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NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Aircraft Performance Group Chairman

Study

(36 Pages)

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

May 11, 2009

Aircraft Performance Group Study

I. ACCIDENT

NTSB Number:	DCA09MA027
Location:	Clarence Center, New York
Date:	February 12, 2009
Time:	2217 Eastern Standard Time (EST)
Aircraft:	Bombardier DHC-8-400 (N200WQ)
Operator:	Colgan Air, Inc.

II. AIRCRAFT PERFORMANCE GROUP

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1.0 INTRODUCTION

On February 12, 2009, about 2217 Eastern Standard Time (EST), a Colgan Air Inc., Bombardier DHC-8-400, N200WQ, d.b.a. Continental Connection flight 3407, crashed during an instrument approach to runway 23 at the Buffalo-Niagara International Airport (BUF), Buffalo, New York. The crash site was approximately 5 nautical miles northeast of the airport in Clarence Center, New York, and mostly confined to one residential house. The four flight crew and 45 passengers were fatally injured and the aircraft was destroyed by impact forces and post crash fire. There was one ground fatality. Night visual meteorological conditions prevailed at the time of the accident. The flight was a *Code of Federal Regulations* (CFR) Part 121 scheduled passenger flight from Liberty International Airport (EWR), Newark, New Jersey to BUF.

The event flight time alignment between the Cockpit Voice Recorder (CVR), Flight Data Recorder (FDR), and Air Traffic Control (ATC) radar data was determined. Radar data were processed and overlaid on a Clarence Center, New York area map.[1] Flight 3407 longitudinal, lateral-directional, engine, and propeller FDR data were plotted and accelerometer data were corrected and integrated to determine the airplane flight path. The FDR and Bombardier SSDD/SPS document data were used to calculate the fuselage angle of attack and expected airspeed low speed cue as a function of time. Based on the FDR data and the calculated fuselage angle of attack data, the REF SPEEDS switch on the ICE PROTECTION PANEL was selected to the INCR position at the time of the event upset. Finally, selected CVR transcript events were used to annotate FDR time history data.

2.0 METHOD

The data sources and methods used in the study are outlined in this section.

2.1 Time Alignment

The CVR, FDR, radar data, and ATC transcript are each recorded as a function of time. However, the “timestamp” value associated with these data is not necessarily explicit. Moreover, data from two or more independent sources that record explicit timestamp information are generally not synchronized to a common or desired reference time basis. In particular, the CVR and the FDR do not explicitly record a time value with each respective event or data sample. In contrast, each record in a radar log, ATC transcript, security video frame, and ACARS entry is associated with an explicit time value, but the time reference used for each may not be synchronized to a common basis.

The time alignment process yields one or more equations that correlate recorded information from independent sources to a reference clock, thereby defining the accident event sequence and elapsed time between events. The reference clock selected is generally the ATC radar time.

The ability to correlate information between any two independent sources is dependent on the existence of at least one common event between the two sources. In practice, the FDR discrete parameters that indicate the activation of the captain’s or first officer’s VHF radio transmit keys provide common event sources because the begin- and end-keying events are typically recorded on the CVR and the FDR. The communication that occurs between the begin- and end-keying event is typically recorded on both the CVR and the ATC recordings.

[1] The Clarence Center, New York area map data were obtained from Google Earth.

2.1.1 Aircraft Recorder Data

The available FDR and CVR data are documented in the Flight Data Recorder Group Chairman's Factual Report and the Cockpit Voice Recorder Group Chairman's Factual Report, respectively.

2.1.2 CVR and FDR Alignment

Common events on the CVR and FDR were identified and used to define the CVR/FDR time alignment constraints. Each FDR common event has an associated begin and end time value due to the discrete nature of the FDR data. Corresponding CVR common events are associated with a single CVR time value, which must be precisely measured. The points on a common event plot of FDR time versus CVR time define the constraints. A curve that satisfies all the constraints defines a mapping from CVR time to FDR time.

2.1.3 FDR and ATC Alignment

The existence of one or more common events between the ATC transcript and the CVR and the CVR/FDR time alignment permits the FDR data to be aligned to the ATC transcript. Time alignment between the ATC transcript and the FDR data is accomplished by choosing a specific ATC clock time to equal a specific FDR time.

2.1.4 FDR and Radar Alignment

The FDR and radar data were time aligned using the FDR pressure altitude and the radar reinforced return altitude information. Given local barometric pressure and knowledge of the pressure reference used on the aircraft, the FDR pressure altitude was corrected for atmospheric deviation from standard day conditions. The radar and FDR time alignment was then accomplished by 1) creating an overlay plot of the pressure altitude versus time from each source, 2) adding a +/-50 foot error band to the radar altitude data, and 3) time shifting the radar data with respect to the corrected FDR altitude data to a point where the FDR altitude curve was bounded by the +/-50 foot radar altitude error band throughout the time period of interest.

2.2 Radar Data

Radar data[2] from the ASR-9 radar at Buffalo, NY (BUF) were converted from range-azimuth format to distance north and distance east of the BUF radar antenna and to latitude-longitude coordinates. The measurement tolerance[3] on the ASR radar range data is ±380 feet (±1/16 nautical mile). The ASR radar azimuth data is subject to a measurement tolerance of ±0.18° (±2 azimuth pulse counts).

The BUF radar data were used to calculate the flight 3407 ground track and to estimate the airplane ground speed, climb rate, and ground track angle.

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[2] The radar data and radar facility parameters are documented in the Aircraft Performance Crash Site Factual.

[3] The aircraft position derived from radar data may not place the aircraft precisely in an expected location. For example, the aircraft may not appear to be aligned on the runway centerline during landing even though the aircraft ground track may be parallel to the runway.

2.3 Flight Data Recorder (FDR) Data

The aircraft performance group reviewed the available FDR data and defined the sequence of significant accident events documented in Table 1. The columns in Table 1, ordered left to right are: FDR subframe reference number (elapsed time in seconds), Eastern Standard Time (hh:mm:ss), FDR calibrated airspeed (knots), FDR pitch attitude (degrees), FDR angle of attack[4] (degrees), vertical acceleration (Gs) and the event description. Each row in Table 1 corresponds to a specific time.

Table 1: Accident event sequence based on FDR data

FDR SRN seconds	Local Time hh:mm:ss	CAS knots	Pitch deg.	AOA deg.	NLF Gs	Event
95460	22:15:04.9	170	+5	+5	1.0	Start of timeline - base leg heading 310 maintaining 2400' at flap 0, autopilot engaged, altitude hold mode selected
95467	22:15:11.9	175	+5	+5	1.0	Select flap 5
95473	22:15:17.9	-	-	-	-	Commence left turn to heading 260°
95515	22:15:59.9	185	+2	0	1.0	Reduce power lever to about 42° (flight idle is about 35°)
95521	22:16:05.9	180	+2	0	1.0	Select landing gear down
95523	22:16:07.9	-	-	-	-	Flight director localizer mode becomes active Commence turn to heading 250°
95525	22:16:09.9	170	+4	+2	1.0	Select condition levers to max
95528	22:16:12.9	165	+4	+3	1.0	Autopilot pitch trim applied in airplane nose up direction
95538	22:16:22.9	140	+7	+9	1.0	Autopilot pitch trim applied in airplane nose up direction
95540	22:16:24.9	-	-	-	-	Ice Detected message posted[5]
95541	22:16:25.9	135	+8	+10	1.0	Flap 10 selected
95542	22:16:26.9	130	+9	+12	1.0	Autopilot disengages A/P disengage event may indicate stick shaker activation
95543	22:16:27.9	-	-	-	-	Aft control column applied Power lever advanced to about 70° (rating detent is 80°)
95545	22:16:29.9	122	+20	+20	1.3	Aircraft begins to roll left wing down Right wing down control wheel applied Airplane nose right rudder pedal applied
95547	22:16:31.9	-	-	-	-	Roll angle reaches 45° left wing down then begins to recover Flight director AltHold (vertical) and LOC (lateral) command modes cancelled
95549	22:16:33.9	90-110	+31	+31	1.3	Aircraft rolls through wings level Flap 0 selected Stick pusher fires as correlated by control column position traces
95553	22:16:37.9	-	-	-	-	Roll angle reaches 105° right wing down then begins to recover
95557	22:16:41.9	90-100	0	+34	1.1	Stick pusher fires a second time
95558	22:16:42.9	-	-	-	-	Roll angle reaches 35° left wing down then begins to recover
95561	22:16:45.9	105-115	-5	+32	1.4	Gear selected up
95563	22:16:47.9	-	-	-	-	Roll angle reaches 100° right wing down then begins to recover
95568	22:16:52.9	110-130	-30	+35	1.9	Aircraft 30° nose down and 25° right wing down
95568.5	22:16:53.4	-	-	-	-	End of FDR data

[4] The FDR angle of attack parameter (e.g., AOAL or AOAR) represents an intermediate angle of attack term that is not generally equivalent to either local vane angle of attack or fuselage angle of attack.
[5] Based on the FDR IceDetected parameter.

The FDR power lever angle (PLA) and condition lever angle (CLA) parameters can be correlated with detent and stop positions on the respective quadrant. For PLA, 0° is full reverse, 20° is discing, 35° is flight idle, 80° is the rating detent, and 100° is the over-torque/emergency position. For CLA, the nominal values are: 0° is fuel off, 35° is start/feather, 55° is min/850 rpm, 75° is 900 rpm, and 95° is the max/1020 rpm position.

The control column limits are about +8.2° forward to about –12.4° aft.[6] The control wheel limits are ±70°. The rudder pedal limits are ±2.35 inches, which equates to about 9.9° left and about 9.7° right at the forward quadrant stops. The elevator control surface limits are 30° trailing edge up and 20° trailing edge down. The aileron control surface limits are ±17°. The rudder control surface limits for flaps up are ±12° and ±18° for other flap selections. The flight spoilers can be deployed to a maximum value of 75°.

General FDR data observations include:

1. The available FDR data do not provide a direct record of the position of the REF SPEEDS switch (located on the ice protection overhead panel).
2. The control column and elevator position were noted to move approximately 1/2 full travel in the aft/trailing edge up direction within 2 seconds of stick shaker activation.[7] They were noted to again move aft/trailing edge up, to near full deflection, in the sequence of events after initial stick pusher activation, and finally to full deflection for the last 6 seconds of the recording.
3. Control wheel angle and aileron surface position were noted to move to near full deflection, in both directions, in the sequence of events following stick shaker activation.
4. The inboard and outboard flight spoilers reached full deflection, in both directions, in the sequence of events following stick shaker activation.
5. Rudder pedal and rudder surface positions reached full deflection airplane nose right, and approximately 1/2 full deflection airplane nose left, in the sequence of events following stick shaker activation.

2.4 Calculated Data

The FDR data parameters required for the airplane flight path, fuselage angle of attack, and low speed cue calculations were interpolated using a cubic spline algorithm and resampled at the times defined by the FDR vertical acceleration parameter. As a minimum quality control check, interpolated data should be compared to the native parameter value, with particular attention given to interpolated results or calculation artifacts in regions of frequent or high magnitude parameter variation.

Bombardier provided the DHC-8 Segment/System Design Document (SSDD) for the Stall Protection System (SPS)[8] to enable the aircraft performance group to calculate the fuselage angle of attack and the expected low speed cue, with and without the selection of the INCR position of the REF SPEEDS switch on the ICE PROTECTION panel, as a function of time.

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[6] According to Bombardier, the limits at the forward elevator quadrant stops are +8.185° forward to –12.363 aft where the control column transducers are attached. For the aft quadrant stops, the values are +6.537° forward to –9.869° aft.
[7] The flight 3407 CVR and FDR each contained stick shaker activation data.
[8] The DHC-8/SSDD/SPS document, dated February 2002, contains Thales Avionics proprietary data.

2.4.1 Calculated Airplane Flight Path

The FDR acceleration parameters (i.e., longitudinal, lateral, and vertical), attitude parameters (i.e., roll, pitch, and magnetic heading), pressure altitude, ground speed, and drift angle were used to calculate a subset of the flight 3407 flight path. The airplane's initial and final positions were anchored by the available radar data and the accident site, respectively. A constant acceleration bias term was independently computed for each FDR acceleration value and applied to ensure that the integrated acceleration data matched the target altitude (i.e., corrected altitude), ground speed, and inertial position data.

