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What ADS-B Data Can Tell Us About HL7525(KAL631) Accident at the CEBU Airport

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Abstract

This research aims to extract useful information from the HL7525 accident ADS-B data archive. The approach used is Exploratory Data Analysis (EDA), which ensures that the ADS-B data quality standards must be met and visualizes the landing position or touchdown, altitude, and speed data, which is then compared with the flight rules for the landing phase. These criteria are based on three important characteristics that ensure the aircraft does not overrun: touchdown point, touchdown speed, and deceleration after touchdown. Data analysis revealed that the stored ADS-B HL7525 data had good data quality, falling within the ICAO standard (tier-1) for 82% of the total data, meaning that this data was 82% representative of the actual environment. In addition, it was found that the aircraft attempted three landings, with the first and second attempts showing the go-around procedure, and the third attempt (the final attempt) landing successfully but ending in an accident. Based on the analysis results, two of the landing criteria were met even though the slope angle exceeded 3^0, and the third criterion was not met because the deceleration process after touchdown was not in accordance with the procedure.

Keywords: ADS-B data; Aircraft Accident; Exploratory data Analysis; HL7525; Landing position

1. Introduction

On October 23, 2022, at 07.30 PM, an Airbus-type Korean Airlines commercial airplane (A333-220) with registration HL7525 and flight code KAL631 took off from Seoul (ICN-South Korea) to Cebu (CEB-Philippines) and experienced an overshot at the Cebu airport on the same date at 11:08 PM. The information reported is that the aircraft suffered substantial aircraft damage, with an aircraft fate status of "written off," but there were no fatalities among the crew or passengers (11 crew and 165 passengers) (Flight safety foundation, 2022). According to the pilot, the problematic touchdown was caused by severe weather, which included heavy rain and thunderstorms (Inso, 2022). An initial data-driven investigation needs to be conducted to better understand and explore this accident. This investigation should use sensor technology to see what happened more clearly and analyze it using this technology in the format of Automatic Dependent Surveillance-Broadcast (ADS-B) data that is prepared and required for all commercial aircraft in 2020 to replace conventional radar (Passarella & Nurmaini, 2022).

1.1. State of the art (SOTA)

Aircraft accident analysis has so far relied solely on blackbox data, where the data stored in the blackbox are FDR (Flight Data Recorder) and CVR (Cockpit Voice Recorder) recordings, where the CVR, which is a recording device designed to be impact-resistant and installed on the aircraft to record crew conversations and radio transmissions, as well as some cockpit sounds (e.g. voice alerts, lever movements). These recordings are at least 30 minutes of closed loop that are continuously recycled, providing a complete audio record of the last 30 minutes (or so) of each flight. The second is the FDR, which is an instrument designed to be 'crash-proof' and installed in the aircraft to continuously record certain operating parameters during flight, such as airspeed, altitude, heading, vertical acceleration, instrument readings, flight control movements and engine performance (Nevile, 2004).

However, this blackbox data has limitations on the ability to record data, such as: there are limitations to the blackbox designed so far, namely if the blackbox is not found within 30 days, then the ultrasonic beam on this tool which is useful for facilitating the search will no longer function. Secondly, the ability to record data for a maximum of 25 hours from the time the aircraft is turned on and will automatically turn off if the aircraft is not turned on. After exceeding this time, the recording will write the previous recording. Third, the voice recorder can store 180 minutes of conversation for CVR devices and 30 minutes for older models. Fourth, in some cases, if the blackbox is damaged, an interface is needed to retrieve the data, and sometimes it takes weeks or months (Kavi Krishna, 2010).

Therefore, with the development of ADS-B technology, research is needed that can be used to ensure that ADS-B data analysis in aircraft accidents can be useful and beneficial to the world of aviation (Passarella, Nurmaini, et al., 2023). Without preceding the official analysis results issued by the official agency that analyzes aircraft accidents, aviation observers can conduct a provisional analysis of an accident event by utilizing ADS-B public data. This is the state of the art (SOTA) of this research.

1.2. ADS-B system

The development of technology by NexGen in the form of ADS-B since 2005 to replace conventional radar, which in its development shows that every year has increased the quality of service very significantly, especially the number of ground stations to help monitor aircraft. More ground stations will improve data quality by shortening the time between ADS-B data update interval messages (FAA, 2020; Richards et al., 2010; Swenson, 2019; System, 2011).

ADS-B performance has been stated to have been better than radar(Zhang et al., 2011). The following study, reported by (Ruseno & Putra, 2021), analyzed the accuracy of aircraft position based on ADS-B data from the flightradar24 website and found good performance, so it was concluded that the flight of commercial aircraft that became the object of research showed that the flight was still following and within the RNP (Required

Navigation Performance) limit as well as research conducted by (Yousnaidi et al., 2023) in developing a machine learning analysis model to predict ADS-B data quality when the aircraft performs take-off and landing phases. While the International Civil Aviation Organization (ICAO) states at point 1.4 of the 40th meeting of the technical commission session on Aviation Safety and Air Navigation Policy that ADS-B provides highly accurate tracking of aircraft anywhere on the earth's surface, the accuracy of aircraft position using ADS-B is known to be equivalent to or better than radar, enabling real-time air traffic separation in many airspaces around the world(Flight Safety Foundation, 2019).

This is evidenced by the ADS-B evaluation study research based on problems that arise in the form of solving asynchronous problems between radar data, ADS-B data, and real-time kinematic (RTK) data caused by differences in update speed. The method is done with a multi-data synchronization technique by extrapolating from data with a low update rate to a high update rate according to speed and direction. The result obtained is that the ADS-B performance is better than radar. Furthermore, unlike a Black Box, ADS-B may keep the flight data of an aircraft without having it to be overwritten (Zhang et al., 2011)

Therefore, we tried to investigate the accident that happened to the aircraft registered HL7525 using ADS-B data. We are trying to get information from the ADS-B data of the last flight of HL7525 that resulted in the accident so that this information will be understood by all of us. In the end, we will get valuable information so that such an accident does not take place again.

