Exhibit 9F

Letter from Captain Mohsen El Missiry, dated 7/29/00,
Egyptian Delegation comments on System Group Chairman's Factual Report, "Study regarding System Group activities and summary of the elevator mechanical failure," and "Detailed study of the elevator mechanical failure (Exhibit A)"

40 pages

July 29, 2000

Mr. Gregory Phillips
National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D. C. 20594-0003

Dear Mr. Philips

Please find attached herewith

- Study regarding System Group activities and summary of the elevator mechanical failure.
- Detailed study of the elevator mechanical failure (Exhibit A)

It is requested to put these studies in the docket

Sincerely,

Captain/Mohsen El Missiry
Chief of Egyptian Investigation Committee

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July 28, 2000

Egyptian Delegation summery study regarding System Group:

This summery study includes summary for the following:

A- System Group activity
B- Egyptian Delegation Study
C- Results of Egyptian Delegation study

Attachment:
Study regarding elevator mechanical failure (Exhibit A)

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A- System Group activity:

- A list of probable elevator failures, which can affect elevator normal operation, has been presented by Boeing to the systems group on December 2, 1999.

- The System group was chaired by NTSB and consisted of:
  - NTSB
  - Egyptian Delegation
  - Boeing

- Systems Group members studied all the presented elevator failures, using information from Boeing 767 Maintenance Manual, and schemes presented by Boeing.

- Preliminary study of the presented failures revealed that failure of two power control actuators (PCA's) on the right elevator side would result in an elevator behavior very close to the elevator behavior recorded by the FDR.

- Boeing was requested to present a study regarding the dual elevator PCA's failures on one elevator side. It was requested that the study should cover the two following types of failures:

  - Dual PCA's valve disconnect, with autopilot engaged and autopilot disengaged conditions
  - Dual PCA's valve jam, with autopilot engaged and autopilot disengaged conditions

- On December 18, 1999 the following Boeing letters were received from Boeing:

  - Document B-H200-16854-ASI regarding Split Elevator Failure Scenario.
  - Document B-H200-16855-ASI regarding High Mach Characteristics

- Document B-H200-16854-ASI regarding Split Elevator Failure Scenario presented information concerning the dual PCA's valve disconnect and dual PCA's valve jam The document included the charts relating stick forces with elevator deflection, and did not include the blowdown charts relating the elevator blowdown deflection with airplane speed at different operational hydraulic systems conditions.

- Document B-H200-16855-ASI regarding High Mach Characteristics included characteristic data for all the flight control surfaces except the elevator surfaces. Egyptian Delegation asked the Systems Group Chairman to forward the rest of the data covering the elevators characteristics which present the core of the investigation, but he showed reluctance to do that. Part of the elevator characteristics charts were presented by the Performance Group Chairman on condition that the Egyptian Delegation could only look at them without keeping any hard copies.

- The elevator blowdown charts used by Boeing, relate elevator deflection with:
  - The airplane Mach no
  - Number of powered actuators (PCA's)
  - Altitude
  - Stabilizer position

  The charts addressed the steady state condition, without considering the effect of body angle variation and the dynamic nature of the event.

- Egyptian Delegation requested to compute elevator blowdown deflection:
  - Using elevator hinge moment charts (Boeing document D613T161)
  - Using elevator hinge moment charts (Boeing document D613T161) considering body angle changes

  And then compare these results, with the results obtained using blow down charts

- These computations have been made by the Performance Group Chairman, and the Egyptian Delegation. Results were almost similar. Results were compared with other results obtained from blowdown charts (available up to M=0.91). All computations are based on steady state conditions, without considering the dynamic situation. It was noticed that:
  - The three methods used to calculate elevator position with dual servo jamming do not give the same results, sometimes differing by more than one degree.
  - The results as obtained by the three means lie in a band, which is very close to the FDR elevator positions and shows the same trends. The maximum difference between the calculated elevator deflection within this band and the elevator deflection as shown by the FDR is about one degree.

  (Results are in Figure 2 and Figure 3)

- Upon the request of the Systems Group Chairman from Boeing to provide documentation of test results recorded during FCTR (iron bird) testing of elevator PCU Conditions, letter No. B-H200-16860-ASI was received from Boeing on December 23, 1999 describing the single PCA main control valve jam, without addressing any dual PCA jam condition.

- Ground test on a Boeing 767-400 test airplane was conducted at Boeing field, Seattle, on December 9, 1999. The purpose of the test was to demonstrate the column forces required to split the elevator surfaces to the angles recorded on the FDR data. Boeing letter B–H200-16856-ASI dated December 18, 1999 included information about the test and some sample results for the column forces, column deflections and elevator deflection. Boeing stated that the result data will be made available in an electronic format and will be submitted to the Performance Group Chairman.
  (This data was forwarded by the Performance Group Chairman to the Egyptian Delegation several weeks later on a CD, the files were not in a readable format. Upon several requests from the Egyptian Delegation side, another CD was forwarded on July 7, 2000. The data were readable but need a lot of processing to get them in charts form for assessing the data, data are still under processing by the Egyptian Delegation)

- Boeing did not include analysis study to the full ground test results. Boeing also did not

include comparison study between the ground test results and the analytical results made by Boeing. However, Boeing concluded that the data shows that the force required to achieve the split elevator positions recorded on EgyptAir Flight 990's FDR are consistent with the analytical results presented previously.
(First elevator failures scenario received by the Egyptian Delegation from Boeing was on December 18, same date as the ground test results letter, no failures scenario was received before that)

- Wreckage recovery took place in the period from December 12 up to December 21, 1999 Only four elevator PCA's were recovered (Total number of elevator PCA's is six)

- Another wreckage recovery took place in the period from March 28 up to April 3, 2000. No additional elevator PCA's were recovered.

- One actuator, identified as that from the right elevator outboard position (S/N 638), contained abnormalities when compared to the remaining three actuators recovered. These abnormalities include the following:

  1. The actuator's piston was found in a fully retracted position (aircraft nose down).
  2. The pin that attaches the spring guide to the slide in the servo valve commanding the actuator was sheared while the pin in the other recovered actuators was not sheared.
  3. The bias spring was found overriding the spring guide while it was in the correct position in the other recovered actuators.
  4. Some particulates were found in the servo cap where the spring coils and spring guide are housed. The chemical composition of one particulate is consistent with the chemical composition of the spring guide while the chemical composition of another particulate is consistent with the chemical composition of the servo cap.

  In addition, examination of the bell cranks for this actuator and the adjacent middle actuator disclosed rivet shears in the direction that may be consistent with a jammed condition in the actuators with input forces to the control column trying to move the elevator to an aircraft nose up position. All the remaining bell cranks recovered were found to have rivet shears in the opposite direction. One of these was from the adjacent right elevator inboard PCA linkage position that still had continuity of the input rod to the middle bell crank.

- On February 8, 2000, Boeing presented the letter B-H200-16882-ASI. This letter included a correction to the Boeing analysis in their previous letter B-H200-16854-ASI regarding the elevator behavior with dual PCA's valve disconnect condition. Boeing newer analysis leads to a quite different elevator behavior compared to the older analysis. All what was mentioned about the operation of the slave cables has been completely altered.
  Upon the request of the system group, Boeing added another failure scenario in their letter addressing the condition of single PCA valve disconnect combined with single PCA valve jam condition.

- Because of the differences in the Boeing analytical results in both Boeing reports and to resolve the ambiguities in the dual PCA's failure elevator behavior, it was decided to carry out another ground test on the B767-400 test airplane, and a demonstration test on the Boeing E-Cab simulator. The purpose of the tests was to investigate and demonstrate the effects failure conditions on the elevator system.

- Egyptian Delegation received the "Systems Group Chairman's Factual Report Addendum Regarding the Ground and Simulation testing" dated May 19, 2000
  This report contains results of:
  - Simulation session carried out on Boeing Engineering Cab on March 29, 2000 at Boeing facilities, Seattle, Washington. The objective of the simulation session was to evaluate airplane controllability following dual elevator PCA failure scenarios to allow comparison of this failure scenario data with MS990 FDR data.
  - Ground tests carried out on Boeing 767-400 test airplane on March 29, 2000 and April 20, 2000 at Boeing facilities, Seattle, Washington. The objective of the ground test activity was to investigate and demonstrate the effects of failure conditions on the elevator system

- A third version of Dual Elevator Power Control Unit Failure Effects (Boeing letter B-H200-16968-ASI dated May 17, 2000) was received as "Appendix A" for the "Systems Group Chairman's Factual Report Addendum Regarding the Dual Elevator Power Control Unit Failure Effects" dated May 24, 2000

- Egyptian Delegation indicated to the NTSB that Boeing letter B-H200-16968-ASI dated May 17, 2000 can not be considered as a factual report. This letter is a study, this study needed validation by the ground test and simulator demonstration.

- Complete analysis to the ground test results has been done by the Egyptian Delegation. The analysis report was submitted to NTSB and Boeing on June 15, 2000

- The following is a summary of the main key findings:
  - For every failure scenario, the column forces induced as the result of the failures were far from what is predicted in the Boeing analysis report.
  - In most cases, column split occurred when it was not expected to occur and the forces at which split occurred were much lower than what was predicted in the Boeing analysis report.
  - In the cases where one column was held in position, the elevator on the side corresponding to the held side was moving with inputs from the opposite column. This is contrary to what was predicted in the Boeing analysis report.
  - In the case of single PCA disconnect failure, the two elevators showed about two degrees deflection difference. This is contrary to what was predicted in the Boeing analysis report.
  - In many cases of single PCA disconnect failure, before the sweep the columns and elevators showed deflection. This is contrary to what was predicted in the Boeing analysis report.

- In several cases, for the same feel pressure condition, each time the control force was equal to the beginning value (before the sweep, at the initial force when changing from push to pull, and at the initial force when ending the pull), the columns and elevator surfaces do not show the same values. This is contrary to what was predicted in the Boeing analysis report.