2.4.2 Calculated Fuselage Angle of Attack (AOA_{FUSE})

The left and right fuselage angle of attack values were calculated for the event time history based on the SSDD/SPS document and the available FDR data. Fuselage angle of attack is a function of local vane angle of attack, body axis pitch rate, and true airspeed, among other parameters, and is an important input to the stick shaker, stick pusher, and low speed cue calculations.

2.4.3 Calculated Low Speed Cue (LSC)

The expected low speed cue values (with and without the selection of the INCR position of the REF SPEEDS switch on the ICE PROTECTION panel) were calculated for the event time history based on the SSDD/SPS document and the available FDR data. The low speed cue is a function of engine torque, propeller speed, fuselage angle of attack, vertical acceleration, flap position, calibrated airspeed, and the position of the REF SPEEDS switch on the ICE PROTECTION panel, among other parameters.

The FDR airspeed and calculated low speed cue data were compared to the expected flight 3407 approach and reference speeds. The Operations Group Chairman's Factual Report documents the expected approach and reference speeds for various configurations, as summarized in Table 2, assuming an airplane landing weight of 54,366 pounds.

Table 2: Bombardier DHC-8-400 approach and reference speeds

Selected Flap	**$V_{APP/REF}$ Non Icing (knots)**	**Icing Speed Additive (knots)**	**$V_{APP/REF}$ Icing (knots)**
0	145	25	170
5	133	20	153
10	124	20	144
15	118	20	138
35	113	15	128

2.5 Reference Stall Speed

The Bombardier DHC-8-400 reference stall speeds documented in the Aircraft Performance Crash Site Factual were used to estimate the reference stall speeds at a flap position of 6.5°, the approximate flap position at the time of the event upset.

3.0 RESULTS

3.1 Time Alignment

The time alignment between the FDR data and radar data is summarized in Table 3 below. The *local time* value is based on the ATC radar time code generated by a GPS clock.

Table 3: Time alignment mapping

Local Time	UTC Time	FDR Time	Plotted FDR Time
22:16:51.658	03:16:51.658	95566.7275	95566.7275

The CVR to FDR time alignment solution was found to be linear over the approximately 15 minute length of the CVR recording selected. The linear solution required to satisfy the common event constraints[9] listed in Table 4 is presented in Table 5, where the time relationship is defined as

CVR Time = (slope)(FDR Time) + intercept

In Table 5, *CVR time* in hh:mm:ss format is converted to total seconds (e.g., 02:01:03.2895 = 7263.2895 seconds).

Table 4: CVR/FDR common event constraints

CVR Time	FDR Low	FDR High	Source	Event
6474.3	94776.9	94777.9	VHF1	Event 1 start
6476.7	94779.9	94780.9	VHF1	Event 1 stop
6484.6	94787.9	94788.9	VHF1	Event 2 start
6489.5	94792.9	94793.9	VHF1	Event 2 stop
6496.7	94799.9	94800.9	VHF1	Event 3 start
6499.8	94802.9	94803.9	VHF1	Event 3 stop
6534.8	94837.9	94838.9	VHF1	Event 4 start
6536.8	94839.9	94840.9	VHF1	Event 4 stop
6555.6	94858.9	94859.9	VHF1	Event 5 start
6558.2	94860.9	94861.9	VHF1	Event 5 stop
6693.6	94996.9	94997.9	VHF2	Event 6 start
6696.6	94999.9	95000.9	VHF2	Event 6 stop
6704.9	95007.9	95008.9	VHF2	Event 7 start
6710.2	95012.9	95013.9	VHF2	Event 7 stop
6725.7	95028.9	95029.9	VHF2	Event 8 start
6730.2	95032.9	95033.9	VHF2	Event 8 stop
6776.5	95079.9	95080.9	VHF1	Event 9 start
6778.5	95080.9	95081.9	VHF1	Event 9 stop
6807.2	95109.9	95110.9	VHF1	Event 10 start
6809.2	95111.9	95112.9	VHF1	Event 10 stop
6993.3	95295.9	95296.9	VHF1	Event 11 start
6995.8	95298.9	95299.9	VHF1	Event 11 stop
7018.6	95321.9	95322.9	VHF1	Event 12 start

[9] The "FDR Low" and "FDR High" times are associated with the VHF parameter value of "Not_Key" and "Key," respectively, at the beginning of a given VHF communication event recorded on the FDR.

7021.1	95323.9	95324.9	VHF1	Event 12 stop
7103.6	95406.9	95407.9	VHF1	Event 13 start
7106.1	95408.9	95409.9	VHF1	Event 13 stop
7173.8	95476.9	95477.9	VHF1	Event 14 start
7178.7	95481.9	95482.9	VHF1	Event 14 stop
7223.1	95525.9	95526.9	VHF1	Event 15 start
7225.3	95527.9	95528.9	VHF1	Event 15 stop

Table 5: Solution to flight 3407 CVR/FDR common event constraints

CVR Time	FDR Time	Slope	Intercept
7263.2895	95566.7275	1.00	-88303.4380

3.2 Calculated Radar Data

The flight 3407 ground track was calculated and overlaid (see red line) on the Google Earth image shown in Figure 1 to correlate the airplane position to local reference points. The BUF radar data were also used to estimate the airplane ground speed, climb rate, and ground track angle data presented in Attachment 1, Figures A1.1-2.

The figures in Attachment 1 present the following parameters, ordered top to bottom as a function of Eastern Standard Time (hh:mm:ss): pressure altitude, calculated ground speed, calculated rate of climb, calculated ground track angle, calculated latitude, and calculated longitude.[10] The smoothed data are based on a running average smoothing algorithm.

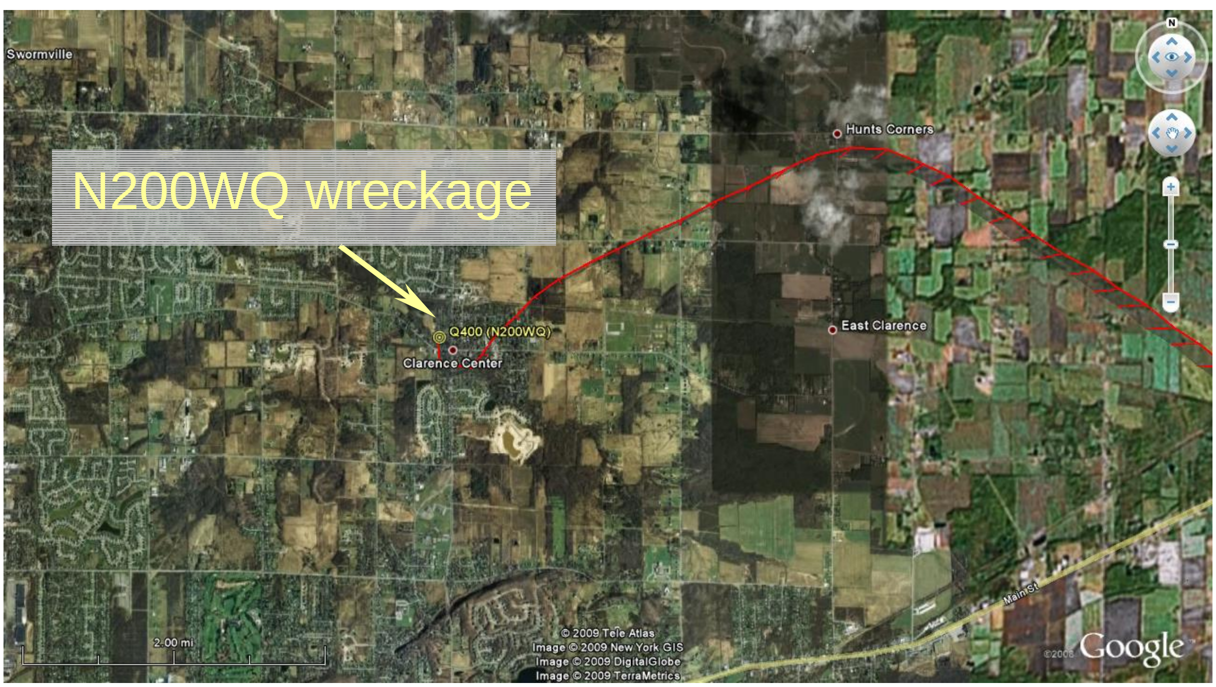

Figure 1: The calculated N200WQ ground track (red line) based on the BUF radar data. The aircraft direction of travel was right to left. The aircraft wreckage was located in Clarence Center, NY. North is toward the top of the photograph.

[10] Calculated latitude and longitude data enable rapid visualization of the airplane ground track (and flight path) relative to representative models of the Earth.

3.3 Longitudinal, Lateral-Directional, Engine, and Propeller FDR data

A subset of the available flight 3407 FDR data is organized on longitudinal axis, lateral-directional axes, and engine and propeller plots in Attachment 2, Figures A2.1-3, respectively, as a function of time. Each plot presents FDR data for a 1 minute time interval. Refer to Section 2.3 for a summary of the significant FDR data events.

The longitudinal axis plot (Figure A2.1) includes the following parameters, ordered top to bottom, as a function of Eastern Standard Time (hh:mm:ss) and FDR subframe reference time (elapsed seconds): pressure altitude, calibrated airspeed, ground speed, longitudinal acceleration, engine power lever angle, condition lever angle, flap selection, flap trailing edge position, landing gear handle position discrete, autopilot discrete, ice detection discrete, left and right stick shaker discrete, stick pusher discrete, master caution discrete, master warning discrete, altitude hold mode discrete, altitude selection mode discrete, bank angle, vertical acceleration, left and right FDR angle of attack, pitch attitude, elevator surface position, control column position, pitch trim position, nose gear down and lock discrete, main gear down and lock discrete, nose gear up and lock discrete, main gear up and lock discrete, and VHF radio discretes. In general, the parameter sign convention is that airplane nose up is toward the top of the page.

The lateral-directional axes plot (Figure A2.2) shows the following parameters, ordered top to bottom, as a function of Eastern Standard Time (hh:mm:ss) and FDR subframe reference time (elapsed seconds): pressure altitude, calibrated airspeed, ground speed, longitudinal acceleration, engine power lever angle, condition lever angle, flap selection, flap trailing edge position, landing gear handle position discrete, autopilot discrete, ice detection discrete, left and right stick shaker discrete, stick pusher discrete, heading mode discrete, localizer mode discrete, bank angle, right aileron surface position, inboard and outboard flight spoiler surface positions, control wheel position, lateral acceleration, magnetic heading, rudder surface position, rudder pedal position, and yaw damper discrete. In general, the parameter sign conventions are that airplane nose right and right wing down are toward the bottom of the page.

The engine and propeller plot (Figure A2.3) includes the following parameters, ordered top to bottom, as a function of Eastern Standard Time (hh:mm:ss) and FDR subframe reference time (elapsed seconds): pressure altitude, calibrated airspeed, ground speed, longitudinal acceleration, engine power lever angle, condition lever angle, flap selection, flap trailing edge position, landing gear handle position discrete, autopilot discrete, ice detection discrete, left and right stick shaker discrete, stick pusher discrete, bank angle, vertical acceleration, engine torque command, engine torque, propeller speed, high pressure rotor speed, low pressure rotor speed, fuel flow, internal turbine temperature, engine oil pressure discrete, propeller beta, and WCP FADEC discrete.

3.4 Calculated Airplane Flight Path

The airplane flight path was computed by integrating the corrected longitudinal, lateral, and vertical acceleration FDR data and comparing the results to corrected FDR altitude, FDR ground speed, and ATC radar position data. The integration results[11] are compared to the available FDR and radar data in Attachment 3, Figures A3.1-2 as a function of time and position, respectively.

[11] The integrated results reflect the subtraction of a constant 2° bias from the FDR magnetic heading parameter, which is supported by a review of the FDR magnetic heading data during the EWR takeoff ground roll.

3.5 Calculated Data

The flight 3407 calculated fuselage angle of attack and low speed cue results are presented in Attachment 4, Figures A4.1-2 as a function of time.

