

National Transportation Safety Board
Office of Research and Engineering
Washington, D.C. 20594

Airplane Performance Study

Specialist Report Timothy Burtch

A. ACCIDENT

Location: Trinity Bay, Texas
Date: February 23, 2019
Time: 1839 GMT (12:39 pm CST)
Airplane: Boeing 767-300, N1217A
NTSB Number: DCA19MA086

B. GROUP

No vehicle performance group was formed.

C. SUMMARY

On February 23, 2019, about 1239 central standard time (CST), Atlas Air flight 3591, a Boeing 767-300, N1217A, entered a rapid descent from 6,000 feet and impacted a marshy bay area about 30 miles from Houston George Bush Intercontinental Airport (IAH), Houston, Texas. The airplane was destroyed and highly fragmented, and the main debris field was approximately 200 yards by 100 yards in shallow water and a muddy marshland. The two pilots and one non-revenue jumpseat pilot were fatally injured. The domestic cargo flight was operating under 14 Code of Federal Regulations Part 121 from Miami International Airport (MIA), Miami, Florida, to IAH.

[Note: Times in the report are quoted in CST as well as Greenwich Mean Time (GMT or “Z”):
CST = GMT – 6 hr.]

D. THE AIRPLANE

A picture of the accident airplane, a Boeing 767-300, is shown in Figure 1. The airplane was manufactured by Boeing in 1992 and was registered to Andromeda Leasing, LLC.

E. WEATHER OBSERVATION

The accident occurred at 1239 CST.

METAR KIAH 231853Z 32011G19KT 10SM SCT035 SCT060 BKN080 BKN250 21/12 A2991

On February 23rd, at 1253, IAH was reporting wind 320° at 11 knots (kt), gusts to 19 kt; 10 statute miles (SM) visibility; scattered clouds at 3,500 feet (ft) above the ground (agl), scattered clouds at 6,000 ft agl, broken clouds at 8,000 ft agl, broken clouds at 25,000 ft agl; temperature 21° Celsius (C); dew point 12°C; altimeter 29.91” mercury.

The Surface Analysis Chart at 1200 depicted a northeast to southwest oriented cold front stretching almost directly over the accident site. The cold front was in the immediate vicinity of the accident site at the time of the accident. (See the Meteorology Group Chairman’s Factual Report for more details.)

F. AIRPLANE PERFORMANCE STUDY

The airplane performance study is based on recovered Flight Data Recorder (FDR) data and Automatic Dependent Surveillance-Broadcast (ADS-B) data provided by the Federal Aviation Administration (FAA). ADS-B is a primary technology supporting the FAA’s Next Generation Air Traffic Control System, or NextGen, which is shifting airplane separation and air traffic control from ground-based radar to satellite-derived positions. ADS-B broadcasts an airplane’s Global Positioning System (GPS) position to the ground where it is displayed to Air Traffic Control (ATC). The GPS position is also transmitted to other airplanes with ADS-B receivers, either directly or relayed through ground stations, to allow self-separation and to increase situational awareness.

GPS has an accuracy of approximately 20 meters (m) in both the horizontal and vertical dimensions. GPS augmented with the Wide Area Augmentation System (WAAS) is accurate to approximately 1.5 – 2.0 m.

The airplane approached IAH from the southeast and was initially descending via the LINKK ONE arrival with the runway 26L transition; however, at 1237, flight 3591 was later given a vector of 270° by ATC in order to circumvent an area of light to heavy precipitation that was about 35 miles ahead. Radar contact was lost less than two minutes later. An overview of the ADS-B ground track with select waypoints from the LINKK ONE arrival are shown in Figure 2.

Figure 3 highlights the descent during the last two minutes of the flight with select paraphrased CVR comments overlaid. The descent appears normal until about 1238:31 and approximately 6,300 ft pressure altitude when the go-around mode was activated using one of the Go-around (G/A) buttons on the throttle quadrant: see Figure 4. There was no mention of initiating a go-around by the flight crew on the cockpit voice recorder (CVR), and flight 3591 had been cleared to descend to 3,000 ft. (The normal load factor, a_n , in Figure 6 shows that the airplane

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encountered turbulence at approximately 1238:25, six seconds before the recorded flight mode transitioned to G/A. The turbulence was likely associated with the cold front mentioned earlier and included instrument meteorological conditions or IMC.)

