HAS THE IMPECCABLE SAFETY OF AIR TRAVEL DILUTED? : AN ANALYSIS IN THE LIGHT OF RECENT AIR CRASHES OF BOEING 737 MAX AIRCRAFT

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1. INTRODUCTION

The design of a modern passenger aircraft has a substantial geometrical resemblance to the the older generations of aircrafts, consisting of a cylindrical fuselage, backward swept wings, fins and rudders. Unlike the other sectors which incorporate tremendous improvements and changes in the technology in a short period of time, including computers, phones, cars, ships, trains and so on, wherein the core technology as well as the geometrical designs have been changing continuously, the civil aviation industries could not incorporate such drastic changes or modifications without meticulously testing its implications, long term performance as well as the effects on other components of the system with which it interacts, which is painfully time-consuming as well as unfathomably expensive. But this slow process can be equated with a high sense of safety as every component of an aircraft has to be tested to its limits to determine the range of safe operation by determining the breaking point of the component material in

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tensile, compressive, shear and fatigue loading and determine the period for which the component or system is designed to not fail in a safe-life design. Depending on its functions and the prescribed life cycles, each components undergoes inspection and replacement, to keep all components of a flight airworthy, at all times, and effectuate anticipated repair works rather than a post-failure repair work scenario. This theory apples to mechanical components as well as the electronic and software elements equally.

The aircraft manufactures has almost perfected this process of maintenance of its fleet by investing on preventive and scheduled maintenance even if it means more expense to sustain the process like clockwork.[1] The number of aircraft accidents has not completely been decimated, but in fact, had occurred in multitude, even in the recent years. After the second instance of the above mentioned aircraft accidents, on May 5, 2019, Aeroflot SSJ-100 aircraft flying from Moscow to Murmansk caught fire during an emergency landing at Sheremetyevo Airport during which 41 of the 78 passengers died and 10 of them suffered injuries.[2] Such accidents are inevitable, pertinent to components or system failures, or negligence or external or environmental adverse conditions. One could argue that these accidents could have been prevented or recovered from by the virtue of a skilled the pilot, but the reliance on competent technology comprising of the sophisticated computer and mechanical assistance to the pilot for controlling the aircraft has rendered the expectation of an exceptional level of finesse for a passenger aircraft pilot, obsolete. Every implementation of new control technology in the aircrafts is to assist the pilot better and provide a safer flying environment. The two instances of

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[1] Remzi Saltoglu et al. *Scheduled Maintenance and Downtime Cost in Aircraft Maintenance Management*, 10 INTERNATIONAL JOURNAL OF AEROSPACE AND MECHANICAL ENGINEERING, 602, 602-03 (2016).

[2] Igor Nadezhdin, *Revealed errors rescuers when extinguishing the SSJ-100*, LENTA.RU (May. 14, 2019, 5:27 PM), https://lenta.ru/brief/2019/05/14/ssj100/.

aircraft accidents discussed in this research paper stands out, as these two could by understood to be the direct consequence of a modification to assist pilots in flight control, bought in to the worlds highest selling aircraft, securing almost 5000 orders and completing more than 350 deliveries world-wide.[3]

2. BACKGROUND

2.1 Development

The development of geared turbofan engines, a technological milestone conceptualised decades ago, had only recently materialised and had immediately proved itself to be much more efficient and exceptionally silent than the conventional turbofans. Pratt and Whitney, had developed this engine using their PW1100G gearbox as a lifetime item with no scheduled maintenance except oil changes, and was sourced to be used in the brand new Airbus A320neo program, launched in 2010. Affixed with the brand new CFM International's LEAP-X and Pratt & Whitney's PurePower PW1100G engines, the modified aircraft would offer 16% better fuel consumption[4] and significantly low nitrous oxide emissions and reduce fuel consumption by up to 15%, cumulatively removing 3,600 tons of carbon dioxide in emissions from a single aircraft.[5] The promising numbers had sky rocketed sales of the brand new

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[3] *Boeing Commercial Orders Standard Report for model 737*, BOEING (Apr., 2019), http://active.boeing.com/commercial/orders/displaystandardreport.cfm?cboCurrentModel=737&optReportType =AllModels&cboAllModel= 737&ViewReportF=View+Report.

[4] Eshna Basu, *What Makes Airbus A320 the World's Best-Selling Narrow-Body Airplane?,* THE MOTELY FOOL L.L.C (Sept. 9, 2014, 11:05 AM), https://www.fool.com/investing/general/2014/09/09/what-makes-airbus-a320-the-worlds-best-selling-nar.aspx.

