# Simulation of the Tanjung Kupang Air Crash

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**Abstract:** The air crash at Tanjung Kupang, Johor on the 4th December 1977 was the first air accident for the Malaysia Airlines (MAS) and the worst for Malaysia. A Boeing 737-200 with 100 passengers and crews was hijacked before it crashed. Evidences from the accident pointed to an interference of hijackers to the aircraft flight operation. Simulating the accident helped investigators to understand the probable cause of the accident. The Trajectory Reconstruction Method was used to obtain necessary data for the accident simulation. Result from the simulation indicated that the ill-fated aircraft experienced three steep pitch-down pitch-up movements before it stalled and crashed.
**Keyword**: Air accident simulation, Trajectory Reconstruction Method.

## History of the Flight

On the 4th of December 1977, the Malaysia Airlines (MAS) flight MH653 departed from the Runway 22 of the Penang Airport at 1921 hrs local time for the Subang International Airport in Kuala Lumpur. With 93 passengers and 7 crews onboard, the aircraft commanded by Captain G.K. Ganjoor, flew uneventfully to Kuala Lumpur. Among the passengers are a minister and an ambassador. At 1946 hrs, the captain reported to the Subang International Airport Control Tower and was given permission to land. The aircraft was then vectored to Runway 33 of the Subang International Airport. Two minutes later, the pilots overshot the runway and reported an emergency to a trailing aircraft. At approximately 1950 hrs, the pilots reported to the control tower that the aircraft was cruising at 3,000 feet over Kuala Lumpur airspace with hijackers on board. The pilots were given permission to land at the Subang International Airport by the control tower but responded that they were heading to Singapore International Airport.

Flight MH653 was permitted to fly to Singapore at cruising altitude of 21,000 feet, following the flight route shown in Figure 1.

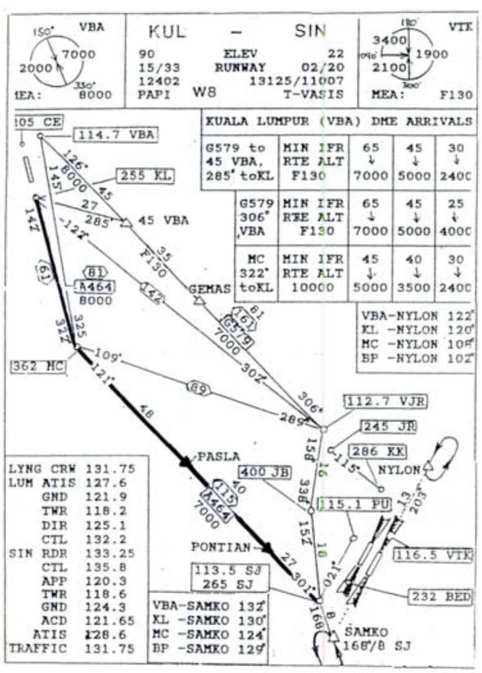


**Fig. 1: Flight Route to the Singapore International Airport [1]**

At 2005 hrs, the aircraft was allowed to descend to 11,000 feet by the Singapore Air Traffic Control. Later at 2012 hrs, the aircraft was directed to descend to an altitude of 7,000 feet for approaching the Singapore International Airport. At 2015 hrs, all communication with the aircraft was lost. Around 2030 hrs, residents of Kampong Ladang in Tanjung Kupang, Johor reported hearing explosions and seeing burning wreckage of flight MH653 in a swamp. No one on board survived the crash.

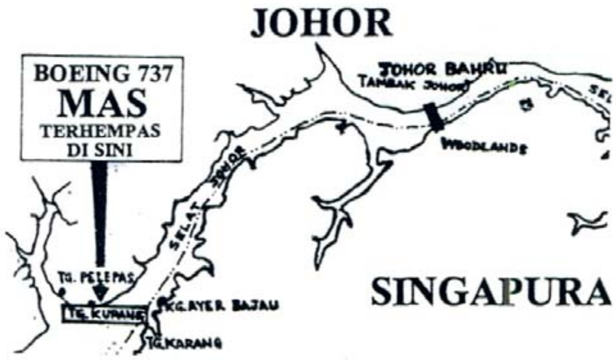


**Fig. 2: Crash Location [2]**

The ill-fated aircraft was a Boeing 737-2H6/Adv with registration number 9M-MBD. The aircraft maximum takeoff weight was 514kN with 91kN of fuel. It was equipped with two Pratt & Whitney JT8D-15 turbofan engines and can fly for 2,400 nm.

