THE ROLE OF CONSENSUS STANDARDS ON SAFETY IN THE LIGHT OF BOEING 737 MAX ACCIDENTS

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ABSTRACT

This paper discusses why consensus standards are needed to achieve better safety level in light of the lessons learned from two Boeing 737 MAX crashes occurred at intervals of 5 months in 2018 and 2019. These events showed the critical role of standards in safety. Based on the timeline of the events, it was seen that even though the main cause of the ac*cidents was sourced by an automation system called MCAS, the pilot was blamed after the first accident. Since the authority assumed that the aircraft was safe enough, the FAA issued an airworthiness directive (AD) to warn pilots to be careful in such conditions instead of grounding aircraft or issuing an AD to improve the design of the automation system. However, just after five months, another 737 MAX accident with the same reason revealed the truth in all aspects. The study aims to prove that the current status of regulation is not sufficient to ensure that aircraft are designed, manufactured and maintained safely. So, there is a need to develop international consensus standards by collaborating with representatives from aviation stakeholders and experts from other industries. In the study, the establishment of the consensus standards is also defined. As can be seen from the results of this study, there is a need for global aviation standards in many ways and the necessary steps should be taken without further delay.*

Keywords: Consensus standards, safety, Boeing 737 MAX, aircraft accident, regulations, type certificate, certification requirements, ICAO

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INTRODUCTION

From the earliest days of aviation, aircraft manufacturers have been designing the aircraft in compliance with the specific standards to ensure that the aircraft is airworthy. Sometimes since the standards are far beyond the advances in technology, some facts emerge as a result of the accidents that resulted in the death of many people. The fact that two Boeing 737 MAX airplane crashes originated from the same automation system occurred at intervals of 5 months in 2018 and 2019, in Indonesia and Ethiopia respectively, resulting in a total of 346 deaths, confidence in automation systems has been profoundly diminished, and the certification requirements of the automation systems were questioned again [Demirci, 2021]. Almost everyone involved in aviation knows that there is a problem in the certification processes after these accidents. Nevertheless, you may consider what impact the consensus standards might have on the occurrence of these accidents. After reviewing the study, you will eventually see how safety will improve, and you will agree on the benefit of consensus standards on safety not only to prevent such accidents but also to reduce the cost and burden of the certification to the aviation stakeholders. You will even question why this issue, which is so helpful and not difficult to implement and has already been used in other fields, has not been done until now. Behind this issue lies the desire to have power in the economy, industrialization and security in other areas. The following statement by the FAA confirms this fact. “As the global leader in aviation, the Federal Aviation Administration (FAA) must engage internationally to increase global safety standards and enhance aviation safety and efficiency. With the US economy and travelling public relying so heavily on global air transportation, we are more committed than ever to strengthening our global leadership and engagement [FAA, 2018]. With this approach, since the center of aviation is shifting to the east, if China becomes a pioneer in aircraft production one day tomorrow, the world can be imposed that the standardization of the Chinese aviation authority is a world standard.

Safety has no borders. If global leadership in safety is the monopoly of a single country, such accidents are inevitable. The fact that a single country dictates that we are the leader in safety in the world and that we will continue to remain that way is the main reason for these accidents. It is not different from the understanding that I know everything. In this context, FAA is considering only the interests of its own country rather than thinking globally.

In order to evaluate the status of aerospace standardization, the Aerospace Industry Association (AIA) Board of Governors established the Future of Aerospace Standardization Working Group in 2003. The Working Group emphasized the importance of developing global standards that would constitute the largest single source of technical data used in the global design, build and support of aviation products to ensure the optimum standards infrastructure for aerospace in line with the advances in science, technology, engineering and manufacturing. The group also stated the necessity for a unified aerospace leadership on standardization to play an integrator and advocacy role for all stakeholders of the world aviation community to provide both technical and business integration in standards issues and solutions [AIA, 2014].

To enhance safety with consensus standards to overcome the issues mentioned above, there is a need for a structure that will prioritize global safety rather than country interests. Even though the ICAO (International Civil Aviation Organization) has assumed the central role regarding aviation standards, this is unfortunately not the case in practice. The ICAO consisting of 192 member states, was established in 1944 to promote international civil aviation's safe and orderly development. It sets standards and regulations necessary for aviation safety, security, efficiency, capacity and environmental protection, amongst many other priorities. The

ICAO's current vision is aimed at establishing consensus standards. Establishing consensus standards under the umbrella of ICAO with the agreement of all member countries will close the gap for aviation safety standards to achieve globally accepted safety standards. The Consensus Standards will provide aviation stakeholders with the opportunity of single auditing and certification process that leads to a leaner auditing and certification opportunity with higher safety standards.

THE MAIN DEFICIENCIES IN 737 MAX CERTIFICATION PROCESSES

Although both 737 MAX accidents occurred due to malfunctioning of an automation system, MCAS (The Maneuvering Characteristics Augmentation System) developed by Boeing, how this system was approved is much more critical. In order to see more closely what happened during the development of the automation system and how the 737 MAX certification process failed, the timeline of the events related to 737 MAX crashes is given in Figure 1.

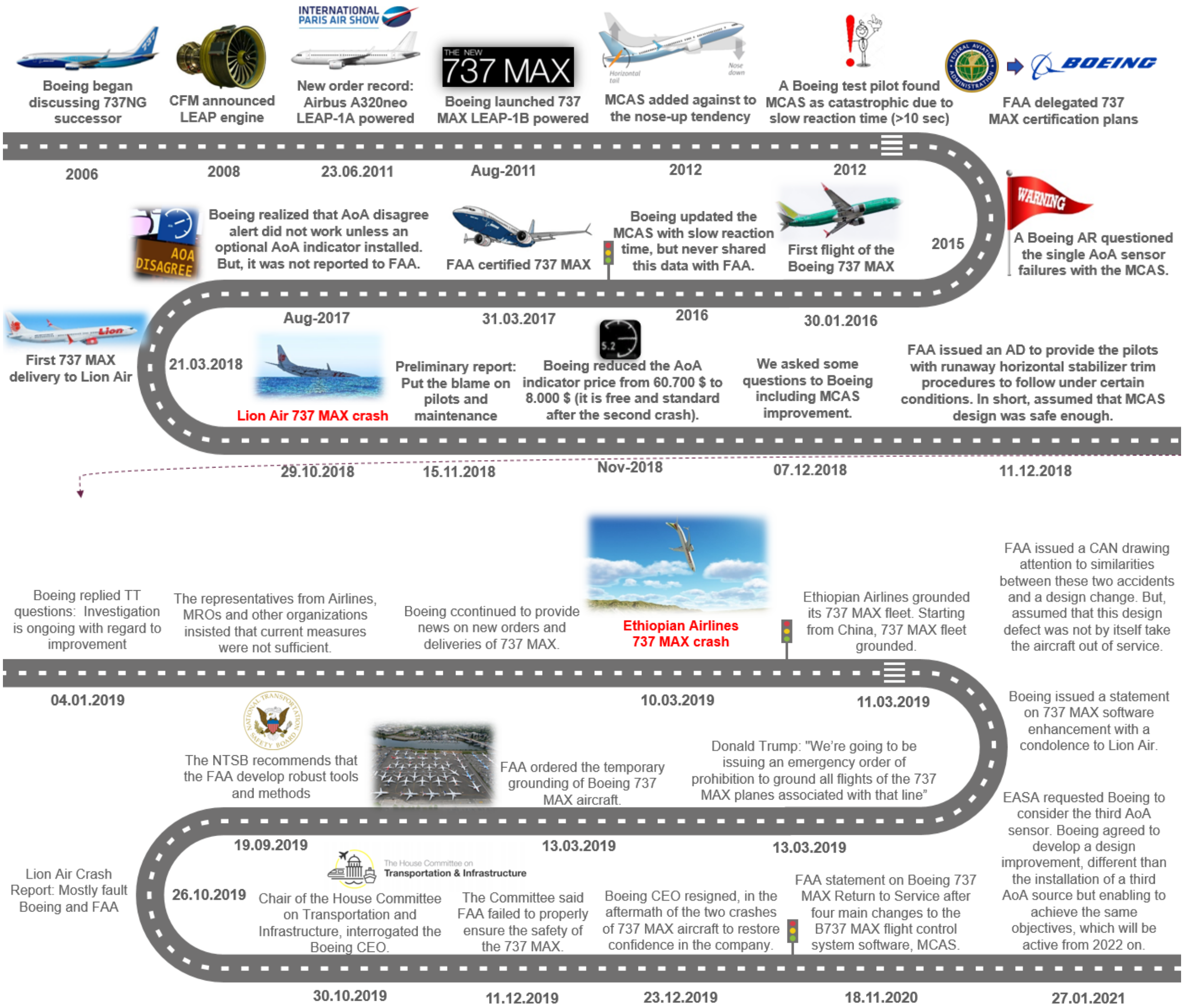

Figure 1 The Events Related to Both 737 MAX Crashes – Timeline

In 2006, Boeing began to discuss a successor for the 737NG. For a while, it considered both replacing the 737 with a brand-new airplane or re-engining the 737NG with more efficient engines and making other changes for a newer generation. In 2010, Rival Airbus announced the A320neo family (neo = "new engine option"), a re-engined, more efficient version of its A320, the main competitor to the 737 [Business Insider, 2020]. On 26th of June, 2011, during the 49th Paris Air Show at Le Bourget, Airbus won about US$ 72.2 billion worth of businesses for a total of 730 aircraft, setting a new record for any commercial manufacturer at any air show [Airbus, 2011]. Just one month later, Boeing announced the 737 MAX, the fourth generation of the 737 family, with the transition from the 737NG as shown in Figure 2.

