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DATA INVESTIGATION OF PK-LQP AIRPLANE VERTICAL DEVIATION USING CLASS 1 AND TIER 1 DATASETS

Summary. The vertical deviation is one of the important stages in commercial aircraft flights because indications of malfunction can be detected faster by the pilot rather than in other flight phases. The purpose of this study is to investigate whether the PK-LQP airplane experienced unusual altitude movements during the vertical deviation phase since the airplane taking off from Seattle (Boeing Manufacture's home base) until the airplane crash. The airplane, which is of the type B737 MAX8, had operated for 83 days, during which it completed 438 flights using a total of 107 flight codes, and it travelled to 36 airports. According to the findings of an investigation of the data, we found that only 69 (39%) were included in tier 1, which had an ADS-B data update interval message below 10 seconds, complying with

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ICAO and FAA-AVN standards. With this class 1 and tier 1 dataset, we conducted an EDA to find the data insight, which revealed that there was a disturbance in the speed and altitude indications on the airplane instrumentation, causing a misperception for the pilot and causing the airplane to drastically drop in altitude (more than 100 feet).

Keywords: airplane accident investigations, ADS-B data quality, message interval updates, vertical deviation phase

1. INTRODUCTION

Aviation is a mode of transportation commonly employed by people for holidays and business travels, with the main focus on decreasing travel time. Thus, airplanes play a pivotal role in human society. Since the Wright brothers' first machine-powered airplane in 1903, airplane technology's speed, fuel economy, size, system and control, and safety have been continually evolving [1]. Rather, the advancements in airplane technology and the aviation sector have boosted airplane technology development [2].

According to the IATA (International Air Transport Association) [3], the aviation sector is growing yearly. Based on the global traffic-schedule passenger reports for 2004-2021, the number of passengers in 2004 was 1,994 million, and the number of passengers in 2019 grew up to 4,543 million [4]. Despite the interruption caused by the spread of COVID-19 since 2020, examples include turnaround operations following the post-pandemic [5], the management lessons learned by General Aviation in Australia following a virus outbreak [6], and research on the impact of the COVID-19 outbreak on the global airline industry [7]. The growth rate of passengers using air transportation is 1.278, or 128 percent, from 2004 to 2019, or an average of 8.522 percent/year, which depicts one of the positive consequences of aviation safety and security measures.

The remarkable safety record of the aviation industry in recent years is likely related to technological advancements that were introduced and then improved throughout the second half of the 20th century. Safety has become a global concern [8], [9]. Airplane safety is a significant concern for this industry to achieve its goal [10]. The manufacturer and other sectors need to follow many regulations before launching commercial flights [11]. Thus, technology is deemed as the primary knowledge field behind the formation of airplanes. Nowadays, technology often promises safety by reducing human errors when operating airplanes by implementing semi-autonomous or autonomous (autopilot) technologies, for instance, studies on shared control between human pilots and adaptive autopilots [12], the behaviour of pilot patterns in autonomous driving [13], and fly-by-wire technology [14] are examples. Furthermore, the aviation sector is expected to apply new processes or integrate new facility designs within airplanes [15].

One of the proposed changes is to replace conventional radar with tracking technology using GPS (Global Positioning System), namely ADS-B (Automated Dependent Surveillance-Broadcast System). The ADS-B technology is one of the novel technologies proposed by the Next Generation Air Transportation System (NextGen) in the United States in 2005. NextGen is an FAA (Federal Aviation Administration)-led modern agency to make air transportation efficient, safer, and predictable. The FAA mandates all general aviation airplanes to be equipped with ADS-B. Airplanes flying in the United States below a transitional altitude of 18,000 feet are more likely to mount the ADS-B UAT (Universal Access Transceiver). According to NextGen, the benefits of ADS-B implementation include its facilitation of more frequent position update rates than radar, ensuring more precise location information of airplanes. The second advantage relates to in-cockpit traffic and weather information, and the third benefit includes improved safety for pilots [16].

ADS-B is a technology for airplane monitoring that is increasingly being employed in commercial aviation. The airplane tracking system sends data related to the airplane's altitude, speed, heading, and position to air traffic controllers (ATCs) and flight information service providers (FISPs). This data also contains a text display that shows information such as the time of day, weather conditions, and the airplane's unique identifying number. According to Meyer [17], ADS-B data can be a source of analytical solutions for traffic behaviour in the airspace. Therefore, the usage of flight history data produced by the ADS-B system can be used for the investigation of airplane accidents. The experimental subject of this study is a B737MAX8 airplane with the registration number PK-LQP that is registered in Indonesia.

After reviewing the National Transportation Safety Committee (*Komite Nasional Keselamatan Transportasi*-KNKT) report and analysis of the PK-LQP accident [18], it was evident that the pilot had reported problems in the phase of take-off, initial climbing, and climbing (vertical deviation) with the plane's altitude movements on October 28, a day before the fatal accident. The vertical deviation is one of the important stages in commercial aircraft flights because indications of malfunction can be detected faster by the pilot rather than in other flight phases. Based on Boeing's official report, currently, the total percentage of aircraft accidents from 1959 until 2020 is 23% of all fatal accidents. In addition, the report also revealed that fatalities occurring based on CICTT (the CAST/ICAO Common Taxonomy Team) aviation occurrence categories on commercial jet fleets from 2011 to 2020 were 694 out of 1775 events, or 39% and had occurred due to loss of control factors in flights [19].

Therefore, we seriously considered the accident summary report made by Boeing as the basis of our research. The fact that commercial airplanes performing vertical deviation have a high percentage of accidents raises the question of whether the PK-LQP aircraft experienced unusual altitude movements during the vertical deviation phase. Since the airplane taking off from Seattle (Boeing Manufacture's home base) until the airplane crash. This also refers to the KNKT's official report on the accident investigation, which states that there was a disturbance in the information on the speed and altitude indication on the day before the accident, especially in the vertical deviation phase.

