NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, D.C. 20594

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Aircraft Performance - Addendum #2

Addendum to Group Chairman's Aircraft Performance Study
by John O'Callaghan

A. ACCIDENT

Location:	Sixty miles South of Nantucket, MA
Date:	October 31, 1999
Time:	0150 Eastern Standard Time (EST)
Flight:	EgyptAir Flight 990
Aircraft:	Boeing 767-366ER, Registration SU-GAP
NTSB#:	DCA00MA006

B. GROUP

Chairman: John O'Callaghan
Senior Aerospace Engineer
NTSB

Members: Mohamed A. Hamid Hamdy
Engineer - General Manager Training
EgyptAir

Maher Ismaiel Mohamed
Head of Airworthiness - Central Administration
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C. SUMMARY

This Addendum to the Aircraft Performance Group Chairman's Aircraft Performance Study documents simulator and airplane ground test work done at The Boeing Company at the request and with the participation of the Aircraft Performance and other investigative groups. The work documented here took place during two visits to Boeing's Seattle, WA, facilities during December 1999 and March 2000.

D. DETAILS OF THE INVESTIGATION

I. December 1999 Activity

In December 1999 the Aircraft Performance Group visited Boeing to review simulator representations of the dive of MSR990 from 33,000 feet and climb back to 24,000 feet as recorded by the Digital Flight Data Recorder (DFDR) and the radar data. Because the details of the flight path of the airplane during the second dive from 24,000 feet to the surface are unknown, the simulator exercises did not include this portion of the accident sequence.

The Group also experienced the column forces required to split the left and right control columns so as to create a split elevator condition similar to that recorded on the DFDR. This exercise was performed during a ground test on a Boeing 767-400 flight test airplane. During this test, the elevator control system was in normal operating condition and was not altered to simulate any kind of malfunction. In a later ground test performed during the March visit to Boeing, the control forces required to move the columns both symmetrically and as required to produce a split condition were determined both with a normal elevator control system, and with several modifications to the control system intended to simulate different types of malfunctions. The March ground tests are documented in detail in an addendum to the Systems Group Chairman's Factual Report.

The simulations reviewed by the Group in December and March were of two types. The first type are called "Background" simulations, and run autonomously on a computer without pilot inputs from a simulator cab. The simulation program calculates the flight control inputs required to make the computed motion of the airplane match approximately the actual motion recorded by the DFDR and radar data.

The second type of simulation reviewed by the Group are "E-CAB" simulations, and incorporate pilot inputs into the computation of the airplane motion by replicating the cockpit environment, instruments, and controls in a fixed base cab. A computer generated visual scene simulates the view from the cockpit windows. The E-CAB simulations can be further subdivided into two types: "Backdrive" simulations, and "Pilot-in-the-Loop" simulations. During the Backdrive simulations, the E-CAB control column, control wheel, throttle, and speedbrake handle are moved by the simulator cab hydraulic control loader and electric motors so as to represent the motion of these items during the accident, as determined by recorded DFDR data or as estimated from the data using various assumptions. The engine cut logic is also driven by the simulation based on DFDR data, though the engine cutoff switches do not move in the cab. During the Backdrive simulations, human pilots do not manipulate the E-CAB controls, but simply witness the motion of the controls, instruments, and visual displays as they are driven by the simulation itself.

During “Pilot-in-the-Loop” simulations, the human pilot manipulates the E-CAB controls as he would the controls in an actual airplane in order to “fly” the simulation. The simulation calculates the control forces with which to resist the pilot inputs so that the same effort is required to manipulate the simulator controls as are required for the real airplane’s controls.

The tests performed using Background and E-CAB simulations are described below.

Simulation Overview

The Background and E-CAB simulations described in this Addendum are special applications of the Boeing 767 engineering simulator and E-CAB. The ways these special cases work are best understood in terms of how they differ from a “standard” simulation, in which a human pilot seated at the cab controls makes control inputs as he would in a real airplane, and the simulation calculates the appropriate response in the control forces, airplane motion, instrument displays, and visual scene.

Figure 1 is a flow chart describing the logic and data flow in a standard simulation. The boxes with bold lines and non-italicized text represent simulation models, that is, units of computer code and data that describe the behavior of a part of the airplane or its systems mathematically. The boxes with non-bold lines and italicized text represent physical quantities or values computed by the simulation models. The arrows indicate which simulator models compute the various physical quantities, and how these quantities are in turn used as inputs by other models.

Starting with the box labeled “Human Pilot,” we see that by manipulating the E-CAB controls the pilot can generate inputs to the column, wheel, throttles, speedbrake handle, flaps, gear, and other cockpit controls duplicated in the E-CAB. He can also provide inputs to the Flight Management Computer and Autopilot. In the case of Background simulations, which run on the computer without a cockpit cab, these “pilot” inputs are accomplished by computer code. In both the E-CAB and Background cases, the pilot inputs are eventually processed by the simulator flight controls model that calculates the appropriate response of the airplane control surfaces, and by the propulsion model that computes the response of the airplane’s engines. The aerodynamic model then uses the surface positions along with the motion state of the airplane (airspeed, altitude, etc.) to calculate aerodynamic forces and moments on the airplane. The propulsion model computes the thrust forces and moments. These forces and moments are used along with quantities calculated by the mass properties model in the solution of the equations of motion that determine the motion states, both angular and linear. Angular states are the airplane’s yaw, pitch and roll angles, and their time derivatives (angular rates and accelerations). Linear states are the components of the three dimensional position of the airplane in space and their time derivatives (velocities and accelerations). These states are also used as inputs in the various mathematical models that compute the quantities that eventually affect the forces and moments.

In the case of the E-CAB simulations, information about the airplane motion states and from the propulsion model are used to drive the visual displays and cockpit instruments in the cab. For simulator cabs on a motion base, the motion information can be used to maneuver the base in an attempt to duplicate, within limits, the acceleration cues felt by the pilots (the E-CAB is a fixed base simulator, and can not be maneuvered in this way).

Though not part of a standard simulation, for the EgyptAir 990 investigation the motion states and other data are also used to drive a stand-alone computer animation. This animation depicts a computer-generated image of a 767 and various cockpit instruments and controls, and moves them as the simulation is running so as to represent the position and attitude of the airplane and the values of instrument readings and control inputs. A still image from the animation is shown in Figure 2.

The details of the assumptions and methods used to produce the December 1999 and March 2000 Background and E-CAB simulations are discussed below. These details are summarized in Table 1, which was prepared by Boeing and indicates the data sources that drive the simulation controls, instruments, and displays.

December 1999 Background Simulations

The objectives of the background simulation developed for the December 1999 visit were to estimate the control surface and pilot control positions required to match approximately the dive from 33,000 feet, assuming symmetric elevator deflections and a fault-free control system, and to confirm that the airplane has the performance to recover from the dive and climb back to 24,000 feet as indicated by the radar data. A simulator “match” of the dive is achieved when the airplane position and attitude calculated by the simulator equals the (corrected) position and attitude recorded by the DFDR. To produce a match, the simulation is trimmed at an initial position and speed prior to the dive and provided with target Euler angles (pitch, roll and heading) to pursue during the dive. The simulation may manipulate the control column, control wheel, and rudder pedals as required to correct any deviations from the target angles, as illustrated by the flow charts in Figures 3a-3c.

As described in the Aircraft Performance Study, during the dive the airplane exceeded Mach 0.91 from the time it passed through 29,000 feet until the end of the data, a period of about 25 seconds. The simulator mathematical models of the aerodynamic characteristics of the Boeing 767 do not contain flight-test validated data at these high Mach numbers, and so the existing, wind tunnel based data was adjusted slightly to improve the match between the motion computed by the simulator and the motion recorded by the DFDR. This adjustment is consistent with the practice of updating the wind tunnel predictions of aerodynamic behavior with measured behavior from actual flights.

The December 1999 Background simulation attempts to match the Euler angles recorded by the DFDR during the period of the elevator split using symmetrical elevator deflections, to be consistent with the capabilities of the E-CAB simulation at that time. For the March 2000 Background simulations, each elevator surface was modeled independently, thereby representing the actual elevator motion during the accident more closely. The March E-CAB simulation was modified to be able to model a split elevator condition, with certain limitations (both the March Background and E-CAB simulations are discussed in more detail below).

The purpose of determining the elevator surface positions required to match the dive from 33,000 feet is so that they can be compared to the elevator positions recorded by the DFDR.

If the surface positions from the simulator match and the DFDR are similar[1], then it is likely that the dive occurred in response to the nose down elevator movements recorded by the DFDR, and not as the result of an external disturbance or failure of part of the structure.

The background simulator match results presented in Figures 4a-c indicate that the elevator positions required to make the simulator match the dive are consistent with the positions recorded by the DFDR. The quality of the simulator match of the motion of the airplane during the dive can be ascertained by comparing the altitude and airspeed calculated by the simulator with the altitude and airspeed recorded by the DFDR and *corrected* for the effects of the static port pressure errors. Figure 4a shows that the simulator altitude and airspeed start to deviate from the raw DFDR data during the dive, but Figure 4c shows that once the DFDR data is corrected for pressure error effects it agrees quite well with the simulator data. This agreement is evidence of the accuracy of both the simulator model and the pressure error corrections presented in the Performance Study.

Note that while the airplane motion during the dive is consistent with the expected response to the elevator movements recorded on the DFDR, the simulation does not provide any information about the causes of the recorded elevator motion. In the simulation, the elevator motion is obtained by moving the control column to match the DFDR pitch angle, but this is simply for convenience, and to determine the control movements and forces required to match the maneuver using pilot inputs. There are other potential causes of elevator motion apart from pilot inputs, including failures in the elevator system. The Systems Group Chairman's Factual Report discusses potential failures that can produce uncommanded elevator motion.

The Background simulation results presented in Figures 4a-c use a different time reference than that introduced in the Airplane Performance Study. The relationship between the TIME variable presented in Figures 4a-c, the Elapsed Time (ET) reference used in the Performance Study, and the Nantucket ASR-9 Radar time is as follows:

0.0 ET (Peformance Study Reference Time)	= 1254.02 TIME (Simulator Time plotted in Figures 4a and 4b)	= 06:50:00 UTC (Nantucket ASR-9 Radar Time)

December 1999 E-CAB Simulations

During the December 1999 visit the investigative team participated in simulator exercises in Boeing's 767 engineering simulator cab (E-CAB). As described above, the E-CAB simulations consisted of "Backdrive" and "Pilot-in-the-Loop" runs, in which the team members witnessed the simulation move the cockpit controls as required to match the dive maneuver using symmetric pilot inputs, and had the opportunity to intervene and manipulate the controls themselves as required to recover from the dive or perform other maneuvers.

[1] An exact match between the simulator and recorded elevator positions would be unexpected because of uncertainties in the flight condition and mathematical models, and because the recorded elevator positions are not necessarily the exact elevator positions experienced in flight. The elevator position signal is filtered before being recorded, so that signals from quick, abrupt movements in the surfaces may not be apparent in the recorded data.

The Backdrive simulations use the (symmetric) elevator angles computed in the Background simulation to match the airplane motion during the dive. The elevator aft quadrant position associated with these elevator angles is used to compute corresponding control column positions. The E-CAB control loader moves the E-CAB columns so as to match these computed positions, as shown in Figure 5.

Other cockpit controls manipulated by the simulation during the Backdrive simulations include the throttle handles and the speedbrake handle. The logic governing the motion of these controls is illustrated in Figures 6 and 7. Note that the simulation can only move the throttle handles at the authothrottle rate limit of about 10.5°/second, but that the DFDR data presented in the Airplane Performance Study indicates that the throttle handles actually moved much faster than that (at about 25°/s). Hence, the backdrive simulations are set up to start the throttle movement at the proper time, but because of the rate limit, the movement of the throttles in the E-CAB is considerably slower than they would have been during the accident.

The simulation can move the speedbrake handle at about 87 degrees/second, and so the rate of movement of this handle in the E-CAB is representative of the rate of movement of the handle indicated by the DFDR (from armed to fully deployed within 2 seconds). While the DFDR data indicates the speedbrakes were not armed before being deployed, the E-CAB requires the speedbrake handle to be in the armed position in order to drive it to the deployed position.

The engine cut logic during the Backdrive scenarios is controlled by the simulation, which triggers left and right engine cutoff signals at times consistent with the engine cutoff discretes recorded on the DFDR. While these signals shut down the simulated engines, the engine cutoff switches in the cab do not move.

During the E-CAB simulation exercises, the participants were given the opportunity to interrupt the Backdrive simulation by assuming control of the simulation at any time and using the cockpit controls in a normal manner to fly the airplane. These "pilot interrupt" scenarios were usually accomplished after witnessing the complete Backdrive simulations a few times without interruption.

Other activities conducted in the E-CAB during the December 1999 visit included pilot-in-the-loop simulations of a failure of the stick nudger system (which exerted a 25 pound force over 5 seconds in the nose down direction on the control column), and simulations of the airplane handling qualities with various hydraulic systems inoperative. Table 2 provides a list of the various types of Backdrive, pilot-in-the-loop ("hand fly"), and stick nudger/hydraulic system failure scenarios flown in the E-CAB.

A large number of individuals, representing the various organizations involved in the investigation, participated in the simulator exercises. To keep a record of the individuals at the controls of the E-CAB, each participant was assigned a number code. The participants and their number codes are listed in Table 3.

A record of the runs flown in the E-CAB is shown in Tables 4a and 4b. For each run, the Table identifies the simulation scenario, the participants at the controls, and the file and case name containing the recorded electronic data for that run. Relevant simulator variables for each of these runs were plotted by Boeing and provided to the NTSB in Adobe .PDF electronic files. These files are included in the public docket for this accident (see Section D-III, “Electronic Data Files,” for more information).

While the E-CAB is a very sophisticated simulator cab powered by a state of the art engineering simulation, not all the characteristics or behaviors of the real airplane are duplicated in the cab. Prior to the E-CAB activity, Boeing personnel briefed the participants on the various limitations in the simulation. The list of limitations presented by Boeing is included here as Appendix A. The Airplane Performance Group consensus was that these limitations did not hamper the usefulness or relevance of the information obtained from the simulator activity.

Split Column Ground Tests

As mentioned above, during the December 1999 Boeing visit the Airplane Performance Group and other investigators also participated in a ground test on a Boeing 767-400 flight test airplane. During this test, the participants experienced the column forces required to split the left and right control columns so as to create a split elevator condition similar to that recorded on the DFDR. Figures 15a and 15b plot the pilot and co-pilot column positions and forces as a function of time during a representative test at two different values of elevator feel pressure. The left and right inboard elevator positions resulting from these control inputs are also shown.

The plan of test and test notes prepared by Boeing personnel for the December ground tests are included here as Appendix B.

II. March 2000 Activity

The March 2000 simulator activity, as the December 1999 activity, consisted of both Background and E-CAB Backdrive simulations. The March simulations differ from the December simulations primarily in that the simulator flight controls model for the March simulations moves the left and right elevator surfaces independently, thereby allowing the simulation to account for an elevator split similar to that shown on the DFDR. However, the new split elevator capability is limited to the mathematical modeling of the elevators, because the control columns in the E-CAB are rigidly linked together and can not be split (unlike the columns in the real airplane). The March E-CAB simulations therefore consist of several scenarios in which the E-CAB control columns are programmed to duplicate either the left or right control column positions and forces, assuming that the split in the DFDR elevators is due to a split in the control columns. These scenarios were performed in support of the Human Performance Group’s investigation.

Other March E-CAB activities that took advantage of the split elevator modeling capability included the simulation of a variety of elevator PCA failures. These simulations allow the response of the simulation under the various failure scenarios to be compared with the airplane motion recorded on the DFDR, and can also be used to determine the workload required to recover from the failures. These simulations were performed in support of the Systems Group’s investigation, and are documented in detail in an Addendum to the Systems Group Chairman’s Factual report.

A series of ground tests on the Boeing 767-400 flight test airplane were also conducted during the March visit. These tests are also documented in the Addendum to the Systems Group Chairman's Factual report.

March 2000 Background Simulations

The March Background simulations are essentially identical to the December simulations, except for some changes to the aerodynamic data tables that attempt to estimate the (untested in flight) aerodynamic characteristics of the airplane above the dive speed of Mach 0.91, and for the manner in which the elevators are controlled in order to match the DFDR recorded pitch angle. In the March simulations, different methods are used for controlling the elevators depending on the information available about their behavior on the accident flight. What is known about the elevators during the accident can be divided into three distinct segments:

For TIME < 1265, the DFDR elevators are not split, and the simulation uses the same (symmetric elevator) method for driving the elevators as is used for the December simulations (see Figure 3a).

From 1275 < TIME < 1290, the DFDR elevators are split, and so the simulation no longer uses symmetric elevators to obtain the desired pitch response. Instead, two different methods are used (each in a separate Background simulation). Each method starts operating at TIME = 1265 seconds, about 10 seconds before the elevator split and at about the time the Mach number exceeds 0.91. In the first method, the simulation elevators are forced to be identical to the recorded DFDR elevators, and any additional pitching moment required to match the DFDR pitch angle is introduced into the simulation artificially, with an additional mathematical term in the buildup of the pitching moment coefficient equations (see Figure 8). This is the "ΔC_M" method. The additional pitching moment coefficient required can be expressed in terms of an equivalent (symmetric) elevator deflection, so that the size of the coefficient can be measured. The second method for matching the DFDR pitch angle during the period the elevators are split is to compute the additional (symmetric) elevator deflection required to match, and then apply the required additional deflection equally to the left and right elevator surfaces (see Figure 9). This is the "$\frac{1}{2}\Delta\delta_e$" method.

For TIME > 1290, there is no DFDR data available and so the behavior of the actual elevator surfaces is unknown. For this segment, the simulation reverts to the symmetrical elevator method used for TIME < 1265 to match the target pitch angle. The target pitch angle in this segment is calculated from an analysis of the radar data and is presented in Figure 14a of the Aircraft Performance Study.

The results of the Background simulations are presented in Figures 10-12. Figures 10a and 10b are the results with using the "ΔC_M" method to match the target pitch angle during 1265 < TIME < 1290. Figure 11 is the equivalent symmetric elevator deflection associated with the "ΔC_M" method. Figures 12a and 12b are the results with using the "$\frac{1}{2}\Delta\delta_e$" method to match the pitch angle during this period, with the changes to the aerodynamic data introduced for the March simulations. Figures 12c and 12d are the results with using the "$\frac{1}{2}\Delta\delta_e$" method, but with the same aerodynamic data that was used in the December simulations. The results in Figures 12c and 12d also differ from those in 12a and 12b in that after TIME = 1290 seconds the rudder pedal is no longer used to actively force the simulator to match the DFDR heading data. This changes the simulator wheel response after TIME = 1290 seconds, but has negligible effect on the longitudinal axis throughout the maneuver.

Note in Figures 12a-d that the elevator angles computed by the simulation with both the December and March aerodynamic data match the DFDR elevator positions well between times 1245 sec. and 1267 sec. However, as the load factor starts to increase at time = 1268 seconds, the elevator positions computed using the March aerodynamic data start to deviate by up to two degrees from the recorded DFDR elevator angles, and remain in a more nose-up position than the recorded angles until the elevator split at time = 1275 seconds. Thereafter, following some transient oscillations, the left and right elevator positions computed by the simulation during the elevator split match the DFDR recorded angles well.

The elevator angles computed using the December aerodynamic data match the recorded angles well all the way through the elevator split at time = 1275 seconds, and are reasonably close to the recorded angles during the split up to about time = 1283 seconds. Then, the simulator requires about one to two degrees more nose up deflection on both the left and right panels than was recorded on the DFDR.

These results illustrate the difficulties of matching the DFDR data exactly in the untested flight regime above Mach 0.91, where the aerodynamics of the airplane are very sensitive to a variety of variables, including Mach number, angle of attack, and elevator deflection. However, the December and March aerodynamic tables bracket the actual aerodynamics of the airplane in this region, since both sets of data produce good matches of the DFDR elevator angles in different areas. More importantly, both sets of data produce a good match of the recorded DFDR elevator angles before and during the initial part of the dive, indicating that the pitching moments that initiate the dive are the result of the recorded elevator motion. Even allowing for the uncertainties in the aerodynamics, the simulations indicate that the pitch angle throughout the accident is driven by the motion of the elevators, though the simulations do not provide any information as to the cause of the elevator motion.

March 2000 E-CAB Simulations

The March E-CAB simulations, like those in December, consisted of Backdrive and pilot-in-the-loop scenarios. The updated simulator flight controls model used in these simulations can allow for asymmetrical left and right elevator movement in response to both elevator system failure and opposing left and right control column input scenarios. However, the physical control columns in the E-CAB are rigidly connected and, unlike in the real airplane, can not be moved in opposing directions. Therefore, In order to backdrive the E-CAB columns to reflect the column motion during opposing left and right column inputs, or to simulate the control forces associated with a column split, several different scenarios had to be established, each with different rules governing the E-CAB column motion and forces.

Four different scenarios were established for the E-CAB simulations to investigate situations involving opposing column movements. Figure 13 presents a flow chart describing the control column position and force calculation methods for each of these scenarios. A different set of scenarios was established to investigate situations involving failures in the elevator control system; these latter scenarios are documented in an Addendum to the Systems Group Chairman's Factual Report. The four split column scenarios are:

1. Backdrive simulation with the E-CAB column forces and positions as required to match the right elevator position recorded on the DFDR. Any column inputs applied externally (i.e., by the simulation participants) do not affect the elevator positions or the flight profile. The match of the DFDR flight profile is obtained by moving the simulation elevators as described in the Background simulations, using the "ΔC_M" method during the times the DFDR elevators are split.

2. Backdrive simulation with the E-CAB column forces and positions as required to match the left elevator position recorded on the DFDR. Any column inputs applied externally (i.e., by the simulation participants) do not affect the elevator positions or the flight profile. The match of the DFDR flight profile is obtained by moving the simulation elevators as described in the Background simulations, using the "ΔC_M" method during the times the DFDR elevators are split.

3. Backdrive simulation with the E-CAB column forces and positions as required to match the right elevator position recorded on the DFDR. However, unlike in Scenario 1, an input to the E-CAB columns will split the simulation's left elevator from the right elevator and the flight profile will follow from the pitch response resulting from the combined left and right elevator positions. The forces required on the left column to split the left elevator away from the recorded right elevator position are accurately represented. These forces can be applied from either the left or right E-CAB columns, since they are linked rigidly. To match the DFDR flight profile, the inputs to the E-CAB columns must be such so as to duplicate the left elevator position recorded by the DFDR. If no inputs are applied to the E-CAB columns, then the simulation's left elevator will match the right elevator and the resulting flight profile will not match the DFDR.

4. Backdrive simulation with the E-CAB column forces and positions as required to match the left elevator position recorded on the DFDR. However, unlike in Scenario 2, an input to the E-CAB columns will split the simulation's right elevator from the left elevator and the flight profile will follow from the pitch response resulting from the combined left and right elevator positions. The forces required on the right column to split the right elevator away from the recorded left elevator position are accurately represented. These forces can be applied from either the left or right E-CAB columns, since they are linked rigidly. To match the DFDR flight profile, the inputs to the E-CAB columns must be such so as to duplicate the right elevator position recorded by the DFDR. If no inputs are applied to the E-CAB columns, then the simulation's right elevator will match the left elevator and the resulting flight profile will not match the DFDR.

In both Scenarios 3 and 4, the participants in the E-CAB have to provide the forces on the column (either push or pull) that will split the elevators and make the resulting elevator positions and flight path match those recorded on the DFDR. During these scenarios, the roll axis can either be backdriven (controlled by the simulation) or controlled manually with the wheel by the E-CAB participants. If the roll axis and control wheel are backdriven, the resulting bank angle will match approximately the bank angle recorded by the DFDR and derived from the radar data. If the roll axis is controlled by the participants, the bank angle will only match the DFDR and radar derived data if the participants make the appropriate wheel inputs. Thus, the workload required to match the accident flight path in Scenarios 3 and 4 is higher if the roll axis is controlled manually.

An additional E-CAB scenario that was flown during the March simulations was one similar to Scenario B of the December simulations. This “Scenario 5” would be started as a backdrive, but at any time during the run the participants could call for full control and the simulator would fly normally (the simulation would not drive any part of the controls).

For Scenarios 1-5, a copy of the Cockpit Voice Recorder (CVR) sounds was available to be played synchronously during the simulation runs. The synchronized playback of the CVR during the backdrive scenarios gave the investigators a sense of the crew communication and cockpit sounds that took place during the dive maneuver replicated by the simulation.

To assist the participants in judging the push or pull forces required on the column to match the computed left and right control column forces in Scenarios 1-4, an animated instrument display containing the instruments shown in Figure 14 was projected onto the simulator visual scene. The green and blue needles on the left and right column force meters in this display are the left and right column forces required to produce the elevator split recorded on the DFDR. The white needle in the center column force meter indicates the actual force being exerted on the E-CAB columns (because the left and right columns are rigidly linked, the needle shows the resultant of the forces applied to both columns). The blue and green bugs on the middle column force meter duplicate the readings of the left and right column force meters and serve as targets for exerting the proper force on the columns. By pushing or pulling on the E-CAB columns so as to align the white needle with either the blue or green bugs, the participants could experience the amount of force required on the left and right columns to produce the DFDR recorded elevator split.

As in the December E-CAB simulations, to keep track of the individuals participating in the E-CAB study, each participant was assigned a number code. These codes are given in Table 5.

A record of the runs flown in the E-CAB during March is shown in Tables 6a-6c. For each run, the Table identifies the simulation scenario, the participants at the controls, and the file and case name containing the recorded electronic data for that run. Electronic files containing plots of the simulation results are included in the public docket for this accident in Adobe .PDF format (see Section D-III below).

As in the December simulations, prior to the March E-CAB activity Boeing personnel briefed the participants on the various limitations and methodologies used in the simulation. A copy of this presentation is included here as Appendix C. After the March activity and in support of the documentation of the simulations described in this Addendum, Boeing prepared additional material concerning the simulator limitations and characteristics. This additional material is presented in Appendix D, and notes the presence of offset and discontinuity discrepancies in the elevator response for Scenarios 1-4. Since the purpose of these Scenarios was to provide the Human Performance group with a sense of the column forces required to cause the split elevator condition, with the preciseness of the airplane response of only secondary concern, the impact of these offset and discontinuity discrepancies on the usefulness of the Human Performance simulations is minimal.

III. Electronic Data Files

Plots of the simulator data recorded in the E-CAB during the December and March activities were generated by Boeing in Adobe Portable Document Format (PDF) format, and are included in the public docket for this accident. The simulator runs from Tables 4 and 6 corresponding to the data plotted in each file can be determined from the naming convention of the files. For each run, there are two corresponding plot files: one for longitudinal parameters, the other for lateral/directional parameters. The naming convention is as follows:

LAT_QQQ_*file.case.*PDF = Lateral/directional plot for file *"file"* and case *"case."*
LONG_QQQ_*file.case.*PDF = Longitudinal plot for file *"file"* and case *"case."*
For example, referring to Table 6c, the plots corresponding to the third entry in the table would be

LAT_QQQ_25.03.PDF (Lateral/directional plot)
LONG_QQQ_25.03.PDF (Longitudinal plot)

Note that no plots are provided for the runs listed in Tables 6a and 6b. The purpose of these runs was to explore various Human Performance items of interest in the simulator cab, and these runs are not relevant to aircraft performance. For a description of the work done by the Human Performance Group, see the Human Performance Group Chairman's Factual Report.

E. CONCLUSIONS

The Background simulations described in this Addendum indicate that the descent of EgyptAir flight 990 from 33,000 feet is consistent with the elevator motions recorded on the DFDR, such that no external force or disturbance is required to provide an additional nose-down pitching moment so as to match the pitch angle recorded on the DFDR. In addition, the simulation results indicate that the airplane has the performance to recover from the dive and climb back to 24,000 feet as indicated by the radar data, even with the engines shut down and the speedbrakes extended.

The E-CAB and ground test activities described in this Addendum afforded the participants from the NTSB, the Egyptian Civil Airworthiness Authority, EgyptAir, Boeing, and other parties to the investigation to experience a recreation of the cockpit environment during the dive of EgyptAir flight 990 from 33,000 feet, as determined from CVR, DFDR, and radar data. The visual scene, cockpit instruments, throttles, speedbrake handle, engine cut logic, and control column and wheel were driven in these simulations. The simulations described here assume that the elevator motion recorded on the DFDR, including the elevator split, result from inputs to the cockpit control columns. An additional set of simulations was performed that explored the consequences of various failures in the elevator control system on the elevator motion and on the flight path and controllability of the airplane. These additional simulations are described in an Addendum to the Systems Group Chairman's Factual Report.

John O'Callaghan
Senior Aerospace Engineer

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	Background Simulation		***E-Cab Simulation***			
	December 1999 Symmetric Elevators	**March 2000 Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Delev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
Gross Weight (lbs)	390,000	390,000	390,000	390,000	390,000	390,000
Center of Gravity	0.233	0.233	0.238	0.238	0.233	0.233
Initial Altitude (feet)	33,000	33,000	33,000	33,000	33,000	33,000
Initial Airspeed (knots)	280	280	0.788 (Mach number)	0.788 (Mach number)	280	280
Flaps	Up	Up	Up	Up	Up	Up
Gear	Up	Up	Up	Up	Up	Up
Initial Speedbrake Handle	Retracted	Retracted	Retracted	Retracted	Retracted	Retracted
Simulation Winds	None	None	None	None	None	None
Initial Trim Time	1235	1235	1239	1239	Not Applicable	Not Applicable
Arbitrary Time Restart Capability	No	No	No	No	Yes	Yes

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 1 of 10) (provided by the Boeing Company).

	Background Simulation		***E-Cab Simulation***			
	December 1999 **Symmetric Elevators**	**March 2000** **Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Delev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
Pitch Control	Assume symmetric elevators: math pilot perturbs control column to target DFDR/radar-derived pitch attitude.	For Time < 1265 and Time > 1290, assume symmetric elevators: math pilot perturbs control column to target DFDR/radar-derived pitch attitude and pitch rate. For Time ≥ 1265 and Time ≤ 1290, backdrive left and right elevator with respective DFDR data, and **Option 1:** math pilot computes Δpitching moment (cmtrm) to target DFDR pitch attitude and pitch rate. **Option 2:** math pilot computes Δelevator (split equally between left and right elevator) to target DFDR pitch attitude and pitch rate.	*Full Backdrive:* pitch attitude is driven by symmetric left and right elevators determined in background simulation; stabilizer is held constant at initial trim setting; net thrust is provided by background simulation; speedbrake handle is moved as a function of elapsed time (delayed ~4 seconds relative to the DFDR data).	*Pilot Takes Over:* pilot flying has full authority over control column, stabilizer, throttle, and speedbrake handle inputs. Note: pilot flying will experience nominal control column forces (i.e., no opposing control column forces due to elevator split are modeled).	*Scenario 1:* throughout the time history, pitch attitude is driven by left and right elevators, stabilizer, and net thrust determined in the background simulation; speedbrake handle is deployed correctly based on the DFDR data. For Time < 1275, prior to the DFDR elevator split, control column position is backdriven via a gain on the average of left and right computed aft quadrant column position based on the DFDR left and right elevator data. For Time ≥ 1275 control column position is backdriven via a gain on the right aft quadrant column position computed to be consistent with the DFDR right elevator (or radar-derived pitch attitude) for the given flight condition. *Scenario 2:* identical to Scenario 1 above, except right elevator/column becomes left elevator/column.	*Scenario 3:* throughout the time history, subject to pilot inputs, pitch attitude is driven by right elevator, stabilizer, and net thrust determined in the background simulation; speedbrake handle is deployed correctly based on the DFDR data. For Time < 1275, prior to the DFDR elevator split, control column position is backdriven via a gain on the average of left and right computed aft quadrant column position. For Time ≥ 1275 control column position is backdriven via a gain on the right aft quadrant column position computed to be consistent with the DFDR right elevator (or radar-derived pitch attitude) for the given flight condition. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* identical to Scenario 3 above, except right elevator/column and left elevator/column must be swapped.

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 2 of 10) (provided by the Boeing Company).