Based on the above comments, it is clear that the information published in Boeing Report Number B-H200-16968-ASI is not consistent with ground test results.

- In response to "The Systems Group Chairman's Factual Report Addendum Regarding the Dual Elevator Power Control Unit Failure Effects", Egyptian Delegation comments and requests were submitted to NTSB and Boeing on June 22, 2000.
  The following were the main Egyptian Delegation requests:

  - Explanation of the discrepancies between the ground test results and Boeing Report B-H200-16968-ASI for all tested failures and at no failure condition.

  - The behavior of the elevator system with dual PCA valve jam failure condition including
    - Column cracking forces (forces required to initially move the columns).
    - Relationship between columns forces and columns and elevators deflections
    - Effect of push/pull column movements rates.
    - All conditions under which the columns split.
    - Deflection of the pogo springs and bottoming conditions

  - Column hysteresis with dual PCA valve jam failure condition at the specific MS990 flight conditions.

  - Effect of the dynamic behavior of the flight control systems.

- Upon Egyptian Delegation request, Boeing provided the technical information about the Mach trim system operation including the inhibitions resulting from the control columns deflection. However, Boeing did not answer the Egyptian Delegation question regarding whether the Mach trim system interfered and moved the stabilizer during the dive of MS990 as scheduled with speed or not.

- It was agreed upon by NTSB, Egyptian delegation and Boeing that it is more efficient to have a meeting at NTSB. Meeting was decided to take place on June 28, and to be also attended by Parker (the elevator PCA's manufacturer) to discuss the results of the actuators examination.

- The meeting was held on June 28, 2000 and was attended by:

  - NTSB
  - Egyptian Delegation
  - Boeing

- Parker
- F.A.A

- The agenda for this Systems Group meeting included the following:

  - Review of the NTSB draft materials lab factual (Bernstein)
  - Review of Egyptian Delegation jam theory (Marx)
  - Review of Egyptian Delegation comments to Failure Effects Factual Report (VanLeynseele/Hamdy)
  - Review of Boeing testing and plans in response to dual bellcrank failure (VanLeynseele).
  - Action Items/Wrap-up

- A presentation was made by Boeing trying to explain the discrepancies between the ground test results and Boeing Report B-H200-16968-ASI for all tested failures and at no failure condition.
  Boeing presentation was generic and did not address the specific discrepancies shown by the Egyptian Delegation analysis for the ground test.
  Boeing mentioned that the data presented to NTSB and Egyptian Delegation is a raw data and was submitted in such form upon the urgent and quick request of the NTSB. Boeing asked all other parties to disregard this data. Boeing promised to forward a complete new package of analysis and data

- Boeing stated during the meeting that a program is being run by Boeing for the examination of the elevators bell crank through the whole fleet of the Boeing 767 world wide.

- The anomalies found in one of the right elevator PCA were discussed during the meeting. System Group Chairman was focusing only on whether the anomalies found in the examined elevator PCA could affect the airplane control system or not, and concluded that these anomalies were due to impact loads. Egyptian Delegation indicated that any conclusion should be supported by complete engineering studies.

- As a result of the meeting, Egyptian Delegation submitted a letter to the NTSB on June 29, 2000, requesting the following:

  - Computation of the acceleration required to shear the pin connecting the spring guide to the slide, to investigate the probability of shear due to impact force
    (Analysis to investigate the possibility of shear as a result of column force has been made by Boeing upon a request from NTSB, and was excluded by Boeing)
  - Study of the possibility of spring guide interference with the servo valve cap as a result of spring roll over the spring guide
  - Study of the possibility of shearing the pin connecting the spring guide to the slide without having the spring guide being held in position.
  - Study concerning the probable causes which could result in spring roll over the spring guide
  - Full details of the servo valve and the over travel limiter mechanism, including the

hydraulic ports and internal passages.

- Some other information regarding the weight, dimensions, material and thread design of some servo components

- Boeing letter No. BE326-C00-099 regarding Boeing explanation for the ground test force bias, was received on July 18, 2000.
  In their letter, Boeing redefined the column forces as the forces imposed by the pilots on the columns in normal and with failure conditions, i.e. the forces induced as result of introducing elevator failures are not measured. Therefore, the measurements for the forces induced as result of failures are not valid. However, Boeing stated in the report that the test results validates the expected analytical results.

- Egyptian Delegation commented about this letter on July 18, 2000, comments were submitted to the NTSB. The following are the Egyptian Delegation comments on this document:

  1. The report identifies bias errors that reportedly existed during the ground tests. The method used to correct for these errors assumes that the force reported is the force on the control column that is applied by a crewmember. By measuring the column force in this way, there is no way to infer the forces imposed by one or two failed servos; a hands-off condition will always give zero force. If that is true, there is no way to validate Boeing analysis regarding the elevator forces induced with PCA failure conditions. Therefore, the statement that "the test results validate the expected, analytical results" is unsubstantiated.
  2. Changes in bias errors are attributed to changes in temperature; however, no temperatures were shown in the data recording the ground testing. To evaluate this possible temperature effect, the temperature dependence of the transducers and the temperature during each test must be provided.
  3. A new set of plots/data that includes the corrections for bias on column force is requested.

- On the meeting with the System Group Chairman on July 19, 2000. The System Group Chairman stated that Boeing reports regarding elevator dual failures scenarios will not be presented as a factual report but as letters from Boeing.

- On a phone conference with Boeing on July 19, 2000, Boeing mentioned that the force bias is function of the temperature, however the temperature is not recorded during the ground test, and Boeing asked just to move the axis vertically to read a force value of zero at the moment before the sweep on all the charts irrespective of the amount of correction among the numerous charts.
  Egyptian Delegation asked Boeing to include all their terms and limitations on whatever studies they provide.

- "System Group Chairman's Factual Report Addendum Regarding the Ground and Simulation Testing (revised addendum 4)" was received on July 26, 2000 including the

Boeing correction for the force bias.

- Egyptian Delegation comment on "System Group Chairman's Factual Report Addendum Regarding the Ground and Simulation Testing" was submitted to the NTSB on July 28, 2000.
  The Egyptian Delegation believes that the method used by Boeing to remove the column force instrumentation biases during the calibration process is technically incorrect.
  In addition, the measurements regarding the forces induced as result of the failures are no more valid.

B- Egyptian Delegation Study summary:

Based on all the current available technical resources, probable elevator mechanical failure study has been done by the Egyptian Delegation (Exhibit A)

Following is a summary of the study:

1- General:

- With a single Power Control Actuator (PCA) jam failure on right side (offset from neutral toward down movement direction), the control columns and both elevator surfaces would slightly move (aircraft nose down direction). With autopilot engaged, this failure is latent. There is no visible or audible warning in the cockpit associated with this failure.

- With another PCA jam failure on the same side (offset from neutral toward down movement direction), the right elevator will move to the blow down position for this flight condition, the left elevator will move down. At high speed it will follow the right side. There is no visible or audible warning in the cockpit associated with this failure

- Elevators schedule as the result of the dual failure is shown in figure 2 and figure 3.

- The blowdown line is plotted up to only 0.91 Mach number. All data presented from Boeing is valid up to Mach number 0.91. No available data for the speed above 0.91 Mach number. However, the airplane speed reached a speed of about 0.99 Mach close to the end of the dive.

2- Egyptian Delegation perspective regarding elevator system mechanical failure:

- A single elevator PCA jam condition could have occurred after the last check (A) on the airplane on the right elevator side.
  The following elevator behavior support this probability:
  - Just after the autopilot disconnect before the event, both elevators moved slightly down (airplane nose down) associated with a change in pitch angle towards nose down. This is consistent with the single elevator PCA jam condition.
  - Through the last flight Cairo/NY/LA/NY/Cairo, the autopilot was disconnected three times during the leg between N.Y/L.A. dated October 30, 1999. Each time, the elevators showed slight downward movement.

- After autopilot disconnect, with all the elevator PCA's at an offset from the neutral position towards down command, a second PCA jam condition could have occurred. The resultant elevator deflection would be very close to the FDR data.

- Lots of considerations including deficiency of cockpit indication and warning,

stabilizer inhibition, 767 checklist, elevator control additional forces, split behavior between the columns, rate of force application, flags in the cockpit, dynamic events, .. etc, might explain why the action of recovering the airplane was not obvious at the first portion of the dive.

- With the speed increasing at the dive, it is logical to retard the throttle levers to reduce engines power, and to deploy the speedbrakes handle to decelerate the airplane. These actions were shown by FDR.

- Upward movement of only the unaffected left elevator at almost the end of the dive, would indicate a successful pull by the elevator columns.

- The engines low oil press came on, with extremely low and abnormal Engine Pressure Ration (EPR) reading during the descent. This situation could indicate condition of engines flameout. According to B767 checklist and to relight the engines during flight, the fuel control switches should be moved to CUTOFF position, then engines inflight procedure should be initiated.

- The anomalies found in one of the recovered elevator PCA's, highly support the possibility of dual PCA jam failure.

- The airplane load factor reached about 2.4 value during the recovery from the dive. With such high load factor, and high speed (much greater than the maximum operating speed (M_{MO}) which is 0.86 Mach), there is a very high possibility of aircraft disintegration. The location of left engine in the west field far from the main wreckage field, and being in an intact condition compared to the remaining wreckage, highly support this possibility.

3- Egyptian Delegation response to Boeing arguments:

- In the last Boeing letter (regarding Split Elevator Failure Scenario) it was mentioned that the FDR elevator data is inconsistent with how the Boeing 767 elevator systems respond to the dual PCU failures. This was based on comparisons at three moments during the dive between FDR elevator deflection and Expected deflection after dual failure. Boeing mentioned the following:

  - "Early in the dive, there was one degree difference"

  - "At time 1:50:09 the elevator deflections shown on the FDR are 4.75 degree for one surface (left), and 5.1 degrees for the other (right), these elevator deflections would not have been possible at this flight condition if the dual PCA failure has been presented".