The challenge is that the data used is ADS-B data, which is secondary data, not primary (Blackbox), and so, the final result of this analysis still needs to be proven again using the results of the official report of the aviation accident investigation agency. Because the data analysis here only looks for insight data retrieved from ADS-B flightradar24, the limitations of this investigation do not correlate data with natural factors such as weather, wind, and pilot health. For the record, the ADS-B data utilized is real-time and tested. According to Flightradar24's official website (Flightradar24, 2022), they aggregate data from many sources, including ADS-B, MLAT (Multilateration), and radar data. Those source data are coupled with airline and airport schedule and flight status data to offer a unique flight tracking experience at www.flightradar24.com and in the Flightradar24 app. As a result, every 4-5 seconds, all receivers submit ADS-B data. MLAT data is regularly uploaded. Data from all sources is aggregated, and the web and app data streams are refreshed every 8 seconds.

In analyzing the ADS-B data, we also refer to (Stephens A. & Smith M., 2012), who state that there are three major elements that make an aircraft vulnerable to an accident or accident caused by an overrun landing. These three factors are touchdown point, touchdown speed, and after touchdown deceleration. These factors will be used to explore what actually happened based on the ADS-B data. Moreover, this demonstrates to international researchers that NextGen's ADS-B data, developed since 2005, has advanced significantly, enabling its use for both aircraft accident analysis and preventive analysis.

In this paper, we organize the analysis accident as follows: The first part is an introduction that contains general information about what happened to the HL7525 aircraft and ends with the purpose of analyzing its flight ADS-B data. The second section is about how the ADS-B data was retrieved and prepared for use, and also provides an explanation of the methods used in achieving the purpose of the analysis. Apart from that, in this section, general data of CEBU airport is also explained to gain insight into the airport. The third section is the results and discussion. In this section, the findings obtained from the KAL631 ADS-B data will be explained so that data insight is obtained. In the end, the conclusions obtained in the form of data insight will be summarized and described in the conclusion.

2. Material and Method

This section will discuss the ADS-B data sources used and how the data is evaluated so that an estimate of what data can offer information can be made. The EDA and data visualization methods are used to get data insight so that it can be determined whether any landing procedures are violated based on the rules of the marking points, speed, and deceleration of the aircraft during the landing phase on the runway.

2.1 Material

In this section, we will discuss the components that are necessary for doing data analysis, beginning with data availability, runway marking rules, aircraft, and weather information.

2.1.1. Data

The data downloaded from the flightradar24 application site on October 25, 2022, as a csv format file containing ADS-B data for flight KAL631 is obtained, with a total of seven variables, including timestamp, UTC (Coordinated Universal Time), callsign, position, altitude, speed, and direction, while the number of data observations (row) is 1246 and the following data information: data size of 90.8 KB (93,008 bytes) with a created stamp and a modified data stamp dated October 25, 2022. This data file has an auto-generated file name of "KE631_2df2dce6".

Figure 1. Cebu airport touchdown landing zone via both runways 22 and 04.

2.1.2. Runway Marking

In realizing aviation security and safety, markings and signs in the aircraft movement area at the airport are mandatory standards, such as runway markings, runway side strip markings, runway center line markings, aiming point markings, and touchdown zone markings (Flight Safety Foundation, 2021).

The most important thing, in this case, is the touchdown zone of runway 22, where this zone is the one where the ill-fated aircraft made a landing. In the results and discussion section, we will look at the position of the aircraft based on the ADS-B data and determine where the landing point is. Does it meet the requirements or procedures? According to (Stephens A. & Smith M., 2012), the touchdown zone or point is 1/3 of the runway length and is denoted with multiple marks on the runway. The touchdown zone for Cebu airport can be seen in Figure 1.

2.1.3. Aircraft Information

The aircraft, registered HL7525 with manufacture serial number 0219, joined Korean Airlines on June 26, 1998. This means that this aircraft is approximately 24 years old. This aircraft was purchased directly from Airbus at the Toulouse (TLS) production facility. This aircraft uses two Pratt & Whitney PW4168 engines and the ADS-B transmitter used is mode-s code with a standard ICAO 24-bit aircraft address (HEX code: 71BD25)(www.planespotters.net, 2022).

2.1.4. Weather Information

Based on the information obtained (Petchenik, 2022), on the day of the accident the weather at the airport had been bad for a few hours before KAL631 attempted to land. The METAR for the time when KE631 landed and went off the runway showed thunderstorms and low clouds. The wind direction was 220^0 and the wind speed was 9 knots, while the pressure was 1010 hPa and the visibility was 8000 meters.

