

Aircraft Performance Study

I. ACCIDENT

NTSB Number:	WPR19FA230
Location:	Oroville Municipal Airport (OVE), Oroville, California
Date:	August 21, 2019
Time:	1132 Pacific Daylight Time
Aircraft:	Cessna CE-560XL, N91GY
Operator:	Delta Private Jets

II. VEHICLE PERFORMANCE SPECIALIST

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Office of Research and Engineering
National Transportation Safety Board (NTSB)

1.0 INTRODUCTION

On August 21, 2019, about 1132 Pacific daylight time, a Cessna 560XL airplane, N91GY, overran the departure end of runway 2 following a rejected takeoff from Oroville Municipal Airport (OVE), Oroville, California. The two pilots and 8 passengers were not injured. The airplane was destroyed by a post-crash fire that consumed a majority of the airplane. The airplane was registered to Jotts LLC, and was operated by Delta Private Jets, as a Title 14 Code of Federal Regulations (CFR) Part 135 on-demand charter flight. Visual meteorological conditions prevailed, and an instrument flight rules flight plan was filed. The flight was destined for Portland International Airport (PDX), Portland, Oregon.

An aircraft performance specialist was requested to determine the actual airplane acceleration and speed, required takeoff distance and reference speeds, and expected rotation capability based on the available factual evidence, witness statements, engineering data, and Cessna 560XL aerodynamics and engine models. The study results indicate that N91GY had adequate takeoff performance capability to safely lift off from runway 2 when configured for a normal takeoff. However, the factual evidence and engineering models indicate that N91GY performance was substantially degraded during the accident takeoff roll by an unexpected retarding force acting at the wheel/runway interface. The magnitude and direction of this unexpected force adversely affected N91GY acceleration and rotation capability during the attempted takeoff as well as deceleration capability during the stop.

2.0 METHOD

This aircraft performance study provides data-driven, quantified assessments of expected Cessna 560XL takeoff performance capability and identifies factors that affected the observed N91GY takeoff performance. The study is based on available N91GY factual evidence and Cessna 560XL aerodynamics and engine data that Cessna engineering and flight test/operations staff used to develop, test, and validate takeoff and stopping performance (and other engineering) models; construct the Flight Operations Manual (FOM) and the Aircraft Flight Manual (AFM); and certify the airplane. All of the Textron Aviation/Cessna foundational factual data and models used in this study predated the accident.

A review of the available Flight Data Recorder (FDR), Cockpit Voice Recorder (CVR), ADS-B, and airport external surveillance camera factual evidence indicated that N91GY was able to accelerate to the rotation speed required for airplane liftoff. The airplane configuration and energy state during the takeoff ground roll are the focus of this study. The scope is primarily from airplane takeoff initiation to the position at which the airplane lifts off from and climbs to a height of 35 feet above runway 2 (accelerate-go scenario) or, in this case, departs from the improved pavement surface (accelerate-stop scenario), which includes the chevroned region at the departure end of runway 2.

2.1 Cessna CE-560XL Excel

A three-view drawing of the Cessna 560XL is provided in Attachment 1. A photograph of N91GY is included in section 4.0 of the NTSB Operational Factors factual report.

2.2 OVE Runway 2/20

A diagram of Oroville Municipal Airport (OVE) is shown in Attachment 2. Runway 2 is constructed of 6,020 by 100 feet of ungrooved asphalt and has non-precision markings. Section 8.0 of the NTSB Operational Factors factual report documents the N91GY overnight parking location and taxi route to runway 2.

2.3 Weather

The Oroville municipal airport automated weather observation system (AWOS) measurement at 1814Z included wind variable at 3 knots, visibility 10 statute miles, clear sky, temperature 27°C, dew point temperature 14°C, altimeter 29.94 inches Hg, and density altitude 1,600 feet. These data are paraphrased from the aircraft CVR transcript. The adjacent 5-minute AWOS readings are listed and defined below.

08/21/19 10:10:31 5-MIN KOVE **211810Z** AUTO **29003KT** 10SM CLR 27/14 A2994 170
45 1600 **270/03** RMK AO2 T02670139

08/21/19 10:15:31 5-MIN KOVE **211815Z** AUTO **VRB04KT** 10SM CLR 27/14 A2994 170
43 1700 **VRB/04** RMK AO2 T02720139

- The first column of time is local standard time, the **red** time is Zulu time in DDHHMMZ.
- **Blue text** identifies wind direction referenced to true north (rounded to nearest 010°) with average wind and gust magnitude
- **Green text** identifies wind direction referenced to magnetic north (rounded to nearest 010°) with average wind and gust magnitude

2.4 Airport Surveillance Camera Video

A portion of the N91GY takeoff ground roll was captured by an OVE video surveillance camera and recorded. The consecutive sequence of images between the initial takeoff roll and the aircraft departure from the camera field of view was cropped, enlarged (maintaining the original image aspect ratio), and packaged in .pdf file format to simplify factual content reference and distribution. The complete image sequence is contained in Attachment 3. The exemplar image in Figure 1 shows the airplane approaching the departure end of runway 2. The ramp pavement surface condition in the foreground of the image is bare and dry. Visibility conditions were clear.

The common event used to time align the video surveillance camera footage, CVR data, and FDR data was the crew preflight action to stow and verify the position of the speed brakes. The video timestamp is known to be inaccurate so the difference between the video timestamp and local time was used to establish the reference time. Section 2.8 documents the local time of paraphrased CVR events. Per the NTSB Flight Data Recorder factual report, "Correlation of the FDR data from [subframe reference number] SRN to the event local time, PDT, was established with an offset provided by the Cockpit Voice Recorder (CVR) Group Chairman. Accordingly, the time offset for the event flight data from SRN to local PDT is the following: PDT = SRN – 67,303."



Figure 1: Exemplar cropped and enlarged image extracted from video recording of N91GY takeoff ground roll on runway 2. The aircraft position is circled. Direction of travel is left to right.

2.5 Excerpts of Crew Statements

The pilot-in-command (PIC) and second-in-command (SIC) interview transcripts were screened for questions and answers regarding takeoff, rotation, pitch attitude, control column, parking brake, and the takeoff abort. A subset of statements from the PIC and SIC that are relevant to aircraft performance follow. A superset of these statements is provided in Attachment 4 of this study. The complete interview transcripts are documented in the Operational Factors factual report, Attachments 2 through 5.

Relevant PIC statement excerpts:

18 Called for **takeoff** power set; it was set. We began rolling
 19 down the runway. He called the V1 -- or airspeed log V1, and then
 20 Vr, and I pulled the yoke back, and it was just a weird sensation.
 21 I pulled back, and the plane didn't lift off. So I pulled it
 22 clear back to my chest, and the nose did not move at all.
 23 And I remember holding it there just long enough to look at
 24 the airspeed, look at the **takeoff** power set. Nothing happened.
 25 And I went into the abort, he yelled abort, and then I pulled the
 1 full TRs and max braking.

11 A. -- I pulled it back, and it just -- there was no feeling
 12 there. I was like -- held it where I normally do, then I pulled
 13 it clear back to my lap, and it just didn't do anything except
 14 that it just stayed there.

15 Q. So the **pitch**, the nose angle --

16 A. Yeah. It didn't --

17 Q. -- just never really --

18 A. Never started to **rotate**.

19 Q. Never changed? Just --

20 A. Never --

1 recall looking down, and I didn't read them, but I saw the V1, Vr
 2 -- like I said, I didn't read them, but I know the airspeed
 3 indicator was above them.

13 Q. Got it. And you guys were -- you were ready to -- you're --
 14 you've got your clearance flight time, you're --

15 A. Yep.

16 Q. -- ready to go. When did -- do you remember turning off the
 17 **parking** brake?

18 A. I do not.

19 Q. You don't remember? When you took the runway, it's set for
 20 the rudder bias check, the location of it, and the flow -- the
 21 before takeoff, do you -- any recollection, turning off the
 22 **parking** brake?

23 A. I do not.

24 Q. No? Okay. Do you believe that the **parking** brake was on --

25 engaged for the takeoff?
1 A. I do not, but I don't know.
2 Q. You don't recall?
3 A. I really don't know.

10 Q. Is that your general expectation of, if the parking brake is
11 set, when you apply power, what do you expect the airplane --
12 A. That's what we were told, that you set the parking brake, you
13 put it up to takeoff, and it shouldn't move.

Relevant SIC excerpts:

1 A. -- so much. I don't know. But I do know that the parking
2 brake was set when we did the rudder bias -- when he did the
3 rudder bias check, the brakes were set. And as I stated before,
4 that was before we left the ramp on the FBO.
5 Q. Got it. Before, okay. So overall again, it sounds like to
6 your knowledge, that point of clearance -- there was no call of
7 parking brake set or -- and then the rudder checks were done,
8 again at the -- in the ramp area.
9 A. In the ramp area, correct.

18 A. We made a call, taking active Runway 2 departure. We took
19 the active, the before takeoff above and below items were called.
20 Per his request, we followed them, I called them, he verified, and
21 we started departure.
22 [Mr. ...] advanced the throttles, as the power was coming up, I
23 said, speeds alive, it's usually around 50 knots or so. Eighty
24 knots, I called crosscheck, panel clear, verified. At V1 I called
25 V1. I called rotate, at which point [Mr. ...] pulled the yoke
1 completely to his chest very quickly, which took me a little off
2 guard.
3 I don't know what the timeline was. It could have been a
4 couple of seconds, it could have been instantaneous, I don't know,
5 but as soon as there was no lift rotation -- literally the nose
6 never came off the ground, I called abort. I don't know where
7 that was on the runway. I don't know how much runway was left.

2.6 N91GY Weight and Balance

The N91GY weight and balance data for the accident flight are documented in sections 6.0–6.7 of the NTSB Operational Factors factual report. The supporting aircraft maintenance records, load manifest, and weight and balance loading envelope are included therein.

This aircraft performance study is based on a takeoff weight of 19,112 pounds and a center of gravity position of about 26 percent mean aerodynamic chord (328.36 inches aft of the datum). These weight and balance data are based on actual reported weights for all passengers and baggage. The N91GY component weights determined for the accident flight by the Operational Factors investigation are summarized in Table 1. The aircraft loading exceeded the maximum zero fuel weight by 142 pounds. With this exception, the N91GY takeoff weight and balance for the accident flight were within the certified weight and balance envelope.

Table 1: N91GY component weight buildup (pounds)

Basic Empty Weight	12,716
Crew	509
Passengers	1,495
Baggage/Other	422
Zero Fuel Weight	15,142
Fuel	3,970
Takeoff Weight	19,112

2.7 Flight Data Recorder Parameters

The NTSB Flight Data Recorder factual report documents the available N91GY parametric data. This aircraft performance study relies primarily on the airspeed, acceleration (longitudinal, lateral, vertical), attitude (pitch, roll, heading), flap, speedbrake, thrust reverser, and microphone keying parameters. A review of the available FDR parametric data indicates that altitude, airspeed, engine N1 (fan speed), pitch, roll, and heading data are intermittently unreliable for some flights or flight segments. These specific parameters are largely unreliable for the accident takeoff but are available for the first, second, third, and fifth takeoffs preceding the event flight (designated herein as takeoff T-1, T-2, T-3, and T-5, respectively).

2.8 Paraphrased Cockpit Voice Recorder Events

The NTSB recorder specialist provided a subset of the aircraft CVR transcript to support the aircraft performance study. Selected CVR events during the takeoff ground roll are defined in Table 2. The CVR event content shown has been paraphrased. Times are expressed in Pacific Daylight Time (PDT). Per Section 2.4, the Flight Data Recorder factual report indicates that PDT = SRN – 67,303, where SRN is the FDR subframe reference number.

Table 2: Paraphrased CVR events

Time (PDT)	Source/Note	Intra-Aircraft Communication
11:01:44.5	START OF RECORDING START OF TRANSCRIPT	
11:20:04.7	HOT-2	The crew gave a V speed briefing indicating speeds of 103, 104, and 121 knots
11:30:50.8	CAM	[Sound of engine RPM increasing]
11:30:58.2	HOT-2	Pilot monitoring acknowledges thrust setting
11:31:17.8	HOT-2	Pilot monitoring makes initial airspeed callout
11:31:19.4	HOT-1	Pilot flying acknowledges
11:31:27.2	HOT-2	Pilot monitoring makes callout for first reference speed
11:31:28.4	HOT-2	Pilot monitoring makes callout for second reference speed
11:31:34.7	CAM	[Sound of four aural chimes]
11:31:38.5	CAM	[Sound of decrease in engine RPM]
11:31:45.7	CAM	[Sound of thrust reverser]
11:32:48.0	END OF TRANSCRIPT END OF RECORDING	

Definition of paraphrased CVR event sources and nomenclature

HOT	Voices or sounds identified as coming through the pilot's headset
CAM	Voices or sounds identified as coming through the cockpit area microphone
-1	Voice identified as the pilot flying
-2	Voice identified as the pilot monitoring
[]	Editorial insertion

2.9 Required Takeoff Distance and Reference Speeds

The NTSB calculated the takeoff field length and reference speeds required for the accident flight loading, configuration (flaps 7, gear down, anti-ice off), and environmental conditions. The calculation inputs and results are summarized in Table 3 and compared to the Textron Aviation values documented in section 9.1 of the Operational Factors factual report. The supporting Cessna 560XL Airplane Flight Manual (AFM) performance data and NTSB calculation details are provided in Attachment 5.

N91GY required a takeoff field length of 4,700 feet with V1, VR, and V2 speeds of 106, 106, and 123 knots, respectively. The NTSB results reasonably match the Textron Aviation data. However, the calculated V1, VR, and V2 speeds exceed the paraphrased CVR speeds in Table 2. The runway 2 length of 6,020 feet exceeded the required takeoff field length by 1,320 feet. As documented in section 9.0 of the Operational Factors factual report, 4,700 feet is the greatest distance needed for the accident flight to comply with the all engine-go, one engine inoperative accelerate-go, and accelerate-stop performance requirements for dry runway operations.

Table 3: Calculated takeoff field length and reference speeds for N91GY (accident conditions)

Flaps 7, anti-ice off, dry runway	NTSB	Valid Range / Textron Aviation
Weight, lb	19112	19000-19500
Temperature, C	28	25-30
Tailwind, kt	3	0-10
Pressure Alt, ft	177	0-1000
TOFL, ft	4697	4638
V1, KIAS	106	106
VR, KIAS	106	106
V2, KIAS	123	123

2.10 Airplane Groundspeed and Acceleration

The FDR longitudinal acceleration data were used to calculate airplane groundspeed during the ground roll for the T-5, T-3, T-2, T-1, and the event takeoffs. The plots in Attachment 6 compare recorded FDR airspeed to calculated groundspeed as a function of time. The change in speed as a function of time (dV/dt) is a measure of aircraft acceleration. The slope of the airspeed and calculated groundspeed lines during the ground roll should be similar in steady wind conditions. The T-5, T-3, T-2, and T-1 plots illustrate the expected match between the airspeed and groundspeed slopes for speeds up to about 120 knots. The accident takeoff FDR airspeed data are unreliable. However, the calculated groundspeed in the documented wind environment (variable winds at 3 knots) for the accident flight indicates that N91GY accelerated to an airspeed in excess of 115 knots, well past the required V1 and VR targets. Figure A6.5, which presents the calculated groundspeed for the event takeoff, is duplicated in Figure 2 for convenient reference.

