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.

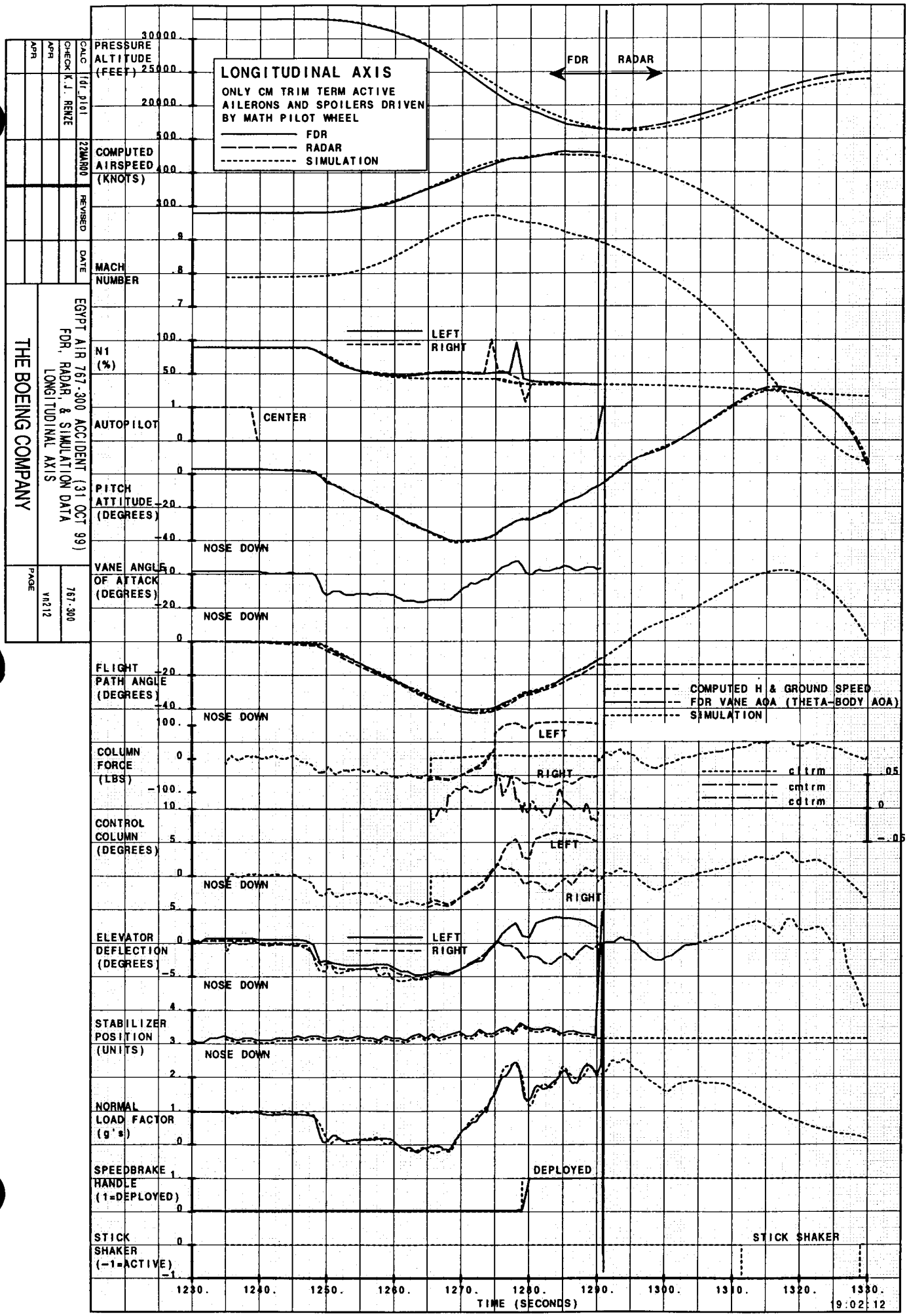
Limitations of the 767E- Cab Simulations (continued)

- 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”)***



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CHECK K.J. RENZE
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REVISED
DATE