[5] Duncan Graham-Rowe, *More Efficient Jet Engine Gets in Gear,* MIT TECHNOLOGY REVIEW (Dec. 13, 2010), https://www.technologyreview.com/s/421992/more-efficient-jet-engine-gets-in-gear/.

aircraft, which was much profitable in an operational and business perspective. Boeing started feeling the heat as its line of the undisputed 737s kept losing business in the face of strong competition from the A320 that continued outshining its counterpart in terms of size, range, and pricing.[6]

This urged Boeing to create a better and efficient aircraft, the Boeing 737 MAX series, which would take on the already loosing competition against the A320neo. These were designed to have the CFM International's LEAP-X engines which were larger and heavier than its prior model CFM56-7B used in the Boeing 737NG.[7] The increased size was not a problem for the Airbus, as it had more room under its wings, unlike the Boeing as dimensionally, the Boeing 737 aircraft seated lower than an Airbus A320 due to shorter wheel base. This posed the challenge to the engineering team of Boeing to fit a larger engine under the wings of an already low seated aircraft. The company ended up affixing the engine forward and above, with respect to the original position. Even though the team had successfully housed the engine with the structure of the aircraft, the flight tests would prove that the aircraft behaved differently than the prior designs. The aircraft, at the time of take off, would pitch up too much, increasing the angle-of-attack (AOA) of the aircraft and causing the plane to stall due to lack of aerodynamic lift generated in the wings. To resolve the issue, the engineers designed changes into the software, by incorporating the Manoeuvring Characteristics Augmentation System (MCAS) which automatically controls the horizontal stabiliser of the aircraft to effect a pitch down, thereby reducing the AOA to regain lift. The MCAS moves the aircraft back to a "normal" flight position, as would a pilot normally push the plane's nose down to recover from a stall. The system repeats the process

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[6] Eshna, *Supra* note 4.

[7] A.K. Sachdev, *Leap-1B Powering the Boeing 737 MAX,* SP'S AVIATION (Dec., 2017), http://www.sps-aviation.com/story/?id=2164&h=LEAP-1B-Powering-the-Boeing-737-MAX.

and works in burst motion, when it detects the plane is still tilted at too steep an angle, and realign the plane continuously to the ideal angle of attack on gaining altitude.[8]

2.2 Piloting Features

The piloting of an Airbus is significantly different from that of a Boeing aircraft. Boeing incorporates a modernised old-school machine featuring a traditional floor-mounted yoke connected to control cables connected directly to hydraulically boosted control surfaces whereas the Airbus utilises the fly-by-wire (FBW) control, which uses a side stick connected to a computer that senses the pilot's input and delivers electrical signals to hydraulically actuated controls. Airbus could be said to have an automation galore which works actively behind the scenes to reduce pilot workload. While the 737 has switches everywhere to control generators, air conditioning, hydraulics, et cetera, the Airbus does most of the work by itself in normal operation.[9] However in the latest iterations of aircrafts from the manufacturers, the brand new 737 MAX 8 as well as Airbus A320, the technology has evolved differently, wherein the Airbus using a well defined and highly secure, computer controlled autonomous system, which basically flies the plane by its own, requiring very less work of the pilot and any overriding of autonomous function could be easily effectuated by specifically overriding the function by manual or software control, and Boeing, incorporating the same traditional ways, but with an inbuilt system which monitors and limits the pilot's erroneous actions and manoeuvres by restricting the motion of the yoke, which could be overridden by applying more force on it. From a pilots perspective, it would seem as if the autonomy is inherent in the Airbus whereas the Boeing would seem rather finessed for manual

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[8] *Boeing 737 Max: What went wrong?,* BBC NEWS (Apr. 5, 2019), https://www.bbc.com/news/world-africa-47553174.

[9] Peter A. Bedell, *Turbine Pilot, Boeing 737NG Versus Airbus A320,* AOPA (May. 5, 2016), https://www.aopa.org/news-and-media/all-news/2016/may/pilot/t_bva.

control and the interference of the computer could seem subtle. But in the turn of events, it would be Boeing, that falls into disaster, when the tenuous interference of the computer, such as the MCAS, becomes invasive and would prove fatal, as it would become a nightmare for the pilots to recognise the action of the computer and promptly disable it. The unfortunate malfunction of the AOA sensors of the aircraft accompanied by the lack of information to the pilots about the working of the MCAS, and a failure to train the pilots on when and how MCAS worked and on how it is disabled, sealed the fate of the Lion Air Flight 610 and Ethiopian Airlines Flight ET302 into disaster.