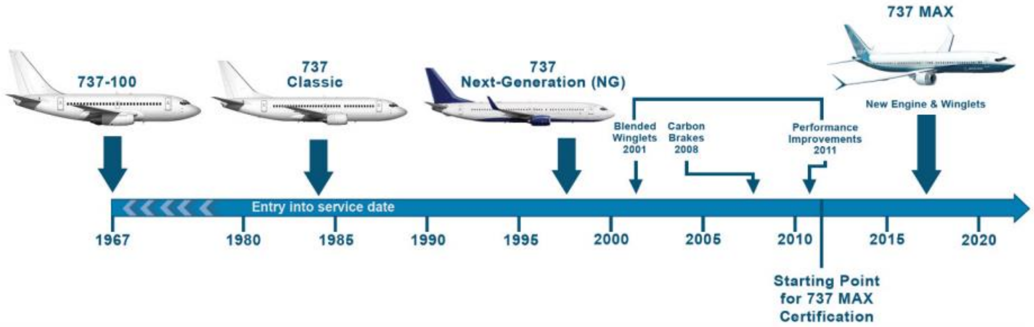

Figure 2 Development Stage of 737 MAX [OIG, 2021]

In order not to lag behind its rival Airbus, Boeing chose to produce a new version of the existing aircraft type to shorten the certification process and maintain a great degree of commonality with its predecessors, meaning that a pool of pilots and ground personnel could work on both aircraft with little training. Boeing advertised 737 MAX as one pilot can fly the 737NG and MAX interchangeably with two days or less with computer-based training and other visual media, without a flight simulator. However, the engines on the MAX were larger, positioned further forward, and higher up on the wing than the engines on the 737NG. That caused the plane to behave differently [Business Insider, 2020].

The 737 MAX aircraft tend to move the nose up due to the additional moment (ΔM) effect arising from their higher thrust (T+ΔT) and larger diameter engine than the 737 NG predecessor airplanes shown in Figure 3.

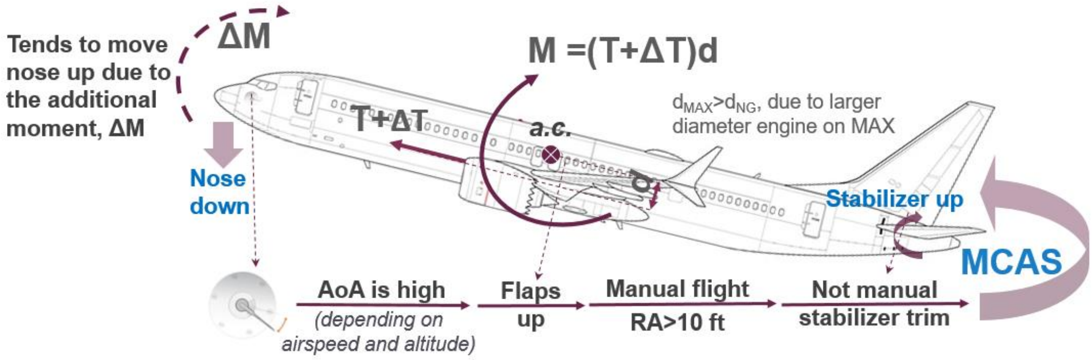

Figure 3 MCAS Function

In case of stall condition due to this movement, Boeing added the MCAS function to 737 MAX by modifying the flight control software to maintain consistent handling characteristics. The MCAS commands stabilizer trim as a function of flap position, AoA sensor, pitch rate, true airspeed and Mach. For MCAS functionality to become active, all conditions must be true: Autopilot is disengaged, Flaps are up, Pilots are not commanding stabilizer trim (manul trim) and Radio altitude>10 feet and weight-off-wheels. When the 737 MAX aircraft reaches the critical AoA, which may cause a stall, the nose of the aircraft is higher than it should be while the flaps are up during manual flight, the MCAS pushes the aircraft's nose down with the stabilizer trim setting activated by the automatic activation of the MCAS without pilot input.

However, Boeing did not realize that the MCAS would give incorrect input in the event of false feedback from one of the angles of attack sensors.

The 737 MAX accidents plunged Boeing into its worst-ever crisis, strained its relationship with the FAA, threw into question the US regulator's position as the standard-bearer for global aviation safety and prompted bipartisan calls in Congress to overhaul how the FAA certifies new airplanes [finance.yahoo, 2020]. The main deficiencies of the 737 MAX certification process which caused both accidents are given below.

Deficiency #1: Delegation of Certification to the Manufacturer

Aircraft certifications aim to ensure safe aircraft designs by requiring aircraft or component manufacturers to conform to defined standards. Federal law authorizes FAA to delegate to a qualified individual or organization, including increased delegation to Organization Designation Authorizations (ODAs) the ability to conduct certain activities on behalf of the agency. The FAA states that “the use of delegation has been a vital part of our safety system since the 1920s, and without it, the success of our country's aviation system likely would have been stifled [FAA, 2021]. Delegation is an effective and reliable way if appropriately used, provided that the principle of auditor's independence is maintained. Boeing did not provide the regulatory oversight necessary to ensure the safety of the flying public. The FAA trusted but did not appropriately verify critical information and assumptions Boeing presented to the agency about the MAX. Moreover, this was at a time when Boeing’s employees, as we learned at our last hearing, reported they perceived undue pressure from management [Government Publishing Office, 2020].

A Committee on Federal Regulation of Securities and Law and Accounting of the Section of Business Law prepared a report proposing four guiding principles of independence requirements. (1) auditors should not have mutual or conflicting interests with their audit clients; (2) auditors should not audit their audit work; (3) auditors should not function as client management or employees, and (4) auditors should not act as advocates for their audit clients - may be acceptable as aspirational goals, but will not be helpful as rules for defining independence [US SEC, 2000]. Even though this guide is for security and law, the same principles can be applied to any type of audit in any field, including aviation. From this point of view, it is a controversial issue that the FAA authorizes Boeing for certification because the activities done by Boeing with this scope impair auditor independence. As seen from Figure 4, FAA delegated 737 MAX certification plans up to one hundred percent [OIG, 2021].

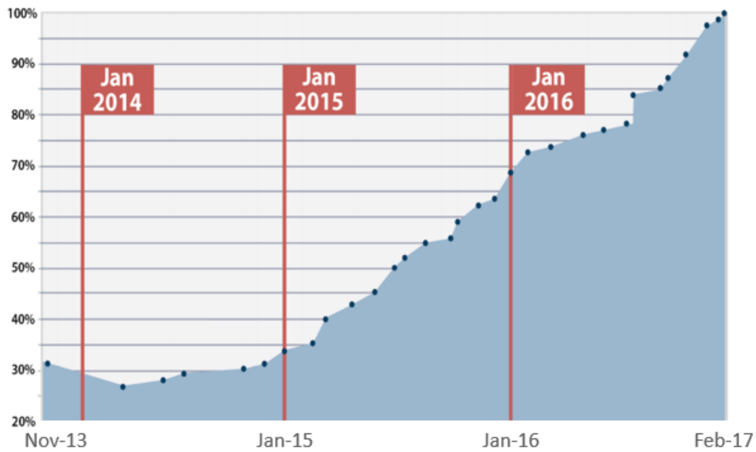

Figure 4 Percentage of 737 MAX Certification Plans FAA Delegated [OIG, 2021]

Members of Congress criticized the FAA’s decision to allow outsourced inspectors in Boeing's certification process. Connecticut Sen. Richard Blumenthal said that the FAA left "the fox guarding the henhouse" by giving Boeing too much control over the people responsible for quality control and safety [Business Insider, 2019]. Following the Lion Air accident, which was initially seen as a human error, the Ethiopian Airlines crash, with the same reason, reveals the need for correction in regulatory approaches.

According to the final 737 MAX Report prepared by Defazio and Larsen [Transportation House, 2020], “While FAA’s organizational entities are responsible for performing their assigned roles and not every FAA official can know of everything, the MCAS re-design example shows that FAA officials could have and should have been more cognizant of critical issues affecting the certification of the 737 MAX. The lack of a centralized FAA authority overseeing the entire 737 MAX certification process contributed to the communication lapses that ultimately affected safety and played a significant role in the 737 MAX crashes.”

Wright [2019], a former FAA executive and President of Wright Aviation Solutions, published a study about managing risk in aircraft certification. He states that “Aircraft engineering, design and manufacturing is geared to ensuring operational safety by adherence to certification standards. When that system fails to achieve the desired result, in part because of deception and overzealous attention to the financial bottom line, trusts are betrayed, and everyone suffers, directly or indirectly.”

On March 19, 2019, A Committee on Transportation and Infrastructure from the US Department of Transportation wrote a letter to FAA Inspector General Scovel that two recent accidents involving the Boeing 737 MAX aircraft in Indonesia and Ethiopia, resulting in a total of 346 fatalities in five months, have raised legitimacy safety concerns among the flying public, aircraft experts, regulators and legislators. Regardless of the specific factors that led to these accidents, we believe that such an examination can enhance the effectiveness of the FAA certification process overall and identify improvements to oversight and safety of all aircraft [Transportation and Infrastructure, 2019]. As seen from the letter, the need to develop the certification processes has been brought to the agenda from the top level.