	Background Simulation		***E-Cab Simulation***			
	December 1999 Symmetric Elevators	**March 2000 Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Δelev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
Roll Control	Math pilot perturbs control wheel to target DFDR/radar-derived roll attitude.	Math pilot perturbs control wheel to target DFDR/radar-derived roll attitude and roll rate.	*Full Backdrive:* roll attitude is driven by inboard and outboard ailerons, rudder, and net thrust determined in the background simulation; control wheel position is driven via a gain on the control wheel position computed in the background simulation. No rudder pedal or rudder trim inputs.	*Pilot Takes Over:* pilot flying has full authority over control wheel, aileron trim, rudder pedal, rudder trim, and throttle inputs.	*Scenarios 1 & 2:* roll attitude is driven by inboard and outboard ailerons, spoilers, rudder, and net thrust determined in the background simulation; control wheel position is driven via a gain on the control wheel position computed in the background simulation.	*Scenario 3:* roll attitude is driven by inboard and outboard ailerons, spoilers, rudder, and net thrust determined in the background simulation; control wheel position is driven via a gain on the control wheel position computed in the background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except left elevator becomes right elevator.
Yaw Control	None.	Math pilot perturbs rudder pedal to target DFDR/radar-derived yaw attitude and yaw rate.	*Full Backdrive:* heading angle "falls out" (i.e., no background simulation data drives rudder pedal or rudder trim); rudder position (e.g., due to yaw damper) and net thrust are provided by the background simulation.	*Pilot Takes Over:* pilot flying has full authority over rudder pedal, rudder trim, and throttle inputs.	*Scenarios 1 & 2:* heading angle is driven by rudder and net thrust determined in the background simulation; rudder pedals are not driven. Capability exists to backdrive rudder pedal via a gain on the background simulation rudder pedal.	*Scenario 3:* heading angle is driven by rudder and net thrust determined in the background simulation; rudder pedals are not driven. Capability exists to drive rudder pedal via a gain on the background simulation rudder pedal. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except left elevator becomes right elevator.

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 3 of 10) (provided by the Boeing Company).

	Background Simulation		***E-Cab Simulation***			
	December 1999 Symmetric Elevators	**March 2000 Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Delev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
Simulator Thrust	Simulation is trimmed with 3 degree of freedom longitudinal trim; trim position of throttle handles yields initial engine N1 for Time < 1247. For 1247 ≤ Time ≤ 1277, throttles are set to forward idle. For Time ≥ 1277, throttles are positioned to 85 percent.	Simulation is trimmed with 3 degree of freedom longitudinal trim; trim position of throttle handles yields initial engine N1 for Time < 1247. For 1247 ≤ Time ≤ 1277, throttles are set to forward idle. For Time ≥ 1277, throttles are positioned to 85 percent.	*Full Backdrive:* Driven by symmetric net thrust determined in background simulation.	*Pilot Takes Over:* pilot flying has full authority over throttle inputs.	*Scenarios 1 & 2:* driven by net thrust determined in background simulation.	*Scenario 3:* driven by net thrust determined in background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except left elevator becomes right elevator.
Engine Fuel Cut	For Time ≥ 1275, right engine fuel cut based on DFDR data; for Time ≥ 1276, left engine fuel cut based on DFDR data.	For Time ≥ 1275, right engine fuel cut based on DFDR data; for Time ≥ 1276, left engine fuel cut based on DFDR data.	*Full Backdrive:* driven based on December background simulation.	*Pilot Takes Over:* pilot flying has full authority over engine fuel cuts.	*Scenarios 1 & 2:* driven based on March background simulation.	*Scenarios 3 & 4:* driven based on March background simulation.
Speedbrake Handle	For Time ≥ 1279, deploy speedbrakes (assume speedbrakes remain deployed throughout radar data time history).	For Time ≥ 1279, deploy speedbrakes (assume speedbrakes remain deployed throughout radar data time history).	*Full Backdrive:* Intent to backdrive based on December background simulation, but E-Cab speedbrake handle deployment is delayed ~4 seconds relative to the DFDR data.	*Pilot Takes Over:* pilot flying has full authority over speedbrake handle inputs.	*Scenarios 1 & 2:* driven based on March background simulation.	*Scenario 3:* driven based on March background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except left elevator becomes right elevator

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 4 of 10) (provided by the Boeing Company).

	Background Simulation		*E-Cab Simulation*			
	December 1999 **Symmetric Elevators**	**March 2000** **Symmetric Elevators, DFDR Split Elevators, & CM trim or Δelev**	*December 1999*		*March 2000*	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
Simulator Stabilizer	Simulation is trimmed with 3 degree of freedom longitudinal trim; trim position of stabilizer is held constant.	Simulation is trimmed with 3 degree of freedom longitudinal trim. This stabilizer trim position is compared to DFDR stabilizer at the trim time point to compute a Δstab. This Δstab is applied to the DFDR stabilizer time history, making simulator stabilizer a function of time.	*Full Backdrive:* E-Cab is trimmed with 3 degree of freedom longitudinal trim; trim position of stabilizer is held constant.	*Pilot Takes Over:* pilot flying has full authority over stabilizer inputs.	*Scenarios 1 & 2:* driven based on March background simulation.	*Scenario 3:* driven based on March background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except left elevator becomes right elevator
E-Cab Throttle Handles	Not Applicable.	Not Applicable.	*Full Backdrive:* driven based on December background simulation, subject to autothrottle rate limitation.	*Pilot Takes Over:* pilot flying commands throttle position.	*Scenarios 1 & 2:* driven based on March background simulation, subject to autothrottle rate limitation.	*Scenario 3:* driven based on March background simulation, subject to autothrottle rate limitation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except left elevator becomes right elevator

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 5 of 10) (provided by the Boeing Company).

	Background Simulation		***E-Cab Simulation***			
	December 1999 Symmetric Elevators	**March 2000 Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Delev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
E-Cab Column Position	Not Applicable.	Not Applicable.	*Full Backdrive:* control column position is backdriven via a gain on the symmetric aft quadrant column position determined in the December background simulation.	*Pilot Takes Over:* pilot flying commands symmetric left and right elevator via control column inputs.	*Scenario 1:* For Time < 1275, prior to the DFDR elevator split, control column position is backdriven via a gain on the average of left and right computed aft quadrant column position. For Time ≥ 1275 control column position is backdriven via a gain on the right aft quadrant column position computed to be consistent with the DFDR right elevator (or radar-derived pitch attitude) for the given flight condition. *Scenario 2:* identical to Scenario 1 above, except right elevator/column becomes left elevator/column.	*Scenario 3:* For Time < 1275, prior to the DFDR elevator split, control column position is backdriven via a gain on the average of left and right computed aft quadrant column position. For Time ≥ 1275 control column position is backdriven via a gain on the right aft quadrant column position computed to be consistent with the DFDR right elevator (or radar-derived pitch attitude) for the given flight condition. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* identical to Scenario 3 above, except right elevator/column and left elevator/column must be swapped.
E-Cab Column Force	Not Applicable.	Not Applicable.	Not Applicable	Not Applicable	See "E-Cab dials on visual display" section.	See "E-Cab dials on visual display" section.

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 6 of 10) (provided by the Boeing Company).

	Background Simulation		E-Cab Simulation			
	December 1999 Symmetric Elevators	**March 2000 Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Delev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
E-Cab Elevator Data (elevator driving the airplane motion)	Not Applicable.	Not Applicable.	*Full Backdrive:* driven based on December background simulation symmetric left and right elevators.	*Pilot Takes Over:* pilot flying commands symmetric left and right elevator via control column inputs.	*Scenario 1 & 2:* throughout the time history, pitch attitude is primarily driven by left and right elevators determined in the background simulation.	*Scenario 3:* throughout the time history, subject to pilot inputs, pitch attitude is primarily driven by right elevator determined in the background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* identical to Scenario 3 above, except right elevator and left elevator must be swapped.
E-Cab Wheel Position	Not Applicable.	Not Applicable.	*Full Backdrive:* control wheel position is driven via a gain on the control wheel position computed in the December background simulation. NOTE: due to a programming error, the direction of wheel movement during these backdrive scenarios is reversed. However, the magnitude of the wheel deflection is correct.	*Pilot Takes Over:* pilot flying commands inboard & outboard ailerons and spoilers via control wheel inputs.	*Scenarios 1 & 2:* control wheel position is driven via a gain on the control wheel position computed in the March background simulation.	*Scenario 3:* control wheel position is driven via a gain on the control wheel position computed in the March background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the left elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except left elevator becomes right elevator

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 7 of 10) (provided by the Boeing Company).

	Background Simulation		***E-Cab Simulation***			
	December 1999 Symmetric Elevators	**March 2000 Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Delev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
E-Cab Aileron Data	Not Applicable.	Not Applicable.	*Full Backdrive:* driven with inboard and outboard aileron positions determined in December background simulation.	*Pilot Takes Over:* pilot flying commands inboard & outboard ailerons via control wheel inputs.	*Scenarios 1 & 2:* driven based on March background simulation.	*Scenario 3:* driven based on March background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the <u>left</u> elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except <u>left</u> elevator becomes <u>right</u> elevator
E-Cab Spoiler Data	Not Applicable.	Not Applicable.	*Full Backdrive:* Inactive December background simulation spoiler position and spoiler pattern information is not provided to the E-Cab.	*Pilot Takes Over:* pilot flying commands spoilers via control wheel inputs.	*Scenarios 1 & 2:* driven based on March background simulation.	*Scenario 3:* driven based on March background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the <u>left</u> elevator, stabilizer, ailerons, spoilers, speedbrake handle*, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except <u>left</u> elevator becomes <u>right</u> elevator
E-Cab Speedbrake Handle	Not Applicable.	Not Applicable.	*Full Backdrive:* Intent to backdrive based on December background simulation, but E-Cab speedbrake handle deployment is delayed ~4 seconds relative to the DFDR data.	*Pilot Takes Over:* pilot flying commands speedbrake handle position.	*Scenarios 1 & 2:* driven based on March background simulation.	*Scenarios 3 & 4:* driven based on March background simulation. If the pilot flying inputs a control column force magnitude that exceeds 20 lbs, s/he has full authority over the <u>left</u> elevator, stabilizer, ailerons, spoilers, speedbrake handle, aileron trim, rudder, rudder trim, and throttles. *Scenario 4:* same as Scenario 3 above, except <u>left</u> elevator becomes <u>right</u> elevator

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 8 of 10) (provided by the Boeing Company).

	Background Simulation		***E-Cab Simulation***			
	December 1999 Symmetric Elevators	**March 2000 Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Delev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
FlightViz Displays	Not Applicable.	Not Applicable.	*Column:* E-Cab simulation variable "colpos" drives control column position (degrees). *Wheel:* E-Cab simulation variable "wheel" drives control wheel position (degrees). *Rudder Pedal:* E-Cab simulation variable "pedc" drives rudder pedal position (inches). *Engine Pressure Ratio:* background simulation array variables "epr[1]" & "epr[2]" drive left and right engine pressure ratio, respectively. *Left & Right Elevator:* DFDR parameters drive left and right elevator position displays (degrees).	*Column:* E-Cab simulation variable "colpos" drives control column position (degrees). *Wheel:* E-Cab simulation variable "wheel" drives control wheel position (degrees). *Rudder Pedal:* E-Cab simulation variable "pedc" drives rudder pedal position (inches). *Engine Pressure Ratio:* E-Cab simulation array variables "epr[1]" & "epr[2]" drive left and right engine pressure ratio, respectively. *Left & Right Elevator:* DFDR parameters drive left and right elevator position displays (degrees).	*Column:* E-Cab simulation variable "colpos" drives control column position (degrees). *Wheel:* E-Cab simulation variable "wheel" drives control wheel position (degrees). *Rudder Pedal:* E-Cab simulation variable "pedc" drives rudder pedal position (inches). *Engine Pressure Ratio:* background simulation array variables "epr[1]" & "epr[2]" drive left and right engine pressure ratio, respectively. *Left & Right Elevator:* background simulation variables "deil" & "deir" drive left and right elevator position displays, respectively (degrees)	*Column:* E-Cab simulation variable "colpos" drives control column position (degrees). *Wheel:* E-Cab simulation variable "wheel" drives control wheel position (degrees). *Rudder Pedal:* E-Cab simulation variable "pedc" drives rudder pedal position (inches). *Engine Pressure Ratio:* E-Cab simulation array variables "epr[1]" & "epr[2]" drive left and right engine pressure ratio, respectively. *Left & Right Elevator:* E-Cab simulation variables "deil" & "deir" drive left and right elevator position displays, respectively (degrees).

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 9 of 10) (provided by the Boeing Company).

	Background Simulation		***E-Cab Simulation***			
	December 1999 Symmetric Elevators	**March 2000 Symmetric Elevators, DFDR Split Elevators, & CM trim or ½Delev**	***December 1999***		***March 2000***	
			Full Backdrive	***Pilot Takes Over***	***Scenarios 1 & 2***	***Scenarios 3 & 4***
E-Cab Instruments or Visual Display Dials	Not Applicable.	Not Applicable.	*Normal Load Factor:* E-Cab simulation variable "nlf" drives normal load factor meter (g's). *Left & Right Elevator:* DFDR parameters drive left and right elevator position displays (degrees). *Engine Fuel Cut:* background simulation variables "engf1" & "engf2" drive left and right engine fuel cut display indicators, respectively.	*Normal Load Factor:* E-Cab simulation variable "nlf" drives normal load factor meter (g's). *Left & Right Elevator:* DFDR parameters drive left and right elevator position displays (degrees). *Engine Fuel Cut:* E-Cab simulation variables "engf1" & "engf2" drive left and right engine fuel cut display indicators, respectively.	*Normal Load Factor:* E-Cab simulation variable "nlf" drives normal load factor meter (g's). *Left & Right Elevator:* background simulation variables "deil" & "deir" drive left and right elevator position displays, respectively (degrees). *Engine Fuel Cut:* background s imulation variables "engf1" & "engf2" drive left and right engine fuel cut display indicators, respectively. *Left Computed Force:* For Time < 1275, prior to the DFDR elevator split, left computed control column force is the average of left and right computed control column force derived from the DFDR left and right elevator data. For Time ≥ 1275 left computed control column force is based on the DFDR left elevator data [or radar-derived background simulation symmetric elevator] (lbs). The total force includes the force required to split the elevators assuming the split is due to differential column movements. *Right Computed Force:* For Time < 1275, prior to the DFDR elevator split, right computed control column force is the average of left and right computed control column force derived from the DFDR left and right elevator data. For Time ≥ 1275 right computed control column force is based on the DFDR right elevator data [or radar-derived background simulation symmetric elevator] (lbs).The total force includes the force required to split the elevators assuming the split is due todifferential column movements. *Flying Pilot Force:* force measured in the E-Cab exerted on the control column by the pilot flying (lbs).	*Normal Load Factor:* E-Cab simulation variable "nlf" drives normal load factor meter (g's). *Left & Right Elevator:* E-Cab simulation variables "deil" & "deir" drive left and right elevator position displays, respectively (degrees). *Engine Fuel Cut:* E-Cab simulation variables "engf1" & "engf2" drive left and right engine fuel cut display indicators, respectively. *Left Computed Force:* For Time < 1275, prior to the DFDR elevator split, left computed control column force is the average of left and right computed control column force derived from the DFDR left and right elevator data. For Time ≥ 1275 left computed control column force is based on the DFDR left elevator data [or radar-derived background simulation symmetric elevator] (lbs). The total force includes the force required to split the elevators assuming the split is due todifferential column movements. *Right Computed Force:* For Time < 1275, prior to the DFDR elevator split, right computed control column force is the average of left and right computed control column force derived from the DFDR left and right elevator data. For Time ≥ 1275 right computed control column force is based on the DFDR right elevator data [or radar-derived background simulation symmetric elevator] (lbs). The total force includes the force required to split the elevators assuming the split is due todifferential column movements. *Flying Pilot Force:* force measured in the E-Cab exerted on the control column by the pilot flying (lbs).

** deployed by default per DFDR data, but pilot can override*

Table 1. Summary of Simulation Methods Used in the EgyptAir Flight 990 Investigation (Page 10 of 10) (provided by the Boeing Company).

Scenario	Description
A	Backdrive Only
B	Backdrive with pilot interrupt
C	Hand Fly
D	Hand Fly with Hydraulic Cut 1 (no runs)
E	Hand Fly with Hydraulic Cut 2 (no runs)
F	Stick Nudger, start with A/P on
G	Stick Nudger, start with A/P off
H	Elevator Jam 4 deg Nose Down
I	Backdrive, Cut Hydraulic 1, Hand Fly, Cut Hydraulic 2
J	Backdrive, Cut Hydraulic 1, Hand Fly

Table 2. December 1999 E-CAB Scenario Codes.

From the Airplane Performance Group:		
Code	*Participant*	*Organization*
1	John O'Callaghan	NTSB
2	John Schade	NTSB
3	Mohamed A. Hamid Hamdy	EgyptAir
4	Maher Ismaiel Mohomed	EgypAir
From the Operations Group:		
Code	*Participant*	*Organization*
5	Capt. PD Weston	NTSB
6	Capt. Harold Simson	FAA
7	Capt. Bill Tafs	Boeing
8	Luck Schiada	NTSB
Others:		
Code	*Participant*	*Organization*
9	John Neff	FAA
10	Capt. Mohsen El Missiry	ECAA
11	Capt. Paul Remington	FAA
12	Capt. Othman Nour	ECAA
13	John Swanson	FBI
From the Human Performance Group:		
Code	*Participant*	*Organization*
14	Alan Brantly	FBI
Investigator in Charge:		
Code	*Participant*	*Organization*
15	Greg Phillips	NTSB

Table 3. December 1999 E-CAB Participant Codes.

Simulator Log - December 8, 1999						
File Name	**Case #**	**Clock Time**	**Left Seat (* flying)**	**Right Seat (* flying)**	**Scenario #**	**Notes**
egypt_demo_1.esa	1	10:46	12	10	A	
egypt_demo_1.esa	2	10:48	12	10	A w/hold	
egypt_demo_1.esa	3	10:51	12	10	A w/hold	
egypt_demo_1.esa	4	10:53:38	12	10 * (10:54:04)	B	
egypt_demo_1.esa	5	10:55:12	12 * (10:55:27)	10	B	
egypt_demo_1.esa	6	10:57:45	12 *	10	C	
egypt_demo_1.esa	7	11:00:23	12	10 *	C	
egypt_demo_1.esa	8	11:03:03	12	5 *	C	
egypt_demo_1.esa	9	11:07:05	15	5	A	
egypt_demo_1.esa	10	11:09:09	15	5	A w/hold	
egypt_demo_1.esa	11	11:11:20	15 *	5	C	Open loop phugoid, hands free/stick free.
egypt_demo_2.esa	1	11:16	6	11	A	
egypt_demo_2.esa	2	11:18:18	6	11	A w/hold	redo - hit i.c.
egypt_demo_2.esa	3	11:19:46	6	11	A w/hold	
egypt_demo_2.esa	4	11:22:32	6	11 *	C	
egypt_demo_2.esa	5	11:24:31	6 *	11	C	
egypt_demo_2.esa	6	11:29:20	3	4	A	
egypt_demo_2.esa	7	11:31:30	3	4	A	
egypt_demo_2.esa	8	11:33:30	3 *	4	C	Inflight restart. Sucessful relight.
egypt_demo_2.esa	9	11:35:52	3	4 *	C	Engine relight again.
egypt_demo_2.esa	10	11:38:15	3 *	4	C	Will release column at engine shutdown. Stick free recovery.
egypt_demo_3.esa	1	11:42:01	13	14	A	
egypt_demo_3.esa	2	11:44:46	13 *	14	C	
egypt_demo_3.esa	3	11:48:30	13	14 *	C	
egypt_demo_3.esa	4	11:51:57	13 *	14	C	
egypt_demo_3.esa	5	11:57:22	8	9 *	C	
egypt_demo_3.esa	6	11:59:48	8 *	9	C	
egypt_demo_3.esa	7	12:02:11	8	9 *	C	

Table 4a. Run log for E-CAB Simulations on December 8, 1999.

Simulator Log - December 9, 1999						
File Name	**Case #**	**Clock Time**	**Left Seat (* flying)**	**Right Seat (* flying)**	**Scenario #**	**Notes**
egypt_demo_5.esa	1		7 *		F	A/P on
egypt_demo_5.esa	2		7 *		F	A/P on
egypt_demo_5.esa	3		7 *		F	A/P off
egypt_demo_6.esa	1	10:02:06	11 *	6	F	
egypt_demo_6.esa	2	10:04:21	11 *	6	F	Cut engines. Relight Engines
egypt_demo_6.esa	3	10:07:40	11	6 *	F	
egypt_demo_6.esa	4	10:12:51	8	2	F	scrub
egypt_demo_6.esa	5	10:13:13	8 *	2	F	
egypt_demo_6.esa	6	10:16:08	8	2 *	F	
egypt_demo_6.esa	7	10:19:00	8 *	2	F	
egypt_demo_6.esa	8	10:22:59	12 *	10	F	
egypt_demo_6.esa	9	10:25:33	12 *	10	F	Recovery immediately after A/P disconnect.
egypt_demo_6.esa	10	10:27:35	12	10 *	F	
egypt_demo_7.esa	1	10:31:49	12	10 *	F	10 - will let go to 20 deg nose down then recover.
egypt_demo_7.esa	2					scrub
egypt_demo_7.esa	3	10:34:48	12 *	10	F	Shutdown engines
egypt_demo_7.esa	4	10:36:44	12 *	10	F	
egypt_demo_7.esa	5	10:39:57	3	4	F	
egypt_demo_7.esa	6	10:41:59	3 *	4	F	Recovery immediately after A/P disconnect.
egypt_demo_7.esa	7	10:45:58	13 *	9	F	Full profile.
egypt_demo_7.esa	8	10:48:52	13	9	F	scrub
egypt_demo_7.esa	9	10:49:10	13	9 *	F	Full profile.
egypt_demo_7.esa	10	10:51:38	13 *	9	F	Recovery immediately after A/P disconnect.
egypt_demo_7.esa	11	10:53:30	13	9 *	F	Recovery immediately after A/P disconnect.
egypt_demo_8.esa	1	10:57:18	5 *	7	F	Add A/P thumb switch. Full profile with successful relight.

Table 4b. Run log for E-CAB Simulations on December 9, 1999 (page 1 of 2).

Simulator Log - December 9, 1999						
File Name	**Case #**	**Clock Time**	**Left Seat (* flying)**	**Right Seat (* flying)**	**Scenario #**	**Notes**
egypt_demo_9.esa	1	11:04:59	5	7 *	F	Add coafio variable - *calibration cab column force. Start with A/P on - full profile.
egypt_demo_9.esa	2	11:08:32	5	7 *	G	*calibration cab column force. Start with A/P off - full profile.
egypt_demo_9.esa	3	11:09:30	5 *	7	F	Recovery after A/P disconnect.
egypt_demo_9.esa	4	11:12:06	2	1 *	F	
egypt_demo_9.esa	5	11:14:47	2	1 *	F	Recovery after A/P disconnect.
egypt_demo_10.esa	1	11:18:00			F	A/P switch to Vnav. Just let A/P go with stick nudger failure. Change c.g. to 33%, then back to 23%.
egypt_demo_10.esa	2	11:24:26			F	Add moderate gust. Add heavy gust. Add heavier gust. Remove gust.
egypt_demo_11.esa	1	13:19:41	2	1	H	Stick free.
egypt_demo_11.esa	2	13:23:27	2	1	H	Stick free.
egypt_demo_12.esa	1	13:33:35	12 *	10	I	
egypt_demo_12.esa	2	13:39:01	12	10 *	J	
egypt_demo_12.esa	3	13:43:33	3 *	4	J	Only one engine failed because took over before it had a chance to turn off
egypt_demo_12.esa	4	13:46:35	3	4 *	J	
egypt_demo_12.esa	5	13:50:26	13 *	11	I	
egypt_demo_12.esa	6	13:53:32	13	11 *	I	
egypt_demo_12.esa	7	13:57:33	2	9 *	I	
egypt_demo_13.esa	1	14:02:57	5 *	7	K	
egypt_demo_13.esa	2	14:05:28	5	7	K	scrub
egypt_demo_13.esa	3	14:05:47	5 *	7	K	
egypt_demo_13.esa	4	14:10:12	5 *	7	K	
egypt_demo_13.esa	5				A	scrub - sound test
egypt_demo_13.esa	6				A	scrub - didn't record
egypt_demo_13.esa	7				A	scrub - didn't record
egypt_demo_13.esa	8				A	scrub - didn't record
egypt_demo_13.esa	9				A	Recorded playback with sound from the cab.

Table 4b. Run log for E-CAB Simulations on December 9, 1999 (page 2 of 2).

Code	Participant	Organization
From the Airplane Performance Group:		
Code	*Participant*	*Organization*
5	John O'Callaghan	NTSB
12	Mohamed A. Hamid Hamdy	EgyptAir
From the Operations Group:		
Code	*Participant*	*Organization*
1	Capt. PD Weston	NTSB
7	Capt. Shaker Kelada	ECAA
8	Capt. Bill Tafs	Boeing
From the Human Performance Group:		
Code	*Participant*	*Organization*
2	Dr. Malcolm Brenner	NTSB
4	Dr. Kristin Bolte	NTSB
From the Systems Group:		
Code	*Participant*	*Organization*
13	Scott Warren	NTSB
Others:		
Code	*Participant*	*Organization*
6	Capt. Mohsen El-Missiry	ECAA
9	Capt. John Cashman	Boeing
10	Capt. Buzz Nelson	Boeing
11	Capt. Gus Stearns	Boeing
14	Rick Howes	Boeing

Table 5. March 2000 E-CAB Participant Codes.

E-CAB Activities, March 30, 2000 - Open Session - No CVR Playback							
File Name	**Case #**	**Clock Time**	**Left Seat (* flying)**	**Right Seat (* flying)**	**Scenario #**	**Pilot Controlling Lateral Axis?**	**Notes**
egypt_demo_23.esa	1	10:17	7	10	1		
egypt_demo_23.esa	2	10:22	7	10	1		
egypt_demo_23.esa	3	10:25	7*	10	3	No	Getting familiar with sim. Normal seat locations
egypt_demo_23.esa	4	10:28	7	10*	4	No	
egypt_demo_23.esa	5	10:32	7*	10	4	No	
egypt_demo_23.esa	6	10:51	7	10	1		Watching timing of events
egypt_demo_23.esa	7	10:58	7	10	1		Flight crew not flying the maneuver. Human Factors people are manually timing events (eng cuts, throttles forward, speedbrakes)
egypt_demo_23.esa	8	11:12	7	10*	4	No	Captain out of seat at start of scenario First Officer: pushes First Officer: cuts engines Captain: throttles forward, speedbrakes deployed
egypt_demo_23.esa	9	11:15	7	10*	4	No	Captain out of seat at start of scenario (back in seat around 30,500 ft alt (time 1260 sec)) First officer: pushes First Officer: cuts engines Captain: throttles forward, speedbrakes deployed
egypt_demo_23.esa	10	11:19	7*	10	3	No	Captain: out of seat at start of scenario Captain: manually pushes throttles & speedbrakes
egypt_demo_23.esa	11	11:24	7*	10	3	No	Captain: out of seat at start of scenario Speedbrakes & throttles auto Captain: uses only 1 hand on column
egypt_demo_23.esa	12	11:27	7*	10	3	No	Captain: out of seat until 1260 sec. Captain: Pushes throttle & speedbrakes deloyed Captain: then back to 2 hands on column
egypt_demo_23.esa	13	11:30	7*	10	3	No	Kinematics observations Captain: out of seat until 1260 seconds Captain: pushes throttle & speedbrakes deployed

Table 6a. March 30, 2000 E-CAB Runs without CVR Playback.

E-CAB Activities, March 30, 2000 - Closed Session - With CVR Playback							
All runs correspond to Scenario 1 (Backdrive with column motion to match DFDR right elevator position)							
File Name	**Case #**	**Clock Time**	**Left Seat**	**Right Seat**	**Scenario #**	**FDR Start Time**	**Notes**
egypt_demo_24.esa	1	3:51	9	7	1	1143	CVR playback Run no good (sim integraters off) CVR & FDR data not synched
egypt_demo_24.esa	2	12:56	9	7	1	1143	CVR playback Run no good (sim integraters off) CVR & FDR data not synched
egypt_demo_24.esa	3	1:02	9	7	1	1143	(Valid Run)
egypt_demo_24.esa	4	1:13	7	9	1	1143	Run no good. CVR & FDR data not synched
egypt_demo_24.esa	5	1:16	7	9	1	1143	Confusion over wheel/yoke movement prior to autopilot disconnect
egypt_demo_24.esa	6	1:30	10	6	1	1235	Short version playback (start @ 1235 sec)
egypt_demo_24.esa	7	1:36	10	6	1	1143	Long version playback
egypt_demo_24.esa	8	1:42	10	11	1	1235	Short version playback (start @ 1235 sec)
egypt_demo_24.esa	9	1:45	10	11	1	1235	Short version playback (start @ 1235 sec)
egypt_demo_24.esa	10	1:49	10	11	1	1235	
egypt_demo_24.esa	11	1:56	8	6	1	1235	
egypt_demo_24.esa	12	1:59	8	6	1	1143	Long version playback
egypt_demo_24.esa	13	2:25	7	10	1	1235	Captain & Chief Pilot entering
egypt_demo_24.esa	14		7	10	1	1235	Observing engine cut times
egypt_demo_24.esa	15		7	10	1	1235	Observing speedbrake time
egypt_demo_24.esa	16	2:46	7	10	1		

Table 6b. March 30, 2000 E-CAB Runs with CVR Playback.

File Name	Case #	Clock Time	Left Seat (* flying)	Right Seat (* flying)	Scenario #	Pilot Controlling Lateral Axis?	Notes
egypt_demo_25.esa	1	10:54	8	6	1		
egypt_demo_25.esa	2	10:57	8	6	2		
egypt_demo_25.esa	3	11:00	8*	6	3	Yes	
egypt_demo_25.esa	4	11:03	8	6*	3	Yes	Slow to initial pull Ended the run during the climb Speedbrakes?
egypt_demo_25.esa	5	11:06	8*	6	4	Yes	Slow to push (wrong direction initially) Speedbrakes not armed
egypt_demo_25.esa	6	11:08	8	6*	4	Yes	
egypt_demo_25.esa	7	11:13	7	1	1		
egypt_demo_25.esa	8	11:16	7	1	2		Speedbrakes not armed
egypt_demo_25.esa	9	11:18	7	1*	3	Yes	Did not keep wings level Extra control inputs in radar data area
egypt_demo_25.esa	10	11:21	7*	1	3	Yes	
egypt_demo_25.esa	11	11:23	7	1*	4	Yes	
egypt_demo_25.esa	12	11:25	7*	1	4	Yes	
egypt_demo_25.esa	13	11:28	7	1	1		Watching for flucuations in bugs on wind screen visuals
egypt_demo_25.esa	14	11:31	7	1	2		Watch for bugs on wind screen visuals
egypt_demo_25.esa	15		7	1			Run no good. Flight crew inadvertently went into "compute".
egypt_demo_25.esa	16	11:35	7*	1	5		Pilot gets to full control @ ~27,000 ft (no split elevators)
egypt_demo_25.esa	17	11:37	7*	1	5		Pilot gets to full control @ ~1275 sec (any split goes back to symmetric) Cuts engines and then re-lights
egypt_demo_25.esa	18	11:40	7	1*	5		Pilot takes over @ ~1274 sec Engines cut
egypt_demo_25.esa	19		7	1	5		Pilot gets control @ ~1265 sec Hands off free response
egypt_demo_25.esa	20		12	13	1		
egypt_demo_25.esa	21	11:48	12	13	2		
egypt_demo_25.esa	22	11:51	12*	13	3	Yes	
egypt_demo_25.esa	23	11:53	12	13*	3	Yes	Pulled a little early
egypt_demo_25.esa	24	11:55	12*	13	4	Yes	
egypt_demo_25.esa	25		12	13*	4	Yes	
egypt_demo_25.esa	26	12:00	-	-	-	-	Run to show column to elevator relationship (column lags the elevator position display used for this demo)

Table 6c. March 31, 2000 E-CAB Runs.