The airplane Euler angles recorded on the FDR are shown in Figure 5. The airplane pitch attitude increased from about -1° airplane-nose-down (AND) before G/A was annunciated to approximately 4° airplane-nose-up (ANU) six seconds later at 1238:37. The airplane then pitched AND to about -49° over the next 18 seconds in response to an AND elevator input.

At 1238:48 and 1238:51, the pilot flying (the first officer in the right seat) made comments about the airplane stalling that were recorded on the CVR. However, Figure 6 shows the recorded airplane wing angle-of-attack and airspeed were below -15° and above 250 kt, respectively. This is well below the airplane's wing stall angle-of-attack.

Figure 7 shows an elevator split between the left and right sides of the airplane: the left elevator is associated with the captain in the left seat, and the right elevator is associated with the first officer in the right seat. The elevator deflections are similar until about 1238:46. At that time, the first officer is heard asking a question about airspeed on the CVR, and the elevators begin to split: the captain begins to pull from 2° to 8° more ANU elevator than the first officer. The split continues until about 1238:56, about one second after the airplane would have broken out of the reported 3,500 ft cloud layer. Both the captain and the first officer subsequently commanded ANU elevator until impact. (The normal load factor recorded by the FDR in Figure 6 is greater than 4g right before impact.)

G. APPARENT PITCH/SPATIAL DISORIENTATION

Figure 8 contains the “apparent” pitch angle that the co-pilot might have “felt” that the airplane was at based solely on vestibular/kinesthetic perception from loads acting in the co-pilot's body coordinate system¹. A common pilot misperception during low visibility take-offs and go-arounds is that the nose of the airplane is excessively high. This is due to the large longitudinal accelerations, n_x , associated with the high engine thrust settings. (A peak longitudinal acceleration of $0.27g$'s was obtained at 1238:42 as shown in Figure 8.) Spatial disorientation can occur when the human body cannot distinguish between the force due to gravity at high pitch angles and the inertial force that results from accelerating the airplane². If the airplane is not flown by reference to the instruments, a natural reaction is to lower the nose in response to the increased acceleration and the misleading perception.^{3,4}

For example, an equation for apparent pitch angle in the airplane body axes (see Figure 9) can be derived from the longitudinal equation of motion⁵:

¹ The pitch angle that would produce the accident airplane acceleration while assuming level 1g flight in the equations of motion: $[n_x, n_y, n_z] = [0, 0, -1]$ with $d\mathbf{u}_{body}/dt$, $d\mathbf{a}_{body}/dt$, and $d\mathbf{\omega}_{body}/dt$ from the FDR.

² FAA Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A, 2008, Chapter 16, http://www.faa.gov/library/manuals/aviation/pilot_handbook/

³ Aeronautical Information Manual (AIM): Official Guide to Basic Flight Information and ATC Procedures. Section 8-1-5, Illusions in Flight.

⁴ Instrument Flying Handbook. FAA-H-8083-15A, Chapter 1.

⁵ Aircraft Structures, D. Peery and J. Azar, 1982, p. 41. Copyright 1982 by McGraw-Hill.

$$n_x = 1/g [\dot{u} + (q_b w - r_b v)] + \sin\theta \quad [1]$$

where,

n_x is the load factor in the x direction, airplane body axes
 g is the acceleration due to gravity
 $\dot{u}$ is the acceleration in the x direction, airplane body axes
 q_b is the angular velocity in the y direction, airplane body axes
 w is the velocity in the z direction, airplane body axes
 r_b is the angular velocity in the z direction, airplane body axes
 v is the velocity in the y direction, airplane body axes
 θ is the airplane pitch attitude

Assuming small angular rates, equation [1] can be rewritten as

$$gn_x \approx \dot{u} + g\sin\theta \quad [2]$$

The contributions to body axis acceleration, gn_x , and the source of the spatial disorientation are clearer in equation [2]. The pilot's "seat of the pants" feel is changing through n_x , but as indicated in reference 2, the pilot cannot distinguish between a change in longitudinal acceleration, $\dot{u}$ (from increased thrust) and a change in pitch attitude, θ (from the climb). If the change is interpreted as the result of a climb, the pilot will input nose-down elevator in response. For this reason, it is important that pilots develop an effective instrument scan in IMC.

