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

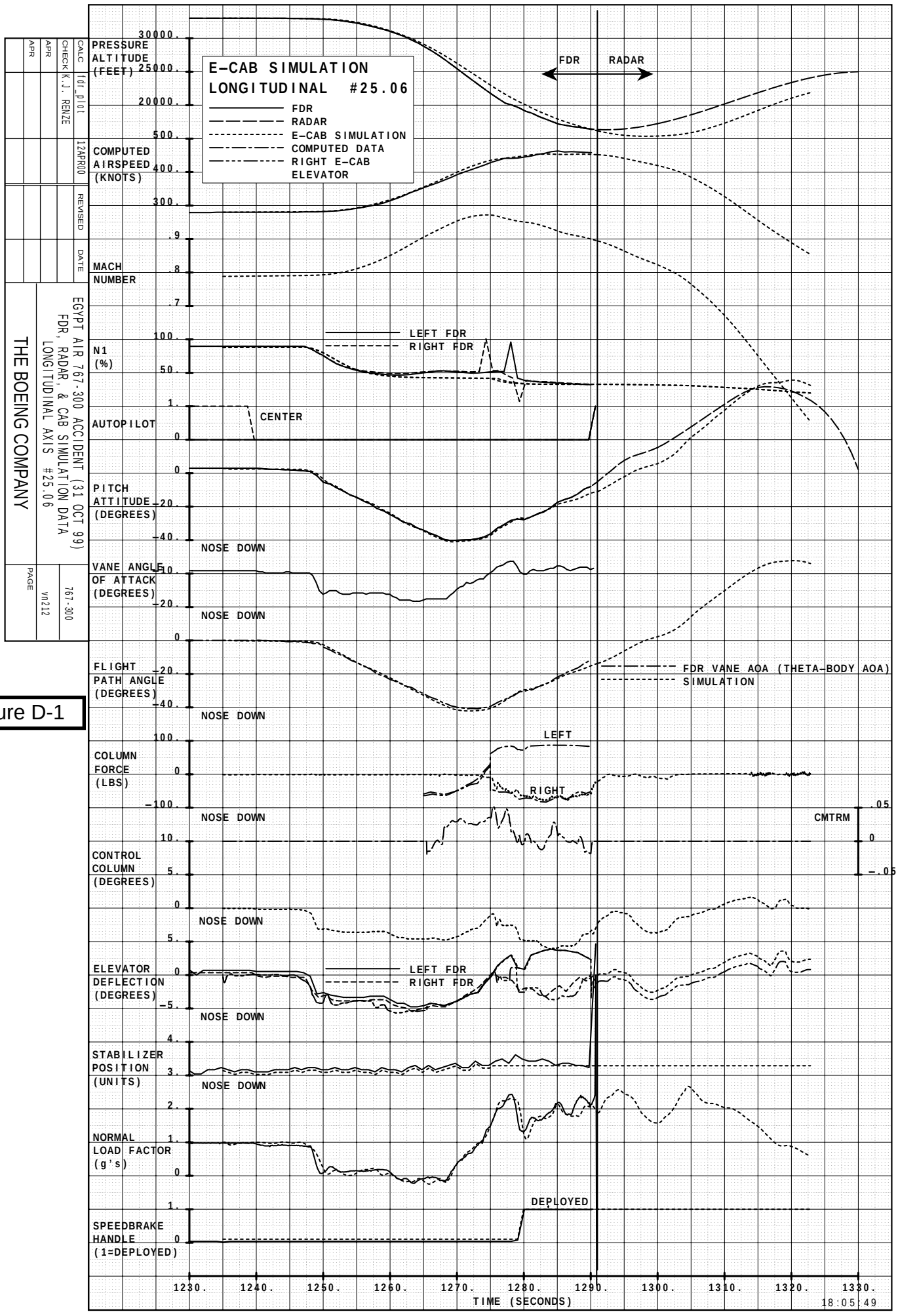
In this case, the flying pilot targets the computed pull force during the FDR elevator split time period (i.e., 1275 < time < 1290). No significant control column inputs are made prior to the split, but the pilot continues to fly