The magnitude of aircraft acceleration is a function of engine thrust setting, environmental conditions, and aircraft speed, loading, and configuration. Normal Cessna 560XL operations do not include derated takeoff thrust settings. N91GY demonstrated an airplane acceleration capability during the takeoff ground roll of 5.5 to 6.5 knots/sec during the T-5, T-3, T-2, and T-1 takeoffs. Airplane loading similarities between the T-2, T-1, and the accident flight legs indicate that the accident takeoff acceleration should have been similar, about 5.5 knots/sec, but the demonstrated acceleration was reduced by about 2.5 knots/sec. Reduced takeoff acceleration capability equates to longer than expected takeoff time and distance required to reach the takeoff decision speed (V1), the takeoff rotation speed (VR), liftoff, and the initial obstacle clearance height of 35 feet (for dry runway operations). If aircraft acceleration is reduced during the takeoff roll due to inadvertent or unexpected wheel brake application, unintended brake disc heating will reduce aircraft deceleration capability in a rejected takeoff (accelerate-stop) scenario.

Measured and Calculated Speed, Event

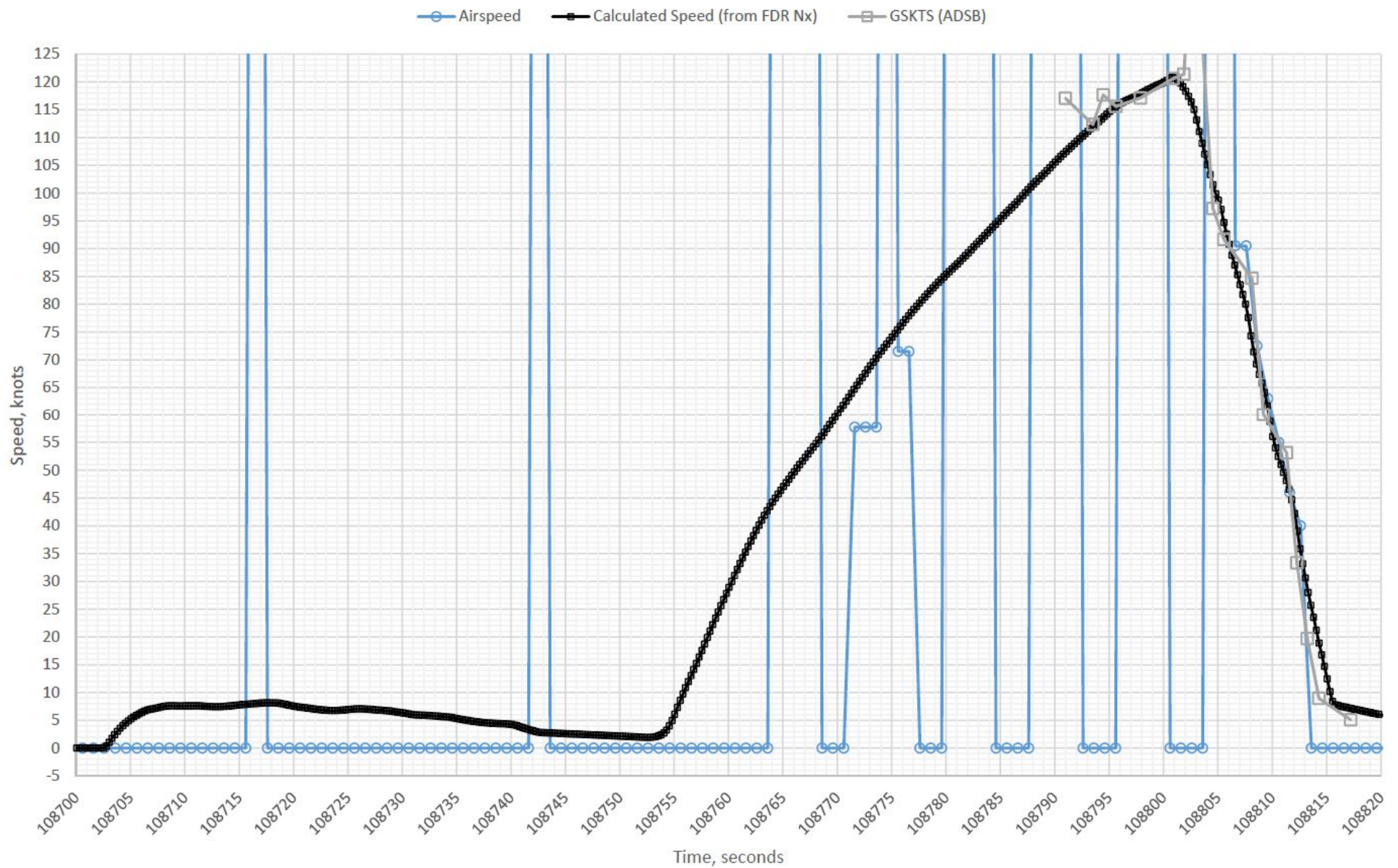


Figure 2: Comparison of calculated N91GY groundspeed data (from FDR longitudinal acceleration, black line and symbols) to ADS-B groundspeed data (grey line and symbols) for the accident takeoff. The FDR airspeed data (blue line and symbols) are unreliable.

2.11 Airplane Braking Coefficient Extraction

The expected airplane braking coefficient during a normal takeoff ground roll is about 0.02 for free rolling (unbraked) wheels. A simplified NTSB aerodynamics and engine model was developed for the CE-560XL with Pratt & Whitney P545A engines to calculate the airplane braking coefficient as a function of time during the N91GY takeoff ground roll. The calculation began at an airspeed of 10 knots and continued until the aircraft departed the improved pavement surface (the chevroned region beyond the departure end of runway 2).

The airplane braking coefficient is calculated using a force and moment balance (or energy conservation) approach to model the aircraft takeoff as a function of time; account for recorded airplane acceleration parameters; calculate the forces and moments due to aerodynamic lift, aerodynamic drag, engine thrust, aircraft loading, and runway slope; and then solve for the resultant retarding force and equivalent airplane braking coefficient at the wheel/runway interface at each time step.

For conceptual reference, the airplane braking coefficient values expected for maximum manual wheel braking with an operative anti-skid system are about 0.40 or above for bare and dry pavement, 0.20 for good braking action, 0.10 for medium (fair) braking action, 0.05 for poor braking action, and 0.02 for unbraked rolling wheels (applicable for normal airplane taxi, takeoff, and unbraked landing rollout segments). The friction coefficient available at the wheel/pavement interface is dependent on environmental conditions (including temperature, precipitation, and contaminant type and depth), pavement conditions (material, grooving, installation quality, macrotexture, microtexture, drainage capability, rubber deposits, painted surfaces, state of repair), and wheel conditions (tire inflation pressure, tread depth, tread pattern). The available friction coefficient is allocated between traction (for longitudinal braking or acceleration effort) and steering or cornering, as conditions permit for the vehicle maneuvering requested.

The N91GY calculated airplane braking coefficient results are compared in Figure 3. The corresponding values of airplane ground speed in knots and airplane acceleration in knots/sec are plotted in Figures 4 and 5. Calculated acceleration values for the accident takeoff (black line, circular symbols) initially increase to about 5 knots/sec but then decrease and remain less than 3 knots/sec for the remainder of the acceleration segment.

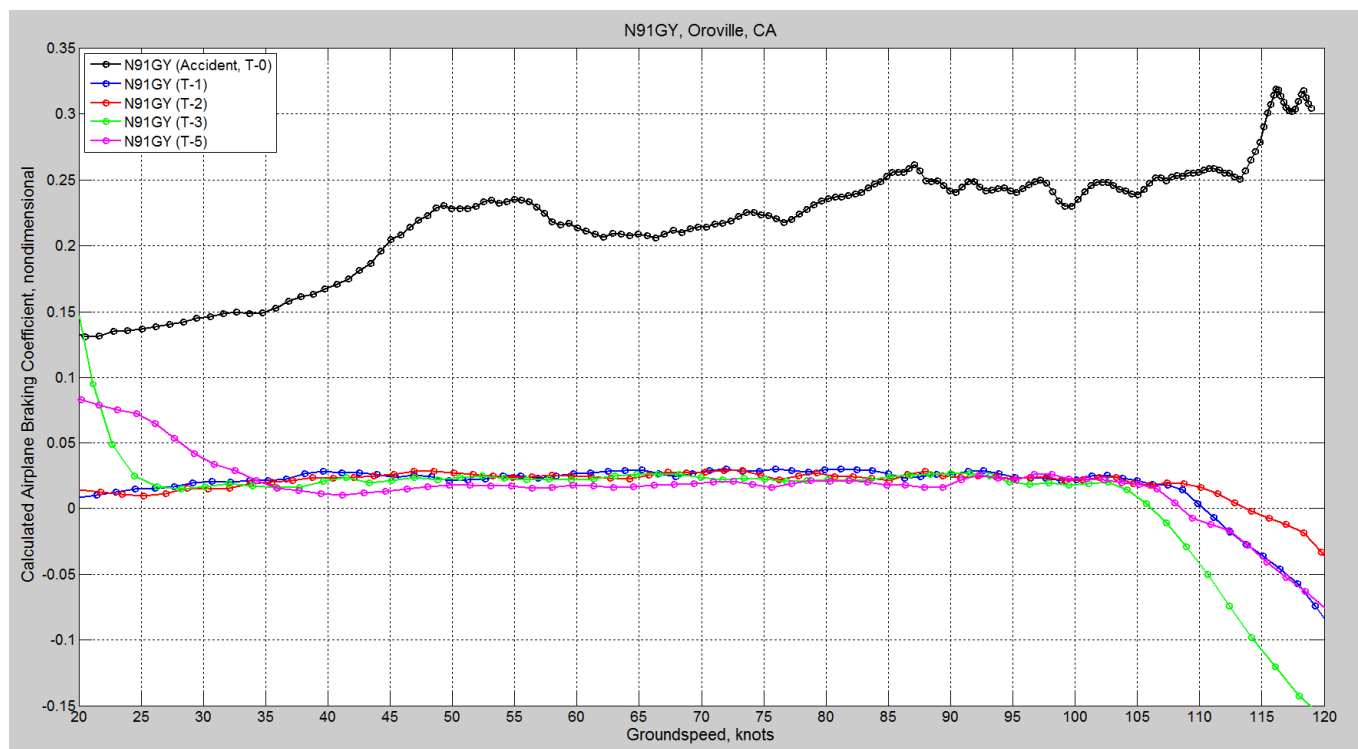


Figure 3: Calculated airplane braking coefficient values during the N91GY takeoff ground roll for the T-5, T-3, T-2, T-1, and accident takeoffs. Engine thrust for each case is based on the accident environmental conditions.

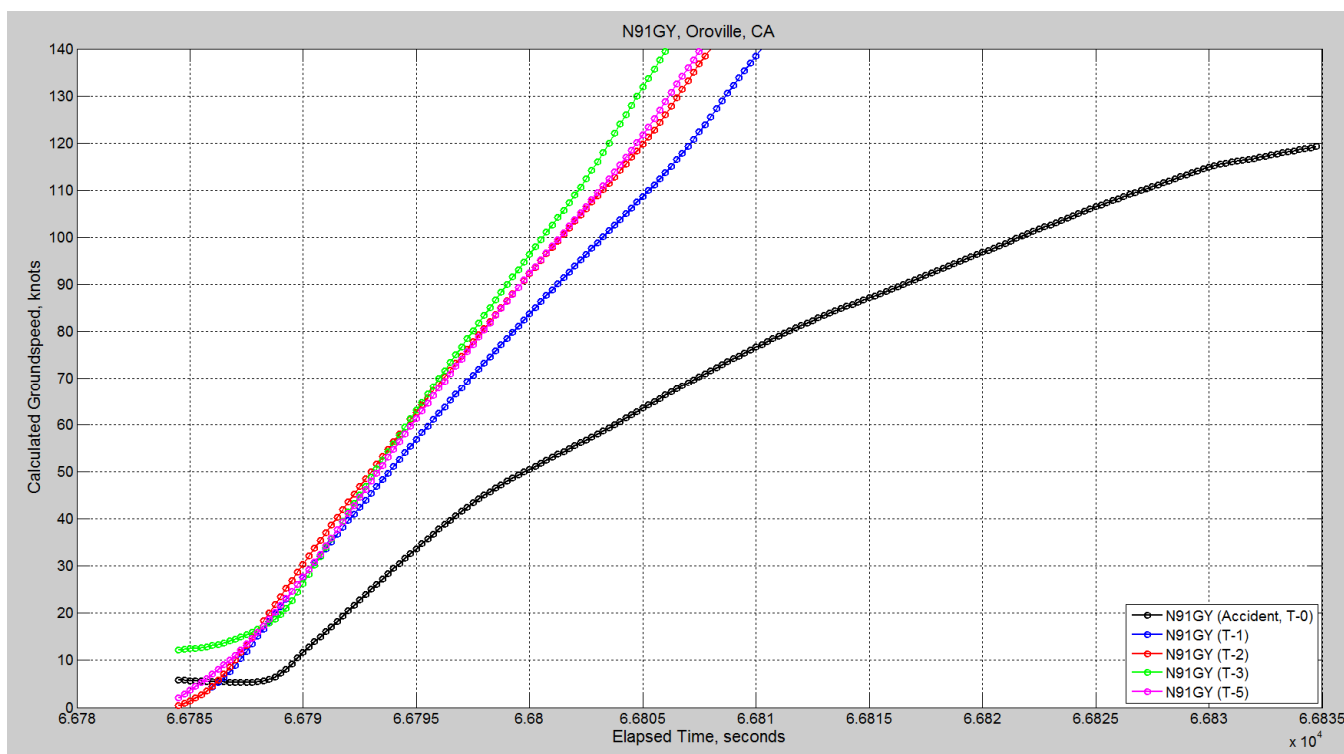


Figure 4: Calculated airplane groundspeed values as a function of elapsed time during the N91GY takeoff ground roll for the T-5, T-3, T-2, T-1, and accident (black line and symbols) takeoffs.