H. SUMMARY AND CONCLUSIONS

Atlas Air flight 3591's approach into Houston George Bush Intercontinental Airport appeared normal with respect to CVR, FDR, and ADS-B data until 1238:31 when the airplane was approximately 38 nautical miles from the airport and likely entering IMC. The recorded G/A mode annunciated at this time, and the airplane accelerated as thrust increased.

The left and right elevator control inputs that immediately followed the annunciation were consistent with a go-around; however, six seconds later, the elevators went from commanding ANU to commanding AND. After ten seconds of being split, left and right elevators both went back to commanding ANU as the airplane likely exited the clouds and the airplane pitch attitude approached 49° AND. The airplane impacted the shallow water seven seconds later. The normal load factor just before impact was over 4g.

Timothy Burtch
Specialist – Airplane Performance
National Transportation Safety Board

I. FIGURES



Figure 1: Accident Airplane, N1217A, a Boeing 767-300

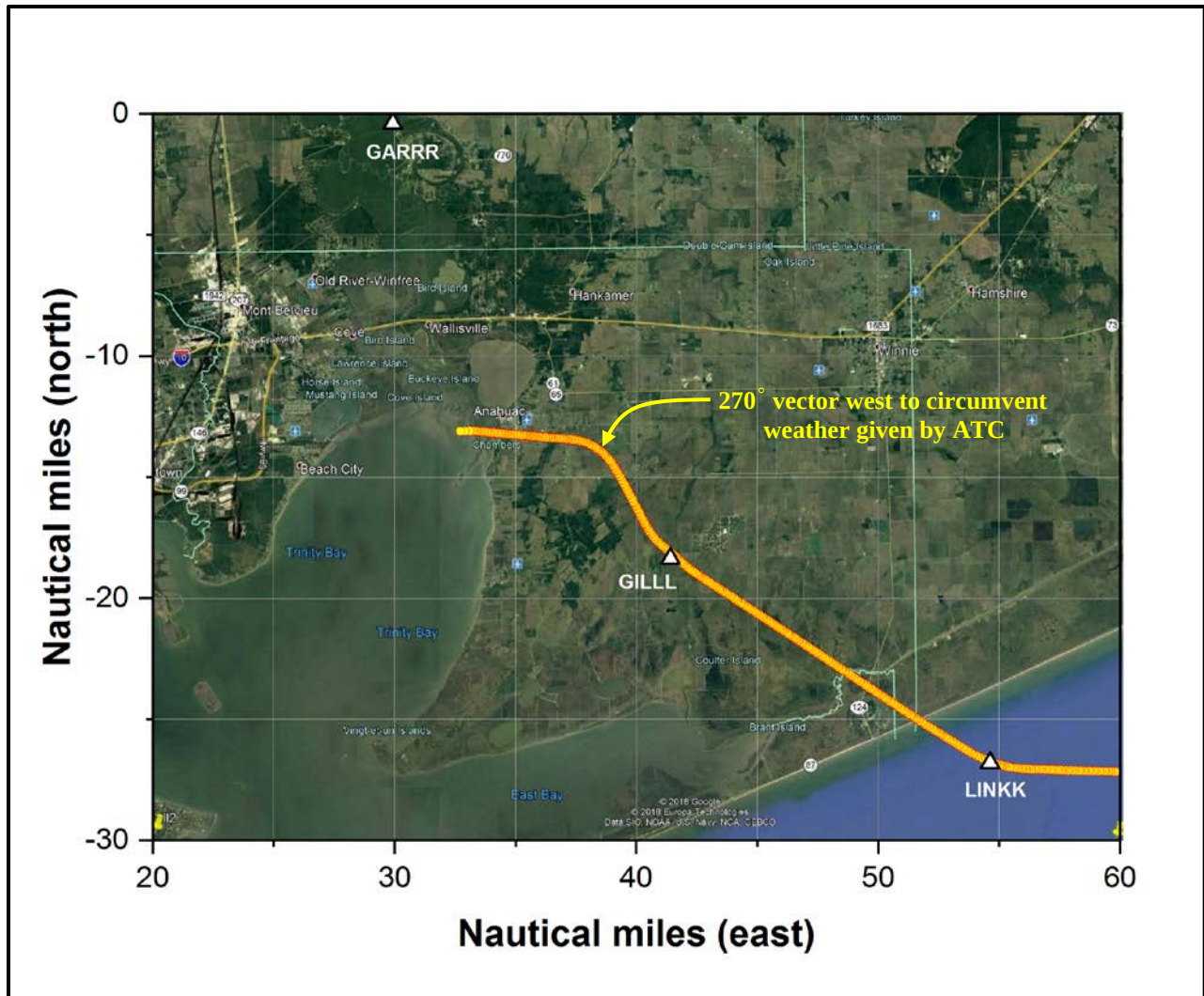


Figure 2: ADS-B Ground Track for Final 7 min of Flight

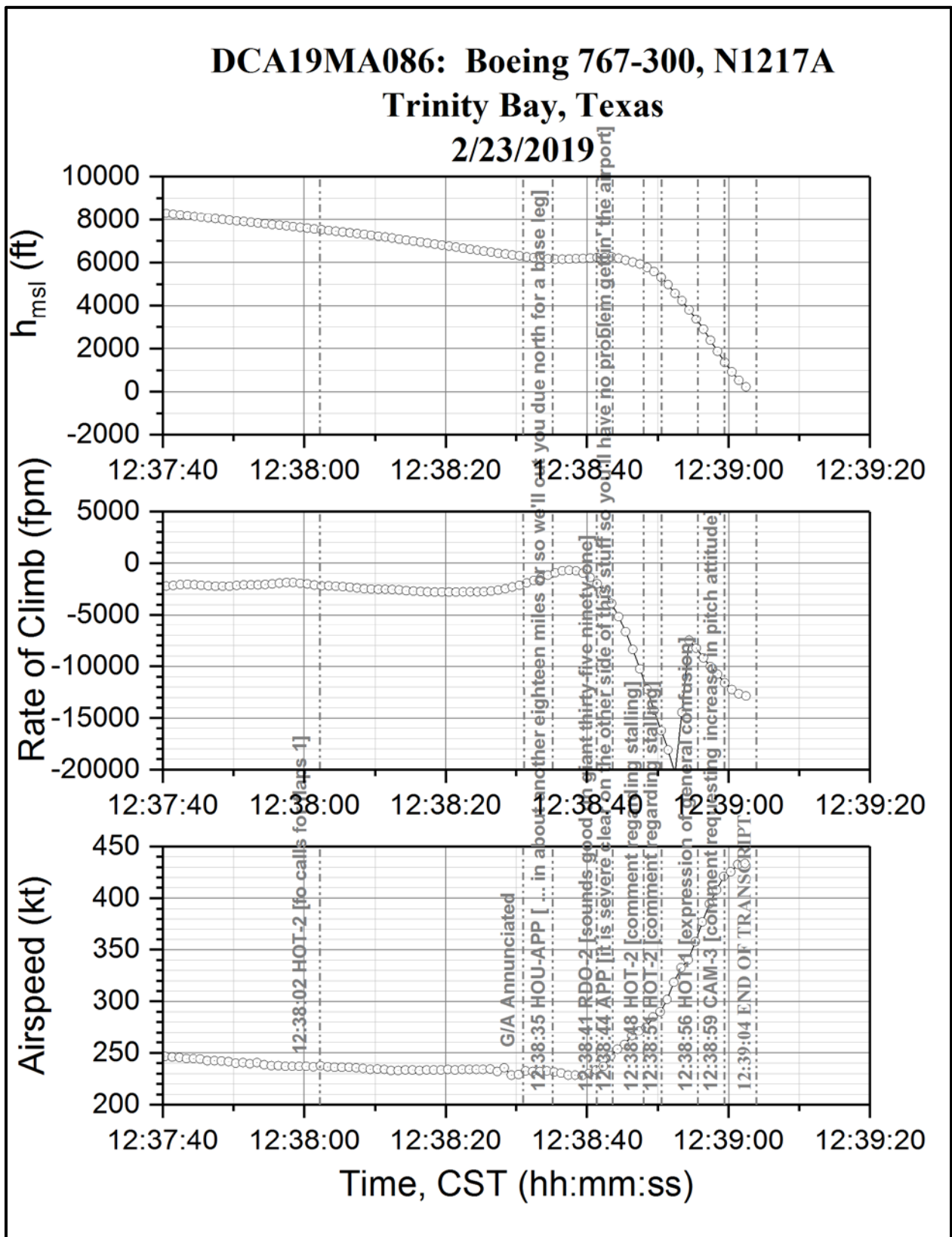