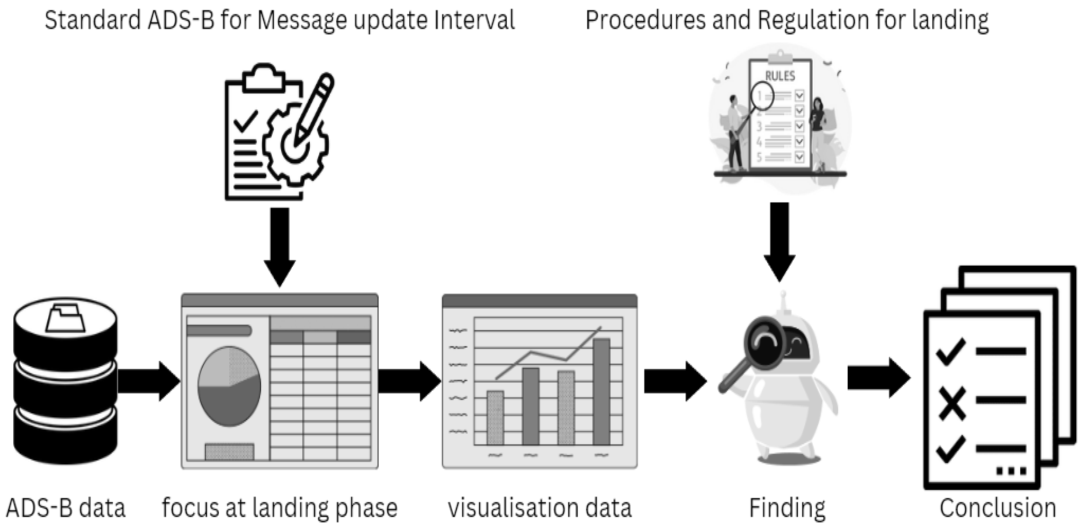


Figure 2**.** The aircraft accident data analysis process used

2.1 Method

In this paper, exploratory data analysis is applied to find the data insight. The process is explained as ADS-B data is checked for quality, referring to ICAO standards. After that, the data is plotted and analyzed to get what percent of the data is included in tier 1 to ensure data quality so that it can provide data insight. The next step is to visualize the landing phase data according to its touchdown position, speed, and altitude. The results are then compared with the procedures and regulations for landing according to the type of aircraft. The process is shown in Figure 2.

The process outlined in Figure 2 centers on the standard ADS-B data for the message update interval segment. Objective analysis relies upon high-quality data, which accurately represents actual events and yields optimized results. Therefore, data quality plays a crucial role in enabling sound decision-making and achieving desirable outcomes.

3. Results and Discussion

In this section, the results obtained using the approach taken will be presented in a structured manner. First, the information about the scene is explained, followed by an explanation of the quality of the data used, and then it goes to the core part, namely, the findings from the first, second, and final or third landing experiments. Furthermore, to clarify the events in the third experiment, we impute data to complete the missing data so that the actual event is obtained. For more details about this, here is a structured explanation.

3.1. Airport Information.

The data at the airport where the accident occurred has the following general information: Magnetic variation: 0.00W with elevation 31 at N100 18'27.1 E1230 58'46.0. Runway information is runway 04-22 with a length of 10827 feet x 148 feet (3300 meters' x 40 meters) of asphalt surface. Runway 22 (225.0) has several supporting facilities for taxiing, take-off, or landing, such as the presence of lighting on the edge, the presence of an approach lighting system (ALS), the presence of an indicator line (Centreline), and the presence of runway end identifier lights (REIL). Runway 22 has a stop way distance of 194 feet (59.13 meters) at the end of the runway.

3.2. Data Quality.

The observation data will be verified for quality using the ADS-B message update interval value as defined by the ICAO standard(ICAO ASIA and Pacific Office, 2021), with the message update interval being considered to have met the quality if the update value is less than 10 seconds(Yousnaidi et al., 2023). Data that falls into this group is termed as Tier 1. Tier division details for ADS-B message update interval data are shown in Table 1.

As for the amount of data included in the tier 1 category, there are 1023 observations, or 82% of the total data (1426 observations), with an average update interval of 4.26 seconds, while the standard error of the data is 0.05 This value has the meaning that the smaller the standard error, the more representative the sample of the entire population in tier 1 is. In addition, this tier 1 data has a positive skewness value of 0.679, which means that the data distribution is more on the left, while the tail of the data distribution is on the right. Thus, "Mode" will be the midpoint of the data as the mode value obtained is three seconds. This preliminary data analysis procedure is a statistical description procedure used to get a fundamental understanding of the data (Passarella, Veny, et al., 2023). Details of the distribution data are shown in Figure 3.

Table 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 Maximum	0.5 < x < 5 0.5 < x < 10	0.5 < x < 20	0.5 < x < 60	x > 60

The second step is to visualize the data by plotting the altitude and speed data (Figure 4). The plotting results show that the flight altitude is in accordance with the flight phase set for commercial flights. Based on the data visualization as shown in Figure 4(A), it can be seen that the aircraft attempted three landing attempts, with the first and second showing the go-around procedure, while in the third attempt (Final attempt) the landing was successful but ended in tragedy.