2.3 International Law on Aircraft Accident Investigation

The international legal regulations for civil aviation is provided under the Convention on International Civil Aviation a.k.a the Chicago Convention, signed on 7 December 1944 by 52 States. The International Civil Aviation Organisation (ICAO), which came into being on 4 April 1947, was formulated under this treaty. Chapter 5 of Annex 13 to the Convention on International Civil Aviation addresses the investigation process prescribing the responsibility for an investigation to the State in which the accident or incident occurred. That State usually conducts the investigation, but it may delegate all or part of the investigation to another State. If the occurrence takes place outside the territory of any State, the State of Registry of the aircraft has the responsibility to conduct the investigation. States of Registry, Operator, Design and Manufacture who participate in an investigation are entitled to appoint an accredited representative to take part in the investigation. Advisers may also be appointed to assist accredited representatives. The State conducting the investigation may call on the best technical expertise available from any source to assist with the investigation. The investigation process includes the gathering, recording and analysis of all relevant information; the determination of the causes; formulating appropriate safety recommendations and the completion of the final report. Chapter 5 also includes provisions regarding: the investigator-in-charge, flight recorders, autopsy examinations, coordination with judicial authorities, informing aviation security authorities, disclosure of records, and re-opening of an investigation. States whose citizens have suffered fatalities in an accident are also entitled to appoint an expert to participate in the investigation.

Article 26 of the Convention on International Civil Aviation provides for the manner of investigation of accidents. It provides that, in the event of an accident to an aircraft of a contracting State occurring in the territory of another contracting State, and involving death or serious injury, or indicating serious technical defect in the aircraft or air navigation facilities, the State in which the accident occurs will institute an inquiry into the circumstances of the accident, in accordance, so far as its laws permit, with the procedure which may be recommended by the International Civil Aviation Organisation. The State in which the aircraft is registered shall be given the opportunity to appoint observers to be present at the inquiry and the State holding the inquiry shall communicate the report and findings in the matter to that State.

3. LION AIR FLIGHT 610

3.1 Preliminary Report Data

On 28 October 2018, a Boeing 737 MAX 8 aircraft registered PK-LQP was being operated by PT. Lion Mentari Airlines (Lion Air) as a scheduled passenger flight numbered LNI610, from Soekarno-Hatta International Airport, Jakarta with intended destination of Depati Amir Airport, Pangkal Pinang at 23:20 UTC. On board the aircraft were two pilots, five flight attendants and 181 passengers consisted of 178 adults, one child and two infants. Shortly after departure, LNI610 was instructed to climb to altitude 27,000 feet but at 23:21:53, the crew requested the controller for approval to maintain the aircraft in a holding altitude due to a “flight control problem”. At 23:22:05 UTC, when the flaps were fully retracted to position 0, the Digital Fight Data Recorder (DFDR) recorded an automatic Aircraft Nose Down (AND) trim active for 10 seconds at an altitude of 2,150 feet followed by flight crew commanded Aircraft Nose Up (ANU) trim. At 23:22:48 UTC, the pilots extended the flaps back to position 5 and the automatic AND trim had stopped. But, at 23:25:18 UTC, the flaps were retracted back to position 0 which again triggered the automatic AND trim intermittently for the remainder of the flight for which the flight crew commanded ANU trim relentlessly to compensate the fatal nose down at low altitude. The DFDR data shows that the MCAS and the pilots were in a tug of war, with the former inferring wrong data from faulty AOA sensors and pushing the plane down to a nose dive and the latter, with less information, struggling to manually regain control. Soon, the aircraft disappeared from the Aircraft Situational Display (ASD). Immediately, the Arrival Controller (ARR) retrieved last known co-ordinates from the ASD and requested nearby aircrafts to fly over and conduct a visual search over the area. At 00:05 UTC, tug boat personnel found floating debris at 5°48'56.04"S; 107° 7’23.04”E, about 33 nautical miles from Jakarta on bearing 56° and was later identified as LNI610, confirming the cash which killed all 189 people on board the aircraft.[10]

3.2 Investigation

Following the recovery process, a Boeing technician and engineering team, a team from the US National Transportation Safety Board (NTSB), personnel from the US Federal Aviation Administration (FAA), Australian Transport Safety Bureau (ATSB) and the engine manufacturer GE Aviation, and a team from Singapore to provide assistance in recovering the aircraft's flight recorders were

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[10] *Preliminary Aircraft Accident Investigation Report, PT. Lion Mentari Airlines Boeing 737-8 (MAX)*, Komite Nasional Keselamatan Transportasi, Republic of Indonesia,

dispatched to the crash site to assist Komite Nasional Keselamatan Transportasi[11] (KNKT) in their investigation of the accident. The involvement of the NTSB of the United States of America as State of design and State of manufacturer, the TSIB of Singapore and the ATSB of Australia as State provide assistant that assigned accredited representatives according to International Civil Aviation Organisation (ICAO) Annex 13 which contains the international standards and recommended practices for aircraft accident and incident investigation.