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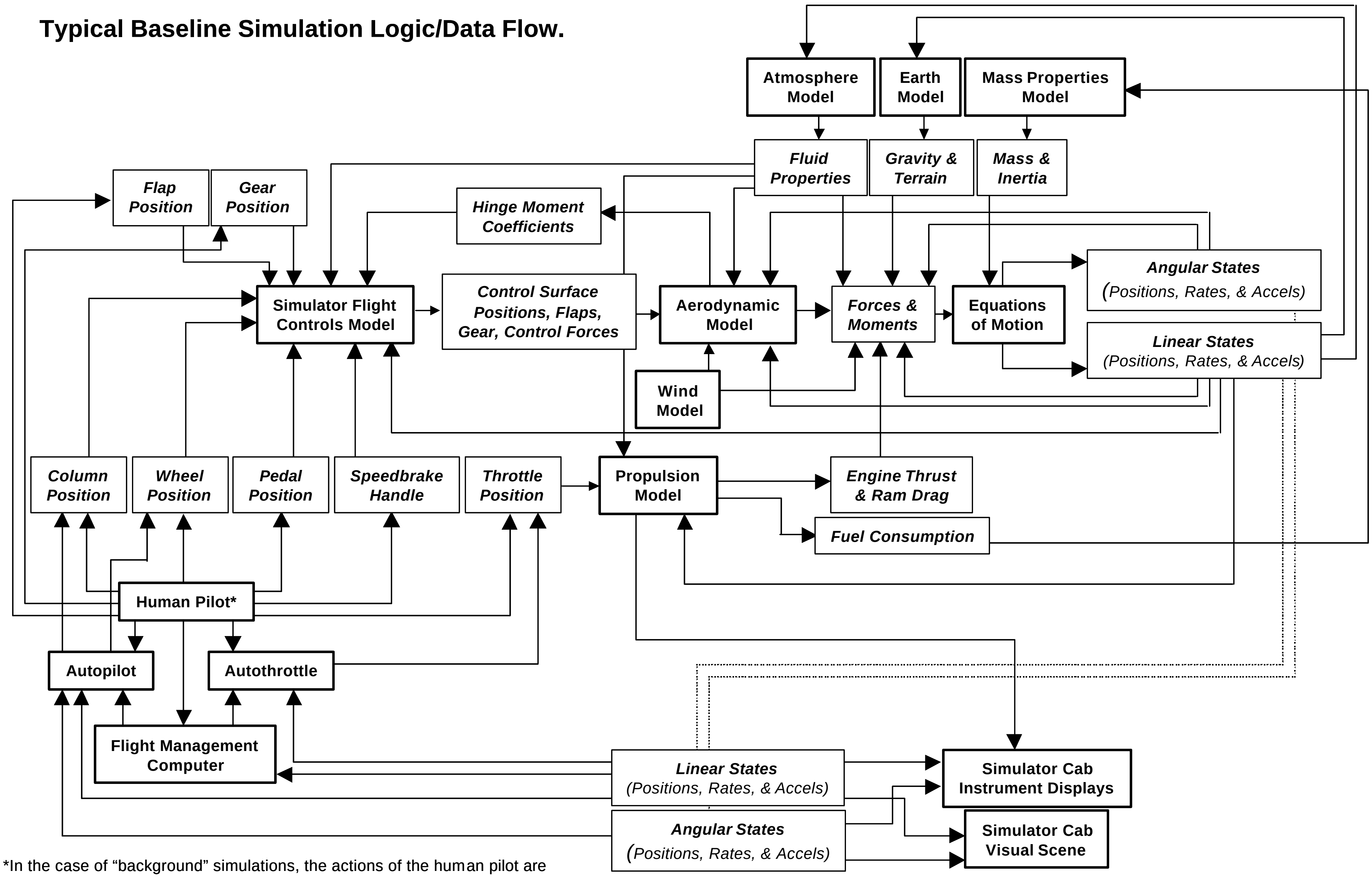
Typical Baseline Simulation Logic/Data Flow.



*In the case of “background” simulations, the actions of the human pilot are replaced by instructions in user defined “scenario file” computer programs.

Figure 1.

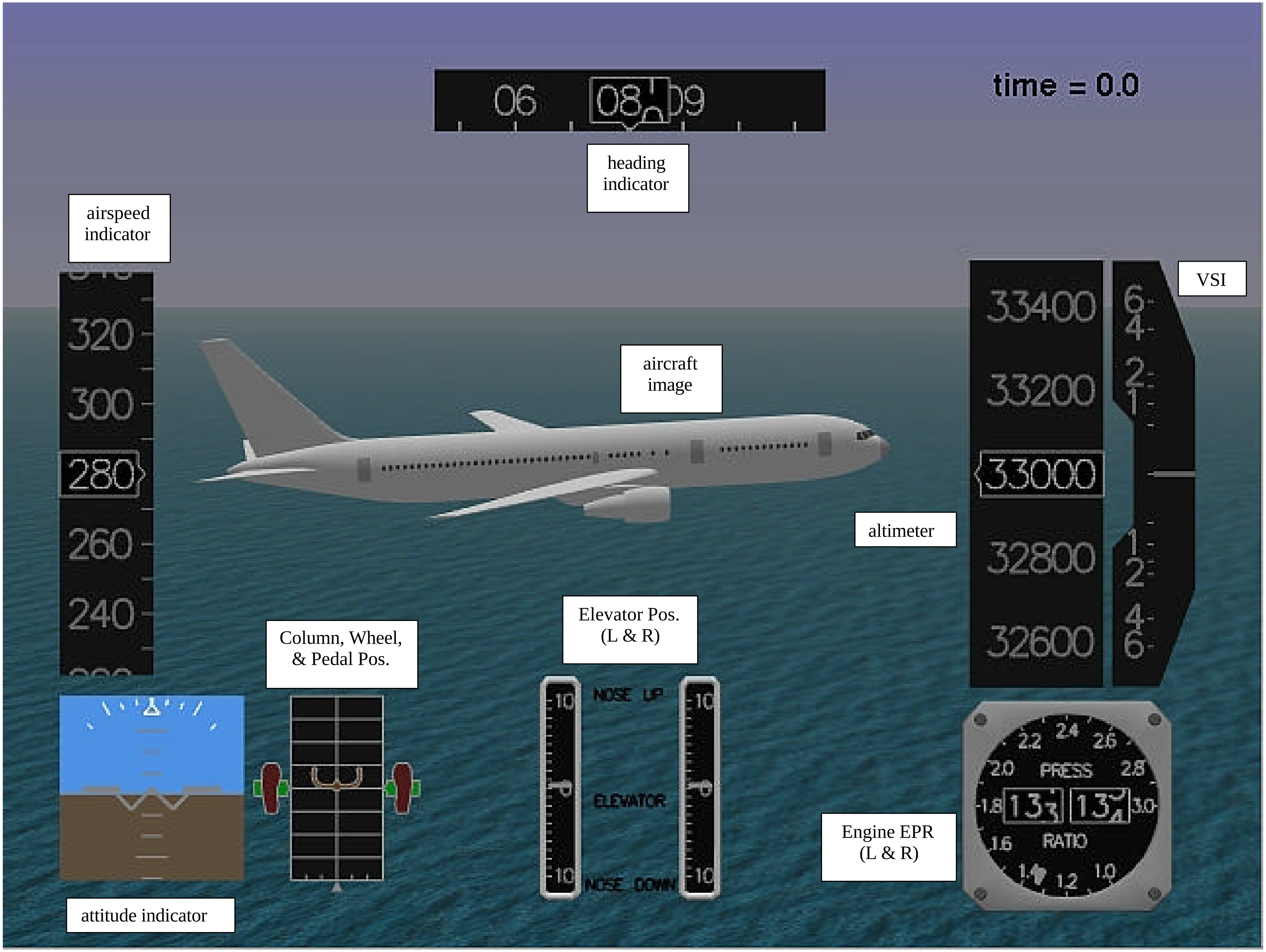

time = 0.0
06
08
09
heading indicator
airspeed indicator
320
300
280
260
240
aircraft image
VSI
33400
33200
33000
32800
32600
altimeter
Column, Wheel, & Pedal Pos.
Elevator Pos. (L & R)
NOSE UP
ELEVATOR
NOSE DOWN
Engine EPR (L & R)
PRESS
RATIO
attitude indicator

Figure 2.

“Background” Simulation Pitch Control Method

December Simulations: Valid for All Times
March Simulations: Valid for for BTIME < 1265 and BTIME > 1290 Only

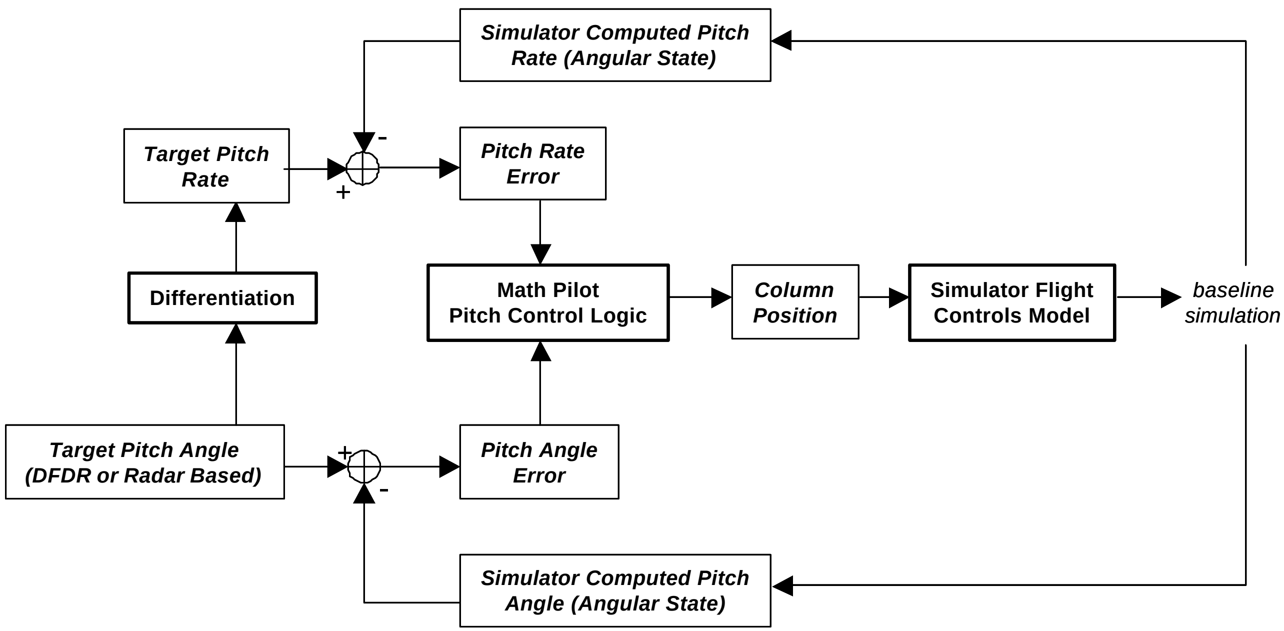


Figure 3a.

"Background" Simulation Roll Control Method

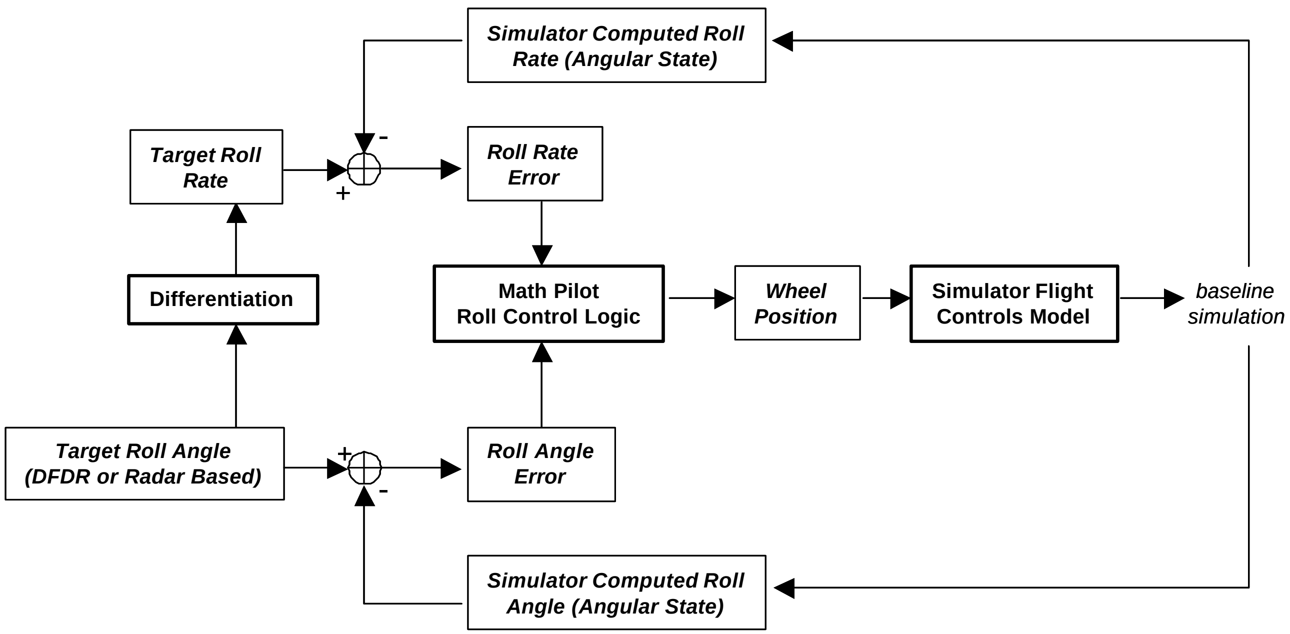


Figure 3b.

"Background" Simulation Yaw Control Method

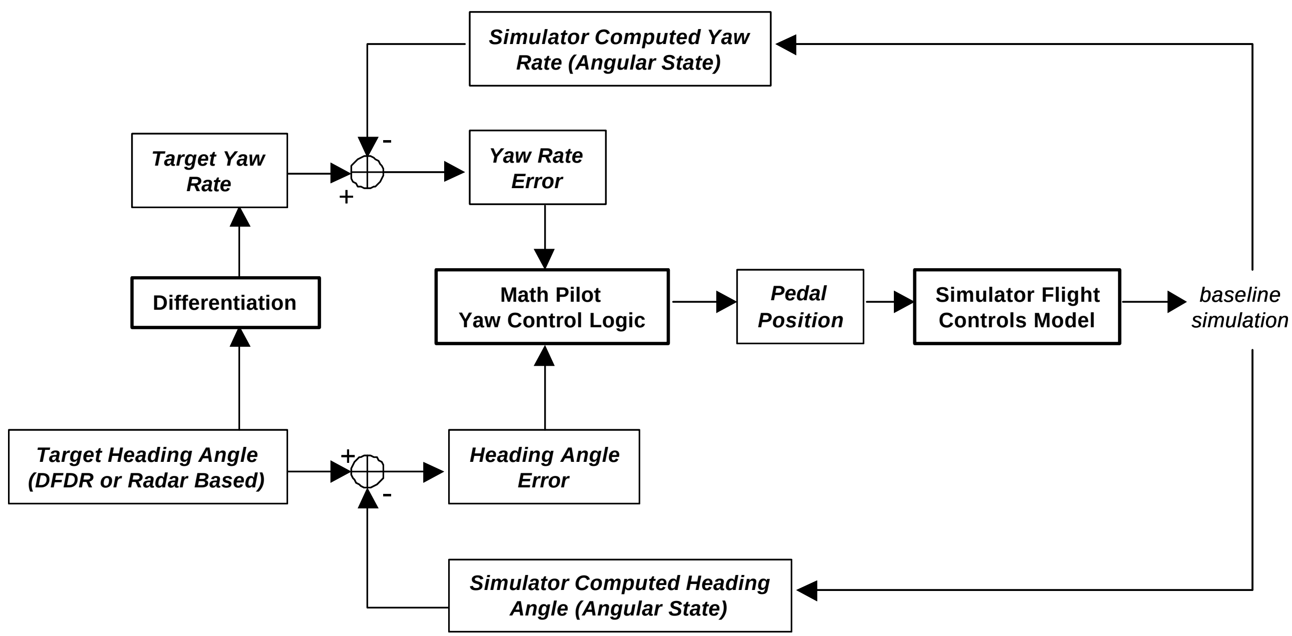
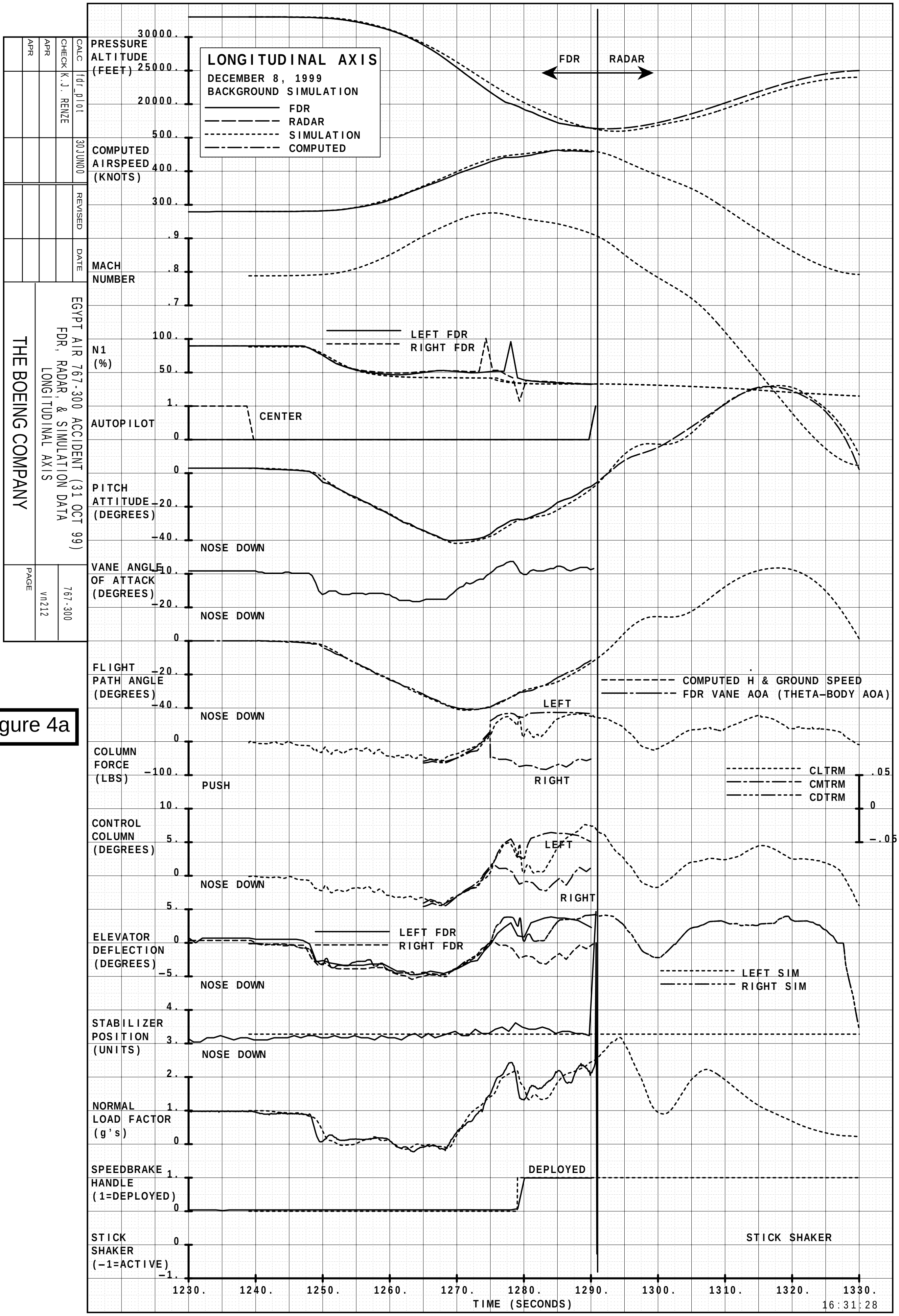


Figure 3c.



LONGITUDINAL AXIS
DECEMBER 8, 1999
BACKGROUND SIMULATION
FDR
RADAR
SIMULATION
COMPUTED
FDR
RADAR
PRESSURE ALTITUDE (FEET)
30000.
25000.
20000.
COMPUTED AIRSPEED (KNOTS)
500.
400.
300.
MACH NUMBER
.9
.8
.7
N1 (%)
100.
50.
LEFT FDR
RIGHT FDR
AUTOPILOT
1.
0
CENTER
PITCH ATTITUDE (DEGREES)
0
−20.
−40.
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
10.
−20.
NOSE DOWN
FLIGHT PATH ANGLE (DEGREES)
0
−20.
−40.
NOSE DOWN
COMPUTED H & GROUND SPEED
FDR VANE AOA (THETA−BODY AOA)
LEFT
COLUMN FORCE (LBS)
0
−100.
PUSH
RIGHT
CLTRM
CMTRM
CDTRM
.05
0
−.05
CONTROL COLUMN (DEGREES)
10.
5.
0
LEFT
NOSE DOWN
RIGHT
ELEVATOR DEFLECTION (DEGREES)
5.
0
−5.
LEFT FDR
RIGHT FDR
NOSE DOWN
LEFT SIM
RIGHT SIM
STABILIZER POSITION (UNITS)
4.
3.
NOSE DOWN
NORMAL LOAD FACTOR (g's)
2.
1.
0
SPEEDBRAKE HANDLE (1=DEPLOYED)
1.
0
DEPLOYED
STICK SHAKER (−1=ACTIVE)
0
−1.
STICK SHAKER
1230.
1240.
1250.
1260.
1270.
1280.
1290.
1300.
1310.
1320.
1330.
TIME (SECONDS)
16:31:28
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LONGITUDINAL AXIS
CALC fdr_plot
CHECK K.J. RENZE
30JUN00
REVISED
DATE
APR
APR
PAGE
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Figure 4a

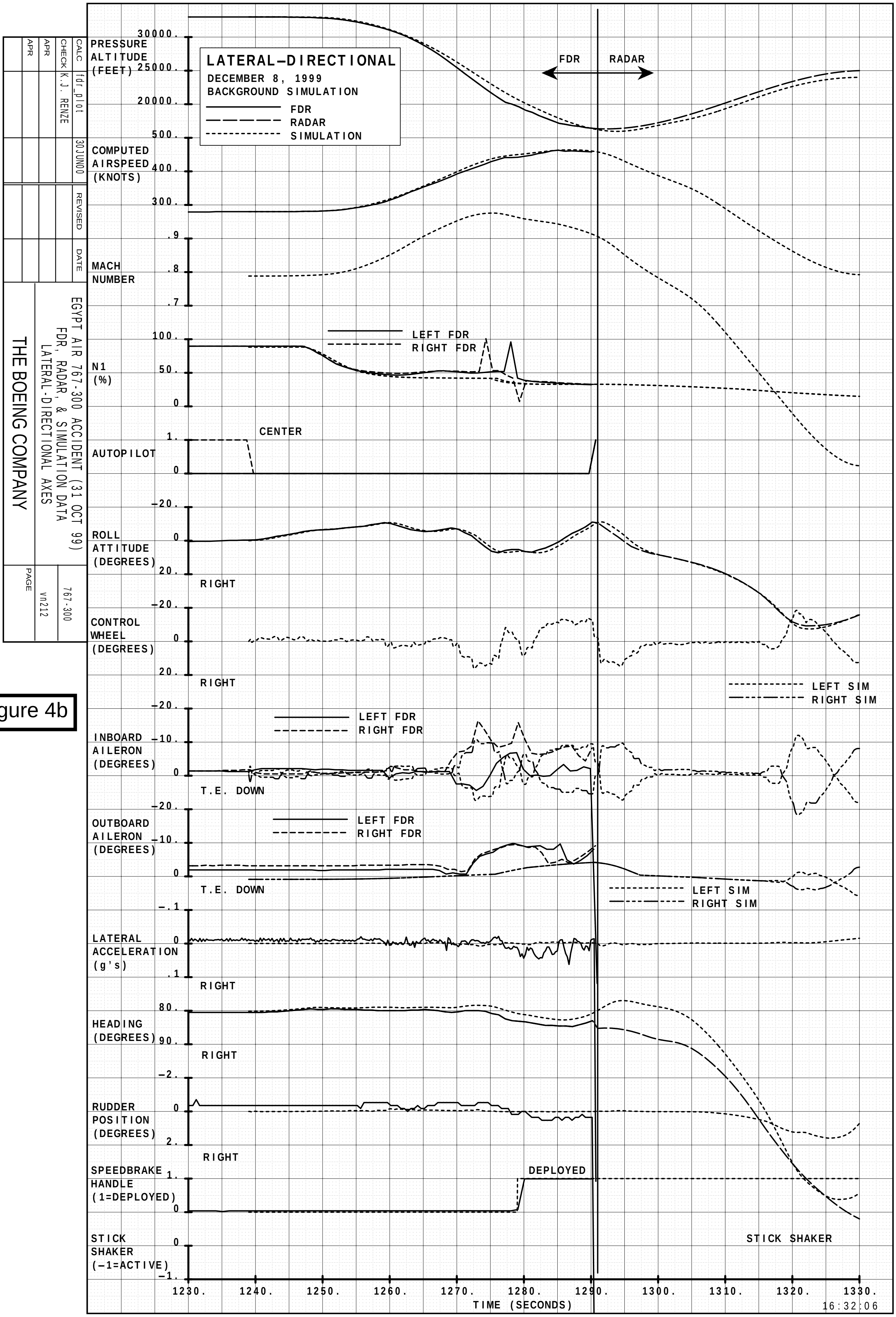
LATERAL–DIRECTIONAL
DECEMBER 8, 1999
BACKGROUND SIMULATION
FDR
RADAR
SIMULATION
FDR
RADAR
PRESSURE ALTITUDE (FEET)
COMPUTED AIRSPEED (KNOTS)
MACH NUMBER
N1 (%)
LEFT FDR
RIGHT FDR
AUTOPILOT
CENTER
ROLL ATTITUDE (DEGREES)
RIGHT
CONTROL WHEEL (DEGREES)
RIGHT
LEFT SIM
RIGHT SIM
INBOARD AILERON (DEGREES)
LEFT FDR
RIGHT FDR
T.E. DOWN
OUTBOARD AILERON (DEGREES)
LEFT FDR
RIGHT FDR
T.E. DOWN
LEFT SIM
RIGHT SIM
LATERAL ACCELERATION (g's)
RIGHT
HEADING (DEGREES)
RIGHT
RUDDER POSITION (DEGREES)
RIGHT
SPEEDBRAKE HANDLE (1=DEPLOYED)
DEPLOYED
STICK SHAKER (−1=ACTIVE)
STICK SHAKER
1230. 1240. 1250. 1260. 1270. 1280. 1290. 1300. 1310. 1320. 1330.
TIME (SECONDS)
16:32:06
CALC fdr_plot 30JUN00
CHECK K.J. RENZE
APR
APR
REVISED
DATE
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LATERAL-DIRECTIONAL AXES
PAGE
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Figure 4b

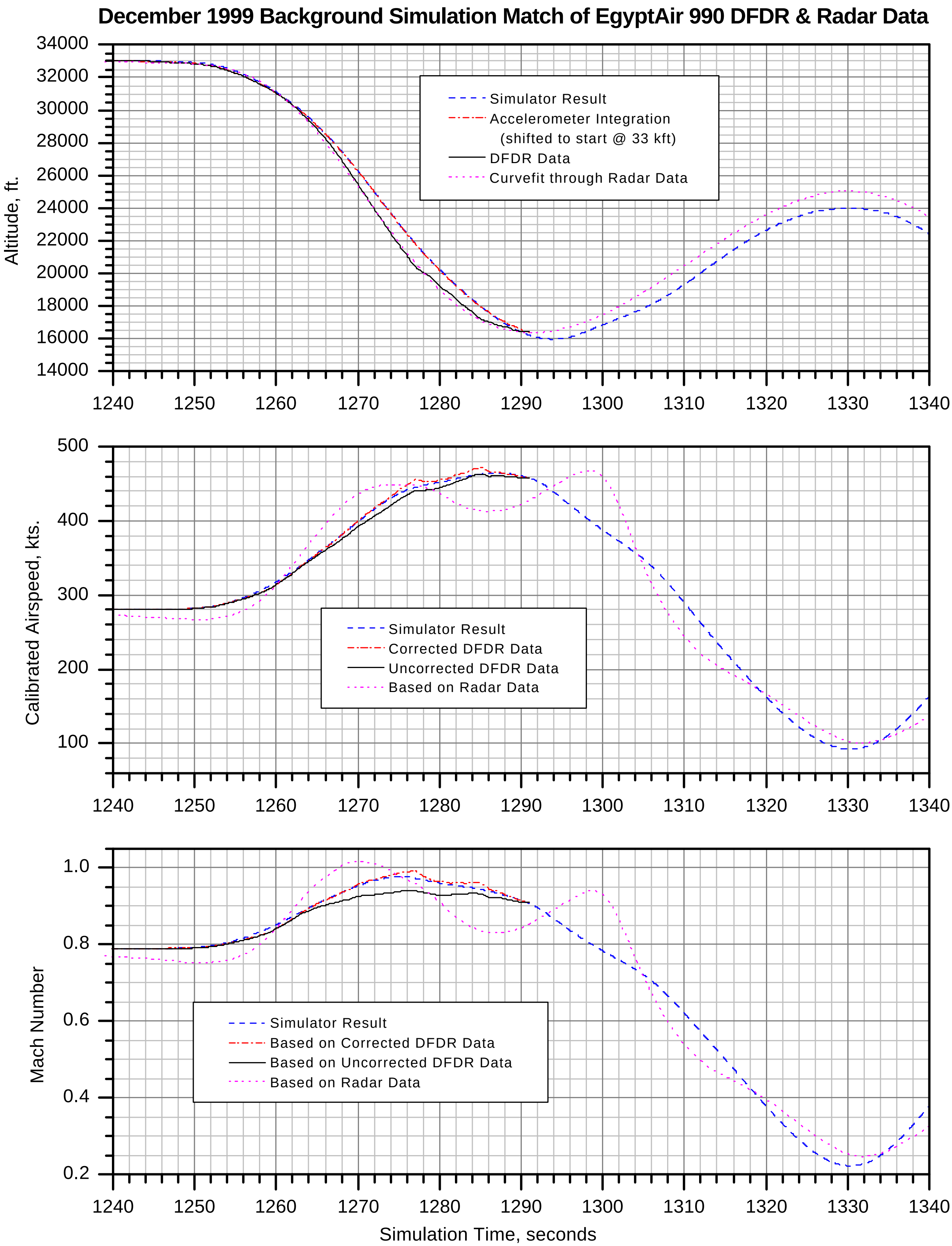

December 1999 Background Simulation Match of EgyptAir 990 DFDR & Radar Data
Altitude, ft.
34000
32000
30000
28000
26000
24000
22000
20000
18000
16000
14000
Simulator Result
Accelerometer Integration
(shifted to start @ 33 kft)
DFDR Data
Curvefit through Radar Data
1240
1250
1260
1270
1280
1290
1300
1310
1320
1330
1340
Calibrated Airspeed, kts.
500
400
300
200
100
Simulator Result
Corrected DFDR Data
Uncorrected DFDR Data
Based on Radar Data
Mach Number
1.0
0.8
0.6
0.4
0.2
Simulator Result
Based on Corrected DFDR Data
Based on Uncorrected DFDR Data
Based on Radar Data
Simulation Time, seconds

Figure 4c.

E-CAB Column Position Calculation – December Simulations

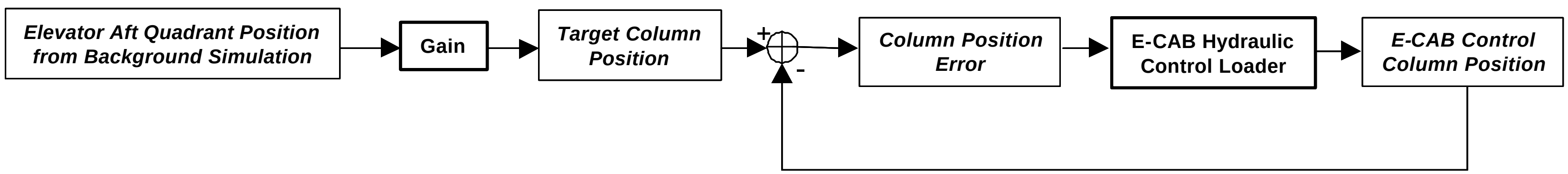


Figure 5.