Upon a request by the Secretary of Transportation, Office of Inspector General (OIG) conducted an investigation about the 737 MAX certification process and prepared a report, “Weaknesses in FAA’s Certification and Delegation Processes Hindered Its Oversight of the 737 MAX 8”, which includes 14 recommendations that FAA concurred with all. The OIG found that the FAA and Boeing followed the established certification process that had limitations in FAA’s guidance and processes that impacted certification and led to a significant misunderstanding of the MCAS. The flight control software identified as contributing to the two 737 MAX accidents for the following reasons. First, FAA’s certification guidance does not adequately address integrating new technologies into existing aircraft models. Second, FAA did not have a complete understanding of Boeing’s safety assessments performed on MCAS until after the first accident. Communication gaps further hindered the effectiveness of the certification process. In addition, management and oversight weaknesses limit FAA’s ability to assess and mitigate risks with the Boeing ODA. For example, FAA has not yet implemented a risk-based approach to ODA oversight, and engineers in FAA’s Boeing oversight office continue to face challenges in balancing certification and oversight responsibilities. Moreover, the Boeing ODA process and structure do not ensure ODA personnel are adequately independent. While the Agency has taken steps to develop a risk-based oversight model and address concerns of undue pressure at the Boeing ODA, it is not clear that FAA’s current oversight structure and processes can effectively identify future high-risk safety concerns at the ODA [OIG, 2021].

Because of the delegation, the FAA was unable to keep a close eye on MCAS-related developments. On paper (The Verge, 2019), “MCAS was only supposed to move the horizontal stabilizer 0.6 degrees at a time. In reality, it could move the stabilizer as much as 2.5 degrees at a time, making it significantly more powerful when forcing the nose of the airplane down.”

Deficiency #2: Feeling Pressure on Critical Decisions: Safety First? No, Not Really

Companies are set up to make a profit, but if you ignore safety while focusing on profit, this will result in undesirable consequences. There is bankruptcy in two places; focusing only on safety or just focusing on profit. It is necessary to maintain a balance. When the root causes of these accidents are addressed, it is seen that the focus is on profit and safety is primarily ignored. As a company, Boeing may have kept economic concerns at the forefront so as not to fall behind its rival Airbus. To compete with Airbus, Boeing put pressure on the FAA A320neo during the certification of the MCAS. However, as an authority whose priority is only safety, it is not acceptable for the FAA to support Boeing in this direction. FAA's delay in the decision to stop the flight of 737 MAX aircraft confirms this concern. Safety first is not just a slogan. It is a way of performing tasks to prevent such unwanted events in aviation.

During the 49th Paris Air Show at Le Bourget, Airbus won about US$ 72.2 billion worth of businesses for a total of 730 aircraft, setting a new record for any commercial manufacturer at any air show [Airbus, 2011]. The New York Times reported that Boeing pushed to develop the 737 MAX to compete with Airbus's A320neo plane. During spring 2011, Boeing was at risk of losing an exclusive 10-year relationship with American Airlines to Airbus. American was considering placing its largest aircraft order ever with Airbus, which had recently announced their fuel-efficient A320neo. American told Boeing it would need to move quickly to retain its business. Boeing launched the MAX program in 2011, and engineers were reportedly asked to complete technical drawings and designs at twice the normal pace. When staff members left the team, Boeing leveraged employees from other departments to ensure that the MAX project stayed on schedule. [Business Insider, 2019]. According to a report published by Softpanorama, Boeing repeatedly subordinated basic considerations of safety to profit, aided and abetted by the federal government. The fact is the Boeing leadership like leadership of the major US technological and manufacturing companies was selected from rabid neoliberals. In this sense, Boeing repeats the trajectory of such companies as IBM, who were destroyed by greed and incompetent management, who were mostly concerned with lining their own pockets via bonuses, and this operated as short-termists incapable of any strategic thinking [Softpanorama, 2021].

All Boeing 737 models are on a common type rating. When an airline pilot transitions from one 737 variant to another, the airline must provide “differences” training. Airlines, of course, hate providing extra (read “expensive”) training and, in any case, were not sufficiently aware of MCAS to know that extra training would be needed. Pilots were similarly in the dark and were never provided training to deal with a malfunctioning MCAS. Both the manufacturer and the airline are keen to minimize this training. The FAA accommodates this by providing five different ascending categories (A through E) of differences training, ranging from merely publishing a manual revision (Level A) to full-blown Level D simulator or aircraft training (Level E). Guess which level of training was involved with MCAS? [Wright, 2019].

Deficiency #3: Regulations Lagging Behind Technology

In general, the automation systems work based on the data coming from different channels. Without checking the validity of the data, it is not safe to use for the automation system activation. Because, in reality, not all the data produced by the sensors are reliable. The key to make sure that the system is functioning in the way intended for the automation systems is to find out where the reliable data is, separate out that data, and discard the rest.

In both the Lion Air and Ethiopian crashes, it was like a fight of a crazy computer with humans in which the computer prevailed: the software was trying to do something that led to loss of altitude, while the pilots were trying to correct its behaviour and resume normal climb-out. They were effectively fighting defective software systems. The fact that the MCAS system on a single sensor to make a decision that could be fatal if sensor malfunction is really strange. Neither gyroscope, not the second sensor was used in determining the action. You need all three for such vital input [Softpanorama, 2021].

The accidents mentioned in the study were the result of the wrong decisions made by the automation system. After the second 737 MAX accident, it was seen worldwide that the explanations in the accident reports that such errors should be noticed and corrected by the pilots were not reasonable. The fact that 737 MAX airplanes were banned from flight more than one and a half year revealed how inadequate this automation system was. To support 737 MAX airplanes to return to normal operations safely, one of the main improvements made by Boeing was the addition of cross-checking between two existing angles of attack sensors and between two FCCs. However, even if there is a comparison in an automation system with binary input, the system will only stop because the MCAS cannot decide which value is correct after the comparison. To address the safety issue about using a single AOA sensor, FAA states that Boeing incorporated a maximum command limit to disable the MCAS and speed trim operations if the stabilizer position exceeds a reference position. This limit ensures sufficient elevator control can provide maneuvering capability using control column inputs alone [FAA, 2020]. However, in this case, as the system could not perform the automation task properly in the rest of the flight, the solutions developed so far have not been convincing. In regard to 737 MAX return to service, EASA states that a single erroneous high AOA sensor input to the FCC on an affected aeroplane during manual flight with flaps up may prompt the MCAS to input incremental nose-down trim. This condition, if not corrected, could lead to a stabilizer position that cannot be fully countered with elevator input, possibly resulting in loss of control of the aeroplane [EASA, 2021].

The 737 MAX had only one device, and now it has a second sensor to answer questions, but the European agency considered a third device to resolve doubts. However, Boeing convinced EASA that one more sensor would be challenging to install and instead proposed to develop a synthetic sensor that will calculate the angle of attack in case of different readings between the two external probes. This new software is expected to debut in 2022 on board the first 737 MAX 10, the largest variant of the jet [Airway, 2021].

During the original certification of the 737 MAX, compliance to specific regulatory requirements for handling qualities was demonstrated by the functionality of MCAS. The airplane-level requirement to be compliant with those regulations remains, so the need for MCAS remains unchanged. In the original design, erroneous data from a single AOA sensor-activated MCAS and subsequently caused airplane nose-down trim of the horizontal stabilizer. After the accidents, in the new design, Boeing eliminated MCAS reliance on a single AOA sensor signal by using both AOA sensor inputs and through flight control law changes that include safeguards against failed or erroneous AOA indications. The updated FCC software with revised flight control laws would use inputs from both AOA sensors to activate MCAS. The updated FCC software compares the inputs from the two sensors to detect a failed AOA sensor. If the difference between the AOA sensor inputs were above a calculated threshold, the FCC would disable the STS, including its MCAS function, for the remainder of that flight and indicate such deactivation on the flight deck [FAA, 2020]. Based on the actions taken after these accidents, it is clear that the current certification requirements are not sufficient and need to be reviewed and improved. How the automation system requirements can be improved is given in the previous study [Demirci, 2021].

Deficiency #4: No Lessons Taken From Previous Accidents

While investigating the Turkish Airlines plane crash near Schiphol in 2009, the Dutch Safety Board was pressured by Americans to downplay the role design errors in the Boeing 737 NG played in the crash, the New York Times reports based on its research. According to the newspaper, there are many parallels between the 2009 crash and the recent crashes with Boeing 737 MAX planes, the successor of the Boeing 737 NG [NL Times, 2020].

The 2009 crash “represents such a sentinel event that was never taken seriously, ”Sidney Dekker, an aviation safety expert who was commissioned by the Dutch Safety Board to analyze the crash, told the newspaper. Dekker's review pointed the finger squarely at Boeing who he said sought to shield its "design shortcomings" by seeking to place blame on the pilots who it said should have been more attentive. Dekker's findings went unpublished by the Dutch Safety Board, which either erased or "amended" its findings in the face of pushback from an American team that included Boeing representatives and US safety officials. Dekker found that the pilots could not have known the computer that controlled engine thrust always relied on the left sensor as it was nowhere in Boeing's pilot manual. In 737 MAX crashes, Boeing had also not given pilots critical information on an automated system that was a factor in the catastrophes. “It is really easy to blame it on the dead pilots and say it has nothing to do with our improperly designed system,” Shawn Pruchnicki, a professor at Ohio State who has experience in investigating accidents, told the New York Times." It just gets frustrating because we keep having the same types of accidents. Both the NTSB and a panel of international experts found that Boeing and the FAA had not sufficiently incorporated lessons from this human factors research when developing and certifying the MAX. However, even though the research has been around for decades, an FAA study recommended in 1996 that the industry and regulators embrace the approach more readily accident investigations have tended to focus on pilot errors while minimizing or ignoring systemic factors, such as design and training problems, experts said [The New York Times, 2021].