4. ETHIOPIAN AIRLINES FLIGHT ET302

4.1 Preliminary Report Data

On March 10, 2019, at 05:38 UTC, Ethiopian Airlines flight 302, Boeing 737-8(MAX), ET-AVJ, took off from Addis Ababa Bole International Airport bound to Nairobi, Kenya Jomo Kenyatta International Airport carrying 157 passengers and crew on board. Almost immediately after the plane lifted off the tarmac, the plane's left angle-of-attack (AOA) sensor readings deviated from the right side sensor of the jet. The left AOA readings spiked from 11.1˚ to 35.7˚ and then to a near-vertical 74.5˚ in three fourth of a second. The right side AOA reached no steeper than 15.3˚. The left stick shaker activated due to the erroneous data from the sensors. The DFDR data also indicated that the airspeed, altitude and flight director pitch bar values from the left side was deviating from the corresponding right side values. After take off, the aircraft on its climb to 32000 feet, the flaps were retracted from position 5 to 0, following which, exactly as in the Lion Air Flight 610, the DFDR recorded an automatic aircraft nose down (AND) activated for 9.0 seconds arresting the climb. The pilots compensated for the AND motion

[11] Komite Nasional Keselamatan Transportasi is the National Transportation Safety Committee (NTSC) of Indonesian government charged with the investigation of air, land, rail, and marine transportation safety deficiencies.

by applying manual control to achieve normal position. At 05:40:41 UTC, approximately five seconds after the end of the ANU stabilizer motion, a third instance of AND automatic trim command occurred following which the First-Officer requested ATC to maintain 14,000 ft and reported that they are having flight control problem. Preparing for emergency landing, at 05:43:11, about 32 seconds before the end of the recording, at approximately 13,400 feet, two momentary manual electric trim inputs were recorded in the ANU direction, after which an AND automatic trim command occurred and the stabilizer moved in the AND direction from 2.3 to 1.0 unit in approximately 5 seconds. The aircraft began pitching nose down and continued, eventually reaching 40° inevitably crashing the aircraft and killing everyone on board.

4.2 Investigation

At around 05:47 UTC, the Federal Democratic Republic of Ethiopia (FDRE) Ministry of Transport and Aircraft Accident Investigation Bureau[12] (AIB) were informed about the loss of radio and radar contact with flight 302. In accordance with article 26 of the Convention on International Civil Aviation and ICAO Annex 13, an Investigation Committee (IC) from Ethiopian AIB investigators was formed by a ministerial decree issued by the Minister of Transport in order to conduct the technical investigation. An investigator-in-charge (IIC) was designated in the same decree to lead and initiate the investigation immediately. As per Annex 13 provisions, the investigation participated European Common Aviation Area (ECAA), European Union Aviation Safety Agency (EASA) and Ethiopian Airlines Group as technical advisor to AIB, NTSB as the accredited representative state of design and manufacturer, Le Bureau d'Enquêtes et d'Analyses (BEA) as accredited representative state which provided facilities & experts for the

[12] The Aircraft Accident Investigation Bureau (AIB) is the investigation authority in Ethiopia responsible to the Ministry of Transport for the investigation of civil aircraft accidents and serious incidents in Ethiopia.

read out of DFDR & CVR, and a Search & Rescue (SAR) team by Ethiopian Air force, Ethiopian Air lines Group and Abyssinian flight service.[13]

5. SIMILARITIES BETWEEN THE TWO ACCIDENTS

The two crashed jets were Boeing 737 Max 8s, a variant of the best-selling aircraft of Boeing powered by the same CFM International LEAP engines. MCAS, a system unique to the MAX variants of the 737, was common and a crucial factor in both the instances of the aircraft accident. The accidents had occurred within a time gap of five months, and investigators have found strong similarities in the angle of attack data from both flights as a piece of a stabilizer was found in the wreckage of the Ethiopian jet with the trim set in an unusual position, similar to that of the Lion Air flight.[14] This indicated that the defect was with the aircraft itself, and the accident could reoccur, and caused regulators worldwide to ground the 737 MAX aircraft.[15] The pilots of both the aircrafts experienced a hinderance to normal ascend of the aircraft following take off, as the MCAS constantly initiated automatic AND trim consequential of the erroneous data transmitted from the faulty AOA sensors. The altitude plotted against time produces an uneven pattern, which can be inferred to have been constant altitude variation caused by the strife between the MCAS and the pilots. Both accidents were the result of the aircraft succumbing to the MCAS control and nosing down,

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[13] Aircraft Accident Investigation Preliminary Report, FDRE Ministry of Transport, AIB, Ethiopian Airlines Group B737-8 (MAX) Registered ET-AV

[14] Andrew J. Hawkins, *Everything you need to know about the Boeing 737 Max airplane crashes*, THE VERGE (Mar. 22, 2019, 9:00 AM), https://www.theverge.com/2019/3/22/18275736/boeing-737-max-plane-crashes-grounded-problems-info-details-explained-reasons.