Left Engine Thrust Calculations for All Simulations and Throttle Command Logic in E-CAB

(Calculations are Similar for Right Engine and Throttle Position)

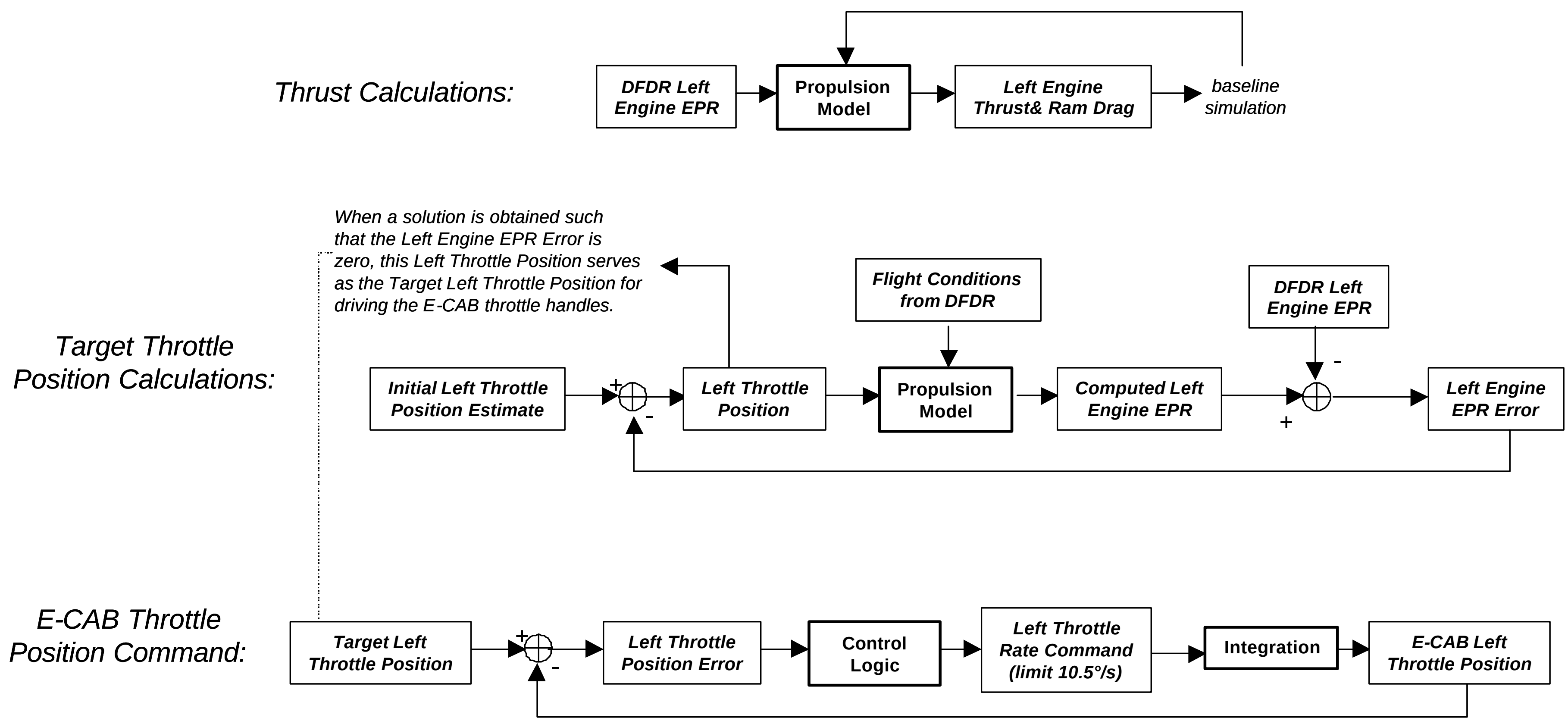


Figure 6.

E-CAB Speedbrake Handle Position Command for All Simulations

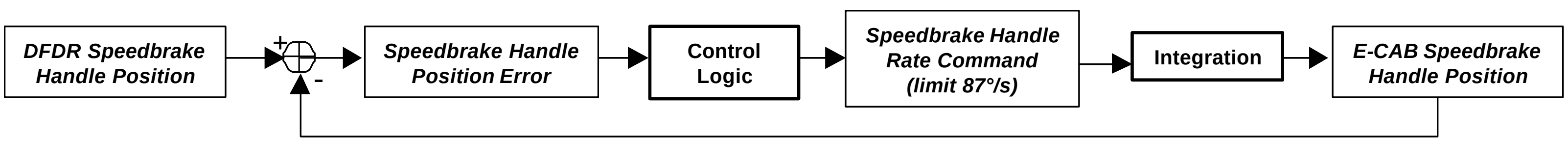


Figure 7.

“Background” Simulation Pitch Control for 1265 £ BTIME £ 1290
DC$_M$ Method (March Simulations Only)

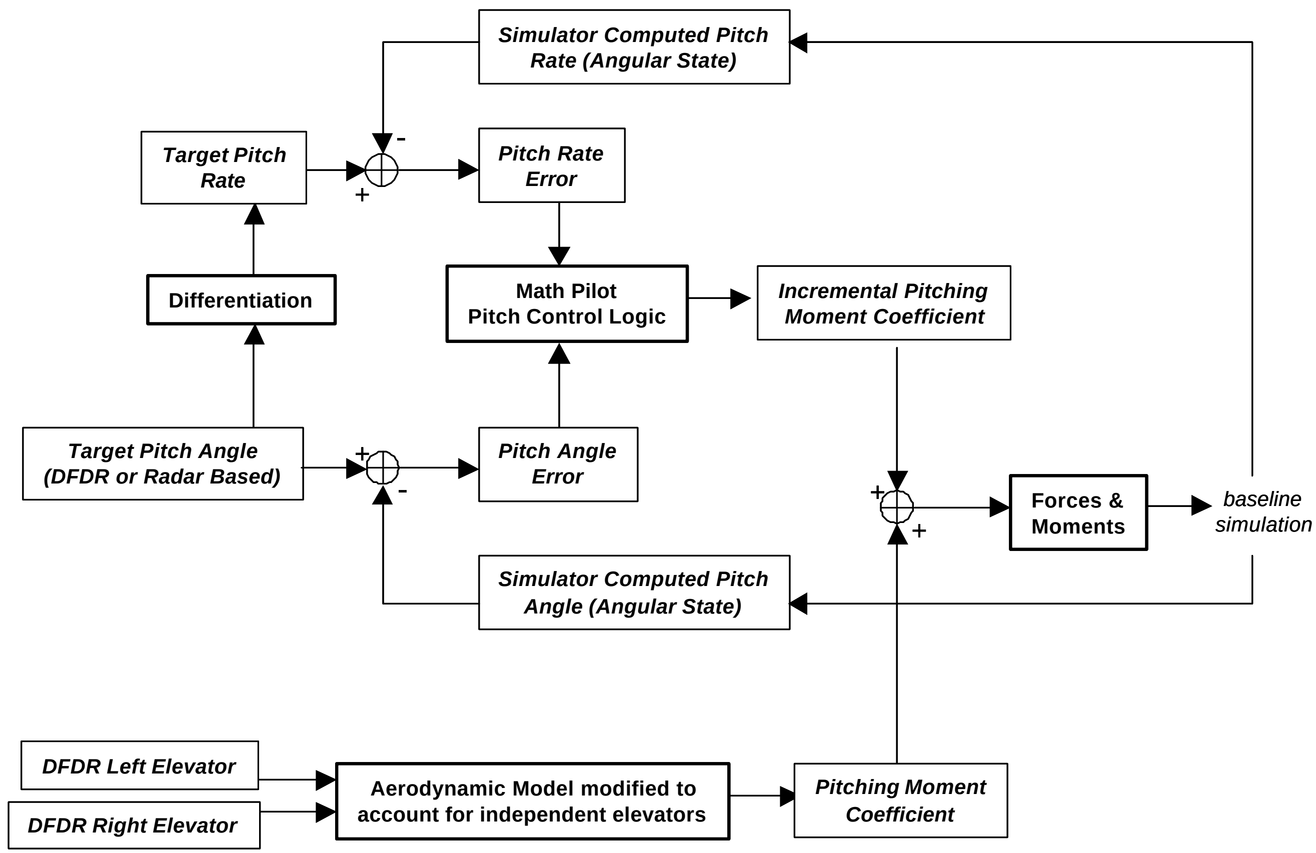


Figure 8.

“Background” Simulation Pitch Control for 1265 £ BTIME £ 1290
0.5 d_e Method (March Simulations Only)

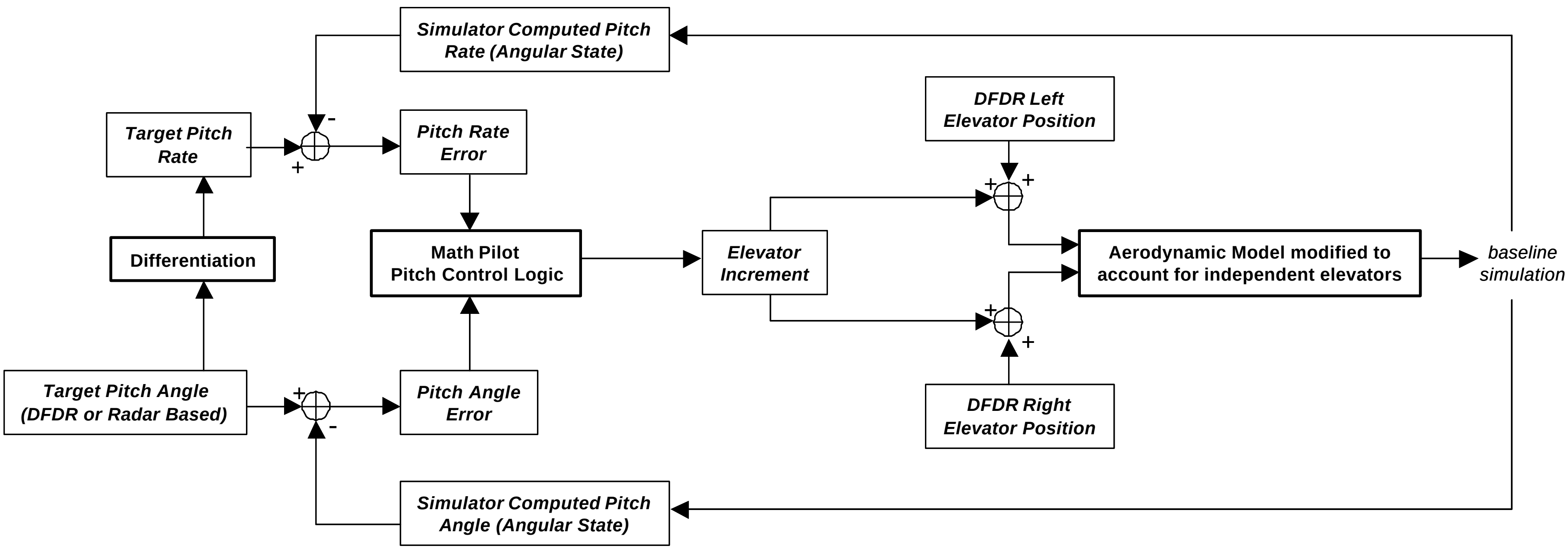
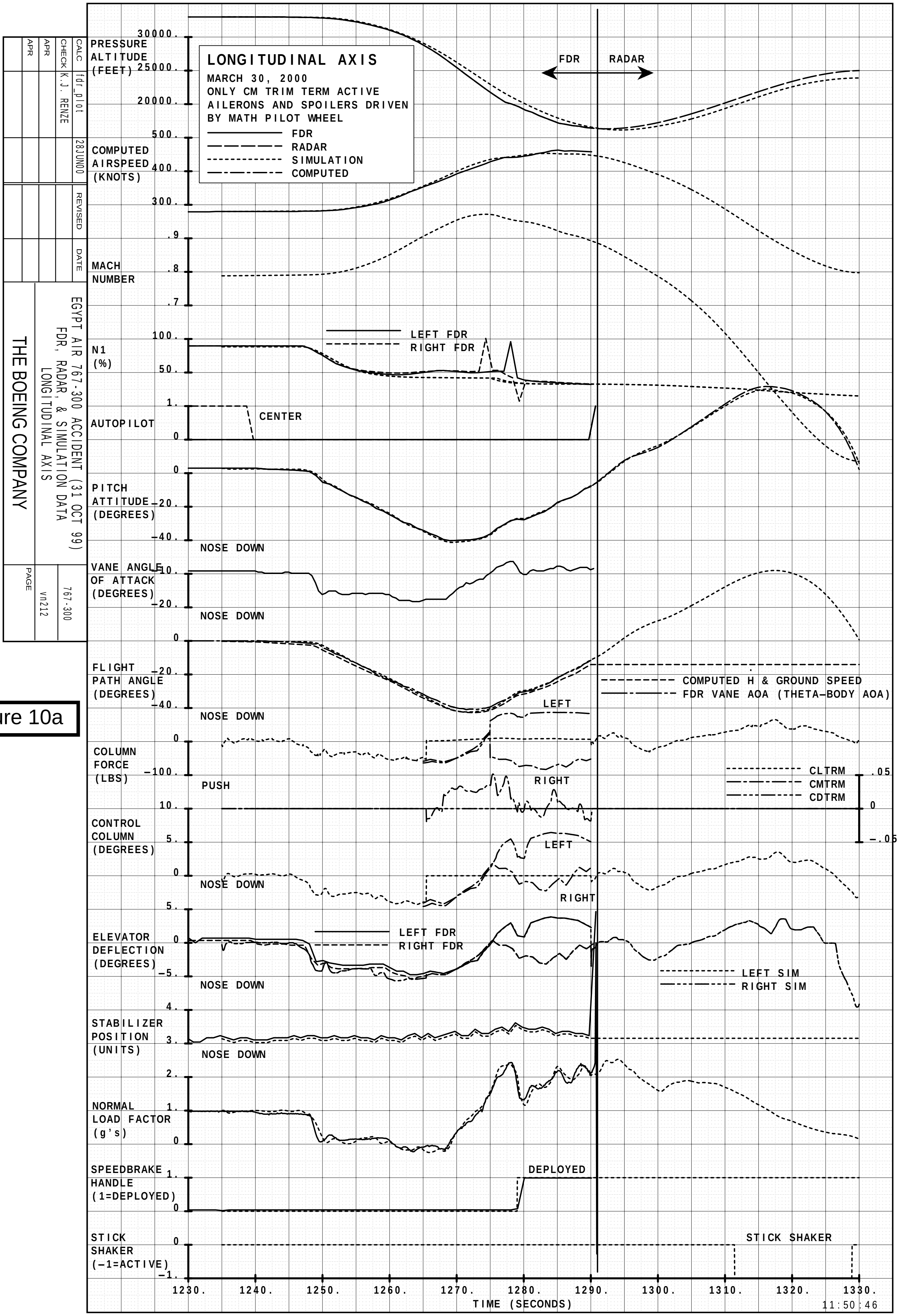


Figure 9.



LONGITUDINAL AXIS
MARCH 30, 2000
ONLY CM TRIM TERM ACTIVE
AILERONS AND SPOILERS DRIVEN
BY MATH PILOT WHEEL
FDR
RADAR
SIMULATION
COMPUTED
FDR
RADAR
PRESSURE ALTITUDE (FEET)
COMPUTED AIRSPEED (KNOTS)
MACH NUMBER
N1 (%)
LEFT FDR
RIGHT FDR
AUTOPILOT
CENTER
PITCH ATTITUDE (DEGREES)
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
NOSE DOWN
FLIGHT PATH ANGLE (DEGREES)
COMPUTED H & GROUND SPEED
FDR VANE AOA (THETA–BODY AOA)
NOSE DOWN
COLUMN FORCE (LBS)
PUSH
LEFT
RIGHT
CLTRM
CMTRM
CDTRM
CONTROL COLUMN (DEGREES)
NOSE DOWN
LEFT
RIGHT
ELEVATOR DEFLECTION (DEGREES)
LEFT FDR
RIGHT FDR
LEFT SIM
RIGHT SIM
NOSE DOWN
STABILIZER POSITION (UNITS)
NOSE DOWN
NORMAL LOAD FACTOR (g's)
SPEEDBRAKE HANDLE (1=DEPLOYED)
DEPLOYED
STICK SHAKER (−1=ACTIVE)
STICK SHAKER
TIME (SECONDS)
11:50:46
CALC fdr_plot 28JUN00
CHECK K.J. RENZE
APR
APR
REVISED
DATE
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LONGITUDINAL AXIS
767-300
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Figure 10a

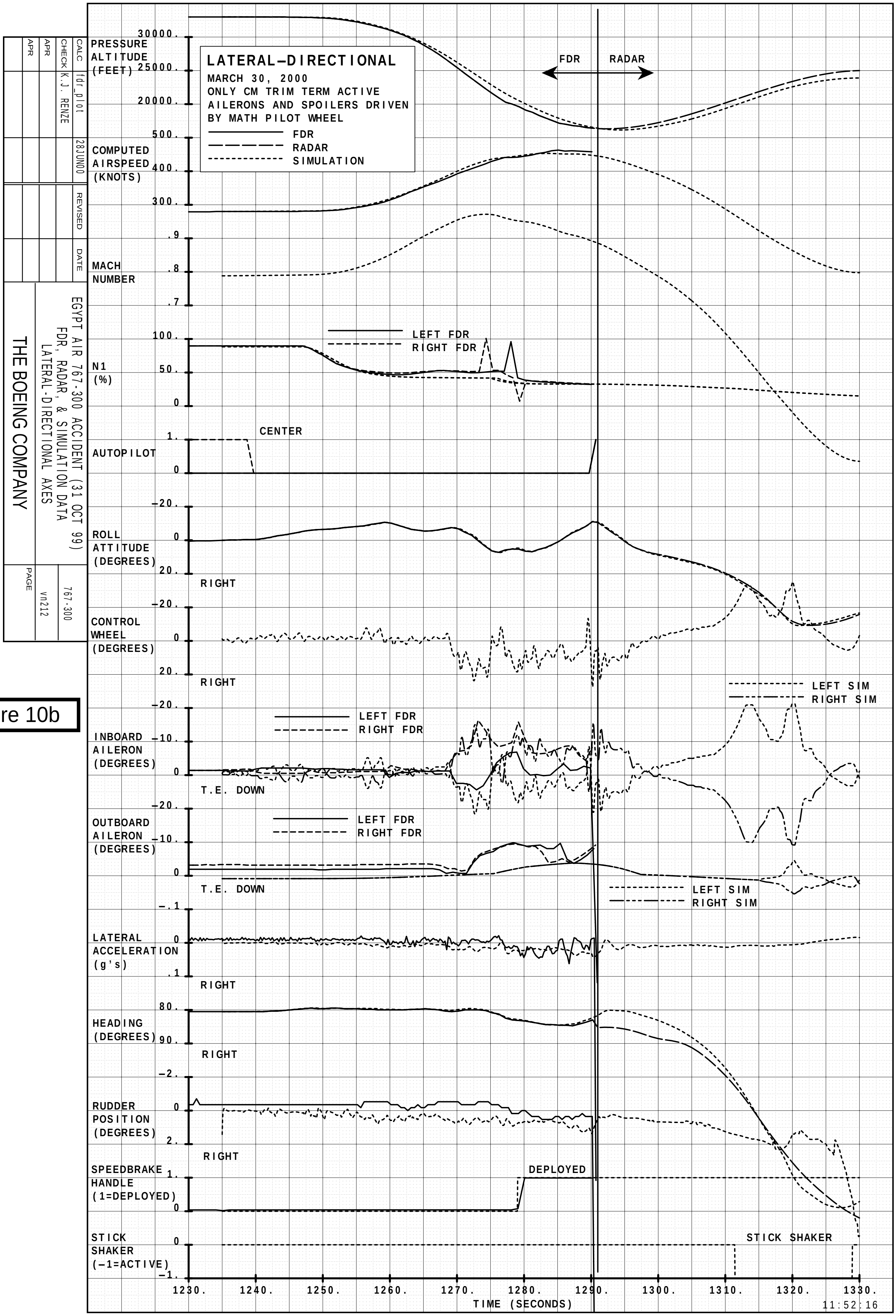
LATERAL–DIRECTIONAL
MARCH 30, 2000
ONLY CM TRIM TERM ACTIVE
AILERONS AND SPOILERS DRIVEN
BY MATH PILOT WHEEL
FDR
RADAR
SIMULATION
FDR
RADAR
PRESSURE ALTITUDE (FEET)
COMPUTED AIRSPEED (KNOTS)
MACH NUMBER
N1 (%)
LEFT FDR
RIGHT FDR
AUTOPILOT
CENTER
ROLL ATTITUDE (DEGREES)
RIGHT
CONTROL WHEEL (DEGREES)
RIGHT
LEFT SIM
RIGHT SIM
INBOARD AILERON (DEGREES)
T.E. DOWN
OUTBOARD AILERON (DEGREES)
T.E. DOWN
LATERAL ACCELERATION (g's)
RIGHT
HEADING (DEGREES)
RIGHT
RUDDER POSITION (DEGREES)
RIGHT
SPEEDBRAKE HANDLE (1=DEPLOYED)
DEPLOYED
STICK SHAKER (−1=ACTIVE)
STICK SHAKER
TIME (SECONDS)
1230. 1240. 1250. 1260. 1270. 1280. 1290. 1300. 1310. 1320. 1330.
11:52:16
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LATERAL-DIRECTIONAL AXES
CALC fdr_plot 28JUN00
CHECK K.J. RENZE
APR
APR
REVISED
DATE
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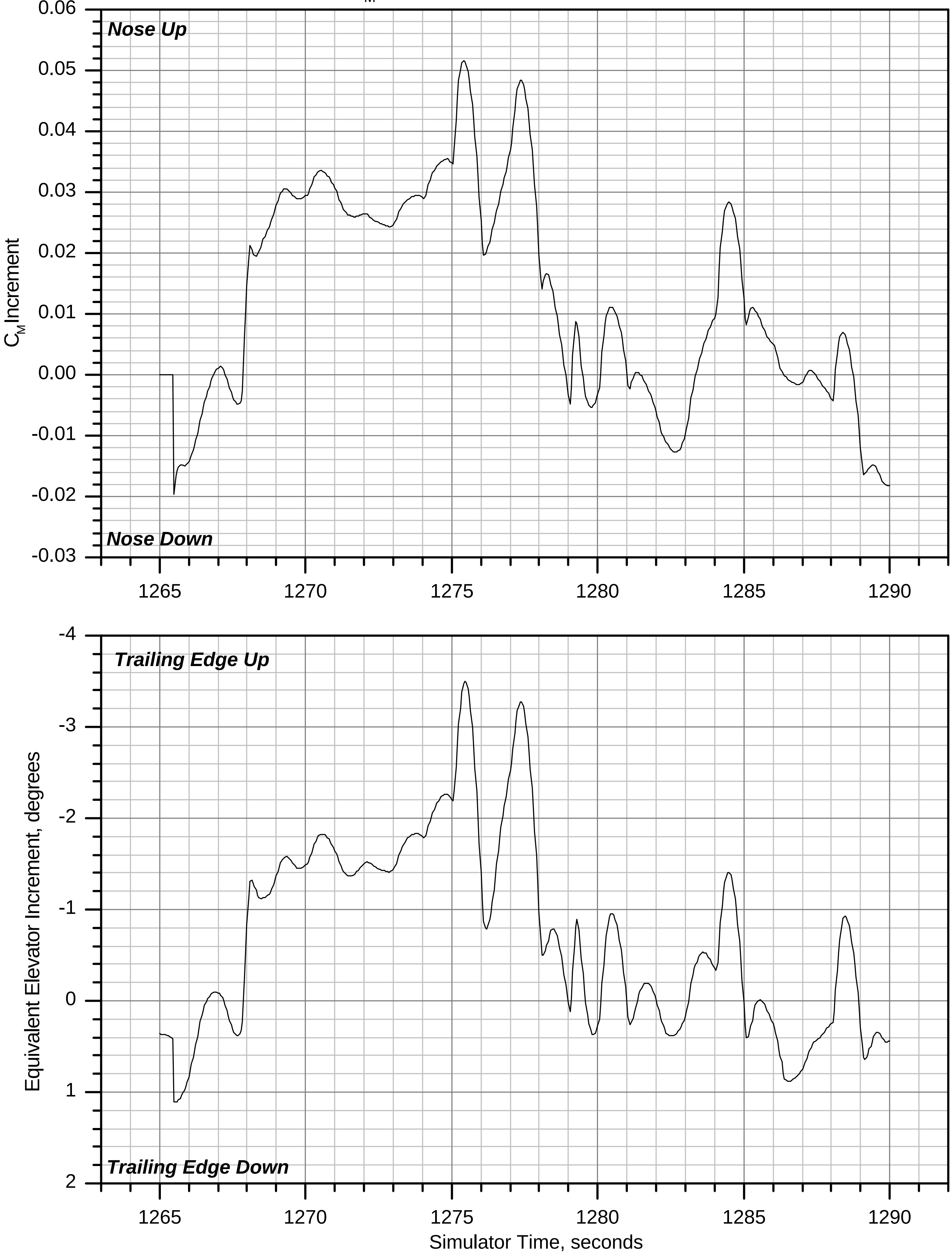
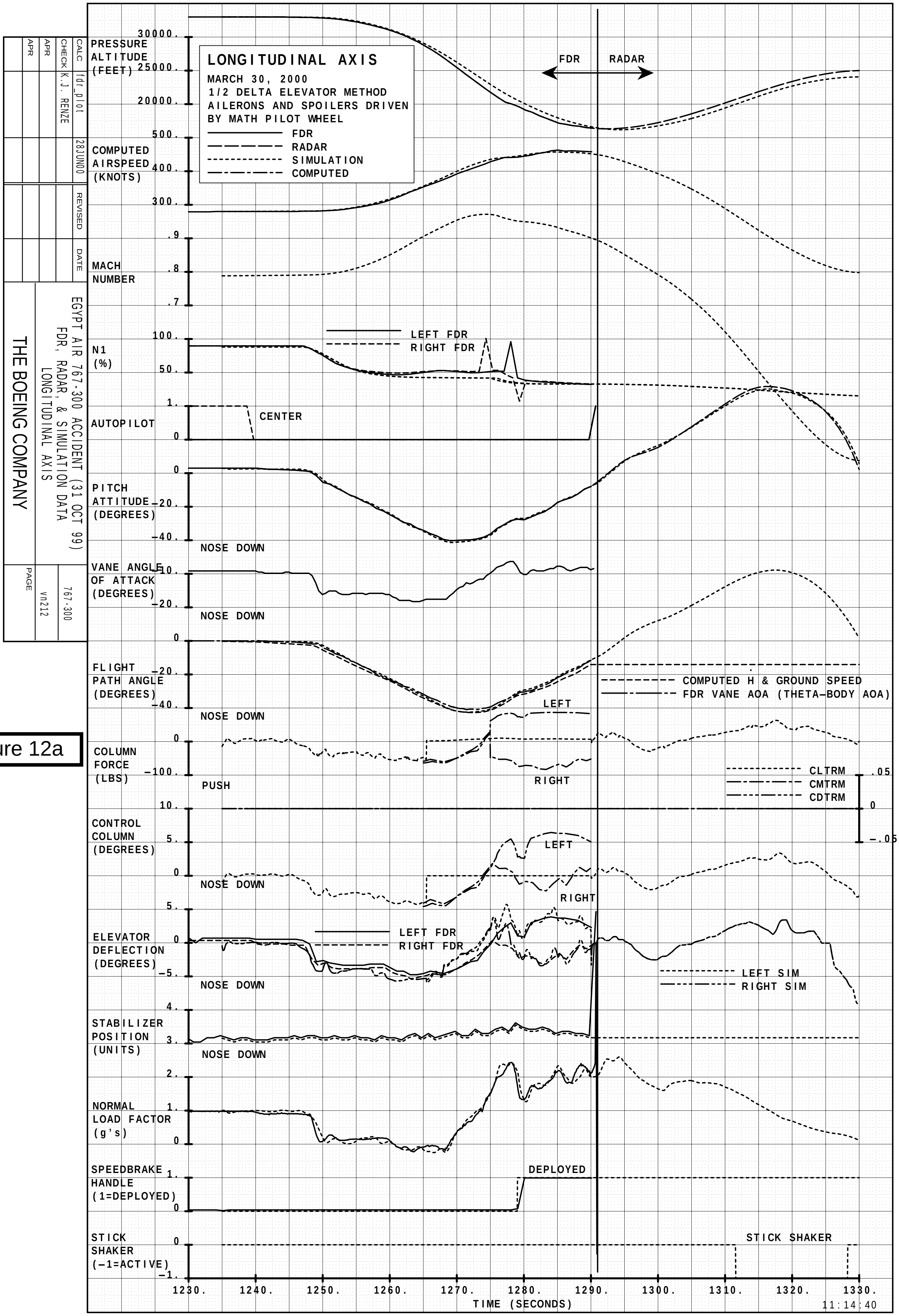
Figure 10b

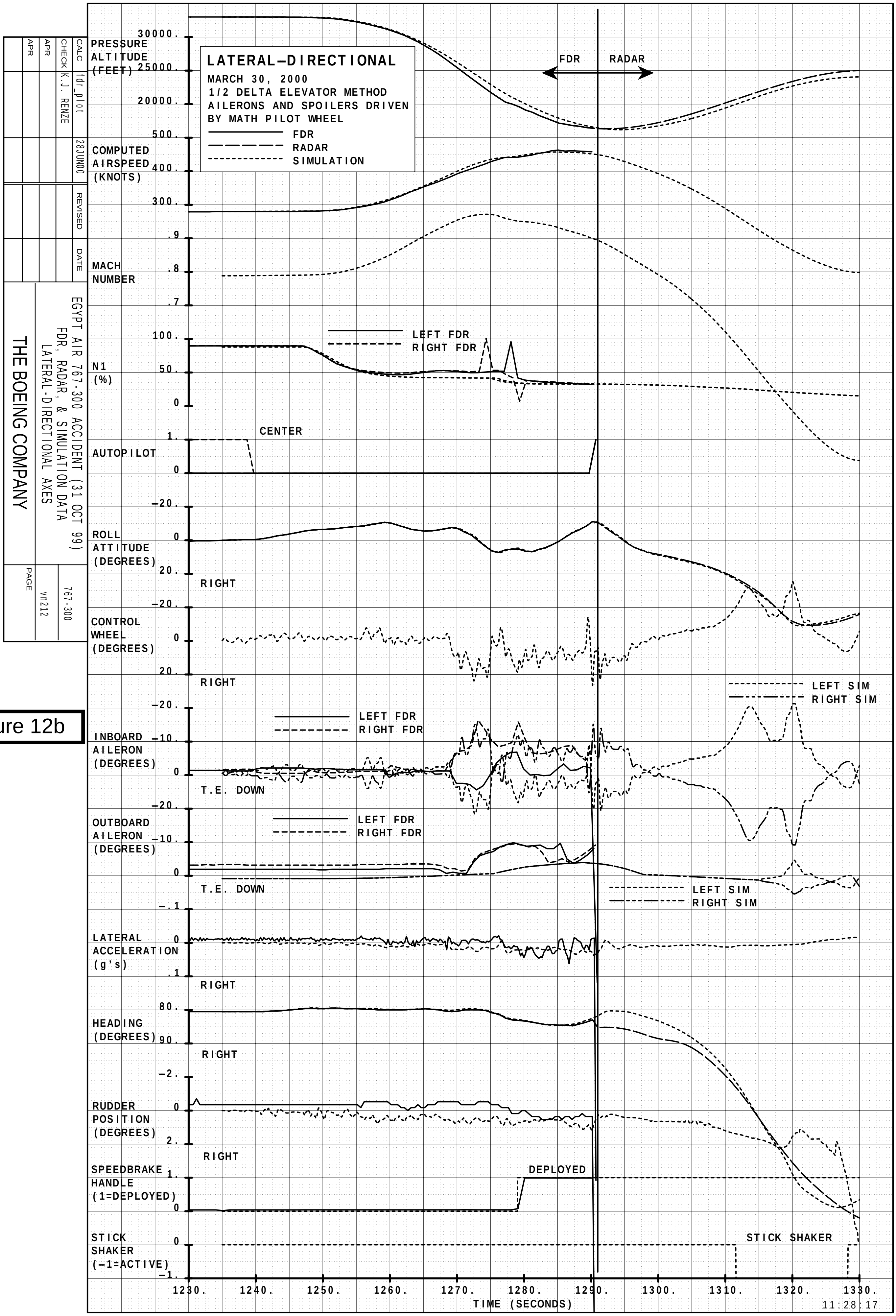
Figure 11: ΔC_M Method Equivalent Elevator Deflection