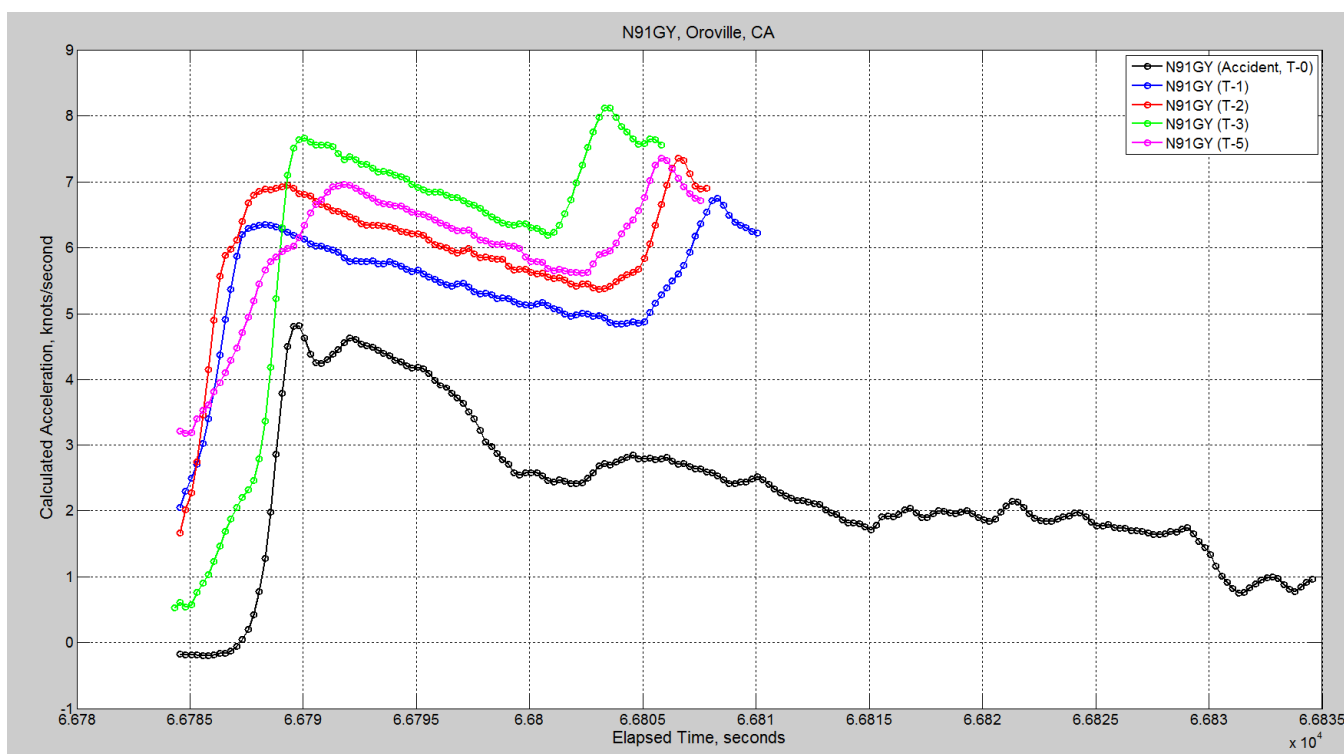


Figure 5: Calculated airplane acceleration values as a function of elapsed time during the N91GY takeoff ground roll for the T-5, T-3, T-2, T-1, and accident (black line and symbols) takeoffs.

Proper interpretation of extracted airplane braking coefficient values is generally dependent on corroborating factual evidence. For example, without specific reference to the N91GY accident flight, hypothetical airplane braking coefficient values in the neighborhood of 0.10 for expected periods of wheel brake application could be explained by purposefully light wheel braking requested by the flight crew; poor runway pavement macrotexture or microtexture; heavy paint markings or rubber deposits on the runway; poor wheel/tire maintenance condition; the presence of significant runway surface contamination (typically due to some form of precipitation), a problem with the wheel brake or anti-skid system; errors or limitations in the underlying aerodynamics or engine models; or improper configuration/application of the aircraft models, engine models, and/or event environmental conditions relative to the event aircraft.

The N91GY FDR was not configured to record the captain's or first officer's commanded engine throttle position, brake pedal position, brake pressure upstream of the anti-skid valves, brake pressure downstream of the anti-skid valves, or individual main gear wheel speeds. Therefore, direct FDR time history evidence of flight crew maximum manual wheel braking requests, purposeful or inadvertent partial wheel brake requests, intentional or inadvertent left or right wheel braking requests for directional control, purposeful partial or full brake release, inadvertent parking brake application or inadvertent failure to fully release the parking brake is unavailable to the investigation. Similarly, there is no direct FDR time history record of the anti-skid system command(s) to release the brakes. The calculated equivalent retarding force time history for each case is presented in Figure 6.

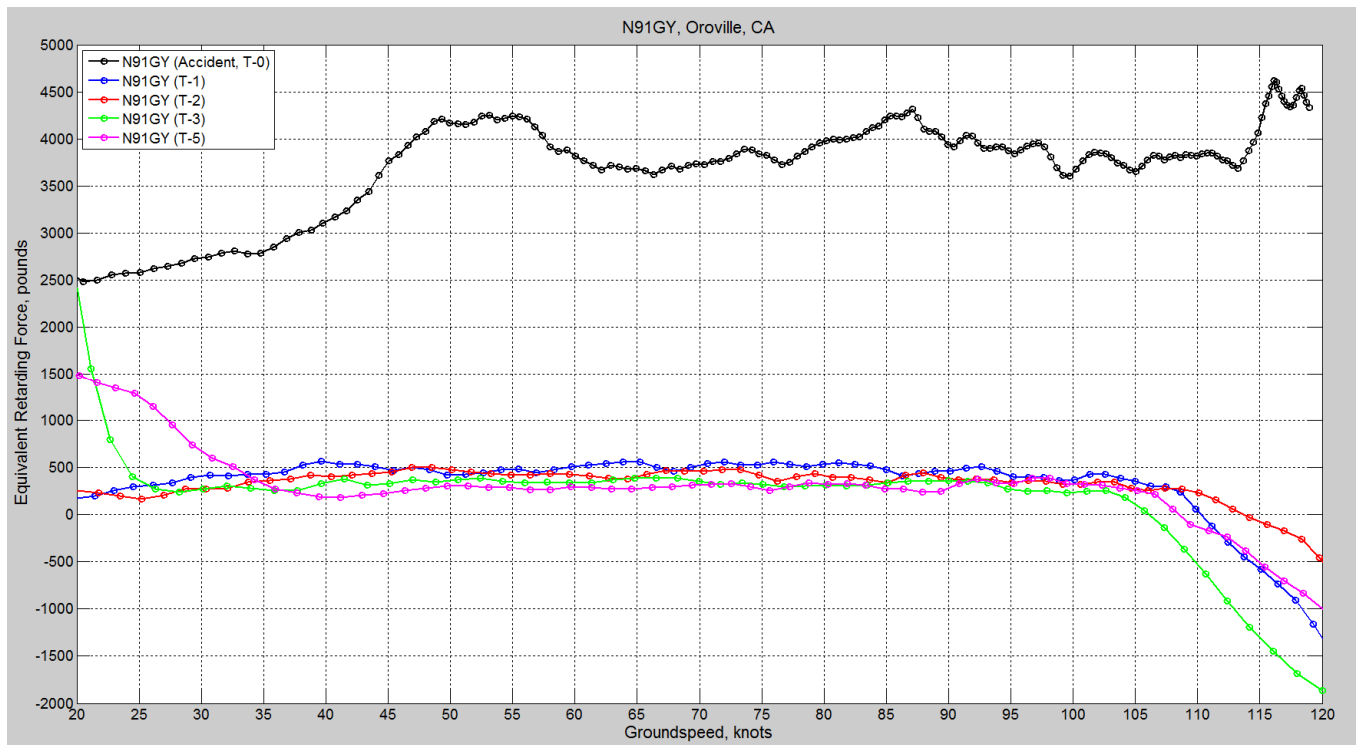


Figure 6: Calculated equivalent retarding force values during the N91GY takeoff ground roll for the T-5, T-3, T-2, T-1, and accident takeoffs. Engine thrust for all cases is based on the accident environmental conditions.

2.12 Validation of Airplane Braking Coefficient Extraction Method (Saab 2000 Example)

The airplane braking coefficient extraction method applied for this investigation has been validated and applied for preceding Saab 2000 and Boeing 737-700 ground roll investigations. For example, Saab 2000 simplified aerodynamics and engine models were used with airplane configuration and loading data to calculate the airplane braking coefficient during the ground roll for a flight test accelerate-stop maneuver. The results in Figure 7 demonstrate expected, nearly constant, rolling wheel friction coefficient values during the takeoff ground roll as well as expected airplane braking coefficient values during a maximum performance stop event (rejected takeoff, RTO) on a bare and dry runway.

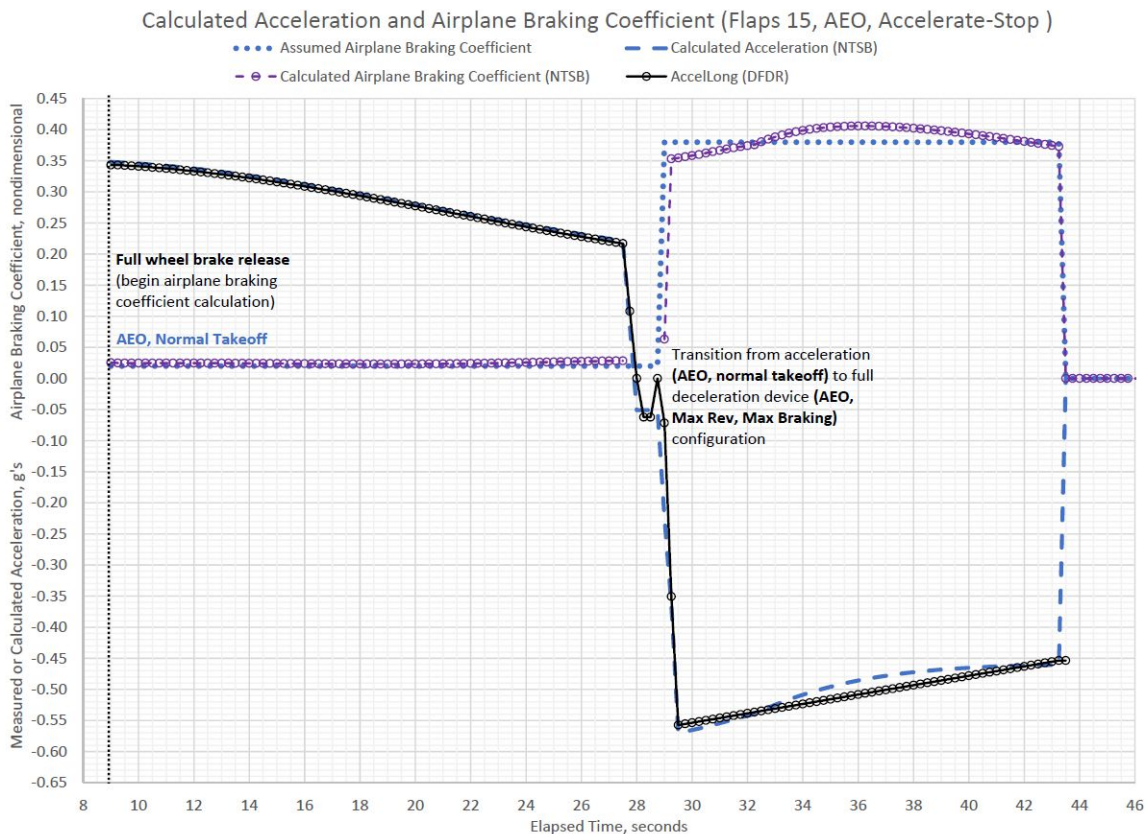


Figure 7: Calculated acceleration and airplane braking coefficient values for Saab 2000 accelerate-stop flight test condition (NTSB simplified Saab 2000 model, with engine reverse thrust transition correction)

2.13 N91GY Ground Track Reconstruction

The paraphrased CVR events in Table 2 were aligned with FDR time history data based on four (4) common VHF microphone keying events. The resulting time correlation between FDR and CVR events yields a time alignment uncertainty of ± 0.2 seconds for the set of four common events. These data establish the time alignment necessary conditions (required event sequence) and sufficient conditions (common event occurrences, such as VHF microphone keying events). Paraphrased CVR events generally represent machine-generated annunciations or flight deck, outbound, or inbound communications.

The NTSB Unmanned Aircraft System (UAS) Aerial Imagery Factual Report documents N91GY witness mark evidence on runway 2. Witness marks attributed to the N91GY left main gear (LMG) wheel path, right main gear (RMG) wheel path, and nose gear (NG) wheel path were added to an NTSB Google Earth ground track reconstruction model.

The time aligned paraphrased CVR events, FDR data, ADS-B data, and calculated equivalent retarding force data are plotted as a function of time in Attachment 7. Similarly, the paraphrased CVR events were positioned on the event ground track reconstruction to yield the runway 2 overview plots in Attachment 8. Calculated groundspeed and distance relative to the runway 2 threshold were added to the ground track at 0.25 second intervals, consistent with the available FDR longitudinal acceleration data.

2.14 Cessna 560XL Pitching Moment Capability

A remaining aircraft performance challenge is to quantify the N91GY airplane nose up (A.N.U.) pitching moment capability of the elevator and horizontal tail for comparison to the airplane nose down (A.N.D.) pitching moment generated by the adverse retarding force acting at the wheel/runway interface.

The airplane weight and balance diagram in Figure 8 can be used to quantify the minimum A.N.U. elevator authority available to counteract the adverse A.N.D. pitching moment generated by the inadvertent retarding force. The N91GY c.g. position is 328 inches and the forward c.g. limit at a weight of 19,112 pounds is 323.5 inches. Since the N91GY c.g. is aft of the forward limit, additional A.N.U. pitching moment should be available (beyond the A.N.U. pitching moment required for a normal configuration takeoff). The minimum additional A.N.U. pitching moment capability in foot-pounds is

$$(N91GY \text{ c.g.} - \text{forward limit c.g.}) \times (\text{weight}) = (328 - 323.5)/12 \times (19,112) = 7,167 \text{ ft-lb A.N.U.}$$

Aerodynamic lift is a function of flap configuration, angle of attack, dynamic pressure, and wing (or tail) planform area. The forward c.g. limit generally defines an elevator pitching moment capability sufficient to rotate the airplane nose up at a target pitch rate at the most adverse combination of flap, weight, c.g., airspeed, and altitude parameters. The most adverse combination of these parameters may equate to an A.N.U. elevator authority for the accident takeoff configuration, loading, and conditions that exceeds 7,167 ft-lb.