[15] Dominic Rushe, *Boeing: global grounding of 737 Max will cost company more than $1bn*, THE GUARDIAN (Apr., 24, 2019, 5:27 PM), https://www.theguardian.com/business/2019/apr/24/global-grounding-of-boeing-737-max-will-cost-company-more-than-1bn.

when in fact no stall occurred. Towards the end of the graph, both aircrafts could be seen to fall from the sky almost vertically as the MCAS eventually brought the plane to almost vertical position, moments before the aircraft plummeted onto the ground. Both instances could be understood to have been the result of providing no information to the pilots regarding the incorporation and working of the MCAS, as a mechanism to deactivate MCAS was already in place. Since the training program for the updated 737 MAX 8 aircrafts did not even mention the word MCAS[16], the consequences could only be amplified by the already delinquently behaving aircraft due to a different position of the new and bigger engines, rendering pilots clueless on trouble-shooting the errors. The Federal Aviation Authority and Boeing has come under a lot of scrutiny for their training and certification procedures. Pilots from various unions around the United States have stated that nor Boeing nor the FAA have informed them properly about the dangers of MCAS.[17] Other similarities between both the aircraft accidents includes the fact that both the crew requested for emergency landing due to flight control problems, minutes after take off from the respective airports. Both aircrafts had uneven vertical airspeeds, and had lost contact within 15 minutes of take off. The other coincidence is that both aircrafts were brand new, and both the flight operating conditions were optimal, due to clear weather. Similarities of the crash sites of both aircrafts wherein the components were broken up into small pieces were also determined.

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[16] Jon Ostrower, *What is the Boeing 737 Max Maneuvring Characteristics Augmentation System?*, THE AIR CURRENT (Nov. 17, 2018), https://theaircurrent.com/aviation-safety/what-is-the-boeing-737-max-maneuvering-characteristics-augmentation-system-mcas-jt610/.

[17] *More shocking facts about the Boeing 737 MAX crashes,* AVIATIONCV.COM (Mar. 20, 2019), https://www.aviationcv.com/aviation-blog/2019/shocking-facts-boeing-737max-crash.

These similarities indicate a pattern and poses the dangerous possibility of future accidents, unless right measures are taken.[18]

6. EXTENT OF FORESEEABILITY

Aircraft accidents are a necessary and inevitable evil to the aviation industry, every instances providing crucial and valuable information which would go a long way in furtherance of the safety of millions of everyday airline passengers all around the world. The information collected from the multitude of aircraft accidents in the past has paved way to a very safe and secure environment of civil air travel. Aircraft accidents were so common in the past, that fear of flight was a very real thing. Component failure, design flaws, material defects and external factors detrimental to the safety of the aircrafts including turbulences, lightning, bird strike etc contributed to majority of crashes in the past and still does in cases of operation of older aircrafts. It is uncommon and surprising for a modern passenger aircraft to crash due to such factors, and ever more unlikely for a faulty sensor data, wrongly interpreted by an uncontrollable and intrusive on board computer to cause a major crash, until recently proven otherwise. In fact the aircrafts were in top notch condition and could have easily flown its chartered flight and back, except for the sensor error, which could have been easily disabled had the controls and information of automatic trim were given upfront. Since one of the main selling point of the mew fleet of 737 Max aircrafts was minimal pilot training to fly the brand new aircraft, the information about the MCAS was lost in the wind, or so the company thought, was not a necessary attribute since the dependence on the computer control was clearly overestimated.

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[18] Devina Heriyanto, *Six similarities between Ethiopian ET302 and Indonesian JT610 plane crashes*, THE JAKARTA POST (Mar. 11, 2019, 06:00 PM), https://www.thejakartapost.com/news/2019/03/11/six-similarities-between-ethiopian-et302-and-indonesian-jt610-plane-crashes.html.

After two fatal crashes that killed all aboard, it emerged that pilots were not made aware of what MCAS was, how it worked or how to safely disable it. Boeing instructions after the first crash were to disable the electric stabiliser trim motors, preventing MCAS from operating at all. However, that led to pilots being forced to rely on the manual backup trim, which may have, in case of the Ethiopian Airways flight ET302, as new theories suggest, after successfully cutting out the electric stab trim per Boeing's instructions, rendered the trim wheel restricted against the huge aerodynamic forces caused by their airliner accelerating towards the ground as the force needed to move the control surfaces is directly proportional to the airspeed.[19] Both instances of the aircraft accident involving the Lion Air Flight 610 and Ethiopian Flight 302 originated from the same malfunction of the sensor, which led to wrong action of the MCAS, but different in case of the latter, as the pilots could have been successful in disabling the system but yet unable to regain control due to huge aerodynamic forces.