LONGITUDINAL AXIS
MARCH 30, 2000
1/2 DELTA ELEVATOR METHOD
AILERONS AND SPOILERS DRIVEN
BY MATH PILOT WHEEL
FDR
RADAR
SIMULATION
COMPUTED
FDR
RADAR
PRESSURE ALTITUDE (FEET)
30000.
25000.
20000.
COMPUTED AIRSPEED (KNOTS)
500.
400.
300.
MACH NUMBER
.9
.8
.7
N1 (%)
100.
50.
LEFT FDR
RIGHT FDR
AUTOPILOT
1.
0
CENTER
PITCH ATTITUDE (DEGREES)
0
−20.
−40.
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
10.
−20.
NOSE DOWN
FLIGHT PATH ANGLE (DEGREES)
0
−20.
−40.
NOSE DOWN
COMPUTED H & GROUND SPEED
FDR VANE AOA (THETA−BODY AOA)
LEFT
COLUMN FORCE (LBS)
0
−100.
PUSH
RIGHT
CLTRM
CMTRM
CDTRM
.05
0
−.05
CONTROL COLUMN (DEGREES)
10.
5.
0
LEFT
NOSE DOWN
RIGHT
ELEVATOR DEFLECTION (DEGREES)
5.
0
−5.
LEFT FDR
RIGHT FDR
NOSE DOWN
LEFT SIM
RIGHT SIM
STABILIZER POSITION (UNITS)
4.
3.
NOSE DOWN
NORMAL LOAD FACTOR (g's)
2.
1.
0
SPEEDBRAKE HANDLE (1=DEPLOYED)
1.
0
DEPLOYED
STICK SHAKER (−1=ACTIVE)
0
−1.
STICK SHAKER
1230.
1240.
1250.
1260.
1270.
1280.
1290.
1300.
1310.
1320.
1330.
TIME (SECONDS)
11:14:40
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LONGITUDINAL AXIS
CALC
fdr_plot
CHECK
K.J. RENZE
APR
APR
28JUN00
REVISED
DATE
PAGE
vn212
767-300

Figure 12a


LATERAL–DIRECTIONAL
MARCH 30, 2000
1/2 DELTA ELEVATOR METHOD
AILERONS AND SPOILERS DRIVEN
BY MATH PILOT WHEEL
FDR
RADAR
SIMULATION
PRESSURE ALTITUDE (FEET)
30000.
25000.
20000.
FDR
RADAR
COMPUTED AIRSPEED (KNOTS)
500.
400.
300.
MACH NUMBER
.9
.8
.7
N1 (%)
100.
50.
0
LEFT FDR
RIGHT FDR
AUTOPILOT
1.
0
CENTER
ROLL ATTITUDE (DEGREES)
-20.
0
20.
RIGHT
CONTROL WHEEL (DEGREES)
-20.
0
20.
RIGHT
LEFT SIM
RIGHT SIM
INBOARD AILERON (DEGREES)
-20.
-10.
0
LEFT FDR
RIGHT FDR
T.E. DOWN
OUTBOARD AILERON (DEGREES)
-20.
-10.
0
LEFT FDR
RIGHT FDR
T.E. DOWN
LEFT SIM
RIGHT SIM
LATERAL ACCELERATION (g's)
-.1
0
.1
RIGHT
HEADING (DEGREES)
80.
90.
RIGHT
RUDDER POSITION (DEGREES)
-2.
0
2.
RIGHT
SPEEDBRAKE HANDLE (1=DEPLOYED)
1.
0
DEPLOYED
STICK SHAKER (-1=ACTIVE)
0
-1.
STICK SHAKER
1230.
1240.
1250.
1260.
1270.
1280.
1290.
1300.
1310.
1320.
1330.
TIME (SECONDS)
11:28:17
CALC
CHECK
APR
APR
fdr_plot
K.J. RENZE
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DATE
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LATERAL-DIRECTIONAL AXES
THE BOEING COMPANY
PAGE
vn212
767-300

Figure 12b

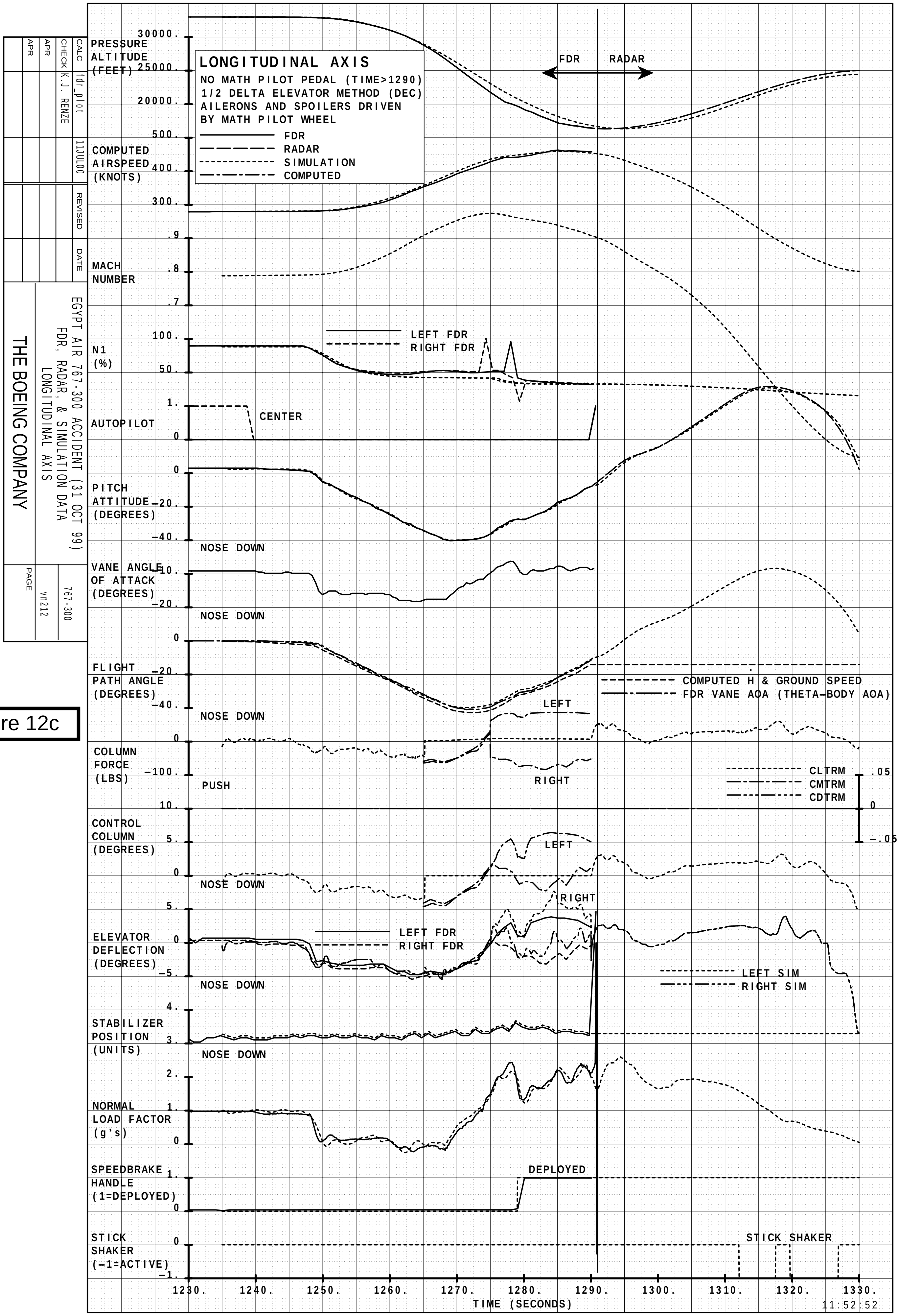
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LONGITUDINAL AXIS
CALC fdr_plot
CHECK K.J. RENZE
APR
APR
11JUL00
REVISED
DATE
PAGE
vn212
767-300
LONGITUDINAL AXIS
NO MATH PILOT PEDAL (TIME>1290)
1/2 DELTA ELEVATOR METHOD (DEC)
AILERONS AND SPOILERS DRIVEN
BY MATH PILOT WHEEL
FDR
RADAR
SIMULATION
COMPUTED
FDR
RADAR
PRESSURE ALTITUDE (FEET)
30000.
25000.
20000.
COMPUTED AIRSPEED (KNOTS)
500.
400.
300.
MACH NUMBER
.9
.8
.7
N1 (%)
100.
50.
LEFT FDR
RIGHT FDR
AUTOPILOT
1.
0
CENTER
PITCH ATTITUDE (DEGREES)
0
-20.
-40.
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
-10.
-20.
NOSE DOWN
FLIGHT PATH ANGLE (DEGREES)
0
-20.
-40.
NOSE DOWN
COMPUTED H & GROUND SPEED
FDR VANE AOA (THETA-BODY AOA)
COLUMN FORCE (LBS)
0
-100.
PUSH
LEFT
RIGHT
CLTRM
CMTRM
CDTRM
.05
0
-.05
CONTROL COLUMN (DEGREES)
10.
5.
0
NOSE DOWN
LEFT
RIGHT
ELEVATOR DEFLECTION (DEGREES)
5.
0
-5.
NOSE DOWN
LEFT FDR
RIGHT FDR
LEFT SIM
RIGHT SIM
STABILIZER POSITION (UNITS)
4.
3.
NOSE DOWN
NORMAL LOAD FACTOR (g's)
2.
1.
0
SPEEDBRAKE HANDLE (1=DEPLOYED)
1.
0
DEPLOYED
STICK SHAKER (-1=ACTIVE)
0
-1.
STICK SHAKER
1230.
1240.
1250.
1260.
1270.
1280.
1290.
1300.
1310.
1320.
1330.
TIME (SECONDS)
11:52:52

Figure 12c

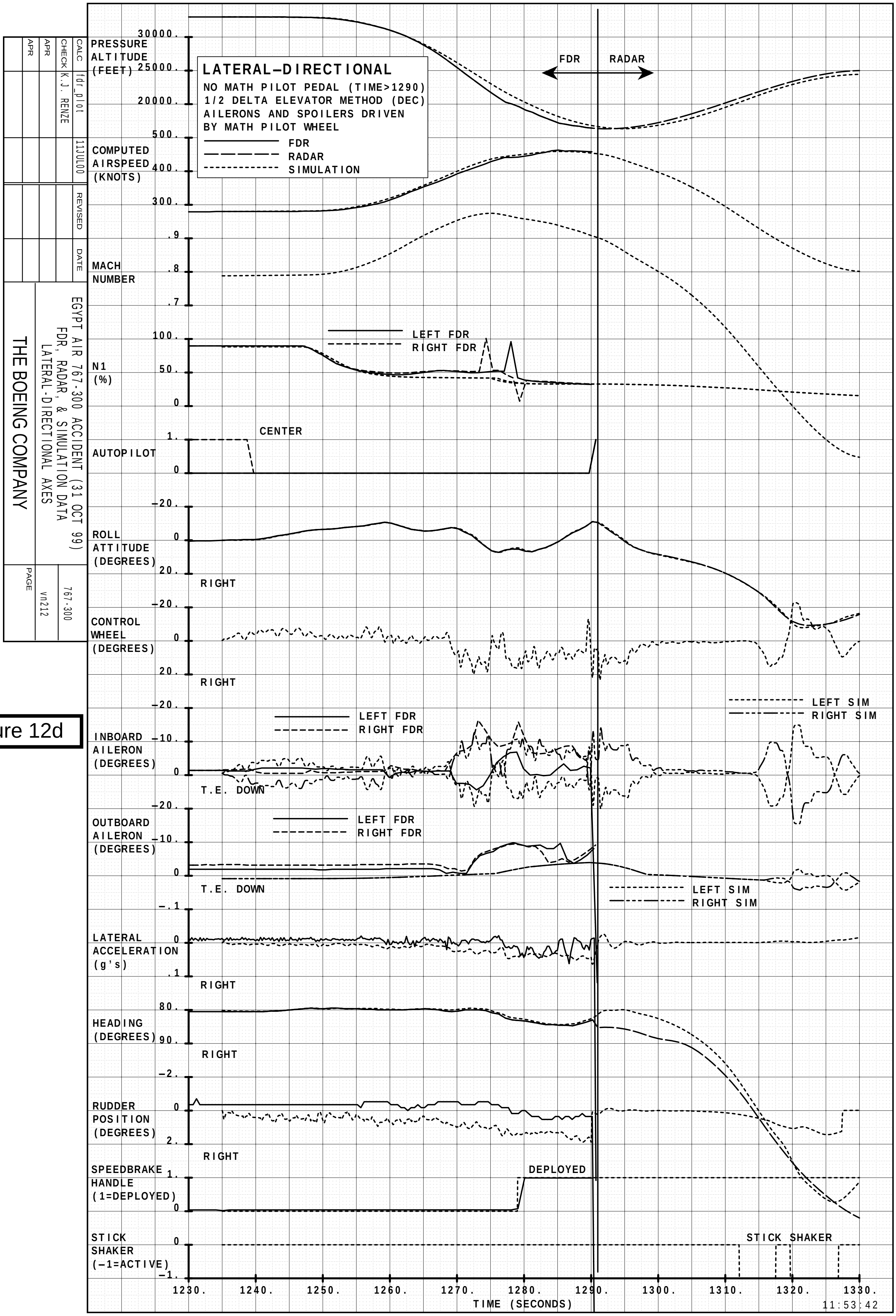
LATERAL-DIRECTIONAL
NO MATH PILOT PEDAL (TIME>1290)
1/2 DELTA ELEVATOR METHOD (DEC)
AILERONS AND SPOILERS DRIVEN
BY MATH PILOT WHEEL
FDR
RADAR
SIMULATION
FDR
RADAR
PRESSURE ALTITUDE (FEET)
30000.
25000.
20000.
COMPUTED AIRSPEED (KNOTS)
500.
400.
300.
MACH NUMBER
.9
.8
.7
N1 (%)
100.
50.
0
LEFT FDR
RIGHT FDR
AUTOPILOT
CENTER
1.
0
ROLL ATTITUDE (DEGREES)
-20.
0
20.
RIGHT
CONTROL WHEEL (DEGREES)
-20.
0
20.
RIGHT
INBOARD AILERON (DEGREES)
-20.
-10.
0
T.E. DOWN
LEFT FDR
RIGHT FDR
LEFT SIM
RIGHT SIM
OUTBOARD AILERON (DEGREES)
-20.
-10.
0
T.E. DOWN
LEFT FDR
RIGHT FDR
LEFT SIM
RIGHT SIM
LATERAL ACCELERATION (g's)
-.1
0
.1
RIGHT
HEADING (DEGREES)
80.
90.
RIGHT
RUDDER POSITION (DEGREES)
-2.
0
2.
RIGHT
SPEEDBRAKE HANDLE (1=DEPLOYED)
1.
0
DEPLOYED
STICK SHAKER (-1=ACTIVE)
0
-1.
STICK SHAKER
1230.
1240.
1250.
1260.
1270.
1280.
1290.
1300.
1310.
1320.
1330.
TIME (SECONDS)
11:53:42
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LATERAL-DIRECTIONAL AXES
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Figure 12d

“Background” Simulation Column Position Required to Match DFDR Elevator Angles Split Elevator Conditions - 1265 £ BTIME £ 1290 (March Simulations Only)

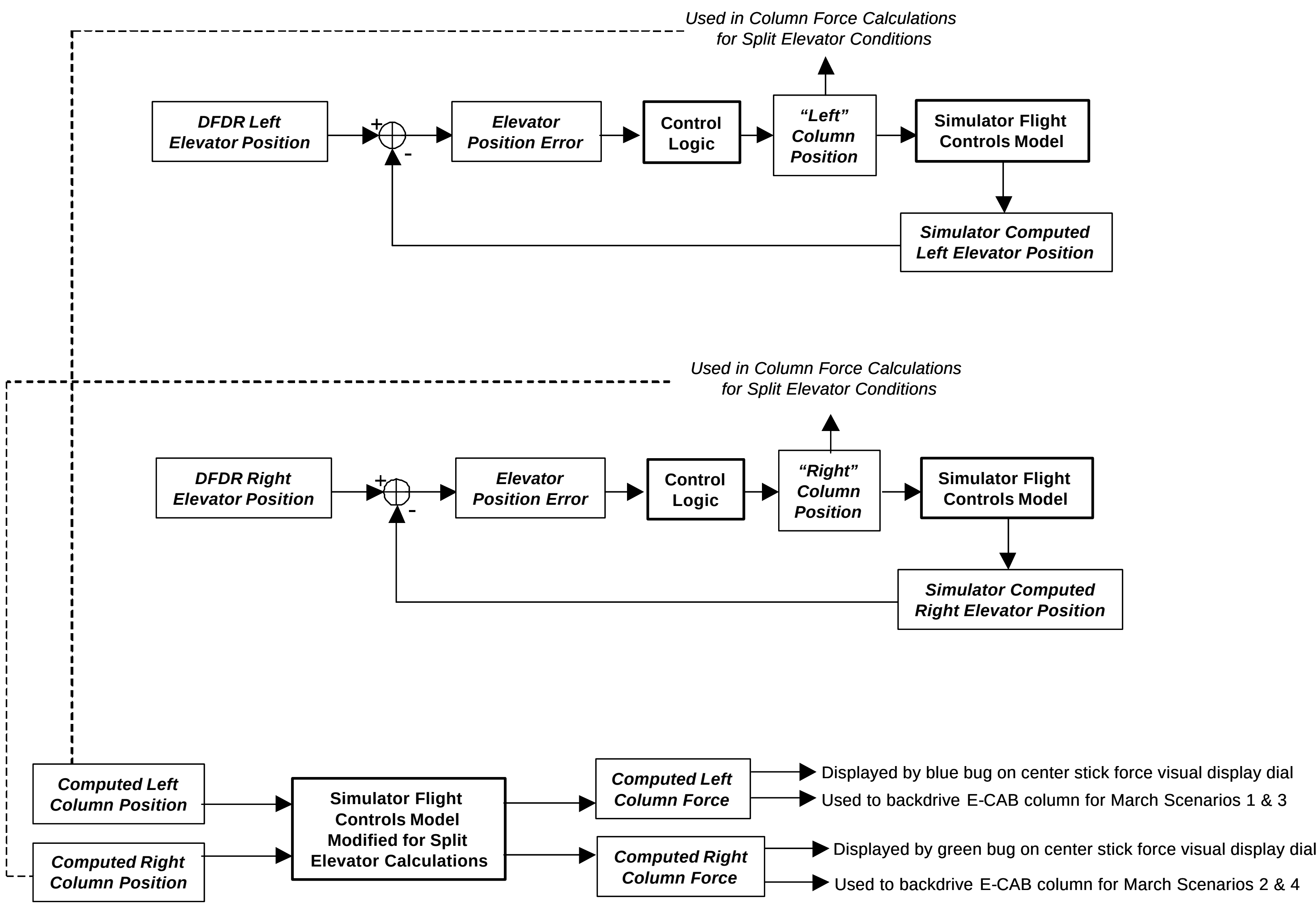

Figure 13.

Figure 14. Visual system instrument display for March 2000 E-CAB simulations.

December 1999 Boeing 767-400 Ground Test

Condition #B1.39.1310.800 - Elevator Feel Pressure = 780 psi

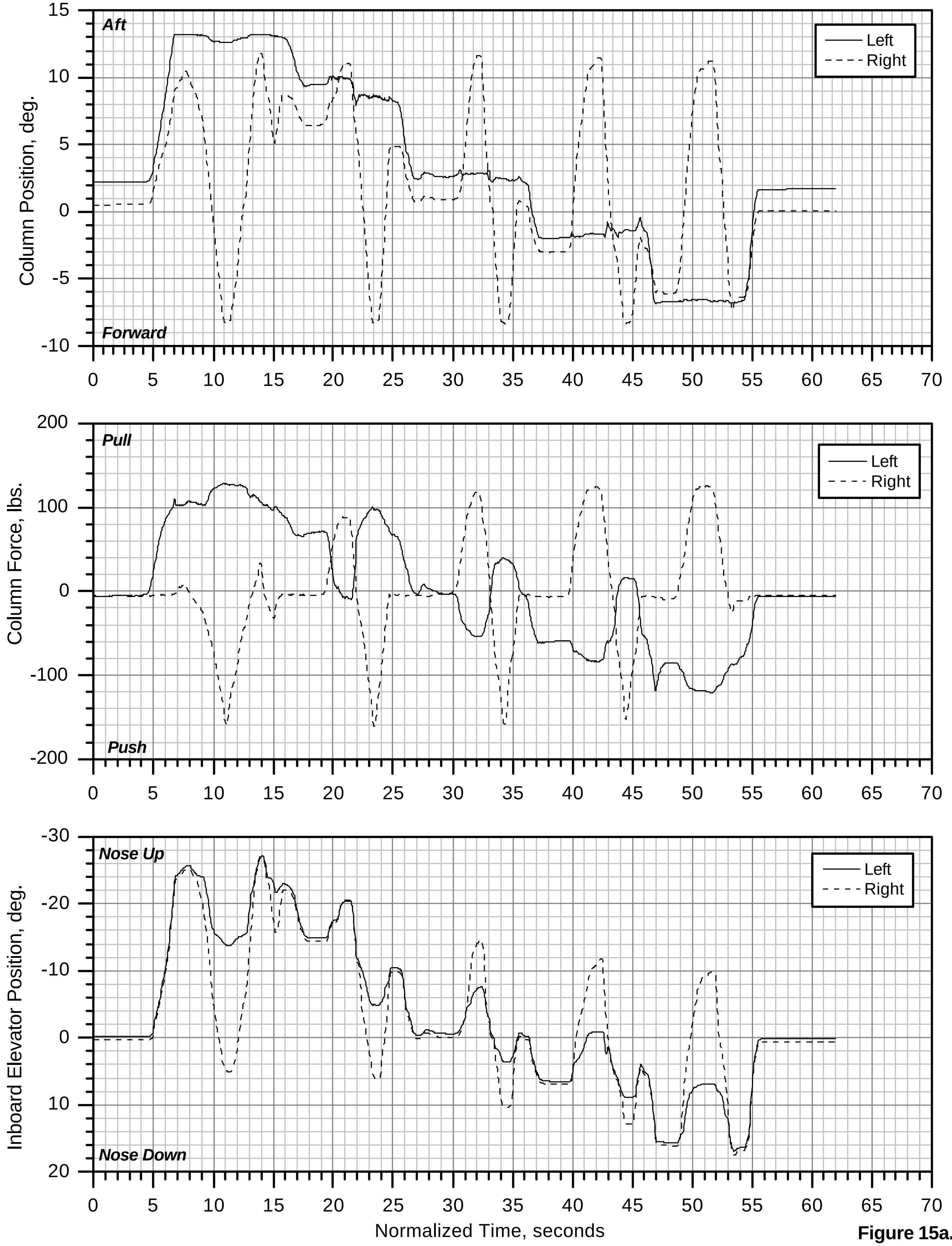

Figure 15a.

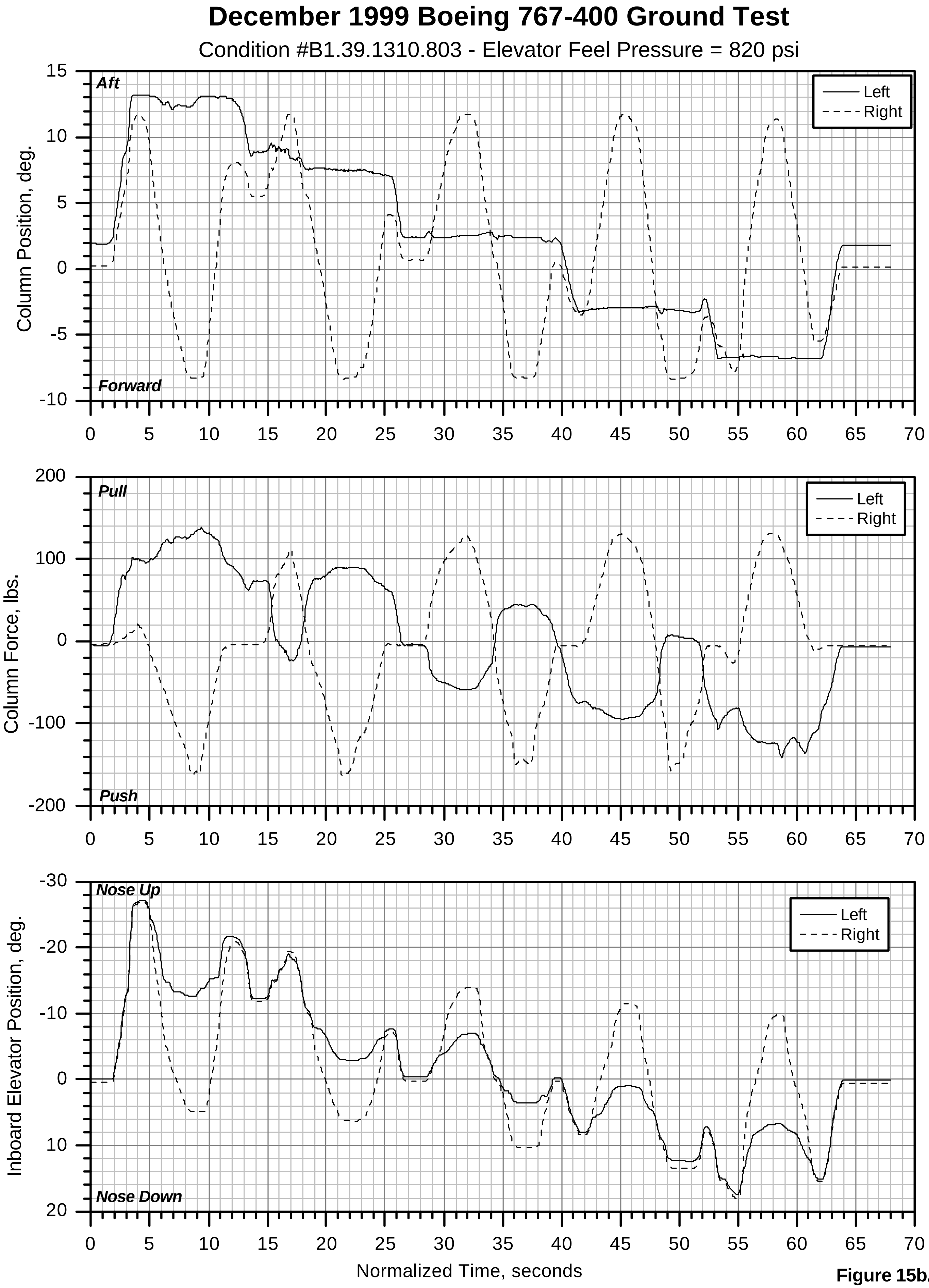
December 1999 Boeing 767-400 Ground Test
Condition #B1.39.1310.803 - Elevator Feel Pressure = 820 psi
Column Position, deg.
Aft
Forward
Left
Right
15
10
5
0
-5
-10
Column Force, lbs.
Pull
Push
200
100
0
-100
-200
Inboard Elevator Position, deg.
Nose Up
Nose Down
-30
-20
-10
0
10
20
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Normalized Time, seconds

Figure 15b.

