurs.

QUESTIONS FROM HON. CONOR LAMB TO JOHN M. COX, CHIEF EXECUTIVE OFFICER, SAFETY OPERATING SYSTEMS

Question 1. Captain Cox, you worked on the investigation of the USAir flight 427 accident in 1994, which tragically occurred in my district. As you know, USAir 427 was the second crash attributable to the same design flaw in the Boeing 737 rudder power control unit. In your testimony, you spoke to the fact that it is unacceptable to have two successive crashes related to the same design flaw.

Does it give you concern that, 25 years later, two 737s have again crashed due to a common design flaw?

ANSWER. I, along with numerous other investigators, spent five years solving the US Air 427 accident. The industry did not learn everything possible from the United Airline accident four years earlier in Colorado Springs (UAL 585). It does concern me that there were two MAX accidents in which there were many similar causal and contributing factors.

Due to the short time between the Lion Air and Ethiopian Airlines accident the investigation of Lion Air was not complete. However, there was compelling evidence of a serious problem with MCAS activation and the resulting impact on controllability.

A review of the assumptions of pilot actions following MCAS activation should have been undertaken after Lion Air.

An accident that is due to the reoccurrence of problem known from a previous accident or incident is the most difficult for accident investigators.

Question 2. Do you recall that pilots were blamed after the first and second accidents in the 1990s? What are your thoughts on this?

ANSWER. There were some people and organizations that attempted to blame the pilots for the United 585 and US Air 427 accidents. NTSB did not agree that the pilots were the cause of these accidents.

Some organizations quickly blame pilots because they are the last people that could have stopped the accident sequence. As an experience accident investigator I have learned that this is simplistic and does not address all of the issues.

All accidents are the result of a complex series of events. Preventing future accidents requires understanding and mitigating all of these contributing factors. Sometimes assessments should be done before the final report is released to ensure continued safety of the fleet.

If human error is a causal factor, evaluation of what caused the error should be done. Human factors and human performance are important parts of accident investigation.

Question 3. What recommendations do you have to ensure that corrective action is taken after an initial crash before a subsequent crash occurs?

ANSWER. Early in an investigation an evaluation of aircraft and crew performance compared to expected performance should be done. If there are discrepancies in either crew performance or aircraft performance an evaluation of the risk to the fleet should be conducted. Could this happen again? Are the assumptions of crew performance the same as accident crew's actual performance? Did the airplane perform as expected?

Conduct a review of fleet history to determine if similar events occurred, even if they did not result in an accident. This information provides data for the likelihood of a future occurrence. This review should be transparent and shared with all parties to the investigation.

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