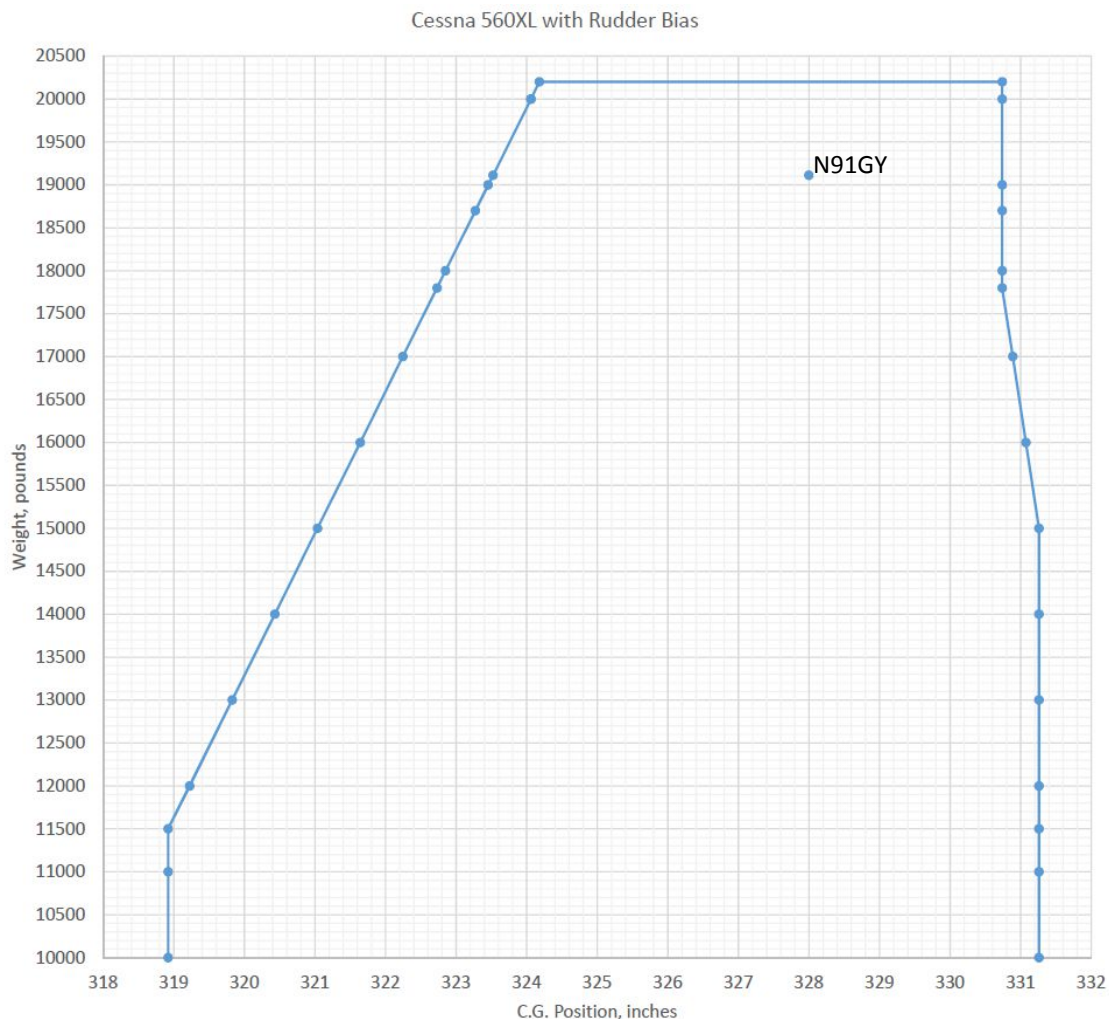


Figure 8: Cessna 560XL weight and balance envelope

Textron Aviation/Cessna was requested to provide nominal 560XL or 560XLS(+) c.g. waterline locations relative to the main gear wheel/runway contact point for the basic operating weight (BOW) and the BOW plus full fuel configurations. The A.N.D. pitching moment due to the calculated equivalent retarding force at the wheel/runway interface during the N91GY takeoff roll is quantified in Figure 9 for a broad range of assumed c.g. waterline locations relative to the main gear wheel/runway contact point. When the Textron Aviation/Cessna c.g. waterline data become available, Figure 9 can be used to estimate the corresponding A.N.D. pitching moment acting on N91GY as a function of groundspeed.

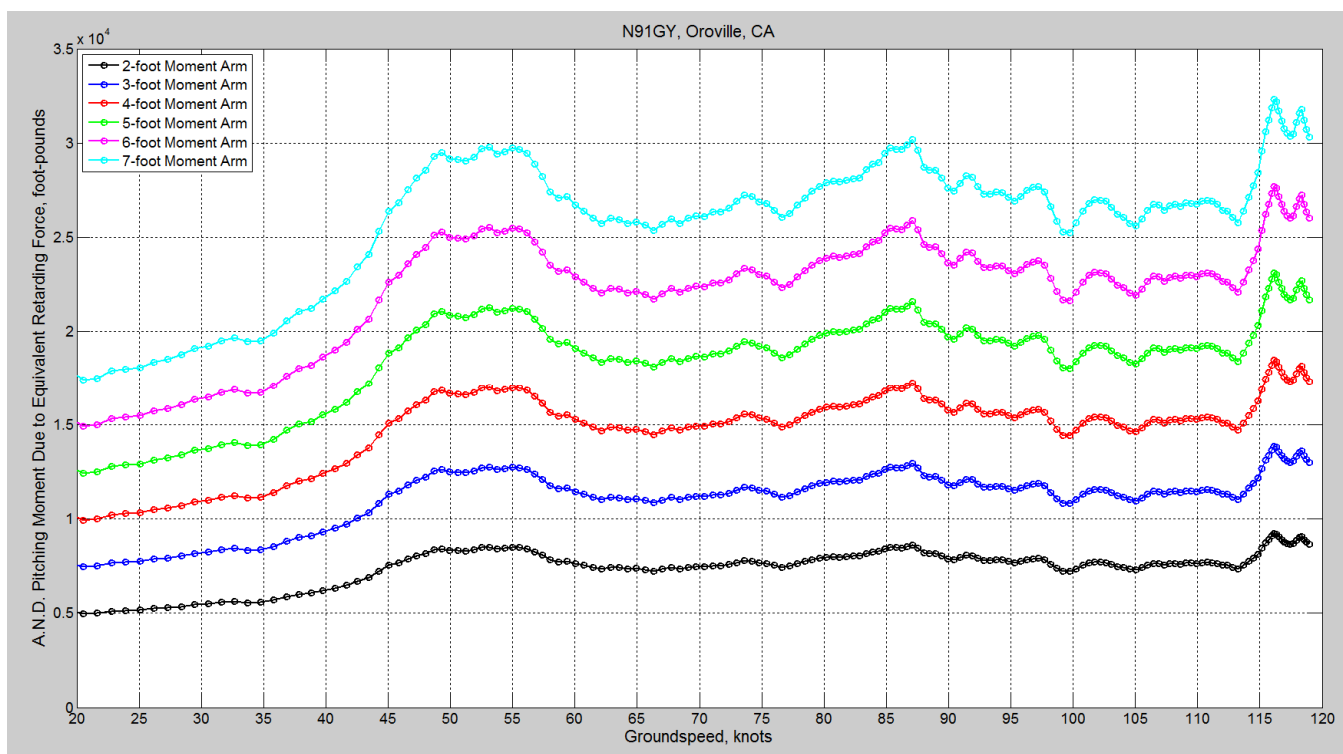


Figure 9: Calculated A.N.D. pitching moment due to calculated equivalent retarding force during the accident takeoff ground roll. Assumed moment arm values are intended to bound the actual N91GY moment arm.

2.15 CVR Sound of Four Aural Chimes

The paraphrased CVR transcript content in Table 2 includes an event described as [Sound of four aural chimes] that precedes an event identified as [Sound of decrease in engine RPM]. NTSB investigators requested Textron Aviation to identify the 560XL candidate condition(s) or configuration(s) that could trigger four aural chimes during the N91GY takeoff ground roll while the airplane was moving on an improved pavement surface. Textron Aviation provided the following written assessment in January 2022:

After a thorough review of engineering documents and the configuration of the above referenced aircraft at the time of delivery [2003 Cessna 560XL; Serial number: 560-5314; REG: N91GY] we have been unable to identify a tone or chime at the frequency and cadence recorded on the cockpit voice recorder. The tones and chimes produced by the airframe systems are at different frequencies and cadences.

2.16 Related Incidents/Accidents

The investigation of the N91GY takeoff runway excursion was hampered by the absence of FDR time history data that documented airplane airspeed, pitch attitude, engine N1, and control column and/or elevator surface position during the accident takeoff roll. However, the Cessna 560XLS involved in the takeoff runway excursion in Farmington, Connecticut on September 2, 2021 (NTSB accident number ERA21FA346) was equipped with an FDR that recorded reliable airplane airspeed, pitch attitude, engine N1, and elevator surface position. These data indicate that the airplane airspeed exceeded V1 and VR and the elevator surface position deflected to the full airplane nose up position, yet the airplane pitch attitude did not increase prior to the airplane's departure from the improved pavement surface.

3.0 SUMMARY

A review of the available Flight Data Recorder (FDR), Cockpit Voice Recorder (CVR), ADS-B, and airport external surveillance camera factual evidence indicated that N91GY was able to accelerate to the rotation speed required for airplane liftoff. Further, N91GY had adequate takeoff performance capability to safely lift off from runway 2 when configured for a normal takeoff. However, the factual evidence and engineering models indicate that N91GY performance was substantially degraded during the accident takeoff roll by an unexpected retarding force acting at the wheel/runway interface. The magnitude and direction of this unexpected force adversely affected N91GY acceleration and rotation capability during the attempted takeoff as well as deceleration capability during the stop.

4.0 ATTACHMENTS

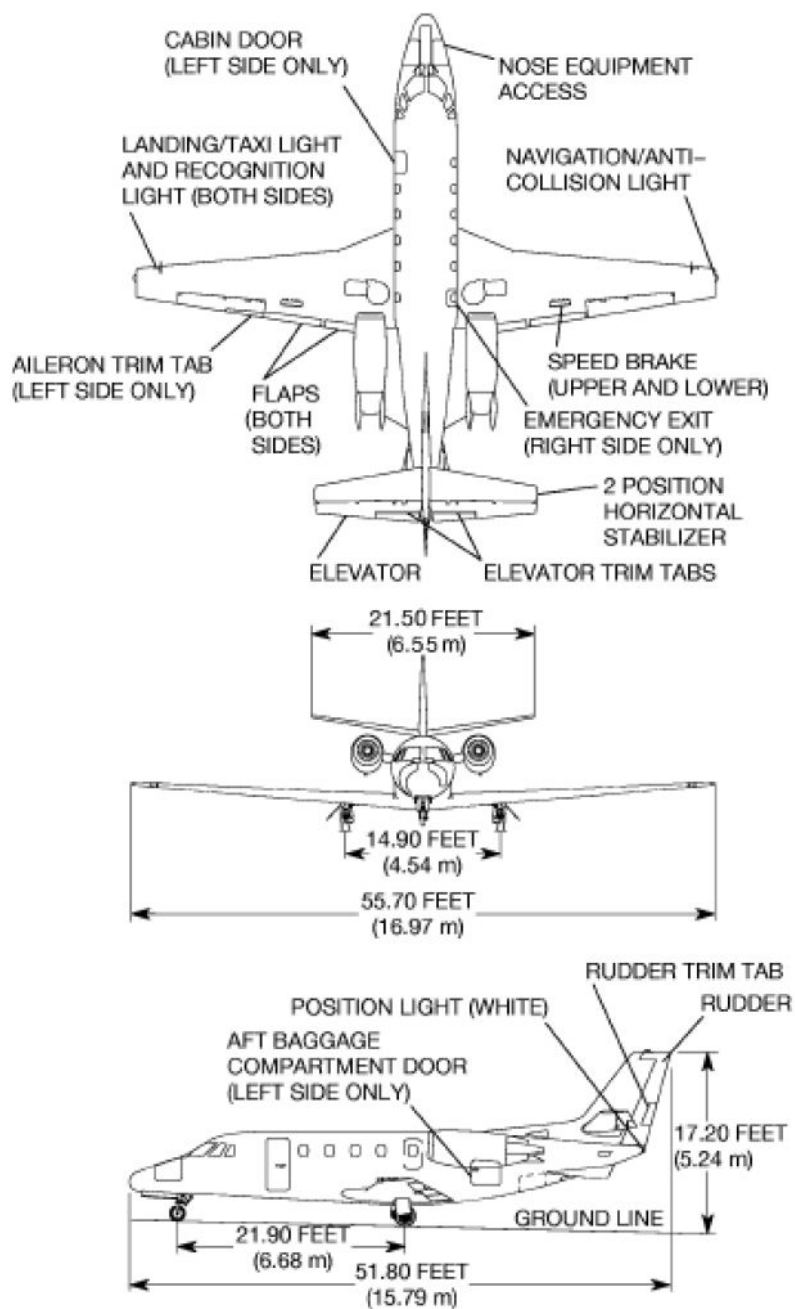
Attachment 1: Cessna 560XL three-view drawing
Attachment 2: KOVE airport diagram
Attachment 3: Image sequence extracted from airport surveillance camera video
Attachment 4: Excerpts from PIC and SIC interview transcripts
Attachment 5: Required takeoff field length
Attachment 6: Calculated N91GY groundspeed
Attachment 7: FDR, paraphrased CVR, ADS-B, and calculated data
Attachment 8: N91GY ground track reconstruction