APPENDIX A

Boeing Presentation on Simulator Methods and Limitations
December 1999

EgyptAir Flight 990 Accident Investigation Simulator & Ground Test Activities at The Boeing Company - 12/8/99

- Introductions & Agenda

- Simulations:
  - "Background" Simulations
  - "Backdrive" Simulation
  - "Backdrive" with Interrupt Simulation
  - "Hand Flown" Simulations

- Important Notes Concerning All Simulations

- Logistics of Demonstrating Cab Simulations

- Control Column Ground Test: VQ002

EgyptAir 990 Simulator Demonstration,
Day 1: Wednesday December 8, 1999
Location: ASL (2-122 Building)

Time:	Topic:	Action Leaders:
9:00 am – 9:15 am	Introductions/Greetings (In large conference room)	NTSB (Greg Phillips, John O'Callaghan, P. D. Weston, Evan Byrne) Boeing: (Rick Howes, Dan Mooney, John Cashman)
9:15am – 10:00 am	Opening Comments/ Expectations	NTSB (JJO, PDW)
	Overview of Simulation Plan	NTSB (JJO, PDW) Boeing (Rex Walter, Tim Mazzitelli) as requested
	Simulator Cab Limitations	Boeing (Bill Tafs)
10:00 am – Noon	Simulator Cab Demonstrations: (basic model (e.g., full hydraulics)) a) Back-drive scenario b) Back-drive with ability to take control	Operations, Performance & Human Perf. Groups Need to keep flexible and let Ops. Group set up pilot pairings as required) General guideline may be 4 pilot pairings; 20 minutes for each pair; time for brief discussion between each pair
Noon – 1:00 pm	Lunch: Box lunches to be provided	Rick Howes
1:00 pm – 1:30 pm	Morning Observations/Discussions	Operations, Performance & Human Perf. Groups
1:30 pm – 3:00 pm	Additional Simulations: More of a) & b) above c) hydraulics system reductions, etc.	Operations, Performance & Human Perf. Groups
3:00 pm – 3:45 pm	Day's End Simulator Discussion: a) Observations b) Plan for Thursday	NTSB (JJO, PDW, EB)
3:45 pm – 4:15 pm	Briefing for Split Column Ground Test	Boeing (Pete Van Leynseele)
4:15 pm – 4:30 pm	Travel to Boeing Field	
4:30 pm – 5:00 pm	Split Column Ground Test	Boeing (Pete Van Leynseele)

EgyptAir 990 Simulator Demonstration
Day 2: Thursday December 9, 1999 (if required)
Location: ASL (2-122 Building)

Time:	Topic:	Action Leaders:
9:00 am – 9:30 am	Today's Plan/Briefing	NTSB (John O'Callaghan, P. D. Weston, Evan Byrne)
9:30 am – Noon	Simulation Analyses, as required	Operations, Performance & Human Perf. Groups
Noon – 1:00 pm	Lunch: Box lunches to be provided	Rick Howes
1:00 pm – 1:30 pm	Morning Observations/Discussions	Operations, Performance & Human Perf. Groups
1:30 pm – 3:00 pm	Additional Simulations, as required	Operations, Performance & Human Perf. Groups
3:00 pm – 4:00 pm	Closing Comments: a) Observations b) Future Plans	NTSB (JJO, PDW, EB)

“Background” Simulations

- Purpose:
  - Determine control inputs required to drive event
  - Verify that airplane has performance to match radar data (through climb to ~24,000 ft.)
  - Validate / adjust simulator aerodynamic database
- Run on engineering workstation - no cab or pilot in loop
- Simulation initially trimmed at 33,000 ft., $M = 0.79$
- Control column driven to match pitch
- Control wheel driven to match roll

“Background” Simulations (continued)

- Where DFDR data is available:
  - Target pitch and roll set to DFDR pitch and roll
  - Engine EPR driven with DFDR data
  - Speedbrake handle driven by DFDR data

- After DFDR data ends:
  - Target pitch and roll derived from radar data
  - Engines assumed to be shut down
  - Speedbrakes assumed to remain deployed

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THE BOEING COMPANY

EGYPT AIR 990
MATH PILOT MATCH FDR & RADAR DATA
ALT = 33,000 FT MACH = .79

767-300ER

PW 4060

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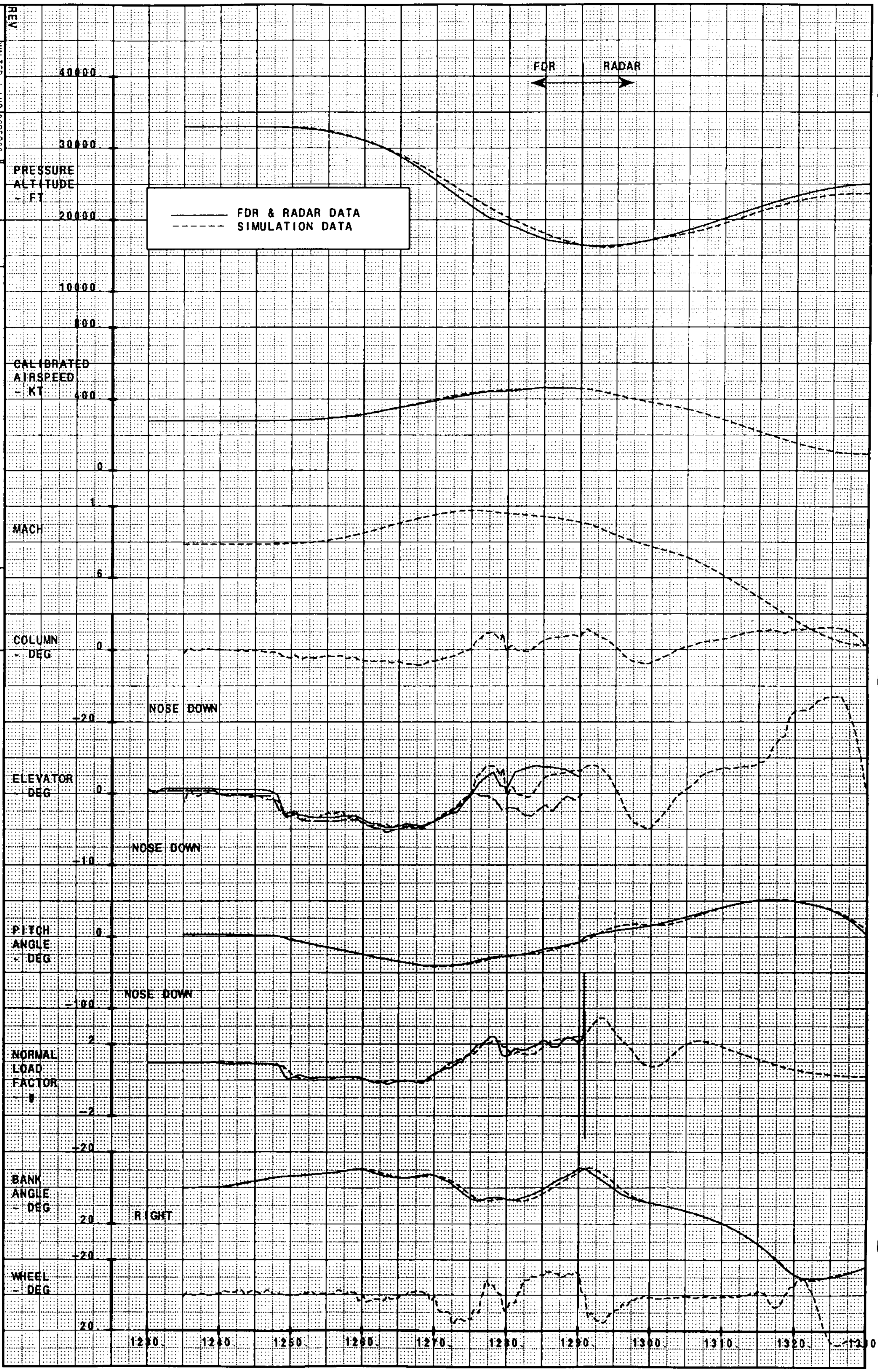
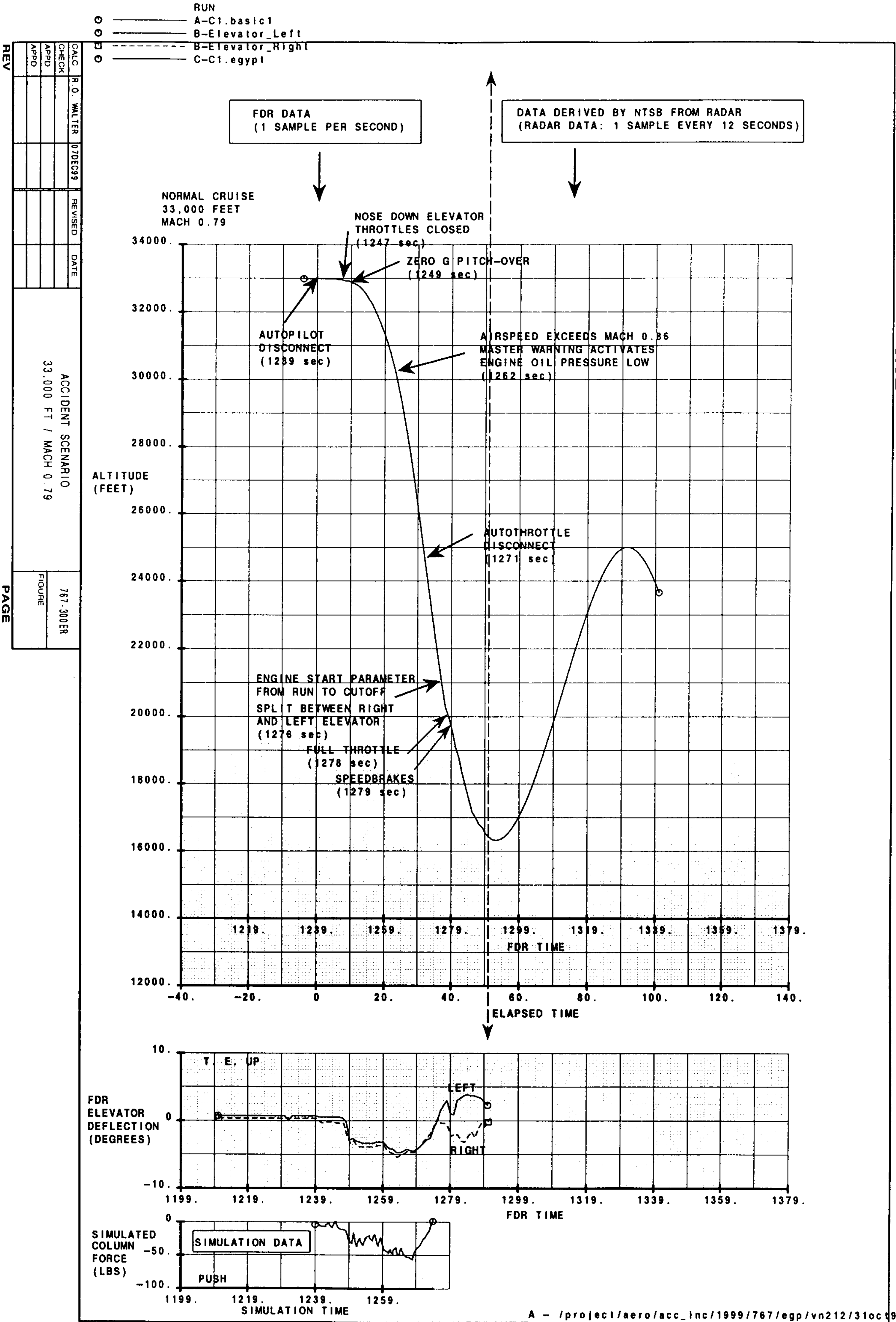


"Backdrive" Simulations

- Purpose:
  - Have cockpit instruments and controls "replay" event
  - Provide unique way of visualizing DFDR / derived data
  - Experience timing of events, force levels, and activity level in cockpit

- Cockpit controls driven with DFDR data:
  - Throttles
  - Speedbrakes,
  - Engine cut logic

- Cockpit controls driven with data derived from Background simulations:
  - Control column
  - Control wheel



A – /project/aero/acc_inc/1999/767/egp/vn212/31oct99/jxl/egp_e
B – /project/aero/acc_inc/1999/767/egp/vn212/31oct99/ntsb/ntsb
C – /project/aero/acc_inc/1999/767/egp/vn212/31oct99/jxl/egp_e

"Backdrive" Simulation with Pilot Interrupt

- Purpose:
  - Allow pilot to take control of aircraft at any point during event to attempt recovery
  - Experience workload / forces required to resume normal flight

- When pilot wants control, call for it and receive response from simulator operator (Mark Dale)

"Hand Flown" Simulations

- Purpose (for example):
  - Experience workload and force levels required to fly "0 g" maneuver
  - Experience workload and time required to restart engines
  - Evaluate handling qualities with reduced hydraulic power

- Operation similar to a simulator training session

- Maneuvers flown are at pilot's discretion

Important Notes Concerning All Simulations

- Data will be recorded, and a record of the flying pilot (if applicable) corresponding to each recorded run will be kept

- Background and Backdrive simulations are driven through climb to ~24,000 ft.

- Final descent to surface not shown

- Control column motion is based on DFDR elevator position only until elevator split

- After elevator split, column motion driven to match pitch angles using symmetric elevators

Important Notes Concerning All Simulations (continued)

- Column and wheel motions after DFDR data ends are driven to match pitch and roll angles derived from radar data - i.e., relatively large uncertainty

- Aerodynamic database modified to reflect best engineering estimate of airplane performance at high Mach

- Simulation is an engineering tool, not a crew training device. Much work done to duplicate B767-300ER cockpit, but certain differences and limitations remain

Simulation Limitations: Simulator Cab

- The cab is fixed-based. Motion is not available
- The visual landscape is a featureless land with a visible horizon
- No Mach or stall buffet is modeled
- Numerous status messages are displayed erroneously on EICAS
- No metric displays for fuel quantity and fuel flow
- No thrust reverser isolation lights
- No stand-by compass
- The mode control panel is different than the EgyptAir configuration (no Control Wheel Steering)
- Wind and engine noise are not modeled

Simulation Limitations: Modeling

- Control columns and elevators can only be moved symmetrically

- No hydraulic decay or elevator blowdown model

- The asymmetry and un-steady aerodynamics of stalls are not accurately represented

- The low oil pressure light does not illuminate, nor does the caution alert (beeper) function during the FDR low oil operation

- Ship's Air Data Computer calibration has not been verified at speeds in excess of M_d = ~~.86~~ .91

  $V_d = 420$

Simulator Limitations: Backdrive Scenario

- Throttle handles can only be driven at autopilot rate (around 10 deg/sec), although the engine information (EPR, N1, N2) are driven at the rates recorded on the flight data recorder

- Prior to back-drive, must manually arm speed-brakes

Additional Simulation Items of Note

- Simulator model accounts for hydraulic power generation (for example, wind-milling engines) independently from hydraulic power usage (for example, flight controls)

- Additional instrumentation has been added to the simulator cab environment to facilitate this investigation:
  - G-meter
  - left and right <u>Flight Data Recorder</u> elevator display
  - fuel cut-out lights (above FDR elevator displays)

- A "chase-plane view" will be displayed on a separate monitor in the cab area and in a briefing room

- The primary altimeters display "off flags" during excessive descent rates (normal operation)

EgyptAir 990 Simulator Demonstration, 12/8/99

Limitations/Modifications/Items of Note

Limitations:

Cab Limitations:

1. The cab is fixed-based. Motion is not available.
2. The visual landscape is a featureless land with a visible horizon.
3. No Mach or stall buffet is modeled.
4. Numerous status messages are displayed erroneously on EICAS.
5. No metric displays for fuel quantity and fuel flow.
6. No thrust reverser isolation lights.
7. No stand-by compass.
8. The mode control panel is different than the EgyptAir configuration (no Control Wheel Steering).

Modeling Limitations:

9. The control columns and elevators can only be moved symmetrically in the cab.
10. There is no hydraulic decay model or elevator blowdown model that simulates the decay of hydraulic pressure as the engines wind-mill and speed decreases.
11. The asymmetry and un-steady aerodynamics of stalls are not accurately represented.
12. The low oil pressure light does not illuminate, nor does the caution alert (beeper) function during the FDR low oil operation . The four items that could cause the aural alert are: alternating current (a/c) power loss, low hydraulic pressure, fuel configuration, and low oil pressure.
13. Ship's Air Data Computer calibration has not been verified at speeds in excess of M = .86

Back-drive Limitations:

14. For back-drive, throttles handles can only be driven at autopilot rate (around 10 deg/sec), although the engine information (EPR, N1, N2) are driven at the rates recorded on the flight data recorder.
15. During back-drive, must manually arm speed-brakes.

Modifications:

- Aerodynamic data have been modified above Mach = .91 for the following terms:
  - Lift Coefficient, Pitching Moment Coefficient, and Drag Coefficient of the Wing-Body.
  - Spoiler Blowdown.
  - Spoiler Lift and Pitching Moment Coefficients.

Items of Note:

1. Simulator model accounts for hydraulic power generation (for example, wind-milling engines) independently from hydraulic power usage (for example, flight controls).
2. Additional instrumentation has been added to the simulator cab environment to facilitate this investigation: G-meter, left and right Flight Data Recorder elevator display, fuel cut-out lights (above FDR elevator displays).
3. A "chase-plane view" will be displayed on a separate monitor in the cab area and in a briefing room. Various airplane/flight deck information will be displayed.
4. The primary altimeters display "off flags" during excessive descent rates (normal operation).

Logistics of Demonstrating Cab Simulations

- Numbered List of Participants: Remember your Number!

- Three groups of four participants + 1 coordinator

- Morning Session: Each group has 40 min. each to review 3 scenarios, totaling 11 runs

- Objective for morning session is for each participant to observe and fly each prepared scenario - discipline on time will be required

- Additional simulator time available in afternoon session and on Thursday if additional testing required

- Non-flying groups can observe proceedings at "chase plane" monitor in cab room or pilot briefing room

List of Participants for the EgyptAir 990 Simulation Demonstration at The Boeing Company, Seattle, WA, December 8, 1999 (9:00 PST)

All participants will be flying the simulator scenario.

From the Airplane Performance Group:

1. John O'Callaghan	NTSB	US
2. John Schade	NTSB	US
3. Mohamed A. Hamid Hamdy	EyptAir	Egypt
4. Maher Ismaiel Mohomed	Egyptian Civil Aviation Authority	Egypt

From the Operations Group:

5. Capt. PD Weston	NTSB	US
6. Capt. Harold Simpson	FAA	US
7. Capt. Bill Tafs	Boeing	US
8. Luke Schiada	NTSB	US

Others:

9. John Neff	FAA	US
10. Capt. Mohsen El Missiry	ECAA	Egypt
11. Capt. Paul Remington	FAA	US
12. Capt. Othman Nour	ECAA	Egypt
13. John Swanson	FBI	US

From the Human Performance Group

14. Alan Brantly	FBI	US

EgyptAir 990 Simulation Demonstration Schedule
at The Boeing Company, Seattle, WA, December 8, 1999
(10:00 PST)

Simulator Group #1: (10:00 - 10:40)

Name	Organization	Pilot #
Capt. PD Weston	NTSB	5
Capt. Bill Tafs	Boeing	7
Capt. Mohsen El Missiry	ECAA	10
Capt. Othman Nour	ECAA	12

Simulator Group #2: (10:40 - 11:20)

Name	Organization	Pilot #
Capt. Harold Simpson	FAA	6
Capt. Paul Remington	FAA	11
Mohamed A. Hamid Hamdy	EgyptAir	3
Maher Ismaiel Mohomed	ECAA	4

Simulator Group #3: (11:20 - 12:00)

Name	Organization	Pilot #
John Neff	FAA	9
John Swanson	FBI	13
Alan Brantly	FBI	14
Luke Schiada	NTSB	8

EgyptAir 990 Simulation Demonstration
The Boeing Company, Seattle, WA, December 8, 1999
(10:00 PST)

Group Simulator Run Schedule

Run #	Scenario	Seat Flying	Comments
0	----	n/a	familiarization with cockpit • 'q' meter • right/left elevator display • Arming of Speed Brake handle • Fuel cutoff light
1	A	n/a	no stops
2	A	n/a	with stops. (see definition of Scenario A with stops)
3	A	n/a	no stops
4	B	L1	left seat pilot(1) takes control at his discretion
5	B	R1	right seat pilot(1) takes control at his discretion
6	C	L1	left seat pilot(1)manually flies maneuver.
7	C	R1	right seat pilot(1)manually flies maneuver.
8	B	L2	left seat pilot(2) takes control at his discretion
9	B	R2	right seat pilot(2) takes control at his discretion
10	C	L2	left seat pilot(2) manually flies maneuver.
11	C	R2	right seat pilot(2)manually flies maneuver.

Scenario Definition

A Backdrive only (no pilot interaction)

B Backdrive with pilot taking over at any point during the simulation

C Manually flown maneuver

EgyptAir 990 Simulation Demonstration
The Boeing Company, Seattle, WA, December 8, 1999
(10:00 PST)

Definition of Scenario A with stops

ET	Stop	Comments
0	no	The simulation begins at auto-pilot disconnect.
8-9	yes	Throttle movement slower than recorded movement. Engines are modeled according to DFDR. Beginning of column input.
10-11	no	Zero G
23	yes	Master warning - overspeed
32	yes	A/T disconnect
37	yes	Engine cutoff (handles do not move see light). Elevators start to split.
41	yes	Throttles move slower than recorded rate. Speed brakes deployed.
51	yes	End of DFDR data. Screens blank out.
101	yes	End of Backdrive data.

Simulator Log

December 8, 1999

File Name (if recorded)	Case #	Clock Time	Left Seat (✓ = flying)	Right Seat (✓ = flying)	Scenario #	Comments

Group 1: (10:00 – 10:40)
Capt. PD Weston = 5
Capt. Bill Tats = 7
Capt. Mohsen El Missiry = 10
Capt. Othman Nour = 12

Group 2: (10:40 – 11:20)
Capt. Harold Simpson = 6
Capt. Paul Remington = 11
Mohamed A. Hamid Hamdy = 3
Maher Ismaiel Mohomed = 4

Group 3: (11:20 – 12:00)
John Neff = 9
John Swanson = 13
Alan Brantly = 14
Luke Schiada = 8

Scenarios:
A = backdrive
B = backdrive w/interrupt
C = hand fly
D = hand fly w/ hyd cut 1
E = hand fly w/ hyd cut 2

Column Push/Pull Ground Test

- Force sensor calibration run with "fish scale"
- Push / Pull tests with same groups as simulator tests
- Human performance group participation
- Air data system rigged for event condition
- Control column position and force & elevator positions will be recorded

APPENDIX B

Boeing Record of 767-400 Split Column Ground Test
December 1999

FLIGHT TEST ORGANIZATION
PLAN OF TEST

TITLE: SPLIT ELEVATOR GROUND TEST

AIRPLANE MODEL	AIRPLANE CUSTOMER & TABULATION NO.
767-432	VQ002 /DAL/769
PLAN & TEST NO.	DATE CONDUCTED
002-08	12/08/99

THIS PLAN OF TEST INCLUDES THE FOLLOWING TEST ITEMS:

EWA NO.	T.I. NO.	TITLE
DEDICATED		
C V2251-003	✓B1.39.1310	767 SPLIT ELEVATOR GROUND TEST
CONCURRENT		
V2251-003	N9.02.0491	INSTRUMENTATION HEALTH MEASUREMENTS 767-400ER VQ 002

PREPARED BY (TEST ENGINEER)	CHECKED BY (PROJECT PILOT)
[redacted]	
APPROVED BY (OPS GROUP ENGINEER)	APPROVED BY (DIR OF FLIGHT TEST)
[redacted]	

.pdf file available

767 - 400 ER
VQ 002
D6T11767-0769P
002-08-A1

RED LABEL EQUIPMENT LIST
VQ002

The list of Red Label (RL) equipment installed on this airplane is extensive. As a cost-cutting effort (e.g., time, paper, ...), the customary RL list was not included in this PL&D.

The entire RL list is available on FTCS and can be accessed as follows:

From the FTCS MASTER MENU select
(8) AIRCRAFT CONFIGURATION

From the AIRCRAFT CONFIGURATION MENU select
(6) RED LABEL (RL) CONFIGURATION

From the RED LABEL (RL) CONFIGURATION MENU select
(3) SEARCH RL EQUIPMENT INSTALLATIONS

Once the SEARCH RL EQUIPMENT INSTALLATIONS screen is available, the entire RL list can be accessed by entering
AIRPLANE NUMBER and DATE OF TEST or TEST NUMBER

Individual components can be searched by entering
AIRPLANE NUMBER, DATE OF TEST (or TEST NUMBER) and PART NUMBER (PN)

767 SPLIT ELEVATORS GROUND TEST - FT

Prep	[redacted]	12/7/99	Conc	[redacted]	12-8-99
	Analysis Engineer	Date		Lead Test Operations Engineer	Date
	[redacted]	[redacted]		[redacted]	[redacted]
App	[redacted]	12/07/99	App	[redacted]	12/7/99
	Lead Analysis Engineer	Date		Analysis Supervisor	Date
	[redacted]	[redacted]		[redacted]	[redacted]

PURPOSE OF TEST

The purpose of this test is to demonstrate the forces required to split the elevators during simulated high speed conditions.

RISK ASSESSMENT

All Test Conditions in the TIP Sheet are considered to be LOW Risk.

REFERENCES

(a) Engineering Work Authorization (EWA) V2251-003, "767 Split Elevator Ground Test"

CONFIGURATION

The test aircraft is a Model 767-400 (Airplane VQ002).

Electric driven pumps are satisfactory for this testing.

All static ports set to same air pressure (atmospheric pressure OK if SAFT Van is not used).

SPECIAL TEST REQUIREMENTS

Configure SAFT van to provide Pitot and Static pressures to Captain's, First Officer's, Auxiliary 1, Auxiliary 2 systems, and Alternate Static Systems. Requires R-3110 shop support.

-OR-

Alternative means of varying pitot system pressure to control elevator feel pressure.

DATA REQUIRED

Data Tapes/**FDR** - ON and RECORDING prior to test start

Manual Data - Test Director: Record events and correlate with IRIG time.

Analysis: Record events and correlate with IRIG time, and monitor ADAMS for condition acceptability.

TEST CONDITIONS

B1.39.1310 SPLIT ELEV - BASELINE FORCE EVAL

Initial Setup

- ☐ Stabilizer set to approximately 3 Units❶
- ☐ Airspeed 420 knots❶
- ☐ Instrumented resistance plug installed on both columns
- ☐ Hydraulic power L, C1, C2, R ACMPs ON

Notes

❶ Airspeed and/or trim to be adjusted to achieve the requried feel pressure. Stabilizer not to go less than 2 units of trim.

❷ If individual column forces are not available via ADAMS, manual force measurements will be taken using hand held force meters (fish scales) at the elevator surface positions and feel pressures indicated.

B1.39.1310 SPLIT ELEV - BASELINE FORCE EVAL

Risk	Cond No	Elev Feel Press (psi)	Airspeed (KCAS)	Impact Press (psf)	Operation
✓ L	.001	770	420	~165	Sweep the column from neutral to full forward, to neutral and then full aft. Conduct sweep for each column

B1.39.1310 SPLIT ELEV - SPLIT COLUMN

Risk	Cond No	Elev Feel Press (psi)	Airspeed (KCAS)	Impact Press (psf)	Operation
L	.100	770	420	~165	Engage the elevator system overrides by pulling the Captain's control column full aft while simultaneously pushing the First Officer's control column full forward. Reverse direction of deflection for each column. Repeat as requested.
L	.101❷	770	420	~165	Engage the elevator system overrides by pulling the Captain's control column aft to achieve a left elevator surface position of –3° (TEU) and pushing the 1st officer's control column forward to achieve a right elevator surface position +1° (TED). Repeat as requested.
L	.102❷	800	420	~175	Engage the elevator system overrides by pulling the Captain's control column aft to achieve a left elevator surface position of –1° (TEU) and pushing the 1st officer's control column forward to achieve a right elevator surface position +2° (TED). Repeat as requested.
L	.103❷	820	420	~175	Engage the elevator system overrides by pulling the Captain's control column aft to achieve a left elevator surface position of –4° (TEU) and pushing the 1st officer's control column forward to achieve a right elevator surface position +3° (TED). Repeat as requested.

RISK ALLEVIATION

None

```
TIMDIS          * * * * AIRPLANE AND TEST ITEM TIME * * * *
AIRPLANE VQ002             TEST TITLE 767 SPLIT ELEVATOR GROUND TEST
TEST NO  002-08  TEST DATE 12/08/99
START TIME 0001    FLT TIME 00+00    NO OF FLTS  0   TOTAL FLTS   16
F/STOP LDGS  0  T/GO LDGS  0  ACCUM FLT TIME    70+03  ACCUM GND TIME    55+00
ENGR TESTS 00+00     SPRT TESTS 00+00     C TRNG 00+00     GND TEST 03+00

TIME  SUFF   TI CODE                    TEST ITEM TITLE
03+00   G   B1.39.1310   767 SPLIT ELEVATOR GROUND TEST
```

P1   Press ENTER to continue ===>

767 - 400 ER
VQ 002
D6T11767-0769P

002-08-B1

VQ002
GROUND TEST ATTENDANCE RECORD

#	Name	Function (Company)	Mail Stop (Address)	Phone
1	GARY GROSS	FTEO	14-KA	655-1429
2	Dennis Asheim	Flight Controls	02-JU	294-7960
3	BILLY RICHARDSON	FLT CONTROLS	02-KE	294-7923
4	Charles Nalley	Instrumentation	14-MC	655-1214
5	RICK MILLER	INSTRUMENTATION	14-MC	655-3581
6	JEFF Nichols	INSTRUMENTATION	14-MC	655-9313
7	STAN ELKINS	INSTRUMENTATION	14-MC	655-4643
8	Nick Newhall	FTEA	14-KF	544-2104
9	Carey Binford	FTEO	14-KA	655-8602
10	John Stoetz	FA	17-89	544-3855
11	MARK WILSON	INSTRUMENTATION	14-MC	655-9314
12	PETE VAN LEYNSEELE	FLT CONTROLS	02-KE	342-3449
13	John T. Swenson	Perfor... FBI		(617) 742-5533
14	John P. Neff	FAA	64-01	227-2591
15	Paul A. Remington	FAA	64-01	227-1291
16	BILL TAFS	BOEING	14-HA	662-1816
17	Luke SCHIADA	NTSB		973-334-6561
18	John Schade	NTSB		202-314-6619
19	JOHN O'CALLAGHAN	NTSB		202-314-6560
20	Steve Brown	Boeing INSTR.	14-MC	(206) 655-9345
21	ALAN C. BRANTLEY	FBI		(540) 720-4902
22	CAPT. M. ELMISSIRY	E.C.A.A.	MOB	202 262 6637
23	EVAN BYRNE	NTSB HP		202-314-6352
24	Harold Simpson	NTSB/FAA		412 262 9034
25	MOHAMED HAMDY	EGYPTAIR		202 2672786
26	PD Weston	NTSB		(202) 314-6358
27	OTHMAN NOUR	ECAA		202-2665435
28	MAHER I. MOHAMED	ECAA		202-2665435

SHEET 1 OF 2	TITLE 767 Split Elevator GT	MODEL	767-432
[redacted]		AIRPLANE	VQ002
TEST NO. 002-08		DOC. NO.	D6T11767-0769P
DATE 12/ 8 /99	BOEING	PAGE	002-08- B2

VQ002
GROUND TEST ATTENDANCE RECORD

29	Rick Howes	Boeing ASI	67-PR	425 2378202
30	Robert S. Nelson	Boeing Aero	67-65	425 237 8066
31	JOHN CASMAN	FLT CREW OPS	14-HA	655-1400
32	TIM MAZZITELLI	S&C	67-65	425-965-5401
33				
34				
35				
36				
37				
38				
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56				

OMRDIARYDIS * DISPLAY DIARY ENTRY * 12/08/1999 21:03 TEOGAG

AIRPLANE NO: VQ002
TEST DATE: 12/08/1999
TEST NO: 002-08

FLT HRS:	0+00	GND HRS:	0+00	FLT QTY:	0
CUM:	70+03	CUM:	52+00	CUM:	16

PREFLIGHT: RELEASE:

TEST DESCRIPTION:
.INSTRUMENTATION UPDATES
.AIRPLANE UPDATES
.MAINTENANCE
.ELEVATOR SPLIT INVESTIGATION G.T.-B

.COMPLETED ELEVATOR SPLIT CONDITIONS WITH 8 DIFFERENT FLIGHT CREWS.