3.5.1 Calculated Fuselage Angle of Attack

The calculated left, right, and average fuselage angle of attack values are plotted in Attachment 4, Figure A4.1. The calculated fuselage angle of attack is about 8° at the time that the FDR autopilot parameter switches from engaged to disengaged in the event upset sequence.

3.5.2 Derived Selection State of the REF SPEEDS Switch

The fuselage angle of attack at which stick shaker activates is a function of the REF SPEEDS switch selection, flap position, engine torque, and Mach number.[12] With icing conditions assumed (i.e., the REF SPEEDS switch on the ICE PROTECTION panel selected to INCR), the calculated fuselage angle of attack for stick shaker actuation in the event upset timeframe is about 7.6°. With non icing conditions assumed, the calculated fuselage angle of attack for stick shaker actuation in the event upset timeframe is about 12°.

3.5.3 Calculated Low Speed Cue (LSC)

The expected low speed cue values with and without the selection of the INCR position of the REF SPEEDS switch on the ICE PROTECTION panel are plotted in Attachment 4, Figure A4.2.

3.6 Reference Stall Speed Data

The Bombardier DHC-8-400 reference stall speeds for a flap position of 6.5° are shown in Attachment 5, Figures A5.1-2 as a function of weight and normal load factor, respectively. FDR data indicate that the flight 3407 upset event occurred at an airspeed of 125 knots. Based on the reference stall speeds presented in the Aircraft Flight Manual, a Bombardier DHC-8-400 would stall at 107 knots in un-accelerated (1-g) flight for the estimated landing weight of 54,700 pounds and flap position of 6.5°. Taking into account the extra lift required to execute a nose up pitching maneuver, a DHC-8-400 airplane with no ice accretions would be able to achieve about 1.38 g before encountering wing stall at 125 knots.[13]

In the case of the accident aircraft, the FDR indicates that it was able to achieve a vertical acceleration of about 1.42 g, or somewhat in excess of the clean aircraft performance assumed in the AFM. The significance of this result is dependent upon uncertainties due to data interpolation, data extrapolation, actual landing weight, and the accident aircraft characteristics.

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[12] The Mach number term in the stick shaker equations is zero for this particular event.

[13] At a calibrated airspeed of 125 knots and a flap position of 6.5°, a Bombardier DHC-8-400 with no ice accretions could lift an equivalent weight of about 75,250 pounds (see Figure A5.1, the intersection of the two green lines).

3.7 CVR Transcript Data

The time alignment results reported in Section 3.1 were used to position the CVR transcript events summarized in Table 6 on the longitudinal axis, lateral-directional axes, and engine and propeller FDR data plots (recall Attachment 2, Figures A2.1-3). The resulting FDR and CVR data overlay plots are available in Attachment 6, Figures A2.1-6. Each plot presents FDR and CVR data for a 30 second time interval.

Table 6: CVR transcript event excerpt

Local Time (hh:mm:ss)	FDR SRN (seconds)	Source	Event
22:14:39.8	95434.9	CAM	[sound similar to engine power increase]
22:15:06.3	95461.4	HOT-1	flaps five.
22:15:08.1	95463.2	HOT-2	what?
22:15:08.8	95463.9	HOT-1	flaps five please.
22:15:11.2	95466.3	CAM	[sound similar to flap handle movement]
22:15:13.5	95468.6	APP	Colgan thirty four zero seven three miles from KLUMP turn left heading two six zero maintain two thousand three hundred until established localizer. cleared ILS approach runway two three.
22:15:22.2	95477.3	RDO-2	left two sixty two thousand three hundred 'til established and cleared ILS two three approach Colgan thirty four zero seven.
22:15:31.7	95486.8	HOT-1	alright approach is armed.
22:15:32.8	95487.9	HOT-2	roger.
22:15:59.5	95514.6	CAM	[sound similar to decrease in engine power]
22:16:04.1	95519.2	HOT-1	gear down...loc's alive.
22:16:06.2	95521.3	CAM	[sound similar to landing gear handle movement]
22:16:06.4	95521.5	APP	Colgan thirty four zero seven contact tower one two zero point five. have a good night.
22:16:07.4	95522.5	CAM	[sound similar to landing gear deployment]
22:16:11.5	95526.6	RDO-2	over to tower you do the same thirty four zero seven.
22:16:21.2	95536.3	HOT-2	gear's down.
22:16:23.5	95538.6	HOT-1	flaps fifteen before landing checklist.
22:16:26.0	95541.1	CAM	[sound similar to flap handle movement]
22:16:26.6	95541.7	HOT-2	uhhh.
22:16:27.4	95542.5	CAM	[sound similar to stick shaker continues for 6.7 seconds]
22:16:27.7	95542.8	HOT	[sound similar to autopilot disconnect horn repeats until end of recording]
22:16:31.1	95546.2	CAM	[sound similar to increase in engine power]
22:16:35.4	95550.5	CAM	[sound similar to stick shaker continues until end of recording]
22:16:37.1	95552.2	HOT-2	I put the flaps up.
22:16:42.2	95557.3	HOT-1	[sound of grunt]
22:16:45.8	95560.9	HOT-2	should the gear up?
22:16:46.8	95561.9	HOT-1	gear up.

22:16:50.1	95565.2	CAM	[increase in ambient noise]
22:16:51.9	95567.0	CAM	[sound of thump]
22:16:53.9	95569.0		End of Transcript; End of Recording

4.0 SUMMARY

The event flight time alignment between the CVR, FDR, and radar data was determined. The flight 3407 radar data were consistent with the reported ILS approach to runway 23 and the available FDR data. A subset of the available longitudinal, lateral-directional, engine, and propeller data from the accident FDR were plotted and evaluated. The FDR accelerometer data were corrected and integrated to determine the flight 3407 flight path, which was overlaid on a Clarence Center, NY aerial image.

The FDR and Bombardier SSDD/SPS document data were used to calculate the fuselage angle of attack and the expected airspeed low speed cue as a function of time. Based on the FDR data and the calculated fuselage angle of attack data, the REF SPEEDS switch on the ICE PROTECTION PANEL was selected to the INCR position at the time of the event upset. Finally, selected CVR transcript events were used to annotate FDR time history data.

Attachment 1: Calculated Data (from BUF Radar)

FIGURE A1.1: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 {OVERVIEW}
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [BASED ON BUF ASR-9 RADAR DATA]

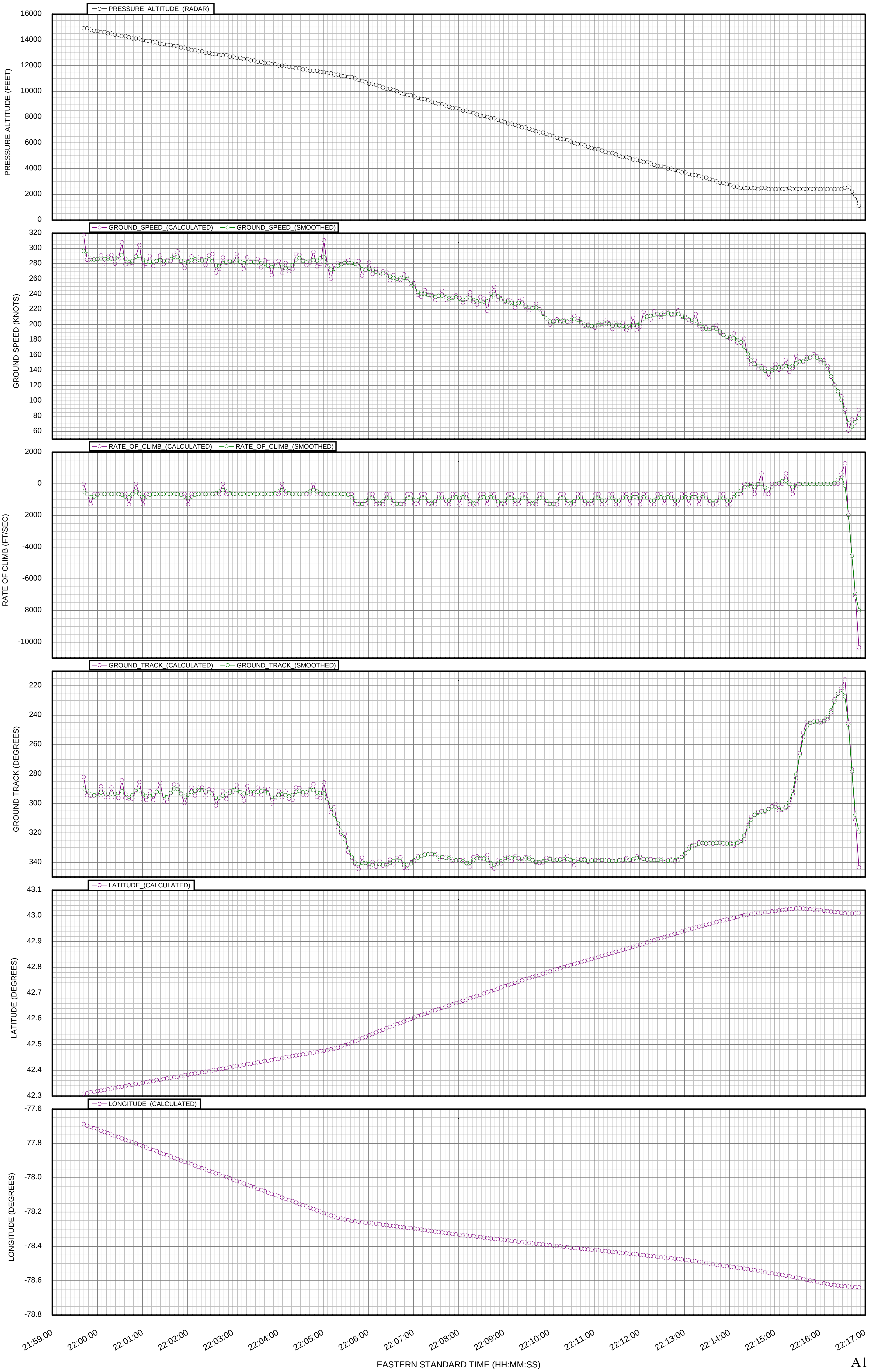

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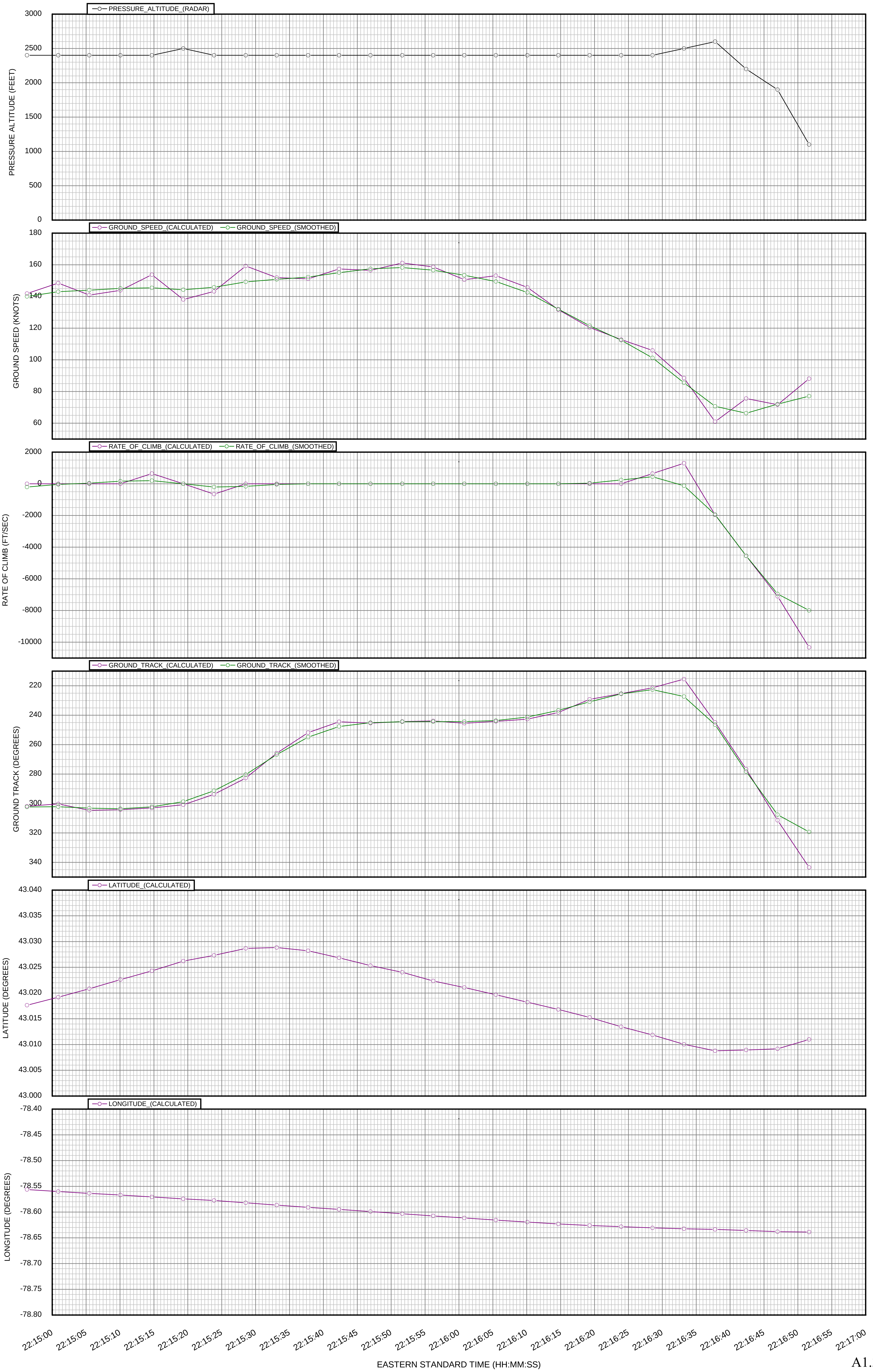
FIGURE A1.2: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 {EVENT}
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [BASED ON BUF ASR-9 RADAR DATA]