To answer this question, we used the PK-LQP flight history data generated by the ADS-B transponder stored on flightradar24 [20] on the airplane to check all the flight data of PK-LQP and ascertain if there were any oddities in altitude movements as reported on October 28, 2018, and on the day of the ill-fated accident (October 29, 2018). If it can be proven that there was an odd altitude movement during the vertical deviation period outside the KNKT report based on the pilot's report and FDR (flight data recorder), then this becomes new information. Before utilizing the ADS-B data, we analysed the data quality and selected the best data according to message interval data for assessing the altitude of PK-LQP airplane movements during the vertical deviation phase. This is done because the data evaluated must be of high quality in order to maintain confidence in the study.

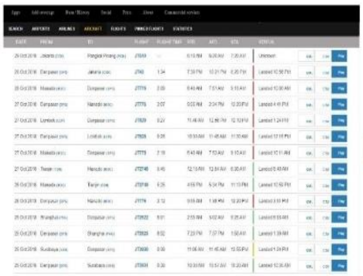
The organization of this paper is as described below. The materials and method section discussing the data sources used and the framework for answering the research objectives are presented in Section 2. Thereafter, the results are discussed in detail in Section 3, while the conclusions are presented in Section 4.

2. MATERIAL AND METHODS

This section explains the applicability and usage of data. Data analysis and investigation methods are applied, which include EDA (Exploratory Data Analysis), to generate data that answers the research question objectively.

2.1. Material

In commercial operations (scheduled passenger flights), the flight phase must follow a pre-set standard according to CICTT. The flight phases include taxi, take-off, initial climbing, climbing cruise, descent, and landing. Based on the commercial flight phase standards and the advancement of ADS-B technology that stores flight history data, we can trace the phase of flight that has been executed by the airplane. The availability and quality of ADS-B data are the keywords of the approach to analysing the flight phase. If we know the stages through which the flight has passed, we might even be able to find strange facts that were not covered in the KNKT report.



Index	DATE	FROM	TO	FLIGHT	File Name
1	08 August 2018	Moses Lake (MWH)	Seattle (BFI)	BOE210	BOE210_080820182.CSV
2	08 August 2018	Seattle (BFI)	Moses Lake (MWH)	BOE210	BOE210_080820181.CSV
3	13 August 2018	Honolulu (HNL)	Guam (GUM)	JT1	JT1_130820182.CSV
4	13 August 2018	Seattle (BFI)	Honolulu (HNL)	JT1	JT1_130820181.CSV
5	15 August 2018	Guam (GUM)	Jakarta (CGK)	JT1	JT1_150820181.CSV
6	18 August 2018	Jakarta (CGK)	Jayapura (DJJ)	JT794	JT794_180820185.CSV
7	18 August 2018	Palembang (PLM)	Jakarta (CGK)	JT337	JT337_180820184.CSV
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
438	29 October 2018	Jakarta (CGK)	Pangkal Pinang (PGK)	JT610	JT610_291020181.CSV

Index	Flight Code	Frequency
1	BOE210	2
2	JT1	3
3	JT204	1
4	JT222	7
5	JT223	7
6	JT240	2
7	JT243	2
.	.	.
.	.	.
.	.	.
107	JT989	2

Fig 1. Experimental materials for detecting anomalies in vertical deviation prior to the accident flight: process of data collection and tabulation

The data used in the study came from Flightradar24 [20], which is a web-based application that stores flight data of PK-LQP in a *.CSV format file, with a total volume of data stored for 438 flights. The next step is to download the data one by one and save it on the local hard drive by naming the file with a unique identifier, such as "JT795_220920186.csv", where JT795 is the flight route code, "22092018" is the date of the flight, and "6" indicates that PK-LQP has flown on that particular day. A unique identifier assignment is mainly done to make the file identification process easier. The detailed process of downloading and tabulating PK-LQP flight data can be seen in Fig. 1.

Generally, each flight file (*.CSV file) has a timestamp, callsign, position (latitude and longitude), altitude, speed, and direction linked details. All flight phases according to the commercial airplane, such as taxi, take-off, initial climbing, climbing, cruise, descent, and landing, are recorded for each line in the recorded data. Later, only the vertical deviation phase will be examined from the whole flight data (raw data).

2.2. Methods

The methodology of this research starts with downloading and tabulating the raw data, which is then separated into three classes based on the ADS-B altitude value recorded during the vertical deviation phase performed for each flight.

Based on the cause of the crash, as reported by KNKT [18], there was a flight disturbance or alarm instrumentation in the flight take-off and initial climb phase. Therefore, the separation of ADS-B flight data based on altitude or flight phase needs to be done to see the facts. Considering and assessing the ADS-B data quality, it is a reasonable assumption that the ADS-B flight history data are comprehensive and can be used for analysis and flight safety. The ADS-B altitude data was divided into three classes based on the flight phase. Class 1 includes flight data that detect altitude at 0 feet, also known as the taxi phase; Class 2 implies the initial airplane detected during the take-off and initial climb phase (greater than 0 feet but less than 1000 feet), and Class 3 is the airplane detected altitude during the climb phase (greater than 1000 feet).