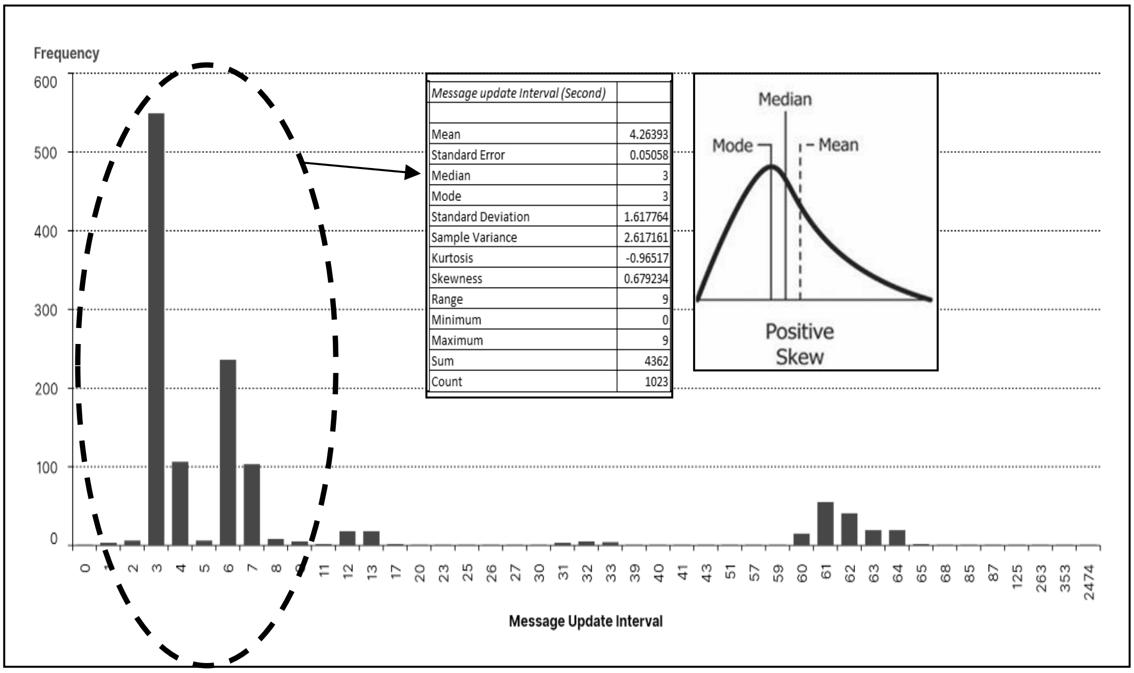


Figure 3**.** Histogram of historical data ADS-B frequency based on message update interval with descriptive statistic

Meanwhile, if you look at Figure 4(B), you can see the speed of the aircraft at touchdown, which is approximately between 100-150 knots. According to the provisions of aircraft maneuvers set by ICAO to make a landing (ICAO, 2018), there are limits to the safety and security of the speed range referring to the aircraft category. For example, the A333 is included in category "C" (typical airline jet) with a range speed of 121 to 140 knots and a distance minimum runway of 5577.42 feet (AIRBUS, 2020; SKYBRARY, 2021).

Therefore, to see more details of these three landing attempts, which we refer to as the first attempt, second attempt, and final attempt, an exploration of 16 data points from each attempt has been conducted and visualized as shown in Figure 5.

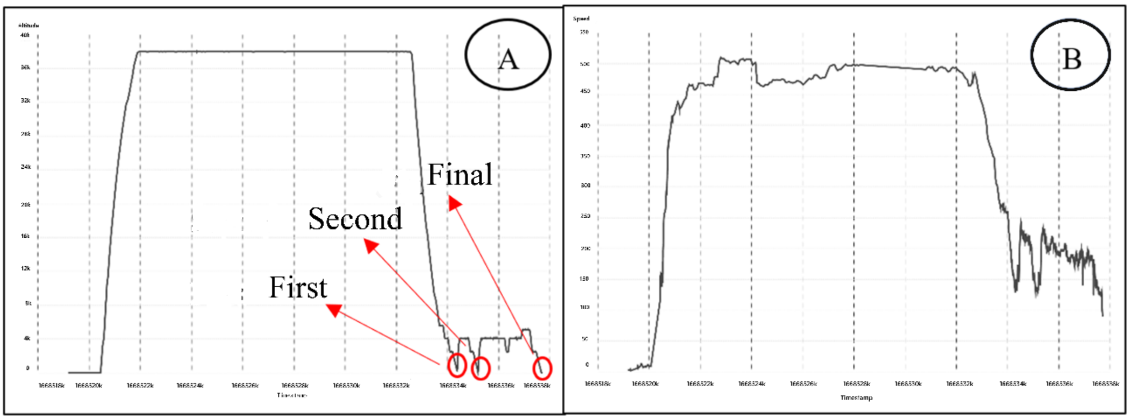
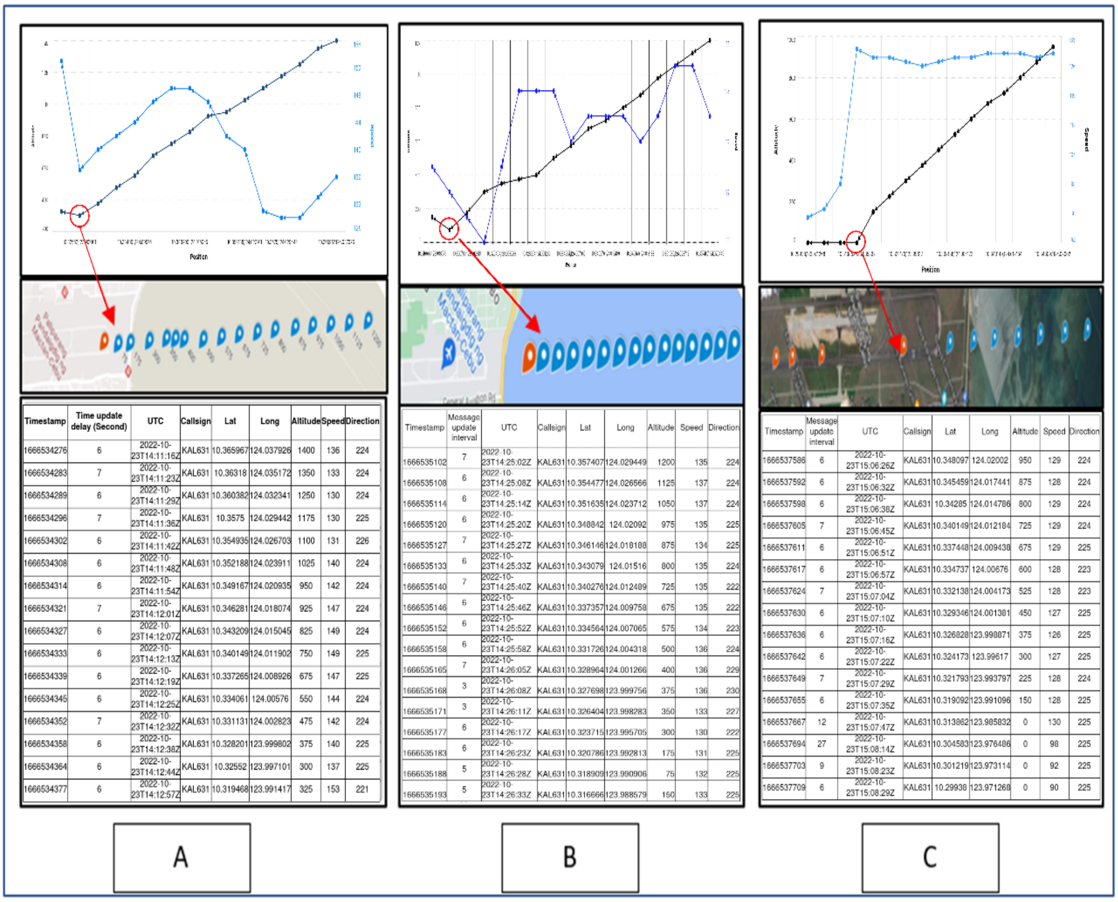