About two months after the first accident, in our correspondence with Boeing, we asked what exactly the operating algorithm of the MCAS system was and what improvements were planned about the MCAS system and its relationship with the MCAS and AoA sensors in order not to happen such a case again. Boeing stated that once a firm understanding of all the data was finalized, any further appropriate recommendations regarding fleet action would be passed along if required. After the Indonesian crash, pilot complaints raised about the 737 MAX. It was understood not only by aviation experts but also by the public that the aircraft had an automation system prone to error.

Thanks to many simulations and advanced technologies today, the effects of events can be analyzed, and necessary precautions can be taken without waiting for an event. The most crucial point that can be deduced here is that in order to learn the real causes of the accidents and to take the necessary precautions, by bringing a change to the slogan that aviation rules are written with blood, the lessons should be taken without waiting for the same accident to repeat and more loss of life. The most crucial difference between them is that there is no second accident as Ethiopian Airlines experienced afterwards. Another common aspect of the two 737 MAX and 737-800 accidents is that there is no audible or visual warning to inform pilots of the error. Sensor failures and failure to provide pilots with information contributed to these crashes. Boeing 737 MAX failed because it did not apply the safety lessons from the fatal 2009 Amsterdam crash caused by a faulty sensor.

Deficiency #5: Insufficient Cross-check Between Authorities

An aircraft certification approved by the leading authorities, FAA or EASA, is also approved by the other country authority through a formal check. However, these events have shown us that evaluating critical issues from a different perspective, similar to the practice of CMTs (Critical Maintenance Tasks) checked by another mechanic in maintenance organizations for error capturing, will make an essential contribution towards increasing safety.

In regard to cross-check, Sgobba (2019) stated that excessive trust quantitative performance requirements cause inefficient risk-based design process and lack of independent design verification. These accidents could have been avoided if EASA had a second eye on the design processes of the MCAS. After the second crash, EASA changed its position by validating the improvements rather than relying directly on it. It is a good improvement in ensuring systems work safely before they go live.

Deficiency #6: No Feedback to Occurrence Reports or Voluntary Reports

Reports from the American Pilots Association and so on were ignored. No need for feedback. There is no transparent data sharing. For example, if there were a database where comments were collected after the Lion Air accident, it would not be the second accident. Unfortunately, the lack of access to such data collection due to economic concerns has been paid with more human lives. Do these rules have to be written in blood, especially for such preventable events?

A similar situation is valid for occurrence reports. The events are shared with the authority, manufacturers and all stakeholders within 72 hours. Unless there are significant events such as accidents, there is no turning back even on apparent design issues. Authorities should be more specific in these situations and help operators to find solutions. Safety has no competition. Regarding this concern, sharing occurrences and accidents data is required with all partners by using a data warehouse in which all recommendations and comments can be entered transparently. Otherwise, even if you report it to the authorities, some issues cannot be answered or remain closed.

Occurrence reporting naturally encompassed reporting incidents and near misses, errors, and the factors that provoke them. Most organizations implemented bureaucratic reporting mechanisms to capture and analyze reports. They also trained investigators, often focusing on interviewing skills. While such skills are essential and need careful development, such training could lead to a perception that the individual is the subject of the investigation. There also tended to be less emphasis on developing investigators to find and facilitate solutions actively. [Flight Safety, 2017]

Deficiency #7: Insufficient Tool to Evaluate the Risks

In the safety risk assessment made by Boeing regarding the MCAS, the failure of the system was determined as either major or hazardous instead of catastrophic. That is, it was assumed that there would be no fatal consequences from this system. However, even that "hazardous" danger level should have precluded activation of the system based on input from a single sensor, yet that is how it was designed [The Seattle Times, 2019].

According to an investigation done by DeFazio [2019], FAA employees did not have the analysis and tools necessary to make the right decisions in the case of the 737 MAX. DeFazio said, "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. The FAA trusted, but did not appropriately verify, key information and assumptions Boeing presented to the agency about the MAX."

Wright defined the risk management and system safety faults that resulted in these tragic events using the four design and procedure categories. First, Boeing may not have done a complete hazard analysis for MCAS. It is likely it did not anticipate a catastrophic result and/or underrated the likelihood of it occurring. Thus, it bungled the first line of defence: a design for minimum risk. Next, it incorporated a safety device, MCAS, that failed to protect against—and even increased the chance of—a loss-of-control event. Third, it failed to provide standard equipment, a warning device that would alert pilots to a malfunctioning AOA sensor. Finally, it did not require additional training on the system or even provide any substantial information on MCAS or its potential failure modes. You might wonder where the FAA was while all this was happening. Under great political pressure, the agency delayed grounding the 737 MAX until after other regulatory authorities took this step and left it with no choice [Wright, 2019].

Deficiency #8: Insufficient Safety Culture

In 2012, a Boeing test pilot took more than 10 seconds to respond to uncommanded MCAS activation in a flight simulator and found the condition "catastrophic" [Business Insider, 2020]. In 2013, Boeing employees devised a strategy on June 7, 2013, to treat MCAS as an "addition to Speed Trim" to help prevent increased "cost" due to changed manuals. The strategy, approved by a Boeing Authorized Representative (AR), is outlined in an email, saying: "If we emphasize MCAS is a new function, there may be greater certification and training impact." Boeing notes its test pilot's slow, "catastrophic" reaction time to uncommanded MCAS activation in its Coordination Sheet for the first time, saying, "A typical reaction time was observed to be approximately 4 seconds. A slow reaction time scenario (> 10 seconds) found the failure to be catastrophic due to the inability to arrest the airplane overspeed." Boeing updated this record, citing this same information, six times from 2015 to 2018 but never shared this data with the FAA. A Boeing AR (Authorized Representative) asked in an email, "Are we vulnerable to single AoA sensor failures with the MCAS implementation, or is there some checking that occurs?" In the end, MCAS was certified with a single AoA sensor. Keith Leverkuhn, Boeing's former 737 MAX program General Manager and Michael Teal, former

Chief Project Engineer on the MAX program, approved the redesign of MCAS that enables it to activate at lower speeds. He sent an email to the FAA requesting permission to remove references to MCAS from the MAX's Flight Crew Operations Manual and training material. Unaware of the MCAS redesign, the FAA official grants this request. A Boeing AR Advisor emailed a colleague and asked, "What happens when we have faulty AoA or Mach number?" The colleague responds, "As for faulty AoA and/or Mach number…if they are faulty, then MCAS shuts down immediately." Faulty AoA data was a major contributing factor in both MAX crashes, and MCAS did not shut down in either of those accidents. Referring to a Boeing test pilot's problem trimming the MAX due to repetitive MCAS activations, a Boeing engineer asks, "Is this considered a safety or certification issue?" A colleague responds, "I do not think this is safety, other than the pilot could fight the MCAS input and over time find themselves in a large wrong trim." This is exactly what happened on both MAX aircraft that crashed. In 2017, following a year of test flights and data-gathering, the 737 MAX gained certification from the FAA [Transportation House, 2020].

The problems with MCAS began when Boeing drastically redesigned it after the original design had been submitted to the FAA for approval to increase significantly the amount of nose-down trim that would be applied when the system activated. Boeing then decided not to inform operators about MCAS and how it operated completely. Oh, and then the system was designed to rely only on one angle of attack (AoA) sensor instead of using both sensors and comparing results. It created a single point of failure in the process [Wright, 2019].

House of Representatives Transportation Committee chairman Peter DeFazio called for a commitment by FAA Administrator Stephen Dickson to investigate why the FAA did not ground the 737 MAX when its analysis TARAM (Transport Airplane Risk Assessment Methodology) performed after the October 2018 crash of Lion Air projected as many as 15 more fatal accidents as shown in Figure 5 over the model's service life if its flight control problem went uncorrected.

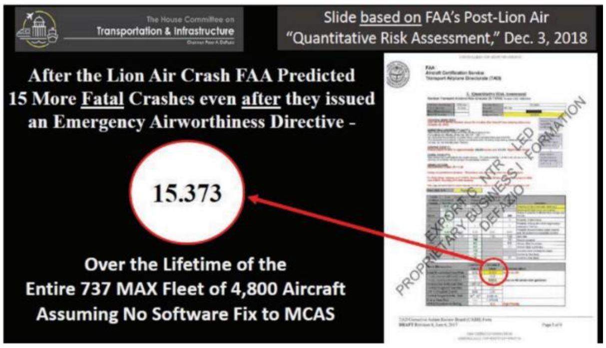

Figure 5 FAA TARAM Report

Defazio said, "The FAA issued an emergency airworthiness directive that purported to inform pilots on how to respond to an erroneous activation of MCAS, while it never mentioned that system by name. Despite its calculations, the FAA rolled the dice on the safety of the travelling 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." DeFazio acknowledged Dickson's lack of direct responsibility for the crash; he questioned why the aircraft was not grounded after the first flight. Dickson declined to answer, instead opting to defend the FAA workforce. "I was not at the FAA when this analysis was done. However, I want to advocate for my people. I want to advocate for my people" he said and added that "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 our highest priority [Government Publishing Office, 2020]. These interviews uncovered broken safety culture within Boeing and FAA.