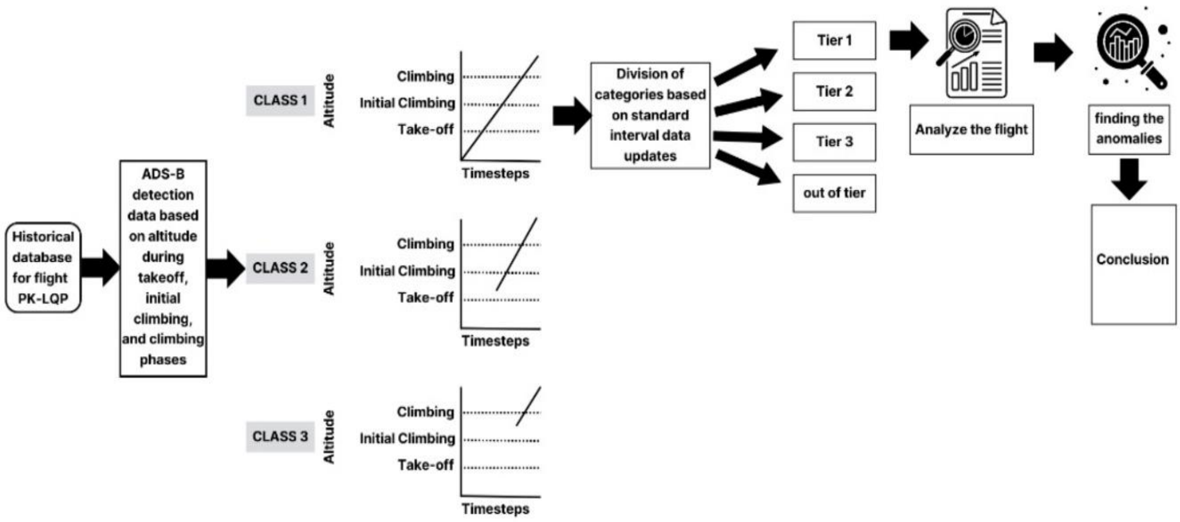


Fig. 2. The scientific process used to find unusual vertical deviations from the past data ADS-B PK-LQP

The time interval between successive position reports is defined as the interval update. This characteristic is examined by gathering all timestamps from reports received on a single airplane and determining the time difference between a row of data. The taxi phase refers to the airplane being at an altitude of 0 feet or equal to the airport surface. The take-off and initial climb phases are the airplane's position at an altitude between 1–1000 feet [21], [22]. The climbing phase is the process of raising an airplane to an altitude of more than 1000 feet above the airport surface and increasing the specified cruising speed and altitude [23] [24]. The Python programming language was used to separate the data into three groups and visualization of data using Scimago Graphica [25].

The first class was grouped for flight data starting from altitude 0 at the departure airport ($X0= 0$), indicating the completion of the taxi phase. The second class was the flight data grouped for altitudes above 0 feet to greater than or equal to 1000 feet ($0<X0\leq1000$); this data group showed that the transponder was turned-on and detected when the airplane was in the take-off phase and initial climbing. The third class collected data from an altitude above 1000 feet ($X0>1000$), meaning that the airplane's transponder data was detected during the climbing or cruise phases. Furthermore, once the raw data has been separated by class, the next step is to investigate the data in class 1. The data in class 1 is analysed again to receive good flight data according to predetermined standards. This division is based on the message quality tier of the ADS-B update interval. After separating by tier, the best quality ADS-B flight data points will fall under tier 1. Thereafter, this data will be further analysed to get insight into the abnormal altitude changes in the vertical deviation phase. In other words, we examine the interval update data quality with a focus on class 1. Afterward, flight data that satisfy the international civil aviation organization (ICAO) requirements for interval update data quality in class 1 will be examined to detect any abnormalities. The process is depicted in Fig. 2.

3. RESULTS AND DISCUSSION

PK-LQP was a Boeing 737 MAX 8 airplane with serial number 43000 LN: 7058 using 2 x CFMI LEAP-1B engines. This airplane was manufactured in 2018 with a certificate of airworthiness issued on August 15, 2018, valid until August 14, 2019. Since its dispatch from the factory, the airplane completed 895 hours and 21 minutes of operation with 443 engine cycles [18].

The airplane served 438 commercial flights for 83 days with 107 flight codes and 36 departure airports. The airplane had made an average of 145 flights per month. This airplane was operated by an Indonesian airline, serving domestic and international passenger flights. PK-LQP was the 10th airplane received by Indonesian Airlines on August 16, 2018. It was part of the historic commitment order made by Lion Air Group for 201 units of 737 MAX airplanes on November 17, 2011 [26], [27]. PK-LQP had an OEM (Original Equipment Manufacturer) amended ADS-B Out type certification, ensuring that the Boeing airplane was compliant with FAA and EASA (European Union Aviation Safety Agency) requirements. The 737 MAX model uses a certified ATC (Air Traffic Control) transponder DO-260B [28].

A flight link map was obtained based on PK-LQP's historical record data of its operation spanning from August 8, 2018, to October 29, 2018. A connection map is a graph of node-airport relationships with geospatially positioned nodes. The relationship between nodes refers to departure and arrival (flow map). Fig. 3 depicts the airport connectivity map that PK-LQP generated. According to the studied data, from the 438 flight records of PK-LQP, 11 international commercial flights have been completed, and 427 flights were domestic flights. In other words, 98.6 percent of this airplane's flights were operated within Indonesian airspace.

After the 438 flight data points have been viewed, the next step is to view each flight data point, which contains timestamps, time, GPS, altitude, speed, and direction. This data was obtained from ADS-B. But before that, it must first be ensured that the quality of the recorded ADS-B signal is good enough.

According to a document from the International Civil Aviation Organization Asia and Pacific Office [29], there are five things that must be taken into account when implementing and operating ADS-B to monitor its performance: The percentage of an airplane with good integrity reports; ADS-B horizontal position accuracy (based on reference sensors); the difference between geometric and barometric altitude; the number of position jumps; and message interval update. In this study, we monitor the performance of ADS-B data based on the message interval update.