Figure 4. Line plot of aircraft HL7525 data based on ADS-B altitude (A) and speed (B) data



Timestamp	Time update delay (Second)	UTC	Callsign	Lat	Long	Altitude	Speed	Direction
1666534276	6	2022-10-23T14:11:16Z	KAL631	10.365967	124.037926	1400	136	224
1666534283	7	2022-10-23T14:11:23Z	KAL631	10.36318	124.035172	1350	133	224
1666534289	6	2022-10-23T14:11:29Z	KAL631	10.360382	124.032341	1250	130	224
1666534296	7	2022-10-23T14:11:36Z	KAL631	10.3575	124.029442	1175	130	225
1666534302	6	2022-10-23T14:11:42Z	KAL631	10.354935	124.026703	1100	131	226
1666534308	6	2022-10-23T14:11:48Z	KAL631	10.352188	124.023911	1025	140	224
1666534314	6	2022-10-23T14:11:54Z	KAL631	10.349167	124.020935	950	142	224
1666534321	7	2022-10-23T14:12:01Z	KAL631	10.346281	124.018074	925	147	224
1666534327	6	2022-10-23T14:12:07Z	KAL631	10.343209	124.015045	825	149	224
1666534333	6	2022-10-23T14:12:13Z	KAL631	10.340149	124.011902	750	149	225
1666534339	6	2022-10-23T14:12:19Z	KAL631	10.337265	124.008926	675	147	225
1666534345	6	2022-10-23T14:12:25Z	KAL631	10.334061	124.00576	550	144	224
1666534352	7	2022-10-23T14:12:32Z	KAL631	10.331131	124.002823	475	142	224
1666534358	6	2022-10-23T14:12:38Z	KAL631	10.328201	123.999802	375	140	225
1666534364	6	2022-10-23T14:12:44Z	KAL631	10.32552	123.997101	300	137	225
1666534377	6	2022-10-23T14:12:57Z	KAL631	10.319468	123.991417	325	153	221

Timestamp	Message update interval	UTC	Callsign	Lat	Long	Altitude	Speed	Direction
1666535102	7	2022-10-23T14:25:02Z	KAL631	10.357407	124.029449	1200	135	224
1666535108	6	2022-10-23T14:25:08Z	KAL631	10.354477	124.026566	1125	137	224
1666535114	6	2022-10-23T14:25:14Z	KAL631	10.351635	124.023712	1050	137	224
1666535120	6	2022-10-23T14:25:20Z	KAL631	10.348842	124.02092	975	135	225
1666535127	7	2022-10-23T14:25:27Z	KAL631	10.346146	124.018188	875	134	225
1666535133	6	2022-10-23T14:25:33Z	KAL631	10.343079	124.01516	800	135	224
1666535140	7	2022-10-23T14:25:40Z	KAL631	10.340276	124.012489	725	135	222
1666535146	6	2022-10-23T14:25:46Z	KAL631	10.337357	124.009758	675	135	222
1666535152	6	2022-10-23T14:25:52Z	KAL631	10.334564	124.007065	575	134	223
1666535158	6	2022-10-23T14:25:58Z	KAL631	10.331726	124.004318	500	136	224
1666535165	7	2022-10-23T14:26:05Z	KAL631	10.328964	124.001266	400	136	229
1666535168	3	2022-10-23T14:26:08Z	KAL631	10.327698	123.999756	375	136	230
1666535171	3	2022-10-23T14:26:11Z	KAL631	10.326404	123.998283	350	133	227
1666535177	6	2022-10-23T14:26:17Z	KAL631	10.323715	123.995705	300	130	222
1666535183	6	2022-10-23T14:26:23Z	KAL631	10.320786	123.992813	175	131	225
1666535188	5	2022-10-23T14:26:28Z	KAL631	10.318909	123.990906	75	132	225
1666535193	5	2022-10-23T14:26:33Z	KAL631	10.316666	123.988579	150	133	225