    Egyptian Delegation comment:
    Referring to the Performance Group Chairman computation for the right elevator blowdown deflection, the right elevator should be deflected to 4.3 degrees down

which is very close to the FDR right elevator deflection.
Using Boeing charts enclosed with Boeing letter, the left elevator should be deflected down 3 to 5 degrees, which is exactly consistent with FDR left elevator deflection.

- At the flight condition existing when the elevators reached neutral, the blow down position of the failed surface would have been approximately 2 degrees if the dual PCA failure has present.

  Egyptian Delegation comment:
  There is no data valid at this moment due to speed exceedance. The aircraft speed reached about 0.99 close to the end of the dive. All the charts for elevators blowdown are valid only up to 0.91 Mach. Any data after 0.91 Mach number is considered invalid

Consequently, it is apparent that these arguments can not support the statement that the FDR elevator data is inconsistent with how the Boeing 767 elevator systems respond to the dual PCU failures

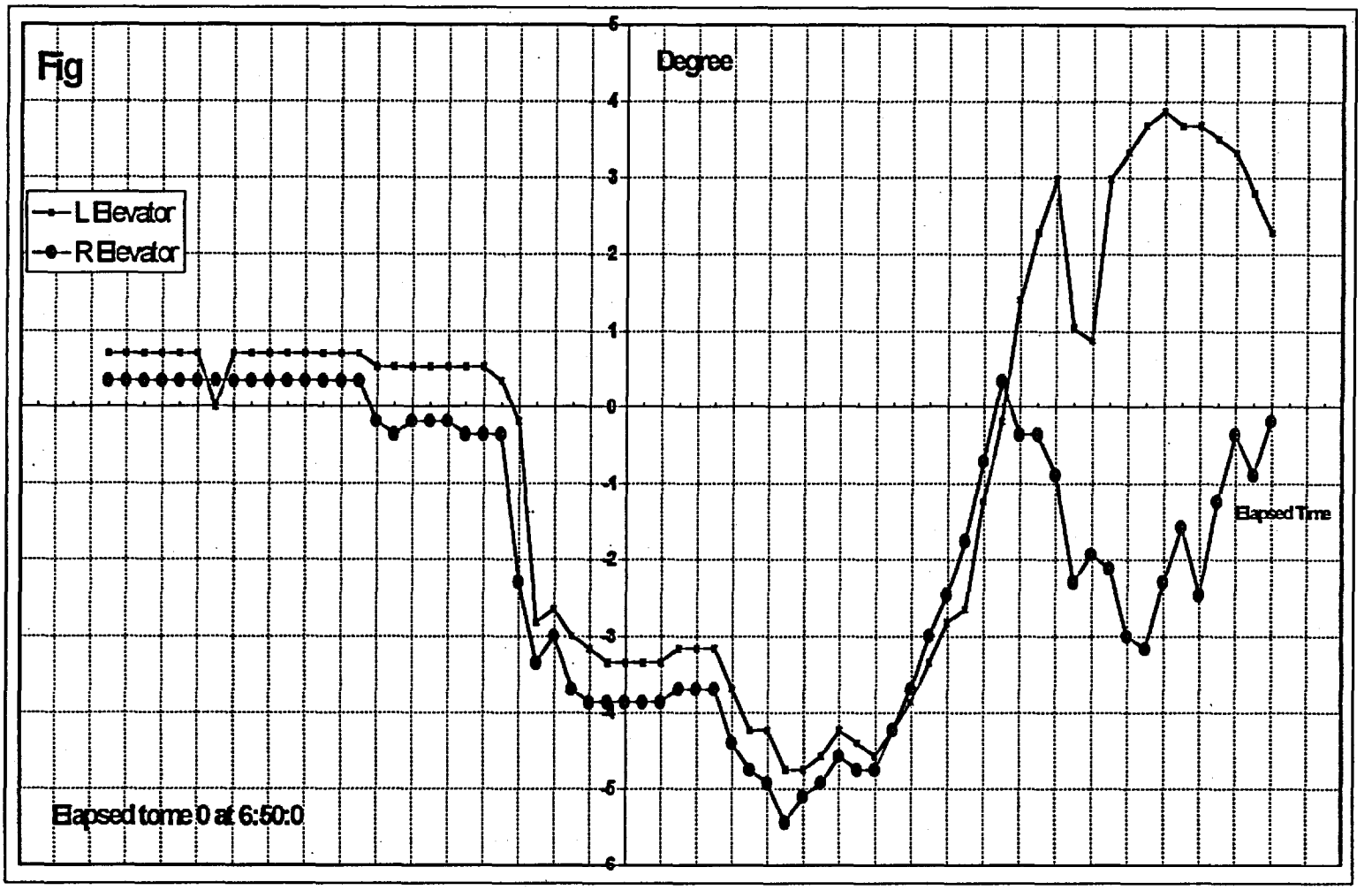
- Following are additional Egyptian Delegation arguments:

  - The ground test results do not validate the dual failure theory presented by Boeing.
  - Because of the limitation of the flight simulator (in particular, the failure to model the connection between the control columns correctly), the testing done was not able to address some of the most critical questions relating to control of the aircraft.
  - The study of elevator blowdown deflection using Boeing data (blow down charts and hinge moments charts) resulted in an elevator deflection band which is very close to the elevator deflection as recorded on the FDR (within about one degree).
  - Elevator control column hysteresis effects are significant; however, they are not considered in the Boeing study.
  - In the Boeing study, only steady state values were used to analyze a very dynamic situation.
  - No data are published by Boeing for Mach numbers in excess of 0.91. It is invalid to extrapolate data into a region beyond the Boeing published data and particularly where supersonic flow will exist.
  - Other abnormal flight control behavior, in particular the behavior of the ailerons during the event, were not studied. If the unusual movement of the ailerons is understood, it may help in the understanding of the movements of the elevators.

C- Results of Egyptian Delegation study:

- A dual PCA valve jam failure is consistent with FDR data.
- The Boeing published data for the elevator dual PCA failure does not accurately predict the actual behavior of the elevator control system. Boeing argument regarding the inconsistency of the dual failure scenario is not technically supported.

Fig.1 FDR Elevator deflection



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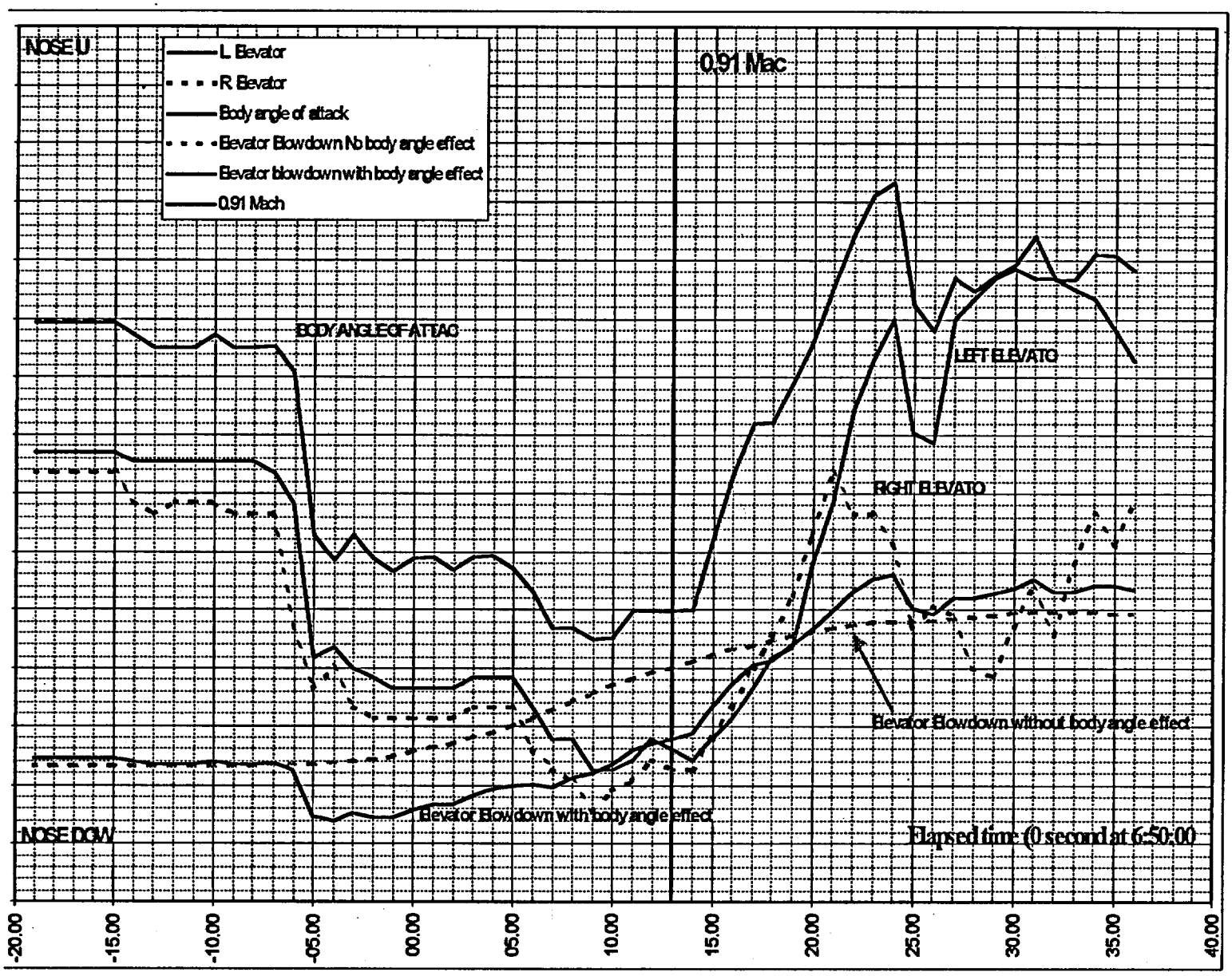