ADS-B transmits data signals from an airplane. These data messages are transmitted at intervals of roughly 0.5 seconds and received by compatible ground stations. In particular, ICAO determines the standard for the update of ADS-B airplane parameters, as presented in Tab 1 [29]. Meanwhile, according to Thomas & DiBenedetto [30], the FAA Office of Aviation System Standards (AVN) sets the ADS-B TIS-B (Traffic Information Services-Broadcast) Verification Update Interval to less than 12.1 seconds. This difference does not reduce our enthusiasm for investigating the PK-LQP ADS-B data's quality. As a result, for the purpose of this investigation, we decided to adopt the parameters that have been established by the ICAO because the data update time employs a short range of pauses, which increases the likelihood that the position of the airplane will be identified. Additionally, we have introduced one category, which is known as "out of tier." This category indicates that the ADS-B data that is sent from airplanes and received by the ground station is delayed by more than sixty seconds (1 minute).

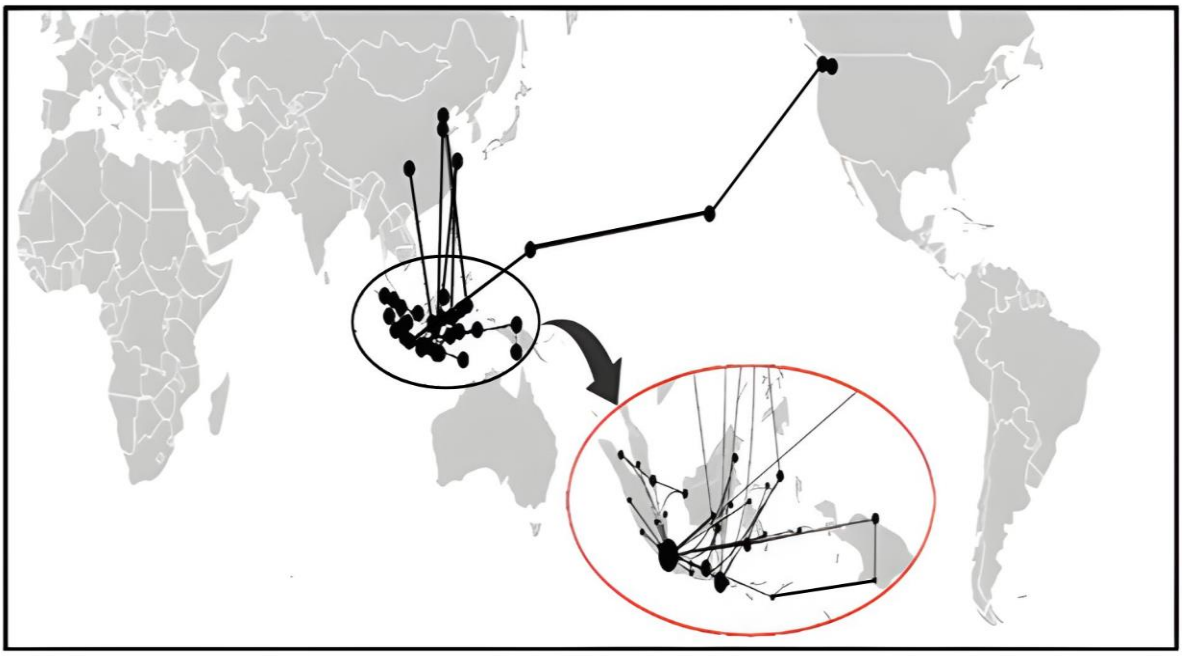


Fig. 3. Historical PK-LQP connection map based on departure and arrival airports covered

Tab. 1

Baseline ADS-B service performance parameter

Parameter	Guidance Interval (x)	Tier 1 Seconds	Tier 2 Seconds	Tier 3 Seconds	Out of Tier Seconds
Airplane updates	Recommended	0.5 < x < 5	0.5 < x < 20	0.5 < x < 60	x > 60
	Maximum	0.5 < x < 10	-	-	-

To evaluate the raw data set (n = 438) as indicated in Fig. 4(A), it is necessary to divide the data into three classes in accordance with the intended method (Fig. 2). We employed the Python programming language to make the process more efficient. As a result, grouping was simpler for us because the flight data point corresponds to the file name data, which already has a unique identifying name. The data point plot was divided into three classes, as indicated in Fig. 4(B), which were then segregated based on the average message update interval data (Tier), resulting in the data visualization depicted in Fig. 4(C). The following phase focuses on the data in class 1, which is then plotted as a histogram. The resulting histogram data are displayed in Fig. 4(D). This is done to display the frequency (number of occurrences) of class 1 data points.

According to the histogram plot of the data in Fig. 4(D), there are 179 flight data in class 1 (41% of the raw data set). When we dig deeper into class 1, we discover that 69 flights, or 39% of the 179 flights, fall into category 1 (tier 1), with an average message data interval update of 0.5 seconds to less than 10 seconds. The entire tier 1 data for these 69 class 1 flights yielded an average value of 9.46 seconds. According to Tab 1, this average value indicates that this data tier 1 is not included in the recommendation guidance but is included in the maximum guidance data for the ADS-B update for airplanes. However, we conclude that these tier 1 data can still be utilized for additional in-depth study. Furthermore, this average number is below the FAA-AVN standard of fewer than 12.1 seconds.