Peter DeFazio interrogated the Boeing CEO, Dennis Muilenburg as well. He said: “You are here today because 346 people—sons, daughters, fathers, and mothers—died on two Boeing 737 MAX aircraft in five months. If you need a reminder of the lives that have been devastated by these tragedies, you can look to the family members of those on Lion Air flight 610 and Ethiopian Airlines flight 302 who are sitting to your left. Their lives have been forever changed as a result of these two crashes, crashes that could have been avoided. Something went drastically wrong, a total of 346 people died, and we have a duty to fix it [Government Publishing Office, 2020].” Dennis Muilenburg resigned as the CEO and board director, in the aftermath of the two crashes of 737 MAX aircraft to restore confidence in the company.

We deemed that the actions taken in the preliminary report were insufficient, and we made a risk assessment regarding this issue and requested the following questions from Boeing. 1) MCAS Function triggering and working algorithms and their connection with AoA sensors? 2) Is there any indication in the cockpit for the awareness of the flight crew when the MCAS function is activated? 3) Is there any preliminary finding regarding the MCAS/AOA working principles that should be improved? If so, what does Boeing plan to improve in this algorithm? 4) We request Boeing to include MCAS system details in the Boeing documentation such as SDS etc. 5) There is no MRB item for the periodical test of the MCAS system; what is the reason behind this decision?

Although we reported our concerns about this issue, we could not get a convincing answer. With regard to the third question above, Boeing said, “Please be advised that an investigation is ongoing, and Boeing continues to cooperate fully and provide technical assistance at the request and under the direction of government authorities investigating the incident. As part of our standard practice following any accident or incident, Boeing examines our systems, and when appropriate, we will issue bulletins or make recommendations, including those that highlight and reinforce our existing procedures. Our teams are evaluating whether further action is required. Once we have a firm understanding of all the data, we will pass along any appropriate recommendations in regards to fleet action (including product support documentation updates) or periodic inspections/test.”

After the second crash, four main changes were made to the B737 MAX flight control system software to prevent future accidents. 1. Angle of Attack (AoA) comparison, 2. MCAS resynchronization, 3. Stab trim command limit, 4. Flight control computers (FCCs) with cross-check. To see the truth, there was no need for the 2nd accident to happen, because as seen here, it was obvious after the first accident that the real cause of this incident was from an automation system based on single sensor data. In these cases, it is obvious that the country's authority where the aircraft is located cannot act independently and solely focusing on safety due to commercial concerns.

Deficiency #9: Lack of Globally Acceptable Level of Safety Standards

FAA Advisory Circular AC 25.1309-1 states that no single failure will result in a catastrophic failure condition [FAA AC, 2011]. This is the basic rule in aviation design. Since it is a guidance for compliance, it can sometimes be overlooked. The FAA has referred to this requirement in

7 places in Part 25 Certification Requirments, which are limited to loss of view by both pilots, exit doors, door locking system, reversing systems, powerplant and auxiliary power units and controls. On the other hand, the EASA Part 25 certification requirements include this statement in 22 places more comprehensively, including almost all systems. As can be understood from this, there is no consensus on even the most basic rule. Similarly, there are essential differences between the requirements for automation. In ICAO, where these rules are based, the topic of automation is almost not mentioned.

That the automation system, the MCAS on the 737 MAX aircraft, was designed to operate by relying on data from a single sensor resulted in two fatal accidents. Robert Canfield, an aeronautical engineering professor and technical director of the Virginia Tech Airworthiness Center said, “When I read that the planes had two angle-of-attack sensors, I could not think of a reason why they would not use both [Claims Journal, 2019]. Considering that a similar design error caused Turkish Airlines 737-800 Amsterdam accident in 2009 and that there have been such accidents, other than these accidents, it is clear that the need to set an acceptable level standard on this issue.

About the critical decision making, sometimes the automation systems may not take any action but provide critical information, and the user makes a critical decision by using it. An example of the accidents in this regard is Air France's Airbus model A330-200 airplane crash on May 27, 2011. Although the plane continued its routine flight, the pilot gave different maneuvers due to the false "STALL" warnings produced by the related automation system 72 times, which resulted in 230 test deaths by crashing the plane. STALL warning is a critical situation for the aircraft, so the automation system produced the warning should be designed with critical importance.

Modern commercial airplanes use multiple, redundant sensors to measure airspeed, altitude, angle-of-attack and other key parameters. Moreover, for decades, pilots have had so-called “disagree” indicators in the cockpit to warn of possible malfunctions. They are also armed with training and checklists to diagnose and address problems as they arise, critical safeguards that have helped pilots avoid disaster many times [Claims Journal, 2019]. AoA disagree indicator was an option for 737 MAX aircraft. Most airlines did not choose it because it was expensive. Just a month after the Lion Air accident, AoA price reduced from 60.700 USD to 8000 USD. After the second crash, this indicator became standard and free. Similar to this issue, no indicator for RA disagree was available in 737NG aircraft. As understood from these events, no consensus standard is available when the indicator in the cockpit is required.

In order to ensure safe operation of the 737 MAX aircraft upon return to service, EASA requires that pilots perform the return to service training, including ground and flight training in a suitable full flight simulator, before operating the affected aeroplanes [EASA, 2021]. Initially, Boeing omitted the MCAS in any manual, including training manuals considering that the automation system will work in the background. It also shows the need for a standard that specifies the need for training at a globally acceptable safety level.

Although not directly related to the accidents described in this study, another lack of standards is the requirement for developing the designs in accordance with Murphy’s Law. Error tolerance of designs had already been recognised in the early days of civil aviation [Aerosurrance, 2015]. Three generations ago, in the late 1940s, it was recognized that it was a designer’s obligation to eliminate the potential for misassembly in his or her designs. Murphy’s Law ”If anything can go wrong, it will” is not a pessimistic statement but a long-established design law. Certification requirements for the human-centered design of flying controls to minimize or prevent assembly error are unchanged since 1964, warnings in manuals are still allowed in place of the use of fail-safe methods to prevent defects, ambiguous technical publications remain a threat, and designers often have unrealistic expectations of the perfection of others [Flight Safety, 2017].

In events that result from designs that do not comply with Murphy's law, providing information with an educational bulletin telling people to do as specified is a complete solution to prevent similar events means seeing the human as a robot. A classic rule states that if two pieces can be fitted instead of each other, one day they are fitted for each other. In short, if a part can be fitted differently, one day, it is fitted that way. The crash of an aircraft due to installing a fuel gauge belonging to another aircraft type is not a technician fault but rather a lack of certification processes. After such kinds of events, instead of publishing an educational bulletin requiring pilots not to depend solely on the accuracy of the fuel quantity gauges, it is much more effective to develop standards for the design of fuel gauges in such a way that they cannot be installed on unsuitable aircraft.

In 2005, Tuninter ATR 72 accident resulted from fuel exhaustion due to the installation of fuel quantity indicators designed for the ATR 42 in the larger ATR 72 [Wikipedia, 2021]. The gauge could have erroneously shown that the ATR 72 was carrying at least 1,800 kg more fuel than it had. An emergency recommendation was issued to suggest that the gauges should be modified to make it impossible to fit the wrong one to either aircraft type [Flight Global, 2005]. However, since this recommendation is only for this type of aircraft and is not included in the certification standards, it does not set a rule for use in future aircraft.

An article (Flight Global, 2021) states that “the main difference in recertification requirements for the 737 Max between Europe – and Canada – and the USA is the ability to disable the stick-shaker warning if pilots are confident they understand the cause of the AoA sensor fault. Otherwise, he says, the crew would have to perform the remainder of the flight “with the stick continuing to kick for one or two hours.” As seen from this statement, there is a big difference in practice in the safety-related standards. If consensus were to be established here, the practice would have to be expanded.

Deficiency #10: No Objective Evaluation Method for Accidents/Incidents Investigation

The biggest mistake here is that the pilot was blamed and turned a blind eye to the second accident, even though the FAA and Boeing knew that MCAS was the root cause of the Lion Air 737 MAX crash. If China had not grounded the 737 MAX aircraft after Ethiopian Airlines 737 MAX Crash as a country, who knows how many more accidents would have happened. Who knows how many more accidents would have happened if China, which caused the 737 MAX aircraft fleet to be grounded worldwide with its butterfly effect, did not ground its aircraft. Even after the second crash, it is unacceptable for the FAA and Boeing to insist that it is safe enough.

A limitation of ADs is the focus on corrective actions, which means that the description of the incidents is very terse or sometimes missing entirely. The corrective action is frequently expressed as implementing a manufacturer’s service bulletin or installing a new software version, thus, masking the deficiency that caused the issuance of the AD [FAA, 2012].

At the Aviation Safety Symposium organized by the Turkish Air Force Presidency in 2018, the presenter Turan expressed the importance of determining the root causes correctly as follows.