Fig 2 Egyptian Delegation results for Elevator blowdown angles, dual PCA failure

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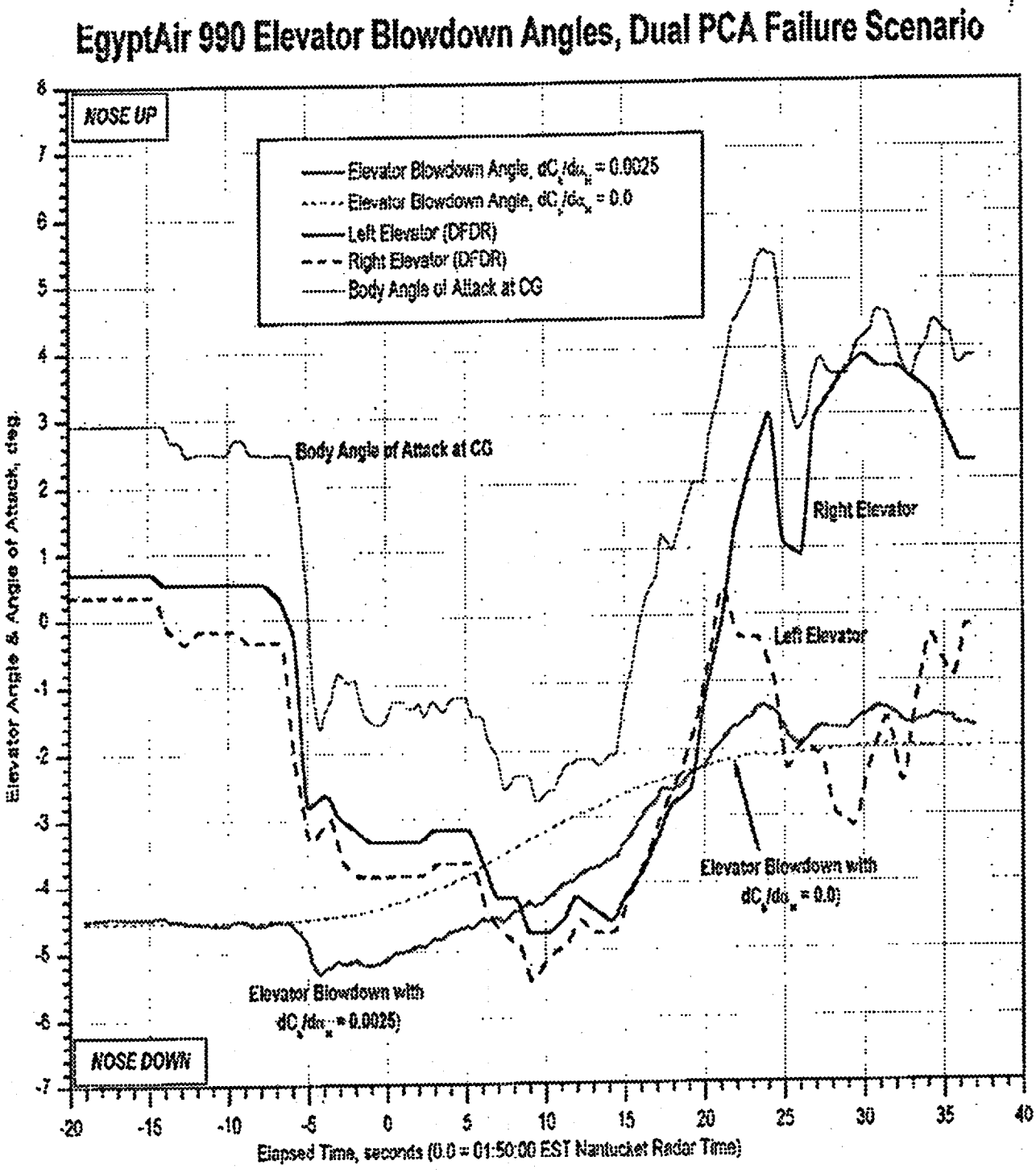

Fig 3 Performance Group Chairman Computation for elevator blowdown angle

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M. Hamdy

Mohamed A. Hamid Hamdy
Aero Engineer- Egyptian Delegation

Exhibit A

July 29, 2000

Detailed technical Study Regarding elevator Mechanical Failure:

References:

- Document B-H200-16854-ASI regarding Split Elevator Failure Scenario dated December 18, 1999.
- Document B-H200-16855-ASI regarding High Mach Characteristics dated December 18, 1999.
- Document B-H200-16882-ASI regarding Split Elevator Failure Scenario dated February 8, 1999.
- Document B-H200-16882-ASI regarding Split Elevator Failure Scenario dated May 17, 1999.
- Results of the Ground tests and Simulator demonstration (E-Cab simulator)

- Based on information presented by Boeing, the effects of the different probable elevator failures were studied. Study revealed the following:

  - With a single Power Control Actuator (PCA) jam failure on right side (offset from neutral toward down movement direction), an induced force of 15 pound would push on the control columns forward resulting in a slight forward movement of the columns and slight downward movement of both elevator surfaces. These movements would decrease with increasing speed as a result of increasing elevator feel pressure opposing control columns movement.
    With autopilot engaged, this failure is latent due to higher authority of autopilot.
    With autopilot disengaged, the failure may not be noticeable, especially at high speed.
    Both elevator surfaces would be controllable from either column sides with an additional force of 15 pounds.
    Note:
    There is no visible or audible warning in the cockpit associated with this failure

  - With another PCA jam failure on the same side (offset from neutral toward down movement direction), following will occur:

    - The columns would be pushed slightly forward as a result of an induced force of 30 pounds. Deflection will be function of the specific flight conditions.
    - The right elevator will blow down. Blowdown deflection is function of aircraft speed, pressure altitude, stabilizer position and angle of attack. This elevator will not be controllable from either column sides.
    - The left elevator would move down. Elevator would deflect to a position resulting from a force of 30 pounds at the specific flight condition. At high speed it will follow the right side. This elevator would be controllable at higher forces from both sides. At 130 pound pulling force from the right column, the two columns will disconnect; thus the right column would not be able to control the left elevator.
      Note:
      There is no visible or audible warning in the cockpit associated with this failure

- The following events were shown by FDR which are consistent with elevator dual PCA's failure:

  - Just after the autopilot disconnect before the event, both elevators moved slightly down (airplane nose down) with slight airplane pitch change (nose down).
    In addition, through the last flight Cairo/NY/LA/NY/Cairo, the autopilot was disconnected three times during the leg between NY/LA dated October 30, 1999. Each time, the elevators showed slight downward movement.

    This support the assumption that a single elevator PCA jam condition could have occurred after the last check (A) on the airplane on the right elevator side.

  - After autopilot disconnect, the two elevators moved on a schedule close to the schedule resulting from a dual elevator PCA's jam failure. This could indicate

occurrence of a second PCA jam condition on the right elevator with the elevator PCA's at an offset from the neutral position towards down command.

- The speedbrake lever was deployed and the throttle levers were retarded to assist in decelerating the airplane.

- Upward movement of only the unaffected left elevator at almost the end of the dive, would indicate a successful pull by the elevator columns.

- The engines low oil press came on, with extremely low and abnormal Engine Pressure Ration (EPR) reading during the descent. This situation could indicate condition of engines flameout. According to B767 checklist and to relight the engines during flight, the fuel control switches should be moved to CUTOFF position, then the engines inflight start procedure should be initiated.

- The following considerations could explain why the action of recovering the airplane was not obvious for the first portion of the dive:

  - There were no visual or aural warning for such failure in the cockpit.
  - There is no flight crew checklist for such failure.
  - Cockpit Crew has no previous training to deal with such failure
    - The Stabilizer might have been inhibited (in the nose up trim direction) if the columns are sufficiently moved forward as a result of the failure (~ 2.5 degrees control column forward movement)
    - The force necessary to control the left elevator is excessively higher than the normal force
    - The force necessary to start right column movement in the nose up direction is not known (not provided by Boeing)
    - Excessive force applied on the right column can disconnect both columns from each other; left elevator will not be controllable from the right column.
    - High rate of force application on the right column could have a significance effect on the elevator controllability (not explained by Boeing)
    - With increasing speed and with the high rate of descend, altitude flags were in view all the time on both sides. The speed flag and instantaneous vertical speed (IVS) flags would came in view several times during the event.
    - The airplane was suffering from severe buffeting condition through most of the dive because of the speed exceedance.

- The anomalies found in one of the recovered elevator PCA's, highly support the possibility of dual PCA jam failure.

- The airplane load factor reached about 2.4 value during the recovery from the dive. With such high load factor, and high speed (much greater than the maximum operating speed (M_{MO}) which is 0.86), there is a very high possibility of aircraft disintegration. The location of left engine in the west field far from the main wreckage field, and being in an intact condition compared to the remaining wreckage, highly support this possibility. Computations indicate that the left engine was most probably separated from the airplane just after the recovery from the dive.

- Egyptian Delegation study indicates disagreement with Boeing statement included in the last Boeing letter (regarding Split Elevator Failure Scenario) "the FDR elevator data is inconsistent with how the Boeing 767 elevator systems respond to the dual PCU failures" This statement was based on comparisons at three moments during the dive between FDR elevator deflection and Expected deflection after dual failure. Boeing mentioned the following:

  - "Early in the dive, there was one degree difference"

  - "At time 1:50:09 the elevator deflections shown on the FDR are 4.75 degree for one surface (left), and 5.1 degrees for the other (right), these elevator deflections would not have been possible at this flight condition if the dual PCA failure has been presented".