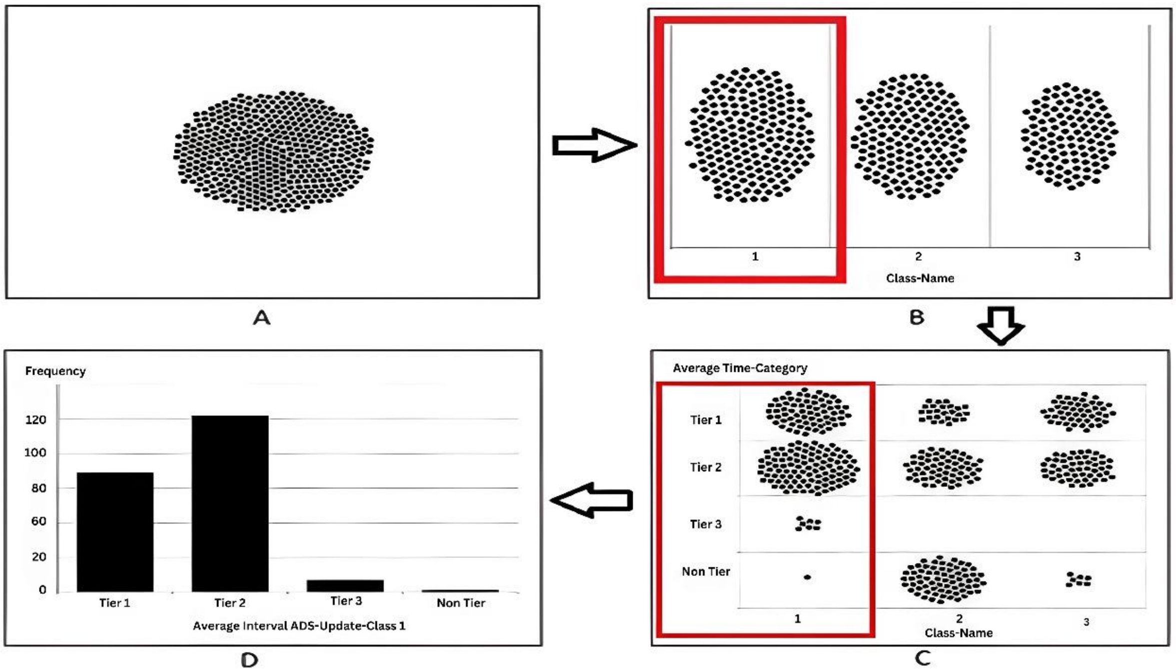


Fig 4. Data processing: analysis of ADS-B insight data from historical PK-LQP flights:
A. Unprocessed Information: the total number of flights recorded (438 flights);
B. Distribution of data points per class for identifying altitude at take-off;
C. Data by class in a histogram graphic for determining take-off starting altitude;
D. Distribution of data points by average level tier (data update interval) and altitude detection class at take-off

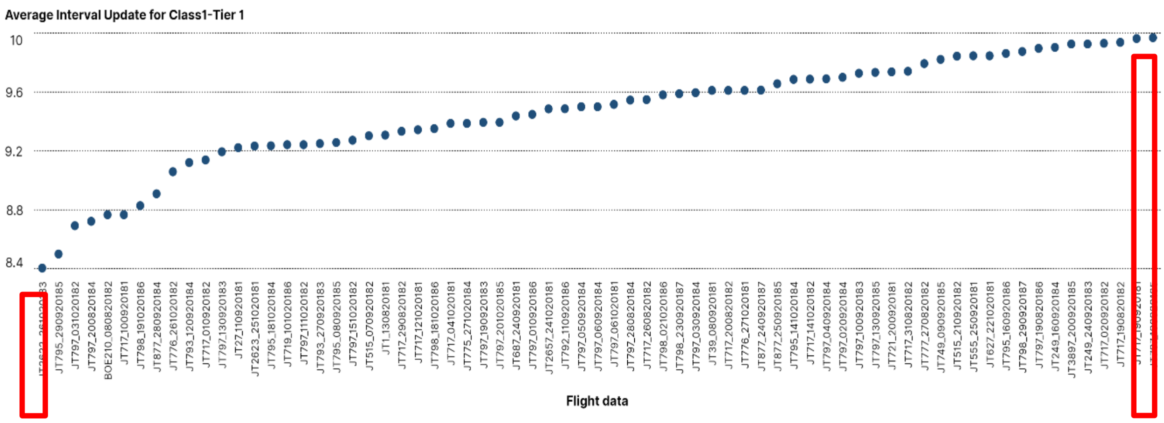


Fig. 5. The distribution data point of class 1 with tier 1 message interval updates according to data flight name

With just 69 flight data points (16%) of the raw data for 438 flights included in tier 1 data, we believe that the ensuing analysis will not be able to detect 100% of the altitude anomalies in the vertical deviations of the PK-LQP airplane, but we believe that the manoeuvring characteristics augmentation system (MCAS) and AoA (angle of attack-sensor) disturbances as reported by KNKT can be discovered in 16% of these data. 16% of this data is therefore spread to illustrate the distribution of the average ADS-B update interval and order from the shortest to the longest average update interval, as shown in Fig. 5