THE BOEING COMPANY

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

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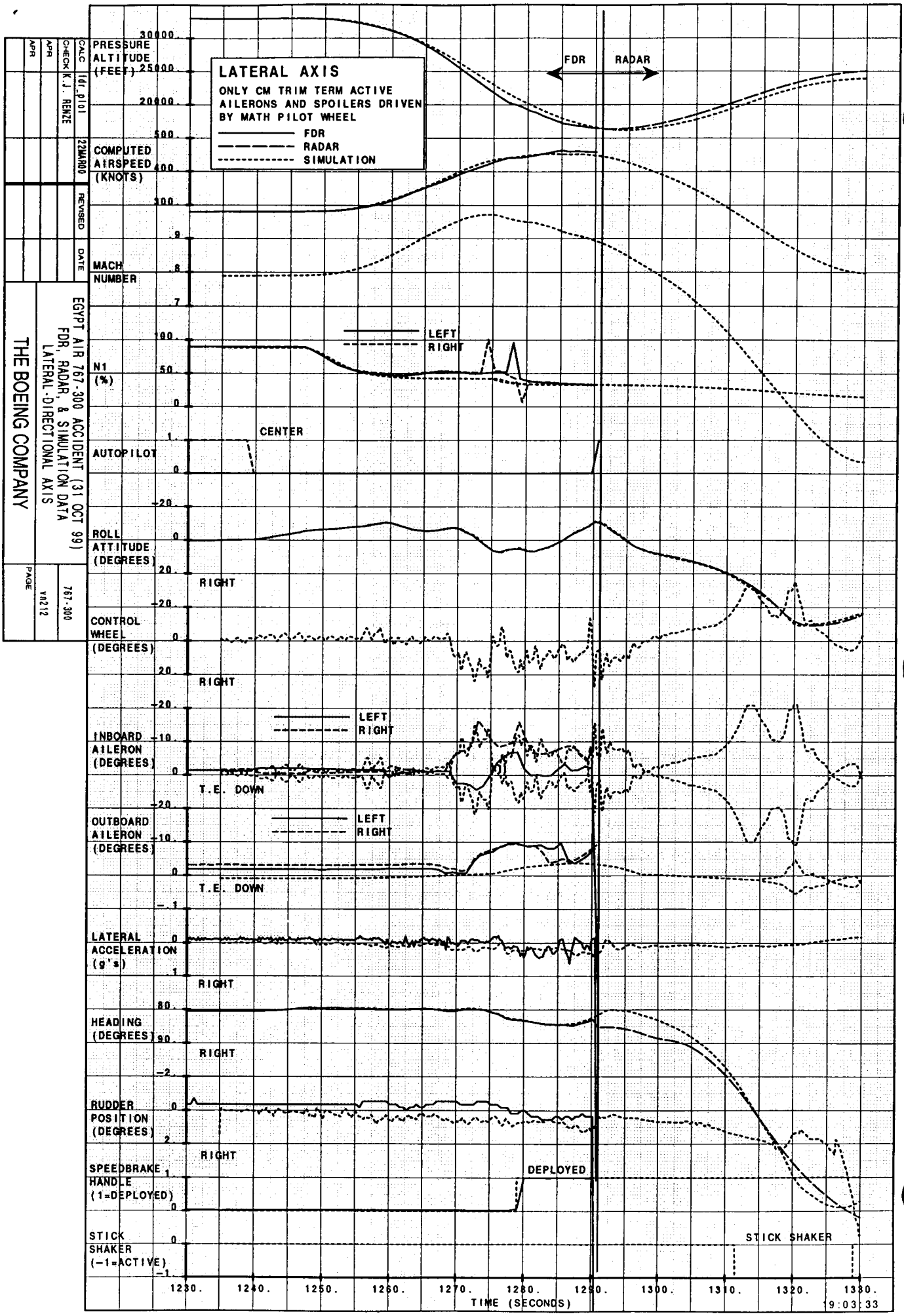
767-300
yn212