    Egyptian Delegation comment:
    Referring to the Performance Group Chairman computation for the right elevator blowdown deflection, the right elevator should be deflected to 4.3 degrees down which is very close to the FDR right elevator deflection.
Using Boeing charts enclosed with Boeing letter, the left elevator should be deflected down 3 to 5 degrees, which is exactly consistent with FDR left elevator deflection.

  - At the flight condition existing when the elevators reached neutral, the blow down position of the failed surface would have been approximately 2 degrees if the dual PCA failure has present.

    Egyptian Delegation comment:
There is no data valid at this moment due to speed exceedance. The aircraft speed reached about 0.99 close to the end of the dive. All the charts for elevators blowdown are valid only up to 0.91 Mach. Any data after 0.91 Mach number is considered invalid

    Consequently, it is apparent that these arguments would not support the statement that the FDR elevator data is inconsistent with how the Boeing 767 elevator systems respond to the dual PCU failures

- Following are additional Egyptian Delegation arguments:

1- Ground Testing:

Numerous inconsistencies were found between the data gathered during the ground testing of an instrumented Boeing 767 and the results expected using Boeing data published in Report Number B-H200-16968-ASI. The following is a brief summary of the most significant of these inconsistencies:

- For every failure scenario, the column forces induced as the result of the failures were far from what is predicted in the Boeing analysis report.
- In most cases, column split occurred when it was not expected to occur and the forces at which split occurred were much lower than what was predicted in the Boeing analysis report.
- In the cases where one column was held in position, the elevator on the side corresponding to the held side was moving with inputs from the opposite column. This is contrary to what was predicted in the Boeing analysis report.
- In the case of single PCA disconnect failure, the two elevators showed about two degrees deflection difference. This is contrary to what was predicted in the Boeing analysis report.
- In many cases of single PCA disconnect failure, before the sweep the columns and elevators showed deflection. This is contrary to what was predicted in the Boeing analysis report.
- In several cases, for the same feel pressure condition, each time the control force was equal to the beginning value (before the sweep, at the initial force when changing from push to pull, and at the initial force when ending the pull), the columns and elevator surfaces do not show the same values. This is contrary to what was predicted in the Boeing analysis report.

Based on the above comments, it is clear that the data published in Report Number B-H200-16968-ASI is not consistent with the ground test results

Note
Boeing explanation for the ground test force bias requested just to move the x-axis vertically to read a force value of zero at the moment before the sweep on all the charts irrespective of the amount of correction among the numerous charts.
Boeing redefined the column forces as the forces imposed by the pilots on the columns in normal and with failure conditions, i.e. the forces induced as result of introducing elevator failures are not measured. Therefore, the measurements for the forces induced as result of failures are not valid.
The Egyptian Delegation believes that the method used by Boeing to remove the column force instrumentation biases during the calibration process is technically incorrect. The force calibration charts should be developed first and then applied to the instrumentation readings.

2- Flight Simulation:

There were several limitations with the E-Cab. The most critical limitation was that the left and right control columns were rigidly connected in the simulator. This does not exactly replicate the 767 elevator control system, where there is a column override between the columns and an aft quadrant interconnect, so a large control column force application will separate the two columns. With the control columns separated, the right column can only control the right elevator. In the failure scenarios of interest, the right elevator is uncontrollable with two servos jammed on the right side.

3- Elevator Blowdown computations:

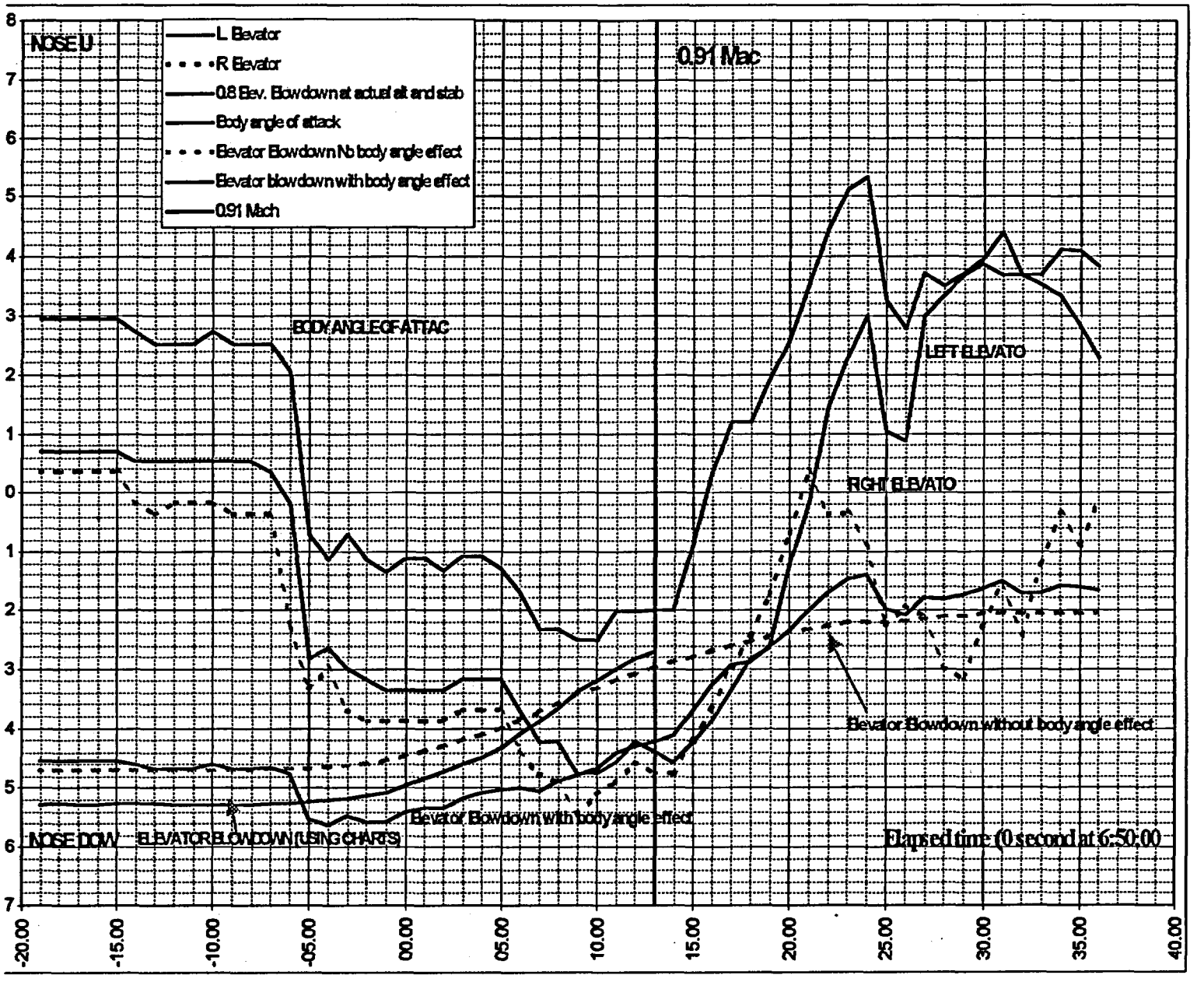
The following figure is a plot of the:

- Right and left elevator positions as recorded by the FDR
- The calculated elevator blowdown position with dual servo failure assuming no pilot input. The three plots represent the blowdown position determined as follows:
  1. Using Figure 3.7-12 on page 3-68 of Boeing Document No. D613T161, Flight Control System Data for the 767 Training Simulator.
  2. Using elevator hinge moment calculations based on Figures 3.6-4 through 3.6-8 from the same document not considering body angle effects.
  3. Using elevator hinge moment calculations based on Figures 3.6-4 through 3.6-8 from the same document considering body angle effects.

There are several issues concerning this figure that need further explanation, and the most important are summarized below.

- The three methods used to calculate elevator position with dual servo jamming do not give the same results, sometimes differing by more than one degree.
- The results as obtained by the three means lie in a band, which is very close to the FDR elevator positions and shows the same trends. The maximum difference between the calculated elevator deflection within this band and the elevator deflection as shown by the FDR is about one degree
- The results as obtained by the three means are based on steady state conditions, without considering the dynamic situation.

(See attachment 1 for the study)


NOSE U
L Elevator
R Elevator
0.8 Elev. Blowdown at actual alt and stab
Body angle of attack
Elevator Blowdown No body angle effect
Elevator blowdown with body angle effect
0.91 Mach
0.91 Mac
BODY ANGLE OF ATTAC
LEFT ELEVATO
RGHT ELEVATO
Elevator Blowdown without body angle effect
Elevator Blowdown with body angle effect
NOSE DOW
ELEVATOR BLOWDOWN (USING CHARTS)
Elapsed time (0 second at 6:50:00
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
-20.00
-15.00
-10.00
-05.00
00.00
05.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00

25

4- Elevator Column Normal Hysteresis:

Figure 3.1 through 3.7 Document B-H200-16968-ASI, Fig 3.2-5 of Boeing Document No. D613T161, clearly show hysteresis in the column force measurements. These figures show that, at the same column force, the resultant elevator deflection lies within a band, the width of which is dependent on the force values, elevator feel pressure, direction of movement, and rate of force application. Any conclusions drawn from an assessment of column force must consider the effects of column hysteresis.

5- Dynamic Effects:

Much of the analysis in the Boeing report depended on the column force for various flight conditions. In that analysis, only steady state values were calculated. By definition, a steady state analysis is independent of the rate at which forces were applied and which direction the column was moving. The accident was a very dynamic situation, and a steady state analysis may give very misleading results.

6- Elevator Behavior at Autopilot Disengagement:

When the autopilot is turned off at time 6:49:45 UTC, the elevators move slightly trailing edge down (TED) and were slightly split. If one elevator servo had jammed in the TED position, one would expect the elevator to move slightly TED when the autopilot was disconnected as a result of the induced force from the pogo on the jammed PCA. This behavior was recorded on the FDR

Through the last flight Cairo/NY/LA/NY/Cairo, the autopilot was disconnected three times during the leg between N.Y/L.A. dated October 30, 1999. Each time, the elevators showed slight downward movement.