**Fig. 3: The ill-fated aircraft 9M-MBD [3]**

The air crash was the first and the worst air crash suffered by the airline. Flight data recorder (FDR) and cockpit voice recorder (CVR) were recovered and analyzed by the Boeing Airplane Company. Results from the FDR and CVR indicated that there was commotion in the cockpit and the aircraft experienced three rapid pitch-down and pitch-up in the final seconds of the flight, suggesting that someone was pulling and pushing the control column [4]. It was believed that security personnel onboard the aircraft were trying to regain the control of the aircraft.

## Methodology

Air crash simulation is a valuable tool in air crash investigation. Using simulation software, an air crash can be reconstructed and visualized using FDR and CVR data. The International Civil Aviation Organization (ICAO) accepts the use of mathematical analysis in investigating air crash. Such an early analysis in the investigation may assist investigator to determine area for specific examination [5]. This will help investigators to find the probable cause of the air crash. The flow chart of the simulation process is shown in Figure 4.

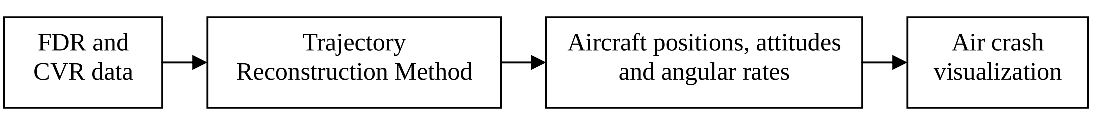


**Fig. 4: Simulation Flow chart**

Since an aircraft has six-degrees of freedom, its positions (x, y, z), accelerations ($V_x$, $V_y$, Vz), attitudes (θ, ϕ, ψ) and angular rates (p, q, r) must known prior to the simulation. Using the Trajectory Reconstruction Method [6], the required data are derived from the FDR and CVR data. The method was developed by Boeing Company and later refined by the University of Dayton Research Institute. It solves the aircraft six-degrees of freedom equations of motion in the initial frame of reference using FDR data as direct input and involves more realistic assumptions. Its numerical technique utilizes iteration, which allows incorporation of more data.

Accuracy of the results from this method depends on the number of iterations. Generally, the smaller the iteration interval *dt*, the more accurate the answer is. But smaller interval imposes more computer run-time and memory. An interval of 0.02 seconds however is sufficed to give an accurate answer [7].

The FDR and CVR data obtained from the official report of the accident are the load factor n, roll angle ϕ, thrust $F_T$, forward acceleration $A_x$, pitch angle θ, pressure altitude H and rate of climb $V_z$ with respect to time [8]. The true airspeed and the climb angle are determined using equation (1) and equation (2), respectively.

$$V_a = \int_{t_1}^{t_{i+1}} A_x \cdot dt \tag{1}$$

$$\gamma = \sin^{-1}\left(\frac{V_z}{V_a}\right) \tag{2}$$

The velocity in x and y directions are determined using equation (3) and equation (4), respectively.

$$V_x = V_a \cdot \cos\psi \cdot \cos\gamma \tag{3}$$

$$V_y = V_a \cdot \sin\psi \cdot \cos\gamma \tag{4}$$

where ψ is the heading angle and is assumed to be zero in the initial condition.

