A review of accidents & incidents on Boeing and Airbus commercial aircraft’s avionics-related system in two decades (1996-2015)

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Abstract. Aviation accidents still hit the news even though the growth of technological advancement on commercial aircraft avionic systems has been impressive. Hence, one of the objectives of this study is to plot the time-based graph of commercial aviation accidents, with direct consequence from avionics instrumentation in the period of two decades, from 1996 to 2015. The second objective is to analyse two main aircraft manufacturers, Boeing and Airbus, in determining specific model of its kind that significantly involved in avionics-related instrumentation as one of the contributing factors that leads to the incidents or accidents. The third objective is to identify which avionics system that most frequently involved in aviation incidents, for both manufacturers. The final objective is to examine the main probable cause that has the highest percentage in those accidents within the said time frame. The method of collecting data is by doing comparative analysis from reliable official websites of four well-known bodies such as National Transportation Safety Board (NTSB), Federal Aviation Administration (FAA), Aviation Safety Network and Flight Safety Foundation. Results show that misfortune occurrences are directly associated with avionics within the said two decades, which mainly involved Autopilot and Flight Management System (FMS) (14% each), meanwhile the aircraft model Boeing 737 carries the highest percentage of avionics-related incidents or accidents. Nonetheless, 67% of the misfortune occurrences within the scope of study are mainly due to human error instead of technology.

Acronyms
ADIRU  Air Data Inertia Reference Unit
AOA   Angle of Attack
ECAM  Electronic Centralised Aircraft Monitor
FCS   Flight Control System
FMS   Flight Management System
FQIS  Fuel Quantity Indicating System
GPWS  Ground Positioning Warning System
INS   Inertial Navigation System
MSAW  Minimum Safe Altitude Warning (MSAW)
NDB   Non Directional Beacon
TOWS  Take Off Warning System
1. Introduction

It is known that air transportation is the safest mode compared to other types of transportation as data have shown that only one passenger fatality per 7.1 million air travellers for scheduled passenger airline service [1]. In fact, the International Air Transport Association (IATA) stated in 2010 that in the global scenario, airline accident rate was one accident for every 1.6 million flights [2]. Meanwhile for year 2018, the rate is slightly higher where the commercial airline industry was reported as having 1.35 accidents per 1 million flight or equivalent to one accident for every 740,000 flights [3]. The fact that air transportation is considered safe, does not change the reality that aircraft accidents and incidents still occur annually even though robust technological advancement is already implemented in the aircraft system. Hence, this study was intended to plot a time-based graph of commercial aviation accidents, which had avionics-related cases within the two decades from 1996 to 2015, for Boeing and Airbus airplanes. The second objective of this study is to determine the significant aircraft model from Boeing and Airbus, which frequently involved in these avionics-related accidents. In addition, it was also an interest to determine the specific avionics system mostly involved in those accidents. Lastly, is to identify the main causes of those avionics-related aviation accidents, within the mentioned time span.

2. Literature Review

The safeness of the air transportation comes from many sources, for example technological improvements where better and reliable aircraft systems are developed with advance avionics and steadfast engines. In addition, the enhanced pilot training, improved weather forecasting, enrichment of air traffic management as well as judicious air accidents investigation have also contributed to the establishment of stringent aviation regulations, giving big impact to this prudent environment [1].

Avionics is one of the key elements that significantly has impacted the overall aircraft systems, which apparently plays critical function in making sure smooth, safe and reliable operation of an aircraft. For large commercial aircraft, avionics involves communication, navigation, cockpit display as well as management of the overall aircraft systems. Manufacturers have designed the avionics system to be reliable enough so that it can detect any inconsistencies of input and output data from the original data setting and information, in making sure a practical aircraft operation as well as part of back up system in case of emergency. However, there are also other issues involved technically or human related with this intricate system.

As an example, Gawron [4] had produced a report listing down all the related accidents involving flight deck automation issues with regards to flight crew, from year 1972 to 2013. He found that the recurring issues correlated with automation were human poor attentiveness, skill deficiency, trust in automation and self-complacent. The findings suggested that in any new automation design, the cultural differences between nations also need to be taken into account when it involves training, certification and aircraft operations as these will directly affect the performance and how automation is used. In an investigation that was carried out after any aviation mishap, a report was released with possible causal factors together with several recommendations to prevent similar event from recurring. Hence, the national authorities and international aviation bodies have proposed as well as imposed stringent regulations when it comes to design issues to the aircraft manufacturers in order to prevent and minimize as well as learned some lessons from such occurrences.