“The secret of success in safety programs lies in respect for the truth. Solutions for problems related to safety must be based on absolute facts. It lies in human genetic codes, innate curiosity and the desire to produce effective solutions to life's problems. As a species, we would not have been able to survive on earth if we did not respect the truth. So much so that human civilization is nothing more than the sum of the solutions it produces under the leadership of reason and science for the problems faced by human beings. The necessity of reaching the truth in order to produce effective solutions to the problems of life is equally valid for the problems encountered in flight safety. Solutions in flight safety that are not based on facts will be insufficient to prevent subsequent accidents [Turan, 2018]."

According to the statistics given in the aviation magazine published by Boeing, approximately 80 percent of the accidents were caused by the machine, and 20 percent were caused by human error when the flight first started. Today, it is reported that this statistic is reversed, and approximately 80 percent of aircraft accidents are due to human error (pilots, air traffic controllers, mechanics, and so on so forth), and 20 percent are machinery (equipment) malfunctions [Boeing, 2008].

However, when the results of the accident analysis report are examined, it is seen that the malfunctions that need to be written to the machine are also written to the human. Especially in an accident caused by automation systems, the pilot's real cause of the accident is seen as the pilot with the explanations such as seeing the change, deactivating the relevant system and taking over the control. This shows that the design requirements for automation systems are not precise.

In the Lion Air crash (2018) preliminary report, the pilot was blamed as the primary cause of the accident. If it had not been for the second accident, it would probably have been recorded this way. However, it was stated in the final report after the accident that the main reason was that the design was applied.

If the sensor is not working as intended, is it user error or sensor error? Let's say, you bought a new car with an automation system which has been developed to prevent it from hitting the barriers and you, as the driver, do not know it. While driving, the system works incorrectly and although the car does not go towards the barriers, but it is assumed that it is so, and the car breaks on the opposite side, and an accident occurs. In this case, is it a system error or driver error? After the accident, it is not reasonable to say that the driver should have seen this and pull this circuit breaker. Moreover, it was neither included in the manuals nor explained to you.

Similarly, it is not acceptable to wait for the pilot to see and correct the adverse movements caused by the faulty sensor on the 737 MAX. Aircraft accident reports are usually issued after one year. Preliminary reports, on the other hand, are published within a month. However, many issues are ignored, only focusing on the last point, as in this one. As seen from this experience, when the authority does not force all the role players, including manufacturers, to take action, operators alone find it difficult to develop effective solutions. ADs are legally enforceable rules issued by authorities to correct an unsafe condition in a product used in an aircraft. If the FAA had also admitted that this error was a sensor error and not a user, the AD without delay would have been issued not only for pilots but also to improve the design of the sensor system.

ICAO Annex 13, Aircraft Accident and Incident Investigation, is used for aircraft accident analysis. However, the content does not include all aviation stakeholders. Therefore, it should be improved to examine all parties, including authorities, with an inclusion of a checklist.

Deficiency #11: No Maintenance Task Card and Poor Information in Manuals

After the Lion Air Crash, when we checked the maintenance and training manuals, we realized that almost no information about MCAS was found in them. About poor documentation, pilots complained that they had not been told about the MCAS or trained to respond when the system engages unexpectedly. This lack of documentation and training is especially dangerous when automated systems are involved, and previous training does not fully apply. Tragically, black box recordings indicate Lion Air pilots frantically attempted to find answers in the manuals before they crashed. Pilots take their documentation extremely seriously. Three reports from the Aviation Safety Reporting System (ASRS), which NASA runs to provide pilots and crews with a way to report safety issues confidentially. Three reports highlighted the next focus on Boeing 737 MAX documentation [Johnston and Harris, 2019].

Additionally, although it is a safety-critical automation system, there is no Maintenance Review Board (MRB) item for the periodic testing of MCAS. After the accidents, new Certification Maintenance Requirements have been defined that provide mandatory maintenance tasks related to several dormant failures identified within the flight control system [EASA, 2021].

CURRENT STATUS OF AVIATION STANDARDS

Certification requirements for commercial aircraft are derived from ICAO Annex 8 Airworthiness of Aircraft. Each ICAO member state then establishes its legal framework to implement the internationally agreed standards and recommended practices. Aircraft certification activities are carried out according to 14 Federal Regulations Law (14CFR) and other regulations such as the EASA Certification Specifications CS-23, CS-25, CS-E/APU, CS-P, CS-VLA. These rules address the development processes of aircraft and systems. Requirements for software or electronic hardware development related to the automation system are not included in these scopes. To this end, the document FAA uses for guidance to determine whether the software will operate safely in an airborne environment is DO-178B, Automate and Streamline Using Code Verification. The EASA has developed the 2017/373 ATM/ANS reference acceptable compliance regulation using ED-12B, an equivalent of DO-178B, and ED-80, Design Assurance Guidance for Airborne Electronic Hardware and similar documents. Oztürk and Ceylan [2008], along with introducing the general lines of the DO-178B standard, explain how a company will follow while developing software suitable for this process.

There are detailed, well understood and internationally applicable regulations covering aircraft systems. Current regulations lag behind not just for the automation systems but also the other systems developed in line with technological development and technical alternatives to pitot tubes, AOAs, RAs and similar measurement devices. In the current status of airworthiness standards, each state authority tries to increase safety by developing extra standards over ICOA Standards and Recommended Practices (SARPs), as shown in Figure 6, without making a synergy to achieve a globally acceptable level of safety.

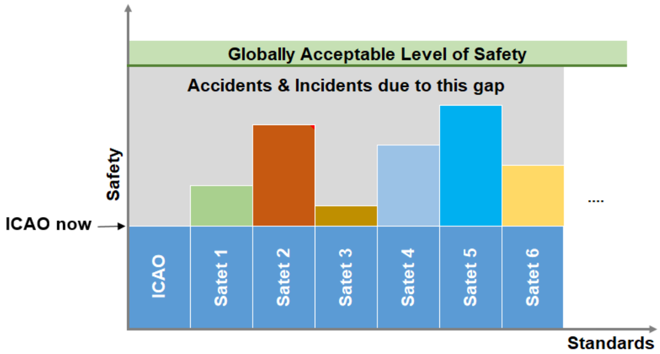

Figure 6 The Effect of Current Standards on Safety

Since there is no requirement in ICAO Annex 8 in regard to automation systems, the FAA and EASA developed the rules based on the document DO-178B. However, DO-178B alone is not intended to guarantee software safety aspects. Safety attributes in the design and implemented as functionality, must receive additional mandatory system safety tasks to drive and show objective evidence of meeting explicit safety requirements [Wikipedia, 2021]. As a result, the EASA and FAA take different approaches for the safety of automation systems. Moreover, differences in safety requirements in automation systems on Airbus and Boeing aircraft appear. For example, while B737 aircraft have two radio altimeters and no cross-check with each other, similar A320 aircraft have three cross-checked radio altimeters.

Audits and surveys arising from the differences in understanding between countries are at an incredible level of workload that exceeds its purpose and does not go beyond a bureaucratic process rather than providing benefits to safety. As there are no standards that follow all innovations and provide mutual trust, it leads to a serious burden and chaos that cannot be said to make a significant contribution to aviation safety with an incredible number of audits/surveys between countries and companies in MROs (Maintenance, Repair and Overhaul Organizations), TOs (Training Organizations), POs (Production Organizations) and DOs (Desing Organizations) as shown in Figure 8.

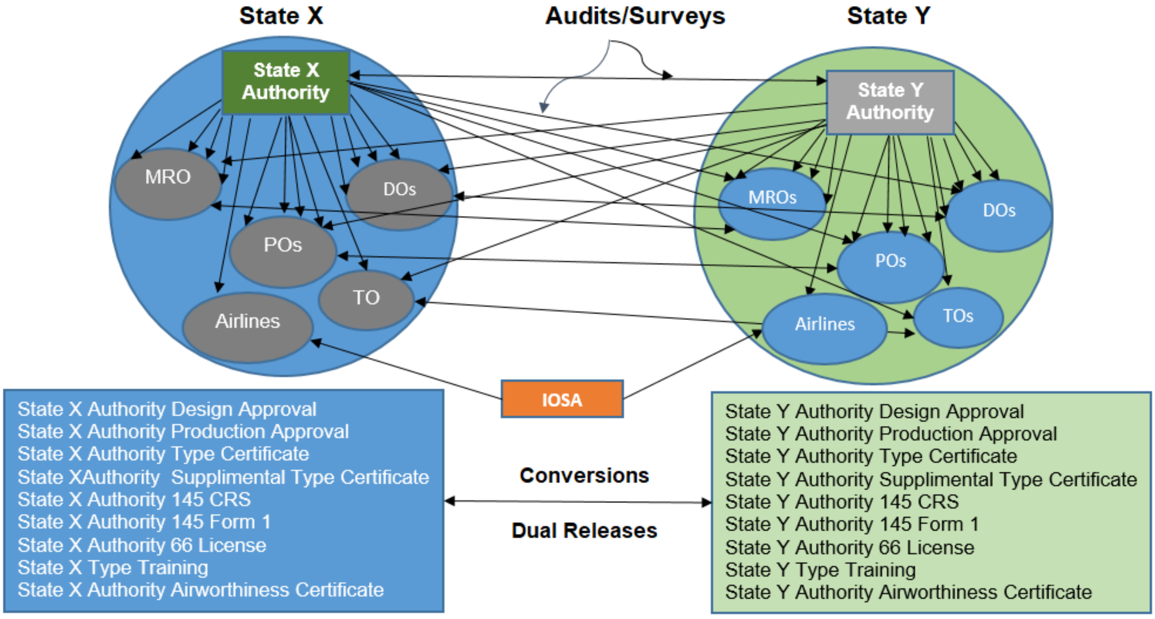

Figure 7 Current Status of Aviation Standards

As seen from Figure 7, the standards used in aviation are not set up to support a global industry. Among the aviation organizations, airlines are in a better situation from the perspective of audits and surveys, because the IATA Operational Safety Audit (IOSA) Program is an internationally recognized and accepted evaluation system designed to assess the operational management and control systems of an airline.