Attachment 1

Cessna 560XL three-view drawing

AIRPLANE THREE VIEW

A35109



A9910T1002

Figure 1-2*

Figure A1.1: Three-view drawing of Cessna 560 XL

Attachment 2

KOVE airport diagram

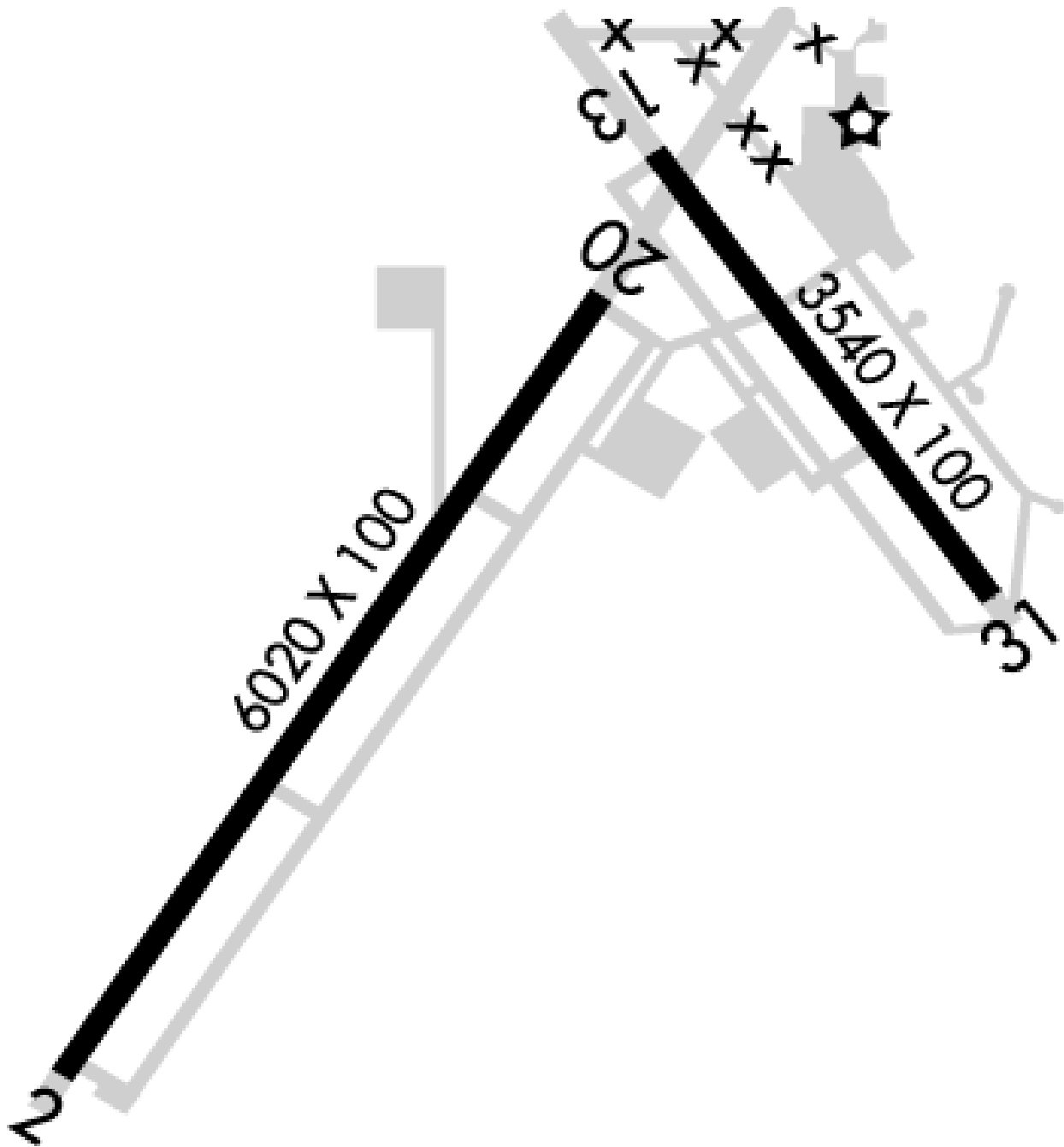


Figure A2.1: KOVE airport diagram (source: <https://www.aopa.org/destinations/airports/KOVE/details>)

Attachment 3

Image sequence extracted from airport surveillance camera video



00001



00002



00003



00004











00013



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00248



Attachment 4

Excerpts from PIC and SIC interview transcripts

Operational Factors – Attachment 2, PIC Interview Transcript 1, August 22, 2019
Screen for “take”

p. 8

18 Called for takeoff power set; it was set. We began rolling
19 down the runway. He called the V1 -- or airspeed log V1, and then
20 Vr, and I pulled the yoke back, and it was just a weird sensation.
21 I pulled back, and the plane didn't lift off. So I pulled it
22 clear back to my chest, and the nose did not move at all.
23 And I remember holding it there just long enough to look at
24 the airspeed, look at the takeoff power set. Nothing happened.
25 And I went into the abort, he yelled abort, and then I pulled the

p. 9

1 full TRs and max braking.

Operational Factors – Attachment 2, PIC Interview Transcript 1, August 22, 2019
Screen for “park”

p. 19

18 Q. So when you're stopped short of the runway, we -- so it's
19 maybe a minute. Did you set the parking brake or do anything?
20 Other checklist items you were -- were you setting the brake or --
21 A. I don't --
22 Q. I don't even know how this brake works, but --
23 A. Yes, I would have set the brake, because the last thing to
24 take the runway would have been the rudder bias check, because I
25 normally don't those, you know, with other planes close by. I'll

p. 20

1 just shove the engines up --
2 Q. Sure.
3 A. -- and I'll get away from everybody. So I set the parking
4 brake and ran the right side, right rudder, you know, run the
5 rudder bias both sides. And he actually saw that, and that's what
6 -- that was the completion of the taxi check.
7 Q. Got it. So it's normal to set the parking brake --
8 A. Yeah. Well, when you don't know the distance or how much
9 time was going to occur too. I normally --
10 Q. Yeah.
11 A. -- just set it.
12 Q. Okay.
13 BY MR.: Q. Did you guys make that callout? When you set
14 the brake, did you call it?
15 A. I do not recall.
16 Q. Okay.
17 BY MR.:
18 Q. So the brake was set, and then you ran up the right engine to
19 50, 70 percent?
20 A. Until you feel the pedal kick --
21 Q. Got it. Okay.
22 A. -- go back to idle, do the other one, same thing.
23 Q. Got it. Okay. That's interesting. And then the callout,
24 what -- can we describe that? So is there a specific callout
25 that's --

p.21

1 A. In general -- I mean, just general aviation, you're going to
2 set the brake, you're going to call out brake set.
3 Q. Okay.
4 Q. Sure. That's much normal callout.

5 Q. So you get the clearance, that checklist -- or the rudder
6 check, power up, power down, and then if you can walk me through
7 the best -- again, just kind of getting onto the runway. Anything
8 -- we've got to hash that out again. Anything specific?
9 A. Not that I recall, no.

Operational Factors – Attachment 2, PIC Interview Transcript 1, August 22, 2019

Screen for “rota” or “pit”

p.14

1 and as we're rolling down the runway, I said something to the
2 effect of nothing. Because I pulled it clear back in my lap and
3 we just stayed planted to the runway.
4 BY MR.:
5 Q. Got it. So during -- V1 comes, Vr, and there's one pull --
6 A. There's one pull about halfway -- it's about halfway, three
quarters is where you feel this little resistance, if you will.
8 And that's normally where the nose just starts to come off.
9 And --
10 Q. Yep.
11 A. -- I pulled it back, and it just -- there was no feeling
12 there. I was like -- held it where I normally do, then I pulled
13 it clear back to my lap, and it just didn't do anything except
14 that it just stayed there.
15 Q. So the pitch, the nose angle --
16 A. Yeah. It didn't --
17 Q. -- just never really --
18 A. Never started to rotate.
19 Q. Never changed? Just --
20 A. Never --
21 Q. This runway has that little downslope, and so it just stayed
22 right there?
23 A. Correct.
24 Q. Okay.
25 A. But I'm -- like, so when I glanced down, I do know that I

p.15

1 recall looking down, and I didn't read them, but I saw the V1, Vr
2 -- like I said, I didn't read them, but I know the airspeed
3 indicator was above them.
4 Q. Got it. So there -- yeah, while we're talking about it,
5 there are speed bugs that you guys can set on this?
6 A. Yes.
7 Q. Okay. Do you remember about what -- or can you recall what
8 they were?
9 A. No.
10 Q. Okay. That's fine.
11 A. I don't recall the exact numbers.

Operational Factors – Attachment 2, PIC Interview Transcript 1, August 22, 2019

Screen for “abor”

p.18

1 Nothing. And then the first officer called abort. Okay.
2 When you apply the thrust reversers and the brakes, did it
3 feel like the airplane decelerated? Did it -- was it a --
4 A. I didn't notice it, no. It honestly just felt like we just
5 kept right on cruising.
6 Q. Got it. Do you remember any sort of marking on the runway of
7 exactly when the abort occurred?

8 A. I don't know the exact, no. the -- I know the blocks -- the
9 mark, you know, the runway indications from the other direction
10 for the touchdown angle points and stuff like that were still in
11 front of us.
12 Q. Okay, okay. So touchdown markers for the opposite runway
13 were still in front. Okay. And again, when the **abort** has
14 happened, you're applying brakes, thrust reversers, it'd be
15 accurate to say that it doesn't feel like the airplane's
16 decelerating?
17 A. Not in my mind, no. It just kept on going.
18 Q. It just kept on going. Any annunciators that you can recall
19 prior --
20 A. No.
21 Q. -- to, you know, impact and, you know, prior --
22 A. No. I -- that I recall seeing, no.
23 Q. Okay.
24 A. My eyes were strictly outside at that point trying to aim the
25 plane.

Operational Factors – Attachment 2, PIC Interview Transcript 1, August 22, 2019 Screen for “col”

p.19

1 Q. All right. Did the control **column** weight feel heavy at all?
2 Did it move freely?
3 A. That's what I -- I characterize the Excel's as a heavy
4 control anyways.
5 Q. Okay.
6 A. Because I came from a CJ plane. So coming to an Excel plane,
7 it definitely feels a lot heavier than that, and I don't recall
8 that feeling, that sensation at all when I pulled it back. Could
9 be that my adrenaline was pumping, or --
10 Q. So it normally feels heavy, and in this case it --
11 A. I just remember pulling back, and doing -- like I said, I was
12 like, pulled it clear back, and I was like, nothing.
13 Q. Got it.

Operational Factors – Attachment 3, PIC Interview Transcript 2, August 28, 2019 Screen for “park”

p.52

13 Q. Got it. And you guys were -- you were ready to -- you're --
14 you've got your clearance flight time, you're --
15 A. Yep.
16 Q. -- ready to go. When did -- do you remember turning off the
17 **parking** brake?
18 A. I do not.
19 Q. You don't remember? When you took the runway, it's set for
20 the rudder bias check, the location of it, and the flow -- the
21 before takeoff, do you -- any recollection, turning off the
22 **parking** brake?
23 A. I do not.
24 Q. No? Okay. Do you believe that the **parking** brake was on --
25 engaged for the takeoff?

p. 53

1 A. I do not, but I don't know.
2 Q. You don't recall?
3 A. I really don't know.

p. 63

17 MR.: Yeah. And that's -- I think that's a good --
18 so overall, the decision to abort the takeoff, the -- can you just
19 walk us through the things that allowed you to continue the
20 takeoff role? What were some of the items that --
21 MR.: Airspeed was still increasing, it wasn't
22 abnormal. I mean it -- granted it was slow, but like I said, I
23 was like, hey, we're heavy, it's high density. I wasn't expecting
24 to be a rocket ship anyways. And like, I keep going back to in my
25 head, it's like if the airspeed was any slower, and after looking

p. 64

1 up systems, like parking brake is set, you don't have anti-skids.
2 If the parking brake is set, you would have flat spotted the
3 tires and they would have blown clear down the runway. If the
4 parking brake is set, they say the airplane won't move. It's
5 like, these type of things are going through my head, after the
6 fact obviously. During the roll, I was -- yep, justified. You
7 know, nothing is really abnormal. Directional control is not --
8 MR.: Yeah.
9 BY MR.:
10 Q. Is that your general expectation of, if the parking brake is
11 set, when you apply power, what do you expect the airplane --
12 A. That's what we were told, that you set the parking brake, you
13 put it up to takeoff, and it shouldn't move.
14 Q. Got it. Have you ever had the airplane move when you had the
15 parking brake set? In your experience in this airplane?
16 A. In this airplane? I don't recall anything in this airplane.
17 Q. Got it. But -- so generally it would be accurate to say, if
18 the parking brake is set, your expectation is --
19 A. That it's not going to move because the parking brake is set.

Operational Factors – Attachment 4, SIC Interview Transcript 1, August 22, 2019

Screen for “park”

1 A. -- so much. I don't know. But I do know that the parking
2 brake was set when we did the rudder bias -- when he did the
3 rudder bias check, the brakes were set. And as I stated before,
4 that was before we left the ramp on the FBO.
5 Q. Got it. Before, okay. So overall again, it sounds like to
6 your knowledge, that point of clearance -- there was no call of
7 parking brake set or -- and then the rudder checks were done,
8 again at the -- in the ramp area.
9 A. In the ramp area, correct.
10 Q. Okay.
11 A. It's the easiest place to do it. There's no aircraft or
12 anything around it --
13 Q. Okay.
14 A. -- that was going to be jeopardized by the advanced
15 throttles.
16 Q. All right. So there's -- any annunciation -- annunciators
17 that you can recall?
18 A. No annunciators were done. And as part of the checklist on
19 startup and everything, you do the rotary test and verify all are
20 working. They were all working.
21 Q. They were all working?
22 A. They were all working.

Operational Factors – Attachment 4, SIC Interview Transcript 1, August 22, 2019

Screen for “take”

p. 10

18 A. We made a call, taking active Runway 2 departure. We took
19 the active, the before **takeoff** above and below items were called.
20 Per his request, we followed them, I called them, he verified, and
21 we started departure.
22 [Mr. ...] advanced the throttles, as the power was coming up, I
23 said, speeds alive, it's usually around 50 knots or so. Eighty
24 knots, I called crosscheck, panel clear, verified. At V1 I called
25 V1. I called rotate, at which point [Mr. ...] pulled the yoke

p. 11

1 completely to his chest very quickly, which took me a little off
2 guard.
3 I don't know what the timeline was. It could have been a
4 couple of seconds, it could have been instantaneous, I don't know,
5 but as soon as there was no lift rotation -- literally the nose
6 never came off the ground, I called abort. I don't know where
7 that was on the runway. I don't know how much runway was left.

Operational Factors – Attachment 5, SIC Interview Transcript 2, August 28, 2019

Screen for “rota”

p. 31

9 Q. Got it. Okay. I want to go back to -- up until the time,
10 you've said this previously, for the aborted takeoff. Is it
11 correct to say that when you saw the captain pull the yoke nearly
12 to his lap or in his lap, is that the main -- is that what caused
13 you to -- is that the main reason of why you called for the abort?
14 A. The yoke came back to his chest after **rotate** -- I called V1
15 **rotate**. He pulled the yoke back quickly to his chest, we looked
16 at each other, and his expression was nothing verbally, at which
17 point I called abort. It was an abnormal situation for the yoke
18 to come back that far and for the nose not to come off the runway.
19 Q. Okay. Is there any point prior to this point that you --
20 there's any indication that would have been given to you whether
21 or not you were seeing anything outside or inside, that you would
22 have wanted to abort or thought about calling for the abort?
23 A. I don't recall seeing any reason to do that. The aircraft
24 built speed in the allotted time for the distance of the runway.
25 I called the speeds as they came up.