OMR01 VALID KEYS: ENTER(PROCESS), PF3/15(END), PF12/24(RETURN).
DOMRDIS PROD PAGE 01 OF 01

ABNORMAL EVENT SUMMARY

(include both planned and unplanned events)

AIRPLANE MODEL **767-432**	TAB # **VQ002**	TEST NUMBER **002 – 08**
TEST DIRECTOR **Gary Gross**	EVENT YES ☐ NO ☒	DATE **December 8, 1999**

STRUCTURES TOL EXCEEDANCES(Analysis focal:)

		IRIG			IRIG
______	Overweight Landing	______	______	High Alpha (>ss or ib)	______
______	Overweight Takeoff	______	______	Vmo/Mmo exceedance	______
______	Nz Exceedance	______	______	Vfc/Mfc exceedance	______
______	CALMS (>100%)	______	______	Vd/Md exceedance	______
______	Qβ exceedance	______	______	Vfe exceedance	______

OTHER EVENTS OF INTEREST TO STUCTURES

		IRIG			IRIG
______	Tail Strike	______	______	Lightning Strike	______
______	Unusual Vibration	______	______	Unusual Noise	______
______	High AVM Hard Landing (>6fps)	______	______	Turbulence > light	______
______	High Derotation (>6 deg/s)	______	______	RTO/Max Braking	______

PROPULSION (Analysis focal:)

		IRIG			IRIG
______	Engine Surge	______	______	Unplanned Shutdown	______
______	Engine Limit Exceedance	______	______	Unplanned EEC Mode Reversion	______

FLIGHT CONTROLS/NAV COM (Analysis focal:)

		IRIG			IRIG
______	Uplanned Control System Event	______	______	GPWC Warning	______

OTHER EVENTS

		IRIG	Description of event
______	Other	______	______

P = PLANNED EVENT U = UNPLANNED EVENT

#	#	H	M	S	No.	COMMENTS
1	1	13	18	28	0	START TAPE CHECKOUT
2	1	13	18	31	0	" " "
1	1	13	21	43	42678	STOP " "
2	1	13	21	43	42119	STOP " "
1	1	16	34	37	49679	START TAPE
2	1	16	34	40	49120	START TAPE
~~1~~	~~1~~	~~[illegible]~~	~~[illegible]~~			
1	1	20	15	44	3040733	Stop
2	1	20	15	45	3039892	Stop

SHEET 1 OF 1	TITLE:	MODEL 767-400
RECORDER		AIRPLANE VQ002 VQ 0
TEST NO. 002-08 STA INSTR	BOEING	DOC. No. D6T11767-07696
DATE 12/8/99		PAGE 002-08-C1

Z:\VQ002\Procedures & Checklists\FlightNotes2Decks.v

VIDEO LOG SHEET VQ002, 767-400

Test No: 002-08 Test Date: 12/8/99

Camera Definitions

Recorder #	Recorder Title	Comments
1	Upper EICAS (center)	
2	PFD (Pilot's Outbd)	
3	ND (Pilot's Inbd)	
4	Lower EICAS (center)	
5		
6		
7		
8		

Recorder #	Tape Set #	Start Time	Stop Time	Comments
1	1	17:26:20	192100	
2	1	17:26:20	↓	
3	1	17:26:20	↓	
4	1	17:26:20	↓	
1	2	19:22:00	20:16:30	
2	2	↓	20:16:30	
3	2	↓	20:16:30	
4	2	↓	20:16:30	
1	3			
2	3			
3	3			
4	3			
1	4			
2	4			
3	4			
4	4			

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VQ 002
D6T11767-0769P
002-08-C2

FILENAME: Z:\VQ002\Forms & Logsheets\Video Log Sheet VQ002 Standard.vsd

12/01/99

	QL VQ2PA	PAGE 1 OF 1	VQ002 PANELS LIST	UPPER-'F'-LOWER	SP COUNTS	
1	9800030	KNOTS	VC	500.0	0.0	
2	9800040	DIM	MACH NUMBER	1.0000	0.0000	
3	9853285	PSID	L SYS DELTA FEEL PRESS	1500.	0.	
4	9853286	PSID	C SYS DELTA FEEL PRESS	1500.	0.	
5	3060107	LBS	STICK FORCE PILOTS	155.2	-155.2	PP
6	3064204	LBS	ELEV STICK FORCE COPLTS	155.2	-155.2	PP
7	3060225	DEG	CONT COL POSPILOT (PROD)	12.50	-6.80	PP
8	3060226	DEG	CNTRL COLUMNPOS F/O PROD	10.22	-7.84	PP
	2222969	GPM	FUEL FLOW RATE E2	55.30	-.30	PP
	950100	E3 LB	GROSS WEIGHT FOR PANELS	2000.00	0.00	
	950201	PCT	COMPUTED CG SELECT FM	100.00	0.00	
	46017	G	NORMAL ACCELCG 1.5 FILTR	3.005	-1.005	PP
	2221964	GAL	E1 FLMTR A FUEL TOTLZER	10114.	-114.	PP
	2222964	GAL	E2 FLMTR A FUEL TOTLZER	10114.	-114.	PP
	2221701	PERCNT	N1ACTIND E1 GE80CFA1	256.0	-256.0	
	2222701	PERCNT	N1ACTIND E2 GE80CFA2	256.0	-256.0	
	2221702	PERCNT	N2 ACTSELE1 GE80CFA1	256.0	-256.0	
	2222702	PERCNT	N2 ACTSELE2 GE80CFA2	256.0	-256.0	
	7441008	PSI	E1 OIL PRESSDPCLH7 317	0.	0.	
	7441007	PSI	E2 OIL PRESSDPCLH7 317	0.	0.	

```
UML.POS#.'P#'.(DN).(UP).(INCR).(DECR),                              VQ2PA
QL,
          ---MESSAGES---
          MT:STARTING RECORDER #2...
          MT:STARTING RECORDER #1...
          MI:STARTING RECORDER #4...
          MI:STARTING RECORDER #3...
          MI:USING RECORDERS: #3 #4

CPU:FSA  84  APA  91  APM  73  43 100 100  DISK:FSA  80   VERSION:v3.32c
 \  W/S  86  APA  97  APM  87 100  86 100         W/S
             AIA  97  DPU  88  99          MNDB  95
4 GC    COMP *VQ2 204 MT   VQ21,VQ22 1004 MI   VQ21,VQ22 1004 QL    VQ22A     0
1 QL    600       1
```

9 L ELEV
10 R ELEV

767 - 400 ER
VQ 002
D6T11767-0769P
002-08-C3

EgyptAir 990 Simulation Demonstration Schedule
at The Boeing Company, Seattle, WA, December 8, 1999
(10:00 PST)

Simulator Group #1: (10:00 - 10:40)

Name	Organization	Pilot #
Capt. PD Weston	NTSB	5
Capt. Bill Tafs	Boeing	7
Capt. Mohsen El Missiry	ECAA	10
Capt. Othman Nour	ECAA	12

Simulator Group #2: (10:40 - 11:20)

Name	Organization	Pilot #
Capt. Harold Simpson	FAA	6
Capt. Paul Remington	FAA	11
Mohamed A. Hamid Hamdy	EgyptAir	3
Maher Ismaiel Mohomed	ECAA	4

Simulator Group #3: (11:20 - 12:00)

Name	Organization	Pilot #
John Neff	FAA	9
John Swanson	FBI	13
Alan Brantly	FBI	14
Luke Schiada	NTSB	8
JOHN O'Callaghan	NTSB	1
EVAN Byrne	NTSB	2

PAUL R. → STAB CHG

JOHN SCHADE	NTSB	15
TIM MAZZITELLI	S+C	16

767 - 400 ER
VQ 002
D6T11767-0769P

~~Greg Phillips~~

002-08-C4

FLIGHT NOTES SHEET

Write clearly and assure good contrast for reproduction!

TIME	COND.							'CAPT	F/O
1630xx		APU START							
3430		DATA TAPES ON							
172120		COLUMN PULL TO CHECK INSTR. — F/O							
24xx		" PUSH " " "							
25xx		COLUMN FORCE CHECKS — CAPT							
27xx		A/P RELEASE							
2855		FLT DATA RECORDER — ON							
		SAFT — USING AMBIENT FOR ALL STATIC PORTS							
30xx	.001	FISH SCALE COMPARES TO PULL AT TOP OF CONTROL WHEEL							
		NOT AS ACCURATE AT BASE OF CONTROL WHEEL —							
		SCALES READ HIGHER THAN INSTR.							
		STAB 3 UNITS							
40xx		250K		AUX	190K		L FEEL	C FEEL	FEEL COMP
44xx		300K	.	"	260K		289	132	550
5010		350K	334 IND	"	300K		404	187	585
5145		400K	382 "	"	350K		542	253	629
5345		420K	402 "	"	380K		603	283	655
5400		STAB 2.9 UNITS							
5600		CAPT FULL SWEEP							
5630		F/O " "							
5720		SPLIT — F/O FWD / CAPT FULL							
5745		" — CAPT FWD / F/O PULL							
5900	—								
		DIFF FEEL = 770 psi							
1910	.100	PULL / PUSH						5	7
1925		NEUTRAL							
2059	.100A	PULL / PUSH							
2115		NEUTRAL							
2430	.101	PULL -3 / PUSH +1							
2445	—								
2544	.102	PULL -1 / PUSH +2							
2605	—								
2650	.103	PULL -4 / PUSH +3							
2715	—								
2804	.100B	PULL / PUSH							
2825	—								

C = Comment **D** = Delay **E** = Exceedance **F** = Flight Deck Effect **P** = Problem

Sheet 1 of 5 | Title: **767 Split Elevator GT** | Model: **767-432**

Recorder [redacted] | Airplane: **VQ002**

Test No. **002-08** Sta. TD | Doc. No. **D6T11767-0769P**

Date **December 8, 1999** | BOEING | Page **002 - 08 - C5**

FLIGHT NOTES SHEET

Write clearly and assure good contrast for reproduction!

TIME	COND.		CAPT	F/O
183150	.200	PUSH/PULL	10	12
3210	~			
3320	.201	PULL -3 / PUSH +1		
3345	~			
3422	.202	PULL -1 / PUSH +2		
3445	—			
3541	.203	PULL -4 / PUSH +3		
3605	~			
3904	.300	PULL/PUSH	6	11
3917	—			
4018	.301	PULL -3 / PUSH +1		
4055	~			
4135	.302	PULL -1 / PUSH +2		
4156	—			
4252	.303	PULL -4 / PUSH +3		
4319	—			
4430	.304	PUSH +3 (SITTING)		
4520	~	PULL -6 (STANDING)		
5000	.400	PULL/PUSH	4	3
5030	—			
5138	.401	PULL -3 / PUSH +1		
5204	—			
5313	.402	PULL -1 / PUSH +2		
5349	—			
5419	.403	PULL -4 / PUSH +3		
5446	—			
5759	.500	PULL/PUSH	13	9
5817	—			
5927	.500A	CAPT NEUTRAL		
5930		F/O FWD		
5933		" NEUTRAL		
5936		" AFT		
5939		NEUTRAL		
190117	.501	PULL -3 / PUSH +1		
0140	—			

C = Comment **D** = Delay **E** = Exceedance **F** = Flight Deck Effect **P** = Problem

Sheet 2 of 5	Title: 767 Split Elevator GT	Model	767-432
Recorder [redacted]		Airplane	VQ002
Test No. 002-08 Sta. TD		Doc. No.	D6T11767-0769P
Date December 8, 1999	BOEING®	Page	002 - 08 - C 6

FLIGHT NOTES SHEET

Write clearly and assure good contrast for reproduction!

TIME	COND.							CAPT	F/O
190206	.502	PULL	-1 / PUSH +2						
0231	—								
0336	.503	PULL	-4 / PUSH +3						
0405	—								
0520	.504	F/O	PUSH +5	(SITTING)					
0538		CAPT	PULL -13	(STANDING)					
0609	—								
1010	.600	[illegible] /	PULL / PUSH					8	14
1035	—								
1142	.601	PULL	-3 / PUSH +1						
1207	—								
1230	.602	PULL	-1 / PUSH +2						
1320	—								
1345	.603	PULL	-4 / PUSH +3						
1405	—	[illegible]							
1500	.600A	PUSH	/ PULL	(FULL)					
1520	—								
1700	.604	CAPT	NEUT.						
1705		F/O	FWD						
1710		"	NEU						
1712		F/O	AFT						
1730	—								
1837	.604A	F/O	NEUTRAL						
1838		CAPT	FWD						
1909		"	AFT						
1915	—								
2235	.700	PULL	/ PUSH					15	16
2254	—								
2330	.700A	PUSH	/ PULL	(FULL)					
2350	—								
2424	.701	PULL	-3 / PUSH +1						
2452	—								
2525	.702	PULL	-1 / PUSH +2						
2550	—								
2622	.703	PULL	-4 / PUSH +3						
2644	—								

C = Comment **D** = Delay **E** = Exceedance **F** = Flight Deck Effect **P** = Problem

Sheet 3 of 5	Title: 767 Split Elevator GT	Model	767-432
Recorder [redacted]		Airplane	VQ002
Test No. 002-08 Sta. TD		Doc. No.	D6T11767-0769P
Date December 8, 1999	BOEING®	Page	002 - 08 - C 7

FLIGHT NOTES SHEET

Write clearly and assure good contrast for reproduction!

TIME	COND.							CAPT	F/O
193842	.305	F/O	PUSH					11	CASHMAN
3849		CAPT	PULL –	ADJ STAB	TRIM –	SWITCHES	THEN	ALTN	
3900		F/O + CAPT –		PULL –	ADJ				
3912	—								
4000	.306	C – A/P ON							
4010		CAPT	L/R	WHEEL	SWEEP				
4030		CAPT	FWD /	AFT	COLUMN				
4045		F/O	L/R	WHEEL		'AUTOPILOT'			
4120		FWD	(F/O) - FULL						
4200	—								
		L FEEL – 784			C FEEL – 776				
4715	.008	40	(FISH SCALE)		36	(INST)		1	2
4725	—								
5127	.800	CAPT	FULL	AFT					
		F/O	SWEEP	(COLUMN)					
5143		CAPT	MID	AFT					
		F/O	SWEEP						
5155		CAPT	NEUTRAL						
		F/O	SWEEP						
5201		CAPT	MID	FWD					
		F/O	SWEEP						
5210		CAPT	FULL	FWD					
		F/O	SWEEP						
5220	—								
5318	.800A	F/O	FULL	AFT					
		CAPT	SWEEP						
5333		F/O	MID	AFT					
		CAPT	SWEEP						
5345		F/O	NEUTRAL						
		CAPT	SWEEP						
5351		F/O	MID	FWD					
		CAPT	SWEEP						
5405		F/O	FULL	FWD					
		CAPT	SWEEP						
5430	—								
56xx		ADJ	STAB FOR 820 FEEL						
		STAB – 2.67							
		L – 820		C – 815					

C = Comment **D** = Delay **E** = Exceedance **F** = Flight Deck Effect **P** = Problem

Sheet 4 of 5		Title: 767 Split Elevator GT	Model	767-432
Recorder	[redacted]		Airplane	VQ002
Test No.	002-08 Sta. 71D		Doc. No.	D6T11767-0769P
Date	December 8, 1999	BOEING	Page	002 - 08 - C 8

FLIGHT NOTES SHEET

Write clearly and assure good contrast for reproduction!

TIME	COND.								
195808	.803	CAPT	FULL	AFT					
		F/O	SWEEP						
5821		CAPT	MID	AFT					
		F/O	SWEEP						
5834		CAPT	NEUTRAL						
		F/O	SWEEP						
5852		CAPT	MID	FWD					
		F/O	SWEEP						
5900		CAPT	FULL	FWD					
		F/O	SWEEP						
5911	—								
5944	.803A	F/O	FULL	AFT					
		CAPT	SWEEP						
200005		F/O	MID	AFT					
		CAPT	SWEEP						
0019		F/O	NEUTRAL						
		CAPT	SWEEP						
0040		F/O	MID	FWD					
		CAPT	SWEEP						
0056		F/O	FULL	FWD					
		CAPT	SWEEP						
0114	—								
0253	.803B	PULL	-4 / PUSH +3						
0327	—								
0630	.804	CAPT	PULL /	F/O PUSH					
0635		CAPT	-TRIM	NU					
0640		F/O	-TRIM	ND					
0649	—								
0837	.805	C -	A/P ON		HDG SEL		HDG HOLD		
0851		CHANGE HEADING							
0914		C/W	L		'AUTOPILOT'				
0939		A/P	DISC						
1000		L/C/R - A/P	ON						
1013		C/W	-R		'AUTOPILOT'				
1030	—								
1100		A/P SET - DISENGAGE W/ PULL BAR							
1200		TESTING COMPLETE							
1500		SAFT - A/S 0							
1530		APU	OFF						

C = Comment **D** = Delay **E** = Exceedance **F** = Flight Deck Effect **P** = Problem

Sheet 5 of 5	Title: 767 Split Elevator GT	Model	767-432
Recorder [redacted]		Airplane	VQ002
Test No. 002-08 Sta. 70		Doc. No.	D6T11767-0769P
Date December 8, 1999	BOEING	Page	002 - 08 - C9

FLIGHT NOTES SHEET

Write clearly and assure good contrast for reproduction!

TIME	COND.	
172857	FDR	ON
4037	250 kts	~~[illegible]~~ 532 Lsyst
	300 kts	548 psi L 566 psi C
	350 kts	584 psi L ~~[illegible]~~ 599 C
	420 kts	654 psi L 666 psi C
	420 kts	stab @ 2.8 units 775 psi
5551	001	pilot column first Cashman (Dry run checkout)
5717	split	
5817	—	Stab @ 2.8 units
181910	100	5 left 7 right ← participants for all cond
1957	—	
2057	100A	
2127	—	
2429	101	5 left 7 right
2450	—	
2542	102	5 left 7 right Done @ 770 feel
2607	—	for x02 & x03
2647	103	5 left 7 right
2716	—	
2807	100B	5 left 7 right
2828	—	
	~~300~~	~~left~~ Participants 10 & 12
3145	200	10 left 12 right
3213	—	
3316	201	10 left 12 right
3347	—	↓ ↓
3419	202	
3445	—	
3540	203	
3608	—	
		Participants 6 & 11
3900	300	6 left 11 right
3919	—	↓ ↓
4015	301	
4057	—	
4133	302	
4158	—	
4250	303	
4321	—	

~~C = Comment~~ D = Delay E = Exceedance F = Flight Deck Effect P = Problem

Sheet 1 of 4	Title Egypt Air Split Elev. Invest	Model 767-400ER
Recorder [redacted]		Airplane VQ002
Test No. 002-08 Sta.		Doc. No. D6T11767-0769P
Date 12/8/99	BOEING	Page 002-08-C10

VQ001_notes (Rev. 03/95)

FLIGHT NOTES SHEET

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TIME	COND.	
4430	304	Capt standing pulling F/O pushing seated
4520	—	F/O pushing first
		Participant 3+4
4958	400	4 left 3 right
5032	—	↓ ↓
5136	401	
5205	—	
5310	402	
5349	—	
5416	403	
5448	—	↓ ↓
		Participant 9+13
5757	500	13 left 9 right
5818	—	
190024	500A	captain hold @ neutral F/O Forw → neutral → Aft → neut
0042	—	looking for breakout
0114	501	
0142	—	
0204	502	
0233	—	
0335	503	
0407	—	
0517	504	Capt standing pulling F/O pushing seated first
0539	captain pulling	
0612	—	
		Participants 8+14
1008	600	8 left 14 right
1036	—	
1140	601	
1209	—	
1228	602	
1323	—	
1342	603	
1408	—	
1458	600A	Capt push F/O pull
1523	—	

C = Comment D = Delay E = Exceedance F = Flight Deck Effect P = Problem

Sheet 2 of 4	Title EgyptAir Split Elev. Invest	Model 767-400ER
Recorder [redacted]		Airplane VQ002
Test No. 002-08 Sta.		Doc. No. D6T11767-0769P
Date 12/8/99	BOEING	Page 002-08-C-11

VQ001_notes (Rev. 03/95)

FLIGHT NOTES SHEET

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TIME	COND.	
191658	604	Capt hold neutral F/O push to breakout → neutral → aft
1730	—	
1848	604A	Reverse controls F/O hold neutral
1919	—	Capt push to breakout → neutral → aft
		Participants ~~1 & 2~~ 15 + 16
2232	700	15 left 16 right
2256	—	1'
2328	700A	opposite direction
2353	—	
2423	701	
2455	—	
2523	702	
2556	—	
2620	703	
2646	—	
		~~Participants 1 + 2~~
3858	305	P. Remmington left J. Cashman right
		Pilot trimming stab in direction of column (pull)
		F/O push Pilot pull adjust stab F/O will then
3913	~~39~~ —	pull and adjust
40~~15~~45	306	C A/P ON Captain left whl
4046		F/O left whl then right whl
4128		full forward F/O
4208	—	F/O whl pos. not instrumented
		Participants 1 + 2
4630	~~300~~ 008	1 left 2 right
4715	—	capt check force w/scale
~~4933~~		
5124	800	Captain 5 stages full aft, mid aft neutral, mid fwd, full fwd
5224	—	F/O just the opposite cycling
5315	800A	repeat switching direction capt. cycling
5433	—	
5808	803	Stab 2.67 units 820 psi Feel pressure
5914	—	repeating 800 sweeps
5939	803A	repeating 800A sweeps
200118	—	

C = Comment D = Delay E = Exceedance F = Flight Deck Effect P = Problem

Sheet 3 of 4	Title Egypt Air Split Elev Invest	Model 767-400ER
Recorder [redacted]		Airplane VQ002
Test No. 002-08 Sta.		Doc. No. D6T11767-0769P
Date 12/08/99	BOEING	Page 002-08-C12

VQ001_notes (Rev. 03/95)

FLIGHT NOTES SHEET

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TIME	COND.	
200250	803B	Condition done as written 820 psi feel press
0332	—	
0626	804	Captain pull F/O push then Capt trim Nose up
0652	—	then F/O trim Nose down
0837	805	C A/P adjust control wheel 820 psi feel press
0918		Capt ctrl whl left
0939		A/P disconnect
1010		All 3 A/P ctrl whl right
1031		whl neutral
1040	—	
		Test Done

C = Comment D = Delay E = Exceedance F = Flight Deck Effect P = Problem

Sheet 4 of 4	Title Egypt Air Split Elev Inves	Model 767-400ER
Recorder [redacted]		Airplane VQ002
Test No. 002-04 Sta.		Doc. No. D6T11767-0769P
Date 12/08/99	BOEING	Page 002-08-C13

VQ001_notes (Rev. 03/95)

APPENDIX C

Boeing Presentation on Simulator Methods and Limitations
March 2000

EgyptAir Flight 990 Accident Investigation
Simulation of FDR Data with Split Elevators + Data Derived from Radar
Boeing Airplane Simulation Lab (ASL) March 30-31, 2000

- Introduction and Agenda
- Simulations:
  - Background Simulations
  - Backdrive Simulations on the 767E- Cab – With and Without Pilot Interaction
    - Human Performance Synchronized CVR/FDR Closed Sessions
    - Human Performance Open Sessions
    - Performance and Operations Group Sessions
- Important Details of these 767E- Cab Simulation Sessions
- Limitations of the 767E- Cab Simulations
- Additional Items of Note

Background Simulations

- Purpose:
  - Determine the control inputs required to drive the event
    - Develop a match of the FDR data through the elevator split plus the radar data (through climb to 24,000 feet)
    - Validate an adjusted aerodynamic database
- Run on engineering workstation – no cab or pilot in the loop
- Simulation initially trimmed at 33,000 feet, Mach = .79, Gross Weight = 390,000 pounds, and CG = 23.3% mac.

Background Simulations (continued)

- Simulation – Longitudinal

  - For FDR time 1235 to 1265 (Mach = .91) the control column with equal left and right elevator angles is driven to match the FDR pitch angle.

  - For FDR time 1265 to 1290 (end of FDR data) the simulation is driven by the FDR left and right elevator angles including the split. A small increment in pitching moment coefficient is applied above Mach = .91 to retain a good match with the FDR pitch angle. The flight path angle and normal load factor show good agreement through out the FDR data.

  - Beyond FDR time 1290 the control column (equal left and right elevator angles) is driven to match the pitch angle derived from radar data.

- Simulation – Lateral/Directional

  - For FDR time 1235 to 1290 (end of FDR data) the wheel and rudder pedals are driven to match FDR roll and heading angles.

  - Beyond FDR time 1290 the wheel and rudder pedals are driven to match the roll and heading angles derived from radar data.

Background Simulations: General Information

- For FDR time 1235 to 1290:
  - Throttle starts at the initial simulator trim point. Its movement to idle and the fuel cut are based on FDR timing.
  - Speedbrake handle is driven by FDR data.
  - Stabilizer position follows the FDR data from the initial simulator trim point.
- Beyond FDR time 1290:
  - Engines are assumed to be shut down.
  - Three hydraulic systems and the primary flight controls remain functional until the airspeed decreases below 110 knots.
  - Speedbrake handle remains deployed.
  - Stabilizer position remains constant holding the last FDR value.

Backdrive "Split Elevator" Simulations (Simulator Scenarios 1 & 2)

- Purpose:
  - Provide a replay of the flight deck instruments and controls during the event with and without the CVR ***(No pilot interaction)***.
  - Experience the timing of events, control force levels with split elevators, and sounds on the flight deck.
- Flight deck controls driven with FDR data.
  - Throttles
  - Speedbrakes
  - Engine cut logic
- Flight deck controls driven with data derived from the Background Simulation.
  - Control wheel
  - Rudder pedals
  - Right control column (Scenario 1) or Left control column (Scenario 2)

Backdrive "Split Elevator" Simulations with Pilot Interaction (Simulator Scenarios 3 & 4)

- Purpose:
  - Allow the pilot to take control of the aircraft during the elevator split and experience the workload and control forces required. The pilot is able to control the column, wheel, and stabilizer. To achieve this interaction the pilot must apply a column force that exceeds 20 pounds.

- Elevator Split Cues:
  - Approximately FDR time 1275 seconds
  - Indication of Engine Cut

- Scenario 3**:** The pilot flying pulls left column

- Scenario 4**:** The pilot flying pushes right column

Important Details of these 767E- Cab Simulation Sessions

- The cab area contains a mockup of the aft bulkhead of the flight deck including the entry door, adjoining lavatory, and the passage way between them. Two jump seats are also located at the rear of the flight deck.
- Data will be recorded and a time history of each run will be kept.
- The backdrive simulations (all 4 Scenarios) continue through the climb to an altitude of 24,000 feet.
- The simulation beyond the climb to 24,000 feet has not been verified.
- The backdrive simulations with pilot interaction (Scenarios 3 and 4) are designed for the pilot to take control during the elevator split.
- Aerodynamic database extended from Mach = .91 to Mach = .98.
- Computer generated instruments are displayed on the windscreen (elapsed and FDR time, normal load factor, engine off lights, left and right elevator angles, left and right computed column forces, and the column force for the pilot flying).

Important Details of these 767E- Cab Simulation Sessions (continued)

- For FDR time 1235 to 1265 the left and right computed column forces are based on an average of the recorded left and right FDR elevator angles. For FDR time 1265 to 1290 they are based on their respective FDR elevator angles.
- The simulation backdrive may be started at any arbitrary time between FDR time 1235 and 1330.

Limitations of the 767E- Cab Simulations

- The cab is fixed base. Motion is not available.
- The visual landscape is featureless land with a visible horizon.
- No Mach or stall buffet is modeled.
- Certain status messages are displayed erroneously on EICAS.
- No metric displays for fuel quantity and fuel flow.
- No thrust reverser isolation lights.
- No stand-by compass.
- The mode control panel is different than the EgyptAir configuration (no Control Wheel Steering).
- Wind and engine noise are not modeled.
- Single control loader. Control columns move symmetrically.

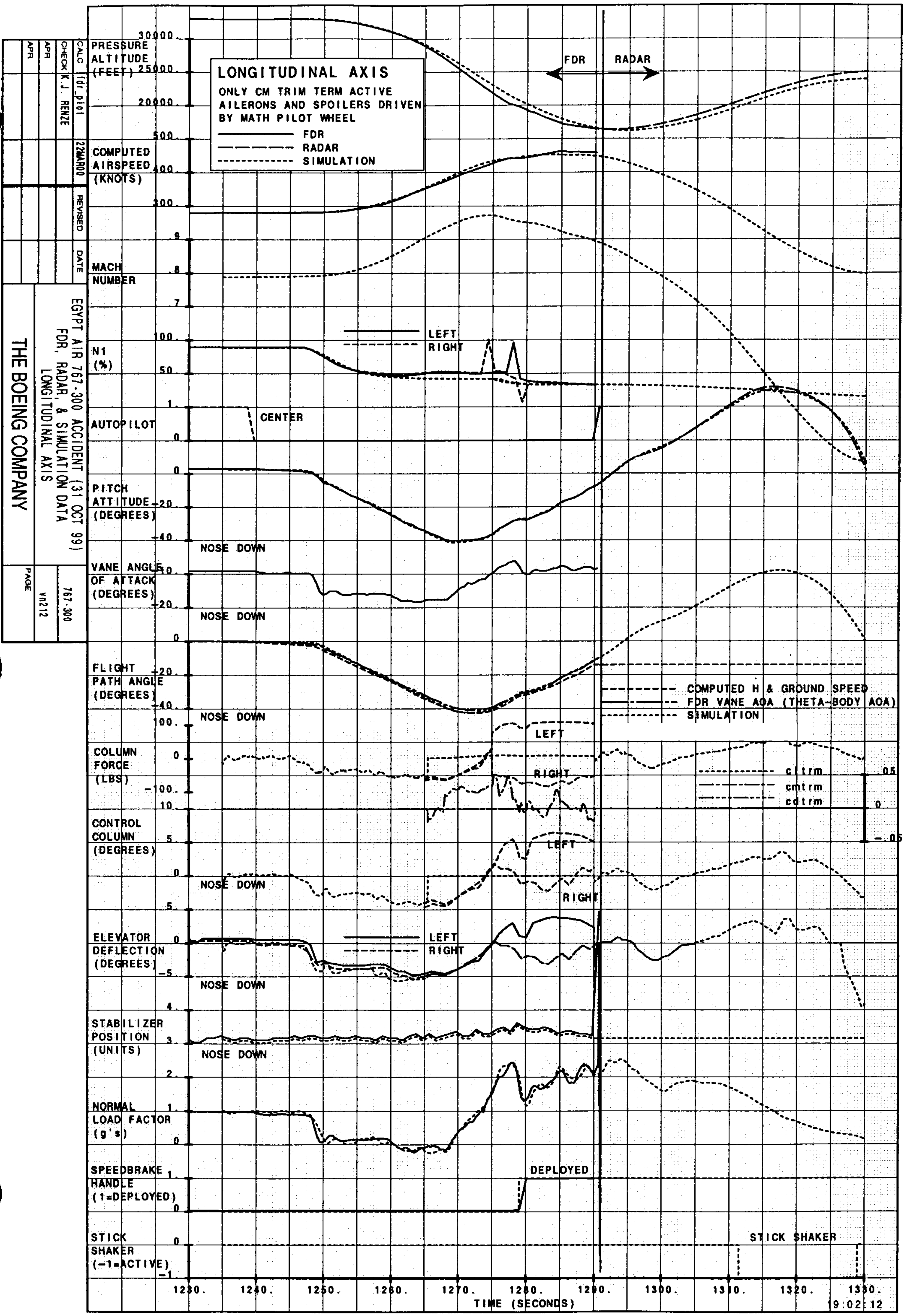
Limitations of the 767E- Cab Simulations (continued)

- No hydraulic decay model or elevator blowdown model that simulates the loss of hydraulic pressure and maximum elevator capability as airspeed decreases with windmilling engines.
- The asymmetry and un-steady aerodynamics of stalls are not accurately represented.
- The low oil pressure light does not illuminate, nor does the caution alert (beeper) function during the low oil operation noted on the FDR.
- The auto-throttle rate of the cab throttle handles is limited to the autopilot rate (around 10 degrees/second), but the engine parameters respond to FDR throttle and fuel cut timing.
- Prior to starting the simulation the speedbrakes must be armed manually.

Additional Items of Note

- A "chase-plane view" of the airplane and a duplication of the windscreen display will be presented on separate monitors in the cab area.
- The FDR airspeed and altitude are derived from the airplane's Air Data Computer (ADC). The calibration of the ADC has not been verified for speeds above MD/VD (.91/420 knots).
- Electrical stabilizer trim using the pickle switches on the wheel is not available after the fuel cuts.
- The column cut-out switches do not inhibit stabilizer trim when the columns are split (one forward and the other aft).