Attachment 2: Flight 3407 FDR Data

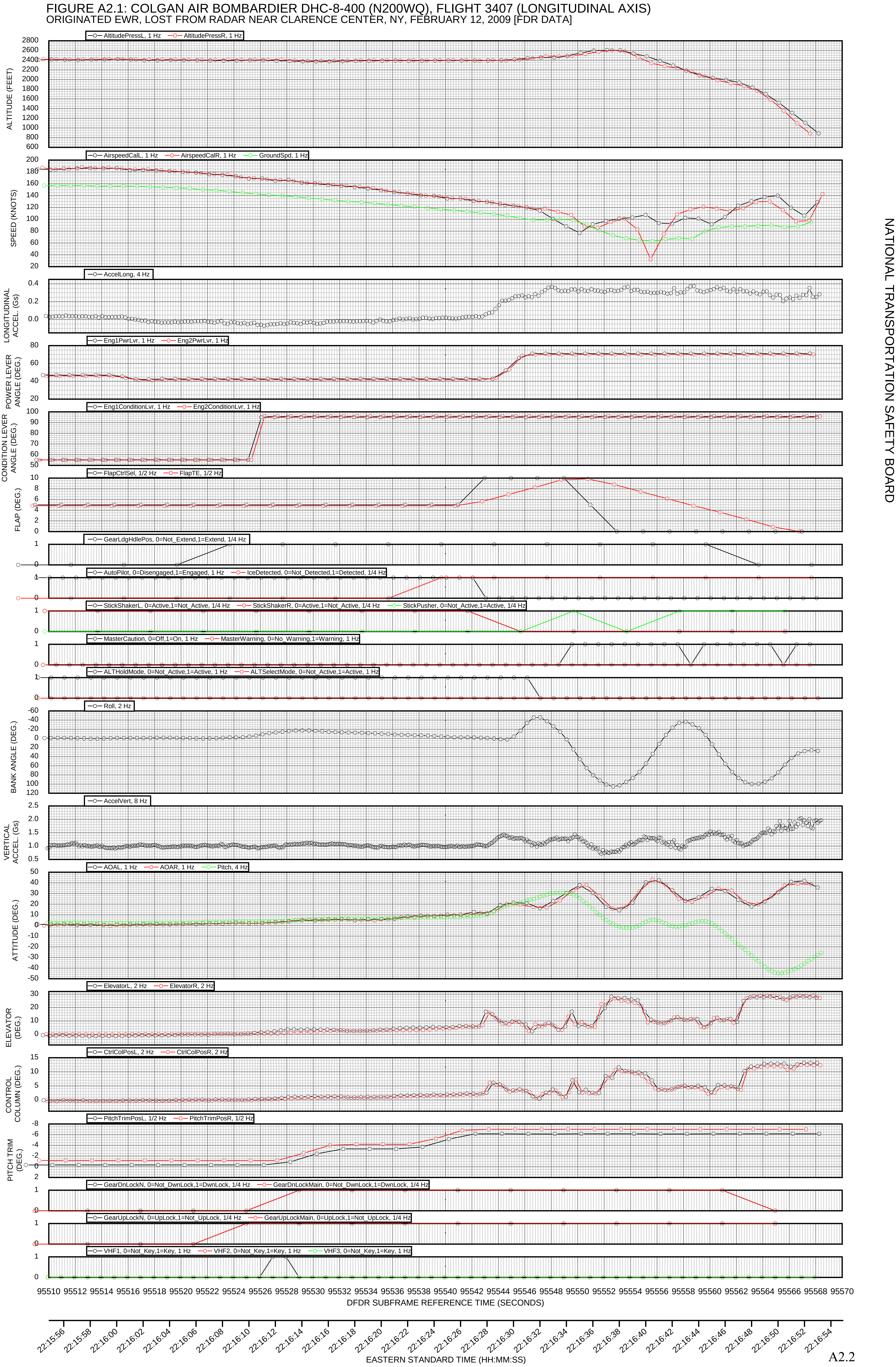


FIGURE A2.1: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (LONGITUDINAL AXIS)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR DATA]
AltitudePressL, 1 Hz
AltitudePressR, 1 Hz
ALTITUDE (FEET)
AirspeedCalL, 1 Hz
AirspeedCalR, 1 Hz
GroundSpd, 1 Hz
SPEED (KNOTS)
AccelLong, 4 Hz
LONGITUDINAL ACCEL. (Gs)
Eng1PwrLvr, 1 Hz
Eng2PwrLvr, 1 Hz
POWER LEVER ANGLE (DEG.)
Eng1ConditionLvr, 1 Hz
Eng2ConditionLvr, 1 Hz
CONDITION LEVER ANGLE (DEG.)
FlapCtrlSel, 1/2 Hz
FlapTE, 1/2 Hz
FLAP (DEG.)
GearLdgHdlePos, 0=Not_Extend,1=Extend, 1/4 Hz
AutoPilot, 0=Disengaged,1=Engaged, 1 Hz
IceDetected, 0=Not_Detected,1=Detected, 1/4 Hz
StickShakerL, 0=Active,1=Not_Active, 1/4 Hz
StickShakerR, 0=Active,1=Not_Active, 1/4 Hz
StickPusher, 0=Not_Active,1=Active, 1/4 Hz
MasterCaution, 0=Off,1=On, 1 Hz
MasterWarning, 0=No_Warning,1=Warning, 1 Hz
ALTHoldMode, 0=Not_Active,1=Active, 1 Hz
ALTSelectMode, 0=Not_Active,1=Active, 1 Hz
Roll, 2 Hz
BANK ANGLE (DEG.)
AccelVert, 8 Hz
VERTICAL ACCEL. (Gs)
AOAL, 1 Hz
AOAR, 1 Hz
Pitch, 4 Hz
ATTITUDE (DEG.)
ElevatorL, 2 Hz
ElevatorR, 2 Hz
ELEVATOR (DEG.)
CtrlColPosL, 2 Hz
CtrlColPosR, 2 Hz
CONTROL COLUMN (DEG.)
PitchTrimPosL, 1/2 Hz
PitchTrimPosR, 1/2 Hz
PITCH TRIM (DEG.)
GearDnLockN, 0=Not_DwnLock,1=DwnLock, 1/4 Hz
GearDnLockMain, 0=Not_DwnLock,1=DwnLock, 1/4 Hz
GearUpLockN, 0=UpLock,1=Not_UpLock, 1/4 Hz
GearUpLockMain, 0=UpLock,1=Not_UpLock, 1/4 Hz
VHF1, 0=Not_Key,1=Key, 1 Hz
VHF2, 0=Not_Key,1=Key, 1 Hz
VHF3, 0=Not_Key,1=Key, 1 Hz
95510 95512 95514 95516 95518 95520 95522 95524 95526 95528 95530 95532 95534 95536 95538 95540 95542 95544 95546 95548 95550 95552 95554 95556 95558 95560 95562 95564 95566 95568 95570
DFDR SUBFRAME REFERENCE TIME (SECONDS)
22:15:56 22:15:58 22:16:00 22:16:02 22:16:04 22:16:06 22:16:08 22:16:10 22:16:12 22:16:14 22:16:16 22:16:18 22:16:20 22:16:22 22:16:24 22:16:26 22:16:28 22:16:30 22:16:32 22:16:34 22:16:36 22:16:38 22:16:40 22:16:42 22:16:44 22:16:46 22:16:48 22:16:50 22:16:52 22:16:54
EASTERN STANDARD TIME (HH:MM:SS)
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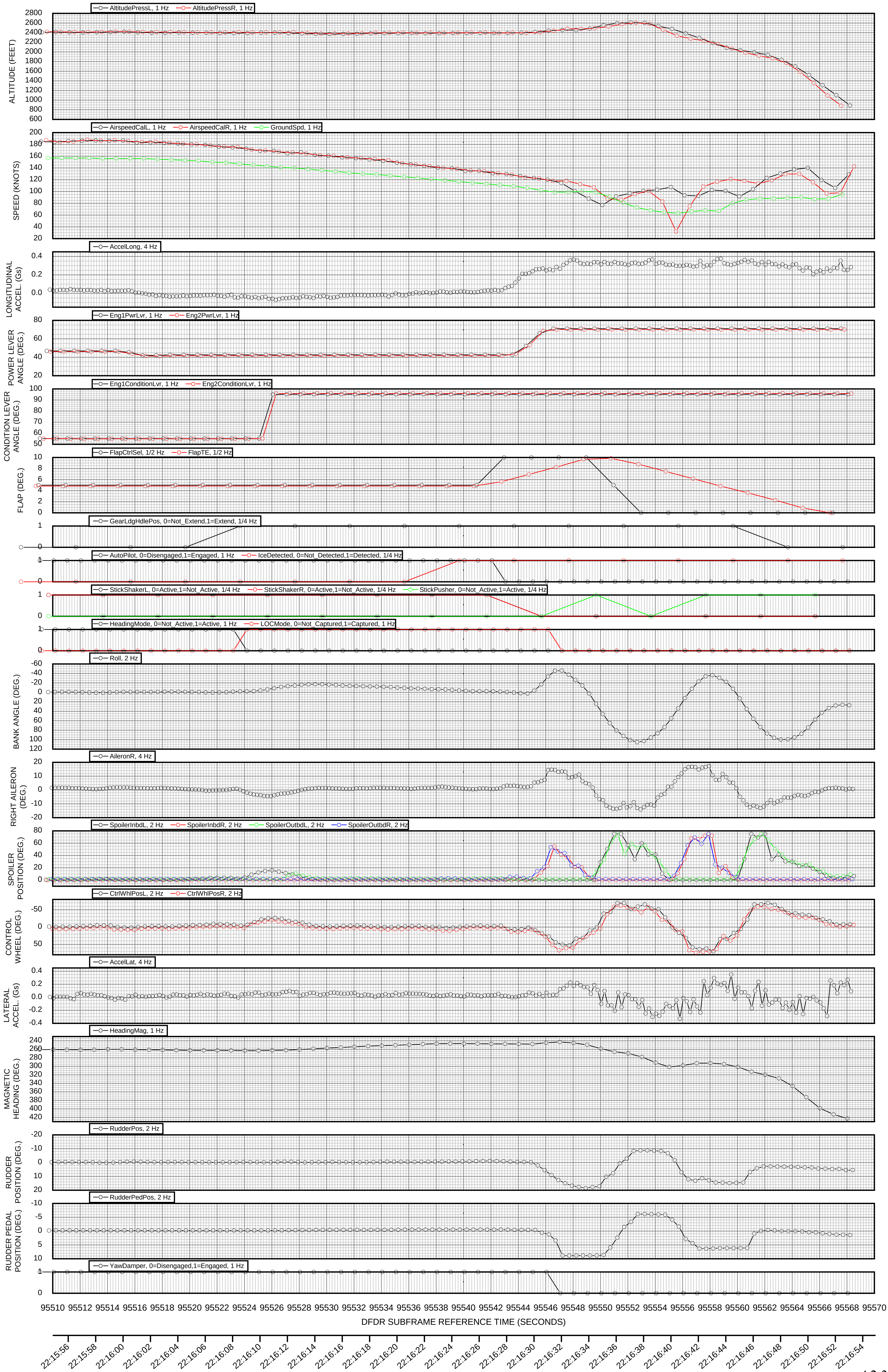
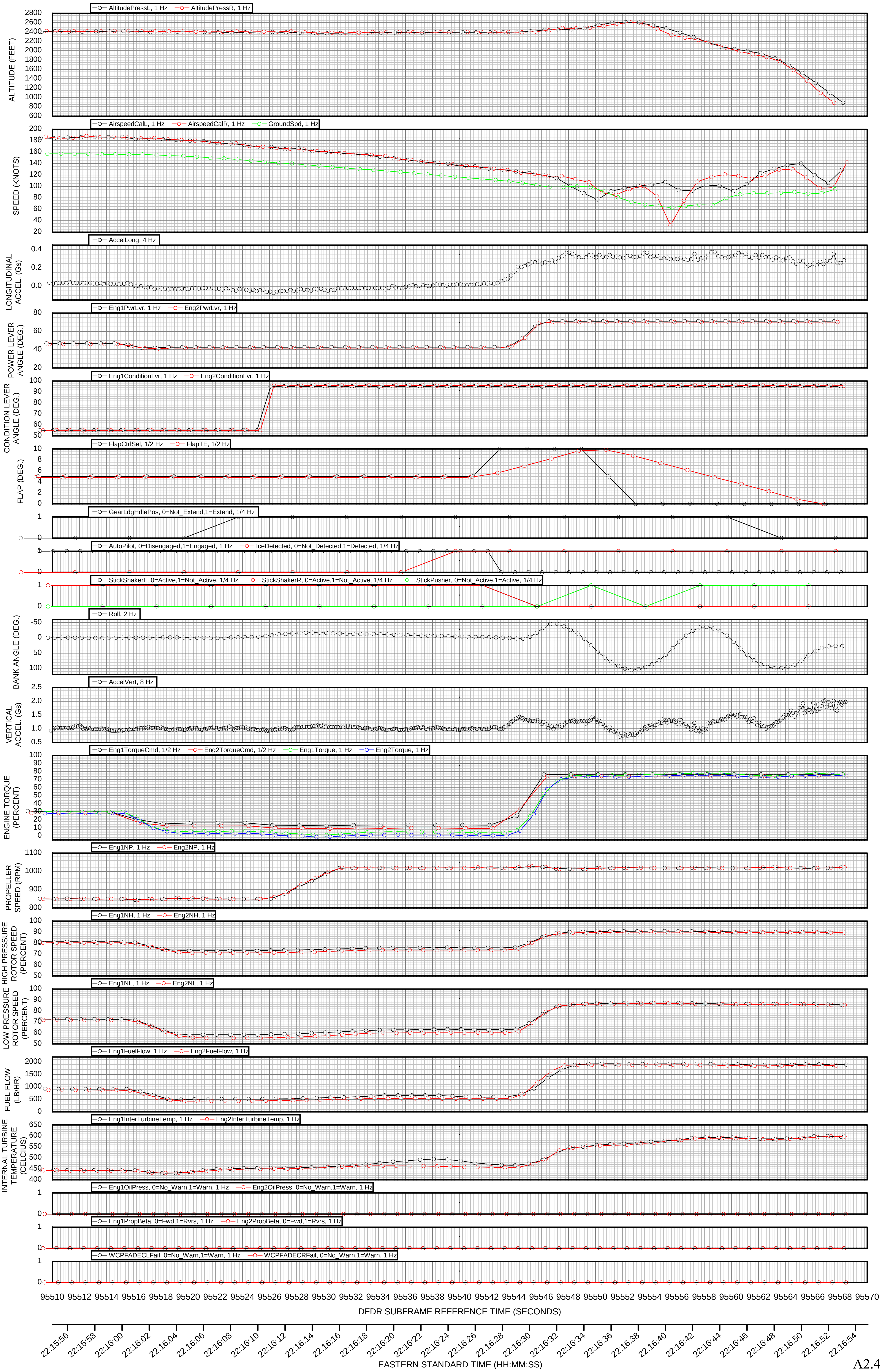
FIGURE A2.2: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (LATERAL-DIRECTIONAL AXES)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR DATA]