There can be three broad standards on which liability may be premise, namely negligence, strict products liability, and warranty. The negligence standard in aviation is a simple common law negligence and any person injured in a general aviation accident by the negligence of another, as long as the negligence is the proximate cause of the injury, may bring an action for liability. Within the area of strict products liability, in order to hold a person liable for manufacturing or design defects, the product must have been defective at the time the product left the control of the manufacturer, as judged against the reasonably feasible design and engineering standards which existed at the time of manufacture. The product must also be used in a manner for which it was designed and manufactured. This second change precludes liability in situations where the aircraft was used in a manner for which it was not

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[19] Gareth Corfield, *Boeing admits 737 Max sims didn't accurately reproduce what flying without MCAS was like*, THE REGISTER (May 20. 2019 2:28 PM), https://www.theregister.co.uk/2019/05/20/737_max_flight_simulators_not_accurate_report/.

designed or manufactured, eliminating what is commonly known as the "crashworthiness" doctrine.

The concept of liability and insurance policy of an aircraft conceptualises from the fundamental foresight of an accident which could be fatal since the range of operation of aircrafts is normally at 30,000 feet and any malfunction, even the most insignificant ones could bring down the aircraft. Even though the instances of fatal accidents has been lowered to minuscule numbers in the recent times, accidents still happen, and as would a reasonable prudent man would assume, will happen again in the future. Foreseeability is only one limited factor in determining whether a manufacturer has a legal duty. The principle that "liability" or "duty" is distinct from foreseeability has clearly been recognised by courts throughout. Foreseeability alone as a basis for legal duty has been rejected, and rightfully so, as applied to the so-called "crashworthiness" theory. There are many other elements, in addition to foreseeability, that are necessary to create a legal duty. If foreseeability were the sole test of a legal duty, then any person cut by a knife would have an action against the knife manufacturer or any person falling from a bicycle, or injured while riding a motorcycle, would have recourse against the respective manufacturer. In case of aircrafts it is "foreseeable" that there will be collisions with other aircraft, buildings or trees or a fire may occur in any aircraft crash or that the aircraft will definitely impact with the ground in case a crash. It is the manufacturers duty to provide reasonably safe product, which is free from design defect as well as manufacturing defect. In US the law identifies no difference between the application of design defects and manufacturing defects which effectuate an accident, as both are detrimental to life and property and inherently dangerous. Liability cannot be imposed upon merely for the dangerous use of an inherently safe aircraft, but it can certainly subsist when the design itself is flawed which could be identified to inevitably cause fatalities.[20] In case of the crashes of the 737 MAX 8 aircrafts, a reasonable person could assume that a pilot who is not familiarised with the new MCAS could find himself meddling cluelessly on the onboard control system with absolutely no idea of what is causing the nose down or how to disable the system, especially in case of a sensor error. Perhaps the company relied too much on its equipment which ultimately malfunctioned, allowing the system to aggressively interfere with flight control causing the crash. A legal principle could be drawn from the case of *Pike v. Frank G. Hough Co*.[21] which involves a claim grounded on a defect in design rather than a defect in manufacture. The court held that the strict liability imposed upon a manufacturer includes injuries which arise from defects in design as well as defects in manufacture. Whether the design defect in the present case is of a nature upon which liability can be imposed involves the factual question of whether it creates an unreasonably dangerous condition, or, in other words, whether the product in question has lived up to the required standard of safety.[22]

Other cases which hold evidence of absence of feasible safety features in design causing plaintiffs injuries was sufficient to avoid a nonsuit include *Boeing Airplane Company v. Brown*[23] wherein a wrongful death action suit in light of an explosion and crash of a military B-52 jet bomber manufactured by Boeing Airplane Company and delivered to the United States Air Force, over California, on February 16, 1956. The cause of the explosion was determined to be caused by an alternator drive manufactured by Thompson's, when the drive's turbine wheel went into excessive overspeed and disintegrated debris from the turbine wheel penetrated a forward body tank causing fuel to leak and

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[20] Donald M. Haskell, *The Aircraft Manufacturer's Liability for Design and Punitive Damages - The Insurance Policy and the Public Policy*, 40 J. Air L. & Com. 595 (1974)

[21] *Pike v. Frank G. Hough Co.*, 2 Cal.3d 465 (1970)