Figure 3: Altitude and Airspeed from FDR with Select Paraphrased CVR



Figure 4: Representative B-767 Throttle Quadrant with G/A Buttons

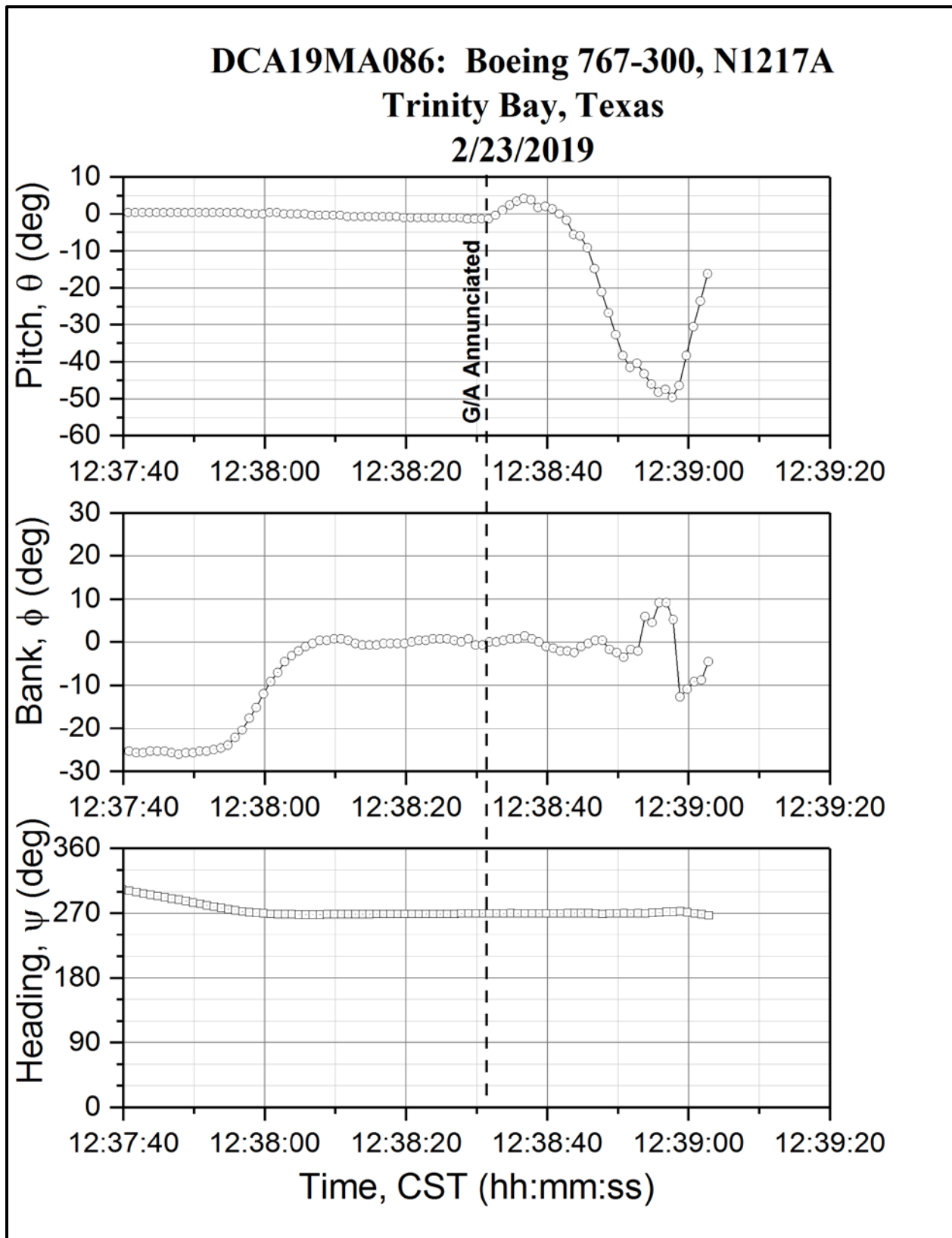


Figure 5: Pitch, Bank, and Heading from FDR

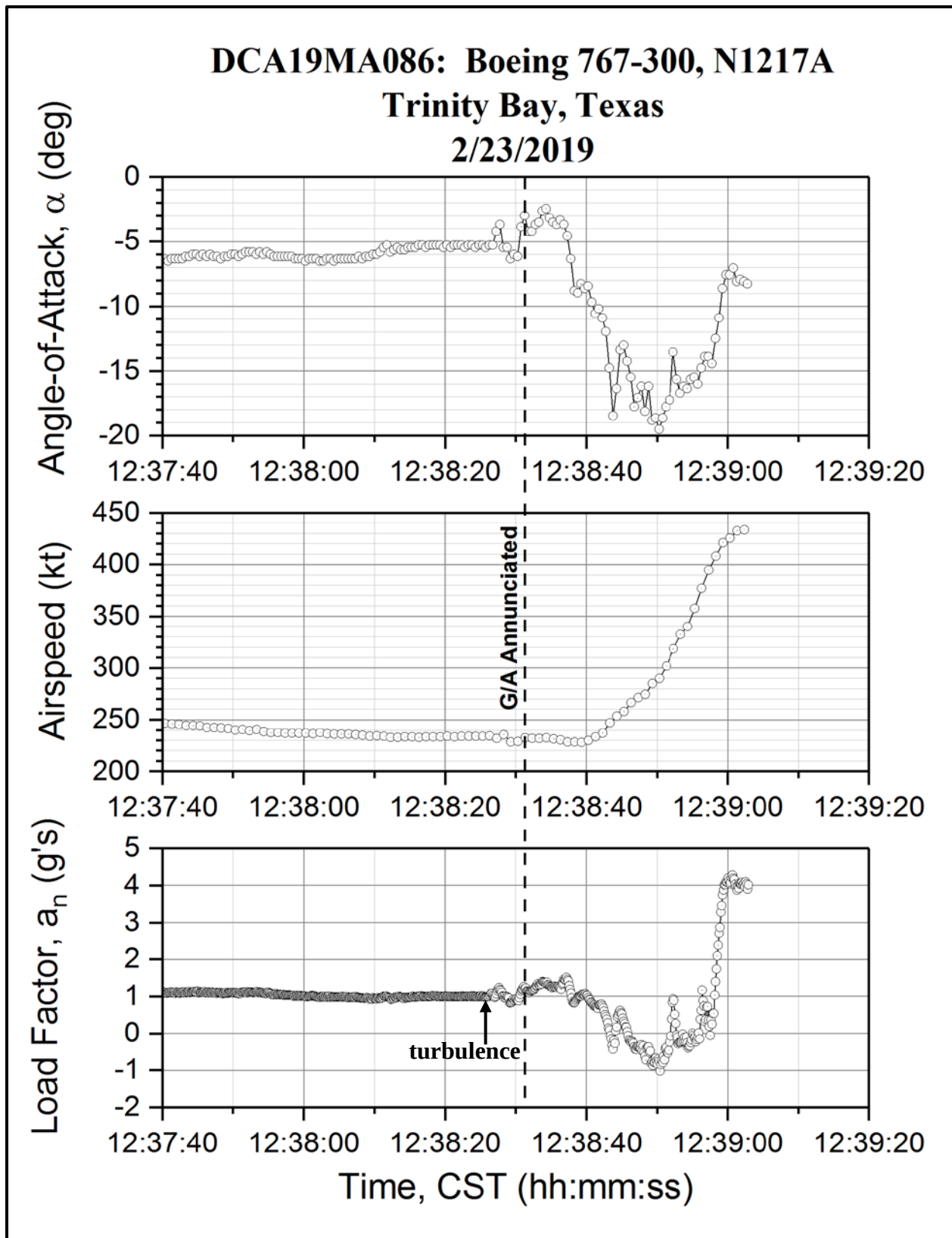