Timestamp	Message update interval	UTC	Callsign	Lat	Long	Altitude	Speed	Direction
1666537586	6	2022-10-23T15:06:26Z	KAL631	10.348097	124.02002	950	129	224
1666537592	6	2022-10-23T15:06:32Z	KAL631	10.345459	124.017441	875	128	224
1666537598	6	2022-10-23T15:06:38Z	KAL631	10.34285	124.014786	800	129	224
1666537605	7	2022-10-23T15:06:45Z	KAL631	10.340149	124.012184	725	129	224
1666537611	6	2022-10-23T15:06:51Z	KAL631	10.337448	124.009438	675	129	225
1666537617	6	2022-10-23T15:06:57Z	KAL631	10.334737	124.00676	600	128	223
1666537624	7	2022-10-23T15:07:04Z	KAL631	10.332138	124.004173	525	128	223
1666537630	6	2022-10-23T15:07:10Z	KAL631	10.329346	124.001381	450	127	225
1666537636	6	2022-10-23T15:07:16Z	KAL631	10.326828	123.998871	375	126	225
1666537642	6	2022-10-23T15:07:22Z	KAL631	10.324173	123.99617	300	127	225
1666537649	7	2022-10-23T15:07:29Z	KAL631	10.321793	123.993797	225	128	224
1666537655	6	2022-10-23T15:07:35Z	KAL631	10.319092	123.991096	150	128	225
1666537667	12	2022-10-23T15:07:47Z	KAL631	10.313862	123.985832	0	130	225
1666537694	27	2022-10-23T15:08:14Z	KAL631	10.304583	123.976486	0	98	225
1666537703	9	2022-10-23T15:08:23Z	KAL631	10.301219	123.973114	0	92	225
1666537709	6	2022-10-23T15:08:29Z	KAL631	10.29938	123.971268	0	90	225

Figure 5. Data visualization (A) First attempt; (B) Second attempt; (C) Final attempt.

3.3. Finding: First Attempt

After flying for 13,931 seconds (3 hours 54 minutes) from Seoul airport, KAL631 attempted its first landing at the Cebu airport. To analyze the landing activity data, we took 16 data points during the landing process, in which at the 16th data point, the aircraft performed a go-around procedure. Based on the 16 data points before landing (Figure 5(A)), from the analysis data, the average speed of change is 140 knots, with the average altitude change of each data point being 78 feet. All data points are included in the tier 1 category with an average message update interval of 6.3 seconds. This shows that the ADS-B data for the first attempt has good data quality even though, in realization, the weather at that time was stated to be thunderstorms and low clouds (Petchenik, 2022; Polek, 2022).

To see whether the aircraft is preparing for landing with a slope that matches the landing angle set by (Airbus et al., 2017), it is necessary to perform calculations., Thus, based on the ADS-B data, we already have the altitude and position (latitude and longitude) for each data point. Furthermore, the base of runway 22 has a known GPS point. Using the haversine formula (Robusto, 1957; Williams, n.d.) as in equation (1),

$$d = 2r\, arcsin\sqrt{sin^2\left(\frac{\emptyset_2-\emptyset_1}{2}\right) + cos(\emptyset_1)\,.\,cos(\emptyset_2).\,sin^2\left(\frac{\gamma_2-\gamma_1}{2}\right)} \quad \ldots\ldots\ldots..(1)$$

The symbol r is the earth's radius (6371 km), and $\emptyset$ and γ are the latitude and longitude, respectively. The degree will convert into radians as 1 degree equals 0.0174532925 radians.

In the first attempt, we calculate the ground distance between two GPS points on the aircraft and the base of the runway for each data point. The next step is to calculate the resultant or sloping side so that the value is obtained using the Pythagorean theorem as in equation (2):

$$R = \sqrt{y^2 + x^2} \ldots\ldots\ldots\ldots\ldots..(2)$$

Where R is the resultant or sloping side, y is the elevation (altitude in meters), and x is the ground distance (meters).

The last step is to calculate the angle using equation (3).

$$\partial = \sin^{-1}\left(\frac{y}{x}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Where ∂ is the angle in degrees. All calculation results are tabulated as shown in Table 2, and an illustration of the approach to getting the slope can be seen in Figure 6.

According to Table 2, the aircraft had a speed of 137 knots before deciding to do the go-around process, as well as an altitude of less than 300 feet. However, the resulting slope, which should have been 3^0, did not match the procedure, instead, the data gave 4.63^0, a difference of 1.63^0. So, it made sense that the pilot decided to perform the go-around procedure.

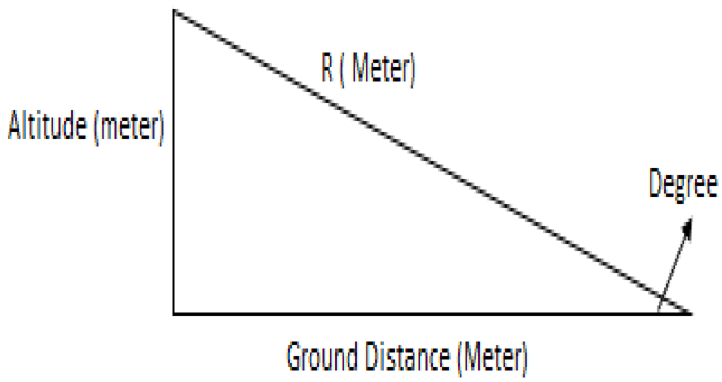


Figure 6. Illustration to obtain landing slope based on altitude and distance calculation between aircraft position and runway

Table 2. ADS-B data point first attempt tabulation to calculate landing slope.