- ***Please keep hands and feet free of simulator controls prior to re-initialization ("IC")***



CALC fdr_pilot 22MAR00
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EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LONGITUDINAL AXIS
THE BOEING COMPANY
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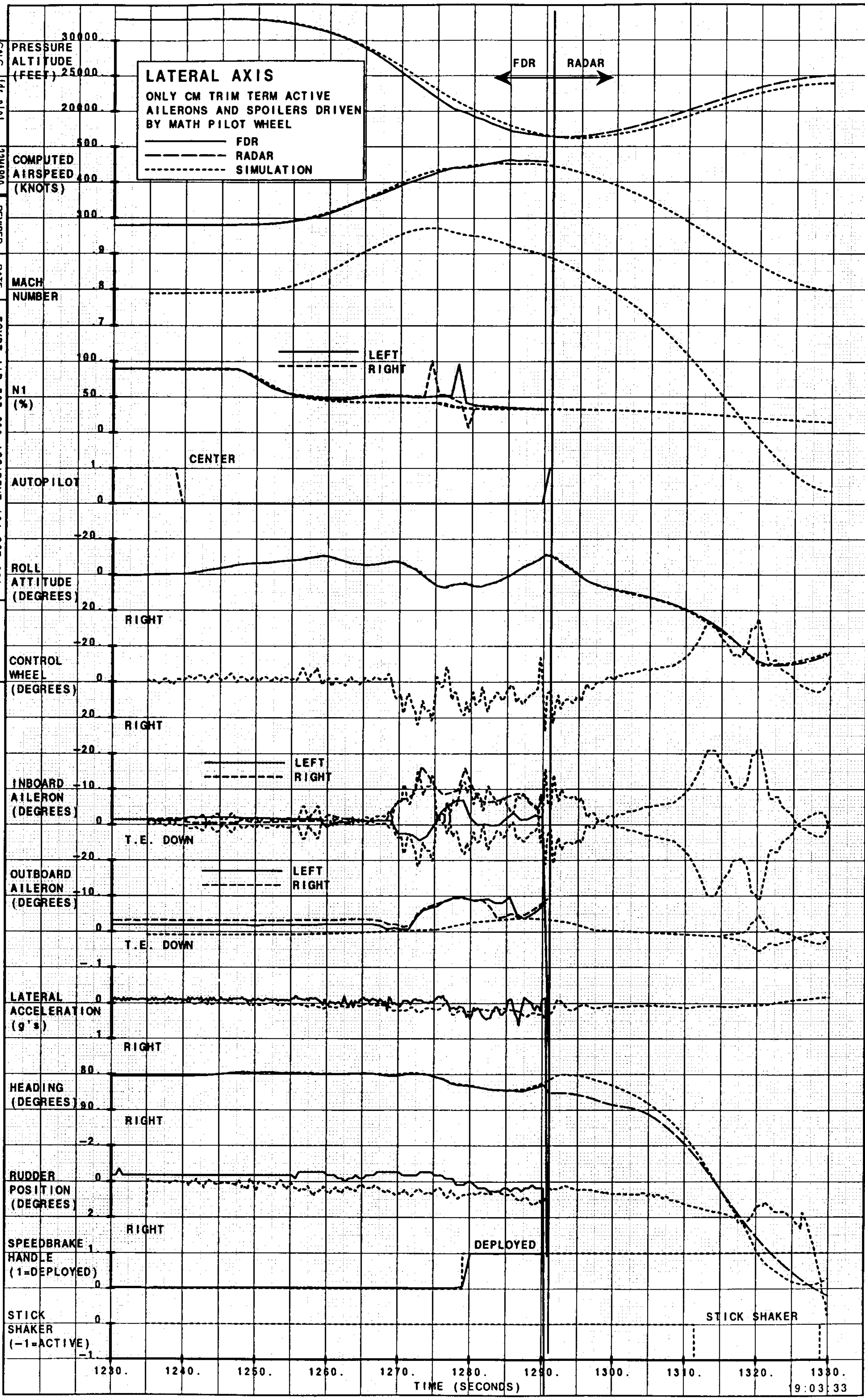
LONGITUDINAL AXIS
ONLY CM TRIM TERM ACTIVE
AILERONS AND SPOILERS DRIVEN BY MATH PILOT WHEEL
FDR
RADAR
SIMULATION
FDR
RADAR
PRESSURE ALTITUDE (FEET)
30000.
25000.
20000.
COMPUTED AIRSPEED (KNOTS)
500.
400.
300.
MACH NUMBER
.9
.8
.7
N1 (%)
100.
50.
LEFT
RIGHT
AUTOPILOT
1.
0.
CENTER
PITCH ATTITUDE (DEGREES)
0.
-20.
-40.
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
10.
-20.
NOSE DOWN
FLIGHT PATH ANGLE (DEGREES)
0.
-20.
-40.
COMPUTED H & GROUND SPEED
FDR VANE AOA (THETA-BODY AOA)
SIMULATION
NOSE DOWN
COLUMN FORCE (LBS)
100.
0.
-100.
LEFT
RIGHT
cltrm
cmtrm
cdtrm
.05
0
-.05
CONTROL COLUMN (DEGREES)
10.
5.
0.
LEFT
RIGHT
NOSE DOWN
ELEVATOR DEFLECTION (DEGREES)
5.
0.
-5.
LEFT
RIGHT
NOSE DOWN
STABILIZER POSITION (UNITS)
4.
3.
NOSE DOWN
NORMAL LOAD FACTOR (g's)
2.
1.
0.
SPEEDBRAKE HANDLE (1=DEPLOYED)
1.
0.
DEPLOYED
STICK SHAKER (-1=ACTIVE)
0.
-1.
STICK SHAKER
1230.
1240.
1250.
1260.
1270.
1280.
1290.
1300.
1310.
1320.
1330.
TIME (SECONDS)
19:02:12



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EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & SIMULATION DATA
LATERAL-DIRECTIONAL AXIS

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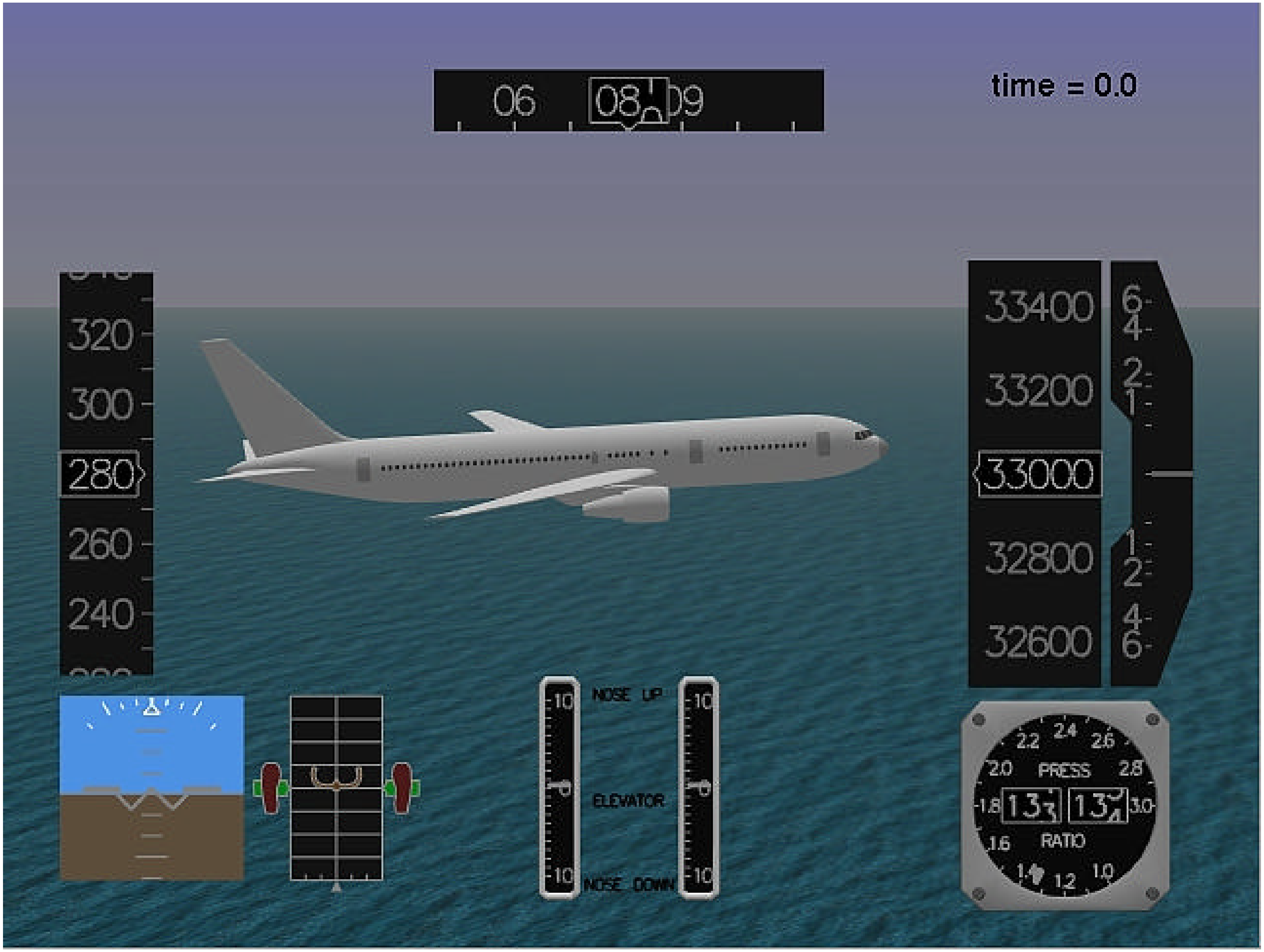
PAGE


ELAPSED TIME
96.9
FDR TIME
1331.8
ENGINES
OFF
OFF
LEFT
RIGHT
NOSE UP
ELEV SPLIT
NOSE DOWN
LEFT
RIGHT
NORMAL LOAD FACTOR
STICK FORCE
LEFT COMPUTED
FLYING PILOT
RIGHT COMPUTED


time = 0.0
06
08
09
320
300
280
260
240
33400
33200
33000
32800
32600
NOSE UP
ELEVATOR
NOSE DOWN
PRESS
RATIO

APPENDIX D

Boeing's additions to the March 2000 "cab limitations" presentation

2) Boeing's additions to the March 2000 "cab limitations" presentation:

Review of the March 2000 Performance Group E-Cab simulation data revealed two anomalies (i.e., an offset and a discontinuity) with respect to piloted elevator response. We identified the error sources in the flight controls model and implemented a fix. The elevator offset error was caused by an inconsistent gain between the E-Cab control forces and the corresponding elevator command. The elevator discontinuity was caused by a bookkeeping error between the aft pogo breakout force contribution to cable stretch, the aft quadrant column position, and the feel unit force.

Scenarios 3 and 4 from the March 2000 demonstration were repeated by Boeing's Operation Group member, Bill Tafs, in June 2000. The E-Cab simulation data recorded in June 2000 are presented below for comparison to the baseline March E-Cab data.

2a. March 2000 E-Cab performance demonstration, Case 25.06, longitudinal plot [Figure D-1].
Purpose: illustrate elevator offset anomaly

In this case, the flying pilot targets the computed push force during the FDR elevator split time period (i.e., 1275 < time < 1290). No significant control column inputs are made prior to or subsequent to the split, as evidenced by the E-Cab simulator column force time history. From time 1275 to 1290, the flying pilot pushes right elevator while the simulator flies the left elevator pull. At time 1290, when the flying pilot releases the column, the left and right E-Cab simulation elevators should converge on the left elevator time history, but a nearly constant 1.5 degree elevator offset remains.

2b. June 2000 E-Cab elevator offset anomaly check, Case 31.06, longitudinal plot [Figure D-2].
Purpose: verify fix to elevator offset anomaly

Similar to Item 2a, the flying pilot targets the computed push force during the FDR elevator split time period (i.e., 1275 < time < 1290). No significant control column inputs are made prior to or subsequent to the split, as evidenced by the E-Cab simulator column force time history. From time 1275 to 1290, the flying pilot pushes right elevator while the simulator flies the left elevator pull. At time 1290, when the flying pilot releases the column, the left and right E-Cab simulation elevators converge on the left elevator time history, as expected. The difference between left and right elevator position from time 1317 to 1324 is due to the fact that the E-Cab simulation enforces stick nudger for the right elevator, but the left elevator continues to be driven by background simulation data, which does not incorporate the stick nudger model.

Note: Items 2a and 2b illustrate the March E-Cab elevator offset problem and resolution for the case in which the flying pilot controls the right elevator only during the FDR elevator split time frame. Parallel results exist for the case in which the flying pilot controls the left elevator only during the FDR elevator split time period. That is, the March 2000 results include the elevator offset anomaly for Scenarios 3 and 4. The elevator offset anomaly has been resolved in the June 2000 E-Cab simulation data for Scenarios 3 and 4.

2c. March 2000 E-Cab performance demonstration, Case 25.09, longitudinal plot [Figure D-3].
Purpose: illustrate elevator discontinuity anomaly

In this case, the flying pilot targets the computed pull force during the FDR elevator split time period (i.e., 1275 < time < 1290). No significant control column inputs are made prior to the split, but the pilot continues to fly the airplane after time 1290, as evidenced by the E-Cab simulator column force time history. From time 1275 to 1290, the flying pilot pulls left elevator while the simulator flies the right elevator push. At time 1303 the flying pilot pushes the column aggressively. The corresponding control column force, column position, left elevator, and normal load factor time history indicate a rapid airplane nose down response. However, at time 1313 in the apparent absence of any significant control column force or position change, the left elevator position moves rapidly in an airplane nose up direction, causing a measurable increase in normal load factor.

2d. June 2000 E-Cab elevator discontinuity anomaly check, Case 31.07, longitudinal plot [Figure D-4].
Purpose: verify fix to elevator discontinuity anomaly

Similar to Item 2c, the flying pilot targets the computed pull force during the FDR elevator split time period (i.e., $1275 < time < 1290$). No significant control column inputs are made prior to the split, but the pilot continues to fly the airplane after time 1290, as evidenced by the E-Cab simulator column force time history. From time 1275 to 1290, the flying pilot pulls left elevator while the simulator flies the right elevator push. In this case the flying pilot pushes the column aggressively at time 1290. The control column force, column position, left elevator, and normal load factor time history indicate a rapid airplane nose down response. In fact, the control column position, left elevator, and normal load factor respond to control column force inputs throughout the airplane recovery, as expected.

Note: Items 2c and 2d illustrate the March E-Cab elevator discontinuity problem and resolution for the case in which the flying pilot controls the left elevator during and after the FDR elevator split time frame. Parallel results exist for the case in which the flying pilot controls the right elevator during and after the FDR elevator split time period. That is, the March 2000 results include the elevator discontinuity anomaly for Scenarios 3 and 4. The elevator discontinuity anomaly has been resolved in the June 2000 E-Cab simulation data for Scenarios 3 and 4.

The March 2000 E-Cab simulation elevator offset and elevator discontinuity errors impact the E-Cab elevator position and the resulting flight profile for Scenarios 3 and 4. However, the computed control column forces required to match the DFDR split elevator position are not affected. Therefore, the Human Factors control column force demonstration is valid. There is no impact from these two E-Cab simulation elevator limitations on the March 2000 Systems Group demonstrations.

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EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & CAB SIMULATION DATA
LONGITUDINAL AXIS #25.06

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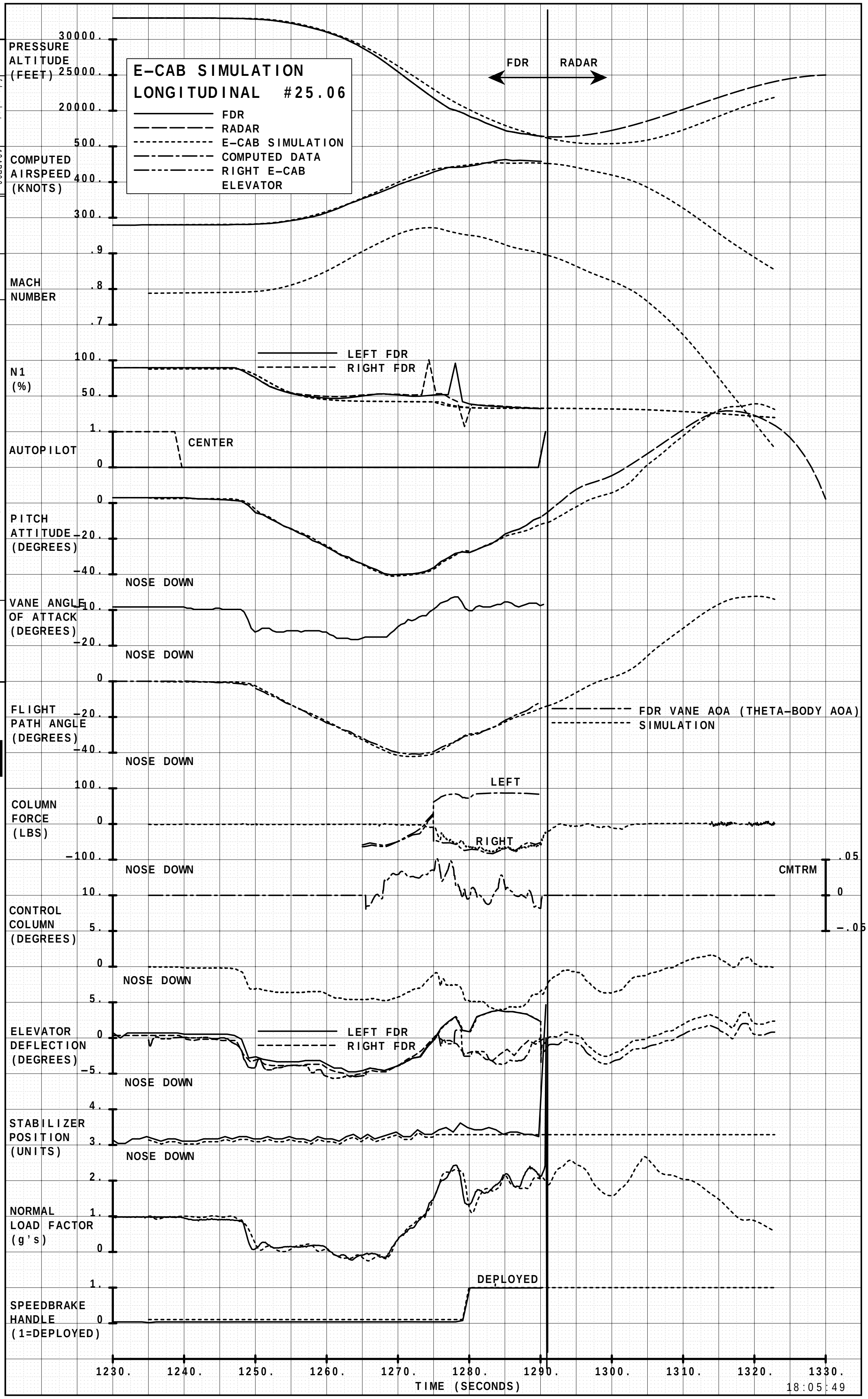
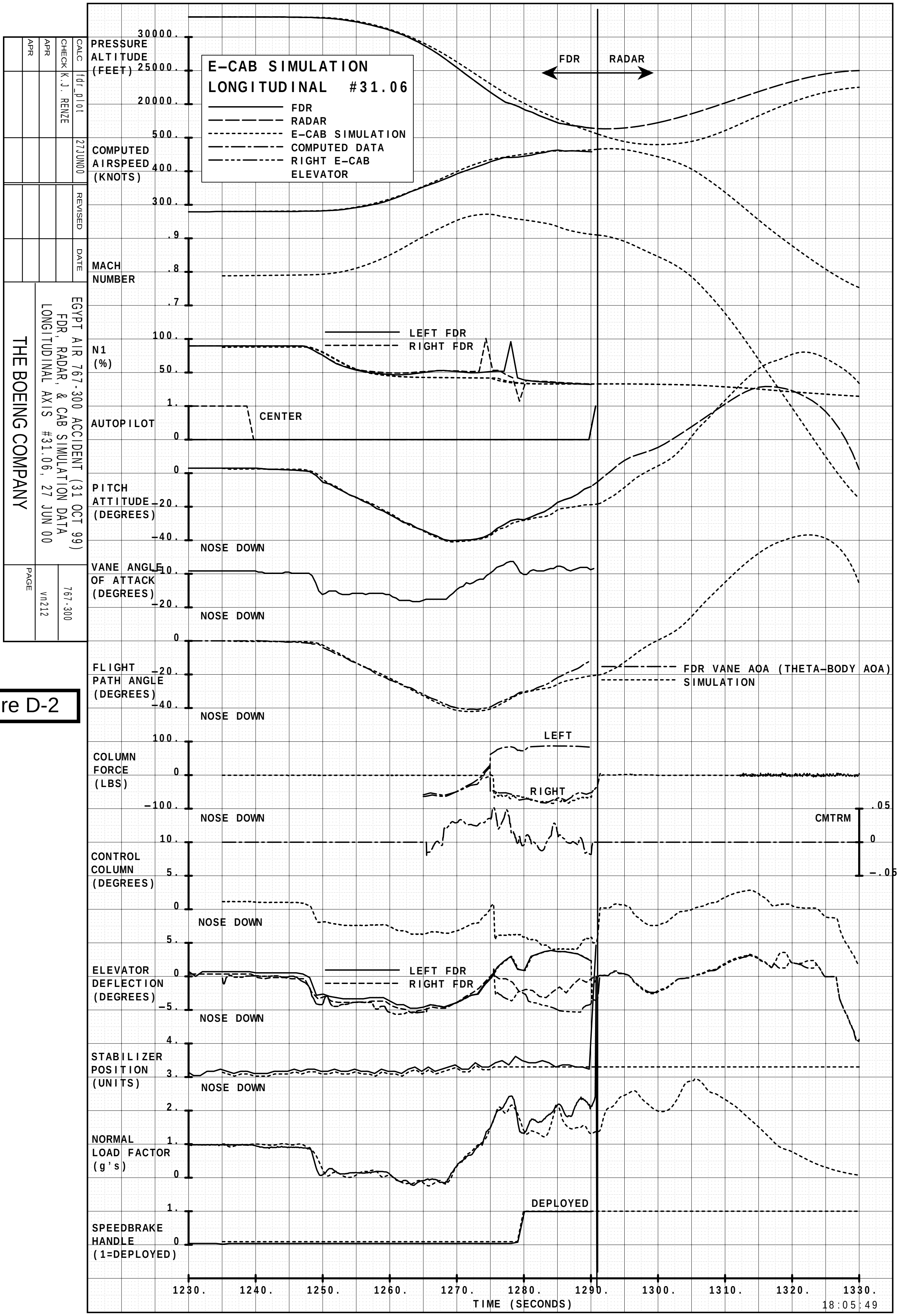
Figure D-1




E-CAB SIMULATION
LONGITUDINAL #31.06
FDR
RADAR
E-CAB SIMULATION
COMPUTED DATA
RIGHT E-CAB ELEVATOR
PRESSURE ALTITUDE (FEET)
COMPUTED AIRSPEED (KNOTS)
MACH NUMBER
N1 (%)
LEFT FDR
RIGHT FDR
AUTOPILOT
CENTER
PITCH ATTITUDE (DEGREES)
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
FLIGHT PATH ANGLE (DEGREES)
FDR VANE AOA (THETA-BODY AOA)
SIMULATION
COLUMN FORCE (LBS)
LEFT
RIGHT
CMTRM
CONTROL COLUMN (DEGREES)
ELEVATOR DEFLECTION (DEGREES)
STABILIZER POSITION (UNITS)
NORMAL LOAD FACTOR (g's)
SPEEDBRAKE HANDLE (1=DEPLOYED)
DEPLOYED
FDR
RADAR
TIME (SECONDS)
1230. 1240. 1250. 1260. 1270. 1280. 1290. 1300. 1310. 1320. 1330.
18:05:49
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & CAB SIMULATION DATA
LONGITUDINAL AXIS #31.06, 27 JUN 00
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DATE
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Figure D-2

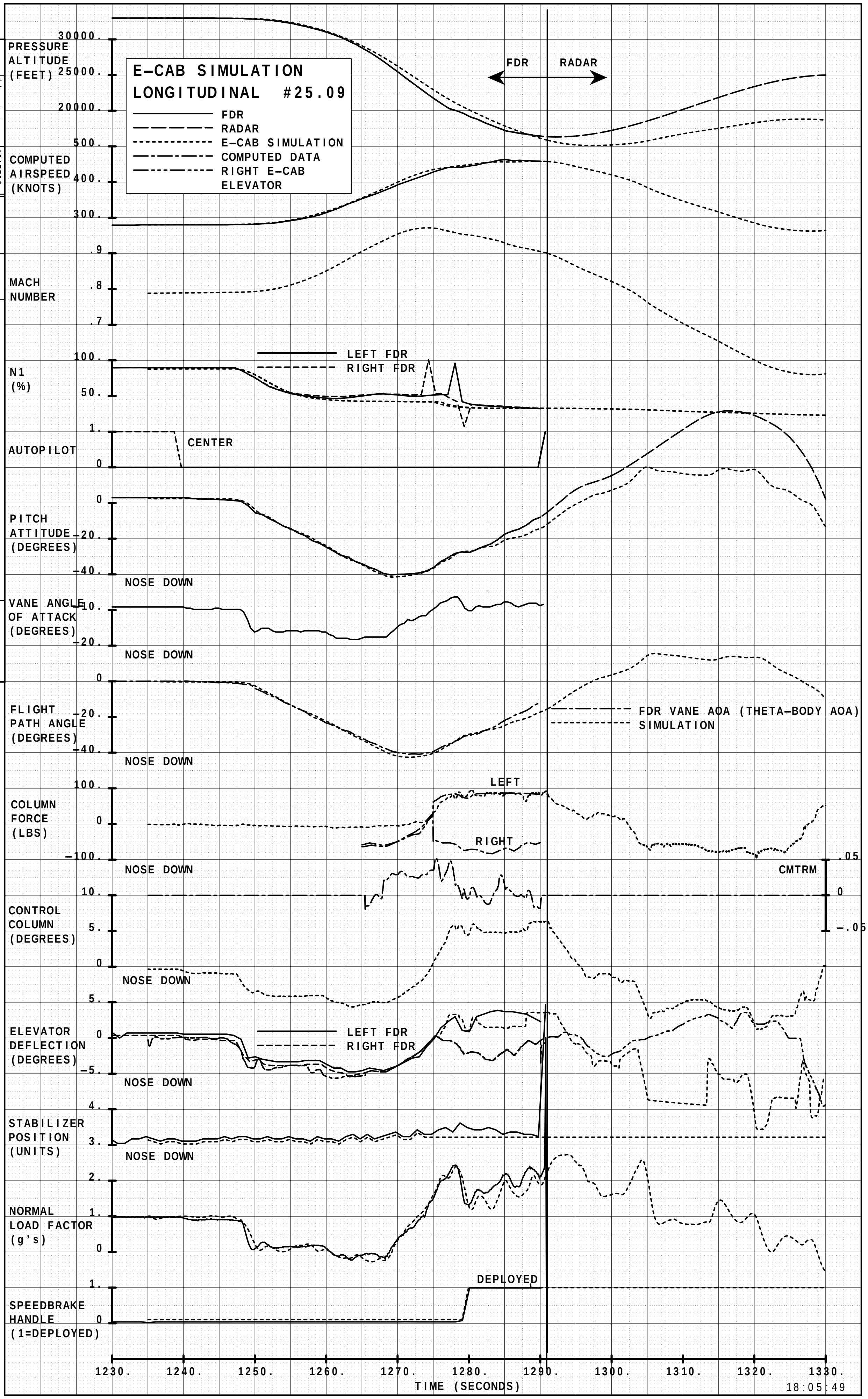
E–CAB SIMULATION
LONGITUDINAL #25.09
FDR
RADAR
E–CAB SIMULATION
COMPUTED DATA
RIGHT E–CAB ELEVATOR
PRESSURE ALTITUDE (FEET)
30000.
25000.
20000.
FDR
RADAR
COMPUTED AIRSPEED (KNOTS)
500.
400.
300.
MACH NUMBER
.9
.8
.7
N1 (%)
100.
50.
LEFT FDR
RIGHT FDR
AUTOPILOT
1.
0
CENTER
PITCH ATTITUDE (DEGREES)
0
–20.
–40.
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
–10.
–20.
NOSE DOWN
FLIGHT PATH ANGLE (DEGREES)
0
–20.
–40.
FDR VANE AOA (THETA–BODY AOA)
SIMULATION
NOSE DOWN
COLUMN FORCE (LBS)
100.
0
–100.
LEFT
RIGHT
NOSE DOWN
CMTRM
.05
0
–.05
CONTROL COLUMN (DEGREES)
10.
5.
0
NOSE DOWN
ELEVATOR DEFLECTION (DEGREES)
5.
0
–5.
LEFT FDR
RIGHT FDR
NOSE DOWN
STABILIZER POSITION (UNITS)
4.
3.
NOSE DOWN
NORMAL LOAD FACTOR (g's)
2.
1.
0
SPEEDBRAKE HANDLE (1=DEPLOYED)
1.
0
DEPLOYED
1230.
1240.
1250.
1260.
1270.
1280.
1290.
1300.
1310.
1320.
1330.
TIME (SECONDS)
18:05:49
CALC fdr_plot
CHECK K.J. RENZE
APR
APR
12APR00
REVISED
DATE
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & CAB SIMULATION DATA
LONGITUDINAL AXIS #25.09
THE BOEING COMPANY
767-300
vn212
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Figure D-3

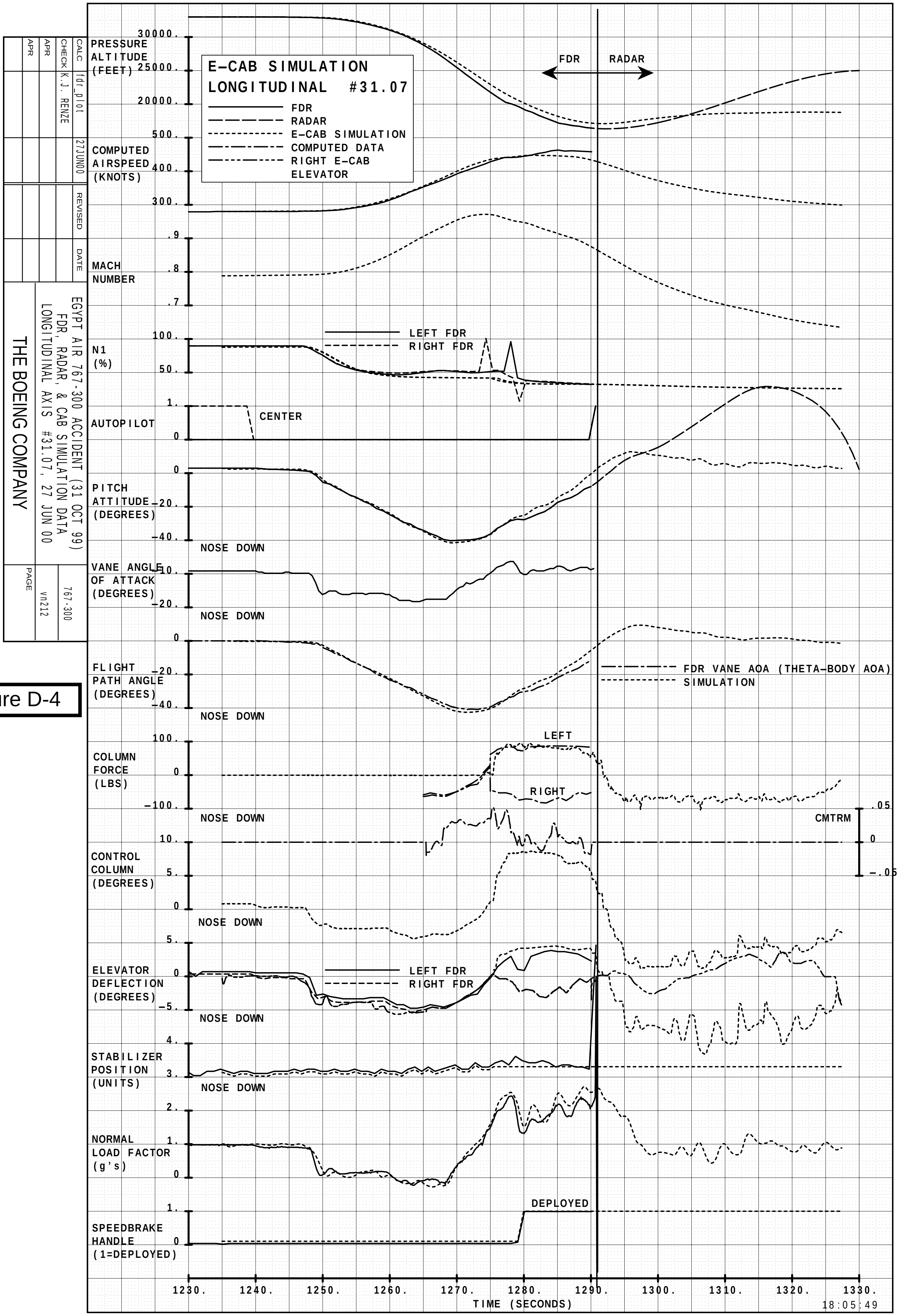
E-CAB SIMULATION
LONGITUDINAL #31.07
FDR
RADAR
E-CAB SIMULATION
COMPUTED DATA
RIGHT E-CAB ELEVATOR
FDR
RADAR
PRESSURE ALTITUDE (FEET)
30000.
25000.
20000.
COMPUTED AIRSPEED (KNOTS)
500.
400.
300.
MACH NUMBER
.9
.8
.7
N1 (%)
100.
50.
LEFT FDR
RIGHT FDR
AUTOPILOT
1.
0
CENTER
PITCH ATTITUDE (DEGREES)
0
-20.
-40.
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
10.
-20.
NOSE DOWN
FLIGHT PATH ANGLE (DEGREES)
0
-20.
-40.
NOSE DOWN
FDR VANE AOA (THETA-BODY AOA)
SIMULATION
COLUMN FORCE (LBS)
100.
0
-100.
LEFT
RIGHT
NOSE DOWN
CMTRM
.05
0
-.05
CONTROL COLUMN (DEGREES)
10.
5.
0
NOSE DOWN
ELEVATOR DEFLECTION (DEGREES)
5.
0
-5.
LEFT FDR
RIGHT FDR
NOSE DOWN
STABILIZER POSITION (UNITS)
4.
3.
NOSE DOWN
NORMAL LOAD FACTOR (g's)
2.
1.
0
SPEEDBRAKE HANDLE (1=DEPLOYED)
1.
0
DEPLOYED
1230.
1240.
1250.
1260.
1270.
1280.
1290.
1300.
1310.
1320.
1330.
TIME (SECONDS)
18:05:49
CALC
fdr_plot
27JUN00
CHECK
K.J. RENZE
APR
APR
REVISED
DATE
THE BOEING COMPANY
EGYPT AIR 767-300 ACCIDENT (31 OCT 99)
FDR, RADAR, & CAB SIMULATION DATA
LONGITUDINAL AXIS #31.07, 27 JUN 00
767-300
vn212
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Figure D-4