NATIONAL TRANSPORTATION SAFETY BOARD

FIGURE A2.3: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (ENGINES AND PROPELLERS)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR DATA]



Attachment 3: Calculated Flight Path

FIGURE A3.1: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (CALCULATED FLIGHT PATH DATA)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [BASED ON FDR AND RADAR DATA]

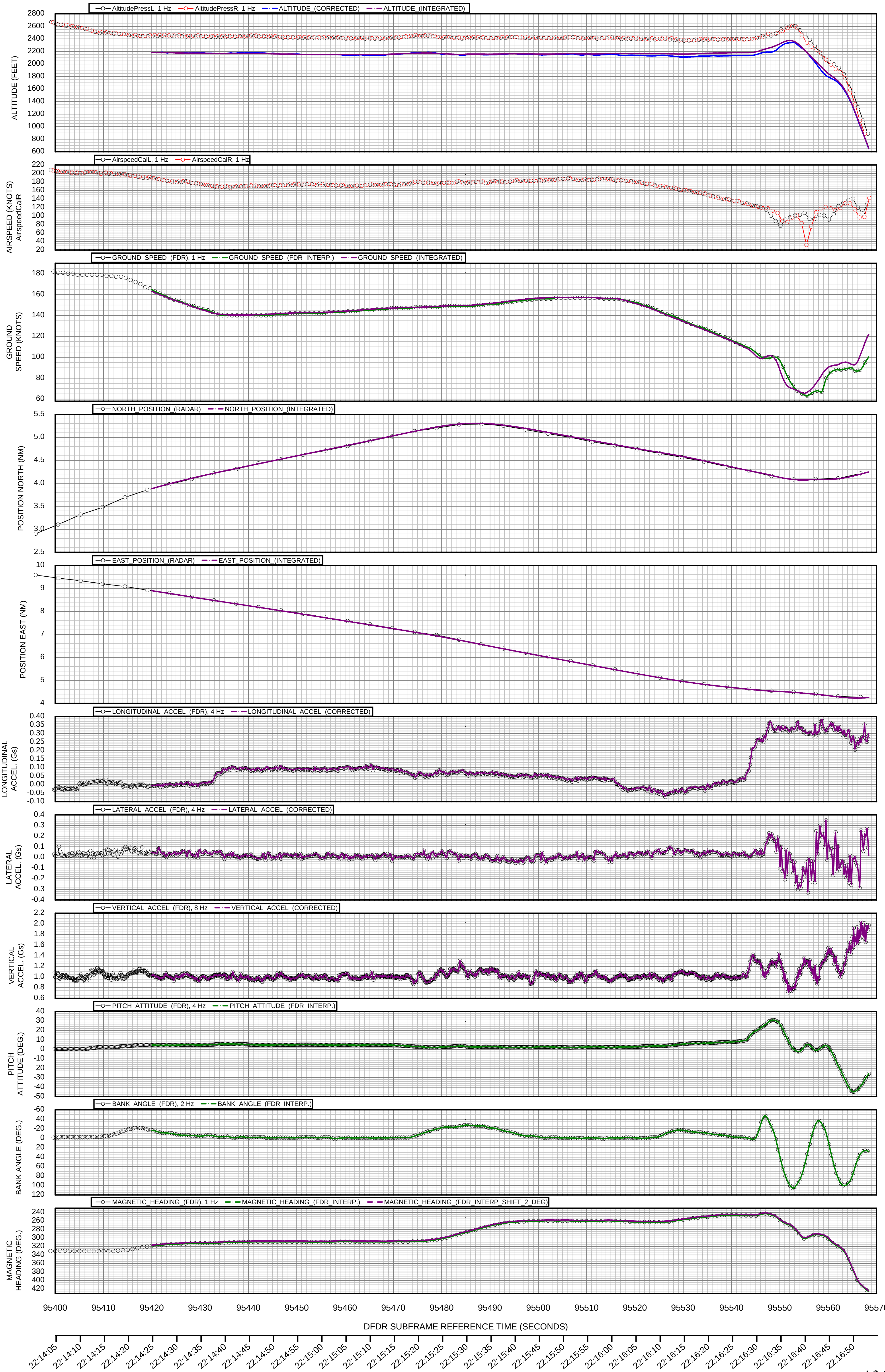
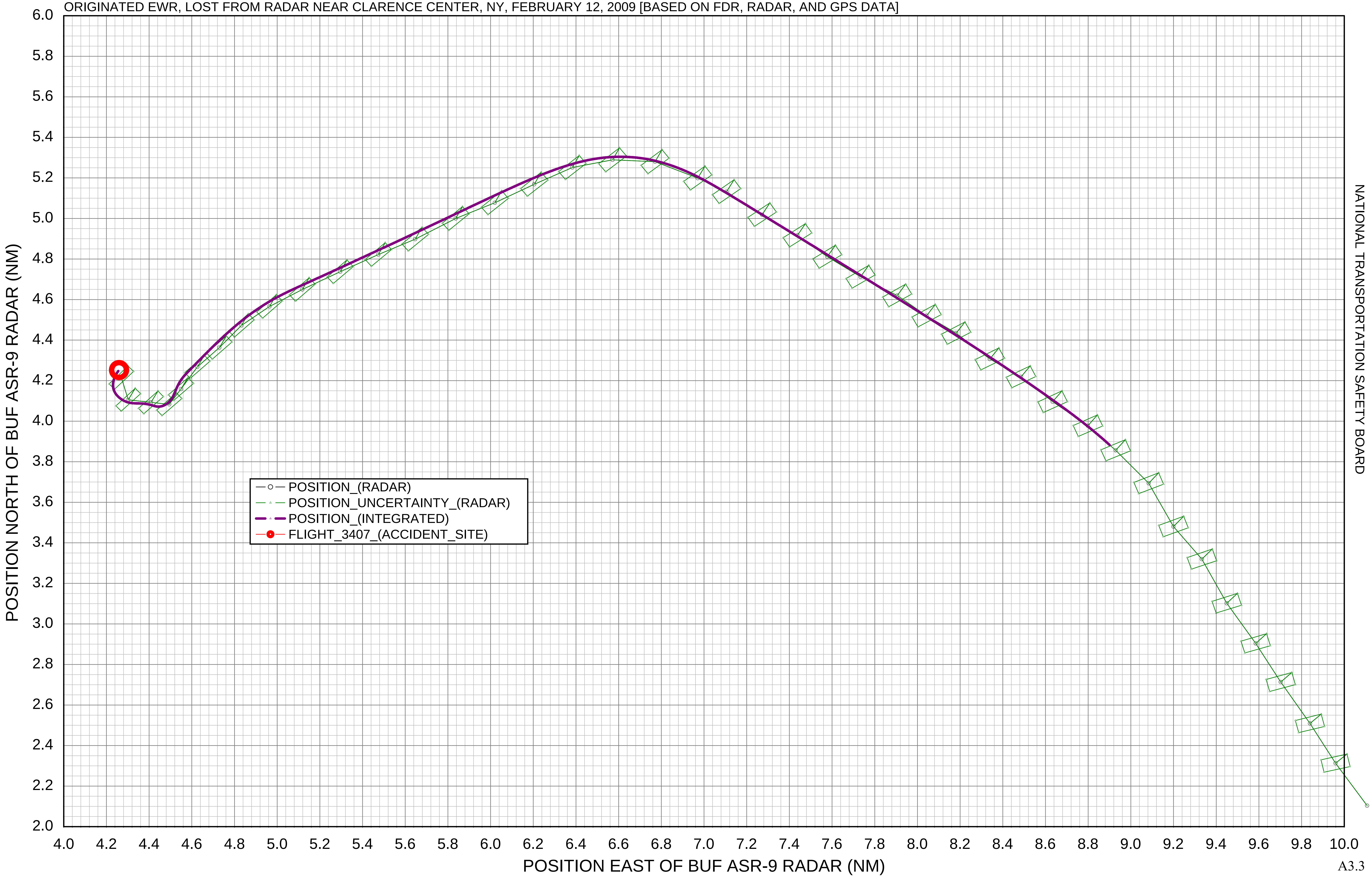