Latitude (ADS-B)	*Longitude (ADS-B)*	*Latitude Runway 22*	*Longitude Runway 22*	*Speed knots*	*Altitude (Feet)*	*Altitude (Meter)*	*Ground Distance*	*R (Meter)*	*Angle (Degree)*
10.365967	124.037926	10.3181267	123.9900396	136	1400	426.72	7465.71	7477.90	3.27
10.36318	124.035172			133	1350	411.48	7033.54	7045.57	3.34
10.360382	124.032341			130	1250	381	6594.59	6605.59	3.31
10.3575	124.029442			130	1175	358.14	6143.76	6154.19	3.33
10.354935	124.026703			131	1100	335.28	5730.34	5740.14	3.34
10.352188	124.023911			140	1025	312.42	5298.42	5307.63	3.37
10.349167	124.020935			142	950	289.56	4830.65	4839.33	3.43
10.346281	124.018074			147	925	281.94	4382.41	4391.47	3.68
10.343209	124.015045			149	825	251.46	3906.53	3914.62	3.68
10.340149	124.011902			149	750	228.6	3422.88	3430.51	3.82
10.337265	124.008926			147	675	205.74	2966.02	2973.14	3.96
10.334061	124.00576			144	550	167.64	2469.15	2474.84	3.88
10.331131	124.002823			142	475	144.78	2011.61	2016.81	4.11
10.328201	123.999802			140	375	114.3	1547.71	1551.92	4.22
10.32552	123.997101			137	300	91.44	1128.08	1131.78	4.63
10.319468	123.991417			153	325	99.06	212.01	234.014	25.04

3.4. Finding: Second Attempt

The second attempt took place 817 seconds (or 13.6 minutes) after the first failed attempt (go-around). Figure 5(B) depicts the detailed ADS-B data and data visualization during the second landing attempt. The second attempt process experienced a decrease in altitude of an average of 75 feet per data point within 93 seconds with an average speed of 134 knots and had ADS-B data quality included in Tier 1 with an average message update interval of 5.8 seconds. This means that the data from the second attempt was the same as that of the first attempt.

Next, we need to calculate the landing slope just like the first attempt. We got the tabulated results as shown in Table 3. Based on this tabulated data, the aircraft was only 128 meters away from the landing zone starting point with an altitude and speed of only 75 feet (22.86 meters) and 132 knots, but the slope angle was very large at 10.23^0. Finally, the pilot decided to perform the go-around procedure for the second time by increasing both the speed and altitude. Based on the ADS-B data in Table 3 for this second attempt landing process, it appears that the pilot had made the right decision.

Table 3. ADS-B data point second attempt tabulation to calculate landing slope.

Latitude (ADS-B)	*Longitude (ADS-B)*	*Latitude Runway 22*	*Longitude Runway 22*	*Speed knots*	*Altitude (Feet)*	*Altitude (Meter)*	*Ground Distance*	*R (Meter)*	*Angle (Degree)*
10.354477	124.02657			137	1125	342.91	5683.53	5693.87	3.45
10.351635	124.02371			137	1050	320.04	5239.32	5249.08	3.50
10.348842	124.02092			135	975	297.18	4803.75	4812.93	3.54
10.346146	124.01819			134	875	266.71	4380.46	4388.57	3.49
10.343079	124.01516			135	800	243.84	3905.07	3912.67	3.57
10.340276	124.01249			135	725	220.98	3478.04	3485.05	3.64
10.337357	124.00976			135	675	205.74	3037.31	3044.27	3.88
10.334564	124.00707	10.318127	123.99004	134	575	175.26	2609.49	2615.37	3.85
10.331726	124.00432			136	500	152.41	2174.03	2179.37	4.01
10.328964	124.00127			136	400	121.92	1720.58	1724.89	4.06
10.327698	123.99976			136	375	114.31	1504.16	1508.49	4.35
10.326404	123.99828			133	350	106.68	1288.54	1292.95	4.74
10.323715	123.99571			130	300	91.44	877.63	882.38	5.98
10.320786	123.99281			131	175	53.34	423.66	427.01	7.23
10.318909	123.99091			132	75	22.86	128.64	130.66	10.23
10.316666	123.98858			133	150	45.72	227.84	232.38	11.57

3.5. Finding: Final Attempt

Based on the data, in this final attempt, it was found that the ADS-B message interval update quality before landing had an average value of 6.25 seconds, which means it was included in Tier-1, and after landing until the accident occurred, the message interval update quality changed to Tier-2, which was an average of 12 seconds. In addition, the average altitude loss until the aircraft touched the runway was 79 feet with an average speed of 128 feet.

Table 4. ADS-B data point final attempt tabulation to calculate landing slope.

Latitude (ADS-B)	*Longitude (ADS-B)*	*Latitude Runway 22*	*Longitude Runway 22*	*Speed*	*Altitude (Feet)*	*Altitude (Meter)*	*Ground Distance*	*R (Meter)*	*Angle (Degree)*
10.3481	124.02002			129	950	289.56	4675.64	4684.59	3.55
10.34546	124.017441			128	875	266.7	4268.69	4277.02	3.58
10.34285	124.014786			129	800	243.84	3858.21	3865.91	3.62
10.34015	124.012184			129	725	220.98	3444.52	3451.59	3.67
10.33745	124.009438			129	675	205.74	3019.74	3026.74	3.91
10.33474	124.00676			128	600	182.88	2599.42	2605.84	4.03
10.33214	124.004173			128	525	160.02	2194.94	2200.76	4.18
10.32935	124.001381	10.31813	123.99	127	450	137.16	1759.44	1764.78	4.47
10.32683	123.998871			126	375	114.3	1367.29	1372.06	4.79
10.32417	123.99617			127	300	91.44	949.61	954.01	5.52
10.32179	123.993797			128	225	68.58	578.92	582.97	6.81
10.31909	123.991096			128	150	45.72	157.72	164.21	16.85
10.31386	123.985832			130	0	0	660.87	0	0
10.30458	123.976486			98	0	0	2113.42	0	0
10.30122	123.973114			92	0	0	2638.78	0	0
10.29938	123.971268			90	0	0	2926.19	0	0

When looking at the detected landing point, the distance obtained is 2178.48 feet (664 meters) from the base point of runway 22, or the aircraft has used 20% of the runway at a speed of 130 knots. Based on this data and referring to (AIRBUS, 2020; Eurocontrol, 2020; ICAO, 2018; SKYBRARY, 2021), it can be concluded that aircraft landed in the touchdown zone.