Attachment 5

Required takeoff field length (accident flight)

Flaps 7, anti-ice off, dry runway		As implemented	
Weight, lb	19112	NTSB Valid Range	19112 19000-19500
Temperature, C	28		28 25-30
Tailwind, KT	3		3 0-10
Pressure Alt, FT	177		177 0-1000
TOFL, FT	4697.4		4697.4 4638 Textron
V1, KIAS	106.2		106.2 106
VR, KIAS	106.2		106.2 106
V2, KIAS	123.2		123.2 123

SECTION IV - PERFORMANCE TAKEOFF

MODEL 560XL

TAKEOFF FIELD LENGTH - FEET (OVER 35 FOOT SCREEN HEIGHT)

FLAPS - 7° SEA LEVEL

CONDITIONS: DRY RUNWAY
RUNWAY GRADIENT - ZERO
LANDING GEAR - DOWN
SPEED BRAKES - RETRACT

ANTI-ICE OFF
INOPERATIVE ENGINE - WINDMILLING AFTER V1
OPERATIVE ENGINE - TAKEOFF THRUST

SOME CONDITIONS DO NOT MEET CLIMB REQUIREMENTS. OBTAIN ALLOWABLE WEIGHT FROM MAXIMUM TAKEOFF WEIGHT TABLES.

Sea level, flaps 7, anti-ice off, dry runway

Weight 19500 lb							
Temp	0.6	10 KT TW	10 KT TW	0 KT WIND	0 KT WIND	VR	V2
C	V1	DIST	V1	DIST	VR	V2	
KIAS	FT	KIAS	FT	KIAS	FT	KIAS	KIAS
25	107	5440	107	4160	107	124	
28	107	5824	107	4400	107	124	
30	107	6080	107	4560	107	124	

Sea level, flaps 7, anti-ice off, dry runway

Weight 19000 lb							
Temp	0.224	10 KT TW	10 KT TW	0 KT WIND	0 KT WIND	VR	V2
C	V1	DIST	V1	DIST	VR	V2	
KIAS	FT	KIAS	FT	KIAS	FT	KIAS	KIAS
19000	106	5490	105.2	4162	106	123	
19112	106.2	5564.8	105.6	4215.3	106.2	123.2	
19500	107	5824	107	4400	107	124	

10 3 0 0.3
4620.2 ft

Sea level, flaps 7, anti-ice off, dry runway

Weight 19000 lb							
Temp	0.6	10 KT TW	10 KT TW	0 KT WIND	0 KT WIND	VR	V2
C	V1	DIST	V1	DIST	VR	V2	
KIAS	FT	KIAS	FT	KIAS	FT	KIAS	KIAS
25	106	5130	104	3970	106	123	
28	106	5490	105.2	4162	106	123	
30	106	5730	106	4290	106	123	

Flaps 7, anti-ice off, dry runway

0.177							
Pressure Alt	DIST	Tailwind	Weight	V1	VR	V2	
FT	FT	KT	lb	KIAS	KIAS	KIAS	
0	4620.2	3	19112	106.2	106.2	123.2	
177	4697.4	3.0	19112.0	106.2	106.2	123.2	
1000	5056.7	3	19112	106.2	106.2	123.2	

WEIGHT = 20000 LBS												VENR = 160 KIAS												WEIGHT = 19500 LBS												VENR = 160 KIAS											
TEMP DEG C	TAILWIND 10 KTS		ZERO WIND		HEAD WINDS								VR	V2	TEMP DEG C	TAILWIND 10 KTS		ZERO WIND		HEAD WINDS								VR	V2																		
					10 KTS		20 KTS		30 KTS		10 KTS									20 KTS		30 KTS																									
	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST				V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST			V1	DIST	V1	DIST	V1	DIST												
	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT																	
-25	109	4910	108	3660	108	3440	109	3220	109	3000	109	126	-25	107	4650	106	3500	106	3290	107	3070	107	2870	107	125	-25	107	4650	106	3500																	
-20	109	4980	108	3720	108	3500	109	3280	109	3060	109	126	-20	107	4710	106	3570	106	3340	107	3130	107	2920	107	125	-20	107	4710	106	3570																	
-15	109	5050	108	3790	108	3560	109	3340	109	3120	109	126	-15	107	4780	106	3630	106	3400	107	3190	107	2980	107	125	-15	107	4780	106	3630																	
-10	109	5120	108	3850	108	3620	108	3400	109	3180	109	126	-10	107	4840	106	3690	106	3460	107	3240	107	3030	107	125	-10	107	4840	106	3690																	
-5	109	5190	108	3910	108	3680	108	3460	109	3230	109	126	-5	107	4910	106	3750	106	3520	107	3300	107	3090	107	125	-5	107	4910	106	3750																	
0	109	5260	108	3980	108	3740	108	3520	109	3290	109	126	0	107	4970	106	3810	106	3580	107	3360	107	3140	107	125	0	107	4970	106	3810																	
5	109	5330	108	4040	108	3800	108	3570	109	3350	109	126	5	107	5040	106	3870	106	3640	107	3410	107	3200	107	125	5	107	5040	106	3870																	
10	109	5400	108	4100	108	3870	108	3630	109	3410	109	126	10	107	5110	106	3930	106	3700	107	3470	107	3250	107	125	10	107	5110	106	3930																	
15	109	5470	108	4170	108	3930	108	3690	109	3470	109	126	15	107	5180	106	3990	106	3760	107	3530	107	3310	107	125	15	107	5180	106	3990																	
20	109	5540	108	4230	108	3990	108	3750	109	3530	109	126	20	107	5240	106	4050	106	3820	107	3590	107	3360	107	125	20	107	5240	106	4050																	
25	109	5750	109	4350	109	4100	109	3880	109	3640	109	126	25	107	5440	107	4160	107	3920	107	3690	107	3460	107	124	25	107	5440	107	4160																	
30	109	6450	109	4840	109	4580	109	4320	109	4080	109	126	30	107	6080	107	4560	107	4310	107	4070	107	3830	107	124	30	107	6080	107	4560																	
35	109	7360	109	5490	109	5200	109	4910	109	4630	109	125	35	107	6910	107	5150	107	4870	107	4600	107	4340	107	124	35	107	6910	107	5150																	
40	109	8590	109	6360	109	6030	109	5700	109	5380	109	125	40	107	8020	107	5940	107	5630	107	5320	107	5020	107	124	40	107	8020	107	5940																	
45	109	10370	109	7600	109	7210	109	6820	109	6450	109	125	45	107	9810	107	7050	107	6680	107	6320	107	5970	107	124	45	107	9810	107	7050																	
47	109	11330	109	8270	109	7840	109	7420	109	7020	109	125	47	107	10450	107	7640	107	7240	107	6850	107	6470	107	124	47	107	10450	107	7640																	
													48	107	10940	107	7970	107	7560	107	7150	107	6760	107	124	48	107	10940	107	7970																	

WEIGHT = 19000 LBS												VENR = 160 KIAS												WEIGHT = 18500 LBS												VENR = 160 KIAS											
TEMP DEG C	TAILWIND 10 KTS		ZERO WIND		HEAD WINDS						VR	V2	TEMP DEG C	TAILWIND 10 KTS		ZERO WIND		HEAD WINDS						VR	V2																						
					10 KTS		20 KTS		30 KTS									10 KTS		20 KTS		30 KTS																									
	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST				V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST			V1	DIST																				
	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT				KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT	KIAS	FT			KIAS	FT	KIAS	FT																		
-25	106	4390	104	3350	104	3140	105	2940	105	2740	106	123	-25	105	4150	102	3200	102	3000	103	2800	103	2610	105	122																						
-20	106	4460	104	3410	104	3200	105	2990	105	2790	106	123	-20	105	4210	102	3260	102	3050	102	2850	103	2660	105	122																						
-15	106	4520	104	3470	104	3250	105	3040	105	2840	106	123	-15	105	4270	102	3310	102	3110	102	2900	103	2710	105	122																						
-10	106	4580	104	3520	104	3310	104	3100	105	2890	106	123	-10	105	4330	102	3370	102	3160	102	2960	103	2760	105	122																						
-5	106	4640	104	3580	104	3360	104	3150	105	2950	106	123	-5	105	4390	102	3420	102	3210	102	3010	103	2810	105	122																						
0	106	4700	104	3640	104	3420	104	3210	105	3000	106	123	0	105	4440	102	3480	102	3260	102	3060	103	2860	105	122																						
5	106	4770	104	3700	104	3480	104	3260	105	3050	106	123	5	105	4500	102	3530	102	3320	102	3110	103	2910	105	122																						
10	106	4830	104	3760	104	3530	104	3310	105	3100	106	123	10	105	4560	102	3590	102	3370	102	3160	102	2960	105	122																						
15	106	4890	104	3820	104	3590	104	3370	105	3160	106	123	15	105	4630	102	3640	102	3430	102	3220	102	3010	105	122																						
20	106	4960	104	3870	104	3650	104	3430	105	3210	106	123	20	105	4680	102	3700	102	3480	102	3270	102	3060	105	122																						
25	106	5130	104	3970	105	3740	105	3520	105	3300	106	123	25	105	4840	102	3790	103	3570	103	3350	103	3140	105	122																						
30	106	5730	106	4290	106	4050	106	3820	106	3600	106	123	30	105	5390	104	4080	104	3840	104	3610	105	3390	105	121																						
35	106	6490	106	4840	106	4570	106	4310	106	4060	106	123	35	105	6090	105	4540	105	4290	105	4040	105	3800	105	121																						
40	106	7490	106	5550	106	5250	106	4980	106	4680	106	122	40	105	7000	105	5190	105	4900	105	4630	105	4360	105	121																						
45	106	8910	106	6550	106	6200	106	5860	106	5530	106	122	45	105	8270	105	6080	105	5750	105	5430	105	5120	105	121																						
48	106	10090	106	7360	106	6970	106	6590	106	6220	106	122	50	105	10030	105	7300	105	6910	105	6530	105	6160	105	121																						
50	106	10920	106	7930	106	7510	106	7110	106	6710	106	122	52	105	10860	105	7860	105	7450	105	7040	105	6650	105	121																						

SECTION IV - PERFORMANCE
TAKEOFF

MODEL 560XL

C	F
0	32
100	212
15	59
28	82.4

TAKEOFF FIELD LENGTH - FEET
(OVER 35 FOOT SCREEN HEIGHT)

FLAPS - 7°
1000 FEET

CONDITIONS: DRY RUNWAY
RUNWAY GRADIENT - ZERO
LANDING GEAR - DOWN
SPEED BRAKES - RETRACT

ANTI-ICE OFF
INOPERATIVE ENGINE - WINDMILLING AFTER V1
OPERATIVE ENGINE - TAKEOFF THRUST

SOME CONDITIONS DO NOT MEET CLIMB REQUIREMENTS. OBTAIN ALLOWABLE WEIGHT FROM MAXIMUM TAKEOFF WEIGHT TABLES.

1000 ft, flaps 7, anti-ice off, dry runway							
Weight 19500 lb							
	0.6 10 KT TW	10 KT TW	0 KT WIND	0 KT WIND			
Temp	V1	DIST	V1	DIST	VR	V2	
C	KIAS	FT	KIAS	FT	KIAS	KIAS	
25	107	5980	107	4500	107	124	
28	107	6412	107	4812	107	124	
30	107	6700	107	5020	107	124	
1000 ft, flaps 7, anti-ice off, dry runway							
0.224 10 KT TW 10 KT TW 0 KT WIND 0 KT WIND							
Weight	V1	DIST	V1	DIST	VR	V2	
lb	KIAS	FT	KIAS	FT	KIAS	KIAS	
19000	106	6036	106	4540	106	123	
19112	106.2	6120.2	106.2	4600.9	106.2	123.2	
19500	107	6412	107	4812	107	124	
		10	3	0	0.3		
			5056.7 ft				

1000 ft, flaps 7, anti-ice off, dry runway							
Weight 19000 lb							
	0.6 10 KT TW	10 KT TW	0 KT WIND	0 KT WIND			
Temp	V1	DIST	V1	DIST	VR	V2	
C	KIAS	FT	KIAS	FT	KIAS	KIAS	
25	106	5640	106	4270	106	123	
28	106	6036	106	4540	106	123	
30	106	6300	106	4720	106	123	

WEIGHT = 20000 LBS										VENR = 160 KIAS										WEIGHT = 19500 LBS										VENR = 160 KIAS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
TEMP DEG C	TAILWIND 10 KTS		ZERO WIND		HEAD WINDS						VR V2		TEMP DEG C	TAILWIND 10 KTS		ZERO WIND		HEAD WINDS						VR V2																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
					10 KTS		20 KTS		30 KTS									10 KTS		20 KTS		30 KTS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST		V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST	V1	DIST</

WEIGHT = 19000 LBS										WEIGHT = 18500 LBS									
TEMP DEG C	TAILWIND 10 KTS V1 DIST KIAS FT	ZERO WIND V1 DIST KIAS FT	HEAD WINDS						VR V2 KIAS	TEMP DEG C	TAILWIND 10 KTS V1 DIST KIAS FT	ZERO WIND V1 DIST KIAS FT	HEAD WINDS						VR V2 KIAS
			10 KTS		20 KTS		30 KTS						10 KTS		20 KTS		30 KTS		
			V1	DIST	V1	DIST	V1	DIST					V1	DIST	V1	DIST	V1	DIST	
			KIAS	FT	KIAS	FT	KIAS	FT					KIAS	FT	KIAS	FT	KIAS	FT	
-25	106 4580	104 3490	105 3270	105 3060	105 2860	106 123	-25	105 4330	102 3330	103 3130	103 2920	103 2730	105 122						
-20	106 4640	104 3550	105 3330	105 3120	105 2910	106 123	-20	105 4390	102 3390	103 3180	103 2980	103 2780	105 122						
-15	106 4710	104 3610	105 3390	105 3180	105 2970	106 123	-15	105 4450	102 3450	103 3240	103 3030	103 2830	105 122						
-10	106 4770	104 3670	105 3450	105 3230	105 3020	106 123	-10	105 4510	102 3510	103 3290	103 3080	103 2880	105 122						
-5	106 4840	104 3730	104 3510	105 3290	105 3080	106 123	-5	105 4570	102 3560	103 3350	103 3140	103 2930	105 122						
0	106 4900	104 3790	104 3570	105 3350	105 3130	106 123	0	105 4630	102 3620	103 3400	103 3190	103 2990	105 122						
5	106 4970	104 3850	104 3630	105 3400	105 3190	106 123	5	105 4700	102 3680	103 3460	103 3250	103 3040	105 122						
10	106 5040	104 3920	104 3690	105 3460	105 3250	106 123	10	105 4760	102 3740	103 3520	103 3300	103 3090	105 122						
15	106 5110	104 3980	104 3750	105 3520	105 3300	106 123	15	105 4830	102 3800	103 3580	103 3360	103 3150	105 122						
20	106 5180	104 4030	104 3800	105 3580	105 3350	106 123	20	105 4890	102 3850	103 3630	103 3410	103 3200	105 122						
25	106 5240	104 4090	104 3860	105 3640	105 3410	106 123	25	105 4950	102 3910	103 3690	103 3470	103 3260	105 121						
30	106 5300	104 4150	104 3920	105 3700	105 3470	106 123	30	105 5010	102 3970	103 3750	103 3530	103 3320	105 121						
35	106 5360	104 4210	104 3980	105 3760	105 3530	106 123	35	105 5070	102 4030	103 3810	103 3590	103 3380	105 121						
40	106 5420	104 4270	104 4040	105 3820	105 3590	106 122	40	105 5130	102 4090	103 3870	103 3650	103 3440	105 121						
45	106 5480	104 4330	104 4100	105 3880	105 3650	106 122	45	105 5190	102 4150	103 3930	103 3710	103 3500	105 121						
47	106 5540	104 4390	104 4160	105 3940	105 3710	106 122	47	105 5250	102 4210	103 3990	103 3770	103 3560	105 121						
49	106 5600	104 4450	104 4220	105 4000	105 3770	106 122	49	105 5310	102 4270	103 4050	103 3830	103 3620	105 120						

