**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)
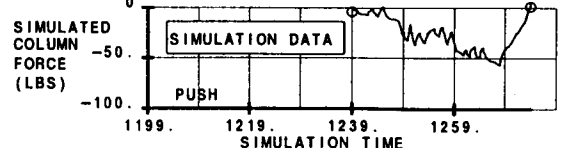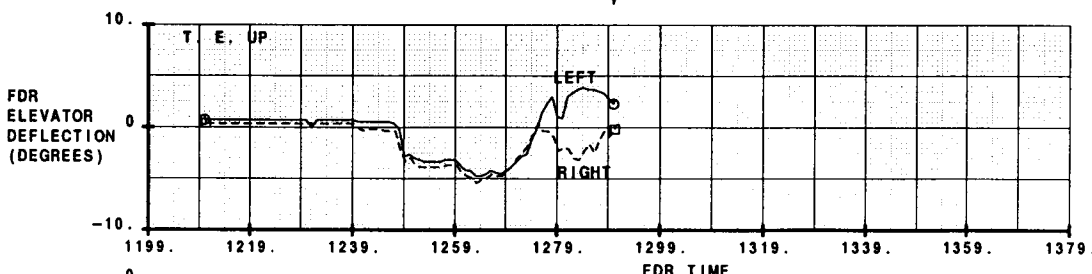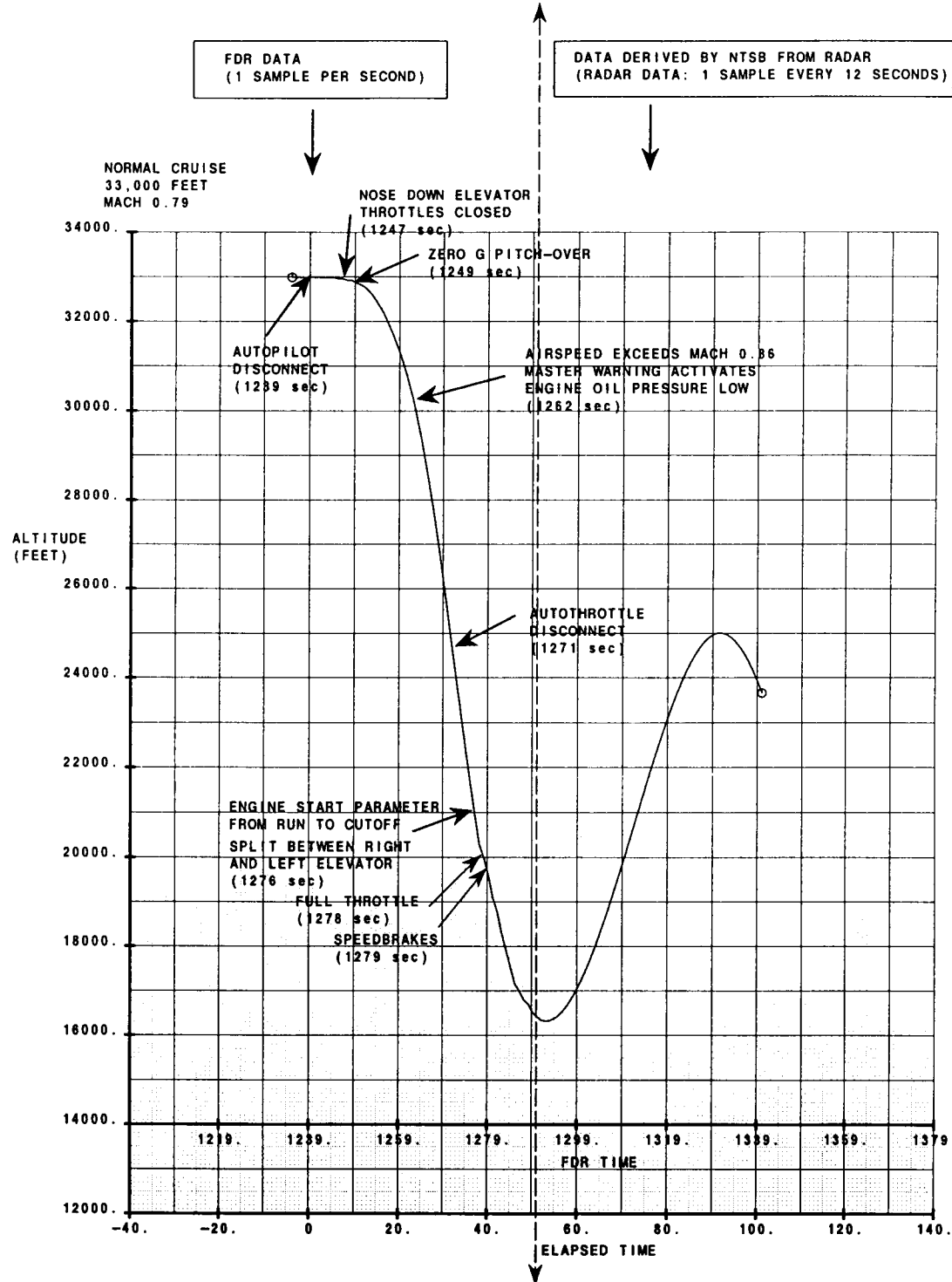
- Where DFDR data is available:

    - 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

FOR ◄──► RADAR

FDR & RADAR DATA
SIMULATION DATA

PRESSURE
ALTITUDE
- FT

40000

30000

20000

10000

CALIBRATED
AIRSPEED
- KT

400

400

0

MACH

1

6

COLUMN
- DEG

0

NOSE DOWN

-20

ELEVATOR
DEG

0

NOSE DOWN

-10

PITCH
ANGLE
- DEG

0

NOSE DOWN

-100

NORMAL
LOAD
FACTOR
-

2

-2

-20

BANK
ANGLE
- DEG

20

RIGHT

-20

WHEEL
- DEG

20

1250   1260   1250   1260   1270   1280   1290   1300   1310   1320   1330

# "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

ACCIDENT SCENARIO
33,000 FT / MACH 0.79

FIGURE 767-300ER

PAGE

BOEING

RUN
A-C1.basic1
B-Elevator_Left
B-Elevator_Right
C-C1.egypt

FDR DATA
(1 SAMPLE PER SECOND)

DATA DERIVED BY NTSB FROM RADAR
(RADAR DATA: 1 SAMPLE EVERY 12 SECONDS)

NORMAL CRUISE
33,000 FEET
MACH 0.79

NOSE DOWN ELEVATOR
THROTTLES CLOSED
(1247 sec)

ZERO G PITCH-OVER
(1249 sec)

AUTOPILOT
DISCONNECT
(1239 sec)

AIRSPEED EXCEEDS MACH 0.86
MASTER WARNING ACTIVATES
ENGINE OIL PRESSURE LOW
(1262 sec)

ALTITUDE
(FEET)

AUTOTHROTTLE
DISCONNECT
(1271 sec)

ENGINE START PARAMETER
FROM RUN TO CUTOFF
SPLIT BETWEEN RIGHT
AND LEFT ELEVATOR
(1276 sec)
FULL THROTTLE
(1278 sec)
SPEEDBRAKES
(1279 sec)

FDR TIME

ELAPSED TIME

T.E. UP

FDR
ELEVATOR
DEFLECTION
(DEGREES)

LEFT

RIGHT

FDR TIME

SIMULATED
COLUMN
FORCE
(LBS)

SIMULATION DATA

PUSH

SIMULATION TIME

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<br>• 'q' meter<br>• right/left elevator display<br>• Arming of Speed Brake handle<br>• 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**

## 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