FIGURE A3.2: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (CALCULATED FLIGHT PATH DATA)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [BASED ON FDR, RADAR, AND GPS DATA]



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Attachment 4: Calculated Data (from SSDD/SPS)

Fuselage Angle of Attack

Expected Low Speed Cue

FIGURE A4.1: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (CALCULATED FUSELAGE AOA DATA)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [BASED ON FDR DATA AND SSDD/SPS DOCUMENT]

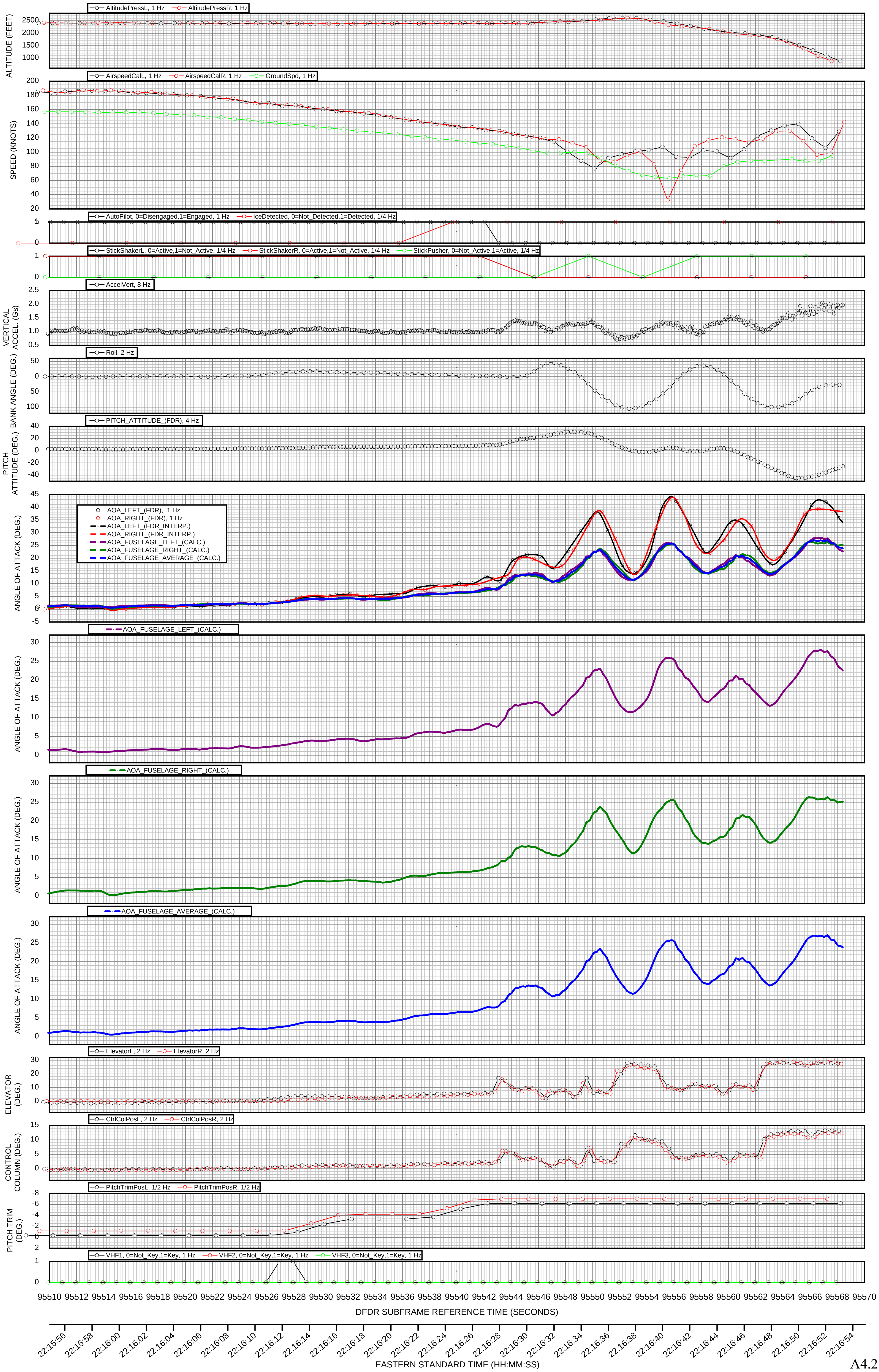

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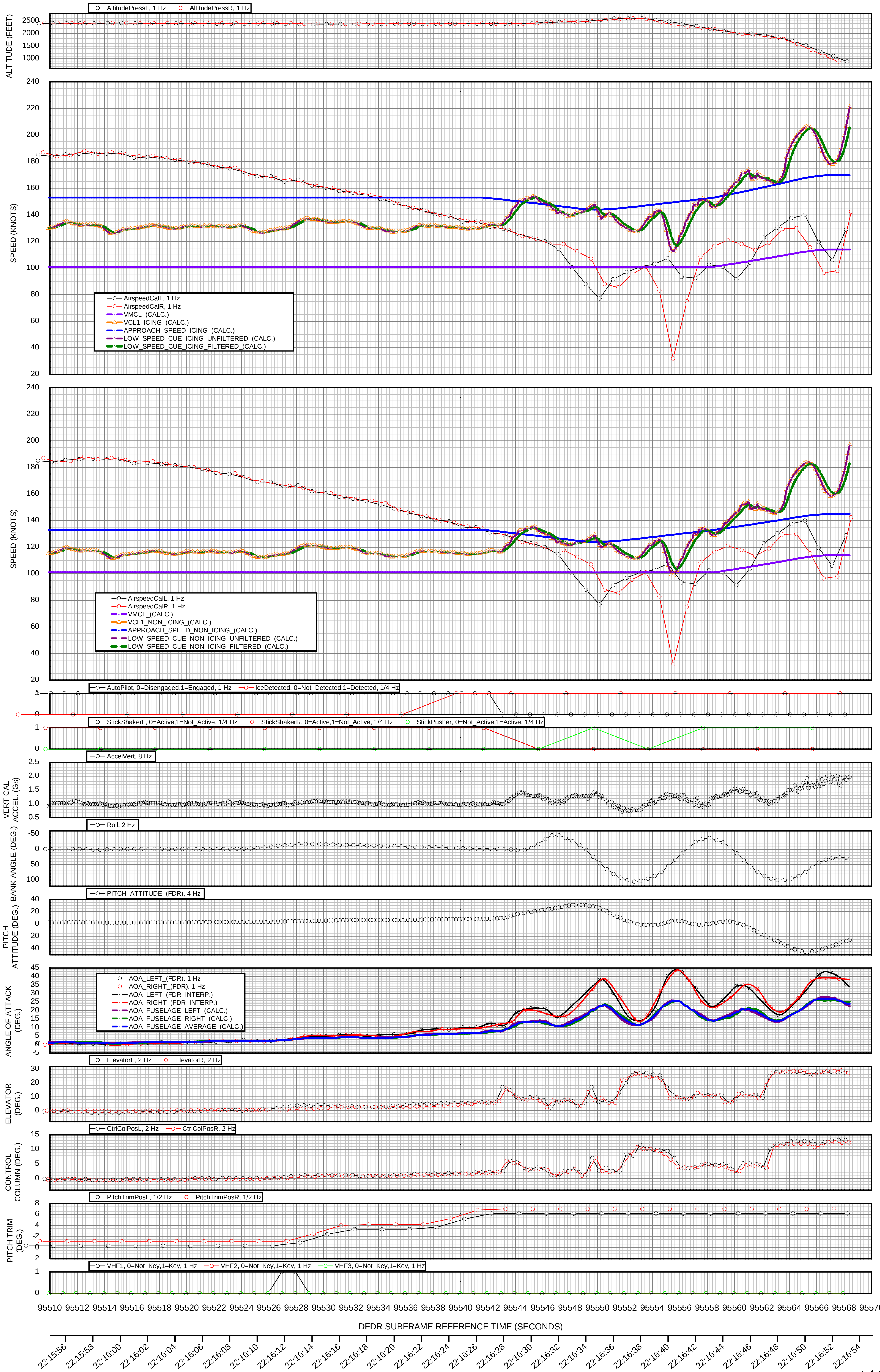
FIGURE A4.2: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (CALCULATED AIRSPEED LOW SPEED CUE DATA)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [BASED ON FDR DATA AND SSDD/SPS DOCUMENT]