Thus, using equation (3) and equation (4), the x, y and z locations with respect to an initial frame are obtained.

$$x = \int_{t_i}^{t_{i+1}} V_x \cdot dt \tag{5}$$

$$y = \int_{t_i}^{t_{i+1}} V_y \cdot dt \tag{6}$$

$$z = \int_{t_i}^{t_{i+1}} V_z \cdot dt \tag{7}$$

The body angular rates are determined through the following equations.

$$p = \dot{\phi} - \dot{\varphi} \sin\vartheta \tag{8}$$

$$q = \dot{\theta}\cos\phi + \dot{\varphi}\cos\theta \cdot \sin\phi \tag{9}$$

$$r = \dot{\varphi}\cos\theta \cdot \cos\phi - \dot{\theta}\sin\phi \tag{10}$$

The reduction of the aircraft weight due to the burning of fuel is calculated using equation (11).

$$W_{i+1} = \int_{t_i}^{t_{i+1}} -sfc \cdot F_T \cdot dt + W_i \tag{11}$$

The initial weight $W_i$ of the aircraft for the simulation was 353kN with specific fuel consumption *sfc* of 17.05 x $10^{-6}$ kg/Ns.

The author and his team developed two computer programs. The first computer program generated the required data for visualization of the cockpit instruments and the aircraft orientation with respect to the horizon. It allows air crash investigators to be inside the cockpit of the ill-fated aircraft and understand what had happened.


**Fig. 5: Cockpit instrument visualization**

The second computer program shows the aircraft attitudes in three-dimension. The attitudes are used to confirm eyewitness reports.

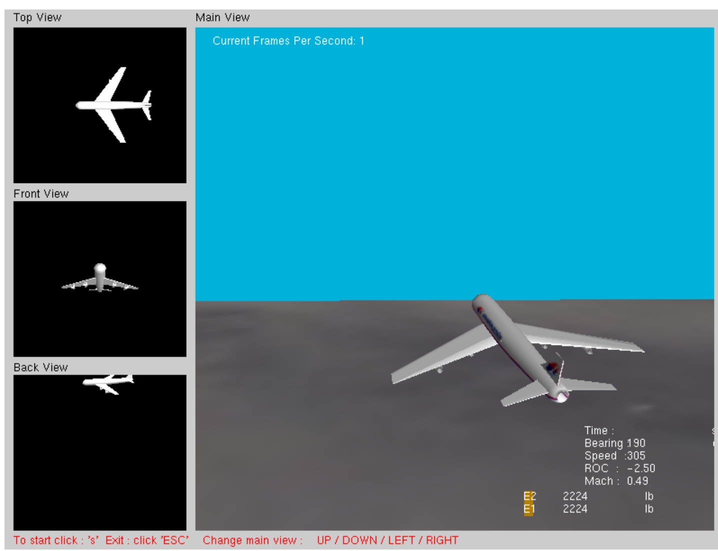


**Figure 6: Three-dimensional visualization**

## Result and Discussion

Data gathered from the Trajectory Reconstruction Method analysis are shown in Figure 7. At 240 seconds from impact, the aircraft was at an altitude of 15,640 feet above sea level and descending. It started to pitch-down until its pitch angle reaching -11.3 degrees before pitching-up again 14.8 seconds later. The abnormal pitch-down caused the aircraft to lost 2090 feet; a rate of descent of 8,475 ft/min.