the airplane after time 1290, as evidenced by the E-Cab simulator column 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

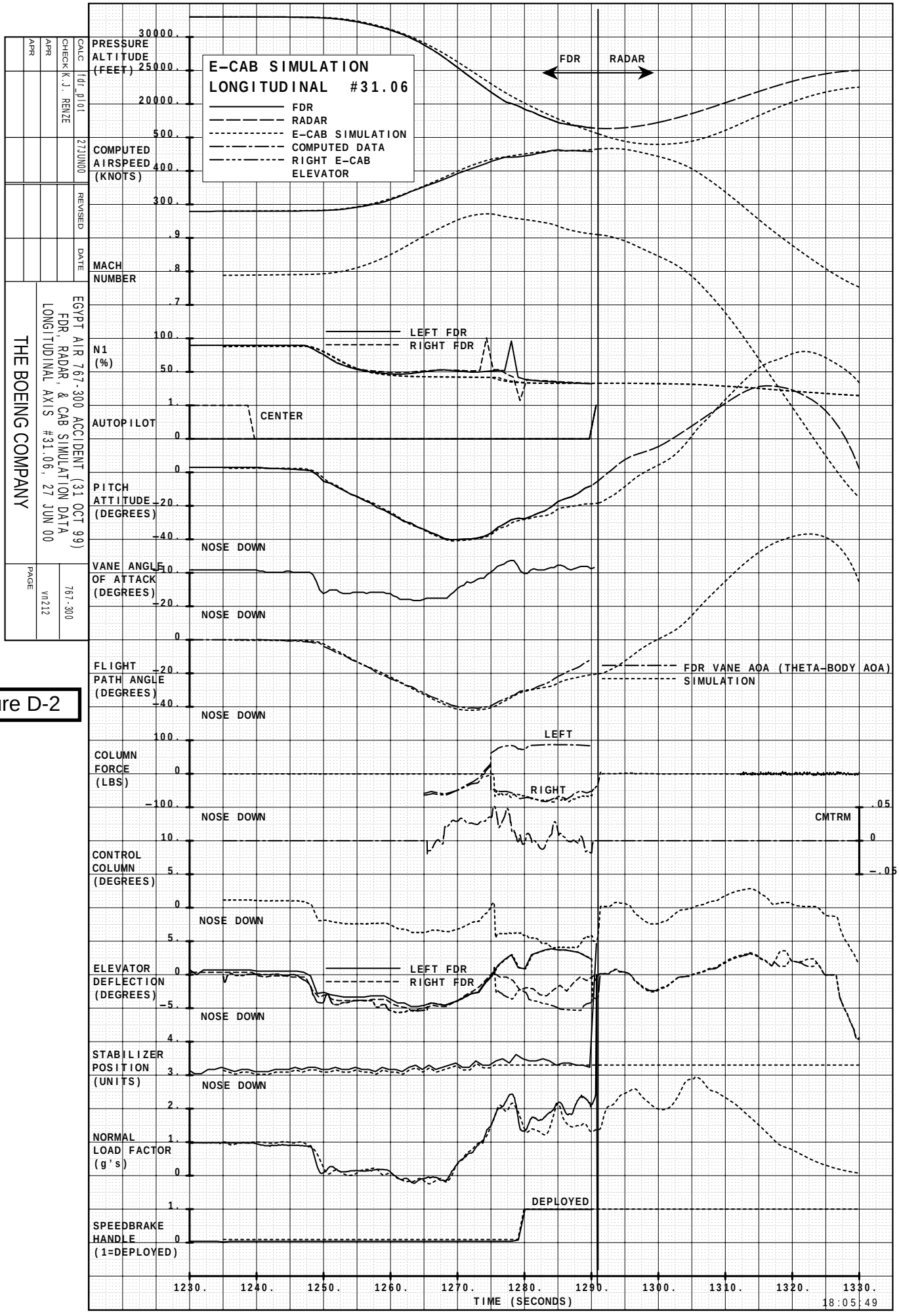
E-CAB SIMULATION
LONGITUDINAL #31.06
FDR
RADAR
E-CAB SIMULATION
COMPUTED DATA
RIGHT E-CAB ELEVATOR
FDR RADAR
PRESSURE ALTITUDE (FEET)
COMPUTED AIRSPEED (KNOTS)