[22] *Id.*

[23] *Boeing Airplane Company v. Brown*, 9 Cir. 291, 310 (1961)

ignite upon which the aircraft exploded and crashed, killing Major Albert K. Brown. On an appeal against the judgement by the trial court which decreed against Boeing, the appellant contended that the findings of fact do not deal with the duty of care of the manufacturer which has incorporated in the article which it sells a component part designed and manufactured by another. That duty, appellant argues, is to exercise reasonable care in ascertaining whether there is a defect inherent in the design and manufacture of the component. The trial court, as appellant points out, made no express finding that Boeing either knew or by the exercise of reasonable care should have known of a defect inherent in the design and manufacture of the alternator drive by Thompson's. The appellate court determined that the real negligence is with the Air Force, who had been established to have had knowledge about the defect and yet continued to use, sometimes beyond its operational limits. Other cases including *Robinson v. Reed-Prentice Corporation*[24] and *Darling v. Caterpillar Tractor Co.*[25] discuss upon the feasibility and reasonability of requirement of safety features in the design and liability in case of breach of safety and injury to persons.

"Unreasonablity" is a negligence concept and has no basis in the law of strict liability.[26] Of course, contributory negligence is no defence, and that includes the failure to discover the defect.[27] In California the defect can be patent and obvious' and misuse of the product is no defense to the manufacturer if it was foreseeable.[28] Additionally, even though the manufacturer may have discovered a defect in his product and issued a warning to the employer of an injured plaintiff, the employer's disregard

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24 *Robinson v. Reed-Prentice Corporation*, 9th Cir. 286, 478 (1961)

25 *Darling v. Caterpillar Tractor Co.*, 171 Cal. App. 23, 341 (1959)

26 *Cronin v. J.B.E. Olson Corp.*, 8 Cal. 3d 121, 433 (1972)

27 *Luque v. McLean*, 8 Cal.3d 136, 443 (1972)

28 *Thompson v. Package Mach. Co.*, 22 Cal. App. 3d 188, 281 (1971)

of it is not a defence if it was reasonably foreseeable.[29] The heart of an aviation products liability case is discovery, which necessitates easy access to thousands of documents in the manufacturer's file cabinets, running from original design proposals and engineering changes to service department deficiency, defect and malfunction reports.[30]

7. LIABILITY

Aviation litigation is a sophisticated process involving various potential theories of liability under domestic and international law and a multitude of different defendants to choose from and different courts with multiple jurisdictions. To establish liability on a party for an aviation accident, the litigating party should reasonably prove that the person responsible failed to meet an industry standard related to operation of the aircraft, engineering, or certain regulatory issues. Although the circumstances leading to every aircraft accident is unique, generally claims for personal injury or death resulting from an aviation accident are controlled by the legal theories of negligence, product liability, or some combination of the two. Negligence is the legal term for the failure to do or not do something that a reasonable prudent person would have done or not done under the circumstances, in order to protect others from foreseeable risks of harm. Pilots, airlines and airline maintenance providers are generally susceptible to such negligence claims in the instance of an aviation accident. Product liability is the legal responsibility on the manufacturers and sellers for providing defective products. If it can be proved that a defective product somehow contributed to an aviation accident, then product liability may allow recovery against the manufacturer or seller of the defective product. Liability for negligent design is now fairly well established in products

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[29] *Balido v. Improved Mach Inc.*, 29 Cal. App. 3d 633, 890 (1972)

[30] Albert R. Abramson,*Where to Sue in Aviation Products Liability Cases*, 40 J. Air L. & Com. 369 (1974)

cases. However, particularly since aircraft manufacturers are already heavily regulated by the government, manufacturer's liability for defective design, even under negligence theories, should be based only upon legislative and regulative standards, and not upon the unpredictable morass of standards that result from case-by-case litigation of design problems. Liability for a design defect under strict liability, without any evidence of negligence of the aircraft manufacturer, only penalises technological innovation and encourages the imposition at the time of verdict of design criteria generally not recognised at the time the aircraft was manufactured.[31]

In these cases of the Lion Air Flight 610 and Ethiopian Airlines Flight 302 accident, the liability could be established upon the manufacturer for defective design. It has to be noted that no components except the AOA sensors of the aircrafts malfunctioned, which without the MCAS could not have caused a crash. Since the plane has redundant systems to compensate the mechanical failure of a device or a system, a single faulty sensor data could be easily identified and rejected, by calculating the same from other sensor variables. For example, the aircrafts have at least a pair of AOA sensors on both sides, and any malfunction can be determined by comparing the value to a the calculated angle-of-attack derived from equating rate of change of altitude and the airspeed obtained from the RADAR, and discarding the data from the malfunctioning sensors. The data was available, and any reasonable pilot could have averted the disaster, except for the fact that the MCAS was discreetly operational behind the scene, a system designed to prevent stall, but with the wrong sensor data, caused a confusing situation, wherein the autopilot and the pilots had contradicting control inputs and the former prevailed.