The Future of Aerospace Standardization Working Group (FASWG) prepared a report for the future of aviation standardization, including the following conclusions [AIA, 2014].

- The nation needs a national aerospace standards vision and strategy which supports the development and use of global aerospace standards.
- There needs to be an aerospace standardization integrator/advocacy body to facilitate the development and implementation of this vision and strategy.
- Government and industry need to recognize the critical role standards play as enablers for aerospace.
- Standards need to be developed through processes that serve and are used by the entire aerospace community.

This study supported the idea of global aviation standards gathered in a single source of big data used in design, production, maintenance, and training for the aviation industry, which is rapidly transforming into a global industry.

In the current situation, the shortcomings of the aviation standards are as follows:

Shortcoming #1: Lack of Global Leadership

Following the second 737 MAX crash, there was a lack of global leadership in grounding aircraft. The FAA was the last country to ground airplanes as it also considers the country's economic interests. The failure of the FAA, which received thousands of notifications from many aviation experts, pilots and other stakeholders to focus on the real root causes rather than blame the pilots after the first 737MAX accident, demonstrates the need for an independent joint leadership that considers world aviation safety rather than the interests of the country. Although the ICAO assumed the leadership role in aviation, it is limited. Because the ICAO takes an abstention attitude in making decisions in critical situations, the ICAO should take necessary steps to improve the global leadership role in safety and regularity as an integrator and regulator.

Shortcoming #2: Large and Complex Standardization

As shown in Figure 8, the structure of aviation standardization is large and complex. The FASWG states that the aerospace industry uses hundreds of thousands of standards, including documents from 150 different standards that continue to grow. Moreover, there are thousands of technical experts to develop the standards. Each state authority has an infrastructure to develop its standards. So, each authority spends time, effort and resources without a snergy.

Due to these redundant standards, there are unnecessary audits, surveys, conversions and dual releases with little or no benefit. There are significant advantages of harmonizing the standards to reduce the efforts for duplications and increase efficiency. The optimization provides significant cost savings on the factors shown in Figure 8 and helps consolidate the processes of standardization.

Figure 8 Cost Factors Involved in Standards [AIA, 2014]

Basu (2017) stated that there should be a balance between an acceptable level of safety standards and the severity of rules from the practicability point of view. As Figure 9 shows, adding safety rules after a particular stage increases the cost very much but is impractical as it has little impact on safety.

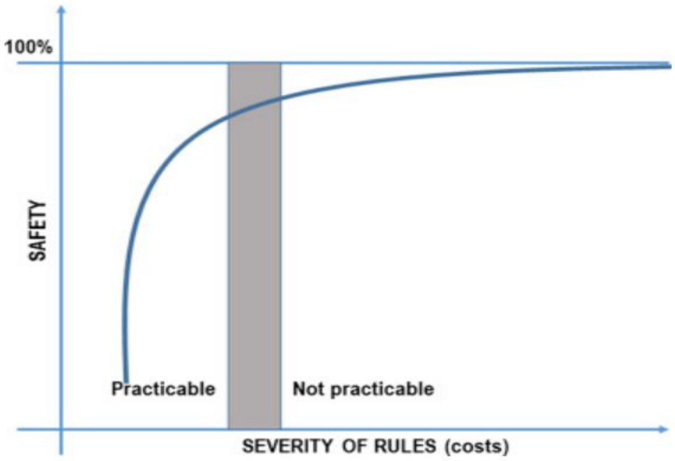

Figure 9 Severity of Airworthiness Standards [Basu, 2017]

Aviation standards are becoming more and more stringent and complex. It makes sense to develop separate safety rules for balloons, drones and helicopters. However, it is not reasonable to develop various safety standards for different aircraft categories with respect to weight, passenger numbers. For example, there is no separate safety standardization for cargo aircraft with a few people on board. It is not understandable why an aircraft certified in accordance with FAR/CS-23, because its weight is little below large aircraft. Safety standards should be harmonized for all aircraft to collect the experience gained and lessons learned in one place.

Shortcoming #3: No Link Between Civil and Military Standards

Many innovations have been developed in military aviation and then applied in civil aviation. Considering that the MCAS, which caused both 737 MAX planes to crash, was previously used on Boeing KC-46 military aircraft developed from Boeing 767, safety standards can be developed to support each other. Earlier military versions of MCAS had features to prevent misfires implicated in two 737 MAX crashes.

Strategic issues related to defence may not be shared. However, when it comes to safety, there is no distinction between military and civilian. So, experts from military aviation should be involved in the development of global standards.

Shortcoming #4: Lack of Globally Acceptable Standards

Each authority develops its standards according to its lessons and experiences; there are differences in standards that affect safety. However, globally acceptable standards will be developed with a consensus; all critical issues come together in advancing safety. The FAA and EASA signed an agreement on cooperation in the regulation of civil aviation safety. The agreement requires that the FAA and EASA develop and adopt procedures for regulatory cooperation in civil aviation safety and environmental testing and approvals. The objectives of the agreement are 1) To exchange rulemaking intentions and priorities of the participants to align as much as possible their respective rulemaking programmes; 2) To identify rulemaking initiatives of common interest that through regulatory collaboration would allow the FAA and EASA to avoid unnecessary divergence and duplication of work, maximize available resources and further harmonisation [FAA, 2014]. With this agreement, the FAA and EASA made an important decision to develop consensus standards between them. However, developing an automation system relying on a single source as seen following the 737 MAX accident indicates a significant difference between the FAA and EASA.

Since aviation is a global industry, any aviation stakeholder, including space researchers, can design, manufacture, operate and maintain anywhere with globally acceptable standards. Since the global standards are accepted and recognized worldwide, any aviation certification or approval is valid anywhere in the world.

Globally acceptable standards are developed by taking data from all stakeholders to not fall behind technology and even steers technology. If the regulations come from behind, it becomes prohibitive, whereas if it follows the innovators, they develop together and lead to developments. Elon Musk criticized the FAA, saying, "We are trying to have a really big impact in the space industry. If the rules are such that you can't make progress, then you have to fight the rules [FS, 2021].

All aviation stakeholders, including international aviation organizations such as IATA and ICAO, should emphasise achieving globally acceptable standards which are safer, cost-effective, and easily accessible.

THE ROLE OF CONSENSUS STANDARDS IN ACHIEVING BETTER SAFETY

The definition of consensus standards is given by AMPP [2019] as "standards that are developed by a process that involves the cooperation of people and groups who have an interest in participating in the development and/or use of the standards." Actually, the adoption of consensus standards is not a new idea. It has been used for food, health, medicine and other similar standards. In aviation, the FAA accepted consensus standards for light sport aircraft. For the first time, the FAA has used consensus standards for aircraft design, manufacturing, and maintenance with the acceptance of 15 standards developed by ASTM (American Standards for Testing and Materials) International Committee on light sport aircraft (Newsroom, 2005). Although the many benefits of consensus standards have been discussed under this consensus, it is unclear why they are limited to sports aircraft only.

In today's technology, many simulations and similar advanced technologies can analyze the effects of events and take necessary precautions without ever. The most crucial point that can be deduced here is that in order to learn the real causes of the accidents and to take the necessary precautions, by bringing a change to the slogan that aviation regulations are written in blood, the lessons should be taken without waiting for the same accident to repeat and more loss of life. Using a proactive approach instead of the traditional method, one must ensure that the standards are sufficient before applying technological innovation to an aircraft design. Consensus standards provide invaluable resources of guidance for aviation authorities to apply in their roles to ensure that aircraft are designed, manufactured, maintained and operated in a globally acceptable level of safety, not only for a state. The consensus approach inspires collaboration by bringing different participants and perspectives together. The experts who represent a broad cross-section of industry and every state safety agency representative can contribute to the consensus standards in the light of the lessons learned worldwide. Thus, instead of deficient or insufficient separate rules, stronger rules are obtained that everyone can benefit from.

Although consensus standards reflect best practices, the countries may sometimes look beyond compliance. Country-based regulations are slow to change, often out-of-date and sometimes can not provide a minimum standard since technology has changed quickly and airworthiness standards lag behind existing knowledge. However, in line with the latest technological advancements, consensus standards fill the gaps where the standards are not available to reach globally acceptable safety levels, as shown in Figure 10. Driving continual improvement and effectiveness for consensus standards can help operators prevent such accidents. Certification and design of the aircraft following consensus standards will enhance safety and ensure people's trust.