Figure A5.2: N91GY takeoff field length data and calculations (accident takeoff)

Attachment 6

Calculated N91GY groundspeed (from integration of FDR longitudinal acceleration data)

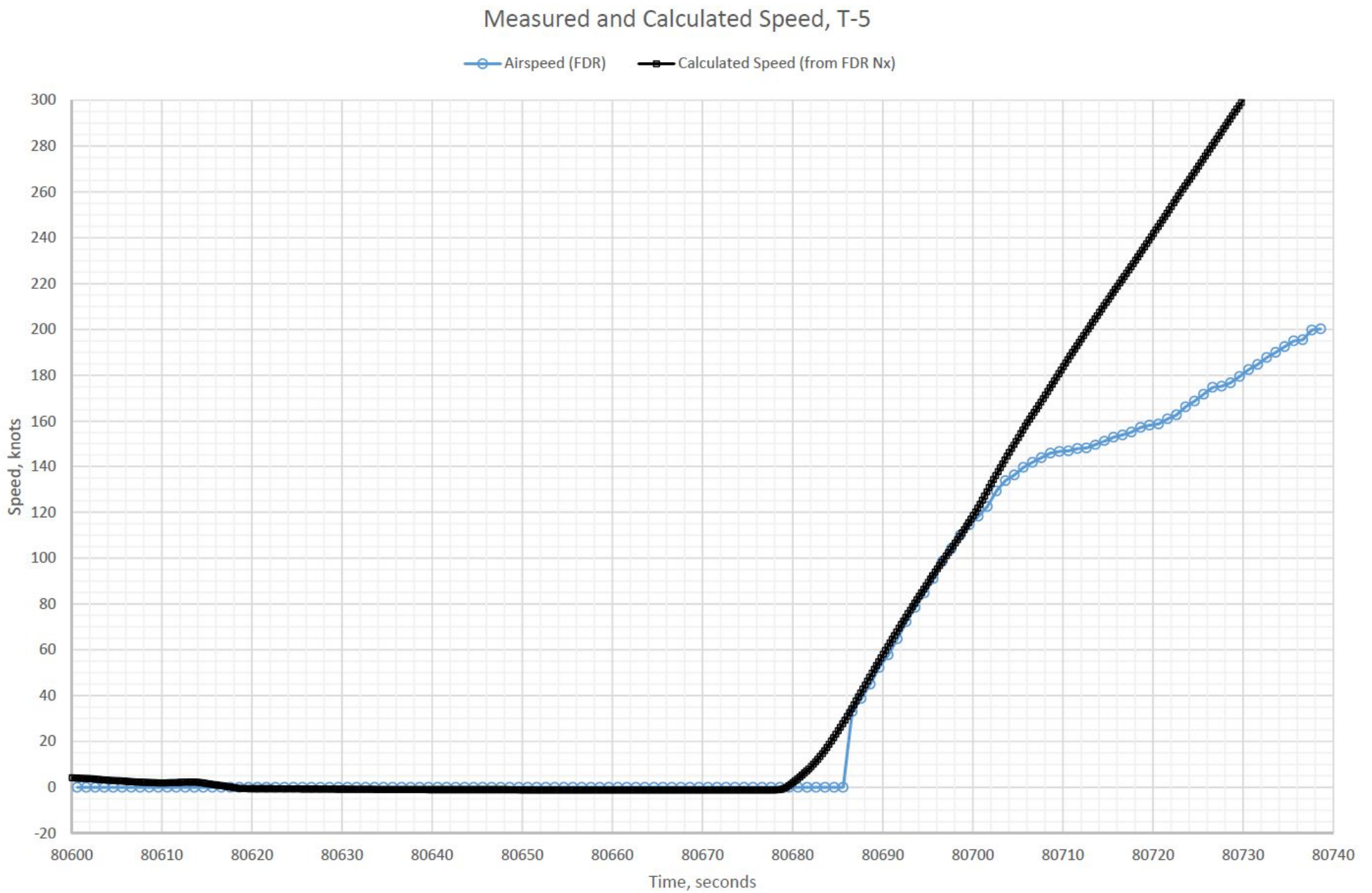


Figure A6.1: Calculated N91GY groundspeed from FDR longitudinal acceleration (fifth takeoff before accident takeoff)

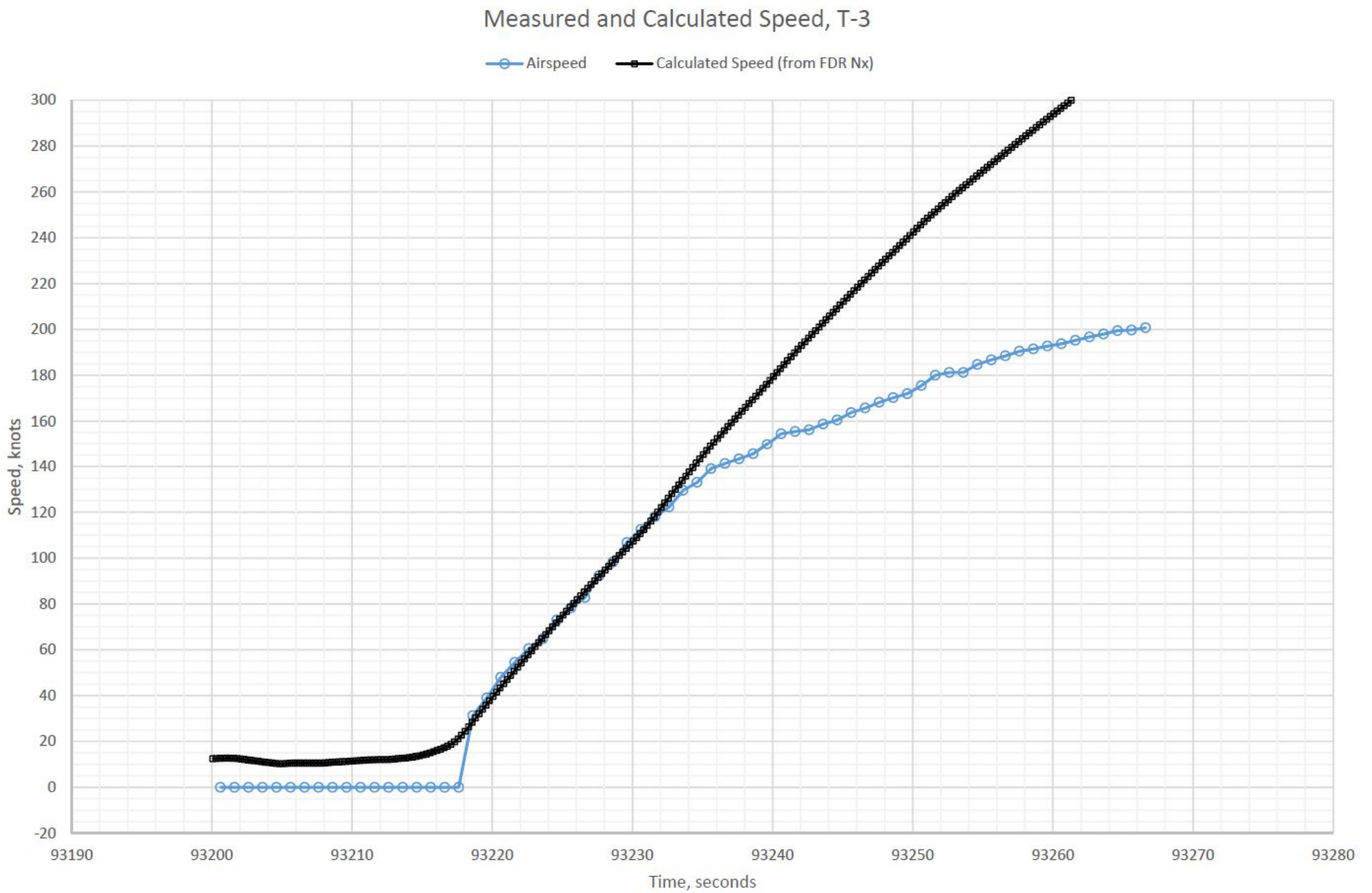


Figure A6.2: Calculated N91GY groundspeed from FDR longitudinal acceleration (third takeoff before accident takeoff)

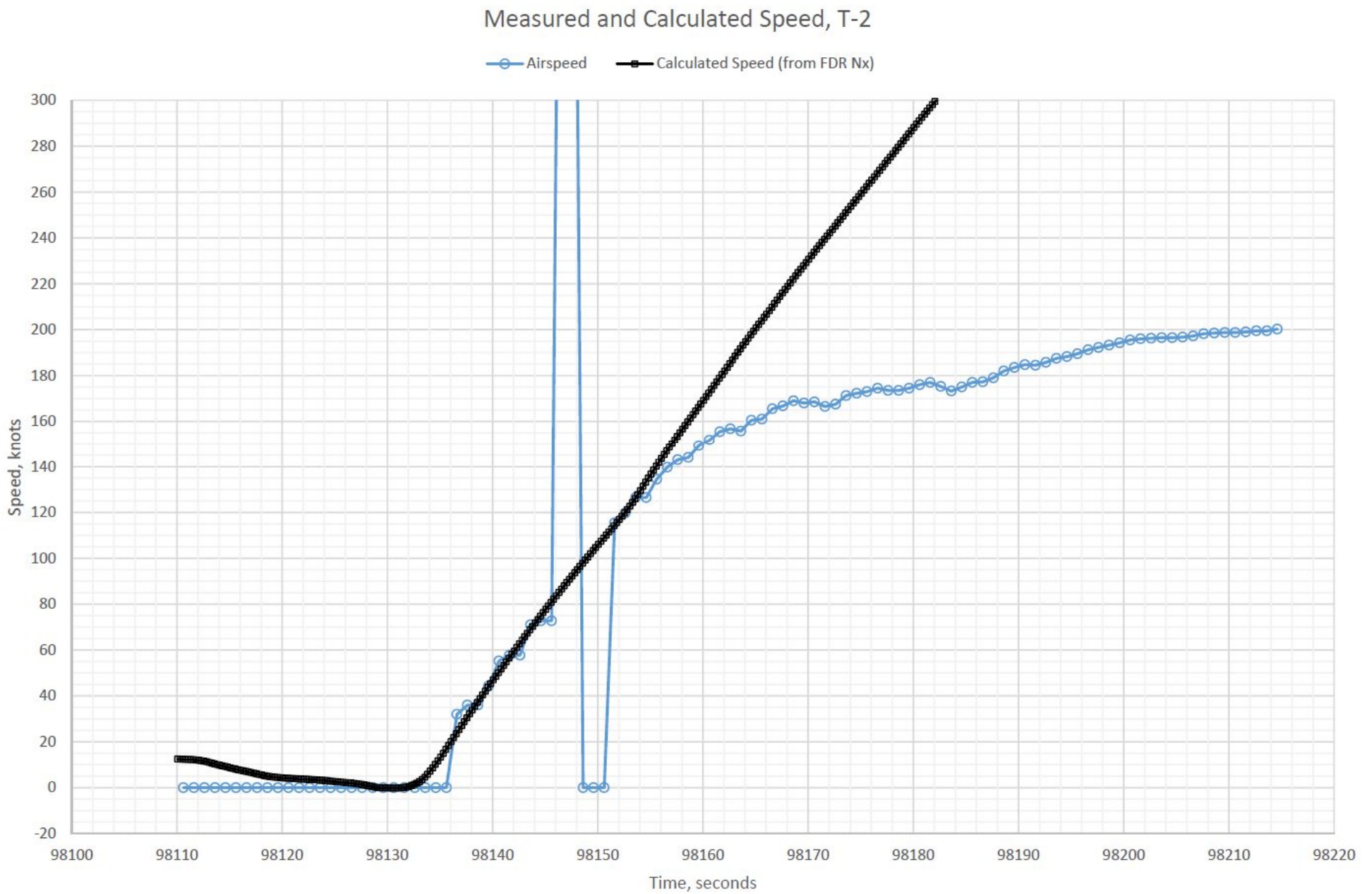


Figure A6.3: Calculated N91GY groundspeed from FDR longitudinal acceleration (second takeoff before accident takeoff)

Measured and Calculated Speed, T-1

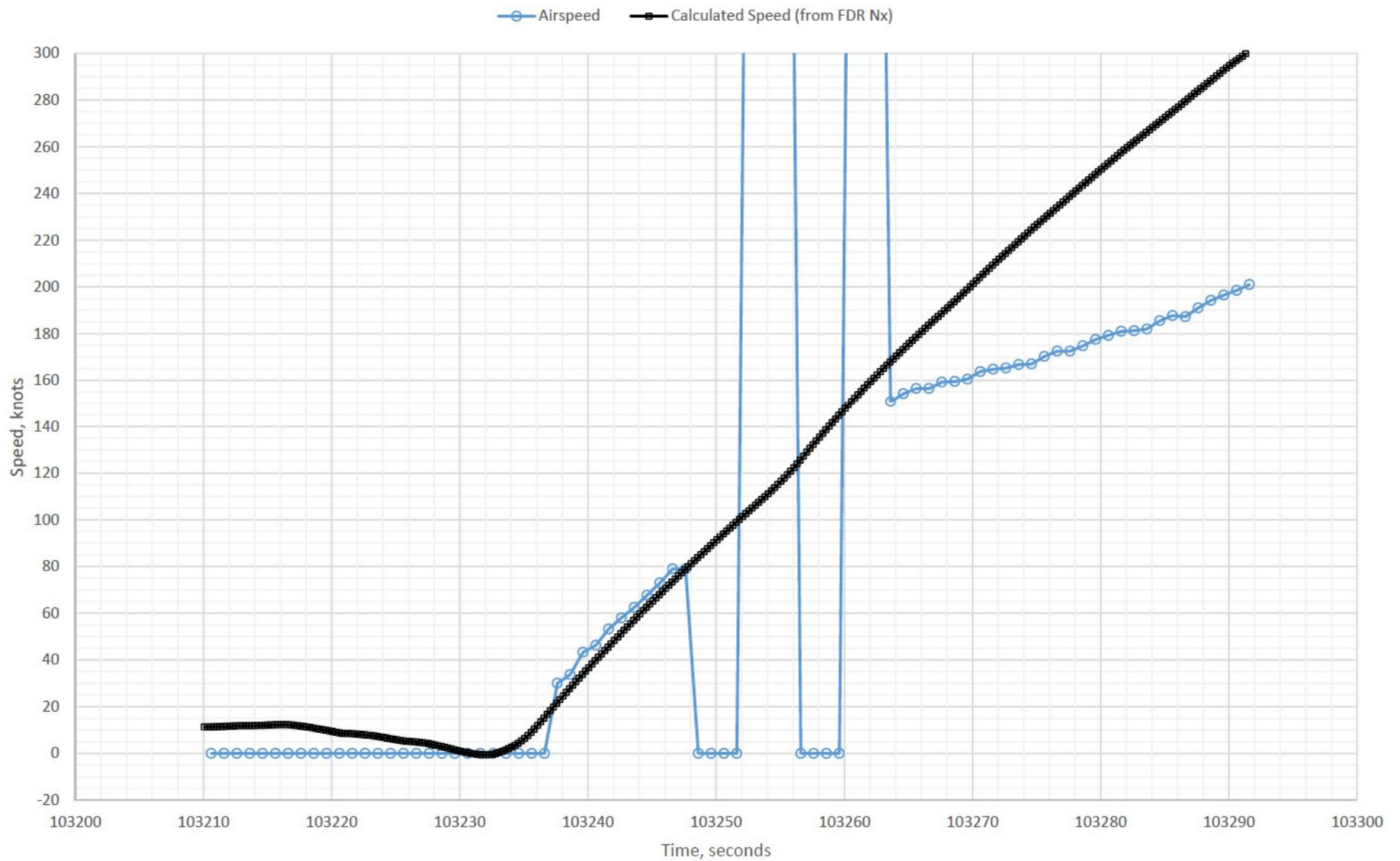


Figure A6.4: Calculated N91GY groundspeed from FDR longitudinal acceleration (takeoff before accident takeoff)