In fact, a researcher had done a lot of study on the aviation accidents, came up with theories on what could have caused such events [5]. The well-known James Reason [5] stated that any high profile accidents in this world, not limited to aviation alone (eg. aerospace, nuclear, marine, rail) happened due to failed defences in every chain of interlink events that contributed to such disasters, rooted from the organisational environment where safety culture was not really inculcated in every level of company structure. Cooper [6] and Civil Air Navigation Services Organisation (CANSO) [7] described that safety culture involves three aspects: psychological, behavioural and situational. Nevertheless, in general view it was found that 70% to 80% of aviation accidents were attributed by human error [8].
3. Methodology
This study looked into air incidents and accidents of two aircraft manufacturers that have the highest market share for commercial aircraft, Airbus and Boeing [9] within two decades of time, from the year 1996 to 2015, specifically on their avionics systems. The method used in this study was by comparative study, through analysing the published secondary data from well-known and reliable official websites of aviation bodies such as National Transportation Safety Board (NTSB), Federal Aviation Administration (FAA), Aviation Safety Network and Flight Safety Foundation. Based on the published official investigation reports and data taken from these four websites, each case was scrutinized and compared for accuracy and consistency. Those cases were then compiled by arranging them according to date, year, location, aircraft operator, aircraft manufacturer & model (Airbus or Boeing), aircraft registration, its main cause of accident/ incident and in particular its specific avionics system involved. From this list of commercial aviation accident cases in twenty years’ period, emphasis was given on the avionics-related incidents and accidents. This allows further examination on the overall picture of avionics system feasibility experienced in those two decades.

It is important to emphasize here that in any air disaster investigation one single cause does not lead towards the unfortunate incident. In reality, several interlink contributing factors do have discernible impact to a particular air disaster [8]. However, this study utilized the official reports in the mentioned official websites to identify the main probable cause. The accuracy of the data was mainly based on the information provided in those four websites. Therefore, any air disaster data which were not published in those websites, are not included in the discussion of this paper.

4. Results and Discussion
The data of aviation accidents from the official websites of NTSB, FAA, Aviation Safety Network and Flight Safety Foundation were compared to, cross referenced and compiled based on specific date, location, aircraft operator, aircraft manufacturer & model (Airbus or Boeing), aircraft registration, its main cause and whether it is avionics system-related. Based on the data obtained, Figure 1 presents the trend of the accidents/incidents of Airbus and Boeing aircraft in the period of 1996 to 2015.

Figure 1 shows the fluctuations on the rising of commercial aircraft accidents every year. Nevertheless, the cases that involved avionics instrument slightly decreased. The fact that fast development in aviation industry such as in technological innovation [10] has encouraged frequent use of aircraft as one of the main transportations.

Based on the data collected within the period of 1996 to 2015, there were 405 cases of commercial air accidents involving both aircraft manufacturers, based on those four official websites alone. 42 cases of them involving direct causal or related with avionics system.

Based on the same data, there were 314 total air accident cases for Boeing, which 25 (8%) out of them involved avionics-related cause. Meanwhile for Airbus models, a total of 91 cases were involved in general air disasters, and 17 (18.6%) of them involving avionics instruments as shown in figure 2.
Figure 1. Trend of aircraft accidents & incidents (Airbus and Boeing) year 1996-2015

Figure 2 shows the details on accidents and incidents involving avionics instruments between these two major manufacturers for each year within the two decades, with 42 cases. Out of 42 cases related with avionics, 25 cases involved Boeing aircraft which reflects to 59.52% of the total cases. Airbus types with 17 cases (40.48%), which shows that avionics instrumentation in Boeing aircraft has significant contribution towards aircraft accidents compared to Airbus in those years. The highest cases of Boeing aircraft were in 1996 where those cases involved with autopilot, barometric altimeter, Flight Management System (FMS), Fuel Quantity Indicating System (FQIS) and static port. However, these cases do not represent the flaw of the avionics technology as an isolated system, but other contributory factors were tangled, as example the maintenance error, pilot error, design or environmental factors.

Figure 2. Comparison of Boeing & Airbus accidents/ incidents involving avionics instruments (1996 – 2015)
4.1 Specific Avionics Instruments
To look into details of the instruments involved in commercial aviation accidents and incidents in the year 1996 to 2015, the following figure 3 reflects the specific avionic systems involved.

Figure 3 shows that Flight Management System (FMS) and Autopilot are the most frequent instruments contributed to the air accident/incident which involves both manufacturers, Airbus and Boeing. Each manufacturer had three cases for each type instrument system, covering 14% from the overall instruments as shown, within the said period of time under study. For the record, most of those cases happened during landing. The subsequent avionic systems which contributed the highest to the misfortune events were anti-skid (10%) and altimeter (7%) systems.