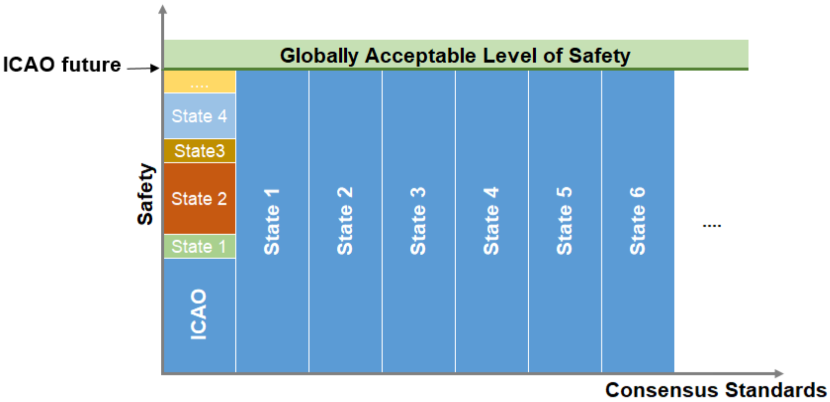

Figure 10 Enhanced Safety via Consensus Standards

The structure in which consensus standards will be developed can be made very effectively by ICAO, of which 192 states are members. If a critical situation such as grounding the aircraft fleet is needed, the consensus decision of the representatives of the countries will be much more effective and reasonable than the decision of a single country's authority. Consensus standards grant a single source of recognized authority, as shown in Figure 9. Since consensus standards are developed through careful activities and must be approved by the representatives authorized by ICAO, the companies rely on them to drive continuous improvement and accident prevention. Since the right to fly between countries is provided by ICAO, sanctions can be applied through it when necessary. In the about ICAO section of ICAO's web page, it is seen that the global role of ICAO in terms of rules is not sufficient for consensus standards. In this direction, the vision and mission of ICAO should be improved.

International Consensus Standards (ICSs) provide MROs, TOs, DOs and POs the opportunity of single auditing and certification process, leading to a leaner auditing and certification opportunity with higher safety standards, as seen in Figure 11. ICS approach is not different than common standards such as ISO 9001, AS9100, AS9110. ICS approval on any subject is approval with worldwide validity and does not require another inspection and approval as in the standards AS9100, Aviation Space and Defence Certification and AS9110, Requirements for Aviation Space and Defence Maintenance Organisations. The civil aviation authorities of the ICAO members are directly accepted as ICSA (International Consensus Standards Auditor). However, any other organization can be ICSA if any authority of the ICAO member states approves. Non-ICAO member states can benefit from the experience of the ICSs as well.

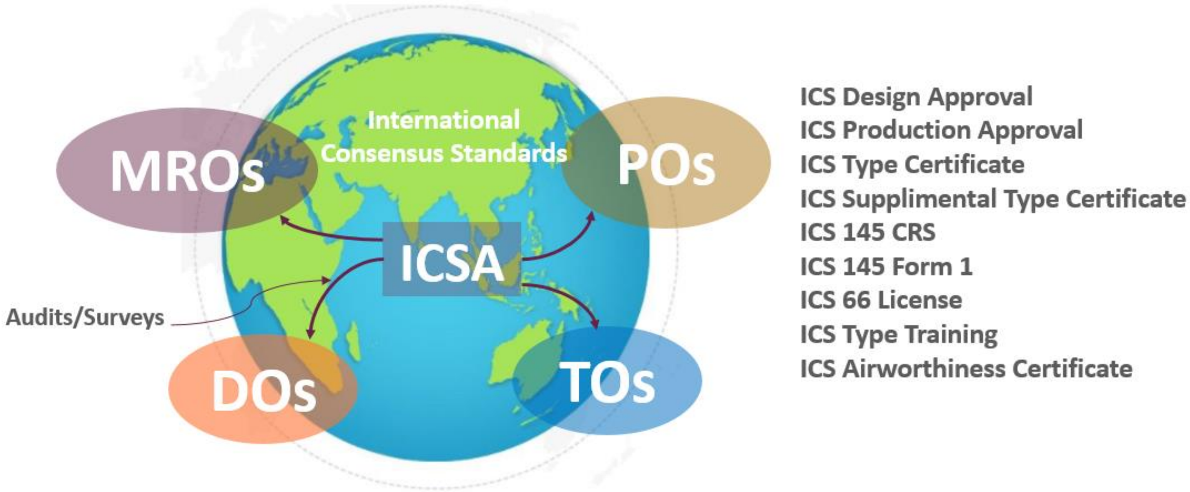

Figure 11 Enhanced Safety via Consensus Standards

As in IOSA, since the certificate given to a place audited by an ICSA according to the consensus standards will be recognized in other countries, it will not be necessary to regulate the FAA, EASA or other requirements again. The FAA, EASA and other country authorities will have an opportunity to spend their man-hour auditing the companies and certification processes instead of developing the standards. Thus, the FAA will not have to delegate its oversight functions by performing inspection and auditing itself, which was one of the leading causes of the 737 MAX crashes.

The development of consensus standards is carried out with the International Consensus Standards Working Group (ICSWG), which consists of the representatives from Civil Aviation Authorities, MROs, TOs, DOs, POs, airlines, experts from universities or any other industries and voluntary groups with the head of the ICAO coordination similar to Regional Aviation Safety Groups (RASGs) which are in charge of guiding the future development of safety management provisions [ICAO]. In cooperation with the representatives, ICSWG will continue to build the standards which improve safety in line with technological advancements, as shown in Figure 11. In this case, in addition to developing the standards by taking lessons from accidents and incidents reactively, consensus standards will be developed to guide aviation safety proactively.

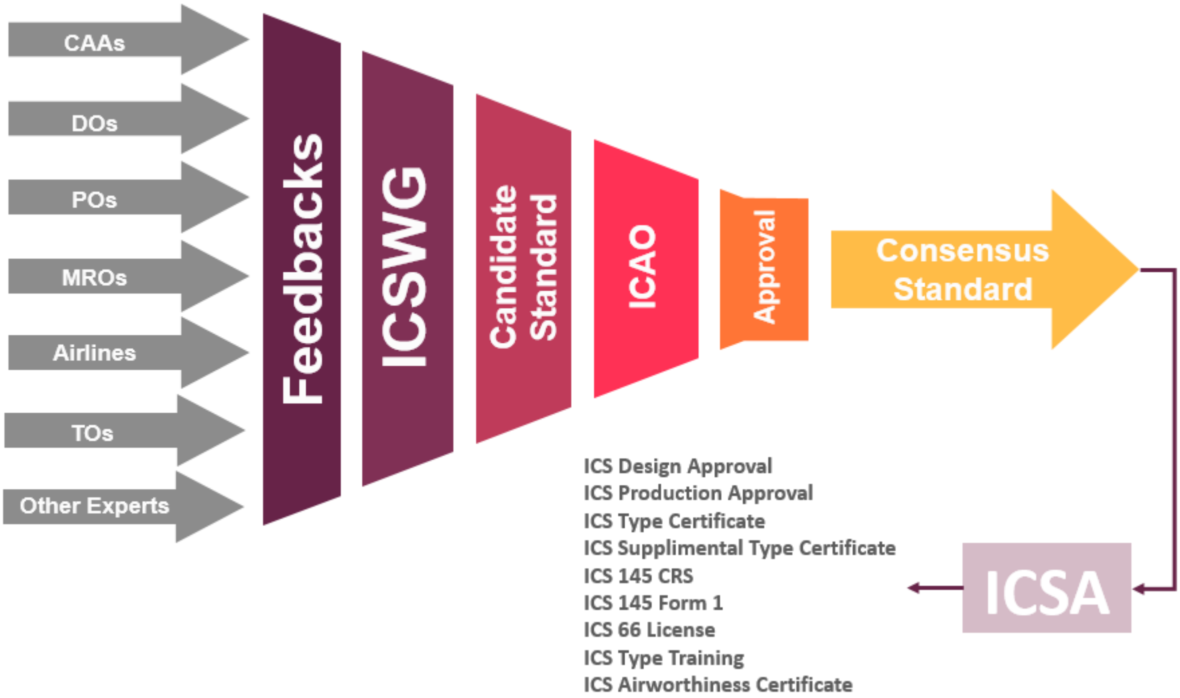

Figure 11 Development of International Consensus Standards (ICSs)

To keep up with innovations through collaborative approaches to safety instead of fix-it-as-we-go attitudes in the current status of aviation regulations, the ICSs approach should be implemented as soon as possible.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the study brought to light the following items:

- Current regulations lag behind not just for the automation systems but also the other systems developed in line with technological development and technical alternatives.
- There is a need to develop international consensus standards with the collaboration of the representatives from aviation stakeholders
- The current regulatory system has no objective methodology to analyse the accidents and/ or incidents to take the lessons and apply them correctly.
- There is a need for a structure that will prioritize global safety rather than country interests.
- The structure in which consensus standards will be developed can be made very effectively by ICAO, of which 193 states are members.
- International Consensus Standards (ICSs) provide MROs, TOs, DOs and POs the opportunity of single auditing and certification process, leading to a leaner auditing and certification opportunity with higher safety standards.
- ICS approval on any subject is an approval that has worldwide validity and does not require another inspection and approval as in the standards.
- Since the certificate given to a place audited by an ICSA according to the consensus standards will be recognized in other countries, it will not be necessary to regulate the FAA, EASA or other requirements again.
- In cooperation with the representatives, ICSWG will continue to build the standards which improve safety in line with technological advancements.

- Since ICSs are compatible with technological developments, an innovative product can be allowed to put in real life using a proactive approach.
- Since the current airworthiness standards are not sufficient, the ICSs approach should be implemented as soon as possible to achieve better safety.

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