Foreseeability of failure of a component or a system is inherent in aviation design. Parts are intentionally made of weaker materials to

[31] Donald, *supra* note 20, at 603

reduce weight and increase efficiency. But most important aspect of aerospace design is with respect to critical parts, which include the powerhouse, control surfaces etc. The control of an aircraft is the ultimate system which under no circumstances can fail, and hence the companies had designed in multiple redundant system to ensure that a plane is always under control. But even with all those in place, a continuously wrong automated control input by the MCAS, created the disastrous situation with no mechanical failure, but merely an unwarranted software interference moving the stabiliser to cause AND motion. Provided the MCAS had not wrongly identified the situation, the crashes would not have happened. Hence it can be inferred that the MCAS had in fact made an inherently safe design of the manufacturer precarious, when a simple failure such as a sensor effectuated a plane crash as the on-board computer directed the plane to the ground.

8. CERTIFICATION

The certification process of the new software system in the 737 MAX aircrafts has to be analysed in to determine how such a foreseeable event of a sensor malfunction could be converted to a potentially fatal situation by the MCAS, which has a dangerous control over the aircraft, that is the AND trim function, which can cause the plane to face vertically towards the ground when at flight. In the US, the country of incorporation of Boeing, the Federal Aviation Administration (FAA) performs the function of certifying the components involved in civil aviation. But it’s simply not possible for the FAA or any civil aeronautics agency to have the entirety of expertise necessary to do it themselves, hence has been delegating the certification process to the company itself, creating a process of self-certification. Certainly design elements of the 737 MAX led to software improvements to enhance the safety of the aircraft, but which are vulnerable to faulty Angle of Attack readings. The risk created by such an error was understated during the certification process could not be reasonably stated that the FAA could have done a better job on this score.[32]

Further the United States Supreme Court discussed the “discretionary function defence” in a case *United States v. Varig Airlines*[33] wherein a Boeing 707 commercial jet aircraft owned by respondent airline was flying from Rio de Janeiro to Paris when a fire broke out in one of the aft lavatories producing thick black smoke throughout the cabin. Despite a successful effort to land the plane, most of the passengers on board died from asphyxiation or the effects of toxic gases produced by the fire, and most of the plane's fuselage was consumed by the post-impact fire. Respondent airliner bought action seeking damages for the destroyed aircraft and a wrongful death action by respondent families and representatives of the deceased passengers. Respondents alleged that the Civil Aeronautics Agency, the FAA's predecessor, was negligent in issuing a type certificate for the Boeing 707 because the lavatory trash receptacle did not satisfy applicable safety regulations. The court held that it was this sort of judicial intervention that the discretionary function exception was designed to prevent. It follows that the acts of FAA employees in exercising the "spot-check" program are also protected by that exception, because respondents alleged only that the FAA failed to check particular items in the course of its review.[34]

9. CONCLUSION

Aviation industry is one which has a plethora of lessons learnt the hard way at the expense of millions of lives lost in aircraft accidents,

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32 Gary Leff, *Why the FAA Delegates Certification to Boeing — and Why That’s a Good Thing*, VIEWFROMTHEWING (Mar. 25, 2019), https://viewfromthewing.boardingarea.com/2019/03/25/why-the-faa-delegates-certification-to-boeing-and-why-thats-a-good-thing/.

33 *United States v. Varig Airlines*, 467 U.S. 797 (1984)

34 *Id*. at 799

paving way to the impeccable safety of air travel we have envisaged for today's as well as tomorrow's world. Every air crash investigation conducted in history could be said to have been done, not to determine liability but to understand what went wrong and how to correct the problem. The aircraft manufactures as well as the component manufacturers have in time devised new ways and method to overcome the limit of even the fundamental material strength common to materials, by altering its lattice structures, complex amalgamations, specific chemical and other treatments, rendering components working at higher resistance to deformation and failure, and each of these new inventions fuelled by the uncompromising desire for safety. The fruit of this research would be to determine that lesson which could be learnt from the crashes of Lion Air Flight 610 and Ethiopian Airlines Flight 302. The grounding of the entirety of the fleet of the 737 MAX 8 aircrafts world wide, in spite of the invasive MCAS system, following the crash, costing the company as well as airliners billons of dollars, should make the aviation companies understand that certain fundamental principles including adequate training of pilots in case of any modification or alteration of the control system of an aircraft, is indispensable. The conclusion in this research paper would be that every new automated control should be evident and mechanisms should be placed, with adequate information and training given to the pilots on how the system works and on how to disable such components, since a pilot is always the better judge in analysing the situation and determining the safety of the passengers.

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