The above analysis also shows why such a failure is latent. The only situation in which this failure could possibly be detected is when the autopilot is turned off during a stable trimmed condition and then elevator deflections are thoroughly examined.

7- Flight Speed Effects:

At about time 6:50:13 UTC, the Mach number passed 0.91. All data used for flight control system analysis are valid up to a Mach number of 0.91. Any conclusion based on data extrapolated beyond its range of validity is highly suspect. This is true in all engineering applications, but it is especially true when it is known that significant changes in the physics of the problem are likely to occur. In this case, it is known that shocks will form on various surfaces as Mach number increases, but it is not known how the pressure distributions and force coefficients will change at these speeds. Just

as it is invalid to extrapolate data into a region where a lifting surface is stalled, it is invalid to extrapolate data into a region where supersonic flow will exist.

Conclusion:

- A dual PCA valve jam failure is consistent with FDR data.
- The Boeing published data for the elevator dual PCA failure does not accurately predict the actual behavior of the elevator control system. Boeing argument regarding the inconsistency of the dual failure scenario is not technically supported.

M. Hamdy

Mohamed A. Hamid Hamdy
Aero Engineer- Egyptian Delegation

Attachment 1 to Exhibit A

Objective:

- To evaluate the effect of the body angle variations on the elevators deflection, in a dual elevators PCA's failure (in one side) scenario.

Body angles Computation:

Body angle is function of:

- Vane angle of attack (alpha angle)
- Mach number

The following data has been received from Boeing:

Mach no	Body angle of attack	alpha angle(deg.)
.40	-10.0	-30.4239
.40	+20.0	+20.4237
.80	-10.0	-30.3099
.80	+20.0	+18.6297
.91	-10.0	-30.0781
.91	+20.0	+16.79695

With linear (straight line) calibration curves for the above shown Mach numbers

Results are shown in the following tables and chart after interpolating for the Mach number

Time UTC	E-time seconds	Press. Alt ft	Airspeed Knots	mach	Vane Angle degree	BAOA degree
6:49:0.98	-59	32992	280	0.788374523	-9.14	2.965
6:49:1.98	-58	32992	280	0.788374523	-9.14	2.965
6:49:2.98	-57	32992	280	0.788374523	-9.14	2.965
6:49:3.98	-56	32992	280	0.788374523	-9.14	2.965
6:49:4.98	-55	32992	280	0.788374523	-9.14	2.965
6:49:5.98	-54	32992	280	0.788374523	-9.14	2.965
6:49:6.98	-53	32992	280	0.788374523	-9.14	2.965
6:49:7.98	-52	32992	279	0.785817099	-9.14	2.962
6:49:8.98	-51	32992	280	0.788374523	-9.14	2.965
6:49:9.98	-50	32992	280	0.788374523	-9.14	2.965
6:49:10.98	-49	32992	279	0.785817099	-9.14	2.962
6:49:11.98	-48	32992	279	0.785817099	-9.14	2.962
6:49:12.98	-47	32992	279	0.785817099	-9.14	2.962
6:49:13.98	-46	32992	280	0.788374523	-9.14	2.965
6:49:14.98	-45	32992	279	0.785817099	-9.14	2.962
6:49:15.98	-44	32992	279	0.785817099	-9.14	2.962
6:49:16.98	-43	32992	280	0.788374523	-9.14	2.965
6:49:17.98	-42	32992	280	0.788374523	-9.14	2.965
6:49:18.98	-41	32992	279	0.785817099	-9.14	2.962
6:49:19.98	-40	32992	279	0.785817099	-9.14	2.962
6:49:20.98	-39	32992	279	0.785817099	-9.14	2.962
6:49:21.98	-38	32992	279	0.785817099	-9.14	2.962
6:49:22.98	-37	32992	279	0.785817099	-9.14	2.962
6:49:23.98	-36	32992	279	0.785817099	-9.14	2.962
6:49:24.98	-35	32992	279	0.785817099	-9.14	2.962
6:49:25.98	-34	32992	279	0.785817099	-9.14	2.962
6:49:26.98	-33	32992	279	0.785817099	-9.14	2.962
6:49:27.98	-32	32992	279	0.785817099	-9.14	2.962
6:49:28.98	-31	32992	279	0.785817099	-9.14	2.962
6:49:29.98	-30	32992	279	0.785817099	-9.14	2.962
6:49:30.98	-29	32992	279	0.785817099	-9.14	2.962
6:49:31.98	-28	32992	279	0.785817099	-9.14	2.962
6:49:32.98	-27	32992	279	0.785817099	-9.14	2.962
6:49:33.98	-26	32992	279	0.785817099	-9.14	2.962
6:49:34.98	-25	32992	279	0.785817099	-9.14	2.962
6:49:35.98	-24	32992	279	0.785817099	-9.14	2.962
6:49:36.98	-23	32992	279	0.785817099	-9.14	2.962
6:49:37.98	-22	32992	279	0.785817099	-9.14	2.962
6:49:38.98	-21	32992	279	0.785817099	-9.14	2.962
6:49:39.98	-20	32992	280	0.788374523	-9.14	2.965
6:49:40.98	-19	32992	280	0.788374523	-9.14	2.965
6:49:41.98	-18	32992	280	0.788374523	-9.14	2.965
6:49:42.98	-17	32992	280	0.788374523	-9.14	2.965
6:49:43.98	-16	32992	280	0.788374523	-9.14	2.965
6:49:44.98	-15	32992	280	0.788374523	-9.14	2.965
6:49:45.98	-14	32992	280	0.788374523	-9.49	2.751
6:49:46.98	-13	32992	280	0.788374523	-9.84	2.536
6:49:47.98	-12	32992	280	0.788374523	-9.84	2.536

6:49:48.98	-11	32992	280	0.788374523	-9.84	2.536
6:49:49.98	-10	32992	280	0.788374523	-9.49	2.751
6:49:50.98	-9	32960	280	0.787862186	-9.84	2.536
6:49:51.98	-8	32960	280	0.787862186	-9.84	2.536
6:49:52.98	-7	32928	281	0.789903025	-9.84	2.538
6:49:53.98	-6	32928	281	0.789903025	-10.55	2.103
6:49:54.98	-5	32864	281	0.788877846	-15.12	-0.696
6:49:55.98	-4	32832	282	0.790912769	-15.82	-1.124
6:49:56.98	-3	32768	283	0.792429805	-15.12	-0.694
6:49:57.98	-2	32672	284	0.793427655	-15.82	-1.122
6:49:58.98	-1	32544	286	0.796433636	-16.17	-1.335
6:49:59.98	0	32384	289	0.801418156	-15.82	-1.115
6:50:0.98	1	32224	292	0.806357799	-15.82	-1.104
6:50:1.98	2	32000	295	0.810215452	-16.17	-1.311
6:50:2.98	3	31776	299	0.816497134	-15.82	-1.081
6:50:3.98	4	31520	303	0.822179287	-15.82	-1.069
6:50:4.98	5	31264	308	0.830218669	-16.17	-1.268
6:50:5.98	6	30944	315	0.841918705	-16.87	-1.680
6:50:6.98	7	30592	322	0.852881058	-17.93	-2.322
6:50:7.98	8	30208	330	0.865462429	-17.93	-2.300
6:50:8.98	9	29728	339	0.87850108	-18.28	-2.500
6:50:9.98	10	29248	346	0.88661573	-18.28	-2.487
6:50:10.98	11	28672	354	0.895179575	-17.58	-2.028
6:50:11.98	12	28096	361	0.901246275	-17.58	-2.017
6:50:12.98	13	27456	368	0.906044052	-17.58	-2.008
6:50:13.98	14	26752	376	0.911770887	-17.58	-1.998
6:50:14.98	15	26016	384	0.916735919	-15.82	-0.860
6:50:15.98	16	25280	393	0.923612139	-14.06	0.288
6:50:16.98	17	24512	400	0.925507793	-12.66	1.194
6:50:17.98	18	23776	407	0.927804112	-12.66	1.201
6:50:18.98	19	23040	414	0.929970622	-11.6	1.891
6:50:19.98	20	22304	421	0.932013414	-10.55	2.575
6:50:20.98	21	21600	429	0.936455042	-9.14	3.502
6:50:21.98	22	20928	435	0.937319644	-7.73	4.417
6:50:22.98	23	20288	441	0.938632546	-6.68	5.102
6:50:23.98	24	20000	441	0.933954408	-6.33	5.307
6:50:24.98	25	19616	442	0.929692356	-9.49	3.250
6:50:25.98	26	19104	445	0.927255044	-10.2	2.784
6:50:26.98	27	18784	448	0.927884789	-8.79	3.695
6:50:27.98	28	18304	453	0.929744624	-9.14	3.476
6:50:28.98	29	17920	456	0.929309371	-8.79	3.700
6:50:29.98	30	17536	461	0.932612013	-8.44	3.939
6:50:30.98	31	17152	463	0.93027023	-7.73	4.388
6:50:31.98	32	16992	460	0.922161266	-8.79	3.672
6:50:32.98	33	16800	461	0.921014089	-8.79	3.668
6:50:33.98	34	16704	460	0.917657123	-8.09	4.104
6:50:34.98	35	16512	459	0.912815448	-8.09	4.084
6:50:35.98	36	16416	458	0.909475856	-8.44	3.846

Table 1 : Body angle vs Vane angle and Mach number

Body Angle of Attac
BAOA-Linear
BAOA-parabolic
Elapsed Tim
-20.
-15.
-10.
-05.
00.
05.
10.
15.
20.
25.
30.
35.
40.