Attachment 5: Reference Stall Speeds

Figure A5.1: Bombardier DHC-8-400 Reference Stall Speeds

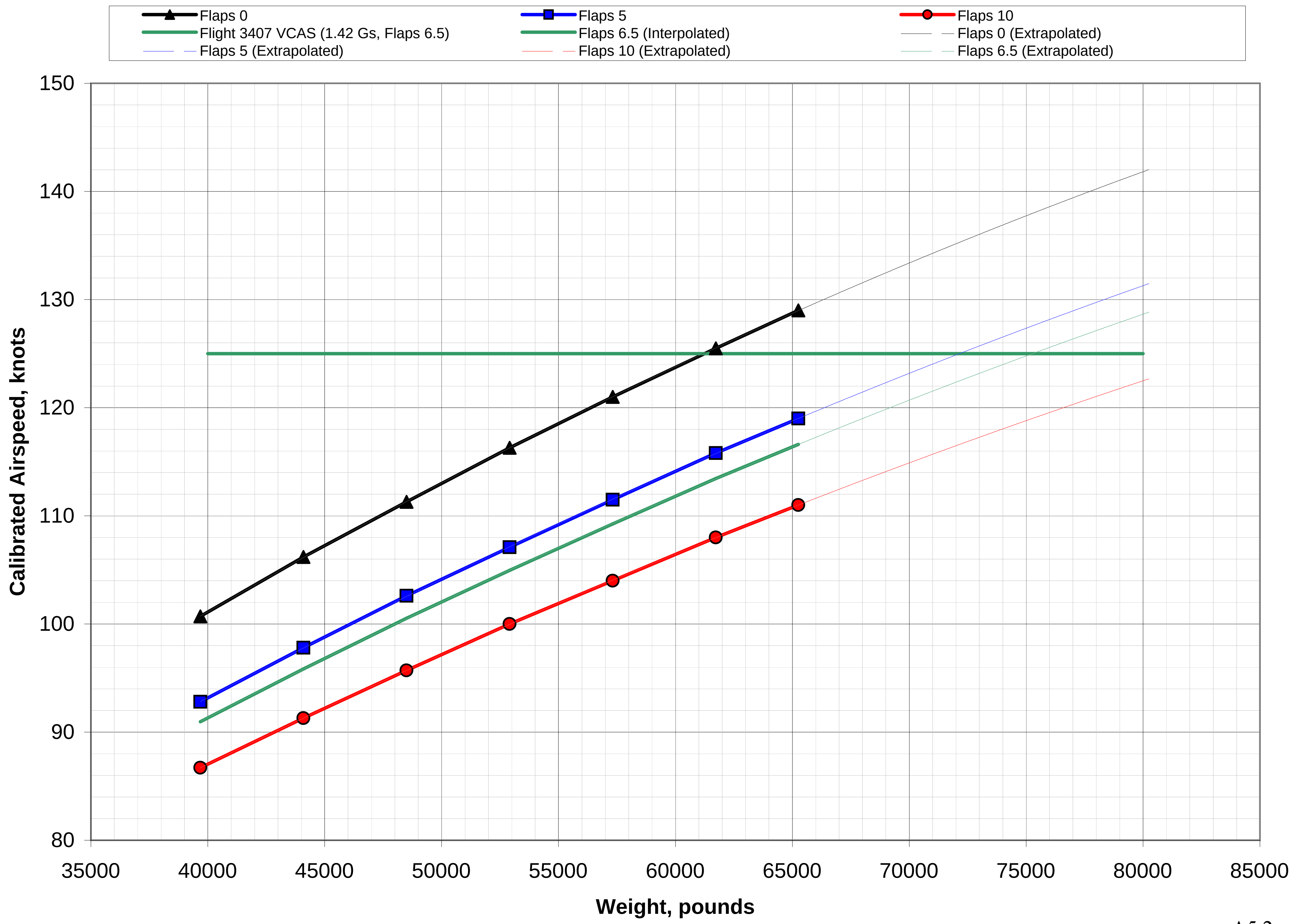
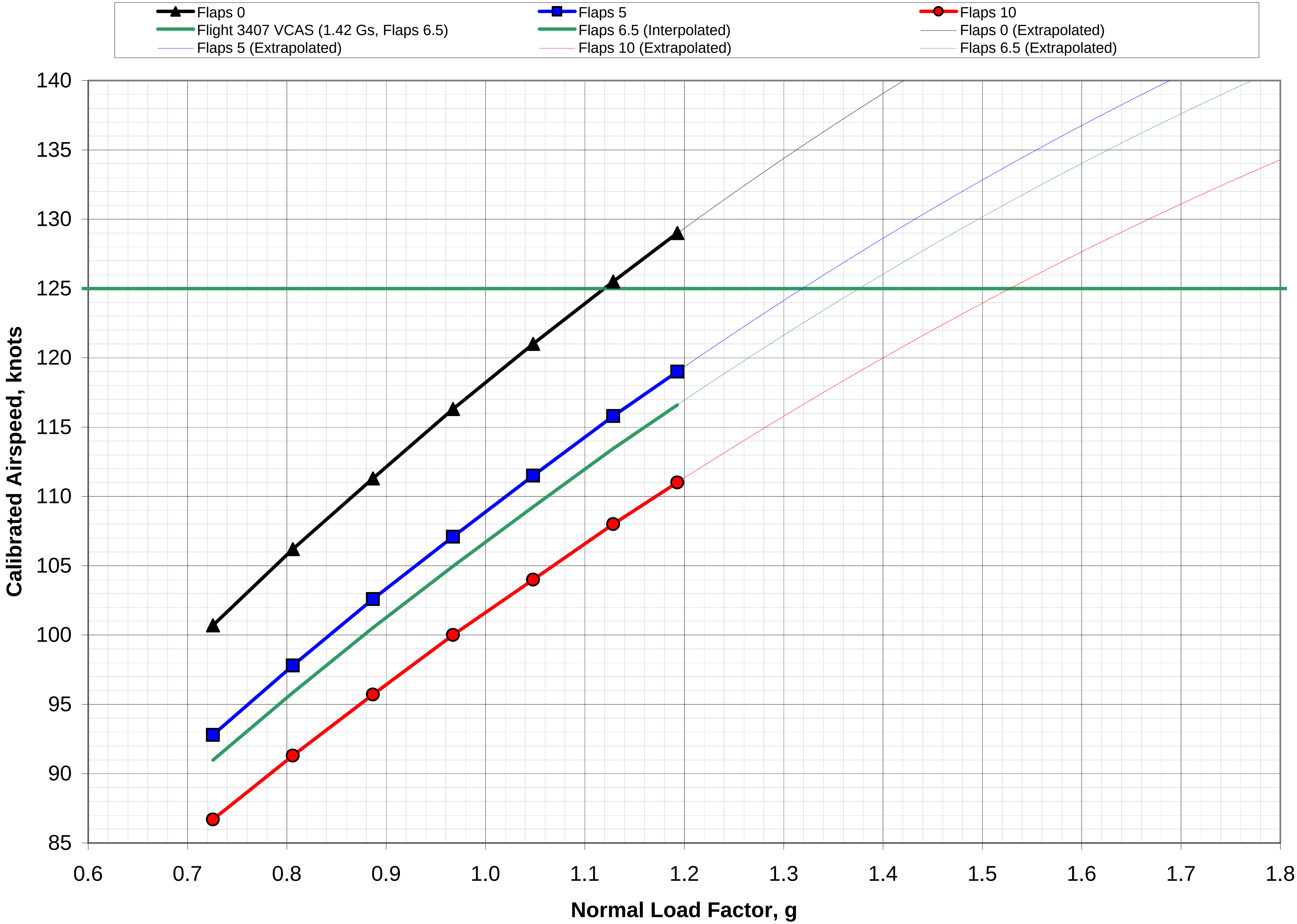


Figure A5.2: Bombardier DHC-8-400 Reference Stall Speeds (Weight 54,700 lb)



Attachment 6: FDR and CVR Data

FIGURE A6.1: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (LONGITUDINAL AXIS)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR AND CVR DATA]

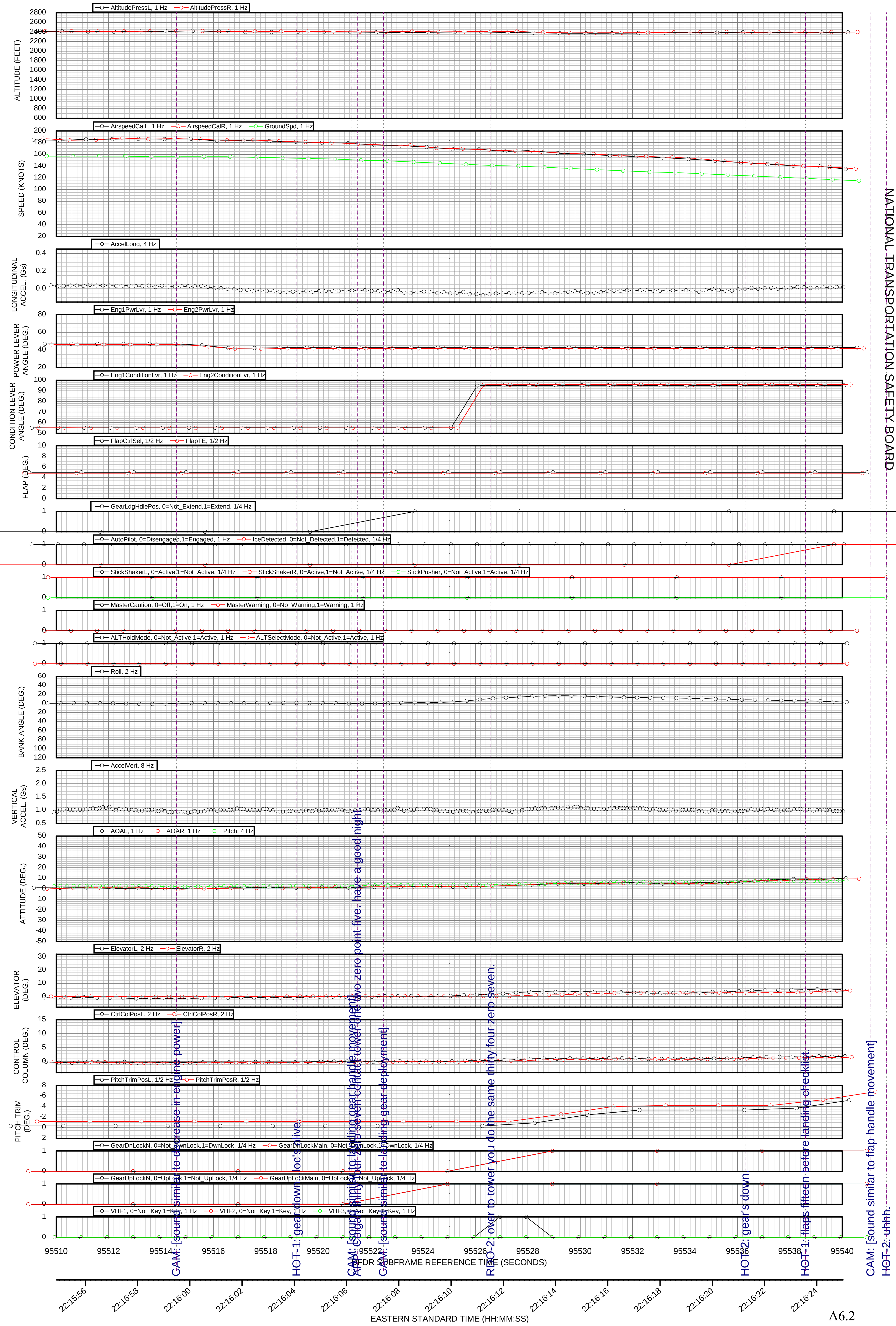


FIGURE A6.2: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (LONGITUDINAL AXIS)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR AND CVR DATA]

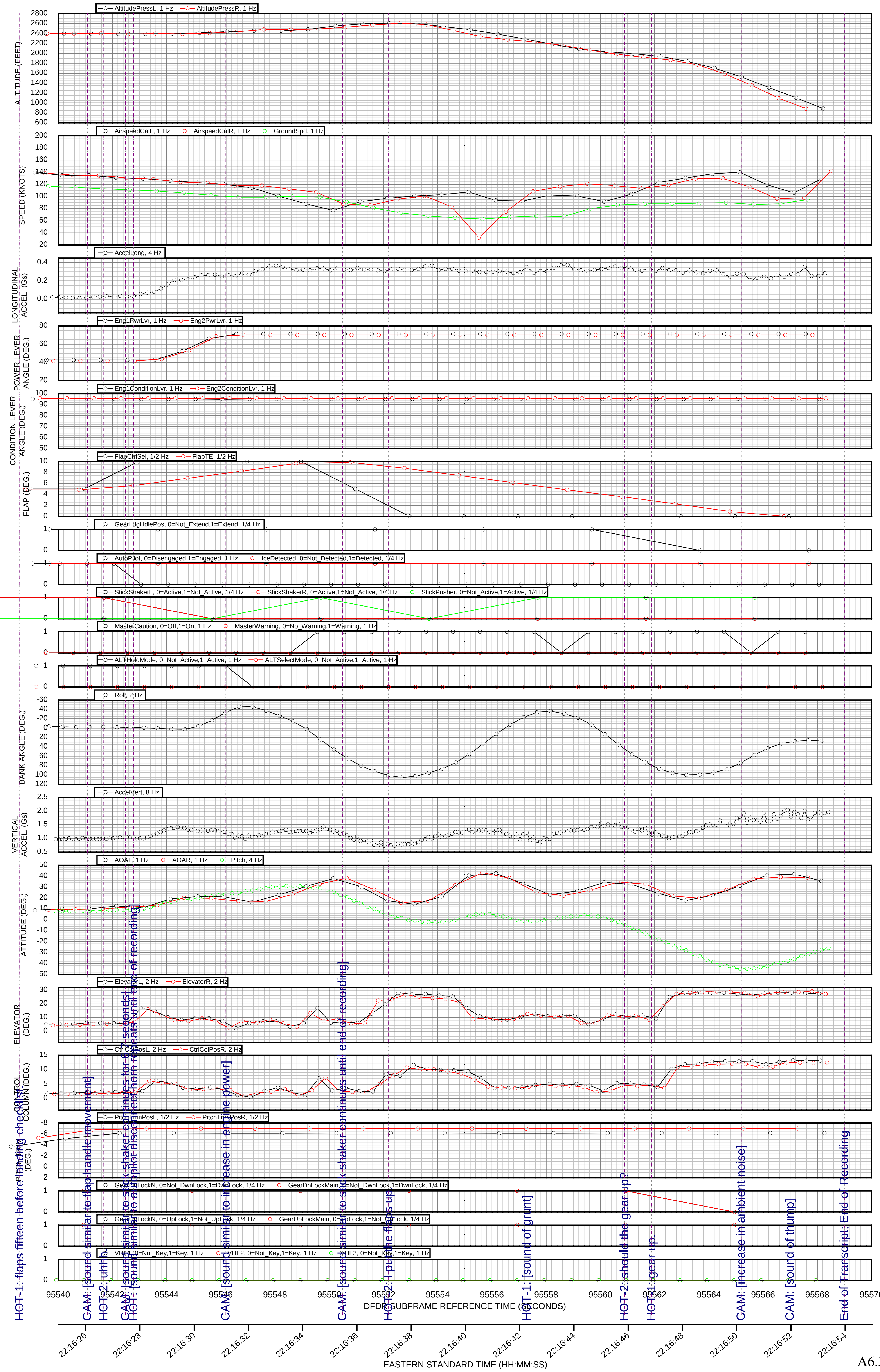


FIGURE A6.3: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (LATERAL-DIRECTIONAL AXES)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR AND CVR DATA]