Measured and Calculated Speed, Event

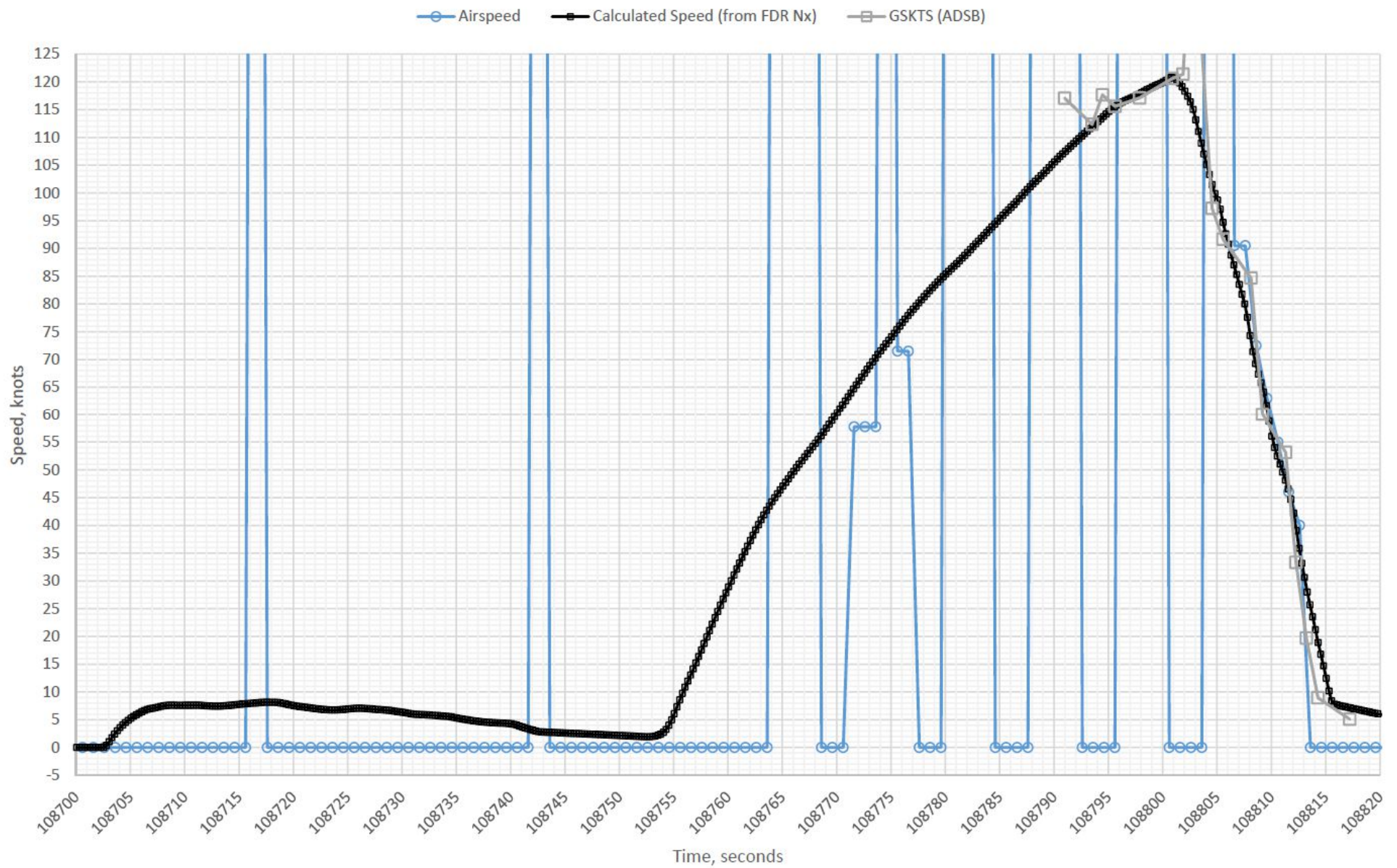


Figure A6.5: Calculated N91GY groundspeed from FDR longitudinal acceleration (accident takeoff)

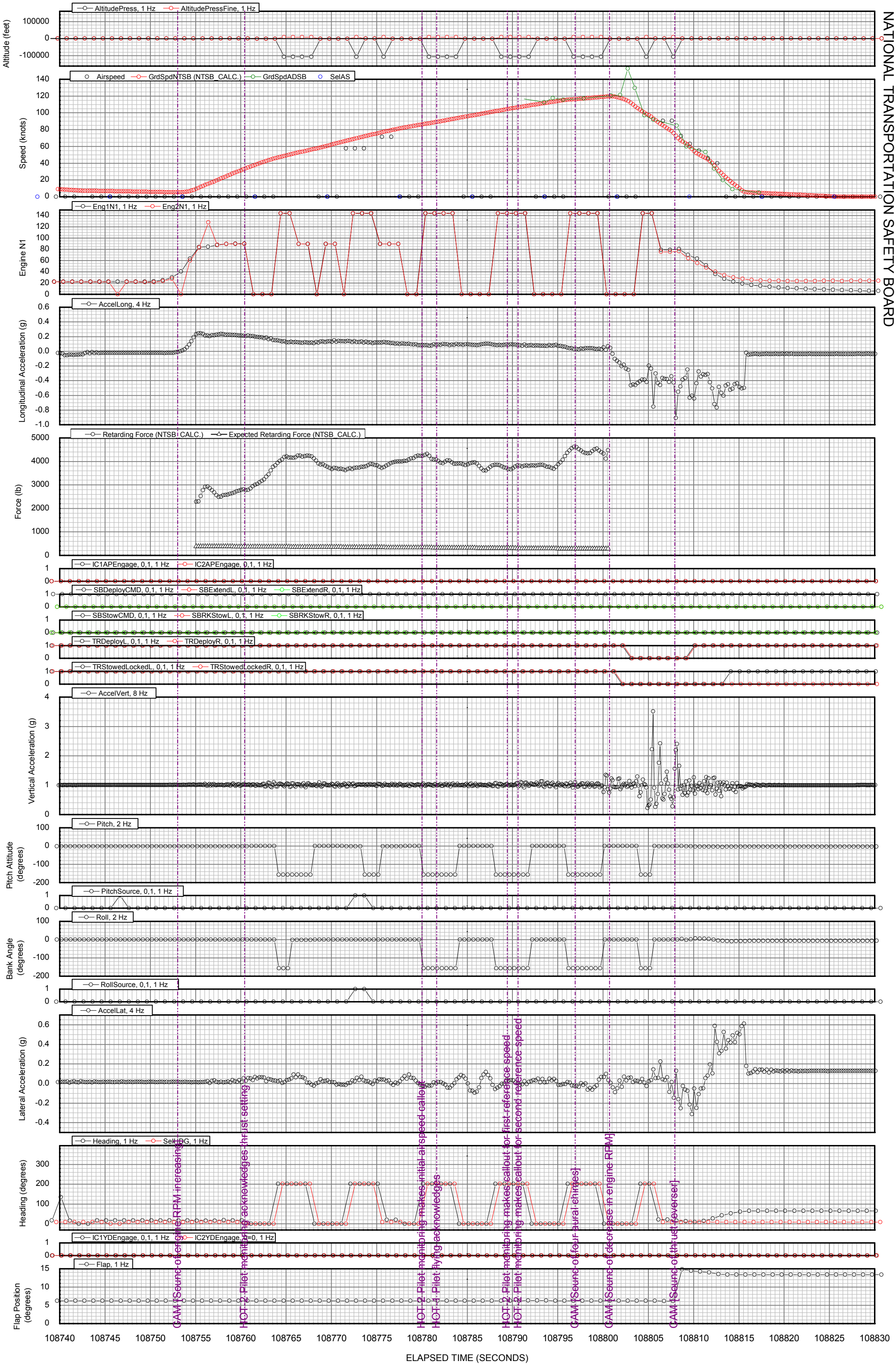
Attachment 7

FDR, paraphrased CVR, ADS-B, and calculated data

DELTA PRIVATE JETS CESSNA 560XL (N91GY) TAKEOFF RUNWAY EXCURSION

RUNWAY 02, OROVILLE MUNICIPAL AIRPORT (OVE), OROVILLE, CA, AUGUST 21, 2019

[FDR, CVR, ADS-B, AND CALCULATED DATA]



Attachment 8

N91GY ground track reconstruction

(Based on FDR, paraphrased CVR, and ADS-B data; tire witness marks; and surveillance camera video)

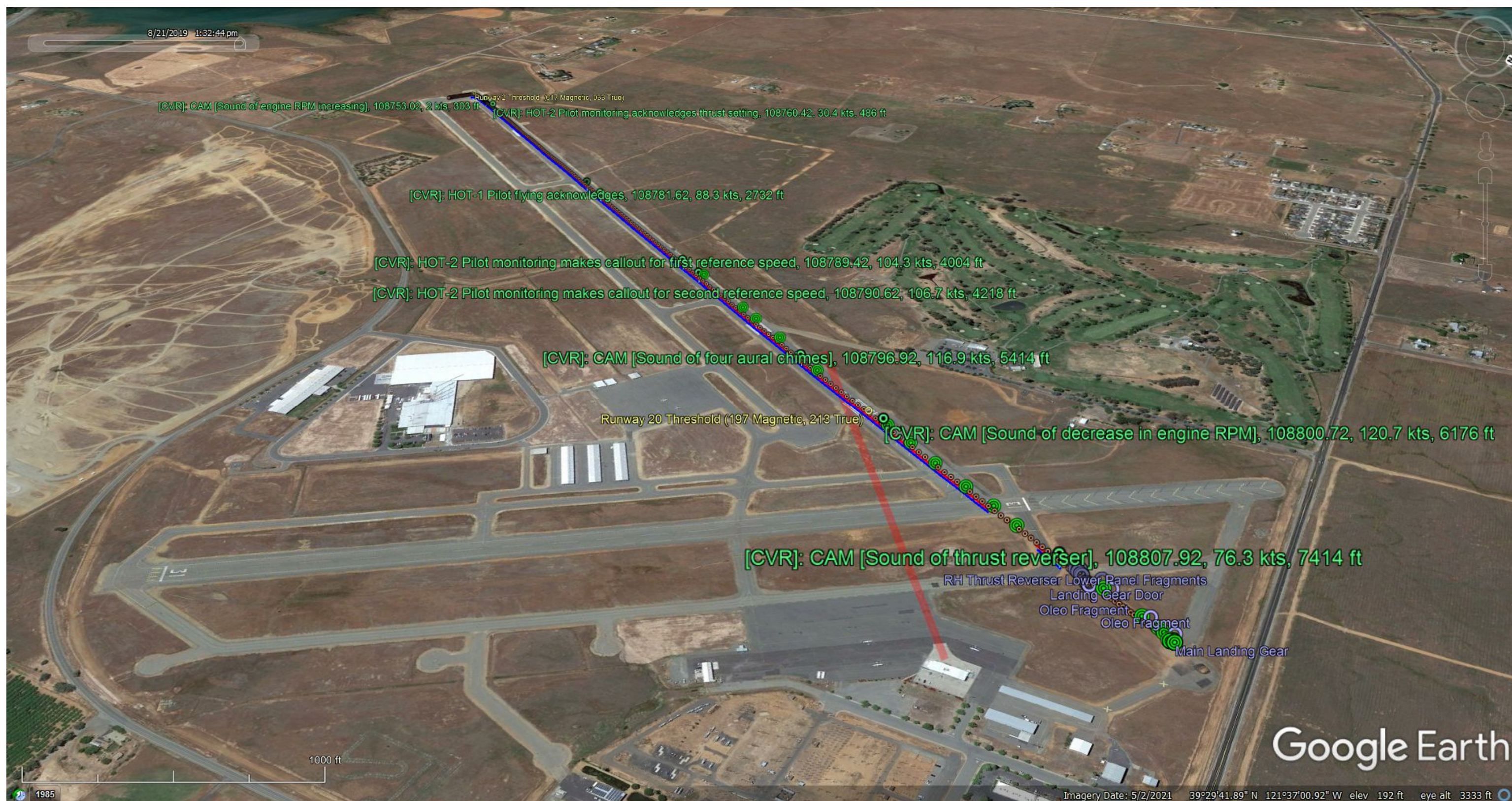


Figure A8.1: N91GY ground track reconstruction, based on FDR, paraphrased CVR, and ADS-B data; tire witness marks; and surveillance camera video evidence.



Figure A8.2: N91GY ground track reconstruction, based on FDR, paraphrased CVR, and ADS-B data; tire witness marks; and surveillance camera video evidence. Initial takeoff acceleration period.



Figure A8.3: N91GY ground track reconstruction, based on FDR, paraphrased CVR, and ADS-B data; tire witness marks; and surveillance camera video evidence. Takeoff acceleration reaches V1 and VR.



Figure A8.4: N91GY ground track reconstruction, based on FDR, paraphrased CVR, and ADS-B data; tire witness marks; and surveillance camera video evidence. Takeoff rejected.