MACH NUMBER
N1 (%)
LEFT FDR
RIGHT FDR
AUTOPILOT
CENTER
PITCH ATTITUDE (DEGREES)
NOSE DOWN
VANE ANGLE OF ATTACK (DEGREES)
FLIGHT PATH ANGLE (DEGREES)
FDR VANE AOA (THETA-BODY AOA)
SIMULATION
COLUMN FORCE (LBS)
LEFT
RIGHT
CONTROL COLUMN (DEGREES)
CMTRM
ELEVATOR DEFLECTION (DEGREES)
STABILIZER POSITION (UNITS)
NORMAL LOAD FACTOR (g's)
SPEEDBRAKE HANDLE (1=DEPLOYED)
DEPLOYED
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Figure D-2

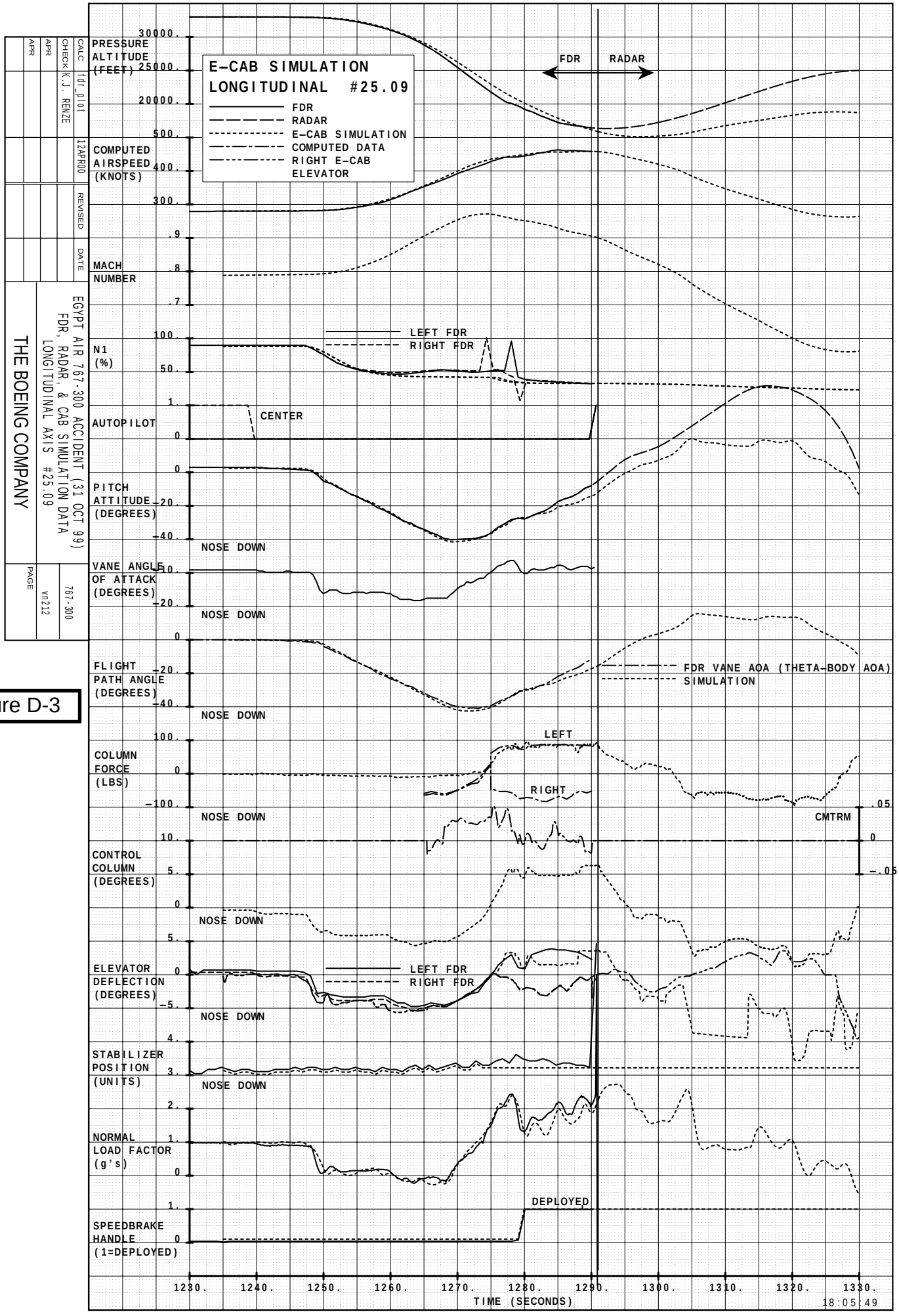

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Figure D-3

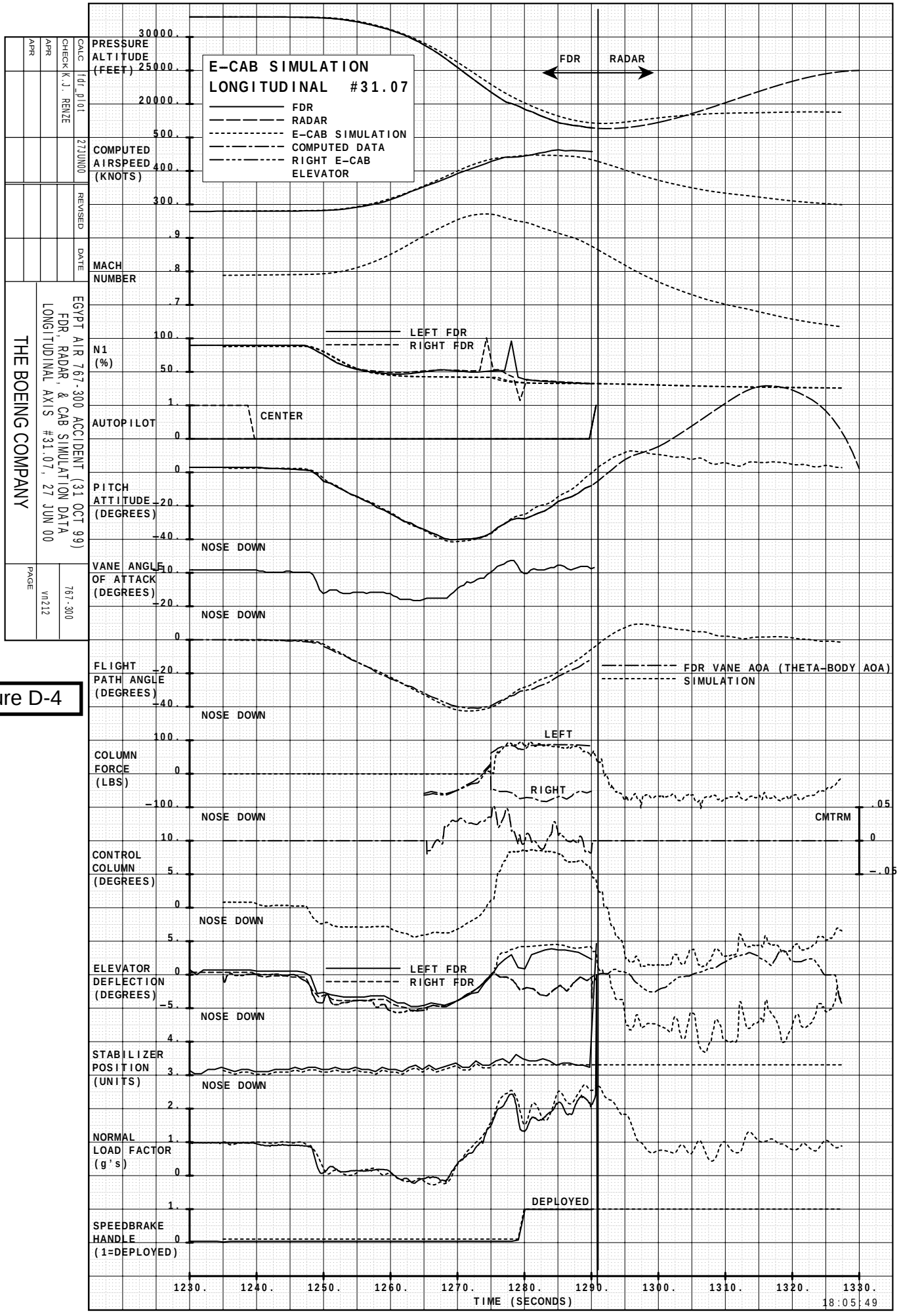

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Figure D-4