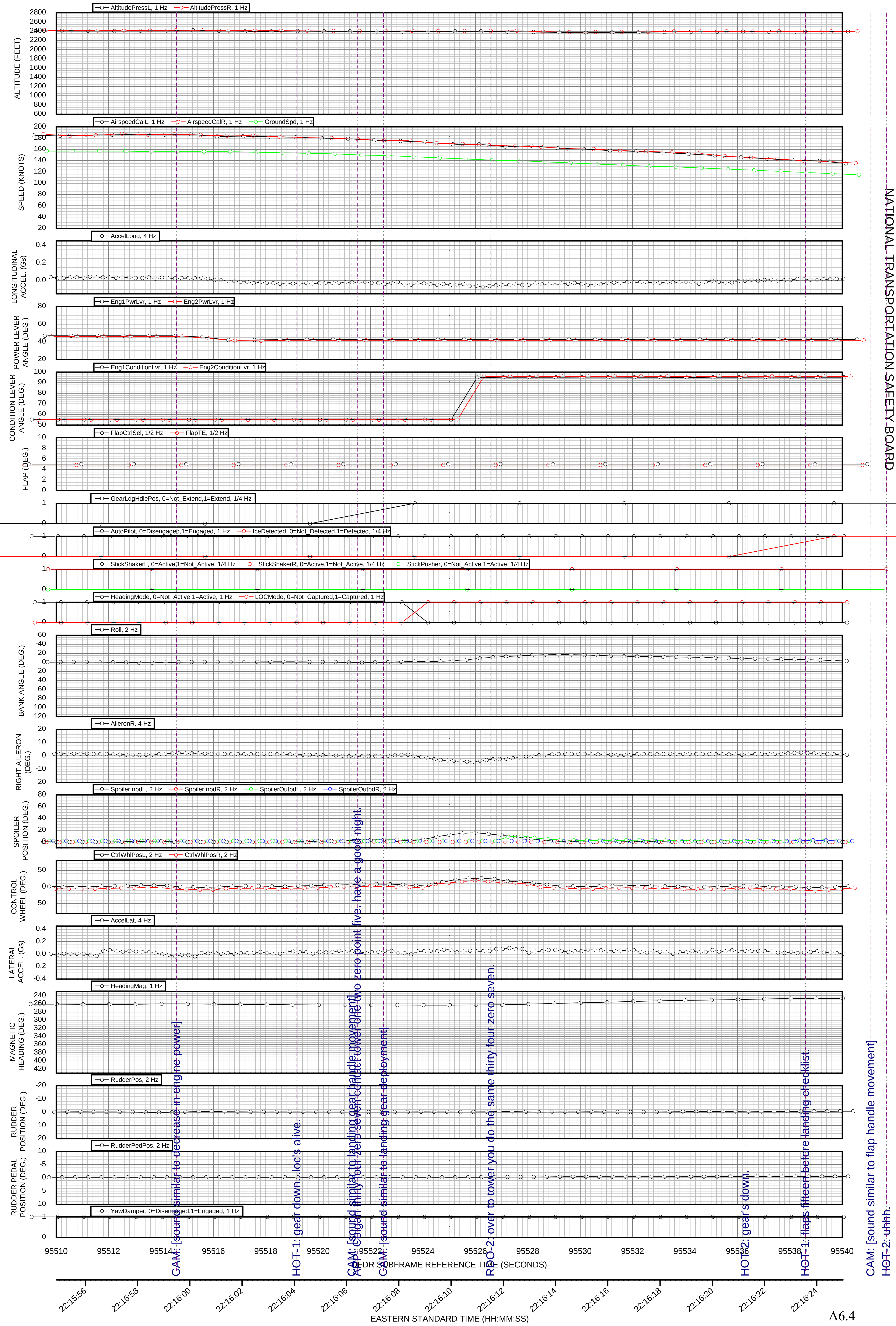


FIGURE A6.4: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (LATERAL-DIRECTIONAL AXES)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR AND CVR DATA]

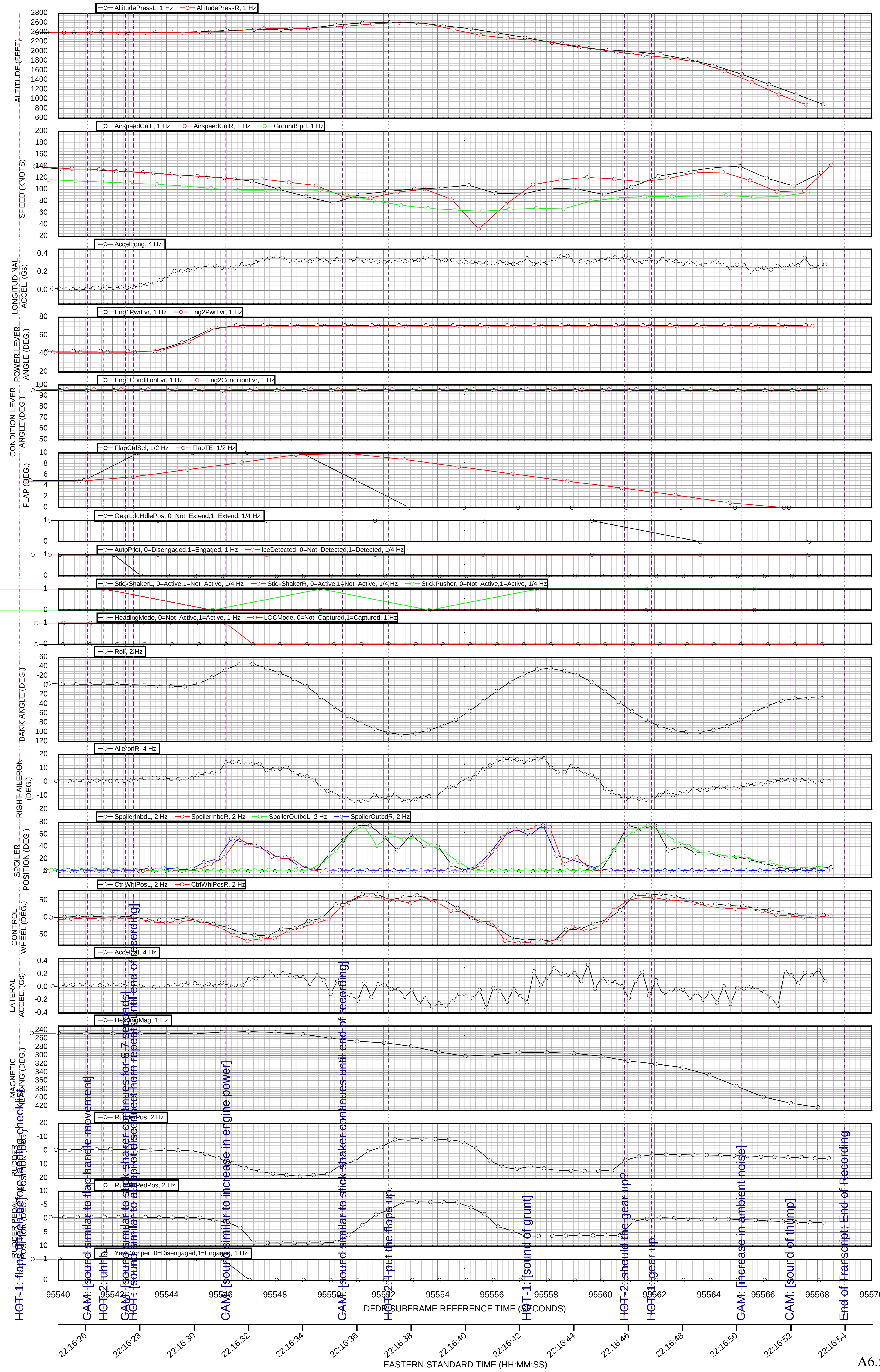


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FIGURE A6.5: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (ENGINES AND PROPELLERS)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR AND CVR DATA]

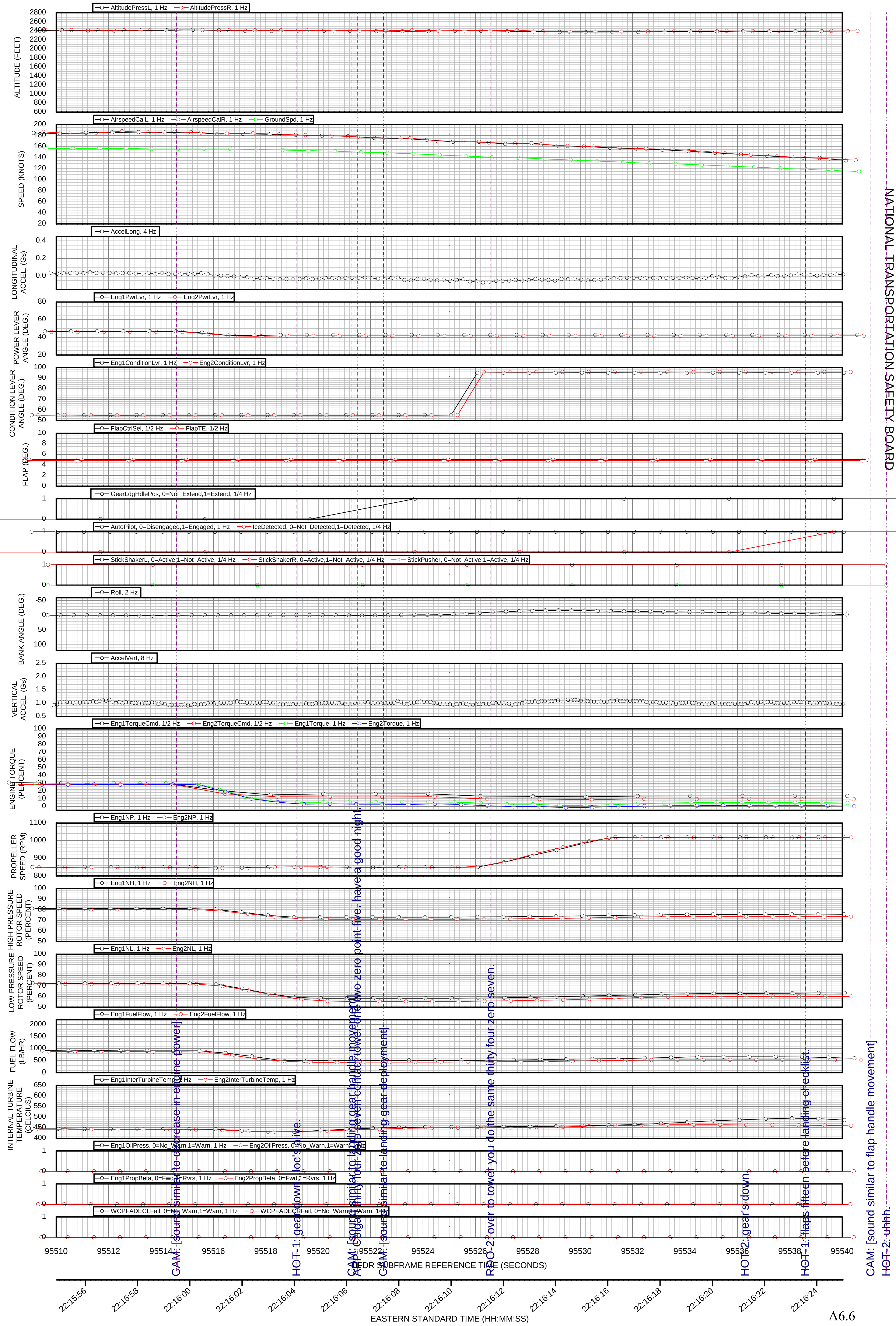

FIGURE A6.6: COLGAN AIR BOMBARDIER DHC-8-400 (N200WQ), FLIGHT 3407 (ENGINES AND PROPELLERS)
ORIGINATED EWR, LOST FROM RADAR NEAR CLARENCE CENTER, NY, FEBRUARY 12, 2009 [FDR AND CVR DATA]