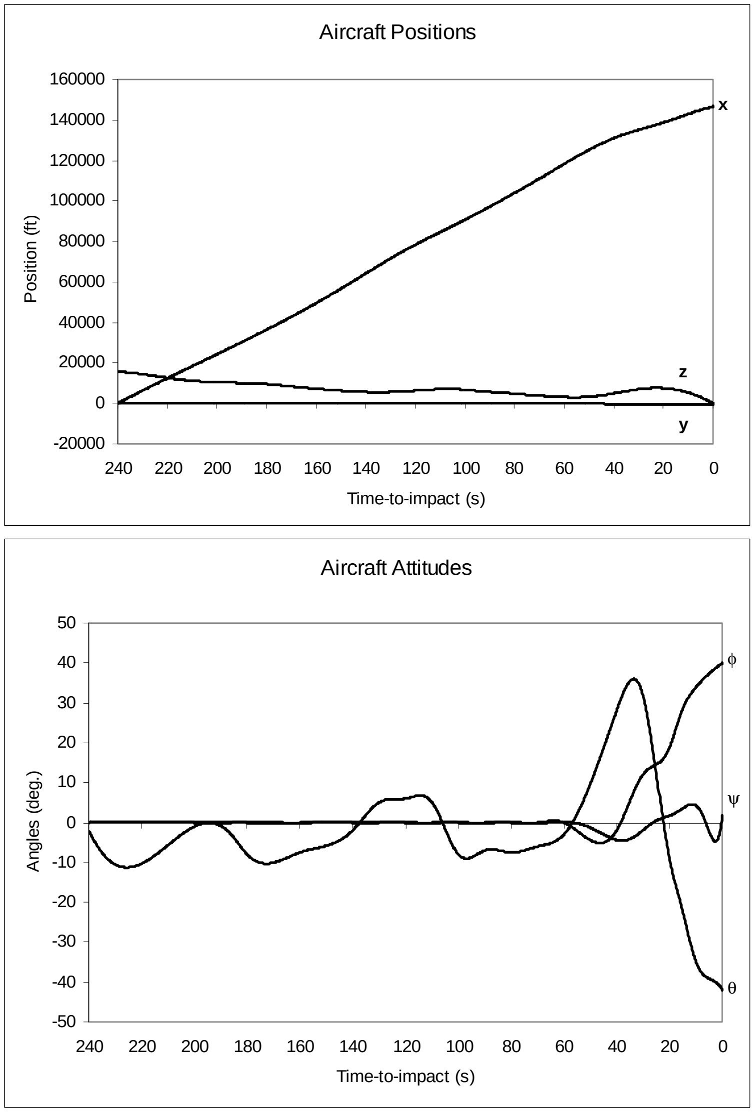


**Fig. 7: Positions and attitudes of the 9M-MBD**

The aircraft began to level 45 seconds later for a few seconds before experiencing the second pitch-down motion. Its pitch angle reached -10.3 degree before the aircraft started to pitch-up. It continued to pitch-up until the pitch angle reached 6.8 degrees, 125 seconds before impact. This caused the aircraft to climb above its glide slope. The aircraft entered its third pitch-down motion at 114 seconds from impact, reaching pitch angle of -9.0 degrees, 17 seconds later. Then, the aircraft pitch up again before leveling 47 seconds later.

The situation in the cockpit had obviously been critical 60 seconds before the impact. The aircraft not only pitched-up, but it also experienced roll and yaw. It banked slightly to the right before banking uncontrolled to the left. It also yawed to the right before yawing back to the left.

Unable to maintain the aircraft directional and lateral control while the aircraft was losing altitude rapidly, the pilot excessively pitched-up the aircraft from 0 degree to 36 degree in 23 seconds, reaching up to altitude of 6,470 ft. As the aircraft stalled 34 seconds from impact, it dived at an increasing rate of descent in a steep nose down attitude; further aggravated by high rate of roll and yaw. On impact, the aircraft struck the ground at pitch angle of -42 degree, roll angle of 40 degree and yaw angle of 2 degree.

Visualization of the air crash data provides a clear picture of what had happened to flight MH653. Figure 8 shows the cockpit views while the Figure 9 represents the aircraft in three-dimension.


**Fig. 8: Cockpit views of the 9M-MBD**


**Fig. 9: Three-dimensional representation of the 9M-MBD**

Investigation of the erratic flight paths and instrumentation readings indicated that the pilots had difficulty of maintaining the aircraft altitude, attitude and airspeed. This may be due to the commotion in the cockpit. During this period, there could have been inadvertent disturbance to the control column. The aircraft entered a tight spin before it impacted the ground. Witnesses, who observed an almost vertical plummeting down aircraft, confirmed the final phase of the aircraft.

## Conclusion

Simulation an air crash using FDR and CVR data provides an important tool to the investigators. Although these data cannot provide a magic answer to any air crash, they are very useful in determining the probable cause. Simulation on the Tanjung Kupang air crash confirmed that there was a commotion in the cockpit. Someone was interfering with the control column, which hampered the controlling of the aircraft.

There had been desperate attempt to recover the aircraft, indicating that the pilot or the co-pilot was in full awareness of the situation and still trying hard as possible to handle the critical situation. However, there was an alarming descent rate and rapid lost of altitude in the final seconds. No recovery attempts had been made in the final dive indicating that both pilots were in no condition of handling the aircraft or possibly were killed. Allegation of shooting in the cockpit however cannot be confirmed from this simulation.

## Acknowledge

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