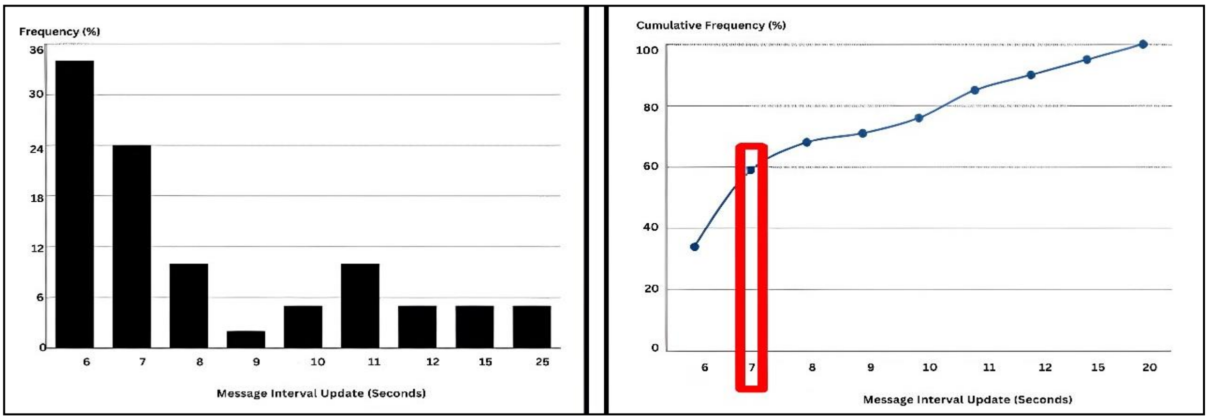


Fig. 6. The data insight of JT2622_261020183: the plot of percentage of frequency versus message interval update and the plot of percentage of cumulative frequency versus message interval update

Fig. 5 depicts a distribution from which we sampled the shortest and longest values. The shortest sample has the minimum average update interval value (JT2622_261020183 with 8.4 seconds), whereas the longest sample has the maximum update interval value (JT797_190920185 with 9.9 seconds). From these two samples, the data is examined in greater detail to determine the quality of the data and to provide the representation of data analysis.

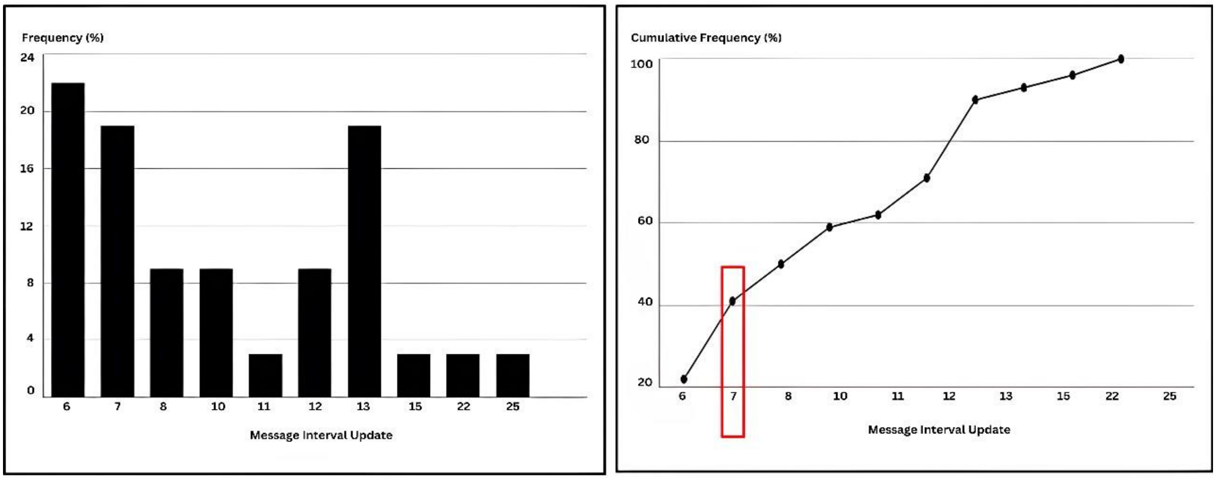


Fig 7. The data insight of JT797_190920185: the plot of percentage of frequency versus message interval update and the plot of percentage of cumulative frequency versus message interval update

The histogram plot (Fig. 6) of the update interval time of the recorded ADS-B messages shows that 34% of JT2622_261020183 of the vertical deviation data is distributed at a 6-second update interval time. Meanwhile, the cumulative frequency distribution shows that airplane PK-LQP contributed 59% of all places claimed to have an update every 7 seconds. According to these explanations and observations, update intervals will be increased in areas with poor reception of airplane ADS-B data. This claim is identical to the one made by Verbraak [31].

If we examine the flight data with the highest data interval in Fig. 7, we can see that the frequency of occurrence of message update intervals for 6 seconds is 22%, while the cumulative frequency distribution shows that 41% of the data is updated every 7 seconds. Therefore, the difference in message interval update duration between JT2622_261020183 and JT797_190920185 for 6 seconds is -12.2% (minus indicates a decrease) from the shortest to the longest span data point in tier 1 at class 1, and the duration of the 7-second update interval message demonstrates a disparity of -18%.

The FAA requires pilots to avoid losing more than 100 feet of altitude during manoeuvres in vertical deviations [32]-[34]. This is because the movement of airplanes, especially commercial airplanes, when taking off and manoeuvring in the air, must maintain the stability of the plane and the passengers it carries. If there is a manoeuvring movement in this position, the airplane loses 100 feet in less than 10 seconds, causing passenger discomfort and air pressure disturbances in the cabin. From the history data of PK-LQP, totalling 438 flights, we focused on class 1 data.