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DATE

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

767-300
yn212

PAGE


ELAPSED TIME
96.9
FDR TIME
1331.8
2.5
3
3.5
2
1.5
1
.5
NORMAL LOAD FACTOR
-.5
-1
-1.5
ENGINES
OFF
OFF
LEFT
RIGHT
10
5
0
5
10
NOSE UP
ELEV SPLIT
NOSE DOWN
LEFT
RIGHT
-30
30
-60
60
-90
90
-120
120
-150
150
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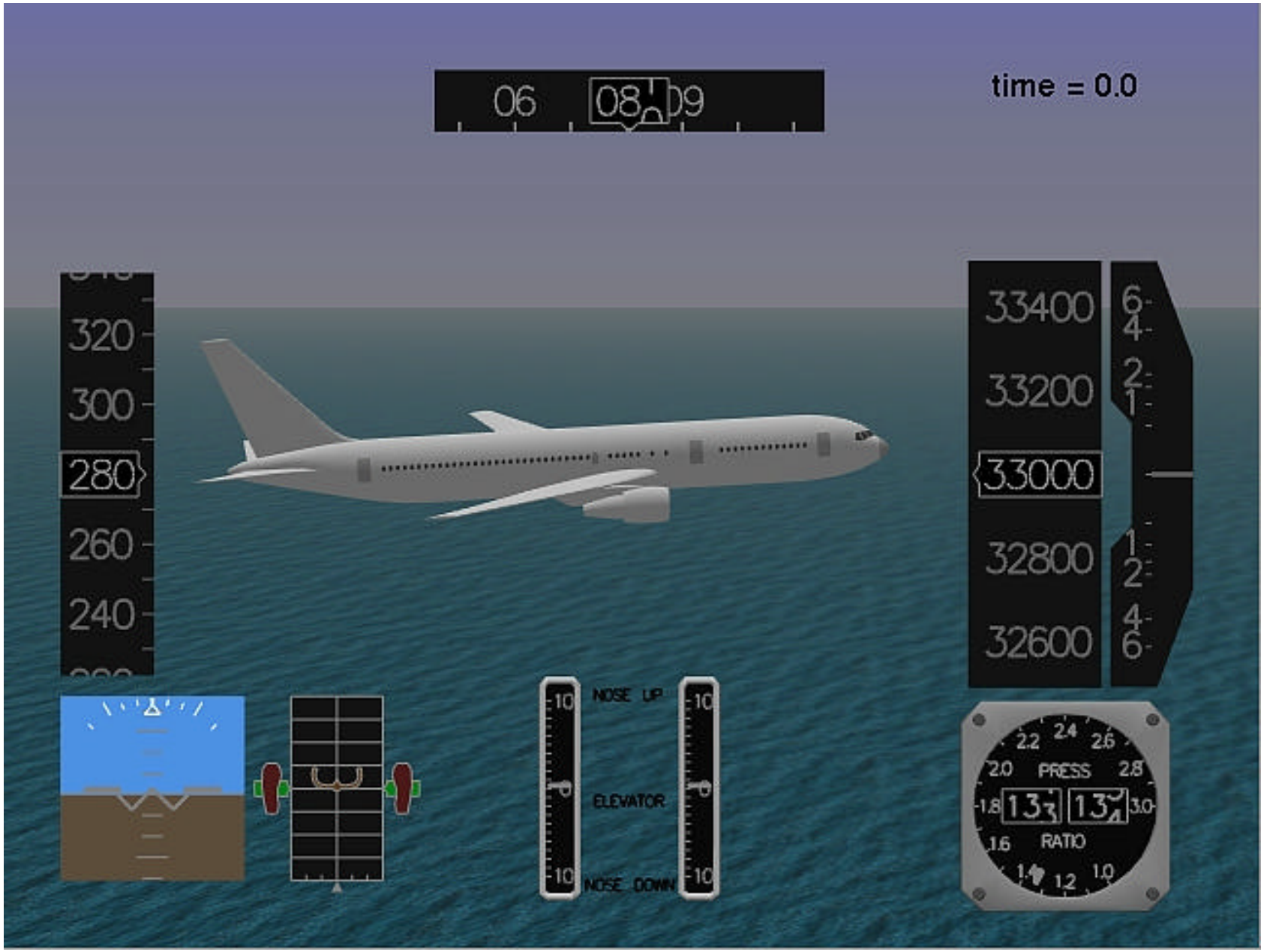
LEFT COMPUTED
FLYING PILOT
RIGHT COMPUTED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NOSE UP
ELEVATOR
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2.2
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2.6
2.0
PRESS
2.8
1.8
3.0
1.6
RATIO
1.4
1.2
1.0