Mathematical Analysis for Elevators blowdown:

1- Elevator command reduced to PCU compliance:

For static balance on Elevator,

$\delta_{E\,com} = \delta_{E\,com}(q=0) - P_L / K_S$ (Actuator command due to PCA compliance)

$\delta_{E\,com}$ = Commanded surface position

($\delta_{E\,com} = 20.5$, max elevator command , ref. B767 A.M.M)

$P_L = (K_L\, C_{h\,\delta E}\, q) / (n\, L_{EMA})$

Where:

P_L = Load Press.
q = Dynamic press. of the undisturbed stream
L_{EMA} = Length of the Effective Moment Arm
n = Number of effective Power Control Actuators
K_L = $S\,C / A_P$
S = Reference area (3050 sq. ft)
C = Reference Chord
A_P = PCA Piston Area

The net effective hydraulic press driving the elevators = 2*2990-3600
= 2300 psi

n = number of hydraulic systems operating = 2300/2950 = .78

$$C_{h\,\delta E} = C_{h\,\delta E}\{M=.91, \alpha_H=0, \delta_E=0\} + (\partial C_{h\,\delta E} / \partial \alpha_H)\,\Delta\alpha_H + (\partial C_{h\,\delta E} / \delta_E)\,\Delta\delta_E + (\partial C_{h\,\delta E} / \partial M)(M - 0.91)$$

Assuming $(\partial C_{h\,\delta E} / \partial M) = 0$ (for small deflections of elevators)

Then,

$$\delta_{E\,com} = \delta_{E\,com}(q=0) - [(K_L\, C_{h\,\delta E}\, q) / (K_S\, n\, L_{EMA})][C_{h\,\delta E}\{M=.91, \alpha_H=0, \delta_E=0\} + (\partial C_{h\,\delta E} / \partial \alpha_H)\,\Delta\alpha_H + (\partial C_{h\,\delta E} / \delta_E)\,\Delta\delta_E]$$

$$\delta_{E\,com} = \delta_{E\,com}(q=0) - C\,[C_{h\,\delta E}\{M=.91, \alpha_H=0, \delta_E=0\} + (\partial C_{h\,\delta E} / \partial \alpha_H)\,\Delta\alpha_H] - C\,(\partial C_{h\,\delta E} / \delta_E)\,\Delta\delta_E]$$

Where

$C = (K_L\, C_{h\,\delta E}\, q) / (K_S\, n\, L_{EMA})$

33

$$\delta_{E\,com}[1+C(\partial C_{h\,\delta E}/\delta_E)] = \delta_{E\,com}(q=0) - C[C_{h\,\delta E}\{M=.91, \alpha_H=0, \delta_E=0\} + (\partial C_{h\,\delta E}/\partial \alpha_H)\Delta\alpha_H]$$

$$\delta_{E\,com} = [\delta_{E\,com}(q=0) - C[C_{h\,\delta E}\{M=.91, \alpha_H=0, \delta_E=0\} + (\partial C_{h\,\delta E}/\partial \alpha_H)\alpha_H] / [1+C(\partial C_{h\,\delta E}/\delta_E)]$$

= (Elevator command reduced to PCU compliance)

Using FDR for stabilizers data

$\alpha_H = \alpha_B - \varepsilon + i_{FRL}$

$i_{FRL} = 2 - i_{FDR}$

$\varepsilon = C_L / \pi AR$

Where,

α_B = Body angle

ε = downwash angle caused by the wing

i_{FRL} = Stabilizers Fuselage Reference LineAngle

i_{FDR} = Stabilizers deflection in degrees as recorded in FDR (Boeing convention)

C_L = Lift Coefficient

AR = Wing Aspect Ratio

$(\partial C_{h\,\delta E}/\partial \alpha_H)\Delta\alpha_H - (\partial C_{h\,\delta E}/\partial \alpha_H)(1 - (\partial \varepsilon/\partial \alpha_B))\Delta\alpha_B$

$\partial \varepsilon/\partial \alpha_B = (\partial C_L/\partial \alpha_B)/(\pi AR)$

Using data from Boeing charts:

$C_{h\,\delta E}\{M=.91, \alpha_H=0, \delta_E=0\} = -0.005$

$(\partial C_{h\,\delta E}/\partial \alpha_H) = 0.0025 \text{ deg}^{-1}$

$(\partial C_{h\,\delta E}/\delta_E) = 0.009 \text{ deg}^{-1}$

$K_S / P_L = 107.6 / 1130 = 0.0952$

$L_{EMA} = 0.415$

AR= 7.88 meter

$(\partial C_L / \partial \alpha_B) = 0.15 \text{ deg}^{-1}$ (from B767 P.E.M.)

$(\partial \varepsilon / \partial \alpha_B) = 0.006062$

$q = \frac{1}{2} \rho V^2$

$q = \frac{1}{2} \gamma p_0 \delta M^2$

$p_0 = 2116.21662$ lb/sq. ft (Standard press at S. L.)

$\gamma = 1.4$

$q = 1481.3 \ \delta M^2$

$C = 0.2941 \ q$

$$\delta_{E\,com} = [\, 20.5 - 0.2941 * 1481.3 * \delta M^2 \, (- 0.005 + 0.9939 * 0.0025 \, \Delta\alpha_B)] / (1 + 0.2941 * 1481.3 \, \delta M^2 * .009)$$

$$\delta_{E\,com} = [\, 20.5 + \delta M^2 \, (2.1783 - 1.0826 \, \Delta\alpha_B)] / [\, 1 + 3.921 * \delta M^2]$$

= (Elevator command reduced to PCU compliance)

Results are shown in Table 2

2- Elevator Blowdown Position:

$P_L = (K_L C_{h\delta E}\, q) / (n L_{EMA})$

$P_{LBD} = (K_L C_{h\delta E}\, q) / (n L_{EMA}) = 2300$ psi

$C_{h\delta E} = (P_{LBD}\ n L_{EMA}) / (K_L\ q)$

$C_{h\delta E} = C_{h\delta E}\{M=.91, \alpha_H=0, \delta_E=0\} + (\partial C_{h\delta E} / \partial \alpha_H)\, \Delta\alpha_H + (\partial C_{h\delta E} / \delta_E)\Delta\delta_E$

(Assuming $(\partial C_{h\delta E} / \partial M) = 0$ for small deflections of elevators)

$\Delta\delta_E = [(P_{LBD}\, n L_{EMA}) / (K_L\ q) - (\partial C_{h\delta E} / \partial \alpha_H)\, \Delta\alpha_H - C_{h\delta E}\ ] / (\partial C_{h\delta E} / \delta_E)$

substituting for :

$P_{LBD}\ n = 2300$ psi
$L_{EMA}) = 0.415$
$K_L = 107.6$
$(\partial C_{h\delta E} / \delta_E) = 0.0025$
$C_{h\delta E} = 0.009$
$q = 1481.3\ \delta M^2$

$\Delta\delta_E = 0.5556 - 111.111\, (\partial C_{h\delta E} / \partial \alpha_H)\, \Delta\alpha_H + 0.6654 / \delta M^2$
$= 0.5556 - 110.433\, (\partial C_{h\delta E} / \partial \alpha_H)\, \Delta\alpha_B + 0.6654 / \delta M^2$

$\delta_E = 0.5556 - 0.2778\ \Delta\alpha_B + 0.6654 / \delta M^2$ at $(\partial C_{h\delta E} / \partial \alpha_H) = 0.0025$ (introducing the effect of body angle)

$\delta_E = 0.5556 + 0.6654 / \delta M^2$ at $(\partial C_{h\delta E} / \partial \alpha_H) = 0$ (not introducing the effect of body angle)

$\alpha_H = \alpha_B - \varepsilon + i_{FRL}$

$i_{FRL} = 2 - i_{FDR}$

$\alpha_B = \alpha_H - \varepsilon + i_{FDR} - 2$

i_{FDR} = 3.2 at $\alpha_H = 0$

$\alpha_B = 1.2 + \varepsilon$

Computation of the downwash angle:

Using cruise flight data:

At 1: 48 : 04 ET

Press altitude = 32992 ft
CAS = 280 Kts
Press ratio = 0.334572
M = 0.788375
S = 3050 sq. ft.

L = 4518122.485 $\delta M^2 C_L = n W$

n = Load Factor
w = A/C Weight

for n = 0.97 weight = 389120 lb (FDR data at 1:48:04)

$C_L = 0.5196$

$\varepsilon = 0.5196 / (\pi * 7.88)$

$\varepsilon = 1.2$ degree

$\Delta \delta_E = 0.5556 - 0.2778 (\alpha_B - 2.4) + 0.6654 / \delta M^2$ at $(\partial C_{h\delta E} / \partial \alpha_H) = .0025$ (introducing the effect of body angle)

$\Delta \delta_E = 0.5556 + 0.6654 / \delta M^2$ at $(\partial C_{h\delta E} / \partial \alpha_H) = 0$ (not introducing the effect of body angle)