Tab. 2

Flight data for JT43_281020182 from 0 to 10000 feet altitude

Timestamps	**Altitude (feet)**	**Speed (knots)**	**Direction (degree)**	**Altitude gap (feet)**	**Message Interval Update**
1540736503	0	171	87	0	0
1540736509	175	172	87	1	6
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
1540736559	1575	190	90	50	7
1540736580	1350	234	86	-225	21
1540736586	1525	242	86	175	6
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
1540736721	5550	282	88	725	18
1540736742	4850	307	90	-700	21
1540736748	4625	324	90	-225	6
1540736773	5400	303	87	775	25
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
1540736960	9800	335	1	75	6

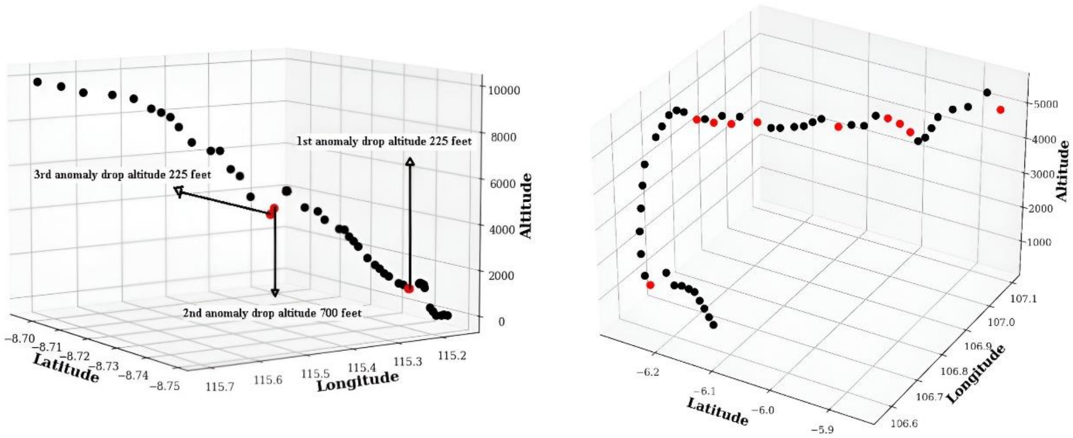
In class 1, which consists of 179 flight data points, there are three tiers of average message interval updates: 69 data points in tier 1, 102 in tier 2, and 8 data points in tier 3. Then, we search for altitude data demonstrating the airplane's altitude loss throughout the vertical deviation (0–10,000 feet) in each tier. In the results obtained, we did not find an altitude drop of more than 100 feet during the vertical deviation phase on 69 flight data in tier 1. While on 102 data flights in tier 2, we found one flight data that experienced an altitude drop, namely flight JT43_281020182. This flight flew from Denpasar (DPS) to Jakarta (CGK) and was the last flight on October 28, 2018. Only 2 flights, namely JT775_281020181 and JT43_281020182, were detected to have been operated on this date according to the PK-LQP data.

In the PK-LQP accident report, it was explained that flight JT775_281020181 was reported by the pilot to have experienced interference with airspeed and altitude indications. When the JT775 airplane landed safely in Denpasar, further action was taken by ground maintenance teams to replace the AoA sensor and conduct an installation test in accordance with the procedure. When the airplane was declared airworthy, it completed flight JT43. On this flight, the airplane successfully landed in Jakarta, but the pilot reported that the airplane had problems with "IAS and ALT Disagree shown after take-off" and "FEEL DIFF PRESS light illuminated." This causes abnormal movement or behaviour of the airplane in vertical deviations. Trace data from this anomaly can be detected with our approach, which found altitude drop data of more than 100 feet, namely 225 feet to 775 feet, at several altitude points. Evidence of an altitude drop is shown in Tab 2. To get a detailed view, we visualized the flight data of JT43_281020182 in 3D, as shown in Fig. 8(A).

As illustrated in Fig 8(A), according to the data, the PK-LQP airplane's altitude first dropped by 225 feet as detected by ADS-B data at the 77th second or about 1 minute 29 seconds after take-off from Denpasar airport. This altitude drop occurred again 162 seconds later at an altitude of 5550 feet. In just 21 seconds, the plane dropped 700 feet. This 3D visualization is based on the data given in Tab 2, which also shows that the airplane lost cruising altitude in a speed position that increased by 25 knots (307 knots to 282 knots), or the equivalent of 12.9 meters per second. Meanwhile, the airplane was not in a turning position because the data shows only a 2-degree change in direction. We believe that the pilot received incorrect information from the onboard data instrumentation about its speed and altitude position, so the pilot attempted to control and reposition the airplane, which resulted in an anomalous movement in the phase vertical deviation. Despite JT43_281020182 flight disturbances based on the data insight and KNKT report, the airplane made a successful landing at the airport in Jakarta (CGK).

After examining the data from class 1 in tiers 1 and 2, the final stage was to examine the information from tier 3. We followed the same procedures on the tier 3 flight data as we did on tier 1 and tier 2 flight data, although we did not discover any substantial altitude loss (more than 100 feet).

For further conviction, we also visualized the data from the day of the accident, that is, October 29, 2018, from the Jakarta to Pangkal Pinang flight with flight code JT610. In our dataset, this flight is stored in the file JT610_291020181.csv, and based on our approach, this data is included in class 2. Since the flight data began to be detected at an altitude of 350 feet with an average ADS-B message update of 12.5 seconds, it is included in tier 2. The JT610 flight visualization image is shown in Fig. 8(B). Based on the results of the 3D plot visualization, flight JT43 experienced only 3 times loss of altitude of more than 100 feet (Fig. 8(A)), while flight JT610 indicated 10 instances of the plane losing more than 100 feet of altitude until the plane fell into the Java Sea (Fig. 8(B)).