![Avionics Instrument related to aircraft accidents/incidents of Boeing & Airbus (1996-2015).](image)

4.2 Specific Aircraft Model
Figure 4 presents which aircraft model frequently involved in the avionics-related aviation accident. In general, it can be stated that within a total of 42 cases involving avionics-related incidents of Boeing and Airbus models in the said period (1996 - 2015), the prominent aircraft model was B737 which had 15 cases (35.7%) followed by A320 model which involved in 9 cases (21.4%). Hence, the B737 model involved in avionics-related accident was higher by 14.3% compared to A320. In fact, these two models are popularly utilized for single aisle aircraft design throughout the world especially for low cost carriers.

Nevertheless, Business Insider stated that, “From 1984 to the present (January, 2019) the A320 has outsold the B737 by 439 planes” [11]. This means that A320 could have higher flight operations in the aviation world for single aisle design, yet this model has less impact towards avionics-related issues in aviation accidents compared to B737 model.
4.3 Main Contributing Factor towards Avionics-Related Aircraft Accidents/ Incidents

Many research on aviation accidents claimed that aviation accidents/incidents were caused by several contributing factors [1, 5, 8, 12, 13, 14, 15]. Technological advancement or avionics instrumentation could be one of the contributing factors to such misfortune cases [4, 8]. From the data that were collected and compiled, the following figure 5 shows the general summary of the main factors of the aviation accidents/incidents which related to avionics instrumentation, within the two decades of 1996 - 2015.

Figure 5 shows that there were three main categories that have caused the aircraft accident/incidents related to avionics system which mainly Flight Crew (Human Error) with 54%, Faulty Design / Technical Error contributed 33% and Ground Crew (Human Error) with 13%. If both groups of human error are combined, it accumulates to 67%, which is consistent with the study done by Shappell and his researchers [12]. However, as mentioned earlier it is not easy to simply identify the main cause of any accident as a single main factor since any mishap occurs due to interlink events, when all defences were failed to prevent the next occurrence as explained in Swiss Cheese model of James Reason [5]. Yet, this chart was concluded from the data collection based on published investigation reports of the recognized websites as stated earlier.
Thus, it can be pointed out that human error was still the prominent contributing factor towards aviation accidents, even though avionics instruments were auspiciously placed in the aircraft system. Wiegmann and Shappell [13] had specified five different perspectives of human error that led towards an aviation disaster. These were the limitations that we as human need to cope [12] where there are elements around us that cannot be controlled. In terms of automation system, we can only control the input while the outputs are processed by the system based on designed input data, which could have not responded efficiently as predicted in the preliminary stage that could create outcome disparity. The relationship between human expectations and systems efficiency could give unfavourable repercussion if the existing conditions were not sufficiently conducive, especially with external factors such as environmental stress, organisational hierarchy issues and many more [14].

Looking at the overall data presented in this study, most of the designed avionics systems were quite robust as can be seen from the reduction of air accidents (due to avionics-instrument), compared to overall commercial aviation accidents. There is always a grey line in identifying the actual main factor contributed to any accidents as mishap could happen due to multiple linked factors and not mainly as a result of one single cause. Johnson and Holloway [15] also emphasized where if human error was determined as the main cause of an accident, the organisational influence should also be looked into. In many cases, the organizational factors and accountability do give direct impact towards individual human error at work environment.

Another critical element is the process of how an accident investigation was carried out, which would reflect the findings of the probable versus contributory causes in an aviation accident investigation report. Shappell and his researchers [12] reported that human error components in aviation accident should be scrutinized further as any accident report could be inherently biased or incomplete.

In the meantime, Boeing and Airbus had forecasted that the global fleet is projected to essentially double in size in the near future to 42,730 [16] and 37, 400 [17] respectively by year 2037. Consequently, due to this projection, they need to do extensive research development to increase the safety of their aircraft systems. This includes inculcating the safety culture [6,7] within all related supply chain organisations associated with the manufacturers especially when the regulatory implementations are in place. Issues associated with pilots’ additional training on any new upgraded avionics system, as an example, should not be compromised for the sake of cost reduction within all levels in the aviation industry hierarchy.

Moreover, market share competition between these two giant manufacturers should not jeopardize the passengers’ safety and affect the airlines businesses with their rivalry on offering lower cost of technological improvements. This is crucial especially when newly implemented software requires additional obligatory safety features. Studies have shown that the cases of human errors in

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**Figure 5.** General summary of causes of avionics-related aircraft accidents & incidents (1996 -2015)
aviation do increase with the use of automation [14, 15], hence fail-safe measures should be taken into account when any new automation system is proposed by original equipment manufacturer (OEM).

5. Conclusion
In conclusion, as the fluctuation of the aircraft accident rises, avionics-related incidents seemed to decrease within the time frame under study. It was found that the avionics-related cases were mostly originated from Boeing B737 and Airbus A320 models from the whole avionics-related accidents. FMS and autopilot were the two main avionics systems that carry the highest contributory factors to incidents, followed by anti-skid and pitot-static system. Nevertheless, even with steadfast technological advancement, human error still carries the highest percentage of causal factor in aviation accidents.

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