Results are shown in table 2 and figure 2

Radar Time	Left Elevator Deflection FDR	Right Elevator Deflection FDR	Body Angle	Modified Elev. Command	Elev Blowdown no body angle effect	Elev Blowdown with body angle effect
RAD. TIME	ELL	ELR	BAN	elevcommand	elevatbd0	elevatbd25
1:49:31	0.7	0.35	2.932253	20.5	-4.721228996	-4.573369035
1:49:32	0.7	0.35	2.932253	20.5	-4.721228996	-4.573369035
1:49:33	0.7	0.35	2.932253	20.5	-4.721228996	-4.573369035
1:49:34	0.7	0.35	2.932253	20.5	-4.721228996	-4.573369035
1:49:35	0.7	0.35	2.932253	20.5	-4.721228996	-4.573369035
1:49:36	0	0.35	2.932253	20.5	-4.721228996	-4.573369035
1:49:37	0.7	0.35	2.932253	20.5	-4.721228996	-4.573369035
1:49:38	0.7	0.35	2.932253	20.5	-4.721228996	-4.573369035
1:49:39	0.7	0.35	2.940188	20.5	-4.694246902	-4.544182809
1:49:40	0.7	0.35	2.940188	20.5	-4.694246902	-4.544182809
1:49:41	0.7	0.35	2.940188	20.5	-4.694246902	-4.544182809
1:49:42	0.7	0.35	2.940188	20.5	-4.694246902	-4.544182809
1:49:43	0.7	0.35	2.940188	20.5	-4.694246902	-4.544182809
1:49:44	0.7	0.35	2.940188	20.5	-4.694246902	-4.544182809
1:49:45	0.53	-0.18	2.726454	20.5	-4.694246902	-4.603558065
1:49:46	0.53	-0.35	2.51272	20.5	-4.694246902	-4.662933321
1:49:47	0.53	-0.18	2.51272	20.5	-4.694246902	-4.662933321
1:49:48	0.53	-0.18	2.51272	20.5	-4.694246902	-4.662933321
1:49:49	0.53	-0.18	2.726454	20.5	-4.694246902	-4.603558065
1:49:50	0.53	-0.35	2.511195	20.5	-4.693438681	-4.662548714
1:49:51	0.53	-0.35	2.511195	20.5	-4.693438681	-4.662548714
1:49:52	0.35	-0.35	2.517286	20.5	-4.665935115	-4.633353192
1:49:53	-0.18	-2.29	2.083498	20.5	-4.665935115	-4.753859505
1:49:54	-2.81	-3.34	-0.71063	20.5	-4.664326682	-5.528459443
1:49:55	-2.64	-2.99	-1.13447	20.5	-4.637110035	-5.618987047
1:49:56	-2.99	-3.69	-0.70368	20.5	-4.609373992	-5.471575439
1:49:57	-3.16	-3.87	-1.12988	20.5	-4.581124637	-5.561724661
1:49:58	-3.34	-3.87	-1.33863	20.5	-4.52704515	-5.565636311
1:49:59	-3.34	-3.87	-1.11502	20.5	-4.448710909	-5.425183028
1:50:00	-3.34	-3.87	-1.10564	20.5	-4.372682057	-5.346548671
1:50:01	-3.34	-3.87	-1.31351	20.5	-4.297346965	-5.328959581
1:50:02	-3.16	-3.69	-1.08592	20.5	-4.201992461	-5.170382402
1:50:03	-3.16	-3.69	-1.0746	20.5	-4.109494767	-5.074739986
1:50:04	-3.16	-3.69	-1.27509	20.5	-4.000122697	-5.021062746
1:50:05	-3.69	-4.39	-1.68711	20.5	-3.856142829	-4.99154236
1:50:06	-4.22	-4.75	-2.32853	20.5	-3.720369998	-5.03395588
1:50:07	-4.22	-4.92	-2.30703	20.5	-3.575576339	-4.883189672
1:50:08	-4.75	-5.45	-2.50497	20.5	-3.423256407	-4.785858462
1:50:09	-4.75	-5.1	-2.49101	20.5	-3.310411337	-4.669133954
1:50:10	-4.57	-4.92	-2.03088	20.5	-3.188625117	-4.419523405
1:50:11	-4.22	-4.57	-2.01886	20.5	-3.086975148	-4.314534133
1:50:12	-4.39	-4.75	-2.00923	20.5	-2.989649984	-4.214533705
1:50:13	-4.57	-4.75	-1.99759	20.5	-2.885178401	-4.106829017
1:50:14	-4.22	-4.22	-0.85755	20.5	-2.786342986	-3.691291077
1:50:15	-3.87	-3.69	0.293715	20.5	-2.683419196	-3.268545072

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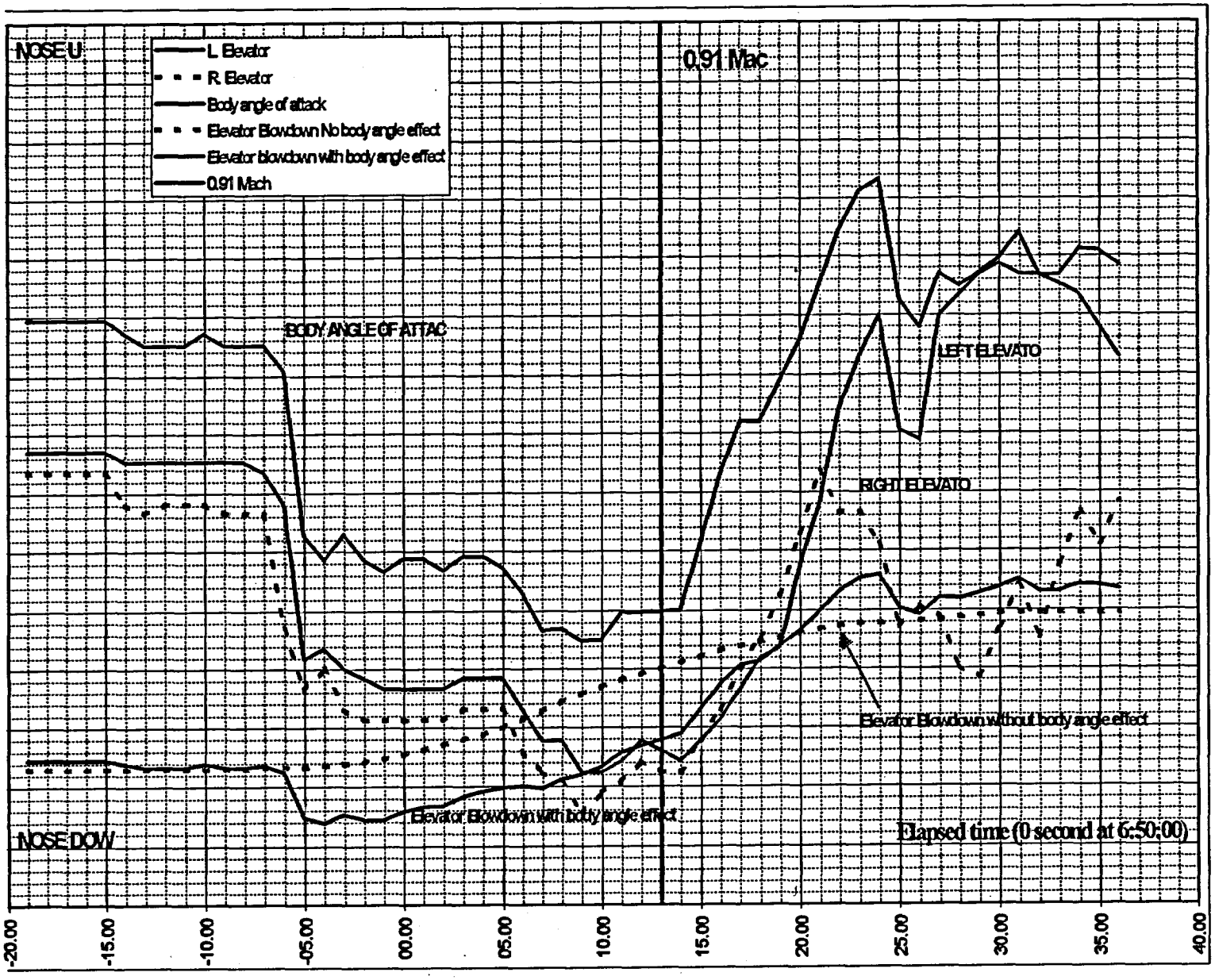
1:50:16	-3.34	-2.99	1.202023	20.5	-2.604927308	-2.937725185
1:50:17	-2.81	-2.46	1.210254	20.5	-2.530789393	-2.861300899
1:50:18	-2.64	-1.76	1.90267	20.5	-2.460254672	-2.598412846
1:50:19	-1.23	-0.7	2.589518	20.5	-2.393095502	-2.340447374
1:50:20	-0.18	0.35	3.522	20.5	-2.321979157	-2.010287426
1:50:21	1.41	-0.35	4.43991	20.5	-2.269280511	-1.702593453
1:50:22	2.29	-0.35	5.127642	20.5	-2.219057143	-1.46131832
1:50:23	2.99	-0.88	5.328426	20.5	-2.215587753	-1.402071064
1:50:24	1.05	-2.29	3.264164	20.5	-2.204145577	-1.964080824
1:50:25	0.88	-1.93	2.795094	20.5	-2.17782756	-2.06807046
1:50:26	2.99	-2.11	3.707599	20.5	-2.154229495	-1.790978575
1:50:27	3.34	-2.99	3.490429	20.5	-2.116497905	-1.813576592
1:50:28	3.69	-3.16	3.71438	20.5	-2.093391259	-1.728256474
1:50:29	3.87	-2.29	3.956519	20.5	-2.058578889	-1.626177938
1:50:30	3.69	-1.58	4.403673	20.5	-2.042542202	-1.485921709
1:50:31	3.69	-2.46	3.680583	20.5	-2.058927348	-1.703181372
1:50:32	3.52	-1.23	3.675213	20.5	-2.050889936	-1.696635894
1:50:33	3.34	-0.35	4.10913	20.5	-2.055955965	-1.58115952
1:50:34	2.81	-0.88	4.085827	20.5	-2.060083728	-1.591760955
1:50:35	2.29	-0.18	3.845966	20.5	-2.065235647	-1.66354629

Table 2: Elevators Blowdown Deflections


NOSE U
L Elevator
R Elevator
Body angle of attack
Elevator Blowdown No body angle effect
Elevator blowdown with body angle effect
0.91 Mach
0.91 Mac
BODY ANGLE OF ATTAC
LEFT ELEVATO
RIGHT ELEVATO
Elevator Blowdown without body angle effect
Elevator Blowdown with body angle effect
NOSE DOW
Elapsed time (0 second at 6:50:00)
-20.00
-15.00
-10.00
-05.00
00.00
05.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00