Figure 6: Angle-of-Attack and Load Factor from FDR

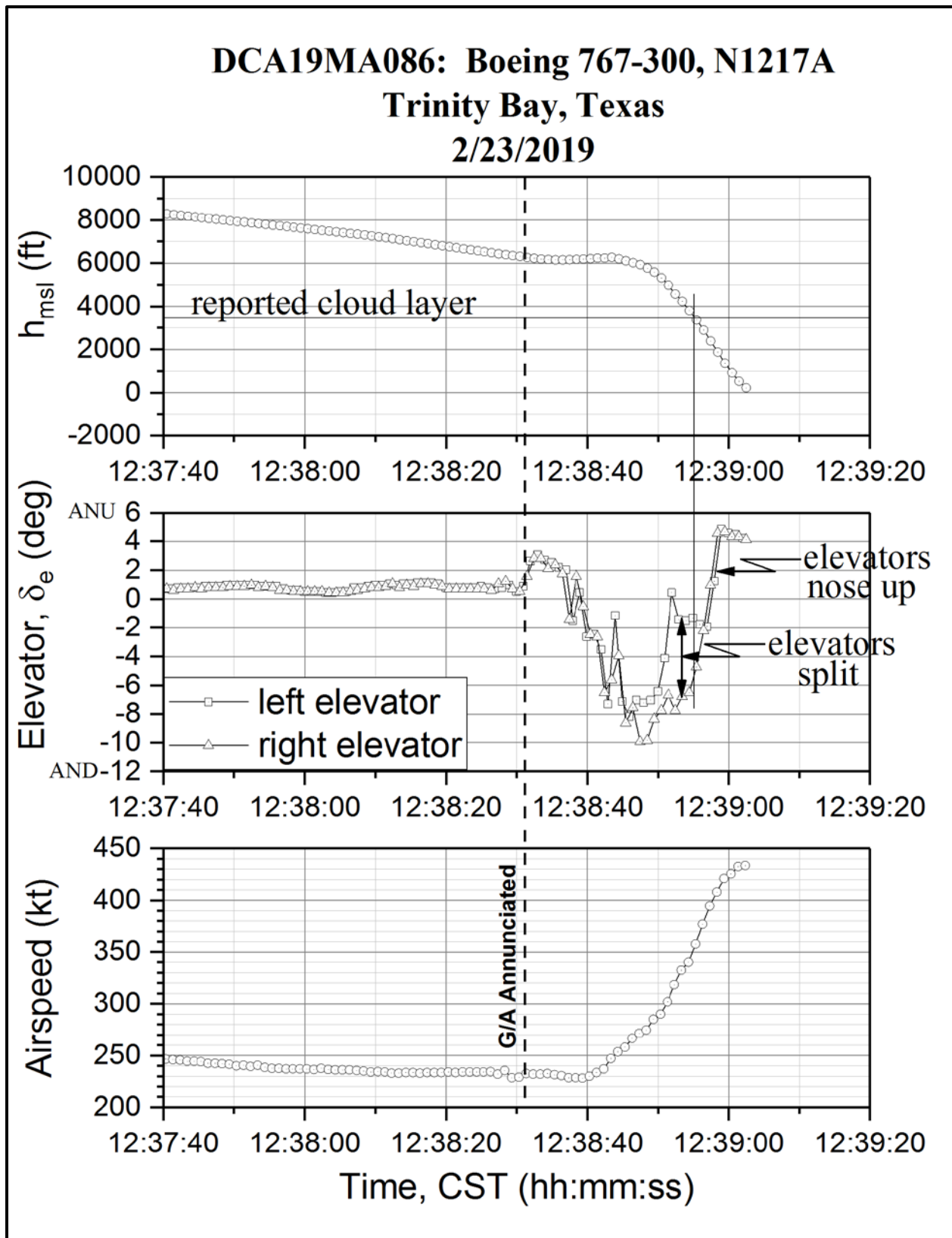


Figure 7: Elevator Split

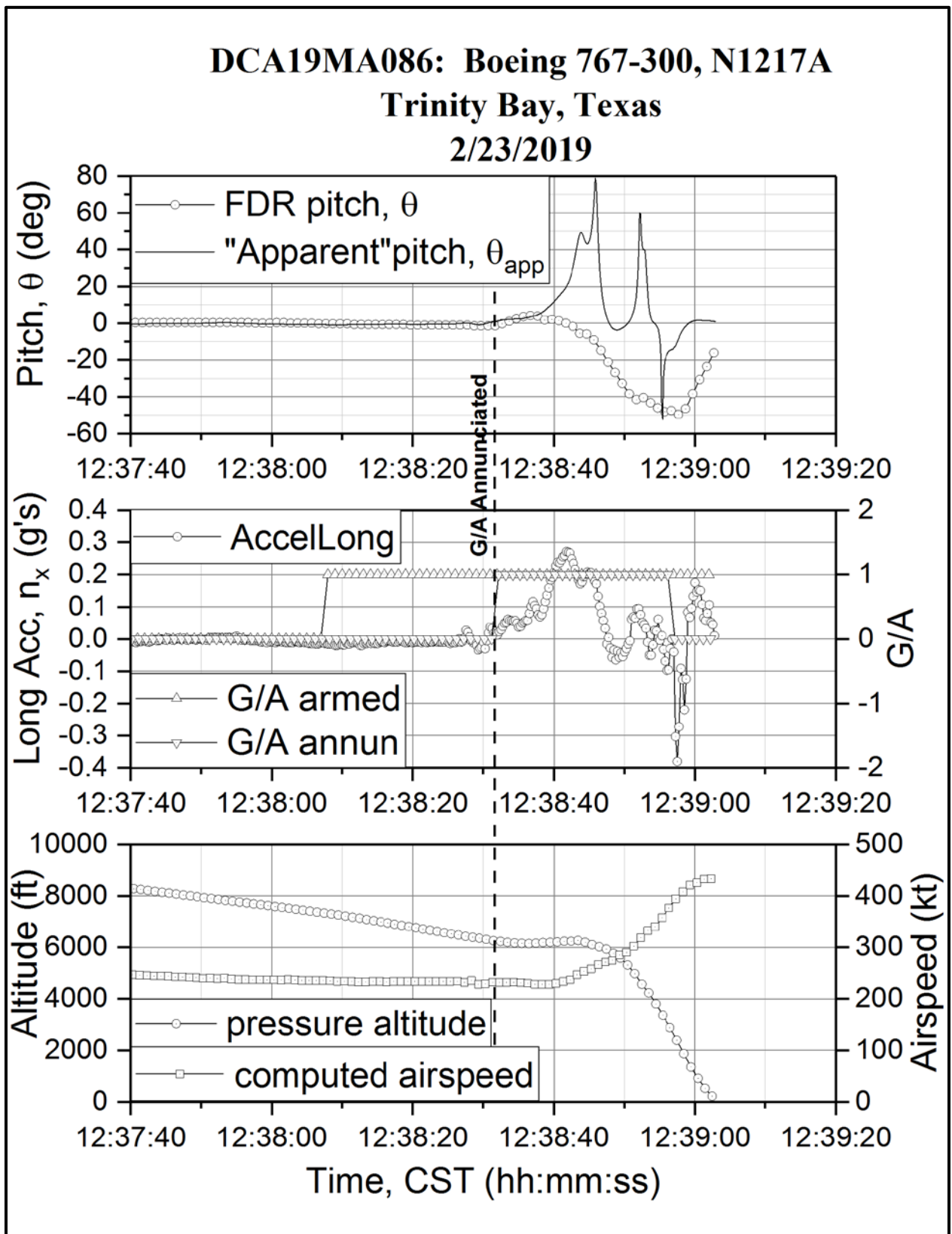


Figure 8: Computed "Apparent Pitch" and Longitudinal Acceleration from FDR

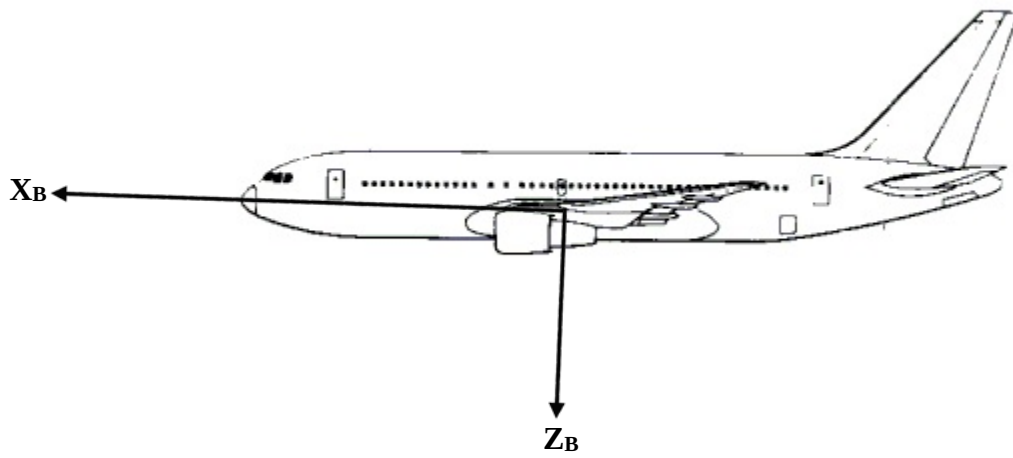


Figure 9: Airplane Body Axes