Using the same approach as in the first and second attempts, we calculated the slope angle of the aircraft during the final attempt as shown in Table 4. In Table 4, it can be seen that when the last ADS-B data was used to make a landing, the aircraft speed was in accordance with the Airbus and ICAO recommendations of 128 knots, but the landing slope angle was very large at 16.8^0, having a 13.8^0 difference due to the optimum slope angle (3^0) (Airbus et al., 2017; ICAO, 2018). This can cause hard landings (Airbus et al., 2017).

Based on (Stephens A. & Smith M., 2012) when the aircraft has landed in the touchdown zone, as shown in Figure 5(C) and is in the process of deceleration at the time of passing 1/3 of the runway (touchdown zone), the safest aircraft speed must be less than or equal to 80 knots, and the remaining runway to be travelled should be 2/3. Table 4 also reveals that the updated ADS-B data showed that the aircraft had used 88.67% of the runway at a speed that was still 90 knots within 54 seconds of touchdown. The data also shows that the decrease in aircraft speed from 130 to 90 knots over 54 seconds gives a speed decrease of 1.67 knots per second.

3.6. Data Improvement (for Final Attempt)

The data used in the final attempt has several missing values (especially ADS-B data on the runway), so it is necessary to carry out the imputation process (Piyushimita, 2010). The imputation method used in this study is linear regression due to the characteristic of a time-series dataset where each value in the attribute is dependent on the previous value. In order to impute the missing value that occurred in the dataset, the linear regression model uses the previous data points to predict the missing value. By using the linear regression method, the integrity of the data can be maintained, and hence, it can provide useful information in the analysis process. The result from the imputation process is shown in Figure 7.

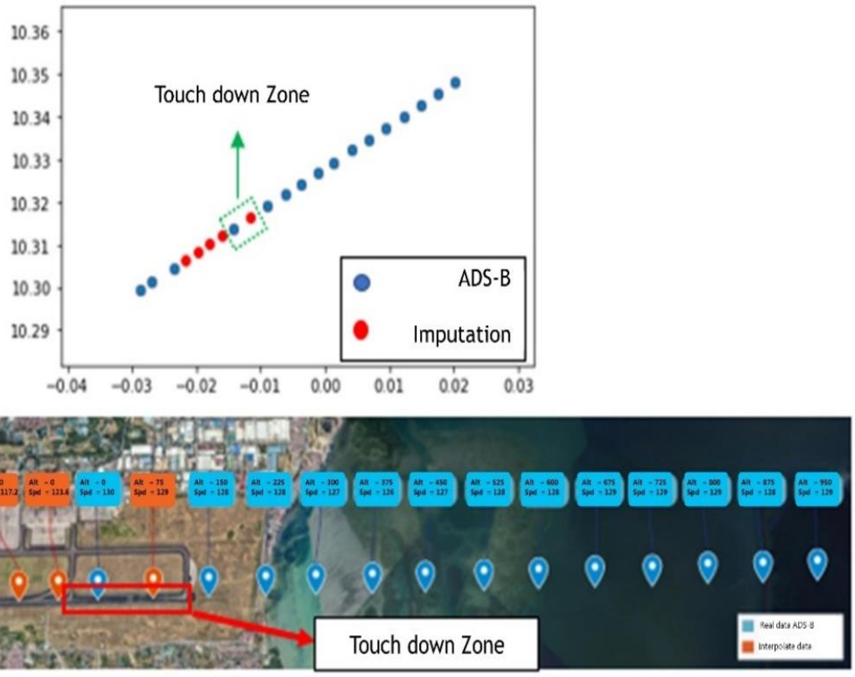


Figure 7. The plotting of the final attempt data with Imputation process

At the end of the analysis, we came to a conclusion and tabulated it in Table 5, which follows three parameters in analyzing accidents that can result in overrun or overshoot (Stephens A. & Smith M., 2012).

Table 5. The summary of data insight from ADS-B data of the aircraft accident with registration code HL7525.

Critical point	Regulation	ADS-B value	Results
Touchdown point	*TDZ*	*TDZ*	*Compliant*
Touchdown speed	*121-140 Knots*	*130 knots*	*Compliant*
After-touchdown deceleration	*Less than 80 Knots*	*90-123 knots*	*Not Compliant*

4. Conclusion

With the mandatory use of ADS-B for all commercial aircraft, preliminary analysis can be done without having to wait for Black Box analysis. This is done to see what actually happened based on timestamp, position, altitude, speed, and direction data. The accident that happened to the commercial aircraft with register HL7525 is interesting to analyze using ADS-B data. Based on the investigation, we found that 82% of the ADS-B history data falls under ICAO Standard Tier 1, so the analysis results will have that level of confidence as well. The results of the insight data obtained based on the three critical parameters in ensuring the aircraft does not experience overrun, namely touchdown point, touchdown speed, and after touchdown deceleration, show the results of the HL 7525 aircraft giving one critical point that fails to be fulfilled, namely "after touchdown deceleration". The speed of the aircraft decreases slowly, which could be due to aircraft mechanics or aquaplaning (hydroplaning), therefore field investigations need to be carried out.

In addition, the approach taken in this analysis shows that the quality of the data referring to ICAO standards has been very helpful in providing a factual picture of the accident events that occurred in the data analysis.

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Rossi Passarella: Conceptualization, Methodology, Investigation, Writing- Original draft preparation. *Siti Nurmaini*: Supervision, Reviewing Data curation, Validation. *Muhammad Naufal Rachmatullah*: Visualization, Investigation, Software. *Harumi Veny*: Data Curation, Reviewing and Editing, Formal analysis