JT43_281020181

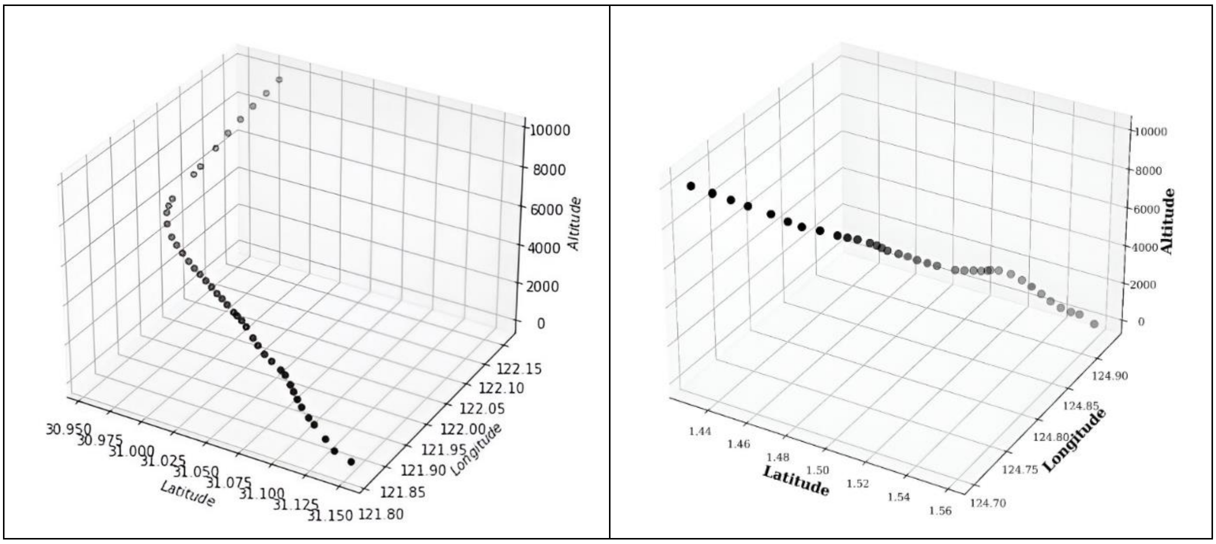
A

JT610_291020181

B

Fig. 8. Data point visualization between two flight concerns:
A. Vertical deviations phase 3D plot for JT43_281020182 data;
B. Vertical deviations phase 3D plot for JT610_291020181 data

To gain more certainty, we performed 2 sample 3D plots for flight data that are in class 1 and are included in the message interval update in tier 1. These two flights are JT775_271020184 and JT877_240920187, as shown in Fig. 9. From these two plots, it is clear that when an airplane makes a vertical deviation, the position of the airplane, which is shown by the detected point, does not lose the predetermined altitude, even if the airplane moves in the direction of flight, which means that its latitude and longitude change.



JT775 JT877

Fig. 9. Sample flight data from Class 1 tier 1 that did not experience an altitude loss of more than 100 feet in the vertical deviation phase

The research's findings demonstrate that ADS-B data can serve as a preliminary analysis for aircraft accidents or as a preventive measure to avoid similar incidents in the future. ADS-B data can be used to analyse an airplane accident or prevent future incidents involving the Boeing B737 MAX 8. This research demonstrates the closeness of ADS-B data to actual events. This validates the studies conducted by [35] that validate ADS-B position data.

The obtained results also demonstrate that accident investigators, during the process of searching for the black box, can analyse flight data during the incident or historical data to identify traces of a system failure influencing changes in altitude, flight direction, or speed. This initial analysis will provide an opening for the accident investigator to understand what happened. However, the final analysis must refer to the voice recorder and other box data. Furthermore, according to the research reported by [36] in his report, the establishment of an obligation for each aircraft to install and turn on the ADS-B transmitter has led to a very significant reduction in accidents by 89%. These findings are in line with the concept of using more ADS-B data for preventive purposes.

4. CONCLUSION

According to the findings of an investigation of the data, the PK-LQP airplane, which is of the type B737 MAX 8, had operated for 83 days, during which it completed 438 flights using a total of 107 flight codes, and it travelled to a total of 36 airports. We categorized these 438 data points into one of the three classes based on the initial altitude detection provided by the ADS-B data. Class 1 contains the most valuable information. The amount of data collected in class 1 is 179 (41%). From the results of the in-depth examination of class 1 data, we found that only 69 (39%) were included in tier 1, which had an ADS-B data update interval message below 10 seconds, complying with ICAO and FAA-AVN standards. While for tier 2, there are 102 (59%) update interval messages below 20 seconds, and the last is tier 3, for below 60 seconds, as many as 8 (4%).

With this class 1 and tier 1 dataset, we conducted an EDA to find the data insight, which revealed that there was a disturbance in the speed and altitude indications on the airplane instrumentation, causing a misperception for the pilot and causing the airplane to drastically drop in altitude (more than 100 feet). The trace of this abnormality should be visible in the ADS-B data record.

As a result, we discovered abnormal data in class 1 data, specifically JT43_281020182. According to ICAO regulations, this data is included in tier 2; however, FAA-AVN includes the JT43 281020182 flight data in its standard (below 12.1 seconds). Thus, this is consistent with the KNKT's conclusions, which allege that on the day before the accident of flight JT43 281020182, there were anomalies in the speed and altitude indicators in the vertical deviations phase based on the pilot's written report.

Aside from flight JT43_281020182, we found no indicators of anomaly detection in class 1 data; however, data in classes 2 and 3 were not evaluated because the stored ADS-B data could not be processed as it did not meet ICAO or FAA-AVN criteria. As a result, we can state that the analysis has a 41% confidence level. This proportion is determined by the amount of data examined, which is the total class 1 data divided by the total number of flights (438).

Based on the findings of this study, we believe that with the improvement in ADS-B technology and the increase in the number of ground station receivers, the message update interval will be reduced, and all flight data will be class 1 and tier 1. If this is done, we think that in the future, ADS-B data, along with data from the FDR on the black box, can be used as a second opinion while investigating an incident involving a commercial airplane.

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